Synopsis and introduction — Colonial Geology Surveys 1947–1956

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The Imperial Institute Building, London. View of the Main Building, looking east, in which accommodation has generously been made available by The Imperial Institute for the Directorate and Mineral Resources Division of Colonial Geological Surveys. Block loaned by courtesy of The Imperial Institute. Plate I.
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Contents

Synopsis

The progress of geological survey work in the British Colonial and Dependent Territories is reviewed for the 10-year period beginning with the formation of the Directorate of Colonial Geological Surveys in London in January 1947 and ending in December 1956. During that time the total number of senior officers engaged overseas has been increased from 50 to 212 and there has been a corresponding increase in the junior staff. This great increase in staff, largely financed from Colonial Development and Welfare funds, coupled with the provision of aerial photographs of much of the area of the territories concerned, has been responsible for the very large increase in basic geological mapping that has been carried out.

The report begins with an outline of the progress made in geological mapping, mineral investigations, engineering geology and water-supply development in the various territories concerned—more than a score in all—and gives an account of the specialised work of the Directorate and Mineral Resources Division at their headquarters in London. An account is also given of the many courses of instruction for geologists organised by the Directorate, and of the assistance rendered by British Universities and other institutions.

The progress of geological survey work in each of the territories during the period under review is then described in more detail after brief introductory summaries of results previously achieved. A list of publications issued, or in course of preparation, during this period is given for each territory. Many original illustrations including maps and photographs accompany the report, and there is an index to the chief mineral occurrences mentioned in the text.

1 Report of the Committee on Colonial Geology, July, 1944; Colonial Office Memorandum C. M. No. 8.

Introduction

On the first of January, 1947, a central organisation for overseas Geological Surveys was inaugurated in London by my appointment as Geological Adviser to the Secretary of State for the Colonies and Director of Colonial Geological Surveys. The setting up of this new body resulted from a recommendation by a Committee of eminent scientists and mining engineers who had been invited by the Secretary of State in February, 1944, to advise him on the need for an expansion of geological work in overseas territories and the best organisation for bringing this about.' Ten years have thus elapsed since the organisation began its work, so that a convenient opportunity is now afforded for reviewing the progress made during this period, both in the light of the Committee's recommendations and against the historical background of previous geological investigations.

The new organisation, under the title of Directorate of Colonial Geological Surveys, began in a modest way in offices generously made available by the Imperial Institute, South Kensington, London, where the important help of its Mineral Resources Department and Library was at hand. Within easy reach there were also the British Museum (Natural History), the Imperial College of Science and Technology, and the Geological Survey and Museum of Great Britain, thus affording opportunity for close association of which full advantage was taken. Shortly after my appointment, a

geologist was also appointed, and a geophysicist was recruited in February, 1949. A start was then made with the establishment of a photogeological section, housed first at Bushey Park, but later at Tolworth in the Headquarters of Colonial (Geodetic and Topographic) Surveys, where it has access to the great stock of air photographs held by that Directorate. Work continued to expand rapidly, and it soon became necessary to create two posts of Deputy Director, one for general administration and the other for geophysical and photogeological investigations; Mr. E. S. Willbourn and Dr. S. H. Shaw were appointed to these two posts respectively. In April, 1949, the Colonial Office took over responsibility for the Mineral Resources Department of the Imperial Institute, which then became the Mineral Resources Division of the new organisation and continued its valuable work on a wide range of questions and research problems covering not only the mineral resources of the Colonial territories but the mineral industry in general. The Division was made responsible for the publication of a new periodical " Colonial Geology and Mineral Resources " as successor to the Mineral Resources section of the former " Bulletin of the Imperial Institute ", but planned on more comprehensive lines and with a definite Colonial emphasis. It also continued to publish the "Statistical Summary of the Mineral Industry ", and began the compilation of new monographs on specific minerals. As the work of the central organisation expanded, plans were put into effect, as described below, for increasing its establishment and modernising its equipment, and the cost of this expansion was met from Colonial Development and Welfare funds.

Meanwhile, I made many visits to overseas territories to establish contacts and to learn how geological investigations could best be speeded up. After consultations with the eleven Governments which already had Geological Survey Departments at the beginning of the period under review, it soon became apparent that the greatest need was for increased staffs of geologists, geophysicists and geochemists, with the necessary additional buildings and equipment. These facilities were provided in due course, and were paid for during the first few years from C.D. and W. funds, but most territories eventually took over complete responsibility for the cost of their Geological Surveys. In thirteen other territories it was necessary to set up new Geological Surveys, although in a few instances where only one geologist was needed—possibly for a limited period—this was effected by the secondment of an officer from a territory already possessing an established Geological Survey.

More recently, additional facilities have been provided in London by the setting up of a Geochemical Prospecting Research Centre at the Imperial College of Science and Technology with the help of a grant from the Geological Survey Central Allocation of C.D. and W. and from the Department of Scientific and Industrial Research. Some of the overseas Geological Surveys have already made use of these facilities by sending their geologists to receive training in the new technique and by inviting staff from the Centre to carry out research in their territory. Moreover, owing to the great increase in the rate of geological mapping during the past few years, and the fact that many of the overseas Surveys are wholly dependent on assistance from London for their fossil deter-, minations, arrangements have been made with the Geology Department of the British Museum (Natural History) to increase its specialist staff so as to cope with the considerable amount of fossiliferous material now requiring examination; the cost for this is also being defrayed from the funds of the Geological Surveys Central Allocation of C.D. and W.

Throughout the 10-year period reviewed the Directorate and the overseas Geological Surveys have been represented at many international geological, hydrological, mining and other related conferences, including the last three Sessions of the International Geological Congress, the Fifth Commonwealth Mining and Metallurgical Congress, various United Nations conferences, the Economic Commission for Asia and the Far East, the Caribbean Geological Conference, and, in Africa, the Regional Geological Committees, organised by the Committee for Technical Cooperation South of the Sahara (C.C.T.A.). Visits have also been made by members of the central organisation to the East, Central, or West African territories almost every year, and to those in the West Indies, the

Far East, and elsewhere every two or three years, thereby enabling close touch to be maintained with overseas developments so that advice could be given on a wide range of specialist problems.

In the preparation of this Report I have had the co-operation of the Heads of all overseas Geological Surveys, and I acknowledge their assistance with gratitude.

Geological mapping

Very few Colonial territories had accurate topographic maps before 1947 at scales as large even as 1 inch to one mile and where maps of smaller scales, such as 1 : 250,000 or 1 : 500,000, were available they were not only too small to allow sufficient geological detail to be shown on them but often they were of very variable accuracy. Geologists were consequently obliged to make their own maps by conventional plane-tabling and traversing methods, yet even then they were usually handicapped by the absence of any reliable trigonometrical network to which their work could be tied. Very valuable results were nevertheless achieved and showed that more extensive geological investigation would certainly enable more rapid progress to be made in the economic development of the natural resources of the overseas territories. A fundamental change in geological mapping has since resulted from the advent of aerial photographs of overseas territories and the establishment of the Directorate of Colonial (Geodetic and Topographic) Surveys, under Brigadier Hotine, with the task of producing topographic maps from these photographs. Geologists are thus relieved of much of their topographical mapping and eventually they should be free to concentrate with increased speed and accuracy on the geological side of their work. In this respect, however, the period under review has been one of transition, as considerable time must elapse before topographic maps can be made available for all parts of the Colonial territories. Increasing numbers of "preliminary plots", or uncontoured sheets showing some of the main topographic detail in true plan position together with photographic centres, are, however, now being issued at scales of 1 : 50,000 and 1 : 125,000, and use is being made of "print lay-downs", or uncontrolled photo mosaics at reduced scales, in areas not yet mapped; moreover, the individual aerial photographs are available for the use of field geologists. It may therefore be said that, next to the great increase in geological staffs, the topographic mapping programme of the Colonial (Geodetic and Topographic) Surveys has become more and more responsible for the increased rate of geological mapping in Colonial territories during the period reviewed.

Some salient facts relating to the progress of geological mapping are given below, more detailed information being given under the appropriate sections dealing with the individual countries concerned. In Kenya, for instance, 17,790 sq. miles had been geologically mapped on various scales prior to 1947, but since then a further 58,470 sq. miles has been covered and the published reports have usually been accompanied by coloured geological maps on the scale of 1 : 125,000. During this period of more extensive mapping, the succession and structure of Jurassic and Cretaceous sediments in north-east Kenya and of Karroo to Recent sediments near the coast have been proved. Indications have also been found that the coastal Karroo extends downwards into the Carboniferous and that the lowest beds, possibly of Ecca or Dwyka age, may be concealed by faulting. In many parts of the country the succession and complex structures of the Basement Rocks have been studied, and some success has been attained in unravelling some of the numerous problems they present. In western Kenya the mapping of the known goldfields has been completed in reasonable detail, and several carbonatite complexes have been mapped including that discovered by the Geological Survey at Mrima Hill in Coast Province.

In Uganda, 7,100 sq. miles had been geologically mapped on scales of 1 : 50,000 or larger before 1947, most of the territory being examined by reconnaissance traverses along roads and tracks; various unpublished geological maps had also been prepared on a scale of 1 : 250,000. In 1950, a

systematic programme of geological mapping was begun on a scale of 1 : 50,000 and an additional 16,500 sq. miles had been mapped by the end of 1956, largely as a result of staff increases and the availability of air photographs and preliminary plots. This mapping has revealed the structure, petrology and mineralogy of carbonatite complexes in eastern Uganda, and has enabled the character and disposition of Basement Complex rocks in Karamoja and in West Nile to be plotted. It has shown the widespread occurrences and varied relationships of the charnockitic rocks of West Nile. The distribution and mutual relationship of granitic rocks and metasediments in central Buganda have also been determined and correlated with the Karagwe-Ankolean of the type area. Further data have been gathered concerning the character of the Plio-Pleistocene sediments of the Albert Rift depression, and an investigation has been made of the general structure and lithology of the Ruwenzori Mountains. The economic mineral deposits of south-west Uganda, notably tin, wolfram, columbite-tantalite, beryl and bismuth, have been studied in detail.

The Geological Survey of Tanganyika was established at the end of 1925, and had already made considerable progress with geological mapping before the beginning of the period under review. Thus a reconnaissance of the Lupa, Musoma and south-west Mwanza goldfields had led to the publication of results that stimulated intensive prospecting and exploration. Geological reconnaissance mapping had further revealed the presence of large deposits of coal in the Ruhuhu area in the south-west, and the possibility of mineral development in the west had attracted mining companies there. Important extensions had also been shown to occur in the mineral fields previously known, as for instance in the Karagwe tinfield, the Singida goldfield, the Uruwira mineral field, and the mica deposits. In 1947, however, the Geological Survey began to expand, greatly assisted by funds provided under Colonial Development and Welfare Acts; accelerated progress in geological mapping thus became possible and is described elsewhere in this review.

There was no Government geological organisation in Northern Rhodesia prior to July, 1950, but the British South Africa Company and associated mining companies and concession holders had done much geological reconnaissance and prospecting between 1926 and 1940 which had led to outstanding success with mineral developments. Geological investigation on this earlier scale was, however, suspended for some time during World War II. The Government Survey came into being in July, 1950, and became a Geological Survey Department under its own Director in January, 1952. It has conducted geological mapping in two main regions, namely, the Zambezi Valley and the Mumbwa District, the former including the valley proper in the Gwembe District and its flanks and the plateau up to the railway line in the Mazabuka and Choma Districts. In 1956, regional mapping was extended to the Eastern Province east of the Luangwa River. At the time of writing a total of 6,000 sq. miles of country has been covered. A small amount of other geological mapping has also been done in connection with special projects as, for example, the Kafue Gorge hydro-electric project, the investigation of ring structures or carbonatites, and limestone exploration. In the course of this mapping, material contributions to the geological knowledge of the territory have obviously been made, for they include the establishment of the Karroo succession in the Zambezi Valley on the Northern Rhodesian side and its correlation with the Southern Rhodesian succession; the recognition of a glacial stage at the base of the Karroo, which establishes for the first time this most northerly extension of the Dwyka glaciation; the discovery of Dinocephalian remains in the Karroo of the Zambezi Valley; the identification of a carbonatite and associated minerals near Isoka in Northern Province, and the discovery of a new phosphate mineral,, isokite; the discovery of a group of carbonatites in Feira District; the working out of the succession and structure in the Katanga System in the Mumbwa-Lusaka District, and the demonstration of granitisation at the base of the Katanga System and the post-Katanga age of certain granitic intrusions. Limited advances were possible in regard to correlation over inter-territorial boundaries, but much remains to be achieved in this direction.

The original geological survey of Nyasaland was made in 1906–09 by A. R. Andrew and T. E. G. Bailey on behalf of the Imperial Institute, and later, from 1921 onwards, a small staff continued the work under the direction of Dr. F. Dixey; these early investigations laid the foundations of our knowledge of the geology and mineral resources of the Protectorate. An increase of staff during the 10-year period has enabled systematic geological mapping to be started in Southern Province, and this is being maintained except when interrupted by the need to direct staff to special investigations in other parts of the Protectorate. A large part of southern Nyasaland has now been mapped geologically on the scale of 1 : 50,000, much valuable light being thrown on the nature, succession and structures of the Basement Rocks in this area.

In the Somaliland Protectorate, geologists were attached to Water Supply Schemes and to Boundary Surveys prior to 1947 and to the General Survey from 1943 to 1950, and geological maps of some areas were made. In addition, oil company geologists mapped most of the areas of sedimentary rocks between 1922 and 1948. The Government Geological Survey started in April, 1952, with the primary object of mapping the Basement Rocks and following this up in more detail when minerals of economic importance were found. Of approximately 8,000 sq. miles of Basement outcrops, the preliminary geological mapping of about 7,000 has now been completed as well as that of some areas of adjacent sedimentary rocks. Preliminary plots on the 1 : 125,000 scale are becoming available, and in the light of these and the complete air-photograph cover provided by the Directorate of Colonial Surveys it is apparent that some revision of previous work is necessary. All geological mapping, however, is now being carried out with the aid of air photographs in the field and subsequent plotting of the 1 : 125,000 maps.

Mr. E. J. Wayland, formerly Director of Geological Survey in Uganda, was appointed to the Public Works Department of the Bechuanaland Protectorate in 1943, and began a general geological survey with a view to the development of mineral resources and water supplies. A separate Geological Survey Department was founded under Mr. Wayland in 1948, and a reconnaissance geological map of Bechuanaland was published with the Department's Annual Report for 1953. Some detailed geological mapping was done in potential coalfield areas, at the Moshaneng asbestos mine, and near Lobatsi. In 1954, geological mapping began on a scale of 1 : 125,000 with print lay-downs as a topographic basis. At the end of 1956, seven quarter-degree sheets had been completed and seven were in hand. A new provisional geological map of the Protectorate was published in the Annual Report for 1955. The strati-graphical succession of the rocks of the Protectorate has been worked out and correlated with that of neighbouring territories.

Government geological investigations in Swaziland began in 1942, most of the work until 1947 being connected with mineral development.

By that time some 217 sq. miles of territory had been mapped geologically at scales from 1 : 20,000 to 1 : 50,000, but from 1947 to the end of 1956, the area mapped had increased to about 5,200 sq. miles, with less than 1,300 remaining to be completed.

Official geological surveys in Nigeria began in 1903, their results being published between 1906 and 1914 as " Colonial Reports—Miscellaneous."

Later, in 1919, the Geological Survey Department was instituted, but a large part of the staff prior to 1947 was engaged on mapping economic mineral deposits so that comparatively little regional mapping was possible. Some systematic basic geological mapping, however, was carried out early in the 10-year period 1947 to 1956 which included one half-degree sheet on the Ilesha goldfield, four in Kabba Province, and a half-degree sheet in Bamenda Province of the Southern Cameroon. By the end of 1955, three degree sheets on a scale of 1 : 100,000 had been completed on sediments in the Gongola and Benue valleys in north-eastern Nigeria, and work was in progress on a fourth. Mapping

is at present proceeding in the area north of Zungeru, comprising parts of Niger, Zaria and Sokoto Provinces, also on the Abeokuta and Lagos sheets, and in a large area around the Niger-Benue confluence. In addition, nine quarter-degree sheets are being mapped on a scale of 1 : 50,000 in the Plateau Tinfields. In the Gold Coast, a reconnaissance geological map of the whole territory had been completed before 1947 and detailed maps of the goldfields had been prepared and Bulletins and Memoirs published. With the exception, however, of the Tarkwaian rocks, which constitute a comparatively straightforward series, little had been done to subdivide and classify the sedimentary, metamorphic and igneous rocks of the pre-Cambrian.

Some progress in this difficult task has since been made and should become more rapid when the remaining staff vacancies are filled with field geologists with good petrological training. The systematic mapping so far completed has disclosed indications of copper and asbestos which will be further investigated.

The first Government Geological Survey of Sierra Leone began in 1918 and ended in 1921, and a geological map was published. Geological Survey work was resumed in 1926, and before 1947 some provisional geological maps had been prepared on scales of 1 : 1,000,000 and 1 : 250,000. During the period 1947–1956 rather more than 2,000 sq. miles were geologically mapped in various districts and on scales varying from 1 : 63,360 to 1 : 5,000.

In the Federation of Malaya geological mapping began as long ago as 1903. Several editions of a geological map of the peninsula and of the neighbouring islands had been published prior to 1947, and for many years most of the geological mapping was based on topographic maps on a scale of one inch to a mile. The systematic geological mapping carried out from 1947 to 1956—particularly during the latter half of the period when the number of field geologists had been increased—has added greatly to the knowledge of Malayan stratigraphy. The areas of Triassic sediments are now known to be smaller than previously mapped, and proof has recently been obtained of the presence of rocks of Ordovician and Cambrian age in the north-western part of Malaya and the adjoining islands.

The Geological Survey Department of the British Territories in Borneo was established in 1949 to operate in Sarawak and North Borneo, and, when required, in Brunei. Geological information of the territories had previously been restricted to unpublished reports and maps, most of which were based on exploration results of the Shell group of oil companies. " The Geology of the Colony of North Borneo " by M. Reinhard and E. Wenk, published with geological maps in 1951, was based on such work. The Geological Survey Department has lately published geological maps covering 7,300 sq. miles of country on a scale of 1 : 125,000, and surveys of a further 22,500 sq. miles are in progress. The Department's geological mapping has thrown much new light on the geological history of the territory.

Mr. E. H. Jaques served as Senior Geologist in Aden from January, 1951, until the latter part of 1952. Little systematic geological mapping could be done because of the lack of a reliable topographic map, but advice was given on underground water supplies. The Geological Survey was closed down when it had shown that there was no likelihood of metalliferous ores occurring in economic quantity. Such advice as is required about water supply has since been given by the Directorate of Colonial Geological Surveys.

Prior to the inauguration of the Government Geological Survey in Cyprus in 1950, the Geological Section of G.H.Q. Middle East had published a geological map in 1940 on the scale of 4 miles to an inch. Some results gathered during oil exploration were published in 1949 in the " Quarterly Journal of the Geological Society " in a paper by Messrs. Henson, Browne and McGinty entitled "A Synopsis of the Stratigraphy and Geological History of Cyprus." In addition, various papers and maps had

been published by other geologists who had visited the island from time to time. From 1950 to the end of 1956 the Geological Survey, however, has concentrated on mapping the complicated geology of the Troodos igneous massif on a scale of 1 : 5,000, and an area of more than 400 sq. miles has so far been completed. The work is designed to assist in an assessment of further mineral potentialities. Three adjoining areas are also being mapped, and work on a fourth, where sedimentary rocks are dominant, has recently been started in connection with water supply and agricultural development.

The first geological map of British Guiana was made by C. B. Brown and J. G. Sawkins from information gathered during their traverses of the principal rivers between the years 1867 and 1873. The late Sir John Harrison was appointed Government Analyst and Geologist in 1889, and, with assistance, he made more detailed studies of rocks and soils until his death in 1926. Geological maps were published in 1908, 1913, and 1924 respectively under his direction. Then followed a considerable amount of reconnaissance geological mapping by a number of geologists between 1925 and 1947, and the resulting mineral developments showed that a larger Geological Survey Department would probably be a powerful factor in hastening the development of the interior. Despite recruiting difficulties and other adverse conditions, the programme of geological mapping and prospecting has since progressed at an accelerated pace, and has been extended to include the Cuyuni and Mazaruni river basins, the Pakaraima Mountains and the bauxite areas of the coastal plains. Great assistance is being given by air photographs and aerial survey maps which are becoming increasingly available.

Notes on the geology of British Honduras appeared in reports written as early as 1879, but the first geological map of the Colony was produced as the result of a survey by the late L. H. Ower between the years 1922 and 1926. A Government geological survey of the southern half of British Honduras was carried out between 1950 and 1955 by the Senior Geologist of British Guiana, who was,seconded for that purpose. He also conducted a water-supply survey in the country north of the Maya Mountains which is likely to prove of considerable value in relation to agriculture and rural settlement. An oil company has carried out extensive exploration since 1951; drilling operations began in 1955 and ceased in August, 1956.

In Jamaica, prior to the 10-year period under review, many geologists had made investigations, and indeed as early as 1827 Sir Henry Thomas de la Beche had published " Remarks on the Geology of Jamaica ", with a map of the eastern portion of the island. Later, in 1869, " Reports on the Geology of Jamaica " by J. G. Sawkins were published with a geological map. Various reports by other geologists followed, and C. A. Matley undertook a geological survey of the island between 1921 and 1924 for economic purposes, chiefly in connection with water supply. H. E. Hose, in 1950, gave a very useful account of the geology and mineral resources of Jamaica (Colon. Geol. min. Resour., Vol. 1), and described the discovery of the large deposits of bauxite in the island. The present Government Geological Survey was inaugurated in 1949, and by the end of 1956 approximately 3,057 sq. miles of territory had been mapped geologically, largely in connection with urgent requirements for the development of underground water-supplies. This mapping, coupled with the information gained elsewhere by reconnaissance surveys, has enabled a provisional geological map of the whole of Jamaica to be prepared on a scale of 1 : 50,000. Mineral occurrences discovered in the meantime have aroused the interest of mining companies, and an oil company has embarked upon an intensive search for oil. The importance of geological work in Jamaica in the successful development of underground water-supplies is so apparent that a hydrologist from the United States Geological Surveys' Groundwater Branch has been seconded for six months to the Department under the auspices of the United Nations Technical Assistance Administration. He will supervise a survey of underground water-resources in certain areas of the island and, with the experience so gained, the Department will be able to set up a permanent hydrological service.

Geological surveys were made in the Leeward Islands between 1951 and 1956 by a geologist

seconded from British Guiana, and resulted in water supplies from underground sources being considerably improved. Drilling is proceeding in Antigua. Similar duties have now been taken up by the same officer in the Windward Islands.

The first official geological survey of Trinidad was made by P. G. Wall and J. G. Sawkins of the Geological Survey of Great Britain, and their report was published in 1860. Later, between 1904 and 1907, some papers by E. H. Cunningham Craig were published by the Government of Trinidad. Apart from the work of these authors, most of the geological investigations on Trinidad have been conducted by the staffs of the oil companies; indeed, it seems probable that in no other area of comparable size in the world have they done so much geological survey work as in the southern part of this island, where the geology is exceedingly complex. It was realised that a correct interpretation of the great accumulation of geological data could be of material assistance, in developing the reserves of oil, and a Government geologist was therefore appointed for the period from 1949 to 1951 to compile a geological map from all available sources of knowledge. The map was duly completed and is available for consultation at the Directorate in London: it differs in certain minor respects from that already published by Dr. H. H. Suter (" The General and Economic Geology of Trinidad, B.W.I. "; Colon. Geol. min. Resour., Vols. 2 and 3, 1951 and 1952). It is understood that the oil companies have decided to finance the writing of a full and comprehensive volume on the geology of Trinidad, which will be awaited with interest.

A Government Geological Survey was founded in Fiji in 1951, but, owing to illness and the pressure of other important work, there were long interruptions in its programme of geological mapping. Valuable work was nevertheless done, and between 1952 and the end of 1956 approximately 660 sq. miles in Viti Levu were mapped on scales varying from 1 : 15,840 to 1 : 633,600.

The Government Geological Survey in the British Solomon Islands Protectorate began with one senior geologist in 1950; two additional geologists were appointed at the end of 1953, and the programme of geological mapping was further helped by two expeditions of experienced geologists from the University of Sydney. Geological mapping has taken place in Guadalcanal, Ysabel, Florida, Malaita, San Cristoval, the Shortland Islands, and the Santa Cruz group. A great deal of valuable knowledge has been gained, and it has been shown that the economic mineral possibilities are good.

Mineral investigations

If attention now be directed only to mineral investigations, it will be seen that important results have been achieved during the 10-year period under review. With due allowance for the earlier work of the Geological Survey Departments in the various territories overseas, the Colonial Geological Surveys have been directly or indirectly responsible for the discovery and/or preliminary investigation of the following major mineral deposits now in production or approaching production: the Sukulu apatite-pyrochlore, the Busumbu phosphate, and the Kilembe cobalt-copper of Uganda; the columbite in weathered granites of Northern Nigeria, and the lead-zinc deposits of south-eastern Nigeria; the ilmeniterutile of Sierra Leone; the manganese of British Guiana; the gypsum of Jamaica; and the manganese of Fiji. Other deposits now under active investigation by mining companies with a view to production include a number of East and Central African carbonatites containing apatite, niobium and rare earth minerals, and vermiculite—particularly Sukulu in Uganda, Mrima in Kenya, Mbeya and four others in Tanganyika, Nkombwa in Northern Rhodesia, Chilwa Island, Tundulu and Kangankunde in Nyasaland; also gypsum in the Somaliland Protectorate, ilmenite-rutile in southern Nyasaland, and bauxite in Sarawak. Other major deposits of potential importance are the coals of Tanganyika, investigated by the Colonial Development Corporation, and those of Northern Rhodesia, Bechuanaland, Swaziland, and Sarawak; iron ores in Tanganyika, the Gold Coast, Swaziland, and Jamaica; and the niobium- and uranium-bearing pyrochlore-granite of Northern Nigeria. Moreover,

the Geological Surveys have played an essential part in the establishment of cement industries in all the East and Central African territories as well as in Nigeria. The actual and potential values of these major deposits—apart from many smaller deposits—and their importance in the general development of the territories in which they are situated clearly far exceed the sums, including about £2½ million from Colonial Development and Welfare funds, spent on the expansion of the Colonial Geological Surveys since World War II.

The main mineral discoveries in Kenya before 1947 were gold, graphite, and kyanite-bearing rocks, but during the course of mapping carried out since 1946 numerous other deposits have been investigated and several new ones discovered. Many are small—or so placed as to have no apparent economic interest at present—but others may be of immediate value, as for instance the pyrochlore-monazite occurrences of the carbonatite centres, and the deposits of kyanite, asbestos, graphite and bentonitic clays. Other discoveries include deposits of copper, zinc and chromite ores, magnesite, talc, fluorite, mica, sillimanite and wollastonite. Considerable attention has also been paid to the mapping of possible oil-bearing areas with the result that some oil companies have carried out preliminary examinations of part of north-east Kenya. More work, too, has been carried out in south-east Kenya where a large oil combine took out a licence in 1954 to explore for oil.

In Uganda, during the 28 years of investigations by the Geological Survey prior to 1947, the Department had discovered the mineralised areas of the south-west where cassiterite, wolfram, columbite-tantalite, beryl and bismuth are mined; those of the south-east, where gold, pyrochlore, apatite, vermiculite and iron ores occur; those of central Buganda with wolfram, bismuto-tantalite, gold and amblygonite; and those with mica and asbestos in the northern part of the Protectorate.

Since then, a detailed examination of the carbonatite rocks of Tororo and Sukulu has led to the establishment of a cement factory, and more than 200 million tons of apatite/pyrochlore-bearing material has been proved in residual soils overlying the carbonatite at Sukulu. Commercial interest is being shown in the production of vermiculite from an extensive deposit at Namekara and Busumbu, and phosphate rock is in commercial production. The copper-cobalt deposits at the Kilembe Mine have reached the production stage.

In Tanganyika, mineral exploration has always been one of the main functions of the Geological Survey, and, as already indicated, geological mapping prior to 1947 was primarily undertaken in the various mineral fields with this end in view. During the 10-year period 1947 to 1956 an increase in staff enabled the work to be intensified and also the setting up of a special Mineral Exploration Organisation within the Geological Survey Department, the main achievements in this field being concerned with the coal and iron deposits in the south-west and the pyrochlorebearing carbonatites in various parts of the territory. During this period the detailed prospecting of the coal resources was taken over by the Colonial Development Corporation. At the time of writing, the Department's Mineral Exploration Team is drilling the titaniferous magnetite deposits north of the Ruhuhu coalfields in Njombe District. Seven carbonatites have been located, and that at Panda Hill, west of Mbeya in the south-west, having been examined by surface prospecting and diamond drilling, is now under investigation with a view to development by the Billiton Company in association with the Colonial Development Corporation. Four of the other carbonatites are being examined by mining companies. Other investigations include the location of adequate reserves for cement manufacture and studies of occurrences of mica, vermiculite, graphite, gypsum, tin, wolfram, gold, copper, kyanite, magnesite, meerschaum, garnets, kaolin and clays.

The geological investigation and prospecting by mining companies and concession holders in Northern Rhodesia resulted in the establishment of that country's very productive and valuable mining industry prior to 1947. The Government Geological Survey, founded in 1950, has, however, made a number of important mineral discoveries, including pyrochlore, monazite and apatite in the

carbonatite of Nkombwa Hill, Isoka District, and some 25 to 30 million tons of coal in the main seam of the Kandabwe coalfield.

In Nyasaland the Geological Survey had, prior to 1947, discovered large deposits of bauxite on the Mlanje Plateau, and a number of other mineral occurrences. Its investigations included a study of the Chilwa Series of southern Nyasaland, which led to the first standard work on carbonatites in Africa. During 1947 to 1956, rare-earth phosphates and niobium minerals were found to be associated with the carbonatites, and mining companies took up Exclusive Prospecting Licences over Kangankunde Hill, Tundulu Hill and Chilwa Island. The Tundulu carbonatite contains a rich deposit of apatite. The following mineral deposits are also under active investigation by mining companies: the ilmenite-rutile of the Port Herald hills, the monazite sands of the southern shores ofLake Nyasa, various radioactive minerals in the Tambani area, the kyanite of the Kirk plateau, and the vermiculite of Middle Shire.

In Somaliland, although considerable exploratory work was done by oil companies before 1947, the search for oil has been resumed during the period under review. Since the Government Geological Survey began in 1952 a number of small mineral discoveries have been examined. At present, however, apart from oil, the most hopeful prospect of mineral production lies in the millions of tons of gypsum and anhydrite to be seen within 9 to 25 miles of Berbera harbour.

In Bechuanaland, prior to 1947, the Bushman Copper Mine had been in operation and abandoned, and few other mineral occurrences were known. Since it was founded in 1948, the Geological Survey has investigated and helped in the development of various mineral deposits, including the Moshaneng asbestos and a kyanite deposit in the Tati Concession. A geological and geophysical survey of the Bushman Mine was completed in 1954, and a mining company has applied for a concession there. Mining companies are also interested in the discovery, made by the Geological Survey, that nickel is associated with the copper deposits at Magogaphate in the north-eastern Bamangwato Reserve. The potential coalfield areas in the Protectorate are being investigated, and a very large tonnage of medium-quality coal is already indicated near the line of the Rhodesia Railways.

The search for minerals in Swaziland began more than 60 years ago, and gold lodes were mined with varying success for many years. Production stopped in 1952, but a mine has recently been reopened. Alluvial tin ore was also obtained in considerable quantities in the past, but production is smaller now, and takes second place after asbestos in the value of mineral exports. The total value of Swaziland's mineral production has increased almost threefold since the beginning of the 10-year period, largely because of an increase in the price of asbestos.

Mineral surveys were inaugurated in Nigeria as early as 1903 and led to the discovery of coal in Onitsha Province, iron ore in Lokoja, and lead-zinc ores at Abakaliki. Following these surveys the Geological Survey was founded in 1919, its main task being the systematic study of mineral deposits. During the period from 1947 to 1956 new discoveries of coal have been made and tested by drilling, and total reserves are now estimated at 240 million tons. The Geological Survey has proved the presence of considerable amounts of ironstone, and has assisted a mining company in an examination of the lead-zinc lodes at Abakaliki. The discovery of columbite in a particular type of biotite-granite on the Jos Plateau has led to mining in the weathered zone. The Department has co-operated with oil companies in their search for oil.

The Geological Survey Department of the Gold Coast was founded in 1913, and from that time up to the beginning of the period under review (1947) had discovered valuable deposits of manganese, alluvial diamonds and bauxite by rapid reconnaissance traversing. The small staff had also been much concerned with the development of the gold mining industry. Promising results have since

come from a number of mineral investigations carried out during the period 1947–1956. Geological mapping of haematite beds in a quartzite series of the Buem Formation has indicated that 80 million tons of ore, containing about 70 per cent. Fe203, are available at 30 miles distant from the water transport which is likely to be developed when the projected Volta Lake is formed. A complete appraisal of limestone resources has been made. Core drilling is being carried out in the Western Region to trace the extension of the manganiferous zone of the Birrimian, and in the Eastern Region the discovery that nickel is associated with sulphides in a sill of basic rock is also being tested by drilling. Drilling in the Birim diamond field has located a breccia-conglomerate that appears to be the source-rock of the diamonds; the rock is weathered to a considerable depth, and the weathered zone is regarded as payable. Continued progress is being made in the evaluation of alluvial diamond areas. Other mineral investigations include possible sources of kyanite, andalusite, ilmenite and monazite. The Gulf Oil Corporation is now engaged on a programme of test-drilling the Cretaceous rocks of the western littoral as a result of information supplied by the Geological Survey.

In Sierra Leone, the Government Geologist discovered the Marampa iron ore deposit in 1926, as well as gold and platinum. Discoveries were subsequently made of iron ore at Tonkolili, chromite near Hangha and Senduma, and further deposits of alluvial gold and diamonds. From 1947 to 1956, with increased staff; the Geological Survey has been able to step up its programme of surface prospecting and drilling, with the result that a number of mining companies are now busy prospecting.

The largest tin mining industry in the world had been established in the Federation of Malaya long before Government Geological Survey work began, and the industry still continues to be the world's biggest producer, in spite of many years of depletion of reserves. Mining companies and prospectors have, however, received considerable assistance in their search for new deposits by the mapping operations of the Geological Survey which began in 1903. Areas where prospecting is most likely to yield profitable results are being marked out. A total cessation of prospecting occurred during the first Tin Restriction Scheme, then before and during World War II, and again for some years when the " Emergency " followed. As soon as full-scale prospecting can be resumed by the many mining companies, it is hoped that the accelerated rate of geological mapping which is now in progress will play a vital part in the search for reserves. Aeromagnetic and air-borne radiometric surveys are shortly to be carried out over one-third of the territory by arrangement under the Colombo Plan.

Extensive geological investigations had been conducted by oil companies in the British Territories in Borneo before 1947, and these led to the establishment of the important oil industries of Brunei and Sarawak. Investigations were originally concentrated on those areas of stratified rocks where oil deposits might be expected to occur, but they are now being extended to those underlying the sea off the shores of Sarawak and Brunei. A search for other minerals had also been made by a number of mining companies, and small amounts of coal, gold, antimony and manganese had been produced. The Government Geological Survey Department was set up in 1949 with the principal task of mapping geologically those areas of non-petroliferous hard rocks in which metalliferous ore deposits, among other useful minerals, might be found. The Survey soon discovered deposits of bauxite, and a company is now investigating these with a view to production.

The work of Government geologists in British Guiana had been an important factor in the establishment of a mining industry long before 1947; indeed, the beginning of an interest in the bauxite deposits of the country can be traced to the discovery by Sir John Harrison in 1910 that this mineral occurred in the Demerara area. Subsequent work by other geologists showed that there were strong possibilities for the development of other mineral deposits, and the work of the Geological Survey became an important factor in the commencement of mining by British Guiana Consolidated Goldfields. There has been a considerable increase in the geological staff during the 10-year period after 1946, with a corresponding stepping up of exploration. Various companies are now prospecting in the territory, and plans are in hand to commence the mining of manganese ore

within the next few years.

Prior to 1947, investigations by several geologists in British Honduras revealed the presence of small occurrences of tin ore and monazite, and gold had been found, but none appeared to be of economic importance.

From 1947 to 1956 a Senior Government Geologist has investigated them thoroughly and has confirmed that none of the known occurrences is worth developing. An oil company has conducted geological and geophysical surveys in areas of sedimentary rocks, but drilling operations, as previously indicated, ceased in August, 1956.

From very early days there has been considerable interest in the mineral resources of Jamaica, and small copper mines were worked in the first half of the nineteenth century. The first really important mineral discovery, however, was made in 1942, when it was found that the red ferruginous earth which is common in White Limestone districts is bauxitic. Large-scale mining operations began in 1952. The present Government Geological Survey Department has operated since 1950, and has discovered deposits of high-grade iron ore in eastern St. Andrew and Portland; it has also estimated the reserves of gypsum by mapping and diamond drilling, and has advised on oil exploration, one test hole having already been drilled. A company has now embarked on an extensive geological and geophysical programme with a view to further test drilling.

The conclusion reached by the Government geologist in the Leeward Islands from 1952 to 1956 was that the only mineral prospect holding immediate promise is the copper-molybdenum mineralisation of Virgin Gorda, British Virgin Islands.

Gold mining in Fiji was carried out on a small scale in Vanua Levu for many years, and indications found by a prospector in 1933 led to the discovery of the important deposits of the Tavua field on Viti Levu, where a flourishing gold mining industry became established. Prior to 1947 no other minerals were mined. Small quantities of manganese were mined in 1950, and the Geological Survey has since played an important part in advancing this new mining industry.

Mining has not hitherto been carried out in the Solomon Islands Protectorate, although the mineral possibilities are considered promising. Favourable results have so far been achieved by the small Geological Survey Department which has operated there for the last six years, and has discovered gold-bearing bodies in Guadalcanal which are now being examined by an important mining company.

Engineering geology and water supply

During the 10-year period under review the Geological Survey in Kenya has given assistance in matters concerning hydro-electric schemes, bridge abutments, dams, the subsidence of buildings, aerodrome surfaces, harbour extensions, the making of new roads and marine erosion, and the Department has also been called upon to advise on the starting of two cement industries. The geologists of the Hydraulic Branch of the Public Works Department have been continually engaged in the siting of water supply boreholes. The Geological Survey in Uganda has also examined the sites of three major engineering projects, the Katonga River dam and tunnel, the Owen Falls hydro-electric scheme, and another hydro-electric scheme four miles down-stream from Owen Falls. The siting and drilling of water boreholes became a responsibility of this Department in 1937, and 4 departmental and 8 contractor rigs were in use by the end of 1946, but by 1956, there were 6 departmental and 25 contractor rigs continuously at work in rural areas. In 1946 the number of boreholes drilled was 104, giving a total footage of 16,000; by 1955, however, the number had risen to 248 with a footage of over 80,000, the rate of success remaining at about 85 per cent. In

Tanganyika, materials for the manufacture of cement have been found, and various companies are now interested. The Geological Survey has also investigated numerous dam sites in connection with irrigation projects and hydroelectric supplies.

The Geological Survey Department in Northern Rhodesia made investigations at a dam site in the Kafue River for a hydro-electric project and assisted with the Kariba scheme. It helped also to locate reserves of limestone for a cement factory. The geologists and geophysicists of the Water Development and Irrigation Department have been continuously employed in siting water boreholes. In Nyasaland, materials suitable for the manufacture of cement were located and sampled, and geological surveys of dam sites were made in connection with the Shire Valley Project. The Geological Survey in this territory is in charge of the development of rural water supplies.

In Bechuanaland, the Geological Survey has been responsible since 1943 for selecting borehole sites for water-supply development, and in Swaziland, too, the Geological Survey has given advice on various engineering problems and has sited a number of boreholes for underground water-supply.

In Nigeria, advice has also been given on many occasions regarding the suitability of foundations for bridges and major construction projects, and one of the principal functions of the Department is concerned with the geological aspects of water supply.

During the greater part of the period between 1947 and 1956, most of the staff of the Geological Survey Department in the Gold Coast has been engaged in work connected with various development projects. Detailed geological investigations of the great Volta River Project took two geologists four years to complete. Detailed geological mapping with core-drilling was completed for the proposed Bui hydro-electric scheme. Other work was in connection with the design and construction of the new harbour at Tema, extensions to Takoradi harbour, foundations for the 800-foot single arch suspension bridge across the River Volta, routes for new railways, sites in Accra where earthquakes are experienced, and sites at Takoradi where problems arise because sandstone beds are liable to slide on certain sulphurous shales. A water-supply section of the Geological Survey was started in 1937, but lapsed in 1942 after constructing numerous wells, dams and ponds in the Northern Territories. During the period under review the Geological Survey has again been much occupied with the development of water supplies; foundations for dam-sites for seven town supplies have been investigated and an intensive programme of boring for water began in 1953. Sixteen drills are now in operation, usually in gneiss terrain where weathered zones are located by electrical resistivity methods. During the last 12 months for which records are completed, April 1955 to March 1956, 157 wells were bored, 83 per cent. of which provided good rural supplies with an average yield of 1,780 gallons per hour. Usually the water is drawn from depths between 150 and 450 ft.

Valuable advice has also been given by the Departments concerned in Sierra Leone and the British Territories in Borneo, as shown elsewhere in this review, and in Cyprus a major task has been the re-siting of villages affected by the Paphos earthquake in September, 1953. In British Honduras, the Senior Geologist conducted a survey of underground water-supplies which should be of considerable value in relation to agriculture and rural settlement.

In Jamaica, a ground-water survey is being made with a view to increasing water supplies, particularly in drought-stricken areas. A hydro-geologist is now being provided by the United Nations Technical Assistance Administration for six months with a view to organising a permanent Hydrological Service. Already, many boreholes have been sited for the Irrigation and Drainage Branch of the Public Works Department, and for Sugar Estates, mining companies and property owners. Geological reports have been made in connection with many engineering projects including hydro-electric schemes. The water-supply investigations made by the Government Geologist in the Leeward Islands have already been mentioned, and the officer has been seconded to the Windward

Islands for similar work.

Several reports on engineering schemes have been made in Fiji by the Geological Survey, and, with the help of two officers from the New Zealand Department of Scientific and Industrial Research, the Survey has carried out a detailed investigation of the major earthquake of September, 1953.

Recruitment and staff changes

The considerable increase in the number of geologists, geophysicists and geochemists on overseas staffs during the 10-year period under review is shown by the following figures:

1947	1948	1949	1950	1951	1952	1953	1954	1955	1956
58	72	110	157	177	184	196	204	205	212

There are also some experimental officers, field officers, prospectors, records officers and technical assistants who are doing excellent work in various Geological Survey Departments, and experts are sometimes engaged for one year or less on special tasks in overseas territories, but none is included in the above totals. Since World War II, there has been a shortage of well-qualified geologists, geophysicists and geochemists, and as a consequence there are 39 vacancies in the Colonial Geological Surveys.

The rate of recruitment since 1947 has been as follows :

1947	1948	1949	1950	1951	1952	1953	1954	1955	1956
10	21	44	52	23	16	20	24	23	19

During 1956, some 43 geologist and chemist applicants were interviewed at the Colonial Office, others also being interviewed in other Commonwealth countries, and 19 were appointed. Of these, 10 had post-graduate experience, the remaining being new graduates; indeed, 1956 was the first year since World War II when more than half of the recruits had post-graduate experience. They were trained at the Universities or University Colleges of Aberystwyth, Birmingham, Durham, Glasgow, Leeds, London, Manchester, Reading and Swansea.

Competing with us in our continual need for geologists are the mining and oil companies, especially in Canada. The Universities, too, need additions to their staffs. On the other hand, the following table, which gives the numbers of Honours Graduates in Geology at the Universities of the United Kingdom for certain academic years, demonstrates how the output has fluctuated :

1938/39	1947/48	1950/51	1952/53	1953/54	1954/55
20	86	143	115	97 including 7 women	104 including 8 women

These totals include all classes of Honours Degree; for our geological appointments, however, the necessary academic qualification is 1st Class or 2nd Class Upper Division, so that the total numbers available for consideration must be reduced to between 50 and 60 per cent. of those shown. A comparison of the recruitment table with the numbers available from United Kingdom Universities

suggests that each year Colonial Geological Surveys have been taking somewhere between one-quarter and one-half of the number of suitably qualified geologists. A closer estimate is not possible, because our intake figures include geologists with post-graduate experience.

Economic Co-operation Administration Scheme

Under a United States Economic Co-operation Administration Scheme, 16 geologists, 2 mining engineers and 1 chemist were appointed during 1950 and 1951 to serve for periods up to two years with the Geological Survey Departments of Kenya, Tanganyika, Uganda, Nyasaland, Nigeria, Sierra Leone, the British Territories in Borneo, and British Guiana. Passages and some local expenses were defrayed from Colonial Development and Welfare funds, but the largest item, salaries, was paid by the Economic Co-operation Administration itself. These appointments had come during a period when the rapid expansion of Geological Surveys overseas had caused a rather unbalanced situation where there were too few senior officers to supervise the work of young geologists with but little experience; in most of the territories concerned the arrival of the E.C.A. geologists consequently helped to adjust this position. In this way the Economic Co-operation Administration gave supervisory help when it was most needed, and in a number of cases its field work gave valuable results. In Tanganyika, the services of the mining geologist were retained after the E.C.A. scheme had come to an end.

Photogeology and Geophysics

Photogeological Section

This Section was formed in 1949 as part of the Directorate to assist the overseas territories by providing a specialist service in photogeological work and to encourage them to make full use of aerial photographs in their geological mapping. The staff has increased from one in 1949 to five in 1956, and there is at present one vacancy in the establishment. The centralisation of topographic mapping in London in the Directorate of Colonial (Geodetic and Topographic) Surveys and the consequent availability of photographs and draughting and other facilities was an important factor in the decision to house the Section with Colonial Surveys now at Tolworth. In addition to its main work of photogeological interpretation the Section constitutes a valuable liaison between the overseas Geological Surveys and Colonial Topographic Surveys in respect of mapping programmes, the provision of map substitutes such as print lay-downs, and the production of special maps for particular purposes.

The Section holds annual courses in photogeology for newly recruited geologists and for officers who are on leave from the overseas Geological Surveys. The geological interpretation of aerial photographs is a subject not at present included in many University geological courses, and since the Photogeological Section began giving such instruction it has been asked by the Imperial College of Science and Technology and by other colleges of London University to give special lectures on this subject to their geological students.

The photogeological interpretation work of the Section has included both reconnaissance studies of large areas and the detailed mapping of smaller ones. Examples of the former include the photogeological study of parts of North Borneo which led to the recognition, subsequently confirmed in the field, of the presence of intrusive plutonic masses, and by similar studies in Sarawak where preliminary photogeological mapping formed the basis for the planning and routing of a subsequent field expedition. An example of a detailed study is the mapping at photo scale-1 : 30,000—of the Nkombedzi-Sumbu Karroo area in Nyasaland. In all these cases the rocks mapped are predominantly sedimentary, but the Section has also given considerable attention to the question of the

photogeological interpretation of areas of the ancient African metamorphic and igneous rocks frequently referred to as the Basement Complex, and this work has included studies of Somaliland, Nigeria and, more recently, of the Gold Coast. In addition, the Section has undertaken special studies, such as that concerned with the search for ring structures frequently found with carbonatites.

The Section keeps in touch with field work as far as possible, and visits have been made to North Borneo, Sarawak, Malaya, Nigeria and Somaliland. Field geologists while on leave from the individual territories have also spent time in the Section working on photographs of their field areas and in general discussion with members of the Section.

Geophysical Section

Development of the Headquarters' Geophysical Section has, unfortunately, been rather slow, for, although proposals for the formation of a small Section with two geophysicists were made as long ago as 1951, difficulties of recruitment delayed their implementation, and it was not until September, 1955, that the first geophysicist was appointed. The Section is now equipped with a Worden gravimeter and with twelve-channel portable seismic refraction apparatus, in addition to magnetic variometers, electrical resistivity, and self-potential apparatus. While the Section will probably be used mainly by those territories without geophysical facilities of their own, it will also be able, if requested, to assist in, or supplement, the work being done by Geological Survey Departments where facilities are already available. It is hoped in the latter cases that the availability of seismic and gravity equipment will be of particular benefit to the Geological Survey service.

The Section's first assignment has been an investigation by the seismic method of the headwater region of the Lupa River in Southern Tanganyika where the existence of buried drainage channels had been postulated in connection with the derivation of alluvial gold.

Although the Section, as such, has only recently begun its work, the Deputy Director (Geophysics) has advised individual surveys on geophysical matters from time to time and has carried out geophysical surveys and tests in Nigeria (1950), Aden Protectorate (1952) and Cyprus (1951). He also attended in Nairobi in 1952 a meeting of geophysicists from the East African territories arranged as a result of the 1951 Inter-Territorial Geological Conference of East Africa. Two other important geophysical matters with which the Directorate has been, and still is, concerned are the proposals for the setting up of a chain of seismograph stations in East Africa, and the establishment and progress of the work of the seismologist in the Caribbean Region.

Volcanic-seismic research

As indicated above, a project to study seismic and volcanic activity in the Caribbean Region was inaugurated in 1952 under the auspices of the Research Department of the Colonial Office. Its object is to collect information on the frequency and location of local earthquakes and on the activity of fumaroles in the volcanic islands, which will provide a basis for the prediction of future volcanic eruptions. The staff consists of a seismologist and three locally-recruited assistants, and a base office has been established in Trinidad where the interpretation of records from the seismograph network is carried out. Eight Willmore short-period seismographs, suitable for recording local earthquakes, are to be operated on a part-time basis by members of the staffs of various Government Departments.

Preliminary work was begun in November, 1952, by Dr. P. L. Willmore of the Dominion Observatory, Ottawa, and Mr. G. R. Robson, who is now in charge of the scheme. Seismograph stations have been set up in Trinidad, Grenada, St. Vincent, St. Lucia, Barbados, Dominica and Antigua, and one

additional station will be established in St. Kitts in the near future. Local earthquakes are now successfully recorded and epicentres determined, and monthly seismological bulletins have been issued since January, 1953. Measurements of the flow of volcanic heat from all the major fumaroles in the Windward and Leeward Islands were made in 1953, and such measurements have been repeated periodically.

No major outbreak of volcanic activity has occurred since the scheme began, but in October, 1953, submarine volcanic explosions took place a few miles north of Grenada, and, in December, 1953, volcanic gases reached the surface in a new locality in Nevis and have since led to the formation of a new fumarole area.

The Mineral Resources Division

The Mineral Resources Division of Colonial Geological Surveys was formed in April, 1949, by transfer of the Mineral Resources Department of the Imperial Institute to the Headquarters Organisation, thus widening considerably the Organisation's scope and effectiveness both in the field of mineral economics and in chemical and technological research. The acquisition of newer and more specialised equipment was necessary, however, before the Division could play its full part in providing a central intelligence and laboratory service for overseas Geological Surveys, but the period under review (1949–56) is noteworthy for the success attained to this end despite lack of adequate accommodation and extreme difficulty in recruiting specialist staff. The matter of accommodation has been given much attention in view of the fact that the Division will have to vacate its laboratories and offices in the Imperial Institute Building to make room for the expansion of the Imperial College of Science and Technology planned for the site in South Kensington. At the time of writing, it seems likely that the Division will be housed in Gray's Inn Road, near Chancery Lane station.

Throughout the period reviewed the Division has paid particular attention to carbonatite complexes and has done much to stimulate interest in these potentially economic deposits. In view of the discovery of large apatite deposits in the Bukusu complex in Uganda, and the occurrence there, as well as in similar rocks in Southern Africa, of magnetite and vermiculite, the Division suggested that, in the light of the few European occurrences, there were good reasons to hope that the African carbonatites might contain reserves of niobium, and it consequently offered to assist in investigating this possibility. The Uganda Geological ' Survey soon responded by sending some pyrochlore from the Sukulu carbonatite for detailed analysis, and, while the doubtful possibility of ' recovering modest amounts of this mineral as a by-product from cement manufacture was under consideration, the Survey made the welcome discovery of large reserves of pyrochlore, apatite and magnetite in the overlying red soils. This introduced new problems, especially the development of methods for mineralogical examination and chemical assays of the soil, which were vital both to the proving of the reserves and to the carrying out of ore-dressing trials, and a great deal of laboratory and advisory work was undertaken which helped to place the deposit in competent industrialists' hands in 1952. A member of the Division visited Nyasaland in 1951, and discovered pyrochlore at the three principal carbonatite complexes known there, together with some apatite rocks, and, at one centre, remarkable concentrations of monazite. This led to much work with the Nyasaland Geological Survey, and with mining companies who were granted prospecting rights in the following year. At this stage the promise of these mineral discoveries, coincident with high prices offered for niobium and the realisation that rare-earths could be made available to industry in large tonnages, greatly stimulated research in neighbouring territories. Northern Rhodesia's first carbonatite, with pyrochlore and monazite, was found near Isoka in 1952, the Tanganyika Geological Survey brought to light a number of carbonatite and pyrochlore occurrences in 1953, and the Kenya Geological Survey established very important reserves of niobium and rare earths in pyrochlore, monazite and

more unusual minerals at the Mrima carbonatite centre. Naturally some of the carbonatites that were examined were found to be of little economic interest. The Division's share in this work included another African field trip, close liaison with the African Surveys and with the Photogeological Section, some educational work and propaganda in this rapidly growing field, and above all, detailed and rather difficult mineralogical and chemical work. For example, while in some deposits the mineralogy is relatively simple, in others niobium may be distributed between pyrochlore, columbite, euxenite, niobian rutile, or fine-grained secondary complexes; various complex fluocarbonates of the rare earths may be present as well as monazite, and the chemistry may be complicated by an abundance of strontium or barium.

The early decision to issue a quarterly bulletin, " Colonial Geology and Mineral Resources ", as successor to the mineral resources section of the former " Bulletin of the Imperial Institute " has proved particularly fruitful. Within a comparatively short time, and with the support and encouragement of all Colonial Geological Surveys, this publication has made great progress and is to-day regarded as one of the major geological periodicals of the world. Many distinguished geologists continue to contribute to its pages, and the flow of important copy has increased to such an extent that an " over-spill " series of " Bulletin Supplements " has been authorised. At the time of writing, 22 bulletins, 33 separates and 1 supplement have been issued, making a total of 56 publications, or an average of 8 per year.

The Geological and Mining Section, because of its long experience with and wide knowledge of economic minerals, has continued to be regarded and used as a major source of information and advice on every aspect of the mineral industry, notably the nomenclature, nature, properties, production, treatment, testing, specifications, prices, tariffs, markets, uses, substitutes, and sources of minerals. Since its transfer to the Colonial Office, the nature and scope of its work has naturally been focused more on Colonial matters than formerly, although in order to gain a true perspective of the mineral industry it has been obliged to keep abreast of developments not only in the Colonial territories but also in the other Commonwealth territories and in foreign countries. Broadly, therefore, the nature of its work has continued to be much the same as that for which it has long been known, and its services have consequently been used not only by Colonial territories, but by many Government departments, High Commissioners' Offices, research and development departments of private firms, universities and private individuals. Close liaison with the overseas Geological Surveys has been a feature of the period, and an unprecedented number of staff home on leave from overseas have called to discuss developments and problems in the territories with which they are concerned. A much closer liaison with the officers of the Colonial Office has naturally also been built up during the period. The mineral index has expanded considerably in the last ten years especially in view of the return to circulation of many journals that had been suspended during the war, and because of the ever-mounting pace of the appearance of new books. The Section has experienced great difficulty in recruiting staff in the face of competition for geologists from mining, petroleum, engineering and cement-making companies. It has suffered severely from the loss by death and by resignation of experienced officers. It has not been possible therefore to build up to the strength required and during the whole period the Section has been below establishment.

Whilst the inquiry work and the publication of the quarterly bulletin has been carried out under these conditions of staff shortage the rate of output of mineral monographs, which must necessarily give way to more urgent work, has naturally suffered in consequence. A monograph on vermiculite has been published, and this, like its fifty predecessors, was very well received, the first edition being exhausted in a few months, so that a second printing was called for. Other monographs on gypsum, aluminium and bauxite, sillimanite and cobalt are in various stages of preparation.

The Mineralogical Laboratory of the Geological and Mining Section has proved an invaluable asset during the period under review, which has been marked by the acquisition of new equipment to

facilitate the examination of mineral and rock samples by modern physical techniques. A " Mottacutta " rock-cutting machine has replaced previous equipment for the preparation of thin sections, and amongst other adjuncts to the optical examination of minerals may be mentioned a Leitz five-axis universal stage, an automatic point counter for the modal analysis of rocks and particle counts, ultra-violet lamps, and modern refractometers. New equipment for the examination of polished sections of opaque minerals includes a Cooke "Metalore" microscope with a visual micro-photometer and an elliptical compensator, automatic polishing machine, and a metallurgical press for mounting the specimens in Bakelite. A Berman balance was imported some years ago from the United States for the accurate measurement of the specific gravity of small mineral grains, and, more recently, a Cook electromagnetic separator has been installed which permits the separation of weakly magnetic minerals differing but little in magnetic susceptibility. In view of the increasing importance of natural sources of the fissionable elements, all samples are now assayed radiometrically using a " Panax " ratemeter and lead castle. An X-ray set has been ordered and, on its arrival, the Mineralogical Laboratory should be able to undertake almost any mineralogical identification and prepare pure concentrates for chemical analysis.

The Chemical and Testing Section has carried out many analyses on a wide range of rocks and minerals, mainly on behalf of the overseas Geological Surveys. Some of the smaller surveys are without a chemist and have relied upon this service for the bulk of their chemical assistance, while others have sought help with some of their more exacting rock and mineral analyses. As a result, the work of the laboratory in recent years has been largely concerned with the more difficult problems of mineral identification and analysis, including those related to complex niobium, tantalum and rare earth minerals, and the determination of various elements in trace amounts. So as to satisfy this demand much new apparatus suitable for carrying out spectrographic, absorptiometric, spectrophotometric, polarographic and flame photometer determinations has been acquired, and much of the time of the staff has been occupied in modifying existing methods or devising new methods to meet special requirements. As an example of the latter, an improved absorptiometric method of determining niobium has been successfully introduced and has saved much time in the analysis of both high- and low-grade niobium-containing materials. Methods for the more rapid analysis of silicate rocks, which have been recently published, are being tried out and are being introduced after investigation has shown them to be reliable and sufficiently accurate. Eventually, it is hoped to be able to undertake appreciably more analytical work of this nature. With the increasing complexity of the geologists' requirements, a staff is required comprising a high proportion of experienced and highly-qualified chemists, with adequate space for the operation of their specialised equipment. Difficulties have had to be overcome due to the cramped accommodation of the existing laboratories and the difficulty in recruiting and retaining suitable staff. Apart from the analytical work of the Section, the ceramic laboratory has been fully occupied with the investigation of various clays intended for the manufacture of bricks, tiles and pottery, and small-scale trials have been made on the manufacture of portland and pozzolanalime cements. The volcanic ash deposits of St. Vincent have received particular attention and a scheme for a small unit to produce pozzolana-lime building blocks is under consideration. Every effort has been made to assist the Colonial Geological Survey staffs, especially the chemists, who have been welcomed when on leave and invited to discuss problems of common interest and in some cases to carry out short periods of practical work in the laboratories.

The work of the Statistical Section of the Mineral Resources Division has been of special importance during the period under review. Towards the end of the Second World War the Imperial Institute's Advisory Council on Minerals requested that publication of the " Statistical Summary of the Mineral Industry " should recommence and that the first issue should cover the war years. Owing to printing difficulties, the suppression of all statistics during the war, and the shortage of experienced staff, the first volume did not appear until 1948 and covered the period 1938–44, but by the following

year, *i.e.*, 1949, the second volume, covering the years 1941–47, had been compiled and published. Except for one year (1951) the Statistical Summary has appeared annually. In 1954 it was decided that monthly statistics of production of minerals in Colonial and Dependent territories should also be published, and to this end a new feature was included in Vol. 4, No. 3, of " Colonial Geology and Mineral Resources " giving this information, and up-to-date statistics have appeared regularly in subsequent numbers. Assistance is also given in the compilation of mineral and metal prices for that Bulletin. Statistics have been compiled and included in monographs already published and for those in preparation. In addition to the compilation of statistics for publication, information is supplied regularly to certain commercial organisations on a fee basis. Miscellaneous inquiries from official and unofficial sources are constantly being dealt with, including annual requests for statistics for the " United Nations Statistical Yearbook " and the Board. of Trade's " Statistical Abstract of the Commonwealth and Sterling Area." Continued statistical assistance has also been given by the Section to the Colonial Products Laboratory, and in particular a world survey of the trade in canned fruit was undertaken and duly completed.

A Mining Law Section, with a staff of two officers, has recently been established with a view to expanding the work on Colonial mining law which was so ably carried out for many years by the late Dr. A. W. Groves. The expansion became necessary as a result partly of the development of Colonial mineral resources following on the intensification of geological and mineral survey since the war. The section maintains a complete collection of mining laws and regulations, and by a system of annotation each parent law is kept up to date. The collection is much used both by departmental inquirers and by members of the public interested in overseas mining, and advice on the old and the new legislation is given on request. Special studies of certain aspects of Colonial mining law are undertaken, such as a comparative study of the mining laws of the Commonwealth and other countries with a view to the possible improvement of the mining laws of Colonial territories. A revised compilation on " Royalties and Other Duties on Minerals payable in the Colonial Territories " has been completed and will shortly be issued.

Instructional courses and specialist assistance

When young geologists are recruited direct from the universities they sometimes lack practical experience of certain techniques such as topographic surveying and photogeology that are necessary for Colonial geological work, and the Directorate has therefore established regular annual courses which they take before they leave for their first tour overseas. The first photogeology course was given in 1948, the first on surveying in 1951, and instruction is also given in sedimentary petrology and in the elements of geophysical prospecting. The photogeology course now lasts for 3½ weeks, and those on surveying and sedimentary petrology each occupy two weeks. The geophysics course is usually run jointly by the Directorate and the Imperial College, but as it is possible only to give a very brief outline of this very specialised subject, this course is attended only by those who are likely to be called upon, owing to the nature of their appointments, to use simple resistivity and magnetometer methods, and by those who have not already received some introduction to geophysics while at the university. This course lasts for about one week, or slightly longer. The photogeology course is given by the Photo-geological Section of the Directorate, but those on surveying and sedimentary petrology are special courses given by the Imperial College of Science and Technology. The sedimentary petrology course now includes lectures and demonstrations in the techniques of geochemical prospecting, mineragraphy and other special methods of investigating economic minerals.

Special courses have sometimes been arranged, as, for example, when a newly-recruited geologist for Jamaica was given instruction in micro-palaeontology at University College, London. The Shell Oil-Company has also kindly assisted on several occasions by receiving geologists for special studies

at its Headquarters at The Hague. By arrangement with the Imperial College of Science and Technology, Professor Theobald of the Royal College of Science has given two years' training in geochemistry to four chemists serving in Uganda, Tanganyika, Northern Rhodesia and Nigeria. In addition he has supervised refresher courses for two chemists from the Federation of Malaya.

Since 1947, geological researches by geologists of university staffs have been carried out in Kenya, Uganda, Tanganyika, Northern Rhodesia, Nyasaland, Nigeria, Sierra Leone, Federation of Malaya, British Territories in Borneo, British Guiana, Leeward Islands, Windward Islands, Fiji, the British Solomon Islands Protectorate and Ascension Island. In many instances their reports have yielded information of outstanding interest and in some cases developments of economic value have resulted. Recently, for example, Professor K. C. Dunham of the University of Durham has visited Sierra Leone again to do further research for the mining company interested in the mining of chromite ore, and he has also visited Nyasaland. Dr. M. H. P. Bott, Lecturer in Geophysics at the University of Durham, carried out a gravimetric survey in Sierra Leone over the area where the base of the Colony Complex was thought to be in contact with the igneous intrusion forming the Colony hills.

Dr. R. L. Stanton and Dr. P. J. Coleman of the Geological Department of Sydney University carried out geological survey work in the British Solomon Islands Protectorate in the long vacation at the beginning of 1956. Dr. Stanton's aim was to complete the survey of Ysabel, part of which had been undertaken by an earlier expedition led by Professor C. E. Marshall. Dr. Coleman intended to carry out geological survey work in the Russell Islands and the south coast of Guadalcanal. Mr. R. Bradshaw, Lecturer in Geology at University College, London, has spent about six months in British Guiana making studies of the petrology of the pre-Cambrian rocks.

Dr. W. J. Skiba, Lecturer in Geology at the Imperial College of Science and Technology, London, and former Senior Geologist, Fiji, spent three months of the long vacation doing geological research in Fiji, where he was assisted by a geologist of the Fiji Survey. He made a field study of manganese mineralisation based on the geology of south-western Viti Levu, and will complete the laboratory studies in London with a view to supplying a full report. He was able to advise nearly all manganese prospectors and miners on their current work and future development. During his stay there, he was also able in the middle part of the Sigatoka Valley to continue his examination of the Wainimala Series and associated plutonic rocks, work on which he had been engaged in May, 1952.

Following the interest aroused by Professor W. Q. Kennedy's own researches, a Research Institute of African Geology has recently been founded at the University of Leeds as the result of a gift from the Anglo-American Corporation of South Africa. The Institute affords a very welcome additional means of extending the field of university geological research into our Colonial territories.

Laboratory work on problems connected with rocks and minerals of the Colonial territories has also been done at a number of universities. In particular, mention should be made of the long-term research of Professor A. Holmes of Edinburgh on the petrology of the remarkable potash-rich lavas of south-western Uganda and of his valuable work connected with radioactive age determinations. Age determinations of many rocks from African territories have also been carried out under the supervision of Professor J. T. Wilson at the Geophysics Laboratory of the Department of Physics at the University of Toronto, and similar useful work for our overseas territories has been undertaken at several universities in the United States. Palaeontological examinations have been made for Colonial territories at several universities in the United Kingdom.

The Colonial territories have long been indebted to the Director of the British Museum (Natural History) and his staff for the help they have given in examining and identifying rocks and minerals, and, in particular, for the palaeontological reports they have provided. The Museum has also

received geologists from overseas territories and assisted them in their examination of material. Dr. W. Campbell Smith has served in a part-time capacity on special research dealing with the mineralogy and petrology of the carbonatites. Valuable help, too, has been given by the Director of the Geological Survey of Great Britain and by his staff at the Geological Survey and Museum.

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