

Geological Survey under Sir Archibald Geikie, 1882-1901

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[Jump to navigation](#) [Jump to search](#)

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Sir Archibald Geikie (From a photogravure by Henry Dixon & Son, Ltd., after a painting by R. G. Eves, A.R.A.) Plate IV

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Contents

- [1 IV The Geological Survey under Sir Archibald Geikie](#)
- [2 Work programme under Geikie](#)
 - [2.1 Mapping and publications](#)
 - [2.2 Geological Museum and the Royal School of Mines](#)
 - [2.3 Completion of the one-inch survey of England](#)
 - [2.4 Ireland](#)
 - [2.5 Scotland](#)
 - [2.6 England](#)
 - [2.7 District and stratigraphical memoirs](#)
 - [2.8 Petrographical work](#)
 - [2.9 Photography](#)
 - [2.10 Chemical work](#)

- [2.11 Mapping programmes](#)
- [2.12 Water supply](#)
- [2.13 Cartography](#)
- [2.14 Museum](#)
- [2.15 Geikie's work on 'Ancient Volcanoes'](#)
- [3 Retirement and synopsis of achievements](#)

IV The Geological Survey under Sir Archibald Geikie

On the first day of January 1882 Archibald Geikie succeeded Sir Andrew Ramsay as Director-General. The selection of Geikie for this responsible post was a fairly obvious one, as his merits were very generally recognized and he had no serious competitor. Since 1855 he had served on the Geological Survey of Scotland, and had acquired a wide knowledge of field geology and much experience in administrative and literary work. Both Murchison and Ramsay had regarded him with great favour and he had been faithful and diligent in his duties. He was widely known, not only in Britain but in America, as an exponent of geological science.

Sir Roderick Murchison, in order to stimulate the study of geology in Scotland, had offered a substantial sum (£6,000) to the University of Edinburgh in order to found a Chair of Geology. Additional money was obtained from the Government and Geikie was selected to be the first occupant of the Chair. This had undoubtedly been Murchison's intention from the first and the choice was in every way an excellent one. Geikie was allowed to combine his professorial duties with his official work, a matter of no great difficulty, as he lectured only in the winter season and the hour at which he met his class was four o'clock in the afternoon. At that time there was no practical or laboratory instruction, but excursions were given on Saturday afternoons and at the close of the winter session. In this sphere Geikie was a very great success. He was a good lecturer and was a recognized authority on Scottish geology. His classes were very popular, not only with the regular students but also with the outside public, who were enabled to attend owing to the late hour in the afternoon at which the classes met. Geikie had also a very wide knowledge of geological literature, especially English, American and French. His special faculty, however, was his fine literary style. From his earliest years he had been a diligent writer of articles and text-books on his favourite science and his works had a great circulation. When Jukes fell ill Geikie edited a new edition (the third) of Jukes's 'Text-book of Geology'; he was also an important contributor to the 'Encyclopaedia Britannica': as a Professor of Geology he was conversant with all branches of the subject. In due course he produced a 'Text-book of Geology' which is acknowledged to be a classic and for many years served as a standard work that was almost as important as Lyell's 'Principles of Geology' had been to the previous generation. This work was published in 1882, a few weeks after Geikie came to London. It may be recalled that Ramsay was a Professor of Geology for many years. Jukes and Hull were successively Professors of Geology in Dublin, and Edward Forbes and Huxley were Professors at the same time as they held posts on the Geological Survey. The combination of academical and official duties was consequently regarded as perfectly normal.

Archibald Geikie had written several brief Survey Memoirs on the districts in Scotland which he had surveyed, but his principal claims to distinction as a geologist were the papers he had published with the Royal Society of Edinburgh on the Geology of the Inner Hebrides, the Old Red Sandstone and the volcanic rocks of the Forth Valley. These won for him a great reputation, as they were written in a charming literary style with a marked gift of exposition which rendered them completely comprehensible to the non-technical reader. Time has proved that in much of his work there were serious flaws. He was too fond of sweeping conclusions and too much attracted by the picturesque and the spectacular. Cold, logical treatment of the evidence to hand was not his strong point.

Moreover, he had many bitter critics and he paid dearly for his errors. But when he came to London in 1882 he had a brilliant reputation and even his enemies would have been compelled to admit that he was one of the foremost figures in the British geological world.

The task that lay before him was at first a comparatively simple one. The original survey of England was within measurable distance of completion. In Ireland, also, great progress had been made. The organization which Murchison and Ramsay had created was working well, and the senior geologists, who were in control of the field work in the various districts, had all the experience and knowledge that were necessary for the satisfactory conduct of the investigations. Geikie undertook to complete the English and Irish maps in the shortest possible time and the field work was pushed on. The need for revision was considered less urgent and in Lincolnshire, East Anglia and the North of England the districts remaining to be mapped were attacked with great vigour.

Bristow was Senior Director in charge of England and Wales, but in 1882 he had lost the services of Aveline, Penning and Skertchly. Frank Rutley also left on being made Lecturer in Mineralogy at South Kensington. No Director was appointed for Scotland as Geikie considered that he could look after that country himself, but Howell was made District Surveyor and had also the superintendence of most of the work in the North of England. James Geikie resigned from the Scottish Survey and succeeded his brother as Murchison Professor of Geology in Edinburgh University. D. R. Irvine, also, a very able geologist, accepted an appointment in Canada, where in subsequent years he did useful geological work. Steps were not taken immediately to fill the vacancies, but in 1883 the Scottish Survey was strengthened by the appointment of Hinxman and Cadell. Hull continued as Director in Dublin.

The staff of the Survey at this time (1882) was as follows:

Director-General, Archibald Geikie.

	<i>England</i>	<i>Scotland</i>	<i>Ireland</i>
Director	H. W. Bristow	—	E. Hull
District Surveyors	W.T. Aveline H.H. Howell	J. Geikie	G.H. Kinahan
Geologists	7	2	3
Assistant Geologists	16	4	7
Palaeontologists	4		1
Assistants, etc.	2	3	2

Work programme under Geikie

Mapping and publications

The amount of work in hand at this time was phenomenal. In his last Report Ramsay states that 27 English one-inch maps had been published in 1881 (12 Solid and 15 Drift); 60 maps had been sent to the engraver (30 Solid with Drift and 30 Drift alone). In addition to these, 3 Scottish one-inch maps had been published and 11 were engraving. Four Irish maps had also been published. The pressure for publication of maps seems to have been so great that orders had been given to engrave no more six-inch maps in order to expedite the issue of the one-inch maps. Only those six-inch maps of important mineral districts which were already in the engravers' hands were to be completed and prepared for publication.

To accelerate progress also orders had been issued that the Scottish geologists were to do their mapping on the one-inch scale. As the ground under survey at this time was north of the Highland

boundary fault, and as the industrial and densely populated lowlands of Central Scotland had already been surveyed on the six-inch scale, it seems to have been thought sufficient to map the Highlands in a much more simple and rapid manner. It was not suspected that the time would come when the innumerable problems presented by these rocks would absorb the attention of geologists. Petrology and the study of metamorphic rocks were at that time regarded as of little importance. As a matter of fact, the regulation was never effective. Geologists accustomed to six-inch mapping bought and used six-inch sheets and subsequently transferred the lines to one-inch maps. A few endeavoured for a time to map the Highlands on the one-inch scale, but soon the attempt was abandoned as not really saving much time while rendering it impossible to do detailed and accurate work. For a small area of the Highlands only one-inch original maps are still available, but it is essentially true that the whole of the Scottish survey work has been done on six-inch original field maps.

The immediate task which lay before Geikie was the completion of the survey of England and of Ireland. It was his intention at the earliest possible date to announce that the original survey of the one-inch map of the Solid geology of England and Wales was completed. Twenty-six one-inch maps were published during 1883 and 37 were being engraved. It now remained for the staff to bring to completion the publication of the one-inch maps and to write the explanatory memoirs describing the ground that had been surveyed. This meant a great deal of office work which would absorb the energies of the staff for many months. In truth many of these projected memoirs never appeared. There was, for example, no memoir descriptive of the Old Series Sheets of the Northumberland and Durham coalfield or the Whitehaven coalfield or of many Sheets of the north of England. The field work had been pushed ahead at too great a rate. Experience has shown that the explanatory memoir must be written as soon as possible after the map is engraved.

If this is not done the pressure of new work impedes preparation and after a few years the details become more difficult to recollect and to describe, and the task is postponed indefinitely.

As stated in his Report for 1883, Geikie's programme included certain items of importance in addition to the publication of memoirs descriptive of the one-inch maps. He intended to press forward the Drift survey of the south and centre of England, seeing that now six-inch topographical maps were available for those regions. A revision of the coalfields was also proposed, especially of those which had been surveyed so long ago that the maps were no longer of much value. He also contemplated the publication of a full series of Stratigraphical Memoirs 'illustrating the geological formations and industrial resources of the whole country and embodying the final results of the Geological Survey of the United Kingdom.'

Highland mapping on the one-inch scale was soon partly abandoned, for Geikie had decided to begin the survey of the North-west Highlands, the region on which Murchison had twenty years previously published his famous memoir which was in due course to bring much trouble on Geikie's devoted head. It is clear from the statement in which this decision is announced that about that time it was being realized how few of the essential problems of Highland geology had yielded to the attack that was being made on them in the district south-east of the Great Glen, and it was hoped that by starting at the other side of the Highlands a better foundation might be laid for future work. It was confidently anticipated, however, that after the problems in western Sutherlandshire had been solved, one-inch mapping might be resumed in other districts.

Geological Museum and the Royal School of Mines

In the Geological Museum and the Royal School of Mines these early years of Geikie's directorship show some important changes. Percy had sent in his resignation in 1880, and the unfortunate circumstances which attended it had made the authorities reluctant to press their schemes to a final

issue. Warington Smyth remained at Jermyn Street till his death in 1890 and gave lectures to his students each year in the lecture hall of the Museum. His principal assistant was Bennett H. Brough, who taught the class of mine surveying. Huxley made his last report in 1881, but seems to have retained his post of Naturalist to 1885. Etheridge, who had been his faithful assistant, was transferred to the British Museum in 1881. Sharman and E. T. Newton were then appointed palaeontologists and curators of the fossil collections. The chemical and metallurgical laboratories were converted into working rooms for the Survey staffs. In 1883, on the retirement of Robert Hunt, who had been the mainstay of the Mining Records Office for 38 years, that office was transferred to the Home Office and the 'Mineral Statistics' ceased to be published by the Geological Survey. The volume for 1881 was the last to appear. Hunt's assistants, Meade and Jordan, became members of the Home Office staff. Few alterations were made in the Museum at this time, but some of the metallurgical models were sent to South Kensington and the teaching collection of geological specimens that had been used by Ramsay to illustrate his lectures was also finally transferred. About the year 1883 began the transport of scientific books from the library at Jermyn Street to South Kensington, and this continued at intervals for several years. The policy of filling up the cases at Jermyn Street each year with large numbers of additional fossils was actively continued, till it seemed impossible to add any more and almost equally impossible to examine the majority of those that were exhibited. Geikie, however, was more interested in rocks than in fossils and he did something to improve the petrographical side of the Museum.

Completion of the one-inch survey of England

On the completion of the one-inch survey of England, Howell had been appointed to succeed Geikie as Director for Scotland, but the state of the work in the North of England rendered it impossible for him to take up his duties fully and he remained in Newcastle-on-Tyne till May 1884. About the same time five English geologists, Miller, Dakyns, Gunn, Clough and Barrow, were transferred to Scotland. It was considered that the Drift mapping and revision that were contemplated in England would not require so large a staff as had been hitherto employed there, and the state of the Survey in Scotland was far behind that of England and of Ireland. Only about one-third of the country had as yet been surveyed and an increase of staff was urgently needed. In this way the staff of Scottish surveyors was raised to eleven and it was anticipated that there would be rapid progress both in the northern and in the southern Highlands. Additional office accommodation was obtained in Edinburgh but many of the geologists remained in their country quarters during the winter except for short visits to the offices in Edinburgh or in London.

In January 1884 Geikie was able to report that the survey of the one-inch map of the Solid geology of England and Wales had been completed 'within the time estimated in the summer of 1881.' The field geologists had responded splendidly to his call and the task had been achieved in record time. Not only so, but the quality of the work done in these years leaves little room for criticism. Some of these maps, in the North of England, have been revised in recent years and, though a very great amount of additional detail has been collected, it is correct to say that the original mapping was excellent, within its limits. In the East of England and in north Yorkshire many of these maps are still current and serve their purpose. The districts admittedly were not those of prime economic importance in which additional geological information accrues most rapidly. But these maps show the Drift geology in addition to the Solid and are the best of the 'Old Series' Sheets. Unfortunately many of them were printed on topographical sheets which indicated the hills and valleys by dense hachuring; hence they are often rather difficult to read as compared with the modern contoured maps. Memoirs were brought out on many of these Sheets at a subsequent period and are still on sale.

Ireland

Meanwhile in Ireland the work was progressing, though not with the same rapidity as in previous years, owing partly to the complicated nature of the geology of the north-western districts in which the staff was engaged. In 1888 Geikie reported that the original survey of Ireland had been completed during the previous field season, and the task of reducing the last Sheets to suitable form for the engraver was now to be pushed on as rapidly as possible. In order to correlate the results of the work in Ireland with those already achieved in Scotland a party of Irish surveyors was sent to visit the North-west Highlands in 1888, but it is doubtful whether much new light was thrown on Irish geological problems by the discussions that ensued.

Scotland

In Scotland the survey of the North-west Highlands, started in 1882, had made great advances in the years 1883 to 1886. The geologists employed in that country were Peach, Horne, Clough, Hinxman and Cadell. In 1886 Gunn, who was transferred to Scotland in 1884, was added to this group. At a very early period they had proved that the tectonics and succession which had been advocated by Murchison, Geikie and Ramsay were entirely untenable, and that the honours rested with their critics. Geikie abandoned his position at once and in his Report for 1884 he frankly admitted that Murchison's interpretation was no longer worthy of support. In 1886 the first of the one-inch Sheets (Cape Wrath) was published and four others were in process of being surveyed. The Durness and Erriboll Sheet was published in 1889; the others appeared in subsequent years up till 1896. It was not till 1888 that sufficient material had been gathered for a fairly comprehensive account of the work of the surveyors in western Sutherland and Ross, and the well-known Report was published in the Quarterly Journal of the Geological Society of London. Thus ended a memorable controversy that had been carried on for many years with unnecessary acrimony. At the same time a notable contribution was made to the study of the tectonics of British mountains, and the attention of all geologists was attracted to a region full of the most marvellous object lessons in structural geology. This brief synopsis of the results attained in the North-west Highlands paved the way for the great memoir descriptive of the whole district that appeared in 1907 and was the 1st Survey publication edited by Sir Archibald Geikie.

The discovery of the Olenellus Fauna in the rocks of western Ross-shire by A. Macconochie in 1891 established that the Torridon Sandstone was pre-Cambrian and that the fossiliferous rocks resting unconformably upon it must be assigned to the Cambrian. This necessitated a change in the colouring of certain maps though few changes were needed in the boundary lines; the indexes were also corrected and new editions were issued with small alterations in 1893. A few maps of this country have now been colour-printed and a special colour-printed Sheet of the complicated ground about Loch Assynt was published in 1923. The best index to the geology of the district as a whole is the colour-printed map on the scale of four miles to 1 inch, published in 1934.

Meanwhile, as the ground in the North-west Highlands was mountainous and, moreover, could not be surveyed during the shooting season, being mostly deer forest, work was carried forward in the Southern Highlands. Part of the staff remained there during the whole year, and the surveyors who worked in summer in western Sutherland and Ross occupied their time in spring and autumn on lower ground in the Eastern Highlands. In this way a large part of the Highlands south of the Great Glen and around the Moray Firth was gradually completed. The work continued over a number of years, but, in fact, part of the districts south of the Great Glen, in Lochaber and Stratherrick has not yet been mapped. Advance was made in a northerly direction, starting from the well defined 'Highland border line.' The geologists were placed at wide intervals apart, fifty miles or so, and the general superintendence of the work was in the hands of Geikie himself, who made numerous visits

to the field staff during the summer. Gunn, who was a very careful worker, made an excellent survey of Arran, with full details on the six-inch scale. The map was published in 1901 'with a memoir (1903) on the northern part of the island, in which the petrological contributions were by Harker. Gunn did not live to complete the description of the island, but in subsequent years a special memoir was composed by Dr. Tyrrell of Glasgow University. Wilkinson, who was transferred from Ireland in 1889, mapped the island of Islay, and received some assistance from Clough and Peach. Symes, also a recruit from Ireland, mapped part of Kintyre and also the Oban district. Clough worked for many years in the Dunoon district of Cowal, and his memoir on that area (1897) is still a standard work on Highland geology. Hill was placed at Ardrishaig and Inverary and mapped an extensive area round Loch Awe. Dakyns made the first survey of the Loch Lomond district and Balquhiddy. To the east of him Grant Wilson worked for several years in the valleys of the Tay, Tummel and Garry. To Barrow was assigned a very extensive stretch of ground in Forfarshire and Perthshire, while he also did parts of Aberdeenshire, on the south side of the Dee. Barrow was the only one of this group of geologists who had made a study of microscopic petrology, and his contributions to the knowledge of Highland rocks have long occupied a prominent place in the literature. To the east of Barrow, Irvine worked for several years until he resigned and went to Canada in 1882. To the north of Barrow, in Deeside and Donside, Skae and Hinxman surveyed large areas. Much of the Cairngorms and the Monadhliath mountains was first mapped by Hinxman. Horne was at one time stationed in Inverness, and the area he surveyed comprises a large part of the low ground around the Moray Firth and also the Banff and Huntly districts. Linn (who resigned in 1888) was responsible for some of the ground near Elgin and in the valley of the Spey. Hugh Miller (junior), who was transferred from Northumberland in 1885, mapped much of the Old Red Sandstone of the Dingwall and Cromarty districts.

Although part of this work has been revised, much of it still stands. Read has examined and described the ground comprised in the Huntly and Portsoy Sheets, and Cunningham-Craig and Crampton made a revision of the country around Loch Lomond and the Trossachs. Much of the primary survey was of very unequal merit and probably the best was done by Clough and Barrow. Geikie had no appreciation of the difficulties to be encountered in mapping Highland metamorphic rocks. There was no adequate inspection or correlation of the work. Howell, the Local Director, had no control over it. Geikie visited the geologists occasionally in the summer season but never really grasped the problems involved. There was no petrologist in charge. Teall was much too busy with the rocks of the North-west Highlands, though he made some interesting contributions at a later period. Moreover, the geologists were working at such distances apart that they had little opportunity of consulting one another. It is not to be wondered at that this country remains one of the least understood parts of Great Britain and that the number of unsettled questions of its geology is still very great. So far as can be foreseen at the present day many years will pass before there is general agreement on its sequence and structure.

In the North-west Highlands things were entirely different. They had there, after the preliminary stages, a clear knowledge of the succession. The different structural elements were also understood. The survey work was done with extreme minuteness and with full petrological support. Peach acted as District Surveyor and was in general control. He was backed up by the business-like and methodical qualities of Horne. The fullest possible correlation was maintained and Peach did all the palaeontology, with occasional assistance from specialists. Consequently that work attained the highest possible level and the maps and memoirs stand as a monument to a group of geologists who individually and collectively have never been surpassed.

England

Meanwhile in England the descriptive memoirs and the maps of the northern counties were being

got ready or passing through the press. It now became urgent to consider the revision of the areas of which no Drift maps had yet been made. If a line be drawn roughly across England from the Humber to the Mersey the country south of that line was mapped originally on the one-inch scale, and mostly without Drift. The six-inch maps were not used because they had not as yet been published. It is less easy to explain why the Drifts were generally ignored. When the geological survey work started in Devon and Cornwall the Drifts were regarded as of local origin of no great importance. This was also true, in a measure, of Somerset and South Wales. But in North Wales the Drifts were often of great interest, and Ramsay made a very close study of their origin and distribution. As the work spread eastwards from the Welsh borders over the plains of Central England the country proved to be deeply covered with Drift over very extensive areas, but about that time interest was centred on the coalfields of the Midlands and the Drifts were regarded as merely obscuring the solid rocks beneath. In the Jurassic and Cretaceous ground that stretches across the heart of England to the south coast attention was concentrated on the interpretation of the succession, so richly varied and abundantly fossiliferous. But in the country around London, in the Weald of Kent and the Eastern Counties generally a considerable amount of attention had been paid to the gravels, alluvia, boulder-clay, coombe rock, clay-with-flints and other superficial deposits. Their boundaries were often mapped and notes on their characteristics were given in the descriptive memoirs. In Topley's classic memoir on 'The Weald,' published in 1875, there are 45 pages on the gravels, but the other 'recent deposits' receive only 5 pages in all. In Judd's 'Rutland,' published in the same year, only 10 pages are given to the description of the Drifts. This neglect was partly due to the speed with which the mapping was carried on, which left no time for the detailed study of these deposits. But it was also to some extent a consequence of the prevailing ignorance of their origin and classification. Much had been learned in the study of the Glacial and post-Glacial chapters of the history of the country, but the complicated Drifts of the South-east of England still remained a subject of intense controversy. Judd regarded the boulder-clay of Rutland as deposited from floating ice during a general submergence. Woodward, however, in the Norwich memoir, published in 1881, was clearly of opinion that the disturbances in the Chalk of his district indicated the operation of land ice.

The importance of mapping the superficial deposits or Drifts was strongly impressed on the surveyors about the year 1865 when they were, actively engaged on the country about London. A geological map of Middlesex which does not show the gravels, sands, brickearths and boulder-clay would lose half its value, and, so far as was practicable on the one-inch scale, these deposits were shown on the early maps published in 1868. A few years later better editions were issued (1871 to 1876) of the London Sheets and in 1873 a large special Sheet of London and its Environs had been published. These later maps all showed the Drifts.

Where the six-inch sheets were being used by the field staff it was possible to map the Drifts with considerable detail. In the Lancashire district Hull was mapping the superficial deposits that densely cover that country as early as 1861, though the one-inch Drift map was not published till 1874.

In the East Midlands also Hull, Holloway and Skertchly mapped the Drifts around Melton Mowbray and Peterborough. The 'Solid' map of that country was issued in 1872 and the 'Drift' edition followed in 1877.

As the work extended into the eastern counties the importance of the Drifts became more and more obvious.

The Old Series maps of East Anglia and of Lincolnshire, for example, were published only in Drift editions. They are mostly dated from 1882 to 1886 and are excellent examples of complete Drift mapping.

In the North of England, where six-inch mapping was carried on from the beginning of the survey, it

was the exception not to publish the maps in both Drift and Solid editions, but in this respect Lancashire seems to have been more favoured than Yorkshire, as many maps of north Yorkshire were issued only with 'Solid' geology. In Northumberland, Durham, Cumberland and Westmorland, the Drifts were fully surveyed, though not published in all cases.

In Scotland the mapping of the Drifts had been consistently executed, though the amount of detail shown and the classification used were not entirely uniform. In Ireland most of the published maps, especially in the north and west, showed glacial deposits by a stipple of black engraved dots, and alluvium and peat by colour.

The programme of work in England laid down by Geikie and carried on during the middle 'eighties of last century included the completion, engraving and publication of the maps and memoirs on the north and east of England, a task which took several years and, in fact, was never wholly executed; there was also the Drift revision of central and southern England, which involved the re-examination of many areas already published on 'Solid' maps. The ground selected for Drift revision was scattered over the country and it is not easy to understand the reasons for selection. One group of workers was assigned to the region south of the Thames, viz. Berkshire, Hampshire, Surrey and Sussex. These included Reid, Whitaker, Topley, Bennett, Hawkins. Another group worked in Bedfordshire, Oxfordshire, Buckingham and Hertford. They were Blake, Cameron and Jukes-Browne. To Ussher was assigned certain ground in Worcestershire; De Rance revised the maps of Cheshire, and Strahan, Tiddeman and Russell were engaged in partial revisions in the northern counties.

At the same time every opportunity was taken to correct and improve the 'Solid' lines., Geikie reported in 1885:

It is gratifying to be able to state that the published maps of the Geological Survey are on the whole so correct that during the re-examination of the ground for the completion of the mapping of the surface deposits, it has been chiefly in matters of detail that amendments have had to be made upon them. These amendments consist in the insertion of geological subdivisions that were not recognized at the time of the original survey, and in the alteration of boundary lines rendered necessary by the numerous artificial exposures which have in the interval been opened.

A comparison of the older maps with the revised issues, however, shows in most cases a very distinct and desirable improvement. It should be borne in mind that this revision was executed with considerable rapidity, the area reported by each geologist being fifty to one hundred square miles a year.

It is noteworthy that during this period comparatively little was being done to improve the mapping of the coal-fields. South Wales, for example, had to wait another ten years before revision was started. Perhaps this was due to the decision to discontinue the publication of six-inch maps. Some of the Midland coalfields, however, were partly revised about this time. Originally mapped between 1850 and 1855, some of them had had partial revisions about 1868 and the Warwickshire field was republished in a revised form in 1886. Six-inch maps of these Midland fields, however, were not issued till after 1900. The alterations in the 1886 editions of the Warwickshire maps were mainly due to the discovery of Cambrian and older Palaeozoic rocks by Lapworth, which were now given their proper colours and symbols.

The revision of the Isle of Wight on the six-inch scale was put in hand in 1886 owing to representations made by the local authorities that such maps were urgently required. It was entrusted to Strahan and Reid, who completed the work in 1887 and subsequently prepared a

second edition of the memoir, which was published in 1889 and is still the standard work on the geology of the island. The six-inch maps have never been published, but the one-inch map has gone through several editions. The first survey of the Isle of Wight was started by Edward Forbes. He died before the publication of his memoir 'On the Fluvio-marine Formations of the Isle of Wight' (1856), which was seen through the press by Bristow. The projected memoir on the island was taken in hand and completed by Bristow and Aveline and published in 1862. Bristow as Director supervised the work of Strahan and Reid in 1886, but did not live to see the second edition of the memoir published, as he died in 1889 while the book was in the printers' hands.

One of the projects which Geikie started about this time was the preparation of a series of Stratigraphical Memoirs, intended to contain a full description of the rocks of an individual geological formation, such as the Jurassic or the Cretaceous in all their variety and extent through England or Scotland. These memoirs were entrusted to geologists who had specialized in the study of one of the geological formations, and were to be more voluminous and comprehensive than any Survey Memoirs hitherto published by the Geological Survey.

District and stratigraphical memoirs

Up to that time the larger memoirs of the Survey had been on a regional rather than a stratigraphical basis.

They described the geology of a tract of country or province which had certain characters, geographical and geological, that gave it a distinctive unity. Good examples of these are De la Beche's 'Devon and Cornwall,' Ramsay's 'North Wales' and Bristow's 'Isle of Wight.' Certain coalfields also had been described in comprehensive memoirs such as Jukes's 'South Staffordshire' and Green's 'Yorkshire Coalfield,' which appeared in 1878. The stratigraphical type of memoir, however, cut across Survey tradition and practice, which was to assign to a geologist or group of geologists a restricted area for survey and description.

The first of these stratigraphical memoirs to be published (1890) was 'The Pliocene Deposits of Britain' by Clement Reid. The task was exceedingly well done and the book is still a standard work. Evidently Geikie intended the volumes of this series to be geological monographs of a higher standard than most Survey publications had hitherto attained, for he sent Reid to Belgium and to Italy to study their Pliocene deposits and compare them with those of the British Isles. A considerable amount of attention was given to bibliography and to invertebrate palaeontology, and the book was followed in 1891 by a memoir on the 'Vertebrata of the Pliocene Deposits of Britain,' by E. T. Newton. These two volumes were eminently successful and together marked a new departure in Survey literature.

The next of these memoirs to be issued from the press was 'The Jurassic Rocks of Britain.' There were two principal authors, Fox-Strangways and Horace B. Woodward. Fox-Strangways described the Yorkshire rocks of this series, and his memoir appeared in 1892 as Vols. I and II. Three more volumes were issued in 1893, 1894 and 1895, by Woodward, descriptive of the Jurassic rocks of the rest of England. To make this monograph complete it would have been necessary to describe also the Jurassic rocks of Scotland, and, in fact, Woodward surveyed the Jurassic of Raasay, part of Skye, and Sutherlandshire, but no descriptive volume was prepared (though these rocks were subsequently described by other geologists such as Wedd and Lee). 'The Jurassic Rocks of Britain' is the most comprehensive memoir ever published by the Geological Survey. The third stratigraphical memoir to be printed was 'The Cretaceous Rocks of Britain' by A. J. Jukes-Browne and William Hill in three volumes, dated 1900, 1903 and 1904. Jukes-Browne, the principal author, was a geologist of great skill and literary ability, which seems to have been hereditary, as his uncle was J. B. Jukes, long the Director of the Geological Survey of Ireland, and his mother, Mrs. Browne, wrote an

interesting biography of that distinguished geologist. Jukes-Browne mapped extensive areas of Cretaceous in the East of England, the Thames Valley and Dorsetshire, and was undoubtedly a great authority on that formation, but after some years spent in active field work his health began to fail and he relied on the faithful assistance of Hill for particulars of many of the outcrops. Jukes-Browne after his retirement from the service went to live in Torquay and published many interesting geological text-books which were of considerable value to students. His monograph, like that of Woodward and Fox-Strangways, is confined to England and does not contain a description of the Irish or Scottish Cretaceous.

Meanwhile Geikie had authorized the preparation of a memoir on the Silurian Rocks of Britain. It should be kept in mind that he never recognized the necessity for using the term Ordovician, but, in this respect, remained a steadfast upholder of the regime of Murchison. Only the first volume of this memoir has been published; it contains a description of the Ordovician and Silurian of the South of Scotland, by Peach and Horne, and made its appearance in 1899. Lapworth in 1878 and subsequent years, by a succession of classic researches, had shown how thoroughly unsatisfactory was the original survey of the Ordovician and Silurian of the Southern Uplands. About the year 1888 Peach and Horne started the revision. They began with the Moffat Sheet (16) and the Loch Doon Sheet (8), which, though surveyed, had not been published because the maps were not believed to be in a fit state. They were issued in 1889 and 1893. Thereafter, at odd times, especially during the autumn and spring seasons, when work was impossible on their Highland ground, they gradually extended their search and made an exhaustive examination of most, or nearly all, of the important field exposures, adding notes and lines to the original six-inch maps. Peach did the palaeontology and drew the sections; Horne wrote the text, and the memoir rapidly took shape in their hands. For the petrology they had the invaluable assistance of Teall, who had examined the igneous rocks in their Company. The memoir is a work of distinction which does great credit to the authors, especially when we consider the circumstances under which it was produced. New editions of the one-inch maps, however, were not prepared at this date, but most of them have now been published, showing the result of Peach and Horne's revision..

No attempt has been made by subsequent Directors to continue this series of stratigraphical memoirs. As some of them absorbed the principal share of the energies of their authors for nearly twenty years, they involve too great a draft on the bank of time. Moreover, they interfere seriously with, the progress of the routine field surveys, which are the essential work of a Geological Survey. Comprehensive regional memoirs, however, are still in favour; and among these we may mention 'The North-west Highlands,' 'Geology of the Isle of Man,' 'Geology of Anglesey,' 'Tertiary Igneous Rocks of Skye,' 'Tertiary Rocks of Mull.'

Although Geikie himself never wrote a stratigraphical memoir he acted as editor of the 'Geology of the Northwest Highlands of Scotland,' a task in which all his literary skill and judgment proved to be necessary. For many years he diligently collected notes, sections and photographs of the extinct volcanoes of Great Britain, and, as he travelled extensively through the Kingdom, he had many opportunities of making observations. Nothing escaped his quick eye and his facile pen, and he levied contributions from all his staff. The results appeared in his two monumental volumes on 'The Ancient Volcanoes of Great Britain,' published by Macmillan in 1897. He had previously given a condensed account of the subject in his Presidential Addresses to the Geological Society of London in 1891 and 1892. These served as a sort of rehearsal. This book was probably intended by Geikie to be his chief contribution to British geology and it is characterized by all his literary polish and deft handling of the subject. The work, however, marks the close of an epoch rather than the beginning of a new one. A school of geologists was rising that in a few years revolutionized the study of British volcanoes. The first fruits of their activity were probably Harker's descriptions of Skye, Rum and Eigg. This was followed by Peach's work on the Pentlands and Arthur's Seat, Bailey's on East

Lothian and the Campsies, and, somewhat later, the work of Clough and his assistants in Mull. Scrupulously thorough six-inch mapping and full petrographical investigation supported by intensive chemical research mark the output of this school. No department of British geology has made greater progress during the last thirty years than the study of volcanic structures and igneous rocks.

Petrographical work

Undoubtedly the department of Geological Survey work which Geikie did most to encourage was the petrographical. This was in accordance with the general advance of geological science and it made special appeal to Geikie through his interest in volcanological studies. As a matter of fact, Geikie had at an early stage been attracted to microscopical petrography, probably through the work of Zirkel. He had set up a laboratory in Scotland for making microscopical sections of rocks, and in some of his papers he had given descriptions of the microscopical characters of rocks, illustrated by figures. But he was never more than a beginner in petrology and in his later years he trusted mostly to notes furnished to him by Hatch and Watts. As his great book on ancient volcanoes developed he had much need of skilled petrographical assistance. He did not neglect the chemical side of petrology and installed Grant Wilson in Edinburgh in a makeshift laboratory to execute rock analyses.

The first publication that contained descriptions and figures of the microscopic characters of rocks was Clifton Ward's 'Geology of the Northern Part of the Lake District' (1876). Clifton Ward, however, did not persevere in his studies of petrology, for in 1878 he resigned from the Survey and entered the Church. In that year appeared Rutley's 'Eruptive Rocks of Brent Tor,' the first purely petrographical memoir, and it contained a description of the application of the microscope to petrographical research. Rutley made another contribution to Survey petrographical literature in 1885 'The Felsitic Lavas of England and Wales.' He also supplied notes to other memoirs. In 1879 he had brought out a textbook on petrology entitled 'The Study of Rocks,' which was for a time the most popular handbook for students of the subject. In 1882 he resigned his post on the Survey and was appointed Lecturer on Mineralogy in the Royal School of Mines. In 1884, however, he was rendering occasional services in the Museum at Jermyn Street and assisting some of his colleagues with notes for the preparation of their memoirs, but apparently at that date he was not on the regular staff. Rutley did a good deal of work in curating the exhibit of rocks and rock-forming minerals in the Museum, and, as he had artistic abilities, he furnished useful coloured drawings of rock structures.

For a time there seems to have been no regular petrologist on the Survey staff, but in 1886 Geikie secured the appointment of Hatch. He was a student and graduate of the Royal School of Mines and had studied in Germany under von Lasaulx for several years, taking the degree of Ph.D. at Bonn with a petrographical thesis. Hatch was undoubtedly the best trained of the younger petrologists in Britain, and Geikie made extensive use of him not only in the Museum but also for the 'Ancient Volcanoes.' He made some valuable contributions to British and Irish petrology, and his work was marked by great ability and a thorough knowledge of the subject, but little of his output appeared in Survey memoirs. In 1892 he resigned his post and went to South Africa, where, as a skilled mining engineer, he proved a great success, and was soon recognized as one of the most distinguished authorities on the geology of the Rand goldfield.

By 1888, however, it had become obvious that the work in the North-west Highlands of Scotland was destined to attract the keenest attention from geologists in all parts of the world, and Geikie realized that it was advisable that the work of the field surveyors should be supported by petrography of the highest standard. Only one man in Britain had the necessary qualifications, and fortunately his services were secured. Teall was a graduate and Fellow of St. John's College, Cambridge, and a pupil of Bonney. For a time he had been doing academic work, and he had published a volume on British petrography which had immediately taken a very high place in the literature of the subject. A

brilliant original scientist and an enthusiastic worker, he was in every way a most desirable acquisition, and he had the complete confidence of his colleagues both in the field and in the Museum. For a number of years he devoted himself to the petrology of the North-west Highlands, but not exclusively, as he contributed also to memoirs on the Southern Uplands of Scotland, the South-west Highlands, and Cornwall and Devon.

In the same year Hyland was appointed to the Irish staff. He had studied petrology in Leipzig under Zirkel. He seems to have resigned after a year or two, and in 1891 Watts was appointed to fill the vacancy. A graduate of Cambridge and a Fellow of Sidney Sussex College, Watts was one of the most distinguished of the younger petrologists in Britain. For a time his activities were mainly concentrated on Irish petrology, but when Hatch left London Watts took over his duties. He gave special attention to the Museum and collections, and prepared a descriptive 'Handbook of the Rocks and Minerals exhibited in the Dublin Museum.' Watts also gave his colleagues assistance in the field, and both in the Isle of Man and in Charnwood Forest he did most valuable work. Geikie was much indebted to Watts for his petrographical contributions to 'Ancient Volcanoes.' Unfortunately for the Survey Watts could not resist the attractions of academic life, and in 1897 he left to assist Professor Lapworth at Birmingham University.

After the departure of Hyland, Hatch and Watts, Geikie found that one petrologist was not sufficient, especially as the North-west Highland memoir was absorbing the activities of Teall. The need in Ireland seemed most insistent and for a time was met by securing the occasional services of Professor Sollas of Trinity College, Dublin. When Sollas retired in 1897 on his appointment to the Professorship of Geology at Oxford, temporary assistance was obtained from Professor Cole, Professor of Geology in the Royal College of Science, Dublin. In 1898 the vacancy was filled by the regular appointment of Henry Joseph Seymour as Petrographer to the Geological Survey of Ireland. In 1909 he was appointed Professor of Geology and Mineralogy at University College, Dublin.

Photography

Another department of the Survey work which Geikie encouraged was the photography of instructive and typical geological scenes. Several of the geologists were expert photographers; Strahan, for example, took the negatives and actually engraved the plates from which the landscapes were printed that illustrate the Purbeck and Weymouth memoir (1898). Teall also was a skilled photographer. But Geikie, realizing the great value of photographs illustrating geological scenery, had a large series of views taken of the North-west Highlands, the Ayrshire coasts and the shore exposures in Fife. These were subsequently used for Survey memoirs and for his book on 'Ancient Volcanoes.' Many of them are familiar to all students of British geology. Their excellence is largely due to the skill and patience of Robert Lunn, who possessed a combination of geological knowledge and artistic qualities that enabled him to achieve notable results even under the most unfavourable conditions.

Chemical work

Chemical research, however, was allowed to languish.

The rooms in the Jermyn Street Museum that had been used, by Percy, Playfair, Frankland, Dick and others were handed over to the palaeontologists. In Scotland Grant Wilson executed a few analyses for Geikie and Teall, but the accommodation and outfit were both of the most meagre description, and only such time as could be spared from the field and economic work was given to petrographical analyses. In some cases, however, Teall secured the friendly services of J. H. Player, who provided a few analyses of rocks and minerals of special interest.

Mapping programmes

If we turn to the consideration of the arrangements for the field staff and programmes of field work during the last ten years of Geikie's directorship (1890-1900) we find that when Bristow retired in 1888, after 46 years' active service, no immediate successor was appointed in London. Howell, Senior Director for Scotland, was made Senior Director for England also. He remained in Edinburgh, however, and Geikie was assisted in London by Best, who acted as secretary, and by Topley, a very experienced geologist, who, after finishing his geological work in the Weald, had been for some years on Survey work in Northumberland. Howell was in control of the field work in the North of England and presumably also in the South of Scotland where no field work was being done except Peach and Horne's Silurian revision. The control of the Highland districts was never placed under Howell, but Geikie retained it in his own hands. In the north-west and the country round the Moray Firth the real superintendence was in the hands of Horne and, as he and his colleagues worked together with the most friendly understanding, everything went smoothly and efficiently. In the Highlands south of the Great Glen there was no effective supervision. After 1890 the amount of revision work that was being done in the North of England was very small, though there were still a few Northumberland maps and memoirs to edit and see through the press.

In the South of England Whitaker was practically in general charge of the Survey work that was being done, especially in the districts south of the Thames and along the south coast, and afterwards it came to be recognized that Horace Woodward, having finished his Jurassic memoir, had general supervision of the work in the eastern counties. But though Geikie every summer paid numerous visits to districts in England, Scotland and Ireland where field parties were at work or were soon to start work, it may be doubted whether that did much to improve the accuracy and thoroughness of the mapping.

Although the general scheme of field work laid down by Geikie on the completion of the original Solid survey of England in 1883 was still followed on its main lines, several important new developments began to make their appearance. In 1891 Strahan was sent down to South Wales to start a revision of the coalfield. This action seems to have been taken in response to criticism of the state of the geological maps. No six-inch survey of that coalfield had ever been made. The one-inch maps had been constructed about 1842 and never really revised, though some alterations had been made in them about 1857. The original survey was merely sketch work and even the topography of the published maps was completely out of date. Very great advances had been made in the mining operations during the forty or fifty years that had elapsed since De la Beche, Ramsay, Aveline, Williams and Logan surveyed the ground. No part of Great Britain was really more important or had a better claim for good geological maps, and in none were the published sheets more defective. The selection of Strahan for the task was above criticism. During the previous ten years he had performed a diversity of duties. After his revision of the Isle of Wight with Reid he had revised the Dorset coast, and he had a memoir in hand on Purbeck and Weymouth. He had previously done field work in North Yorkshire. With De Rance he had revised the North Wales coalfield and they prepared new editions of the memoirs on 'Rhyl' (1885) and on 'Flint' (1890). When Russell finished the Whitehaven coalfield his work was subjected to a considerable amount of adverse criticism. Strahan was sent there to correct the maps, and made alterations in them, some of which, though by no means all, were improvements on Russell's work. Strahan probably had more experience of coalfield mapping and the interpretation of colliery plans than any other of the senior geologists of that period. Moreover, he was still young enough to be set to a task that was likely to take a good many years before it was completed. As a matter of fact, it proved to be the last piece of field work which he was to do, and it kept him busy till he was taken to London to assist the Director, and for some years thereafter.

At first Strahan was given no assistance, but singlehanded he surveyed 79 square miles in 1892. In 1893 he was joined by Walcot Gibson. In 1894 Dakyns was transferred from Scotland to South Wales, and Tiddeman (from Yorkshire) joined them in 1895. To this group Cantrill was added in 1896, and thus a field unit of normal size was gradually built up. They did not start publishing the revised six-inch maps till 1905, but some of the revised one-inch maps began to appear in 1895. The delay in issuing the six-inch Quarter-sheets was possibly due to the embargo on six-inch publication.

A new field of work was opened in 1889 when Russell was sent from Cumberland to begin the survey of the Isle of Man. Strictly speaking, this island is outside the boundaries of England, but an invitation had been received from members of the House of Keys, and it was willingly accepted. Russell resigned in 1891, and the task was then allotted to Lamplugh. He began in 1892 and finished the field survey in 1897. The one-inch map was published in 1898 and the memoir in 1903. In the petrographical work Lamplugh had the able support of Watts, and together they produced a map and memoir which furnish a complete account of the geology of the island. No part of the subject was neglected and the descriptions of the mines and of the Glacial deposits are fully authoritative.

Work was also resumed in the South-west of England, the ground first surveyed and published by De la Beche. Between 1870 and 1876 Ussher had revised a large area on the borders of Somerset and Devon, including the Quantock Hills. The revision was done on the one-inch scale and was not published till several years had elapsed. Thereafter Ussher spent several years in Warwickshire, Lincolnshire and other parts of the Midlands and eastern counties. In 1887, however, Champernowne, a local landed proprietor who was a keen geologist, handed over to the Survey his very detailed maps of certain districts in South Devon, and Ussher was sent down to continue his lines in the neighbourhood of Torquay and Totnes. Champernowne unfortunately died in the same year, but Ussher continued to work in Devonshire till his retirement in 1909. He ultimately became the chief authority on the stratigraphy and tectonics of that county. After a few years the one-inch revision stopped and the six-inch maps were being used in the field, but for a long time Ussher worked alone in the West Country. He was joined by Hill and Wilkinson in 1898, but it was not till the reorganization of the Survey, on the retirement of Geikie, that a full staff of geologists was engaged on the revision of South Devon and Cornwall. North Devon has not yet been revised and the original maps of De la Beche are, still on sale, though completely out of date.

The Tertiary volcanic rocks of the Inner Hebrides were a subject on which Geikie had lavished much enthusiasm and effort. Some of his earliest contributions to geology were inspired by a visit to Skye, and in 1888 he had written an important paper on 'Volcanic Action in the Tertiary Period' which was published by the Royal Society of Edinburgh. Subsequently, in his 'Ancient Volcanoes' (1897), he had given a graphic account of his researches in that volcanic province. No detailed official mapping of that country had yet been undertaken, and Geikie recognized that this was a task for a geologist with the highest credentials and a complete knowledge of the methods and results of modern petrology. Fortunately, he secured the services of Harker, who was able to spend the summer months in Skye without detriment to the performance of his academic duties in Cambridge during the winter season. Harker began field work in the island in 1895 and finished the mapping of the Cuillin Hills in 1901. During the same period, or somewhat later, Woodward and Wedd mapped the fossiliferous Secondary rocks. The one-inch map appeared in 1904 and the memoir was published in the same year.

Till Harker's conclusions were known the igneous history of Skye was a highly controversial subject on which Geikie and Judd had fought historic conflicts. Although some questions are still held to be open to discussion, it is now agreed that the general succession and structure have been ascertained, and the points which remain to be cleared up are of subordinate importance. Harker's monograph is recognized as a classic worthy of the best traditions of the Geological Survey. It not only provides an accurate and brilliant picture of the local phenomena, but as a treatise on volcanic

action and the structure of denuded volcanoes it has attained a great reputation and has led the way to many important new developments.

In subsequent years Harker went on to survey other volcanic islands of the West of Scotland such as Eigg, Muck and Rum. This, however, was after Geikie's retirement. Harker's survey of Skye may be regarded as the beginning of the minute study of the Hebridean volcanoes, which went on for more than thirty years and forms one of the brightest chapters in the history of the Geological Survey of Scotland.

In the same year (1895) as Harker started work in Skye, Greenly began the revision of Anglesey. The geology of the island was very imperfectly known and from its complexity and variety furnished a most attractive field of research. The earlier views of Ramsay had undergone much correction and emendation since the first maps were published in 1852, and it was known that many interesting problems on the island awaited solution. Greenly had served for several years on the staff of the Geological Survey of Scotland, doing work in the North and North-west Highlands, but the state of his health made it advisable for him to change to a less arduous sphere of activity and, as he was an enthusiast in the study of the crystalline schists, he chose Anglesey. He resigned his official post and, having sufficient means to support him, he worked as a free lance for twenty years on his favourite island. Many amateur geologists have produced excellent geological maps as a labour of love, but this is one of the few examples of a professional geological surveyor, fully trained and highly respected by his colleagues, who decided to abandon official entanglements and to work independently. It is not possible to trace the influence of Geikie in this development, but certainly the enthusiasm derived from the study of Highland Geology in the company of Peach, Horne, Clough, Gunn and the other geologists of that group had a great influence in deciding Greenly to take up the task.

His work was done entirely on the six-inch scale and shows an infinity of detail which rivals the best work of any of his colleagues. When completed the map and memoir were published by the Geological Survey (1919).

Water supply

Towards the close of Geikie's directorship a modest volume was published entitled 'The Water Supply of Sussex.' It was compiled by Whitaker and Reid, who had received some assistance from Topley. This was the first of the special water-supply memoirs, though attention had been given to this subject in not a few of the Sheet memoirs, especially those descriptive of the East of England. In previous cases, however, nothing further had been attempted than an appendix containing selected well sections, with occasionally a few remarks on the distribution of the most important water-bearing strata in the area of the Sheet. This treatment was proving unsatisfactory, as it loaded the memoirs with matter not essentially of geological interest and at the same time afforded insufficient scope for adequate treatment of the hydrology. The great advance in the administration of public health, the growth of population and the insistent demand for more abundant - supplies of water of high quality were throwing on the Survey a great deal of responsible work in furnishing information to local authorities, engineers and private persons. The subject was one that had always interested Whitaker, but other geologists on the English staff were also fully aware of its importance. Hitherto the collection of records had been done in an unsystematic way. Every geologist collected logs of borings in the district which he was mapping, but they were mostly used as sources of information on the solid geology, and much of the information thus obtained was confidential and could not be communicated without permission. No effort had been made to obtain full and authentic records of the borings in any district and particulars of water levels and the quantity of water that could be pumped from the wells. This branch of investigation was in coming years to prove of enormous importance, and the first memoir, published in 1899, was the forerunner of a long series. In the

present century nearly every year has seen the publication of an additional memoir on the wells of English counties, and no part of the Geological Survey's work has had more appeal to the public than its contributions to the study of water-supply. Every day enquiries come in on this subject and are answered as promptly and fully as circumstances permit.

Cartography

In regard to the preparation and publication of maps, very little was being done to improve matters. In fact, this branch of Survey activities was receiving less attention than in the days of Ramsay, as the issue of six-inch geological Sheets which had been suspended in 1882 was not resumed till after Geikie had retired. Strangely enough, Horizontal and Vertical Sections were still being issued, and in most years several of these came from the press. The one-inch maps were still engraved by hand on copper plates, though the new photographic methods of copying were employed to a certain extent. The colouring was done by hand, with water colours, and this work was performed mostly by assistants in the Survey office in Jermyn Street. For many years a house on the west side of the Museum had been occupied partly by the staff engaged on colouring and checking the maps and partly by officers of the Survey during the winter season, when field work was suspended. In this respect Geikie was strongly conservative. Not only were these maps often very beautiful examples of engraving and colouring, but they made it possible to effect changes without destroying a large stock of copies, rendered obsolete through the alterations. It was easy to engrave new lines showing subdivisions of formations previously undivided, and it was also possible to add lines showing boundaries of Drift, to engrave additional symbols and even to make fairly extensive modifications, when the geology had proved to be faulty. The progress of engraving maps at that time was very slow and some maps were in the engravers' hands for many years. They were often started before the whole Sheet was finished, and as the knowledge of the country was increased by the advance of the field surveys changes of a minor nature were not infrequently necessary.

In 1884 the proposal was brought forward to issue a series of maps showing the geology of England and Wales on the scale of four miles to 1 inch (1/250,000 approx.). It was expected that such maps would be especially useful to tourists and teachers. Their preparation was started in that year, but it was not till 1889 that they began to appear, and the series was completed in 1895. They proved to be generally popular and had a good sale. This first complete quarter-inch geological map was similar to the one-inch maps then current, as it was engraved on copper and coloured by hand.

Many years previously Murchison had started the preparation of quarter-inch maps, and in 1858 six of them were published showing the geology of Wales and adjacent parts of England. They were very good maps and are still of interest as evidence of the state of geological knowledge at that time, but they were not extended to Cornwall and the south-west of England, apparently because there were no Ordnance Survey maps on that scale available at that date. Both the topographical and the geological lines were drawn in the Geological Survey Office, and the engraving was not done by the Ordnance Survey. No further Sheets of this map were published, and probably one reason for discontinuing the series was that the work of drawing them made too serious a call on the time of the field geologists. It was impossible, of course, to make the series complete at that period, as more than two-thirds of England was as yet geologically unsurveyed.

It is perhaps also not without significance that in 1858 the Council of the Geological Society appointed a special committee to revise the Greenough Geological Map. Originally prepared at the expense of members of the Geological Society at a cost of £1,300, it had been for a long time the standard authority on the geology of many parts of England and had been of great value. The scale of this map was six miles to an inch and the new edition was published in 1865. As Murchison served on the revision committee it is possible that he thought it advisable to drop the preparation of an official four-mile map, and it is recorded that he placed all the information collected by the Survey at

the disposal of the committee. Greenough's map had already gone through two editions (1819 and 1839).

Geikie's quarter-inch hand-coloured map was so successful that it was difficult to maintain the supply. Moreover, it had taken ten years in preparation. It became obvious that the demand for this map justified the issue of a colour-printed edition. As the complete set of quarter-inch Ordnance Sheets for England was now available there was no difficulty in connexion with the topography. This map, however, was not colour-printed by the Ordnance Survey but by H.M. Stationery Office. The first Sheets were issued in 1889; they were two preliminary trial Sheets of the south-east of England; the remainder, thirteen in number, were on sale by 1896 and second editions of some of them were published in 1901. This map is notable as being the first regular publication of official Geological Survey maps of England in a colour-printed form. In successive editions it has always been on sale since that time and has proved to be extremely popular and useful. It is now being prepared in a third edition.

Museum

Meanwhile comparatively little was being done to improve matters in the Museum of Practical Geology. Rudler succeeded Trenham Reeks in 1879 as Curator and Librarian, and he was assisted by Alexander Pringle, who was appointed in 1877. After Percy resigned in 1880 many of his specimens and models to illustrate metallurgy were sent over to South Kensington. After Warrington Smyth's death in 1890 his teaching specimens and apparatus were transferred to South Kensington, though the Museum continued to exhibit mining tools and models and a certain amount of material relating to metallurgy and the application of rocks and minerals to art and industry. The library was in a state of congestion and several thousand books, principally on mining and metallurgy, but also geological and historical, were passed to the Science Library. The collection of specimens of ores and veinstones that had been formed principally by De la Beche and Warrington Smyth remained substantially unaltered at Jermyn Street. The exhibited fossils were to some extent re-arranged, and when better specimens were obtained the inferior ones were removed to storage. A certain amount of depletion was, in fact, necessary as the shelves and cases were much overcrowded. Few new exhibits of importance or interest were added, though photographs, sections and diagrams were utilized on an increasing scale. A collection of rocks to illustrate the recent advances in the geology of the North-west Highlands was assembled by Geikie and Teall, and considerable additions were made to the exhibited series of Scottish volcanic rocks. The lecture room, no longer needed for the classes of the Royal School of Mines, was used occasionally for the Lectures to Working Men, and was lent to scientific and learned societies for their meetings. The number of visitors to the Museum each year was usually from 40,000 to 60,000.

In Scotland the Science and Art Museum, Edinburgh, now known as the Royal Scottish Museum, had assigned the uppermost gallery of its western wing in 1889 to the Geological Survey of Scotland for the purpose of exhibiting specimens, maps, etc., illustrative of the geology of Scotland. In that year Goodchild was transferred from the English staff to supervise this gallery, and Macconochie was appointed Assistant Curator. Work was started immediately and the gallery was opened to the public in less than a year. Goodchild arranged the exhibits on a regional basis and showed the rocks and fossils side by side with a nearly complete set of the published maps. The gallery was well lighted and very suitable for its purpose, and, with the help of Peach, Goodchild soon had a very fine series of Scottish fossils on exhibition. In 1896, when the Edinburgh Museum of Science and Art acquired the magnificent collection of Scottish minerals that had been made by Professor Forster Heddle of St. Andrews, it was decided to display the best of this series in part of the gallery occupied by the Survey, and Goodchild assisted Heddle for several years in completing the arrangement. The result was a representative assemblage of the minerals, rocks and fossils of Scotland, accompanied by the

geological maps, a collection which has always been a great stimulus to the study of geology in Scotland and has proved of immeasurable value to students. A few geological models interesting to Scottish geologists were placed on view and their number has been considerably augmented of recent years. By the addition of cases containing specimens illustrating the fundamental principles of geology and serving as an introduction to the science, and of diagrams and photographs of Scottish scenery, the usefulness of this gallery has been considerably increased, but the original intentions of Goodchild when he organized the exhibition in 1887 have still been closely followed and the general effect has been entirely satisfactory.

Geikie's work on 'Ancient Volcanoes'

About this period Geikie was very actively engaged in completing his great work on 'Ancient Volcanoes.' Correctly regarded, this had been the work of a lifetime, as though he had written on other subjects, such as glaciation and the Old Red Sandstone, the study of denuded volcanic structures had absorbed his attention for many years. The work was probably as complete as it could be made at the time when it was published. After the publication of his book in 1897 he turned his attention to Survey literature, to which he had made no contributions except his Annual Report for more than twenty-five years. He was well acquainted with the county of Fife, as he had been one of the geologists who originally surveyed that district before 1870. Moreover, it contained some most remarkable relics of ancient volcanic action that had attracted the attention of geologists since the early years of the nineteenth century, but had not yet been adequately described, and at Burntisland, Kinghorn, Elie and St. Andrews wonderful and picturesque volcanic necks and lava flows offered a fitting subject for Geikie's pen. His last books on British geology were his two memoirs on West Fife and East Fife (1900 and 1902). The completion of the manuscripts and the correction of the proofs, in fact, occupied him for some months after his retirement in 1901. His task in Fife was mainly literary, for a partial revision of the field maps was done by Peach and the particulars regarding the coalfields had been diligently collected by Grant Wilson over a period of years, while the petrology was done by Kynaston and others. Sir Archibald did full justice to his subject, and the East Fife memoir in particular is a brilliant production that shows how well he understood how to handle his material.

Retirement and synopsis of achievements

At the end of February 1901 Geikie retired after a service of forty-five years. He was still remarkably active and enjoyed excellent health, but of course his field days were over.

He had still before him, however, a long and distinguished career. In 1903 he became a Secretary of the Royal Society of London and filled that office with great capacity till 1908. In that year he was elected President, and he occupied the chair till 1913. He was already K.C.B., and on his retirement from the Presidency he was awarded the Order of Merit. Full of age and honours, he was the most conspicuous British geologist for nearly twenty-four years after his retirement from the Geological Survey. When the Centenary of the Geological Society of London was celebrated in 1907 Geikie was appropriately chosen to preside over the ceremonies, and filled that post with great distinction. In rapid succession books on many subjects, historical, autobiographical and critical came from his fertile pen, but his active geological research work had ceased and other interests now absorbed his attention.

In the closing months of Geikie's directorship signs of an impending change were clearly evident. The country was passing through one of its recurrent spasms of anxiety about the coming exhaustion of the British coalfields, and in December 1901 a Royal Warrant was issued appointing a Commission to enquire into 'the extent and available resources of the coalfields of Great Britain.'

Teall, Hull and Lapworth represented geology on this Commission from the outset, and Strahan was added in 1903. As in 1866-1871, when the previous Commission had met to consider this subject, attention was bound to be directed to the state of the coalfield maps of the Geological Survey, which provide the scientific evidence for the extent and structure of the coalfields. This was known to be not by any means too satisfactory, and measures to remedy this state of affairs were sure to be proposed.

Apart from this, much criticism was being directed to the conduct of Survey business both from external and from internal sources. Representations had been made repeatedly by public bodies that the state of the maps of their districts was unsatisfactory. 'Requests for acceleration or revision of the survey work had been received from the Isle of Man, Isle of Wight, Hampshire, Cornwall, South Wales, Leicestershire, the Channel Islands and many other quarters. No doubt an effort had been made to meet the more important and urgent of these demands, and revision had been started and was being carried on as rapidly as the condition of the staff permitted, but the public was by no means satisfied, and, in fact, compliance with certain claims increased rather than diminished the pressure of complaints.

A review of the state of the maps in 1901, when Geikie retired, shows that a great deal of useful work had been done, but vast tasks of high importance remained to be undertaken.

The coalfields of Northumberland, Durham, Cumberland, Yorkshire and Lancashire, and also the Scottish coalfields, had all been mapped (and nearly all published) on the six-inch scale. The oldest of these six-inch maps dated from 1860, but most of them had appeared in the seventies of the nineteenth century. Consequently, they were on an average at least thirty years old, and revision was urgently needed.

Revision on the six-inch scale had been in progress for several years in South Wales and had been started in North Staffordshire and Leicestershire, but as regards the publication of new six-inch maps the suspension order of 1881 still held good. No six-inch maps existed of South Staffordshire, Nottinghamshire, Derbyshire, Warwickshire, Denbigh or the West Midlands coalfields, and only a small part of South Wales and Leicestershire had yet been revised.

England north of the Humber and the Mersey had been surveyed with Drifts on the six-inch scale and very considerable areas in the Thames valley, Hampshire Basin, London area, Oxfordshire, Bedfordshire and the south-eastern part of the Midlands had been 'revised for Drift' on the six-inch scale. Some revision had also been done in the western counties (Devon, Somerset, Dorset and Wiltshire). But for nearly half of England there were no six-inch maps, and no Drift maps.

Of Scotland about two-thirds had been surveyed (almost all on the six-inch scale) and six-inch maps had been published of nearly all the coalfields, but these maps were becoming obsolete as they were published between 1861 and 1878. Great areas in the Highlands had not yet been examined and the maps of the Southern Uplands were known to be very unsatisfactory.

The mapping of Ireland had been completed in 1887 and was now being revised in places. Six-inch maps had been used in Ireland since the beginning of the Survey and the Drifts had been outlined, but it was known that the Drift mapping was not completely satisfactory, as on the Irish maps all the Glacial deposits had been grouped together.

Complaints were also being made about the state of publication. All the one-inch maps were hand-coloured, and as each was coloured separately they often contained errors of copying. Moreover, they were expensive and, while they were sold at a price which did not repay the cost of colouring, their price compared very unfavourably with that of the colour-printed quarter-inch Sheets which

had been issued for England between 1889 and 1896. The demand for cheap colour-printed maps was very insistent.

Other causes of complaint were less important. Some maps had been in the engravers' hands for many years; presumably they were held up since it was felt unwise to publish them, because they were unsatisfactory. In some coalfields the publication of six-inch maps was incomplete and there seemed to be no intention to finish it. The style of printing of the memoirs was often deplorable, though an improvement had been made in some of the more recent issues. Owing to the widely 'scattered distribution of the surveyors the time that elapsed between the appearance of one Sheet and the neighbouring Sheets was felt to be excessive.

No doubt many of these criticisms were such as can be levelled against any Survey at any time. It is always easier to make programmes than to get them executed. A wise Director shuns the formulation of optimistic estimates, as death, illness, resignations, bad weather and unexpected complexities in structure may always be anticipated, and if not allowed for they shatter programmes. There is always a natural reluctance to publish work till it is satisfactorily completed, and the geologists had to consider that their reputations as field workers would suffer if slipshod work appeared over their names. As the study of geology was encouraged in the Universities the number of competent critics increased. It was impossible to revise the whole of the south and centre of England at the same time, and those districts which were not receiving attention undoubtedly had some cause for complaint. The Old Series hand-coloured maps were very beautiful, but they were necessarily costly and they were being sold at a loss. When the New Series Ordnance maps were available they were adopted as a topographical basis for the publication of the revision of the south and centre of England and were undoubtedly much superior to the previous topographical editions. The New Series one-inch geological maps, Solid and Drift, based on a revision of the Old Series Sheets, began to be issued about 1893. Nearly two hundred of these New Series maps are now on sale.

About this time, also, very serious dissatisfaction was being felt among the staff of the Geological Survey at the conditions of employment and the organization of the service. These found expression in questions in Parliament and a memorial which was presented by the staff to the Board of Education asking for an official enquiry.

The demand was granted, and in April, 1900, a Committee was appointed by the Duke of Devonshire, President of the Board of Education, 'to enquire into the Organization and Staff of the Geological Survey and Museum of Practical Geology; to report on the progress of the Survey since 1881; to suggest the changes in staff and the arrangements necessary for bringing the Survey in its more general features to a speedy and satisfactory termination, having regard especially to its economic importance; and further, to report on the desirability or otherwise of transferring the Survey to another public department.' This Committee was presided over by the Right Hon. J. L. Wharton, M.P., and its members were Mr. Stephen Spring Rice (H.M. Treasury), Mr. T. H. Elliott (Board of Agriculture), General Festing (Victoria and Albert Museum), Dr. H. F. Parsons (Local Government Board), Mr. Blanford (formerly Director, Geological Survey of India) and Professor Lapworth. They met on thirteen occasions before the end of July 1900, and submitted their report on 20th September of that year.

The evidence laid before the Committee showed that since the days of Murchison there had been a progressive diminution of scientific staff.

1867	1900
1 Director-General	1

2	Directors	0	Directors
4	District Surveyors	2	District Surveyors 1 Senior Geologist
14	Geologists	17	Geologists
39	Assistant Geologists	17	Assistant Geologists
1	Palaeontologist	1	Palaeontologist
1	Assistant Palaeontologist	1	Assistant Palaeontologist
1	Naturalist	1	Assistant Curator of Fossils
1	Assistant Naturalist		
-		-	
65	Total	41	Total

Even more striking, however, was the number of vacancies in the higher grades. When Bristow retired in 1888 Howell was made Senior Director for England and Wales also, and was especially entrusted with the charge of field work in the north of England. The personal supervision of the work in the rest of the country was retained by Archibald Geikie. When Hull retired in 1890 no appointment was made, but Nolan was promoted to 'Senior Geologist'; in 1899 Howell retired and the vacancy was not yet filled, though Horne was made 'Acting Director' and given general charge in Scotland.

The two District Surveyors were Woodward in England and Peach in Scotland. It was clearly shown that the lack of superior officers resulted in unsatisfactory correlation and organization of the work of the field geologists and insufficient inspection of the mapping. Moreover, in some districts officers were really in charge though nominally of inferior status and getting less pay than the geologists who worked under them. Some officers had not been inspected in the field for many years.

A necessary consequence of this system was delay in promotion. When the higher posts were abolished or left unfilled there was no opening for the promotion of geologists. Equally pressing were the claims of Assistant Geologists to be admitted to the rank of Geologists. It was shown that some Assistant Geologists had served for 22 to 25 years before being promoted; and some Assistant Geologists were still waiting for promotion after 32 or 35 years' service. To some extent, however this block could be ascribed to the fact that in 1867 and 1868 so many Assistant Geologists had been added to the staff that delay in attaining higher rank was unavoidable.

Another very important grievance was that most of the Assistant Geologists who joined after 1879 had only 'temporary' appointments. Some of them had served in this 'temporary' capacity for more than 25 years. Their posts were not pensionable and it was not clear whether part or the whole of their service would count for pension when they were promoted to geologists.

For many years there had been no improvement in the scales of pay, and the allowances for extra expense, in outstation work and travelling were quite insufficient. In this respect the Geological Survey compared very unfavourably with other branches of the Civil Service doing a similar class of work.

In most of these points the Wharton Committee's decisions supported the claims of the staff, and the subsequent reorganization carried out under the Board of Education remedied most, though not all, of these grievances.

It must be remembered that Sir Archibald Geikie was constantly subjected to pressure from official quarters to complete the geological map and to bring the Survey to a satisfactory termination. Since the days of De la Beche, enquiries had frequently been sent to successive Directors regarding the

time and expenditure that would be required to finish the map. Estimates had been furnished at various times, all of which proved to be misleading. Sir Roderick Murchison showed a bold front, but Geikie was more amenable to pressure. He hastened to complete the Solid map, but he also insisted that Drift maps were absolutely indispensable. The gradual diminution of staff was partly a consequence of the opinion held in official circles that the work could be completed, or at least reduced to a state in which only a limited amount of revision was called for. This is clearly shown by the reference to the Wharton Committee (p. 139), which was requested 'to suggest the changes in staff and the arrangements necessary for bringing the Survey in its more general features to a speedy and satisfactory termination.'

After 1900 the appointment of candidates was made only after a competitive examination similar to those passed by candidates for the higher branches of the Civil Service. After two years' probation, appointments became permanent, on the usual Civil Service conditions, and were pensionable. The scales of pay and travelling allowances received a substantial increase, while the grade of Assistant Geologist was abolished.

The staff establishment fixed in 1900 was as follows:

- 1 Director.
- 2 Assistants to the Director (England and Scotland).
- 7 District Geologists (including Palaeontologist and Petrographer).
- 31 Geologists.
- 41 Total.

while the Museum staff consisted of a Curator (and Librarian), Assistant Curator and Assistant Librarian.

Additions were also made to the subordinate or technical staff such as fossil collectors, attendants and draughtsmen. It was recommended that maps should be colour-printed if there was a reasonable prospect that they could be sold in fair numbers. The proposal that the Museum should be transferred to South Kensington was not definitely approved, but a number of changes in the accommodation and exhibits in the Museum were regarded as desirable.

In reference to the general efficiency of the Survey the Committee reported:

With regard to the practical uses of the work of the Survey there is no doubt that apart from the scientific and educational aspects it has been of great practical service to the country. It has been shown to us that great benefit has been found to be obtainable from the results of the Survey in the matter of mining, agriculture, water-supply and sanitation; and we believe that the cost of the Survey has been more than justified by the practical services rendered to the country at large.

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Category:

- [History of the British Geological Survey](#)

Navigation menu

Personal tools

- Not logged in
- [Talk](#)
- [Contributions](#)
- [Log in](#)
- [Request account](#)

Namespaces

- [Page](#)
- [Discussion](#)

Variants

Views

- [Read](#)
- [Edit](#)
- [View history](#)
- [PDF Export](#)

More

Search

Navigation

- [Main page](#)
- [Recent changes](#)
- [Random page](#)
- [Help about MediaWiki](#)

Tools

- [What links here](#)
- [Related changes](#)
- [Special pages](#)
- [Permanent link](#)
- [Page information](#)

- [Cite this page](#)
- [Browse properties](#)

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- [Disclaimers](#)

