decomposed and is partly replaced by chlorites and iron oxides; some of the latter mineral is, however, probably original, and appears to be titaniferous. The least altered biotite crystals form irregular wisps between those of the felspar. In this slice but little quartz is visible. There are also a few crystalline grains of a colourless silicate, with low polarization tints, one of which gives straight extinction. Possibly the mineral is zoisite. A second slice shows a larger quantity of quartz in the form of composite grains, probably due to fracture. Felspar and mica are present, as in the last slice, with the addition of a little hæmatite and one or two zircons. The rock is therefore a quartziferous mica-syenite or possibly diorite.

The rock obviously resembles the Malvern syenite. The similarity between the two has been noticed by Professor Phillips, and later by the Rev. W. S. Symonds ("Records of the Rocks," p. 37). Both these authors regard the rock at Martley as Malvernian in age; the former stating emphatically that it is not intrusive, and, in addition, that it differs from all other intrusive rocks in the neighbourhood. This syenite, so far as he could see, did not seem to have produced any alteration on the adjacent rocks.

The underlying quartzite exhibits a somewhat granular and saccharoidal structure. One specimen shows slickensides, another a very distinct and well-rounded pebble. On microscopic examination we find that the rock consists almost wholly of rounded grains of quartz, with a few fragments of decomposed felspar. One or two grains show a composite structure, as if derived from a schist. There are also clots of iron-oxide scattered about the slice. With crossed nicols each quartz grain is seen to be surrounded with a thin zone, evidently a secondary deposit. No strain shadows are visible, but dislocations are seen in parts of the field, and near them the grains are slightly crushed.

A second slice presents a very similar structure, but with a finer texture; the component grains not being so well rounded as in the last specimen. It shows no distinct signs of crushing, but is traversed by minute veins of quartz which occupy cracks.

The rock is therefore a quartzite with well-rounded grains, and is remarkably free from earthy matter. It is identical in every respect with that of the Lickey, and most probably belongs to the same geological age.

NOTICES OF MEMOIRS.

The Geological Survey of Great Britain and Ireland.

[Having, through the kindness of Sir A. Geikie, been favoured with an early copy of the Summary of Progress of the Geological Survey for the past year, and finding it to contain matter of much general interest to geologists, we are glad to give it a special notice in our present number.—Editor.]

SUMMARY OF PROGRESS OF THE GEOLOGICAL SURVEY FOR 1897. By Sir A. GEIKIE, D.Sc., D.C.L., LL.D., F.R.S., F.G.S., Director-General. 8vo; pp. 176. (London: Eyre & Spottiswoode, 1898. Price 1*s*.)

INTRODUCTION.

AS no official publication up to the present time has given an account of the origin, history, organization, methods, and aims of the Geological Survey of the United Kingdom, advantage is taken of the opportunity offered by the preparation of the present Summary of Progress to prefix an Introductory Section, in which these particulars may be specially set forth.

The objects for which the Geological Survey is carried on are of a twofold character, scientific and practical. It is charged with the preparation of a detailed map of the United Kingdom, in which the geological structure of every district is worked out, the boundaries and limits of the various rocks and superficial deposits are traced, and the outcrop of each important seam or vein is represented. Such a map forms the basis for an exact knowledge of the geology of the country, and is thus of fundamental value in the interests of pure science. It is also intimately connected with many of the most important questions of every-day life. Thus, by discriminating and delineating the different kinds of superficial deposits and subsoils, the map provides a basis for the solution of some of the chief problems in agriculture. It affords information which is absolutely necessary in questions of water-supply, drainage, and other sanitary matters. It supplies data required by the engineer in constructing roads and railways, by the architect in providing materials for new buildings, by the mining surveyor in determining the position of new pits and mines.

Besides preparing the map, the Geological Survey constructs detailed sections explanatory of the geological structure of the country; also memoirs descriptive of the geology of the districts represented on the sheets of the map, and larger monographs illustrative of the various geological formations of Britain. It collects specimens of the minerals, rocks, and fossils of each of the three kingdoms, arranges and describes them, and displays them to the public in the Museums in London, Edinburgh, and Dublin.

Besides its contributions to the progress of geology as a science, the Survey from the very beginning of its existence has kept in view the general utility of its operations. It has been constantly called upon by the various public Departments to furnish information in regard to the practical application of geology. The general public, also, has continually sought assistance of a similar kind. Each of the three offices in London, Edinburgh, and Dublin has become a centre of reference for information and advice on questions in which a knowledge of the geology of the country is requisite.

The following introductory pages contain (1) a brief narrative of the origin and progress of the Geological Survey and of the

Museum of Practical Geology, up to the present time; (2) a description of the various kinds of work carried on by the Survey in the field, in the office, and in the museum, with an account of the publications, issued and in preparation, by the establishment.

I. The Origin and History of the Survey and Museum.

The Geological Survey of the United Kingdom and the Museum of Practical Geology, Jermyn Street, owe their origin to Henry Thomas De la Beche—one of the most illustrious geologists of this century. After various geological researches prosecuted early in life on the Continent and in the South of England, he eventually undertook a more detailed examination of the rocks of Devon and Cornwall. Supplying himself with the maps of the Ordnance Survey, on the scale of one inch to a mile, he began to map the geological structure of that part of the country. This labour was carried on with his own hands and at his own charges. As it advanced, he was led to perceive that it might possess great public importance in regard to the development of the mineral resources of the kingdom. An accurate delineation of the courses of the mineral veins, coal-seams, and other useful substances contained among the rocks beneath the surface, and of the bearings of the faults that dislocate and shift them, could hardly fail to prove of much practical value as well as of scientific interest. After he had made some progress with his self-imposed task, De la Beche was induced to apply to the Government of the day for recognition and assistance. The Ordnance Survey, indeed, under the enlightened supervision of Colonel Colby, had already encouraged the surveyors of its staff to keep a record of their observations respecting the relations between variations in the topography of the land and changes in the characters of the rocks underneath. In this manner the geology of the district around Ludlow, together with that of the Forest of Dean and the central parts of Herefordshire, had been with more or less precision traced upon the Ordnance sheets.[1] De la Beche represented to the authorities that the work on which he was engaged would be much more efficiently carried out if it were conjoined with that of the general trigonometrical survey of the whole country, which was then in progress. His views were eventually approved of, and in the year 1832 he was appointed by the Board of Ordnance to affix geological colours to the maps of Devonshire, with portions of Somerset, Dorset, and Cornwall. By the Spring of 1834 he was able to publish four sheets of the geological map of the county of Devon, whereon the general geological structure was depicted with a minuteness and beauty of execution such as had not before been equalled. Three additional sheets of the Ordnance Survey were completed by the end of that year, while another was nearly finished.[2]

This rapid progress and the obvious advantages to be derived from the maps led to a more definite recognition of De la Beche's

[1] Proc. Geol. Soc., vol. i, p. 447.
[2] Op. cit., vol. ii, p. 154.

labours. In the Spring of 1835 the Master-General and Board of Ordnance consulted the Professors of Geology in the Universities of Oxford and Cambridge (Buckland and Sedgwick) and the President of the Geological Society (Lyell), as to the expediency of combining a geological examination of the English counties with the geographical survey then in progress. Supported by the strongly expressed approval of these distinguished men, the Treasury agreed to place on the estimates a grant "to defray the additional expense which will be incurred in colouring geologically the Ordnance county maps."[1] As the sum thus granted amounted to only £300 a year, most of the expense of the mapping still fell upon De la Beche himself. He also undertook the lion's share of the field-surveys, though he had the occasional assistance of some of the Ordnance surveyors who possessed geological experience. But he had gained the first and fundamental object which he had in view. His enterprise was officially recognized as a national Geological Survey, of which he himself became Director.

But De la Beche's bold and far-seeing mind had conceived a much more extensive scheme than the preparation of a geological map, and as soon as he felt himself secure in his first step he proceeded to take the next. In the Summer of 1835 he submitted to the Government a proposal that the exceptional opportunities enjoyed by himself and his staff to collect specimens illustrative of the applications of geology to the useful purposes of life should be taken advantage of, and that such collections, displaying the mineral resources of the country, should be placed in a room or rooms under the Board of Public Works. His plans being eventually accepted, rooms were assigned to him for the accommodation of the Survey collections in Craig's Court, Charing Cross, and he was asked to carry out his scheme under the control of the Office of Woods and Forests. Besides the extensive series of specimens gathered together during the mapping of Devon and Cornwall, there was another large assemblage of samples of British building-stones which had been collected by the Commission (whereof De la Beche was a member) appointed to inquire into the most suitable materials for rebuilding the new Palace of Westminster after the burning of the old Houses of Parliament in 1834. The specimens thus accumulated were arranged by De la Beche with reference to the instruction of the public, in illustration of the mineral resources of the country. Materials for making roads, for the construction of public works or buildings, for useful or ornamental purposes in the arts, for the preparation of metals, were grouped in such a way and with such explanatory labels, maps, models, diagrams, and sections, as to convey a large amount of useful information in the most compact and accessible form. In this manner the Museum of Practical Geology took its rise. The collections were in fair working order by the year 1839, though not ready to be opened to the public for two years later. De la Beche was appointed

[1] Proc. Geol. Soc., vol. ii, p. 358.

Director, an office which for some years he filled gratuitously. The infant museum was in charge of the Office of Woods and Forests, but the Geological Survey still remained under the Board of Ordnance.[1]

A further part of the Director's wide-reaching scheme was soon put into execution in the premises at Craig's Court. He had planned that besides obtaining information from specimens, models, diagrams, and maps, the public should be enabled at a moderate cost to procure analyses of rocks, minerals, and soils from the establishment under his control. He was authorized to fit up a laboratory and to appoint as Curator of the Museum one of the ablest analytical chemists of his time, Richard Phillips. He likewise procured the sanction of the Office of Woods for the institution of lectures, having for their object the illustration of the applications of geology and of its associated sciences to the useful purposes of life. Owing to the want of a suitable theatre and other appliances the design of providing lectures could not be carried into execution for twelve years. But eventually in the Autumn of 1851, when the building in Jermyn Street was inaugurated, De la Beche's scheme was carried out by the opening of the School of Mines.[2]

There was one further department which owes its foundation to the indomitable energy of De la Beche. In 1838 the British Association had memorialized the Government to take steps to collect and preserve all plans recording the mining operations of the United Kingdom, inasmuch as great loss of life and destruction of property had arisen from the want of the proper preservation of such documents. The Director of the Geological Survey was accordingly authorized to form a Mining Record Office as part of his establishment at Craig's Court. This new undertaking started in 1840, under the charge of T. B. Jordan, who was succeeded in 1845 by Robert Hunt. A large series of mining plans was gradually accumulated, and a yearly volume was issued embodying the statistics of the mineral industries of the United Kingdom. These statistics were obtained from the information voluntarily supplied by the proprietors, lessees, and others. Eventually, however, an Act of Parliament compelled the mine-owners to furnish the statistics to the Inspectors of Mines, who published them in their Report to the Home Office. As it thus became unnecessary that two similar returns should be published, and as it seemed desirable that the work of the Mining Record Office should be brought into closer relations with the Inspectors of Mines,

[1] Account of the Museum of Economic Geology, by T. Sopwith, 1843; Buckland, Proc. Geol. Soc., vol. iii, pp. 211, 221; Life of A. C. Ramsay, p. 39.

[2] The School of Mines continued to form part of the Jermyn Street establishment for more than twenty years. The progress of scientific education in that interval, however, demanded more space for practical instruction than the building could supply. Accordingly, in 1872, the departments of chemistry, physics, and biology were transferred to more commodious quarters erected by the Science and Art Department at South Kensington, and the other departments were similarly transferred as space could be provided for them. The last Professor at Jermyn Street was the late Warington W. Smyth, on whose death, in 1890, the mining instruction was also removed to South Kensington.

that office was in the year 1883 transferred to the Home Office, under which the Inspectors serve.

We may now trace briefly the progress of the Geological Survey from its commencement to the present time. As above stated, it was begun as a private enterprise by De la Beche previous to the year 1832, and was first established as a branch of the Ordnance Survey in 1835. Ten years afterwards, in 1845, the staff was considerably increased, and the Survey was transferred from the Board of Ordnance to the "Office of Woods and Works," so that the whole of the geological organization, including the Survey, Museum, and Mining Record Office, was thus united in one Government Department, under De la Beche as Director-General. The Survey, which had hitherto been that of Great Britain, now became that of the United Kingdom. The staff in England and Wales was placed under A. C. Ramsay, as Director for Great Britain, while a small force was placed in Ireland, in charge of Henry James, R.E.

The Great Exhibition of 1851 led to the establishment in 1853 of a Department of Science and Art, under the Board of Trade, to which the Jermyn Street organization was transferred. In 1856 this Department was placed under the control of the Lords of the Committee of Privy Council on Education, and this arrangement has continued up to the present time.

By the time the Geological Survey was transferred in 1854 to the Science and Art Department, great progress had been made in the mapping of England and Ireland. The survey of the whole of Wales had been completed and published, and the field-work was advancing eastwards into the central counties of England. In Ireland, the maps of the counties of Dublin, Kildare, Wicklow, Carlow, Wexford, Kilkenny, Waterford, and almost all Cork had been completed, and the field-work was being pushed into King's County and Queen's County, and across Kerry and Limerick. In the same year, 1854, the operations of the Survey were extended into Scotland, where A. C. Ramsay broke ground in East Lothian.

Up to this time the field-work of the staff in England and Wales had been conducted upon the basis of the Ordnance maps on the scale of one inch to a mile, no larger scale being available. In Ireland, however, maps on the scale of six inches to a mile had been published by the Ordnance Survey, and these from the beginning were adopted as the groundwork of the Geological Survey. Maps on this larger scale were available also in Scotland, and were from the first made use of for geological purposes. As the Geological Survey advanced northwards in England, it found the six northern counties mapped on the six-inch scale, and at once adopted this larger scale as the basis of the field-work.

As the great advantages of the use of the larger scale came to be recognized in practice, it was found that the superficial accumulations could be expressed on this scale without unduly interfering with the delineation of the structure of the rocks underneath. At the same time, increased attention was now being paid to the drifts which had been so long neglected. Their paramount

importance in relation to soils had long been recognized, but their great geological interest as records of the Glacial Period was more gradually perceived. As the possession of a detailed topographical map now enabled the surveyors to trace the superficial accumulations with a precision quite unattainable on the old one-inch sheets, it was determined to delineate the distribution of these surface-deposits at the same time that the boundaries of the underlying rocks were being followed. Hence in the six northern counties of England, Scotland, and thenceforth everywhere in Ireland, the drifts were distinguished and expressed upon the six-inch maps.

The great practical and scientific advantages of carefully mapping the superficial deposits on a large scale were amply shown by the experience of a few years. It was found, however, that the tracing of the distribution of the various kinds of Drift greatly increased the amount of labour entailed in the preparation of the general map of the country, thus necessarily diminishing the area surveyed each year and reducing the rate of progress of the Survey. At last, in 1867, a great increase was made in the strength of the staff, which was also reorganized with a view to greater efficiency. A distinct branch of the service was established for Scotland under a separate Director (A. Geikie), the English branch remaining under the supervision of A. C. Ramsay, and the Irish under J. B. Jukes, while Sir R. I. Murchison, who had succeeded De la Beche in 1855, continued Director-General of the whole.

At this important epoch in the history of its organization, the Survey of England and Wales had completed and published the maps of the country as far north as a line drawn from Liverpool to Selby, and as far east as Retford, Melton Mowbray, Market Harborough, Huntingdon, London, Chatham, and Folkestone. Considerable progress had been made with the mapping of the north of Lancashire and Westmoreland, and a portion of the great Northumberland Coalfield had been surveyed. In Ireland the maps of the larger half of the island had been published, and the field-work had been pushed northwards to a line drawn from Castlebar to Drogheda. In Scotland, where the staff had always been disproportionately small, the maps of the basin of the Forth had been completed from the north of Fife to Berwick-on-Tweed. The backward state of the Ordnance Survey had necessitated the transference of the staff to the west side of the country, where six-inch maps were available, and some progress had been made with the examination of the south of Ayrshire.

The whole energy of the staff was now directed to the completion, as quickly as possible, of the one-inch map of each of the three kingdoms. That of England and Wales was finished in 1883, and that of Ireland in 1887. The completion of these maps liberated some of the officers in England and in Ireland, who were accordingly transferred to the Scottish staff. As the Survey of Scotland was commenced long after that of the sister kingdoms, and was carried on for many years by a staff of only two surveyors, it is not yet completed. At the present time the unsurveyed portions of the

country include the central mountains of Sutherland and Ross, with most of Inverness-shire, the western parts of Argyllshire, and most of the Western Isles.

When the one-inch map of England was completed, most of the staff was detailed for the purpose of mapping the superficial deposits in the southern half of the kingdom, and thus providing materials for a complete agronomic map of the whole of Britain. An opportunity has at the same time been afforded to revise the published maps and bring them up to date. The nature and extent of this revision will be more particularly noticed in subsequent pages. When the one-inch map of Ireland was finished the staff was reduced, partly by transference to Scotland and partly by retirement, only such a number of officers being retained as might suffice for the necessary revisions which the progress of time requires. To these revisions also fuller reference will be made in the sequel.

II. The Work of the Geological Survey.

The combined scientific and practical objects which De la Beche set before himself as his great aim at the first institution of the Geological Survey, have ever since been kept steadily in view. To this day the development of the mineral fields of the country by means of accurate maps, the collection of data for the guidance of those in search of water-supply, the accumulation of information required for the purposes of agriculture, engineering, road-making, architecture—these and many other applications of geology to the arts, manufactures, and practical affairs of our social life continue to form a large part of the work of the Survey. But, as De la Beche and his early associates clearly recognized from the beginning, all such utilitarian uses of geology must be based on a thoroughly systematic examination of the geological structure of the country. So closely are pure science and industrial progress linked together, that at any moment what might be supposed to be a matter of merely theoretical import may be discovered to have a high practical significance and value. Hence the Geological Survey has been conducted as a strictly scientific investigation, and has thus been able to advance the interests of geological science. The geological structure of the British Isles has been traced out in greater detail than was before attempted in any country, and numerous additions have thereby been made to the general body of geological knowledge.

1. Field Work.[1]—The first and most important duty of the Survey is to map in detail the geological structure of the country. When this task was first undertaken by De la Beche the Ordnance Survey maps on the scale of one inch to a mile ($\frac{1}{63360}$) which had then been published for some of the southern counties of England, and which he used as the basis of his work, were imperfect and incorrect in their topography. They were among the first undertakings of the Ordnance Survey, before methods of surveying had

[1] Some portions of the following account of the work of the Geological Survey are taken from a paper communicated by the Director-General to the Federated Institution of Mining Engineers. See their Transactions, vol. v (1893), p. 142.

been brought to the perfection that has since been attained. The possession of a correct topographical map is absolutely necessary as the groundwork of a detailed and accurate geological survey. From the outset the Ordnance maps have afforded the topographical groundwork on which all the geological surveying has been carried on. For many years only the sheets of the general map on the one-inch scale were available, but when, in the progress of the Ordnance Survey, maps on larger scales were prepared, these, as already remarked, were employed for geological purposes.

All the mapping of the Geological Survey is now conducted upon the Ordnance maps on the scale of six inches to one mile ($\frac{1}{10560}$), as has been above remarked. These maps were not available in England and Wales until about two-thirds of the country had been surveyed geologically, and it was only in the six northern counties that they could be adopted. In Ireland, however, and in Scotland, where they were obtainable from the commencement of the geological operations, the whole of the work has been conducted upon them.

It is impossible to overestimate the gain, both in completeness and accuracy, from the substitution of a large-scale map in the general investigation of a complicated geological region. Not only is it then much easier to fix the position of geological boundaries, but an amount of detail may be inserted for which, though of great importance, no room can be found on the one-inch scale. The large map serves at once as a map and a notebook, and numerous detailed observations can be taken and recorded upon it at the localities at which they are made.

Occasionally, where the geological structure becomes excessively complicated, and requires to be mapped out in much detail, maps on the scale of 25 inches to a mile ($\frac{1}{2500}$) are made use of. Ultimately, however, all the work is reduced to the one-inch scale, this being the scale on which the general geological map of the United Kingdom is published.

Geologists had made considerable progress in the study of the solid rocks before much attention was paid to the looser superficial deposits. The Geological Survey in this respect followed the general rule, and for many years made no systematic attempt to represent the numerous and often complex accumulations of superficial materials. Some of these, indeed, were shown on the maps, such as tracts of blown sand and river-alluvium. But it must be remembered that in the south-western counties, where the Geological Survey began its work, superficial deposits are of such trifling extent and importance that they were not unnaturally ignored. Only after most of the southern half of England had been completed was it determined to map the surface-deposits with as much care and detail as had been expended on the older formations lying beneath them. It had been discovered that this course was necessary both on scientific and practical grounds. In the first place, these superficial accumulations contained the records of the later geological vicissitudes of Britain, and were beginning to reveal a story of the profoundest interest, inasmuch as it dovetailed with the history of the human

occupation of the country. In the second place, it was recognized that in many various ways these surface-deposits had a direct and vital influence upon the welfare of the population. In agriculture, in water-supply, in questions of drainage, and of the location of dwellings, it was seen that a knowledge of the soils and subsoils, and of the formations from which these are derived, was of the utmost practical importance. It was therefore determined that henceforth the Geological Survey should not only pourtray the lineaments of the solid earth, but trace out the drifts and other surface-deposits which, like a garment, overspread and conceal them. It was impossible at first to go back over the ground where the surface-geology had been omitted. But it was arranged that when the whole country had once been mapped those tracts should be re-examined wherein the superficial deposits had not been surveyed. And, in the meantime, over all new areas the survey was made complete by tracing out simultaneously both the surface-deposits and the older rocks below them.

The Drift Survey of Wales, and of those parts of England where the superficial deposits were not originally mapped, now occupies the time of a considerable part of the English staff. In Ireland, also, those tracts where the peat and some other superficial deposits were not delineated are now having this omission remedied. In Scotland the drifts are all mapped at the same time with the rest of the geology.

As an illustration of the detail into which the mapping in this department has been carried, it may be mentioned that under the single term "alluvium" we now discriminate and indicate by separate signs and colours a large number of distinct deposits. Thus, there is a group of fresh-water alluvia, beginning with the present flood-plains of the rivers and rising by successive terraces to the highest and oldest fluviatile platforms. Deposits of peat are separately traced, and tracts of blown sand are likewise mapped. Another series, consisting of marine alluvia, ranges in position and age from the mud of modern estuaries and the sands of flat shores exposed at low water, through a succession of storm-beaches and raised beaches, up to the highest and most ancient marine terraces 100 feet or more above the present level of the sea. Regarding the origin of some of the high-level gravels, there is still much uncertainty, but the Survey has taken the first necessary step for their ultimate explanation by carefully tracing their distribution on the ground.

But the most abundant and complex group of superficial deposits is that which may be classed under the old name of Glacial Drifts. These have been mapped by the Survey in detail, and much of the progress of glacial geology in this country has been due to the sedulous investigation thus required. The ice-striæ on the solid rocks have been observed over so much of the country, that maps may now be constructed to show both the march of the main ice-sheets and the positions of the later valley-glaciers. The various boulder-clays have been mapped, likewise the sands and gravels.

The survey of the superficial deposits thus combines a wealth of geological interest with a great deal of practical value. The geologist may find in it the solution of some problems and the presentation of many more; while the farmer, the water-engineer, the builder, the road-maker, and the sanitary inspector may each in turn gain practical information from it for his guidance.

For purposes of distinction, the mapping of the formations of every age that lie beneath the recent superficial deposits is known in the Survey by the somewhat unhappily selected epithet of the "solid geology." The object in this part of the field-work is to represent on the maps the exact area which every formation or group of rocks occupies at the surface, or immediately below the soil and drift, together with all indications that can be obtained of its structure, such as its variations of inclination, its changes of lithological character, and the dislocations by which its outcrop is affected. While the basis of the work is rigorously geological, facts having an industrial bearing, such as the presence of useful minerals, or the depth and variations in thickness of water-bearing strata, are observed and recorded.

In those districts of the country where the rocks have long been well known and where the geological structure is simple, the duties of the surveyor are comparatively light, though it often happens there that the simplicity of the "solid geology" is compensated for by a great complexity in the overlying "drifts." Where, on the other hand, the rocks are varied in character and complicated in structure, where they are partially hidden under superficial deposits, and where they rise into mountainous ground, difficult of access and hard to traverse, geological surveying becomes a most laborious occupation. In such a region as that of the North-West Highlands of Scotland, for example, where the physical impediments are great, where the ground is often both rugged and lofty, where the climate is wetter and more boisterous than almost anywhere else in Britain, and where the quarters to be had are often sorry enough and remote from the scene of work, the surveyor has need of all his enthusiasm to carry him bravely through these preliminary obstacles. But when he comes to unravel the structure of the rocks, he may find it to be sometimes almost incredibly complex. He has to climb the same cliff, scour the same crag, and trudge over the same moor again and again before he begins to perceive any solution to the problems he has to solve.

If the complicated "solid geology" of such a region is enough to tax to the utmost the capacity and energy of the geologist, his task is made still more difficult by the necessity of keeping his eye at the same time ever open to all the variations of the superficial deposits, which in these rugged tracts are often singularly intricate, though they may also be fascinatingly interesting. The ice-striæ on the rocks, the scratched stones high on the mountain-sides that mark where the till once lay, the varieties of boulder-clay, the sand and gravel eskers, the scattered erratic blocks and the detection of their probable sources of origin, the moraine-mounds fringing or

filling the bottom of the glens, the sheets of flow-peat and the ragged peaty mantle that hangs down from the cols and smoother ridges, the recent alluvia and the successive stream-terraces, the lines of raised beach and the estuarine silts—all these and more must be noted as the surveyor moves along, and must be duly chronicled on his map and among his notes.

It is obvious that the progress of the mapping in such ground cannot be rapid. If the work is worth doing at all, it should be well done, and if well done, it must be done slowly and carefully. It is evident also that the total area surveyed in a year, if given in square miles, affords no guidance whatever as to the amount of labour involved. There may be a hundredfold more exertion, physical and mental, required to complete a single square mile in some districts than to fill in twenty square miles in others. It is customary in the Survey to estimate not only the area annually mapped by each officer in square miles, but also the number of miles of boundary-line which he has traced. The ratio between these two figures affords some measure, though an imperfect one, of the comparative complexity or simplicity of the work. In simple ground a surveyor need have no difficulty in mapping from 70 to 100 square miles in a year, each square mile including from 3 to 6 linear miles of boundary. But in more mountainous and difficult districts it may be impossible to accomplish half of that amount of area. In these cases, however, the ratio between area and boundary-lines usually rises to a high proportion. Thus, in the Scottish Highlands the average number of linear miles of boundary-lines sometimes rises to as much as 17 miles in every square mile surveyed.

In mining districts an endeavour is made to express on the maps the positions of the outcrops of all seams and lodes, the line of every important fault and dyke, with the place of such faults at the surface, and where they cut different seams underground. The information necessary to record these data is mainly furnished by the owners and lessees of the mines and pits, who, as a rule, most generously give the Survey every assistance. Details as far as possible are inserted on the six-inch Ordnance sheets. Copies are taken of borings and pit sections, and notes are made regarding variations in the character of the seams or lodes from one part of a mineral field to another. At the same time, the district is surveyed in the usual way, and by exhausting the surface-evidence the surveyor is not infrequently able to supply important additional information beyond what can be obtained from the mining-plans.

It is the necessary fate of all geological maps to become antiquated. For, in the first place, the science is continually advancing, and the systems of arrangement of the rocks of the earth's crust are undergoing constant improvement, so that the methods of mapping which satisfied all the requirements of science thirty years ago are found to be susceptible of modification now. In the second place, in the progress of civilization, new openings are continually being made in the ground: wells, roads, drains, railways, and

buildings are being constructed, whereby fresh light is obtained as to the rocks below. Geological lines which were traced with the imperfect evidence formerly available can thus be corrected, and new lines which perhaps were not originally suspected can be inserted. If this kind of obsoleteness overtakes geological maps even where only superficial openings are concerned, still more does it affect those which depict the structure of mineral-fields still actively worked. The geological maps of Devon, Cornwall, and South Wales, made some two generations ago by De la Beche and his associates, were for their time admirable in conception and excellent in execution. Nothing approaching to them in merit had then been produced in any part of the world. But the mineral industry of the country has not been standing still all these years. Enormous progress has been made in working the ores of the western counties, and in developing the great South Wales Coalfield. Yet most of the maps still remain as they were originally published, though their revision is now in progress.

It is absolutely necessary, if the value of the labour and expense bestowed on the Geological Survey of the United Kingdom is not to be impaired and lost, that the maps should be revised and brought up to date as frequently as may be required. The necessity for such revision has been pressed on the attention of Government by influential memorials from various districts of the country; and, hitherto, as far as the other requirements of the Survey permit, these requests have been complied with. Thus, in consequence of an urgent representation from the proprietors and lessees of the coalfield of South Wales, and from others locally interested in the development of that region, steps were taken a few years ago to place there a staff of surveyors, and the revision of the ground is actively advancing. Already three sheets of the new series of Ordnance Maps of South Wales have been published, and one other is now in the hands of the engraver. The inhabitants of Cornwall, likewise, recently memorialized the Science and Art Department to undertake a revision of the geological maps of that county; and, in response to their request, a beginning of the work has been started. The people of North Staffordshire, anxious for the proper development of their coalfield, made a representation that the time had come when a revision of the maps of their district was necessary, and this task has been undertaken by the Geological Survey. Other districts have sent in similar petitions for re-survey with which it has been hitherto impossible to comply, owing to the smallness of the staff. All these tracts of country were originally surveyed on the old and imperfect sheets of the one-inch Ordnance map. But the revisions are conducted on the modern six-inch scale, and the reductions are made upon the new series of one-inch sheets. There can be no doubt that all the other mineral-fields of the country require similar treatment.

The revision of that large part of England and Wales where the superficial deposits were not originally mapped, in order to complete the Drift survey of the whole country, is carried on upon the six-inch

maps. While this revision is in progress advantage is taken of the re-examination of the ground to make any needful additions or modifications in the "solid geology." The work is reduced from the large field-maps to the new series of the one-inch map. Geological maps on the six-inch scale were formerly published for the mineral-fields, but are now no longer engraved, though a large number of sheets of the coalfields are on sale. But manuscript copies of six-inch maps relating to any parts of the country of which the one-inch sheets are published, are supplied to the public at the cost of manual transcription.

While the field-work is in progress the surveyors collect, for the purposes of their maps and explanatory memoirs. such specimens of minerals, rocks, and fossils as may be found to require special examination. But a more systematic collection is carried out under their supervision by the collectors, for study by the petrographers and palæontologists and for exhibition in the museums. Each branch of the Survey has one or two collectors, who move from district to district as their services are required. When one of them begins work in any area, he is supplied with a map on which the field-officer who surveyed it has marked every locality that should be searched, and also with a list of these localities, giving local details as to the rocks to be specially searched or examined, and the kind of specimens to be looked for and collected. When necessary, the surveyor accompanies the collector to the ground and starts him on his duties. Every specimen which the collector sends up to the office has a number affixed to it, and is entered in the lists, which are also at the same time transmitted to headquarters. The specimens are then unpacked and treated by the palæontologists or petrographers, as the case may be. In this manner a remarkably complete illustration of the geology of the United Kingdom has been accumulated by the Survey, and it is constantly receiving additions and improvements. The chief series is deposited in the Museum of Practical Geology, London; but the geology of Scotland is most fully represented in the Museum of Science and Art in Edinburgh, and that of Ireland in the corresponding Museum at Dublin.

(*To be continued.*)

REVIEWS.

I.—Wachsmuth and Springer's Monograph on Crinoids.[1]

Second Notice.

BEFORE entering on the discussion of morphological questions, the authors very properly define the terms they propose to use. Since all these terms will be familiar to those who have followed the papers of Messrs. Wachsmuth and Springer, P. H. Carpenter, and myself, only a few remarks are needed.

[1] The North American Crinoidea Camerata. By C. Wachsmuth and F. Springer. Mem. Mus. Comp. Zool. Harvard, vols. xx and xxi, containing 838 pp. and 83 plates. (Cambridge, U.S.A., May, 1897.) For First Notice, see June Number, p. 276.