1855 The Murchison succession - Geological Survey of Great Britain (by E.B. Bailey)

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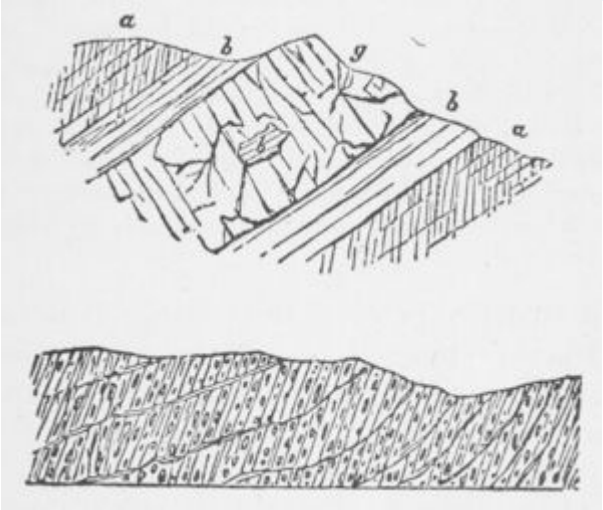

Figure 5 Top: a, slate; b, baked shale, uncleaved; g, intrusive greenstone. Bottom: Pebbles elongated along cleavage. (Quoted from Ramsay, Mem., vol. iii, 1866, pp. 97, 145.)

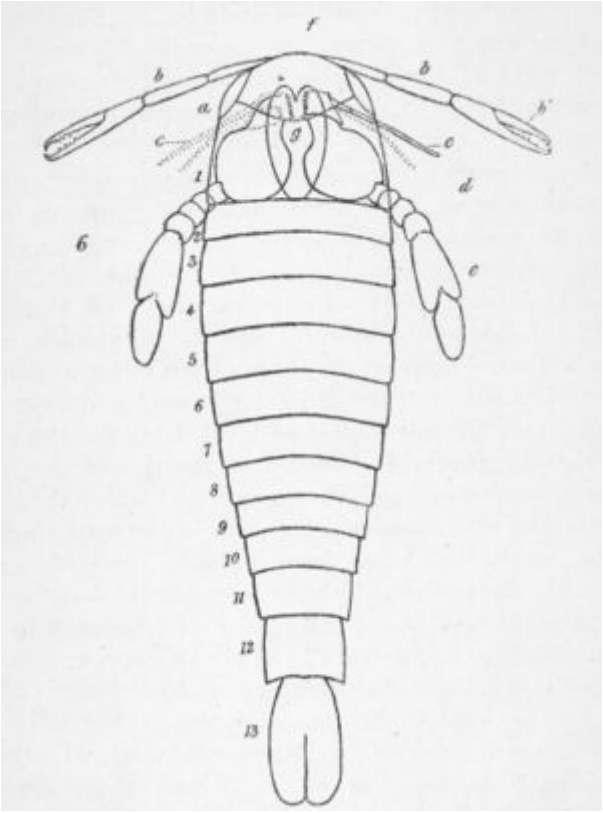

Figure 6 Restoration of *Pterygotus bilobus* (length 6in.) (Quoted from Huxley, Monograph I, 1859, pl. xv.)

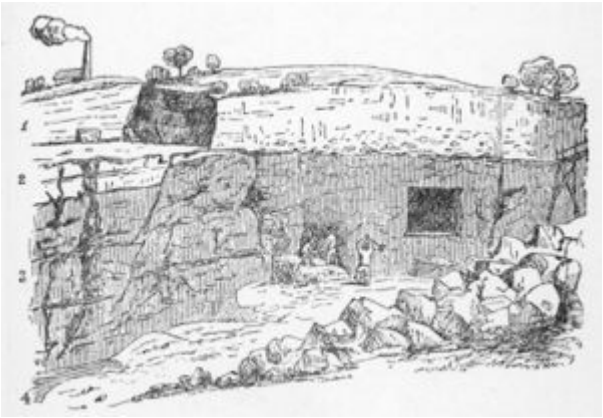
Figure 7 Section of Haematite at Todholes, near Whitehaven. 1. Drift with limestone fragments. 2. Impure limestone roof.' 3. Hmmatite, loft. thick. 4. White 'shale floor.' (Quoted from Warington Smyth, Iron Ores Mem., 1856, p. 21.)

Figure 8 First-edition one-inch map publication in decades 1830-39 (3), 40-49 (4), 50-59 (5), 60-79 (6). (See Figs. 10, 28, pp. 83, 059.)

Figure 9 General Section Shifnal, Shropshire. Keuper: e, Marl; d, Lower Sandstone with breccia at base. Bunter: c, Upper Mottled Sandstone; b, conglomerate; a, Lower Mottled Sandstone. Permian: Unconformably overlain by (a). (Quoted from Hull, Trias and Permian, Midlands, Mem., 1869, p. 30.)

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1855 The Murchison succession

Geikie, in his Memoir of Sir A. C. Ramsay, tells how on various occasions De la Beche had led his lieutenant to understand that he regarded him as his natural successor, and that he would in due season press his claims. Towards the end, however, De le Beche seems to have changed his mind. Geikie suggests that he may have become impatient of Ramsay's opposition to certain of his own latter day plans, which, in the opinion of members of staff, sometimes reflected a mental failure connected with his bodily disablement. Another cause may perhaps be suggested. De la Beche knew full well of a desire at higher levels for expansion of his great institution under conditions that might dissolve the geological cement to which he himself attributed great importance. It is quite possible that he doubted whether Ramsay's standing in official quarters would enable him to hold at bay such unwelcome tendencies. He might quite well have come to this conclusion, and yet have continued to subscribe to the oft-repeated description of Ramsay as the best field geologist in Europe.

Soon after De la Beche's death Ramsay found that vigorous efforts were on foot in favour of the appointment of a most estimable man of good family, who unfortunately possessed only a very slender acquaintance with geology. To counter this danger Ramsay proposed at a meeting of the Jermyn Street professors that Sir Roderick Murchison should be suggested as their next chief. His proposal was accepted and communicated to the President of the Board of Trade. A memorial in the same sense, signed by many distinguished outside geologists, was also dispatched to the Government. Within less than a fortnight Murchison was appointed ; and the announcement was received with general cheers in the House of Commons.

Roderick Impey Murchison was born in 1782 in Ross-shire, the scion of a North-West Highland family. He passed through Great Marlow, and as a boy of seventeen carried the colours of his regiment during the retreat on Corunna. After that, through no fault of his own, he saw little real warfare ; and, with Waterloo passed, in 1815, he married and demobilised. His main interest for the next eight years was fox hunting, which showed at least that he had the stamina for a field geologist. We hear of him in the course of one period of too days riding to hounds i io times; and again, during a trip to Switzerland, in 14 days walking 452 miles, 57 of which he covered on the last day of the outing.

All these years his wife was aiming at something more intellectual ; and in 1823 got her reward. Shooting partridges one morning with Sir Humphry Davy, Murchison discovered that one may pursue philosophy without abandoning field sports, and that entry to the Royal Society could easily be arranged for such as himself. He sold his hunters and settled in London to attend lectures at the Royal Institution and discussions at the Geological Society. He received his baptism in field geology in 1825 from the merry though reverend Professor Buckland, when he rode out with a party of Oxford students to listen enthralled while a landscape was geologically dissected. Next winter he read his first paper to the Geological Society, A Geological Sketch of the North-western extremity of Sussex and the adjoining parts of Hants and Surrey. From this beginning he continued, spending summer after summer geologising at home or on the continent, with a break for the British Association, and with papers written to present each succeeding winter at the Geological Society. His impetuous zeal led to his election to the secretaryship of the Society 1826-31, and to its presidency 1831-33 and again 1841-43. His master subject was stratigraphy. He was an apostle of William Smith, with whom he had the good fortune to see coastal sections of Yorkshire ; and he constantly carried in his pocket Conybeare and William Phillips' Outlines of the Geology of England and Wales. He had no financial worries, and undertook his self-imposed tasks in admirably methodical fashion: he procured the best maps available, studied the literature, inspected museums and consulted anyone who might supply useful information, always taking copious notes. He received great assistance from co-workers, especially paleontologists; and several of his papers were

joint products with one or more of his friends. He himself was famous for his quick perception of the geological significance of topographical features ; and he enjoyed the exertion and excitement of field work.

In 1831 Murchison broke ground beneath the Old Red Sandstone of the Welsh borders; and in 1834 introduced the name Silurian to cover the succession of fossiliferous formations he had there disinterred from oblivion. Sedgwick since 1822 had been engaged on a similar task in the Lake District, and in 1831 extended his investigations to North Wales. One difference between Sedgwick's work and Murchison's lay in the fact that Sedgwick's old rocks, to which in 1835 he gave the name of Cambrian, do not possess a natural top in the districts investigated—whereas Murchison's do. Another difference was characteristic of the two men themselves ; Sedgwick delayed completion of his researches, so that only a very imperfect knowledge of his results was for long available ; Murchison, on the other hand, had his fossils determined season by season and promptly published his findings. For some years the two friends were happily ignorant of the fact that Cambrian and Silurian were in large measure synonymous terms. In 1842, however, a much regretted controversy arose as to ownership. A postmortem adjudication by Charles Lapworth has since inserted a buffer system, Ordovician, between reduced representatives of Cambrian and Silurian. ' He took the oyster,' McKenny Hughes is reported as saying, ' and left the discoverers to hold the shells.' Reverting to the relations that existed between these two great discoverers one may recall that Sedgwick, though in 1855 bitterly resentful on the Silurian issue, was among the signatories who advocated Murchison's appointment to the Director-Generalship of the Geological Survey.

Murchison's other claims to geological fame are so numerous that only the briefest selection can be mentioned. With Sedgwick he correlated the Culm Measures of Devon with the Carboniferous; and soon afterwards, with the same companion, following Lonsdale's as yet unpublished lead, established the Devonian system as time-equivalent in its home county of the Old Red Sandstone farther north. A little later, again with Sedgwick, he equated much of the greywacke of the Rhenish provinces with this Devonian. Then with A. von Keyserling and E. de Verneuil he investigated the geology of Russia, incidentally introducing the title Permian for the lower portion of certain post-Carboniferous red rocks and limestone long studied in Germany. Besides this he made important contributions to the geology of all countries from Italy to Scandinavia. In fact he did more than anyone else to establish and harmonise the main Palozoic stratigraphical features of Europe and, indirectly, of the world. In addition to a multitude of papers he published three important books: The Silurian System, 1839 ; The Geology of Russia in Europe and the Ural Mountains, 1845 ; and Siluria, 1854.

He was elected into the Royal Society in 1826, because, as the President, Sir Humphry Davy, told him, he was an independent gentleman with a taste for science and plenty of time and money for its gratification. He seems to have given little cause for regret to his supporters, since in 1849 we find him awarded the Copley Medal, the highest honour at the Society's disposal. Of the 59 Fellows of the Royal Society who figure on the staff list of the Geological Survey and Museum, only the chemists Hoffmann and Frankland, the physicist Stokes and the biologists Huxley and Hooker share this distinction with the geologist Murchison. He was a founder member and pillar of strength of both the Royal Geographical Society, 1830, and the British Association, 1831. He was knighted in 1846. All this before he took up official duties. In 1864 he received the Wollaston Medal, and in 1866 was created a baronet. He died in 1871.

Murchison's dynamic interest in sport, art, travel and science made him welcome in a wide circle. The receptions which he and Lady Murchison gave were a feature of the life of the Metropolis. Abroad, the crowned heads of Europe invited him to their palaces, for the interest of his conversation and the advantages which his researches brought to their several countries. The presents received from successive Czars are today treasured exhibits in the Museum of Practical

Geology. The memory of his services has survived the October Revolution. In 1942 the Geological Society received the following congratulatory telegram from the Ural Geologists at the State University of Svendlovsk ' We are sending to English geologists with the centenary of Sir Roderick Murchison's establishing the Permian period. We are struggling together for the quickest extermination of our common enemy, the German Nazism.'

Having said so much in favour of Murchison, especially as a pioneer in stratigraphy, it is only fair to recall some of his failings. He was a catastrophist like De la Beche, and a strong opponent of glacial theories. Moreover, he was already 63 years of age on his appointment as Director General.

The beginning

On his first day of office Murchison called a council of Professors to consider the problem of cataloguing the contents of the Museum. Though he inherited only one catalogue from De la Beche, it happened to cover the well chosen collection of Pottery and Porcelain; and it served him in good stead a few days later when the Prince Consort came to talk over plans for the future. The Prince hoped to see the Jermyn Street collections expanded to illustrate all important aspects of applied science, art and manufacture, and spoke of housing the whole in one great building. In the process of time it has required half a suburb, rather than a single building, to accommodate a partial fulfilment of his princely dream.

In 1857 a general descriptive catalogue of the Museum of Practical Geology appeared, followed in 1858-65 by others on Rocks, Minerals, Mining and Metallurgical Models and Fossils. Huxley was as keen as any of his fellow professors. In 1856 he produced an admirable essay on the Methods of Paleontology, which, reprinted, served as preface to a fossil catalogue prepared by himself and Etheridge and issued 1865.

Three months after his appointment Murchison drew up a memorandum of 12 points which he had settled up to date. All are interesting, but only three can be mentioned here.

> 2. I have ordered the lettering of all the colours on the maps.

> 9. I have rendered the titles of all our future volumes uniform—Records of Mines, Decades, Memoirs are all to appear under the general title of Memoirs of the Geological Survey.

> 11. On entering office I made a vigorous stand against a Parliamentary document, drawn up by Playfair as Secretary of the Department at the Board of Trade, whereby Mr. Cole was appointed Inspector General ' of all schools and Museums, whether in the metropolis or country. I insisted upon a special exemption of this establishment from such a rule, and a paragraph to that effect was accordingly inserted.

In relation to item II it is interesting to note that next year, 1856, Playfair himself became Inspector

General; and that, also in 1856, the Department of Science and Art was transferred to the Education Department of the Privy Council, carrying with it Murchison and his charge. Murchison had protested vigorously against leaving the Board of Trade ; but Geikie thinks his objection ' was in good measure personal. Previously the Director General of the Geological Survey had reported direct to a Minister of State, now he would have to conduct his communications through Mr. Henry Cole.' In 1862 Cole acted as Secretary to a small Commission which prefixed Royal to the title of the School of Mines, and established an Associateship in place of the original Diploma.

Memoirs of Murchison's first twelve years

One of Murchison's earliest reforms was the introduction of Sheet Memoirs, or Explanations, to accompany individual one-inch maps. As already mentioned, his instruction in this matter has fully materialised only in Ireland ; but enough has been achieved in Great Britain to make us eternally grateful. England was first starter with Cheltenham by Hull in 1857 ; Ireland followed in 1858 ; Scotland in 1861.

Only three District Memoirs were published during Murchison's first twelve years. Two cover England's geological treasure island, the Isle of Wight, with its Fluvio-Marine Formation described by Forbes (posthumous) in 1856, and its General Geology by Bristow in 1862. The third describes North Wales, 1866, and is numbered volume iii of De la Beche's serial memoirs. In it Ramsay speaks for himself and his field colleagues, while Salter, who had retired in 1863, contributes a copiously illustrated palæeontological appendix.

Ramsay starts with an historical introduction, pointing out that the Geological Survey under De la Beche had in essence accepted and applied Murchison's vocabulary. ' Differences of opinion still exist, but chiefly respecting names and classification, and though these may be interesting to individuals, they neither affect the order of stratification nor the palxontological facts, both of which can be readily understood by whatever names the strata are called.' Ramsay restricts the name Cambrian to relatively old rocks which, excepting annelid burrows, and a doubtful trilobite, have nowhere yielded in England or Wales any well authenticated organic remains.' In fact, much of what Ramsay classes as Cambrian, for instance in Anglesey and the Longmynd, is now called Precambrian. Everything in which respectable Early Palwozoic fossils are found he includes as Silurian. Although there are great generic and specific differences in the fossils of some of the Silurian formations, trilobites, cystidew, brachiopods, etc., are found throughout, and graptolites everywhere except in the Lingula flags.'

The development of knowledge that has come during the progress of the work is sketched, with emphasis on the widespread unconformity detected at the junction of what have later come to be known as the Ordovician and Silurian. A general account of the Paleozoic rocks of Wales and Shropshire follows—the memoir has as frontispiece a geologically coloured map on the scale of ten miles to one inch, which reaches south to the Bristol Channel and west to the Malverns. The difficult matter of local detail for the various sub-districts is admirably handled in a series of short chapters. Slate, copper and gold are mentioned where they occur, but the treatment of economic subjects is disappointing, even when we recall that some have already received separate attention. A strange example of secondary enrichment is noted where the peat of a small moss, after burning in kilns, yielded many thousand pounds worth of copper.

Ramsay's physiographic treatment is according to his new outlook, to be explained more fully later ; but it is brief, probably at the request of the Director General, who thought it mistaken. It is, however, good to read of, the corries of Snowdonia, ascribed to glacial action. ' In all glacial regions, past and present, high circular hollows like these are exceedingly characteristic.'

On turning to Salter's appendix, one feels, so far as stratigraphy is concerned, lifted to a higher, more international, level. Joachim Barrande in 1851 paid a visit to England with the express purpose of comparing his rich palaeontological material from Bohemia with British equivalents. He had already distinguished in the Bohemian Silurian (sensu lato) three successive faunas, of which the earliest, or Primordial, corresponds with what we now called Cambrian. He found from an inspection of the Survey collections that the Lingula Flag of Sedgwick was the exact equivalent of his own Primordial. To follow up this clue entailed much work by Salter, not only in the cabinets, but also in the field, where especially he came to realise the outstanding value of some of Sedgwick's subdivisions, such as the Tremadoc Slate and the Arenig or Skiddaw group—although, till Salter took up the matter, these subdivisions were little more than lithological.

Here it may be recalled that Salter in 1862 had discovered Paradoxides in South Wales, thus opening the door in Britain to pala.ontological research in what is now known as the Middle Cambrian.

His visit to the district was doubly blessed, for it enabled him to enlist the interest of a doctor practising at St. Davids, the redoubtable Henry Hicks, who in company with himself, and before long independently, was destined to accomplish more than any other in zoning the Welsh Lower Palaeozoic formations by their contained trilobites. Salter's appendix was written in 1865—too early for him to make use in it of his joint report with Hicks to the British Association meeting of that year at Birmingham, in which, for instance, the Menevian formation was erected to take the lower, that is paradoxidian, part of the Lingula Flags.

Before the North Wales memoir appeared a new group of publications had been started, illustrative of British Organic Remains. Monograph I, by Huxley, dated 1859, was devoted to the genus Pterygotus.

The Warwickshire (1859) and Leicestershire (I 860) coalfields were given individual memoirs ; and the South Staffordshire coalfield a second edition (1859); while the Iron Ores of Britain were treated in four parts, [856-62, which cover most of England and Wales.

Maps of Murchison's first twelve years

The year 1858 was marked by the appearance of the first Geological Survey map-sheets on the scale of four miles to the inch. Six beautiful examples were issued, covering Wales and the West of England.

Publication of one-inch maps, principal object of the Survey, continued happily: in England spreading mainly eastwards to complete the Midland coalfields and the approaches to London ; in Ireland, south and south-west from Dublin ; in Scotland, through the Lothians and Fife (Fig. 8).

Ordnance Survey facilities, it will be remembered, had allowed of field work in Ireland and Scotland being started on maps on the scale of six inches to a mile. By 1859 a skeleton six-inch Ordnance map became available for London and its environs. Murchison seized the opportunity to use it as a basis for geological work. He was most anxious that engineers and proprietors should see the variations of soil and subsoil in and around the Metropolis delineated with as much fullness and accuracy as could reasonably be expected. The mapping required special characteristics on the part of the surveyor, and was mainly entrusted to W. Whitaker, who showed a flair for interpreting records kept by engineers and others of temporary exposures for foundations and sewers and of bore-holes for water—he himself had been trained as an engineer. In an obituary, [925, it has been said: ' Probably no one has rendered better service to his fellow men than Whitaker in the applications of geology to the needs of civilised life.'

In 1860 Hull was able to start mapping the Lancashire coalfield on the six-inch scale, and this practice was continued in after years northwards from coast to coast. The quality of solid mapping was much improved, and drift mapping became general. Publication of selected six-inch geological maps dates from 1860 in Lancashire and 1861 in Scotland.

Staff additions during Murchison's first twelve years

As might have been expected from the man, Murchison saw to it that his field staff was increased. The main change was delayed twelve years, but even in the interval his fieldsmen numbered on the average 24.4, nearly double the corresponding figure for De la Beche's last ten years. The most interesting acquisitions during this stage were the brothers Archibald and James Geikie (1855 and 1861), W. Whitaker (1857), A. H. Green (1861), Ben N. Peach (1862) and R. H. Tiddeman (1864).

The Geikies came of a gifted Edinburgh family, and from boyhood onward revealed a strong interest in science and literature. Archibald counted among his senior friends, Hugh Miller, editor of the Witness, better known, perhaps, as the Stone Mason of Cromarty. It was to this great man that he owed his first introduction to Murchison. Green was a 6th Wrangler, who both at school and college had learnt to love geology. Ben N. Peach was son of a famous naturalist, Charles W. Peach, employed in the Customs Service.

For many years Peach senior was stationed at Fowey, in Cornwall, where he made striking discoveries in relation to modern and extinct forms of life. Ben used to tell in after years of how his father once wrote to Murchison about a find he had made in 1837 of Ordovician fossils at Gorran Haven. Murchison replied cautiously, suggesting a possible misidentification ; but Peach banished doubt by sealing his next envelope with a cast of a diagnostic species. Transferred to Wick in Caithness, Charles Peach continued to use his opportunities. In 1854 he paid a visit to Durness on the Sutherland coast to ' receive' a wreck, and there he noticed fossils, poorly preserved, in the Durness Limestone. This discovery reawoke general interest in the North-West Highlands, more especially when a subsequent visit in 1857 yielded Peach better specimens, undoubtedly Ordovician in age. Murchison felt so indebted to his friend that he undertook to send young Ben to the School of Mines, at which the latter graduated with the newly established Associateship, to remain eternally grateful for having been brought under the tutelage of Huxley.

Tiddeman was a student of Phillips at Oxford. He achieved fame in his Survey career mainly through his theory of reef-knolls in the Carboniferous Limestone of the North of England, to which we shall recur when we come to the 1888 meeting of the International Geological Congress in London.

Murchison did little to increase De la Beche's final Headquarter Staff. He did, however, introduce G. G. Stokes, 1855, as Professor of Physics, to be followed in 1859 by J. Tyndall, who took particular interest in glacial motion. He also secured E. Frankland as Professor of Chemistry, when Hofmann retired in 1865. His paleontological appointments included Robert Etheridge, 1857, and E. T. Newton, 1865. Murchison first met Etheridge while geologising with Lord Ducie in the Cotteswold Hills. ' Judging from his celerity, his quickness in finding shells and naming them, and in drawing sections, I said to Ramsay [who was one of the party], " This is the man we must have to put our Jermyn Street Museum in order." '

Research during Murchison's first twelve years

The first twelve years of Murchison's reign fell in the most brilliant period of Natural History Sciences in the story of Britain ; and the Geological Survey played a becoming part — though Murchison himself, in the long run, did more harm than good to his scientific reputation. The novelty

of Smithian stratigraphical research had waned, but the accumulated knowledge, combined with better topographical maps, increased the opportunities for preparing geological maps of permanent value for industrial or purely scientific use. Moreover, Darwin's release of his ideas on evolution gave new values to both stratigraphy and palxontology ; while a marked renaissance affected the study of scenery and glaciation.

During this period Murchison polished up a number of his past stratigraphical achievements. Probably his most important contribution was made in 1858 and 1859, when he emphasised faunal comparisons between the Scottish and Russian developments of the Old Red Sandstone, basing largely upon discoveries of Hugh Miller and Robert Dick. Much more attention, however, was attracted to his abortive investigation of the age of the crystalline schists of the Scottish Highlands.

Scottish Highlands

In Sutherland and Ross, Macculloch, between 1814 and 1824, had described a succession which, to use modern names, may be summarised thus: Lewisian gneiss, covered unconformably by Torridonian sandstone, overlain by quartzites and limestone, which alternate with and are succeeded by gneiss and schist forming the main mass of the Highlands. He also pointed to the existence of fossils, including one now called Salterella, in the quartzite series. Salterella is a difficult fossil to place zoologically, and did not seem till much later sufficiently definite to give a geological date ; but Charles Peach's find of more hopeful remains in the limestone in 1854 led Murchison next year to visit the district in company with Professor J. Nicol of Aberdeen. The two observers did not agree in all details, nor did they afterwards adhere in all particulars to the views they formed individually in 1855. Both returned a number of times to the scene of operations. Murchison in 1858 with Charles Peach, who by this time had got his clearly determinable Ordovician fossils; in 1859, with Ramsay ; and in 1860, with Archibald Geikie. Murchison and his two Survey colleagues (Peach's view is not recorded) satisfied themselves that Macculloch's reading of the sections was essentially correct, and that the schists overlying the fossiliferous quartzite-limestone series must be a conformable upward continuation of the latter—and therefore Ordovician. Nicol, on the other hand, considered in 1860 that ' the line of junction [of schists and fossiliferous formations], where this conformable succession is said to occur, is clearly a line of fault, everywhere indicated by proofs of fracture, contortion of the strata, and powerful igneous action.' Nicol, in his sections, always drew his fault very steep or vertical. The true answer, found more than 20 years later, is that the Highland schists here considered have been thrust at a low angle for miles forward over the fossiliferous Ordovician. Nicol was dimly groping towards a realisation of this great structural fact. Murchison, if he ever considered it, dismissed it as impossible. Murchison's failure in this matter is difficult to understand, even allowing for his age and the confidence which long success had given him. As recently as 1848 he had described with detail and conviction a comparable overthrust in the Glarus Alps, which had been demonstrated to him in the field by its discoverer, Escher von der Linth—but then the significance of the Swiss structure was vouched for by fossils, above as well as below the great dislocation.

The authority of Murchison, Ramsay and Geikie's reading of the North-West Highland sections won almost universal acceptance for their views. To the end of his days Murchison could think with self-satisfied smile of the part he had played in the geological interpretation of the home of his fathers. Unfortunately Nicol could not share this pleasure. He died discredited, an object of pity.

Quite apart from their bearing on the age of the Highland schists, Peach's 1857 fossils proved exceptionally interesting. They were determined by Salter, not only as Ordovician, but also as typical of the North American development of the Ordovician. This recalls Portlock's remark of 1843 about the American character of some of the Early Paleozoic fossils of Ireland.

Here, perhaps, we may turn aside to note two remarkable coincidences connected with this research. In the first place Logan had shortly beforebrought to England his Canadian collections for study by Salter as Paleontologist of the home Survey ; and it was this circumstance that made it possible for Salter to realise at once the full significance of Charles Peach's material. In the second place, when the question of structural relations of schist and limestone was reopened in the 80's, no one played a more glorious part in its solution than Ben N. Peach, who owed his education at the School of Mines to his father's discovery of fossils at Durness.

Evolution

In many other directions Murchison did not carry his colleagues with him as he did in the North-West Highlands. This was the case in a paper he published in 1859 on the reptiliferous sandstones of Elgin. Here he was led by field appearances to urge that the reptiliferous sandstones of Elgin are an upward conformable continuation of the Old Red Sandstone of the district ; but he admitted in a postscript that in view of Huxley's careful examination of all the fossils up to date ' it becomes me to pause in my geological conclusions.'

Murchison had long been a progressionist, and, quite apart from Huxley's influence, he had felt that reptiles seemed out of place in the Old Red Sandstone. Still his progressionist views did not bring him to favour Darwin's evolutionary claims as set out in the Origin of Species, 1859. On the other hand, Huxley and many of his colleagues were ready converts. Thus in 1860 Huxley chose the Relation of Man to the Lower Animals as subject for his six-lecture evening course to working men—like the other professors at Jermyn Street, he found these classes particularly stimulating. Similarly, later the same year, he rendered the Oxford meeting of the British Association journalistically memorable with his better-ape-ancestor-than-bishop repartee addressed to an episcopal opponent, the doughty Wilberforce. Murchison, for his part, said little in public, but his private view is recorded in a letter: I flatter myself that I have seen as much of nature in her rough moods as any living man, and I fearlessly say that our geological record does not afford one scintilla of evidence in support of Darwin's theory.'

Rivers

The year 1862 saw the publication by the Geological Society of a famous classic, in which Jukes analysed the river development of Southern Ireland. Jukes explains how, when Murchison decided upon routine publication of Sheet Explanations, he gave him instructions to include descriptions of the form of the ground. Jukes had already devoted much thought to physiography, and was glad to find the subject now included among those with which he had to deal officially as Local Director responsible for editing his colleagues' reports. The Cork district is mainly composed of parallel ridges of Old Red Sandstone, separated by hollows floored with Carboniferous Limestone, or Carboniferous Slate. In keeping with the general practice of the day Jukes calls the rivers of the drainage pattern transverse (he more often says lateral) or longitudinal, according as they run across or along the strike of the geological formations. He argues that the drainage system started on a smooth tilted surface, originally planed by marine erosion ; and he interprets the geographical depressions along the outcrops of the limestone as due to subaerial erosion that kept pace with the downward cutting of the transverse ravines.

He recognises that some of the original transverse brooks have failed to deepen their courses as quickly as their neighbours, and so were eventually drawn down into the longitudinal valleys, and their water carried out to the ravines' maintained by successful rivals. In fact he sketches in clear outline the ideas of consequent, subsequent and obsequent drainage, and of river capture, which have since been so brilliantly elaborated by American authors.

Jukes also naïvely rediscovers the importance of subaerial erosion—he seems never to have read Hutton's arguments, which led that great man to assert: We must conclude at least that all the valleys are the operation of running water in the course of time. If this is granted we have but to consider the mountains as formed by the hollowing out of the valleys.' Jukes also rediscovers the erosional connection which commonly exists between surface form and rock character, already epitomised in Hutton's statement: ' The height of the mountain depends upon the solidity and strength of the stone.'

These rediscoveries were valuable, since most, though not all, of Jukes' contemporaries had lost sight of the physic-graphic treasures stored in the writings of Guettard, Desmarest, and Hutton, and at a later date of Scrope (but see Col. Greenwood's Rain and Rivers; or Hutton and Playfair defended against Lyell and all Comers, 1857).

The most characteristic feature of Jukes' work lies, perhaps, in his approach to the problems of river development armed with a good geological map. In a postscript he asks ' whether it will not turn out to be a general law in all mountain ranges in the world, that the lateral [transverse] valleys are the first formed, running directly from the crests of the ranges down the steep slopes of the mountains, while the longitudinal valleys are of subsequent origin, gradually produced by atmospheric action on the softer and more easily eroded beds that strike along the chains.' He further states that, if later work shows that the Cork principles hold for the Weald of Kent and Surrey, it will be reasonable to suppose that they ' will ultimately be found applicable to all river-valleys in all parts of the world.'

The effect of Jukes' paper on Ramsay may be gathered from one of his letters written to Geikie: By the way, I think I have given up the marine denudation of the Weald. Atmosphere, rain and rivers must ha' done it. I'm coming to that, I fear and hope, and hoping, fearing, trembling, regretfully triumphant, and tearfully joyous with the balm of a truthful Gilead spread upon the struggling soul, bursting the bonds of antique prejudice, I yet expect to moor the tempest-tossed bark of Theory in the calm moral downs of Assurance.'

In the early spring of 1863 Ramsay gave one of his usual courses of six evening lectures to working men at the Museum, using material to a large extent based upon what he had seen during inspection tours of his colleagues' work in various districts. The lectures, taken down in shorthand, were published the same year in a small volume, Physical Geology and Geography of Great Britain, destined to reach a 4th edition by 1874. Ramsay now emphasised the breaching of escarpments in the Weald and other districts, where gentle downstream dips are characteristic. He attributed it to vertical downward erosion of the river concerned, a process that gives opportunity for subaerial development of escarpments and for their subsequent almost horizontal travel in the direction of dip. The new views were soon lucidly developed by C. le Neve Foster and W. Topley, who were responsible for mapping the Weald for the Geological Survey. Their famous Remarks on the Denudation of the Weald were read to the Geological Society in 1865. The same general story of the efficacy of subaerial (as well as submarine) erosion runs through Archibald Geikie's Scenery of Scotland, the first edition of which also appeared in 1865. Whitaker, following up in 1867 in the Geological Magazine, gives a masterly account of the position by that time reached. He is able to quote a personal letter from Lyell pointing out that the latter now considers two of the arguments for subaerial development of escarpments ' unanswerable.' After gathering together a formidable list of supporters, Whitaker adds ' a great number of these sub-aerialists are or have been employed on Government Geological Surveys, and therefore have been accustomed to be constantly in the field.' Of course, the obvious retort of history is: even geological surveyors make mistakes.

Glaciers

Another immensely important physiographic advance of these days concerns the glacial erosion of

many rock basins. Ramsay has recorded that the idea first came to him in Wales, in 1854. He put forward the suggestion to account for minor examples in an essay on The Old Glaciers of Switzerland and North Wales, 1859 ; but it attracted little attention until elaborated in a paper On the Glacial Origin of certain Lakes in Switzerland, the Black Forest, Great Britain, Sweden, North America and elsewhere, read to the Geological Society in 1862. Ramsay here tackles a problem that had always confronted students who relied upon running water for the sculpture of landscape. Hutton had only been able to suggest three possible explanations for lakes: landslip, earth movement and solution. He had indeed included glaciers among his agents of erosion ; but he knew far too little about them to connect them with overdeepening of valleys. Ramsay's contribution to the subject constitutes one of the brightest jewels in the crown of the Geological Survey. Its appearance brought down on its author's head criticisms reminiscent of the assault made on Agassiz and Buckland, 20 years previously. By chance Ramsay, like Buckland, spoke with the prestige of presidency ; otherwise, he used to assert, the Council would have voted against publication except in bare abstract.

Many of the younger men, Darwin, Hooker, Logan, and, on the Survey, Jukes, Geikie and Tyndall (with exaggeration) sided with Ramsay ; but the older men, prominent among them his own chief, Murchison, were hostile. Murchison's Presidential Address to the Royal Geographical Society, 1864, contains a detailed review of the whole subject of glaciated lands, based largely upon personal knowledge of the districts themselves and of the men who had worked on their problems. Reading this Address one realises that it is magnificent, but it is not true. For Murchison the results of floating ice and glaciers can only be distinguished by terminal moraines and common sense.

Floating ice, he says, cannot produce terminal moraines, and glaciers cannot travel over flat or uphill country. Rock basins are for him all products of earth movement. Here one may add that Murchison's various Presidential Addresses to the Geographical Society constitute a most important feature of his tenure of the Director-Generalship of the Geological Survey. He delivered no less than 13 during this period, full of inspiring information regarding current and prospective exploration and research. It is no exaggeration to say that Murchison came to be much more widely appreciated as the champion of men like Franklin and Livingstone than as the founder of the Silurian System.

One cannot but feel admiration for Murchison's decision to meet the supposed heresies of his staff with argument rather than closure. Geikie, speaking of his own Scenery of Scotland, says: ' The volume was dedicated to Murchison, to whose friendship I owed so much. Yet its main thesis [uniformitarian principles of erosion] was in such direct antagonism to his well-known cataclasmic opinions that I was prepared for a protest on his part, though he knew what my opinions were. But he accepted the compliment without demur.'

Glaciation by land-ice came to be much better understood in these years by Ramsay and Geikie and, largely through their influence, by many others. In a wonderful paper on the Glacial Theory and its recent Progress, published in the Edinburgh New Philosophical Journal for 1842, Agassiz had elaborated his contention that boulder clay in Scotland ' must have been transported under the ice.' In the spirit of compromise advocated by Buckland, this portion of Agassiz' theory was for some twenty years set aside by practically all British geologists—an amazing circumstance In 1859 Ramsay visited Geikie at work in Fife, and ' our conversation,' Geikie says, ' turned on the Boulder Clay and the mysteries of its origin. We both felt how unsatisfactory was the received explanation of iceberg action and submergence. I was thus led to study this deposit, and to reach thereby the conclusion, at which Ramsay also simultaneously and independently arrived from a consideration of other evidence [distribution of rock basins], that the great glaciation was the work of land-ice. This change of view was completed before the summer of i861.' One of Geikie's chief arguments was the local nature of most of the debris found in boulder clay.

In January, 1862, Geikie took over from Ramsay, who was far from well, his course of evening lectures to working men at the Museum, and explained to his audience his conversion to land-ice. In February T. F. Jamieson of Ellon, factor, farmer and later agricultural lecturer, gave further independent evidence leading to the same conclusion in a paper read to the Geological Society (followed next year by a vindication of Agassiz' glacier-barred lakes in Glen Roy). In March came Ramsay's paper, already mentioned, on the glacial erosion of rock basins. Truly British geologists were beginning to consolidate Agassiz' conquests and to advance on to new ground. Still, as one may judge from Geikie's classic On the Glacial Drift of Scotland published by the Geological Society of Glasgow in 1863, Ramsay, Jamieson and Geikie at this date retained a great deal more submergence in their philosophy than is commonly admitted today. They thought, for instance, that glacial sands, even if they contained no marine shells, suggested the former presence of the sea, so long as they lay ' far out of the reach of any stream.' Geikie considered that the main submergence might prove to have extended more than 2,000 ft. above present sea level ; and he pictured it as roughly intermediate in date between the glaciation responsible for the boulder clay of the lowlands and that which produced the valley moraines among the mountains.

Devonian System.—From 1865 onwards for a few years, Murchison was subjected to a rather futile crusade led by Jukes, which virtually aimed at dispensing with the Devonian System. Jukes based his judgment mainly on the experience he had gained in Southern Ireland. He claimed that the Old Red Sandstone of South Wales continued without serious modification into Devon, while above it the Carboniferous Limestone had changed over to a Carboniferous Slate facies, miscalled Devonian. In all this, Jukes went much farther than Phillips and De la Beche, who twenty years previously, it will be remembered, had argued for a possible rectification of the line adopted by Sedgwick and Murchison as boundary between Devonian and Carboniferous.

Granitisation

The Director General was probably much less ruffled by an announcement made next year by his other lieutenant in a Presidential Address to the Geological Section of the British Association, meeting at Nottingham. In it Ramsay avowed a long cherished view that granite is a metamorphic rock resulting from heat ' with the aid of alkaline waters.' This particular heresy for a time gained much support in Britain ; and after a long interval, during which it was more or less banished to France, it has recently returned to considerable favour. It is curious that in our country most of its present apostles, like Ramsay in his own day, have close connections with the Royal School of Mines. As regards immediate results, it is probably correct to trace Ramsay's influence (and less directly that of the Canadian, Sterry Hunt) in two papers published by James Geikie in 1866: one in the Quarterly Journal of the Geological Society, the other in the Geological Magazine. Here Geikie sought to demonstrate that what we now know as Ordovician pillow lavas, serpentines, etc., near Ballantrae, and as Devonian granites in the Midland Valley and Southern Uplands of Scotland, are merely altered sediments. The challenge was at once (1867) taken up by David Forbes (brother of Edward) on general grounds, and at a later date (1878) by T. G. Bonney after examination of the Ballantrae exposures. Both these critics were early exponents of microscopic petrology. Geikie was not easy to convince ; but eventually in 1901 we find him joint author with J. S. Flett of a short note delivered at the Glasgow meeting of the British Association, in which one of the above-mentioned granites is spoken of as ' intrusive into Lower Old Red Sandstone' and surrounded by evidences of ' contact alteration.'

Royal Commission on Coal

In 1866 a great event happened in the history of governmental research. A Royal Commission was appointed under the Duke of Argyll ' to inquire into the several matters relative to Coal in the United

Kingdom.' There had been much anxious questioning of the wisdom of exporting coal to foreign countries. The Commission was to take stock of the available resources in exposed and concealed fields, and to estimate probable dates for their ultimate exhaustion. Murchison, Hunt, Ramsay, Jukes and Hull were all included as members of the Commission, and several of their colleagues gave valuable assistance. The Commission continued to sit during the next four years, and did not draw up its Final Report till 1871, by which time Murchison was incapacitated by his last illness. The start of the Commission is mentioned here, because it marks the end of the first stage of the Murchison period. It enabled him and the Secretary of the Department of Science and Art to point to useful work completed, and at the same time to emphasise how much more was now in reach if staff facilities permitted. In Wales, South-West England and the Midlands the Survey had published maps and sections of the coalfields, sometimes accompanied by memoirs—but the field work had been carried out on the inadequate one-inch scale ; in Lancashire and Yorkshire, six-inch mapping was in progress, but far from complete; in Durham, Northumberland and Cumberland, scarcely a start had been made ; in Scotland only half the coalfield area was mapped; in Ireland, unfortunately, the coal resources were known to be very slight.

Staff changes during Murchison's last five years

The urgency of closer coalfield survey appealed to the Government, as also did the importance of supplying adequate drift maps to agriculturists, civil engineers, medical authorities and town planners. It was clear that an increase of field staff was desirable, accompanied by considerable reorganisation. In 1867 the title of Local Director was abandoned. Ramsay, instead of continuing Local Director for Great Britain, now became, with increased salary, Senior Director for England and Wales. Jukes remained in charge of Ireland, but with his title abbreviated to Director. Geikie was promoted to be Director for Scotland, an altogether new position, with Headquarters in Edinburgh. More importtant still, an additional grade, District Surveyor (the District Geologist of later years), was instituted, with Aveline and Bristow appointed in England, Du Noyer in Ireland, and Hull in Scotland. Du Noyer died in 1869 and was succeeded by Kinahan. Twenty-one field geologists were recruited in 1867, and twelve in 1868. In the latter year Ramsay had a staff of 36, Jukes 13 and Geikie 8. As compared with 1866, the field force was a little more than doubled. On the other hand, it is rather sad that only one paleontologist was added to the existing five. In fact, Headquarter staff was actually reduced during Murchison's last five years, for John Tyndall resigned in 1868 and Robert Willis in 1869 from their respective lectureships in Physics and Applied Mechanics at the Royal School of Mines, and no successors were appointed.

Assimilation of a crowd of novices was a painful business for the old stagers among the field staff. Much time had to be given to training, and a depreciated standard had temporarily to be accepted in maps and memoirs. Moreover, the difficulties of the situation were intensified by continuous calls which the Royal Commission on Coal rightly made on the services of senior members.

While of necessity there were a few misfits among the newcomers, the upshot was much better than might have been anticipated. Many of the recruits were destined to make names for themselves by their contributions to geology, for instance: C. E. Fox-Strangways, J. G. Goodchild, W. Gunn, J. Horne, R. L. Jack, J. W. Judd, G. A. L. Lebour, J. Nolan, F. Rutley and H. B. Woodward, who joined in 1867, and W. A. Traill and W. A. E. Ussher, who followed in 1868. Two of the above, Horne and Woodward, eventually rose to be Assistants to the Director (an awkward term introduced in 1901, when the title Director was substituted for that of Director General). Horne came from Glasgow University and was sent for his training to Peach, thus starting an association which in later years won for them Albert Heim's happy designation of Investigator Twins.' Woodward, in choosing geology as a career, followed successfully in the footsteps of his father and grandfather. It seems natural that he is remembered today, not only as an original worker in, but also as a historian of his

science.

James Croll is not mentioned in the foregoing list, because, though appointed in 1867, it was not as a field geologist, nor yet as one of the scientists of the Headquarter staff. Nevertheless, it is impossible to pass over his advent in silence, since he was the most remarkable man ever enrolled in the Geological Survey, in fact a prodigy. Croll was born in 1821, the son of a Perthshire stonemason and crofter. Poverty and ill-health dogged his footsteps; but in 1832 his mind was opened to what was for him a new world, through buying the first number of the Penny Magazine. Thereafter he took every chance of learning more, and soon was captivated by the ' beauty and simplicity' of ' Joyce's famous scientific dialogues.' Croll drifted from one occupation to another, compelled to give up work as a joiner by an accident to his elbow, and failing to make good as a shopkeeper through aggravation of the same injury. Physical ailments, affecting not only his elbow, but also his heart, eyes and hand, were enough in themselves to make existence precarious ; but added to other difficulties was an ' almost irresistible propensity to study ' the principles that underlie science, philosophy and religion. At last in 1859 he was appointed Curator of the Andersonian College and Museum at Glasgow. Here indeed was an opportunity, for, though the salary was a mere pittance, the duties were correspondingly light ; and as Curator he had access to excellent libraries and could arrange a few hours daily for reading and study. His first publication, a book entitled The Philosophy of Theism, had already appeared in 1857 ; and now from 1861 onwards there followed a quiet steady stream of papers dealing with physical subjects, which he communicated to scientific journals, more particularly the Philosophical Magazine. To this latter in 1864 he contributed one of particular interest, On the Physical Cause of the Change of Climate during Geological Epochs, which took charge of his whole subsequent career. In it Croll connected glacial periods with recurrent combinations of different features of the planetary movement of the earth, coupled with such complications as the storage of cold, if one may use the phrase, in winter-made ice. His theory at once attracted very favourable notice from astronomers like Herschel, and from geologists like Lyell, Ramsay and Archibald Geikie. Thus it happened that in 1867 the latter was able to make a provisional offer to Croll of a post in the newly established Edinburgh office of the Geological Survey, as Secretary and Accountant. Croll agreed, and though he failed to pass the prescribed Civil Service entrance examination, he was on Murchison's strong recommendation eventually admitted at 7s. a day, rising to £350 a year. ' My Lords,' as Kelvin has put it, ' accepted his great calculations regarding the eccentricity of the earth's orbit, and the precession of the equinoxes during the last id,000,000 years as sufficient evidence of his arithmetical capacity.' Croll's official duties consisted in forwarding letters to geologists in the field, attending to their wants, ordering maps and keeping accounts. His unofficial occupation was mainly meditative country walks, pencil in one hand, paper in the other, jotting down new ideas to be elaborated on return before going to bed. By 1875, if we may look beyond the Murchison period that we are at present considering, Croll had published in book form his Climate and Time. This, in the following year, was acknowledged by St. Andrews with its Honorary Doctorate of Laws, by London with the Fellowship of its Royal Society and by New York with the Honorary Membership of its Academy of Science.

Up to this stage considerations of space have prevented mention of anyone who did not belong to the Scientific Staff, as that term is understood in the Civil Service—except perhaps Croll, whose classification is difficult. At all times, however, the work of the Geological Survey has depended very largely upon consummate skill developed among Assistants, more particularly Fossil Collectors, such as ; R. Gibbs, 1843-72 ; A. McHenry, 1861, promoted 1877 ; A. I. Macconochie, 1869-1913; J. Bennie, 1872-1901 ; D. Tait, 1897-1934 ; and J. Pringle, 1901, promoted 1913. Here we must also mention R. Lunn, 1861-1921, who made Survey photographs famous.

Jukes died in 1869, by which time the geological mapping of Ireland had been two-thirds completed. He was succeeded as Director in that country by Hull, whose place as District Surveyor in Scotland

was taken by James Geikie. The two brothers Geikie, Archibald and James, were devoted friends of Ramsay, who until 1867 was their proximate chief. Both imbibed from him the fascination of glacial problems, but Archibald presently in large measure left this field to James, and devoted himself more particularly to a study of ancient volcanoes and of the Old Red Sandstone with its lake, or at at any rate continental, deposits—topics again to which Ramsay had made extremely valuable contributions. As we shall see in the sequel, close contact with Croll exercised a profound influence upon James Geikie, and also upon Peach and Horne.

Publication during Murchison's last five years

During the last five years of Murchison's reign, one-inch map publication advanced quickly into the south-eastern and northern counties of England (Fig. 8). Thus by the end of 1871 the area covered by published maps came to include most of the country that lies south-west of a line drawn from Kendal in Westmorland to Southend on the Thames, with an isolated patch near Newcastle-on-Tyne. In Ireland the same five years saw good progress made in a belt reaching south-west from Belfast to Galway, south-east of which everything had already been published. In Scotland the published area was tripled; for, in the east, sheets covering the greater part of Fife and Peeblesshire were added to those standing for the Lothians; and, in the west, most of Ayrshire and Wigtownshire was overtaken.

Six-inch map publication, which had started in the Lancashire and Scottish coalfields in 1860 and 1861 respectively, began in Northumberland in 1867, Durham in 1868 and Yorkshire in 1871. Sections, both vertical and horizontal, continued to appear.

One district memoir and a number of sheet memoirs were published, and there was no reason as yet to anticipate failure of descriptions either in the North of England or in Scotland. The district memoir was by Hull. It dealt with the Midland counties of England and established the classification of the Trias henceforward used on Geological Survey maps.

The end

One November morning in 1870 Murchison's full life came well nigh to a close. While dressing himself he had a shock which paralysed his left side. He recovered sufficiently for a time to be able to drive out in his carriage ; but he never again set foot in the Jermyn Street Office. Faithful Trenham Reeks, Curator of the Museum and Registrar of the Royal School of Mines, visited him daily and arranged for correspondence. In the spring of 1871 he dictated to his nephew his last Presidential Address to the Royal Geographical Society. In October he took a turn for the worse, and on the 22nd of the month passed quietly away at the age of seventy-nine.

Queen Victoria and the Prince of Wales sent their carriages to join the funeral procession. The Prime Minister, Gladstone, followed the bier to the grave. In Livingstone's journal we find a record of how that great explorer, still searching for the sources of the Nile, was affected when the news reached him within ten months of his own end: ' Alas ! Alas !,' he wrote, ' This is the only time in my life that I have felt inclined to use the word.' Few men have deserved such an epitaph.

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