although the most perfect explanation of a chemical reaction consists of a statement of the atomic interchange which takes place between two molecules; or the change of mutual combination between the atoms in one molecule.

It has, however, been proved that the heat of combination affords a measure of its force; and we know that in giving off heat particles of matter undergo a diminution of velocity of motion. We see, accordingly, that substances capable of exerting great force by their combination are those which can undergo a great diminution of the velocity of their internal motions, and reciprocally.

The force of chemical combination is evidently a function of atomic motion.

It has been shown that the relative velocities of certain atomic interchanges afford a measure of the amount of chemical action between two substances; but a vast amount of work will doubtless be required to develop the atomic theory to the point of explaining the force of chemical action in precise terms of atomic motion.

The general terms of chemistry are mere symbols. Each of them serves to recall a group (usually a very large group) of facts established by observation. The explanation of each term is afforded by a careful study of the facts which it is used to denote; and, accordingly, a chain of evidence involving the use of chemical terms can be fully understood only by chemists accustomed to the consideration of such evidence. The general outline of it may perhaps be to some general thinkers of sufficient interest to attract them to further study of our science.

SECTION C

GEOLOGY

OPENING ADDRESS BY A. C. RAMSAY, LL.D., F.R.S., &c., &c., DIRECTOR-GENERAL OF THE GEOLOGICAL SURVEY, PRESIDENT OF THE SECTION

On the Origin and Progress of the Present State of British Geology, Especially since the first Meeting of the British Association at York in 1831

IN the year 1788 Hutton published his first sketch of his "Theory of the Earth," afterwards extended and explained by Playfair in a manner more popular and perspicuous than is done in Hutton's own writings. In this grand work, Hutton clearly explains that the oldest known strata, like their successors, are derivative, and that as far as *observation* can discover, in all geological time, "we find no vestige of a beginning, and no sign of an end." The complement to this far-seeing observation was at length brought about by William Smith, in his original "Geological Map of the Strata of England and Wales" in 1815, followed, in 1816, by his "Strata Identified by Organised Fossils." This great discovery, for such it was, threw a new light on the history of the earth, proving what had before been unknown, that all the "Secondary" formations, at least from the Lias to the Chalk inclusive, contained each a set of distinctive fossils by which it could be recognised. A law was thus provided for the identification of formations which geographically are often widely separated from each other, not only in England in the case of minor outliers, but also easily applicable to great areas on the neighbouring continent of Europe.

In 1811 the first volume of the *Transactions* of the Geological Society was published, and in 1826-27 there appeared the first volume of the *Proceedings*, the object being to communicate to the Fellows as promptly as possible the *Proceedings* of the Society "during the intervals between the appearance of the several parts of the *Transactions*." The last volume of the *Transactions* contains memoirs read between the years 1845-1856, and only four volumes of the *Proceedings* appeared between the years 1826 and 1845 inclusive, after which the title of the annual volume was changed to that of the "Quarterly Journal of the Geological Society." The Geological Society, to which the science owes so much, was therefore in full action when the British Association was founded in 1831, and the memoirs read before the Society from 1831 to this date may be said to show generally the state of British geology during the last fifty years. To this must be added the powerful influence of the first (1830) and later editions of Lyell's "Principles of Geology," a work which helped to lay the foundations of those researches in Physical Geology which both in earlier and later years have attracted so much attention.

Fifty years ago, in this city, Viscount Milton was president of the first meeting of "The British Association for the Advancement of Science," which he explained had for its chief object "to give a stronger impulse and more systematic direction to scientific inquiry." In his address he pointed out the numbers of Philosophical Societies which had by degrees sprung up in all parts of the kingdom; and the practicability, through the means of the Association, "including all the scientific strength of Great Britain," "to point out the lines in which the direction of science should move."

In that year, 1831, Prof. Sedgwick was president of the Geological Society, and the Geological and Geographical Committee of the British Association recommended that geologists should examine the truth of that part of the theory of Elie de Beaumont, in its application to England, Scotland, and Ireland, which asserts that *the lines of disturbance of the strata assignable to the same age are parallel;* that Prof. Phillips be requested to draw up *a systematic catalogue of all the organised fossils of Great Britain and Ireland;* and that Mr. Robert Stephenson, civil engineer, be requested to prepare a report upon *the waste and extension of the land on the east coast of Britain, and the question of the permanence of the relative level of the sea and land.*

In 1881 it seems strange to us that, in 1831, with William Smith's map of "The Strata of England and Wales, with part Scotland," before them, it should have been considered necessary to institute an inquiry as to the truth of the general parallelism of disturbed strata, which, in a limited area like England, had suffered upheaval at different successive epochs; and we may fancy the internal smile with which Phillips, the nephew of Smith, regarded the needless proposal. The masterpiece of the old land-surveyor and civil engineer remains to this day the foundation of all subsequent geological maps of England and Wales; and *as an unaided effort of practical genius*—for such it was—it seems impossible that it should be surpassed, in spite of all the accuracy and detail which happily modern science has introduced into modern geological maps.

The first paper read at York, in the year 1831, was by Prof. Sedgwick, "On the General Structure of the Lake Mountains of the North of England." This was followed by "Supplementary Observations on the Structure of the Austrian and Bavarian Alps," by the Secretary of the Society, Mr. Murchison, a memoir at that time of the highest value, and still valuable both in a stratigraphical point of view and also for the light which it threw on the nature of the disturbances that originated the Alpine mountains, and their relations in point of date to the far more ancient mountains of Bohemia. In his elaborate address in the same year, on his retiring from the president's chair, he largely expatiates on the parallelism of many of the great lines of disturbance of what were then distinguished as the more ancient *schistose* and *greywacké* mountains, and quotes the authority of Elie de Beaumont for the statement, "that mountain chains elevated at the same period of time have a general parallelism in the bearing of their component strata." On a great scale this undoubtedly holds true, as, for example, in the case of the Scandinavian chain, and the more ancient Palæozoic rocks north of Scotland, Cumberland, and even of great part of Wales. The same holds good with regard to the parallelism of the much more recent mountain ranges of the Apennines, the Alps, the Caucasus, the Atlas, and the Himalayas, all of which strike more or less east and west, and are to a great extent of post-Eocene, and even partly of post-Miocene age. The same, however, is not precisely the case with the Apalachian chain and the Rocky Mountains of North America, the first of which trends N.N.W., and the latter N.N.E. The remarkable chain of the Ural Mountains trends nearly true north and south, and is parallel to no other chain that I know of, unless it be the Andes and the mountains of Japan. It is worthy of notice that the chain of the Ural is of pre-Permian age according to Murchison, while Darwin has shown that the chief upheaval of the Andes took place in post-Cretaceous times.

The Apalachian chain is chiefly of post-Carboniferous date, and the Rocky Mountains have been re-disturbed and re-elevated as late as post-Miocene times.

In the same address Prof. Sedgwick entered an eloquent protest against the broad uniformitarian views so powerfully advocated in the first edition of Lyell's "Principles of Geology" in 1830, in which, throwing aside all discussion concerning cosmogony, he took the world as he found it, and, agreeing with Hutton that geology is in no way concerned with, and not sufficiently

advanced to deal "with questions as to the origin of things," he saw that a great body of new data were required, such as engaged the attention of the Geological Society (founded in 1807), and which, along with other foreign societies and private work, has at length brought geological science to its present high position.

And what is that position? With great and consentient labour, many men, gifted with a knowledge of stratigraphical and palæontological geology, have, so to speak, more or less dissected all the regions of Europe and great part of North America, India, and of our colonies, and in vast areas, sometimes nearly adjoining, and sometimes far distant from each other, the various formations, by help of the fossils they contain, have been correlated in time, often in spite of great differences in their lithological characters. It is easy, for example, to correlate the various formations in countries so near as Great Britain and Ireland, or of the Secondary and Lower Tertiary formations of England and France; and what is more remarkable, it is easy to correlate the Palæozoic formations of Britain and the eastern half of the United States and Canada, even in many of the comparatively minute stratigraphical and lithological subdivisions of the Silurian, Devonian, and Carboniferous formations. The same may be said with regard to some of the Palæozoic formations of India, China, Africa, and Australia, and many of the Secondary and Tertiary deposits have in like manner been identified as having their equivalents in Europe. It is not to be inferred from these coincidences that such deposits were all formed *precisely* at the same time, but taken in connection with their palæontological contents, viewed in the light which Darwin has shown with regard to the life of the globe when considered in their relation to masses of stratified formations, no modern geologist who gives his mind to such subjects would be likely to state, for example, that in any part of the globe Silurian rocks may be equivalents in time to any of our Upper Palæozoic, Mesozoic, or Tertiary formations.

For all the latest details of *genera* and *species* found in the British Palæozoic rocks, from those of St. David's, so well worked out by Dr. Hicks, to the Carboniferous series inclusive, I must refer to the elaborate address of Mr. Etheridge, President of the Geological Society, which he delivered at the last anniversary meeting of that society. It is a work of enormous labour and skill, which could not have been produced by any one who had not a thorough personal knowledge of all the formations of Britain and of their fossil contents.[1]

In connection with such subjects I will not in any way deal with the tempting and important subject of cosmological geology, which in my opinion must go back to times far anterior to the date of the deposition, as common sediments, of the very oldest-known metamorphic strata. Cosmological speculations perhaps may be sound enough with regard to refrigeration, and the first consolidation of the crust of the earth, but all the known tangible rocky formations in the world have no immediate relation to them, and in my opinion the oldest Laurentian rocks were deposited long after the beginning and end of lost and unknown epochs, during which stratified rocks were formed by watery agents in the same way that the Laurentian rocks were deposited, and in which modern formations are being deposited now, and the gneissose structure of the most ancient formations was the result of an action which has at intervals characterised all geological time as late as the Eocene formations in the Alps and elsewhere.

The same kind of chronological reasoning is often applicable to igneous rocks. It was generally the custom, many years ago, to recognise two kinds of igneous rocks, viz., Volcanic and Plutonic, and this classification somewhat modified in details is still applicable, the Plutonic consisting chiefly of granitic rocks and their allies, and which though they have often altered and thrust veins into the adjoining strata, have never, as far as I know, overflowed in the manner of the lavas of modern and ancient volcanoes. Indeed, as far as I recollect, the first quoted examples of ancient volcanoes are those of Miocene age in the districts of Auvergne, the Velais, and the Eifel, and the fact that signs of ordinary volcanic phenomena are found in almost all the larger groups of strata was scarcely suspected. Now, however, we know them to be associated with strata of all or almost all geological ages, from Lower Silurian times down to the present day, if we take the whole world into account.

[1] I must also, with much pleasure, advert to Prof. Prestwich's inaugural lecture when installed in the Chair of Geology at Oxford in 1875, the subject of which is "The Past and Future of Geology."

Amongst them, those of Miocene date hold a very prominent place, greatly owing, doubtless, to the comparative perfection of their forms, as, for example, those of the South of France and of the Eifel. Their conical shapes, and numerous extinct craters, afford testimony so plain, that he who runs may read their history. The time when they became extinct would doubtless amaze us by its magnitude, if it could be stated in years, but yet it is comparatively so recent that not all the undying forces of atmospheric degradation have been able to obliterate their individual origin.

It is, however, generally very different with respect to volcanoes of Mesozoic age, for though Lyell stated with doubt, that volcanic products of Jurassic date are found in the Morea and in the Apennines; and Medlicott and Blanford consider that probably the igneous rocks of Rajmahal may be of that age, we must, perhaps, wait for further information before the question may be considered as finally settled. Of Jurassic age no actual craters remain. Darwin also has stated, on good grounds, that in the Andes a line of volcanic eruptions has been at work from before the deposition of the Cretaceo-oolitic formation down to the present day.

In the British Islands we have a remarkable series of true volcanic rocks, the chronology of which has been definitely determined. The oldest of these belongs to the Lower Silurian epoch, as shown, for example, on a large scale in Pembrokeshire, at Builth in Radnorshire, in the Longmynd country west of the Stiper stones in Shropshire, and on a far greater scale in North Wales and Cumbria. Of later date we find volcanic lavas and ashes in the Devonian rocks of Devon, and in the Old Red Sandstone of Scotland. The third series is plentiful among the Carboniferous rocks of Scotland, and in a smaller way interstratified with the Coal-measures of South Staffordshire, Warwickshire and the Clee Hills. The fourth series chronologically is associated with the Permian strata in Scotland, and the fifth and last consists of the Miocene basaltic rocks of the Inner Hebrides and the mainland of the West of Scotland.

In the British Islands the art of geological surveying has, I believe, been carried out in a more detailed manner than in any other country in Europe, a matter which has been rendered comparatively easy by the excellence of the Ordnance Survey maps both on the 1-inch and the 6-inch scales. When the whole country has been mapped geologically little will remain to be done in geological surveying, excepting corrections here and there, especially in the earliest published maps of the South-west of England. Palæontological detail may, however, be carried on to any extent, and much remains to be done in microscopic petrology which now deservedly occupies the attention of many skilled observers.

Time will not permit me to do more than advert to the excellent and well-known geological surveys now in action in India, Canada, the United States, Australia, New Zealand, and South Africa.

On the Continent of Europe there are National Geological Surveys of great and well-deserved repute conducted by men of the highest eminence in geological science, and it is to be hoped the day may come when a more detailed survey will follow the admirable map executed by Sir Roderick Murchison, De Verneuil, and Count Keyserling, and published in their joint work, "The Geology of Russia in Europe and the Ural Mountains."

It is difficult to deal with the Future of Geology. Probably in many of the European formations more may be done in tracing the details of subformations. The same may be said of much of North America, and for a long series of years a great deal must remain almost untouched in Asia, Africa, South America, and in the islands of the Pacific Ocean. If, in the far future, the day should come when such work shall be undertaken, the process of doing so must necessarily be slow, partly for want of proper maps, and possibly in some regions partly for the want of trained geologists. Palæontologists must always have ample work in the discovery and description of new fossils, marine, freshwater, and truly terrestrial; and besides common stratigraphical geology, geologists have still an ample field before them in working out many of those physical problems which form the true basis of Physical Geography in every region of the earth. Of the history of the earth there is a long past, the early chapters of which seem to be lost for ever, and we know little of the future except that it appears that "the stir of this dim spot which men call earth," as far as Geology is concerned, shows "no sign of an end."