# REVIEWS AND NOTICES OF BOOKS.

## *A Manual of Elementary Geology, or the ancient changes of the Earth and its Inhabitants, as illustrated by Geological Monuments.* By Sir CHARLES LYELL, M.A., F.R.S. Fifth Edition. Murray, London. 1855.

There are two kinds of valuable geological Manuals. In one the writer well versed in his subject merely collects and digests the scattered facts and principles, which, in the course of time, have been eliminated by original investigators; in another the author not only thoroughly appreciates, describes, and applies such established truths, but in addition brings to bear upon them much valuable matter in the shape of original investigations, or, by the depth of his views and the breadth of his combinations, he imparts an original value to his work, interesting to the most matured student, as embodying the deliberate convictions of an author who regards the subject from a high point of view, and whose authority carries with it a weight which may influence the opinions, and direct the labours of the rising generation of geologists. To the latter class eminently belong the Manuals that have at various times been published by De la Beche, Phillips, and Lyell. We have ever looked on De la Beche's Manual of Geology (long out of print) as, in its day, a model of arrangement and treatment of the subject. We may also, in passing, advert to the Manual lately published by Professor Phillips, in all respects a remarkable work, clearly and beautifully written, and so full of matter admirably arranged, that it may be safely recommended as a text-book to every student of geology. In the work before us by Sir Charles Lyell, we have new proofs, not only of personal investigations in the field, but of that ever-wakeful industry which allows no valuable novelty to escape, and which, from a high and philosophical point of view, combines the whole so as to bring vividly before the reader most of the known essential points that bear on the study of rocks, their disturbances, metamorphisms, and chronological classification.

Throughout this book, as well as in Lyell's yet greater work, the "Principles of Geology," we mark the workings of the mind of one of the profoundest thinkers that the geological world has yet produced. In spite of the warning voice of the great Hutton, it was, and still is, with some authors, the fashion to build up systems of creation and invent processes of action as if our knowledge of fact and circumstance were alike complete. Such writers are ever apt to assume, down to the latest epochs, the existence of special forces of a kind and intensity more suited to the contracted notions of time still prevalent with the many, than to those sober and sublime ideas which we believe are taught by a more modest interpretation of the still imperfectly understood facts that a study of the earth's crust has revealed to us. The evidence is perfect in past times of the long duration and slow extinction of species, genera, and whole classes of animals; of the slow accumulation of all the ancient strata in the sea, in lakes, and at river mouths, in the same manner that similar beds are found at present; and of the sinking of old sea bottoms, and the submergence and emergence of lands as slowly as the subsidence in these later times of the coral islands of the Pacific. All this can be *demonstrated*, and much more besides; whereas the advocates of spasmodic theories are often less happy in their demonstrations, since (to take one instance) no amount of contortion and inversion of strata proves that this was the result of one act of violence. You may bend a bow so slowly that it is only at intervals the eye can detect the increasing curve. The author of this manual, and those who, like him, most insist on the average uniformity of existing forces in old geological epochs, are, however, often spoken of as theorists *par excellence*, while in reality, as it appears to us, they form the least theoretically inclined portion of the geological community. They do not invent theoretical Titanic powers to explain all those wonderful phenomena of disturbance of rocks, and extermination of races which mark the varied strata, but simply accept what they see and know, that the whole existing economy of nature is ever changing by slow and sure degrees; and he is a bold theorist who asserts that, in the long lapse of geological time, repetitions of seemingly small forces may not produce accumulated results, equal in magnitude to those assumed revolutionary powers which, if they existed, marred the face of nature, and spread ruin and devastation over a world for long periods of time. Avoiding such imaginations, Sir Charles Lyell in his writings constantly insists on the fragmentary state of our knowledge of the history of the earth. He is content to wait and watch till chance or diligent research may reveal to us other lost leaves and chapters of the great book which it is the business of the geologist to decipher. This "is only the last of a great series of pre-existing creations, of which we cannot estimate the number and limit."*

The first six chapters of the Manual deal with the aqueous and igneous characters of rocks, the composition of the rocks, their various forms and peculiarities of stratification, their consolidation, the arrangement and petrifaction of fossils, the elevation and disturbance of strata, and the various effects and results produced by denudation. The 7th explains the mode of the formation of alluvium, and the 8th and 9th the principles of the chronological classification of rocks. From the 10th chapter to the 27th, the author describes the position and structure of the formations from the higher Tertiary to the Cambrian rocks in descending order, copiously elucidating the subject by description and by pictorial illustration of the varied organic forms that

* P. 640.

characterized the successive stages of the world's history. From the 28th to the 33d chapter the author treats of volcanic rocks, their structure and composition, their different ages, and the effects they produced by melted contact with stratified deposits. In the 33d and 34th chapters, he explains the nature of granite and other allied plutonic masses, with their various ages and relations to volcanic rocks, and in the 35th, 36th, and 37th chapters, he proceeds to develop the theories of cleavage, foliation, and other points connected with metamorphism, and to show that these remarkable phenomena are common to rocks of all geological epochs. The last chapter is de-devoted to the subject of mineral veins.

The whole work is alike profound and explicit, and written in a style so interesting, that, apart from its scientific value, it is a pleasure to read the book, and no tyro in geology can rise from its intelligent perusal without at least having his eyes opened to the general scope of the subject. At the same time, we think it would have been better if in the account of the formations, the descriptions had followed the ascending instead of the descending scale. As it stands the order of nature is so far reversed that the history begins in times that geologically immediately preceded our own epoch, and traces events backward to the earlier ages of the world, thus sometimes necessitating allusion to facts with which the reader is yet supposed to be unacquainted, rendering it more difficult for the author to point out, and for the inexperienced reader to understand, the relation of cause and effect in the chronological history of events. For instance, the palæozoic rocks were in places heaved up into lands and mountain ranges, before the deposition of later strata which were formed from their waste; but unless the reader prematurely refer forward to succeeding chapters, he knows nothing of these details. Again, the Purbeck and Wealden strata, and the Eocene rocks of France and England were in great part formed at the mouths of rivers, and the territories through which they flowed consisted, in the first case, of land formed of oolitic and other secondary plains, and also of more ancient hilly palæozoic strata; and, in the second instance, the tertiary waters wasted the chalk, and the Eocene rivers flowed through more ancient rocks of many ages, of which as yet the student is supposed to know nothing. We are well aware, that in proving the aqueous origin of strata and the nature of their fossils, it is essential to follow the example long since set by Steno,* who, reasoning from the known to the unknown—from the strata of to-day to those of ancient epochs—thus proved their general identity of structure, and the analogies in the manner of occurrence of their organic contents. But this being done in the opening chapter of a manual, just as in the obscure history of ancient empires we endeavour to follow events in their order of succession, so, in the history of the earth, it is most instructive and intelligible to trace the order of events as they oc-

* Prodromus to a Dissertation concerning Solids within Solids, 1671.

curred, showing the successive upheavals and depressions of continents and islands, the newer strata that were formed from their denudation, the disappearance of old forms of life and the approximate entrance on the world's stage of new genera and species during different epochs. While thus describing the rocks in ascending order, the occurrence of lost passages in the history are, it seems to us, not only more readily comprehended, but also it is easier to impress on the mind of the student the nature of those grand operations on the earth's surface that most probably conduced to the existence of local blanks.

The arrangement adopted doubtless arises from the circumstance, that the present volume is an extension of previous editions, the first of which originated in an amplification of the fourth book of the first five editions of the Principles of Geology, a work specially intended to demonstrate the relation of the world as it is, to the world as it has been in ancient geological epochs. With this special end in view, it was undoubtedly natural to adopt the arrangement employed in the "Manual of Elementary Geology," as long as it formed a portion of the "Principles;" but when it was found expedient to divide that work, it might, for the reasons we have stated, have been better to have followed the natural order of succession in describing the strata. Let no one suppose, however, that the arrangement adopted materially interferes with the utility of the book. In its own manner the order is so clear, and the descriptions so lucid, that beginners who have all to learn, and experienced geologists who wish to consult it on special topics, will here find a succinct summary of most of the leading points exhibited by the rocky masses ranging downwards from the comparatively recent times of the glacial drift, through Crag and Miocene sediments, Eocene, Cretaceous, Oolitic, Triassic, Permian, Carboniferous, Devonian, and Silurian systems, till he reach the unfathomed depths of the venerable Cambrian slates and grits which in all the British isles nowhere authentically exhibit their base reposing on any older set of rocks, whether igneous or aqueous.

To criticise the subjects treated of in detail, would occupy a space as large as the volume itself, and we shall therefore only offer a few remarks on two or three of the themes brought before us.

In the third chapter, the fresh-water and marine origin of upheaved strata is shown to depend on the generic character of imbedded fossils. At the present day it requires no very profound knowledge of forms to distinguish between the few genera of fresh-water shells and their marine contemporaries; and as we recede in time through the tertiary and secondary periods, the generic forms of the fresh-water molluscs, and a vast number of those found in marine beds, are so closely related to those that still exist, that there is no difficulty in referring some strata to a fresh-water, and others to a marine origin. If a man find oysters, cockles, nautili, and volutes, grouped together, he knows at once the stratum to be marine; and if he find in another *cyclas*, *planorbis*, *paludina*, and *lymnea*, he is sure of its fresh-water origin.

When, however, we come to the palæozoic rocks, the number of extinct genera is so great that in many rich fossiliferous formations, a collector might work for a week without disentombing one existing generic form. Even then, however, we are not without sure guides, for prolonged search has shown that these are sometimes mixed with marine shells that, like the *nautilus* and *lingula*, have inhabited the seas of the world through the larger portion of known time, or again the extinct shells are associated with corals and sea-lilies, which only exist in sea water. Apart from this special knowledge, were some of these ancient palæozoic forms placed in the hands of the palæontolgist for the first time, he might be puzzled (as he still is in the case of some fishes) to give a reason why he should consider them as necessarily marine. Even, however, were there no guiding associations of genera and families, judging from present analogies, the immense areas over which most of the formations occur would of itself solve the question; for, formations that, like the Silurian, Devonian, and carboniferous limestone, stretch across whole continents, cannot have been formed in fresh water. This point being clear, it is a curious subject of inquiry what has become of the fresh-water deposits, which, we presume, were in parts of the world through all time, formed contemporaneously with marine beds. If, indeed, as Mr Henry Rogers supposes, the absence of rock salt from the primary rocks is to be attributed to excess of rain-fall during primary times, then indeed we ought in these earlier periods to have had larger rivers than even the mighty Amazons or the Mississippi, more laden with sediment, and forming deltas of correspondingly ampler magnitude. But not throughout all the aggregate eight miles of thickness of the Cambrian, Silurian, and Devonian strata in the British isles, nor yet in any other region, do we find evidence of a delta, except in a doubtful case in a small part of the Old red sandstone of Ireland. It is not till we come to the Carboniferous rocks that we can with decision speak of fresh-water beds at all; and there are living geologists of unusual timidity or boldness, who even consider these as doubtful. What, then, has become of the fresh-water rocks of the palæozoic age—older than the Carboniferous—and why, in the secondary and tertiary epochs, are they of more frequent occurrence?

From the lowest Cambrian to the recent rocks inclusive, there are twelve great groups, including thirty-five well-marked European formations.

In the (1.) Recent, (2.) Post-Pliocene, (3.) Pleistocene, and, (4.) Older Pliocene epochs, we have respectively of fresh-water beds named in the Manual, 1st, The lake deposits and deltas now forming; 2d, The Loess of the valley of the Rhine, the bluffs of the Mississippi (probably also of the Amazons and many other rivers); 3d, The fluvio-marine beds of the Norwich Crag; and, 4th, The

Aralo-Caspian beds (which are, however, like the bottom of the modern Caspian, of brackish-water origin), together with the indications of rivers afforded by the presence of fresh-water shells in the marine deposits of blue marl, that make part of the sub-Apennine formations near Parma. The Miocene rocks contain fresh-water beds in part of the Molasse of the Alps, and it is doubtful whether or not the lacustrine mammalian beds of the Sewalik hills in India may not be classed as of the same age. Wide tracts of the Eocene strata in the London, Hampshire, and Paris basins, in Belgium, Hanover, on the Rhine, and in other parts of Europe, are in great part composed of fresh-water fluvio-marine and marine interstratifications, and some of these marine strata in one place are doubtless contemporaneous with the fresh-water beds of another. The base of the Cretaceous series is distinguished by the presence of the Wealden fluviatile rocks, and these are directly linked with or merge into the Purbeck limestones and clays which form the topmost part of the Oolites. All the other six great British divisions of the Oolites are undistinguished by fresh-water strata, excepting certain beds that occur in the great Oolite of Yorkshire, marked by the presence of Equisetums, Unios, and Cyprides. In some spots at the base of the Lias, there also occur trifling estuarine deposits. The red Keuper marls and the New red sandstone are, by all geologists, considered to be true marine formations. The whole of the vast palæozoic masses, with the exception of part of the Carboniferous, and perhaps a small part of the top of the Old red sandstone in Ireland, are altogether marine.

The above enumeration gives a tolerably respectable list of fresh-water strata of very different ages, but, at the same time, it must be recollected that throughout the whole range of old geological time, there are only *known* three great estuary deposits, 1st, The Carboniferous; 2d, the Purbeck and Wealden; and, 3d, part of the Eocene formations.

The true history of the first of these is still in many respects a mystery. As a general rule, it is certain that nearly all coal beds lie on the under-clay soil, where the plants grew and decayed probably in swamps and marshy territories. In Shropshire, for instance, we find beds of marine shale, with ironstone, containing Productas and Limuli, alternating with strata full of fresh-water Unios and under-clay (the soil), on which rest beds of coal.* In Scotland there are beds of marine limestone, charged with Productas and Spirifers supporting similar soils, on which rest beds of thin coal, formed of plants, the roots of which still indent the under clay, and every where in this coal field, under various modifications, there are indications of alternations of sea, fresh-water, and land, pointing apparently to a deltoid origin. But there were probably special conditions then in action, of which we have now no actual example in progress. Consider the 12,000 or 14,000

* Prestwich Geological Transactions, vol. ii., pp. 5, 413.

feet of coal measures at the South Joggins in Nova Scotia,* and in South Wales, and it would be difficult to show that we know anything of any other rocks formed or forming under precisely similar circumstances. Consider also the vast extent of these deposits. In the British isles the coal fields are but fragments, for once they probably spread over the whole of the limestone district of Ireland; and in England many now isolated were once united, the existing fragments having been saved from the great planing process of denudation, only by the accident of these portions having been curved downwards into great and small basins, during the contortion of the strata. Consider, again, the prodigious areas occupied by the coal fields of North America, larger than some entire kingdoms of the Old World, and which, in the opinion of the best American geologists, were once united. But though we may allow their deltoid origin, it is not therefore to be supposed, that, (for example) the American coal fields were in any time, however long, formed at the mouth of one great shifting river, though we can easily fancy a state of things by which the structure we now witness in the Coal measures might, by the agency of rivers, have been partly brought about. Suppose a flat continental territory, partly bounded by the sea, and through which many great rivers wandered, similar to those that now traverse the plains of Siberia; then if these, instead of emptying themselves into an icy ocean, formed their deltas in a "moist and equable climate," and if, as the land slowly sank and oscillated, they often shifted their channels, and enlarged their deltas in width, length, and thickness, we can understand how great accumulations of alternate sea, fresh-water, and terrestrial strata might be formed over areas of unusual size. With a vigorous and rapid growth and decay of plants fitted for the purpose, thick accumulations of decayed vegetable matter would be formed, sometimes over large continuous areas, sometimes separated by broad unproductive spaces, or again in little patches repeatedly interrupted. On the whole, all the evidence leads to the conclusion that rivers and marshes had, at all events, much to do with the origin of coal.

That the Purbeck and Wealden strata were deltoid and not lacustrine there can be little doubt, for beds containing plants, insects, and fresh-water shells, alternate with marine bands, showing occasional eruptions of the sea, due either to sudden depressions of the land, or the sweeping away of river bars. With the exception of the lacustrine strata of central France, the same estuarine character belongs to the Eocene beds of England, France, and Germany. If we might imagine the Loess of the Rhine and the bluffs of the Mississippi thrown far back in time and *fossilized*, they would probably be classed but as lower subdivisions of deltas, the modern deposits formed by these rivers constituting higher members, each subdivision being of no more value than the beds of lower, middle, and upper

* Dawson and Logan; Geological Journal, vol. x., p. 39.

Purbeck, in that formation. Eliminating therefore these late tertiary deltas, as we have already stated, we have as yet only discovered three great deltas throughout all the vast abyss of past geological time, and yet at the present day there are about twenty-five first-class deltas on the shores of the four continents, besides a multitude of smaller ones, many of them of considerable importance. Suppose that the eleven great groups that lie between Pliocene and Cambrian rocks had each an equal average number of deltas, then had they been by happy accidents preserved, we might expect to find a large proportion of 275 great deltas, were they all accessible to research, in addition to the multitude of smaller ones which we may be pretty certain contemporaneously existed, if, as we believe, the general economy of land, rain, rivers, lakes, and seas, resembled, in old times, the arrangements of to-day. But (supposing this rough kind of hypothesis to be admissible) we underestimate the argument if we only calculate the probabilities for 11 great geological periods, for no man who knows anything of geology will believe that this mere point in time that we call *recent*, is comparable, for instance, to any one of the great periods indicated by the Silurian, Oolitic, or Cretaceous formations. The Oolitic period is divisible into three distinct groups of formations, or four, if, with some geologists, we include the Lias, and even in the subdivisions of any one of these groups, (as for instance between the lower and upper Lias, or the inferior and Bath Oolite, or the Bath Oolite, and the Cornbrash,) there are differences in fossil contents far greater than those which mark the molluscous faunas of the glacial and recent epochs. One main cause of the difference between the marine fauna of the drift epoch, and that of the present day, is easily traced to change of climate and other physical conditions. During the glacial epoch we are certain that the greater proportions of the continents of Europe, Asia, and America, —sometimes one part and sometimes another,—were submerged and again upheaved into dry land, and in this fact we discern but one passage of many phases of physical geography that elapsed between glacial and recent times. But were the drift and recent formations grouped together, and thrown far back in geological time, they would be considered but as minor subdivisions of one formation, and nevertheless during the existence of the lower subdivision alone, submergences and emergences of continents slowly progressed, sufficient to alter, obliterate, and, with important changes, perhaps reconstruct many of the great river systems of the world. Roughly considering each of the Oolitic formations as of equal value in point of time, we find them divided into ten or twelve subdivisions, each zoologically having differences as important or indeed of more value than the distinctions between the molluscs of the glacial and recent epochs. When there are marked differences in the mollusca of two formations, one of which appears immediately to succeed the other in time, if we adopt the hypothesis that in a given area the disappearance and appearance of new species (apart from special creations) are due to ordinary physical causes, then it is impossible to deny that the Oolitic subdivisions may not have witnessed modifications of climate, and revolutions of continental areas, equal to that recorded of the glacial epoch, with corresponding variations of continental drainage.

Taking all these things into consideration, it appears that with the number of formations the probability of the ancient existence of a number of large deltas (now lost) increases in a remarkable ratio, and the structure of the rocks themselves helps us to this conclusion.

Neither Silurian nor Cambrian rocks show any traces of the beginning of geological time. They are old, and have suffered all those repeated contortions and metamorphisms that old age in rocks frequently implies, but the deepest strata of Cambria are conglomerates formed of pebbles, that might, from their appearance, have been derived from Wales, as it now stands, though, except in the waterworn fragments, all trace of the old lands that yielded them is gone.*

We know nothing of the geography of the land whence these fragments were derived, and it is therefore in our opinion an assumption alike rash and unwarrantable, to hold, with some, that in the earlier geological periods the world was a world of islets. The greater proportion of the enormous masses of broad-spreading Silurian strata are the measure of an equal amount of more ancient land destroyed, wherewith to form them, and the original muddy character of much of these (the lower Silurian strata of Wales, for instance and the upper Silurian mudstones of Murchison), confutes the idea that they were principally formed by the coast waste of scattered islands. It seems more natural to attribute, in part, the origin of the mud to the action of great rivers carrying it out to sea, where it gradually accumulated, for, with rivers like the Ganges, the Mississippi, the Amazons, and the Nile, a large portion of the sediment is carried by ocean currents far beyond the limits of their deltas. The same kind of reasoning that applies to the Silurian mudstones might be applied to the Old red and Keuper marls and the clays of the Lias and Oolites, and most geologists, without difficulty, grant that great part of the carboniferous rocks were directly derived from river sediments. We are sure of the fluviatile origin of most of the Eocene clays. Let it not be supposed that we wish to undervalue coast waste; on the contrary we believe it to be one of the mightiest agents that are for ever

"Sowing the dust of continents to be."

We only claim, for rivers past (though lost) as well as for rivers present, their true value. True, it is easy to surmise that in old times great muddy formations might have accumulated with a rapidity unknown in modern days: how, through warmth and moisture, incessant rains, and excess of carbonic acid in the air the decomposition of the felspars of primeval granitic islands took place with unexampled facility; but this and such like notions we look upon as belonging to

* Ramsay Geological Journal, vol. ix., p. 168.

the wide category of inventions, unsupported and insupportable by true inductive philosophy, and little more deserving of attention than such exploded ideas as that the wavy layers of gneiss were deposited in a boiling sea.

But if numerous deltas, both great and small, existed in olden times, how does it happen that in all the long list of geological formations, only three great ones and a few small traces of others have been discovered? This is due to a variety of causes. First, it must be recollected, that at the present day there are vast ocean tracts like the Pacific, where no large deltas exist, though chalk-like calcareous deposits from Java to the low Archipelago are everywhere forming. 2dly, There are many long continental coasts absolutely destitute of great deltas, like the west coast of America, the north coast of Africa west of the Nile, and the major part of the south and east coasts of that great continent, where there are no rivers of first-class importance. In some cases certain marine deposits in old periods may have accumulated under conditions like those above cited, but it is in the highest degree unlikely that they should apply to all. 3dly, If during older periods the lands were frequently subject to oscillations of level, equal to that which marked the epochs between the beginning of the drift and recent times, (a safe conclusion), then we might expect that many deltas being made of most perishable stuff (loose sand and mud), would at such times be especially liable to destruction, before a happy set of circumstances occasionally admitted of a delta being preserved; and, 4thly, even if consolidated, many (especially the smaller ones) must have been destroyed, for it most frequently happens with disturbed marine formations, that *their present margins have been formed by denudation*, and are removed to unknown distances from the original coasts where contemporary rivers debouched, and under these circumstances, in consequence of repeated disturbances of rocks along the same great lines, accompanied by constant denudations, *the greater the age of a formation the less chance is there of its contemporary deltas being preserved.* When the geology of other parts of the world is as accurately analyzed as that of England, and some other parts of Europe and North America, more deltoid formations will doubtless be discovered, but for the reasons above stated, they will never bear the same proportion to the marine formations of any period that existing deltas do to the marine deposits of the recent epoch.

In accordance with these views we might expect a more frequent occurrence of fresh-water strata in the later than in the earlier epochs of the world's history. An approximate result of an analysis of this subject is given in the following table, in which the letter F signifies that fresh-water strata are found *in some part* of the formation or group that it is placed opposite, the evidence of the occurrence of these fluviatile beds being always of a decided kind.

*Table showing the Geological Epochs, Groups of Formations, and Single Formations, in which Fresh-water Strata occur.*

| *Periods.* | *Epochs.* | *Groups.* | | *Formations.* | |
|---|---|---|---|---|---|
| Post-tertiary, Tertiary, or Cainozoic. | Post-tertiary F | | F | Recent | F |
| | | | | Post-pliocene | F |
| | Upper Tertiary F | | F | Glacial Drift, &c. | 0 |
| | | | | Norwich Crag | F |
| | | | | Red and Coralline Crag | 0 |
| | Miocene F | | F | Miocene | F |
| | Eocene or Lower Tertiary F | Upper Eocene | F | Hampstead Beds (Isle of Wight) | F |
| | | Middle Eocene | F | Bembridge Beds | F |
| | | | | Headon Beds | F |
| | | | | Headonhill Sand and Barton Clay | F |
| | | | | Bagshot and Bracklesham Beds | 0 |
| | | Lower Eocene | F | London Clay | 0 |
| | | | | Plastic Clay, &c. | F |
| | | | | Thanet Sands | 0 |
| | 4 F in all. | 6 F in all. | | | In all 14<br>9 F, or 9-14ths. |
| Secondary, or Mezozoic. | Cretaceous F | Upper Cretaceous | 0 | Chalk | 0 |
| | | | | Upper Greensand | 0 |
| | | | | Gault | 0 |
| | | Lower Cretaceous | F | Lower Greensand | 0 |
| | | | | Weald clay and Hastings sand | F |
| | Oolitic F | Upper Oolite | F | Purbeck beds | F |
| | | | | Portland Oolite | 0 |
| | | | | Kimmeridge clay | 0 |
| | | Middle Oolite | 0 | Coral rag | 0 |
| | | | | Oxford Clay | 0 |
| | | Lower Oolite | F | Great Oolite | F |
| | | | | Fullers' earth | 0 |
| | | | | Inferior Oolite | 0 |
| | | Lias | F | Upper Lias | 0 |
| | | | | Marlstone | 0 |
| | | | | Lower Lias | F |
| | Triassic or New Red Series 0 | Upper Trias | 0 | New red marl | 0 |
| | | Middle Trias | 0 | Muschelkalk | 0 |
| | | Lower Trias | 0 | New red sandstone | 0 |
| | 3 in all—<br>2 F, or 2-3ds. | 9 in all—<br>4 F, or 4-9ths. | | | In all 19<br>4 F, or 4-19ths. |
| Primary, or Palæozoic. | Permian 0 | Permian | 0 | Magnesian Limestone | 0 |
| | | | | Sandstone, marl, and conglomerate (Rothlingendes) | 0 |
| | Carboniferous F | Upper Carboniferous | F | Coal measures | F |
| | | Lower Carboniferous | F | Carboniferous limestone and shale (with Coal, &c., in places) | F |
| | Devonian or Old Red Sandstone F | Upper Devonian | F | Upper Devonian | *F |
| | | Lower Devonian | 0 | Lower Devonian | 0 |
| | Silurian 0 | Upper Silurian | 0 | Tilestone | 0 |
| | | | | Ludlow rocks | 0 |
| | | | | Wenlock rock | 0 |
| | | | | Caradoc sandstone | 0 |
| | | Lower Silurian | 0 | Llandeilo flags | 0 |
| | | | | Lingula flags | 0 |
| | Cambrian 0 | Cambrian | 0 | Cambrian | 0 |
| | 5 in all—<br>2 F, or 2-5ths. | 8 in all—<br>3 F, or 3-8ths. | | | In all 13<br>3 F, or 3-13ths. |

* By some the fresh-water beds at the top of the Old red are considered as of Carboniferous age. This would strengthen the view adopted in this notice.

The result of the foregoing table may be stated as follows, if, in the column of *groups* of strata we consider Post-tertiary, Upper Tertiary, and Miocene respectively, to be of no greater palæontological value than any one of the three divisions of the Eocene strata.

| | Proportion of SINGLE formations containing fresh-water strata. | Proportion of GROUPS of formations containing fresh-water strata. | Proportion of EPOCHS containing fresh-water strata. |
|---|---|---|---|
| Post-tertiary and Cainozoic or Tertiary | $\frac{9}{14}$ths = 0·6428 | All = 6·0000 | All = 4·0000 |
| Mesozoic or Secondary | $\frac{4}{19}$ths = 0·2105 | $\frac{4}{9}$ths = 0·4444 | $\frac{2}{3}$ds = 0·6666 |
| Palæozoic or Primary | $\frac{3}{13}$ths = 0·2307 | $\frac{3}{8}$ths = 0·3750 | $\frac{2}{5}$ths = 0·4000 |

From this it will be seen that in regard to the proportional number of rocks containing fresh-water strata, if we consider the SINGLE FORMATIONS, the primary rocks have a slight advantage over the secondary (0·0202), and the tertiary have a great advantage over both. In the GROUPS of *formations*, the secondary rocks have a slightly greater advantage over the primary (0·0694), than the primary have over the secondary in the previous column, and *all the six groups* of the tertiary rocks contain fresh-water strata. In the column for EPOCHS, the secondary rocks have a decided advantage over those of primary age (0·2666), and of course all the four tertiary epochs exhibit fresh-water strata.

Notwithstanding our very imperfect knowledge of the detailed structure of the greater proportion of the globe, from such data at these, some might argue that in the earlier stages of the world's history there was perhaps less rain than at present, and others, that though there was as much or more rain, there were no large continents to give birth to delta-forming rivers; while others, like ourselves, might think it most probable that the later the epoch, group, or formation in time, the greater is the chance of its more local or fresh-water deposits being preserved.

Two of the most interesting chapters in the Manual are the 11th and 12th, in which are described the phenomena of the icy-drift and boulder-clay formations, and the evidences of the ancient existence of glaciers in the mountain regions of the British isles. These subjects have attracted much attention among able observers, but long after Playfair had indicated the ice-borne character of the Alpine boulders that rest on the Jura, there was a powerful reaction among geologists, the true doctrine fell into discredit, and most writers adhered to the dogma that the heterogeneous mixtures that cover great part of the surface of the northern continents, were the result of mighty sea waves which rushed from the north across Europe, Asia, and America, scattering rocky fragments as they went, which polished and grooved the rocks over which they passed. A few able workers, in England and America. yet adhere to this hypothesis; while on the continent of Europe it is still a universal favourite. In England, however, for some years it has been steadily losing ground, and we believe it will ere long altogether pass into the limbo of exploded theories, and be regarded as scarcely less chimerical than some of the strange old fantasies of Moro, Woodward, and the imaginative Burnet. We recollect well the unbelief and ridicule that greeted the announcements of Agassiz and Buckland in 1840–41, that glaciers once occupied the greater valleys of the Highlands of Scotland and of Wales, and how sceptics and shallow wits, whose geology perhaps rarely extended beyond the precincts of turnpike roads, attributed the grooving and striation of the rocks to cart-wheels and hobnailed boots; and the ice-polished surfaces, to the sliding of the caudal corduroys of Welshmen on the rocks, to slickensides and sea-waves, and to every cause indeed but the true one. Saner views, however, at length prevailed, and there are now few geologists who have studied the effects of ice in the Alps, or are familiar with its action in rivers, or who have carefully perused the writings of Arctic voyagers, but will readily recognize the familiar indications of ice, and more especially those of glacier action in the Highlands of Scotland, in Cumberland, Wales, the south-west of Ireland, and the mountains of the Vosges.

Without criticising the details adduced by Sir Charles in his summary of this interesting question, it is now perhaps universally allowed that all the more important general contours of hill and valley in the continents of the old and new worlds were the same as now previous to the glacial epoch. The land was then slowly depressed beneath the waves, and as it sank its minor features were somewhat modified, for terraces were formed on old shores, and icebergs drifting from the north, and pack ice on the coasts, as they grounded and grated along the shores and sea bottoms, smoothed and striated the rocky surfaces over which they passed, and deposited, in the course of many ages, clay, gravel, and scattered boulders over wide marine areas that had once been land. The grooves and striations on the ice-smoothed rocks (except where locally deflected) still bear witness to the general southward course of the winds and ocean-currents that bore the ice from its birthplace into milder climates.* Evidence of this is abundantly found both in North America† and Europe, and in southern latitudes the same agency of icebergs has transported boulders far northwards over the low lands of South America.‡ In many parts of our own islands it is sufficiently obvious, as for instance on the shores of the Clyde, and the Firth of Forth at Granton, North Berwick, Tyningham, Skateraw, &c., where, in quarries

* Manual, p. 127.
† Lyell, Journal of the Royal Institution. 1855.
‡ Darwin's Naturalist's Voyage, 1852, 247.

newly cleared of till, the smooth surfaces and the ice-ploughed furrows are often as fresh as they might be were a part of Baffin's Bay heaved up to sight and stripped of its overlying mass of modern boulder-clay. These localities are only mentioned as examples of what is common over much of Scotland, both in the plains and high on the summit of Salisbury Crags, the flanks of Arthur Seat, the Pentlands, and many a hill "in the great central valley between the Firth of Forth and the Firth of Clyde."* The same phenomena are visible throughout the length and breadth of Ireland, in the north of England, and over many parts of Wales, from Anglesea to Pembrokeshire. In Anglesea, which is a low country, the whole of the contours of its undulations speak of the moulding effects of ice, and, when freshly denuded of their covering of turf, heath, clay, or gravel, the rocks, like those in Scotland, are often beautifully smoothed, the striations running on an average from 20° to 25° E. of N., transverse to the courses pursued by the great glaciers that contemporaneously descended to the N.W. from one side of the Snowdonian chain.† On the coast also of that island frequent cliffs occur of stiff roughly stratified boulder-clay, with its complement of travelled blocks and well-scratched stones.

In Pembrokeshire, though the phenomena are less marked, the experienced eye has no difficulty in detecting the effects of ice in the peculiar rounded contours of the hills between St David's Head and Fishguard. True, the tooth of time is surely effecting their ruin, but this only renders the origin of their peculiar forms more apparent, in the marked contrast their mammillated forms occasionally present to the broken outlines produced by subsequent ordinary atmospheric disintegration. That the winter climate of the time was intensely cold, is witnessed by the fact, that between the south coast of Cardigan Bay and St Bride's Bay, the low country is covered with great boulders, derived from the higher greenstone hill-tops that rise bare above the drift between Carn-Llidi and Strumble Head.‡ They are neither foreign to the district, nor were they transported on far-travelled icebergs, but resting on, or being mixed with the native drift that forms the smooth slopes of the low lands, they must certainly have been floated and scattered by coast ice that in winter gathered round the low islets, seeing that isolated hills of a few hundred feet high never could have given birth to anything deserving the name of glaciers and large icebergs. This is but one example of what is common in Wales, where it is stated such drift-deposits rise on the mountains in the north to the height of more than 2000 feet.§

* Maclaren, Edin. New Phil. Journal, 1849, p. 161.
† Ramsay, Geological Journal, vol. viii., p. 374.
‡ See De la Beche's Map of Pembrokeshire. Geological Transactions, Ser. 2, vol. ii., p. 1.
§ Ramsay, Geological Journal, vol. viii., p. 374.

The same kind of evidence is conspicuous on and around the hi[illegible] of Charnwood Forest in Leicestershire, from whence long trai[illegible] of greenstone granite and syenite have been borne southwards, d[illegible] ting the drift-covered country as far south as Rugby. The high[illegible] hill in the Forest is about 800 feet. The whole of Shropshire, Cl[illegible] shire, and Staffordshire, are speckled with boulders of granite a[illegible] greenstone, some of them transported, it is said, from the mou[illegible] tains of Cumberland; and on the Derbyshire hills the drift ri[illegible] to the height of 1500 feet, while further south, in the valley of t[illegible] Trent, and on the Lias clay and tabulated Marlstone hills near M[illegible] ket Harborough (and many other places), we find polished [illegible] striated fragments of Derbyshire Mountain limestone and Mills[illegible] grit mingled with chalk flints, and fragments of Lias and Ooli[illegible] limestones. The same indications of travelled drift are familiar [illegible] the geologist in Northumberland and Cumberland, in the Siluri[illegible] valleys and hill-sides in the south of Scotland, in the broad spre[illegible] ing boulder clays and sandy gravels of Ayrshire, Argyllshire, Du[illegible] bartonshire, and on the lower flanks of the mountains of Arran, wh[illegible] the smoother swells that in places rise well up on the mountai[illegible] mark with a clear outline the average limits of the glacial dr[illegible] Near Glasgow, it rises in places to the very summits of the Camp[illegible] hills; and in the Lothians, it lies on the slopes of the Lamm[illegible] muirs, and the Pentland hills;* and in many other parts in Sc[illegible] land, from north to south, too numerous to name. Indeed, o[illegible] the larger part of the British isles, its presence, or indications th[illegible] it has been present, form the rule, its absence is exceptional, a[illegible] even such debateable land as that which lies between the Cotsw[illegible] hills and the Severn is not without some hint of ice.

The intensity and the wide-spreading effects of cold, in wh[illegible] are now temperate climates, is one of the greatest marvels of ge[illegible] logy. It has been suggested, that if the Isthmus of Panama we[illegible] submerged, the current that crosses the Atlantic from the Cape [illegible] the Caribbean Sea would find its way into the Pacific, and there wou[illegible] be no gulf stream abnormally to raise the temperature of the west [illegible] Europe. But even this would not cause cold sufficient to origin[illegible] glaciers in the Highlands and in Wales; and besides it is known th[illegible] the mollusca on the opposite shores of the Isthmus of Panama a[illegible] generally distinct, which would not be the case if a communi[illegible] cation had been open so late as the glacial epoch, the shells of whic[illegible] are almost all of existing species.† In the present state of ou[illegible] knowledge, therefore, the suggestion made by Sir Charles Lyell a[illegible] p. 147 is perhaps the best that has yet been offered, viz. that "if i[illegible] both of the Polar regions a considerable area of elevated dry la[illegible]

* Maclaren.

† There is some kind of evidence that this Isthmus was open during Mioc[illegible] times; for, according to Mr John Carrick Moore, there are Miocene shells fou[illegible] fossil in St Domingo, some of which still live in the Indian Ocean.—*Geologic[illegible] Journal*, vol. vi., p. 39.

existed, such a recurrence of refrigerating conditions in both hemispheres might have created for a time an intensity of cold never experienced since; and such probably was the state of things during that period of submergence to which I have alluded."

It must, however, be remembered that this is but a suggestion, and though there can be no doubt of the long duration of an intense state of cold, still, before the whole mystery is cleared up, much remains to be done; for it must not be forgotten, that from the Gulf of Finland to the White Sea, and on the flanks of the Scandinavian chain, there are traces of the glacial sea, and yet further north in the icy regions lately traversed by arctic voyagers, deposits with marine shells have been observed at heights, which, at some tertiary period, would indicate considerable depression of the northern regions, though, whether that depression was contemporaneous with or subsequent to our glacial epoch, no precise evidence has yet been afforded.

Sir Charles only devotes a short paragraph (p. 137) to the subject of ancient British glaciers; but were the scattered information that is afloat on the subject, respecting this and other quarters of the world, collected, condensed, and printed, it might well claim an extended notice in Manuals from all who appreciate the full importance of glacial geology. It might be well to enumerate and give special instances of the perfect nature of the proofs that indicate the past existence of glaciers in regions where now the snow in mild winters scarcely falls, and in the severest never lies for half the year. Such proofs are to be found in the polishing, scratching, grooving, and deep furrowing of the rocks over which the glaciers flowed, magnificent examples of which occur in many a Highland valley, in Cumberland, Wales, the south-west of Ireland, and the mountains of the Vosges. The bottom of a glacier is covered with fine sand, and dotted with imprisoned stones and blocks, which polish, scratch, and groove the rocky floor over which its weighty mass progresses; and wherever a tributary stream of ice flows into the greater glacial river of the main valley, there the grooves will at first slightly diverge from those made by the sweep of the main current, and as we recede from the point of union of the two streams, the furrows will at length curve fairly round and accommodate themselves to the trend of the tributary valley. In fact, wherever tributary glaciers flow into a main valley, a series of lines will be formed, branching from the general direction of the grooves that mark the bottom and sides of the main valley. This is what takes place at present in all glaciers; and if in Wales any man will ascend the pass of Nant Francon in Caernarvonshire, and examine its tributary valleys, he will find that in the main valley the striæ follow its course (about 20° to 25° west of north), and in the tributary valleys the striæ run east and north-easterly according to their curves, while in entering Cwm Idwal from Nant Francon they curve gradually round from E.S.E. to N.N.E.* The same is equally striking in the neighbourhood of Snowdon, where, in the Pass of Llanberis, the grooves and striæ first strike from 30° to 35° south of east, and gradually curve round to the south, as a portion of them pass into the high tributary valley of Cwm Glas; or again, in Nant Gwynant, where in the main valley they strike to the south-west and branch off first to the north-west, and gradually curve round to the north in the higher part of Cwm-y-llan, and in another instance generally to the west in the vast rocky amphitheatre of Glaslyn and Llyn Llydaw. "In the higher parts of such minor tributary valleys, the grooves converge towards the hollows, at acute angles to the main direction of the valley, in the manner that might be expected from ice pressing or flowing downwards to feed the main icy streams."†

Again, if a great valley be filled with ice nearly to the brim, and if there are short tributary valleys at its sides, bounded by lower spurs that branch inwards from the crested ridges that flank the main valley, the great stream of ice that fills the whole will in its flow over-ride the whole depression, forming its striations on the rocky floor, often transversely to the minor valleys, or in accordance to the course of the average direction of the slope of the whole mass. But if by amelioration of climate the glacier gradually decrease in size, then we shall find *roches moutonnées* and striations (as in Switzerland now), at far higher levels than the surface of the existing glacier. The lower spurs that branch into the valley from the bounding crests will then stand out denuded of ice, the high hollows between them will contain tributary glaciers, and form new striations transverse to those that were formed, when from ridge to ridge the whole great valley was full of ice. Such transverse striations actually crossing each other, are observable in parts of Nant Francon and the Pass of Llanberis; and in other cases close to the mouths of the tributary valleys the grooves on the steep hill sides of the main valleys are often at much greater elevations than many of the striations that, transversely to these, follow the course of the tributary valleys almost to the point where their brooks unite with the principal stream. There is indeed proof in the longitudinal grooves and striations on the hill sides, that in the Passes of Nant Francon and Llanberis the ice once attained the enormous thickness of about 1300 feet; unless indeed, as has been supposed by Dr Hooker, many valleys have been to a considerable extent deepened by glaciers themselves. In this case the *present bottoms* of the Welsh passes would be lower than the *original floors* over which the glaciers flowed when they formed the longitudinal striations that are now 1300 feet above the river in Nant Francon and the stream that feeds Llyn Peris, in the Pass of Llanberis. However this may be, by degrees they

* See Darwin, Phil. Mag., ser. iii., vol. xxi., p. 180; and Ramsay, Geological Journal, vol. viii., p. 371.

† Reports of the British Association, 1854, p. 95.

decreased in size, and there is still beautiful evidence of their gradual decline in the retreating moraines concentrically arranged one within another, as, for instance, in the long mounds on the west side of Cwm Idwal, and also in Cwm Glas and the upper part of Cwm Brwynog on the sides of Snowdon, till at length we find only the last relics of the ice in the remains of tiny moraines far up amid the innermost recesses of the mountains.*

In many of the Vosges, Highland, and Welsh valleys, the moraines are as perfect as those of the Glaciers du Bois and of the Rhone at the present day. In proof of this we would cite the beautiful illustrations of glacial phenomena in the Vosges published by MM. Henri Hogard and Dolfuss; or, to come nearer home, the moraines in Glen Falloch, above Loch Lomond, and those of the Cuchullin Hills, mentioned by Professor J. D. Forbes; or of Ben More, Coigach, and Glen Messan, noticed by Mr Robert Chambers and Mr Maclaren,† or that of Llyn Idwal described by Mr Darwin, or of Cwm Graianog‡ in Nant Francon, or of Llyn Llydaw, together with others at the upper end, of Cwm-y-llan, Cwm-y-Clogwyn, Llyn-du-'r-Arddu, and Cwm Glas, on the flanks of Snowdon, and of Cwm Orthin, near Ffestiniog, where there is a small but well defined moraine less than quarter of a mile below the lake. From the peak of Snowdon the educated eye at once perceives the moraine-shaped form of the semicircular mound, that below one of the lakes stretches partly across Cwm-y-Clogwyn; and he who wishes to see a perfect British terminal moraine may ascend Cwm Glas from the Pass of Llanberis, till he get beyond the great *roche moutonnée* that lies half a mile south of Blaen-y-Pennant. There a long curved ridge of earth and large stones crosses the valley, almost as regular in form as the huge mounds of chalk that form the boundary dykes of any one side of the deep trenches of Old Sarum.

Another proof of glaciers is, that in Wales terminal moraines frequently constitute the confining barriers of mountain lakes and tarns. There are numerous cases of this kind in Switzerland and the Himalayah,§ and the same causes have been at work in the mountains of the Vosges.‖ In Caernarvonshire, Llyn Idwal forms a striking example of this phenomenon, as also does Llyn Llydaw on the flank of Snowdon. In some cases, as in Cwm-Llafar below Carnedd Llewelyn, the ice has first ploughed a long narrow channel through the terraced drift from end to end of the valley, then, the decreasing glacier formed a moraine near its upper end, which, when the ice melted, confined a lake, till the

* Ramsay, Report of the British Association, 1854, p. 94.

† Edin. New Phil. Journal, Mr Maclaren, vol. xl., xlii., xlvii.; Mr R. Chambers, vol. liv.

‡ Ramsay, Geological Journal, vol. viii., p. 375.

§ Hooker, Himalayan Journal, vol. ii., p. 119.

‖ Coup d'œil sur le Terrain erratique des Vosges, par Henri Hogard, 1848, accompagnée d'un Atlas de 32 planches publiée par Dolfuss-Ausset, 1851.

stream that flowed from it cutting a passage to the base of the moraine, the tarn was thoroughly drained. There are other cases of a like nature. Other moraines dam up lakes in a more peculiar manner. The mouth of a valley is surrounded by a high mound, or a series of united mounds curving outwards, formed of earth, angular, subangular, smoothed, and scratched stones and blocks (some of them as large as a small cottage), so arranged that their origin, and the places whence they came, are unmistakeable. A deep clear lake lies inside, and the drift of the glacial sea (also full of boulders), with a long smooth outline, slopes right up to the outside base of the moraine, showing that the glacier descended to the sea-level, and, pushing for a certain distance out to sea, formed a marine terminal moraine, while the ordinary drift detritus of small sediment and boulder stones (partly scattered by floating ice) was accumulating beyond. In the meanwhile the space on and below the sea-level occupied by the glacier was kept clear of debris, and when the land arose, and the climate ameliorated, the hollow within the terminal moraine became replenished with the water-drainage of the surrounding hills, just as in earlier times it was filled with a drainage of snow. Such in Carnaervonshire are the lakes of Llyn Dulyn, Melynllyn, Ffynnon Llugwy, Marchlynmawr, and Marchlyn-bach; and in Scotland it might not be difficult to give parallel cases.* Judging by the present average elevation of these Welsh lakes, when the moraines that confine them were formed, the highest parts of the mountains of Caernarvonshire (the snow drainage of which gave birth to the glaciers), could not have been more than from 1400 to 2000 feet above the sea. The average great intensity of cold may be inferred from this circumstance, for the sea then flowed through some of the greater valleys between the Menai Straits and Cardigan Bay, across the present watersheds. The principal of these are the vale of Conwy, the valley between Bangor and Capel Curig, the Pass of Llanberis, opening into Cwm Gwynant (about 1300 feet high at the watershed), and the valley of Afon Gain, between Caernarvon and Beddgelert. The country was thus broken up into a group of islands, each one of which in great part had its permanent covering of snow and ice.

Another sign of the past occupation of these valleys by glaciers occurs in the *roches moutonnées* (already mentioned), in which they abound. These are not merely "rounded bosses, or small flattened domes of polished rock;"† for, though often small, sometimes they are of such dimensions, that they rather deserve the names of polished hills than of bosses, rivalling as they do in magnitude some of those immense isolated mammillated surfaces which rise in the middle of the valleys of the Aar, of the Rhone, and of Chamouni, marking the former great extension of the Alpine glaciers. In all the British regions where glaciers once existed, they may be

* Phil. Journal, vol. liv., p. 231. Chambers.
† Manual, p. 137.

found of the most various dimensions. In the south-west of Ireland they are almost everywhere amid the mountains. The sides of the Gairloch, Loch Long, and other sea lochs described by Mr Maclaren (often far above the sea-level) are marked by their presence. Some of the rocks of Loch Lomond, that only show themselves when the lake is low, are rounded, polished, and striated; and the scattered isles that gem its surface present on a larger scale all the smoothly curving outlines of ice-worn *roches moutonnées*, although many may find it difficult to believe that the icy stream that once flowed down Glen Falloch ever expanded into the broader space that lies between Ben Lomond and the Luss and Tarbet shore. Similar forms have been described by Mr Chambers and Mr Bryce in Cumberland; and in Wales they may be counted by the hundred; in Merionethshire on the flanks of Aran Mowddwy, in the estuary of the Mawddach between Dolgelli and Barmouth, by the lake in Cwm Orthin, and in Cwm Croesor and Nant-y-mor between Ffestiniog and Beddgelert, and also in Traeth-mawr and Traeth-bach. In Caernarvonshire they are common in almost all the greater valleys of the Snowdonian chain — in Cwm Eigiau, and on the banks of Avon Llugwy and its tributary valleys, on the N.W. slope of Moel Siabod, and also in Cwm Gaseg, Cwm Llafar, and especially in Nant Francon. Magnificent examples occur in this valley above the famous Penrhyn slate quarries, another small one lies opposite Ty gwyn, others described by Mr Darwin at Llyn Ogwen and in the slopes between Llyn Idwal and the waterfall by the bridge, where the whole side of the hill has been mammillated by the grinding ice that descended from Cwm Idwal to Nant Francon. Others not less striking, at the base of Snowdon skirt the shores of Llyn Padarn and Llyn Peris; and further up the Pass, some of large dimensions, plentifully sprinkled with great blocks of stone (*roches perchés*), amaze the passing tourist, who cannot understand how masses rolled from the neighbouring mountains have so frequently been arrested on precarious points from whence they should naturally have made a final bound into the lower depths of the valley, while the well-pleased eye of the experienced glacialist at once divines that they were gently deposited where they lie by the final thawing of the glacier that slowly bore them from the higher recesses of the mountains. Cases scarcely less beautiful occur by Llyn Llydau, and in Cwm Dyli, Cwm-y-Llan, at Llyn-y-Gader, and Beddgelert, where the curious visitor may see in the hall of the hotel framed record of an imperfectly polished and grooved locality in the vicinity, in the writing of the illustrious Buckland.

In some of the valleys *roches moutonnées* peep here and there from underneath a covering of drift, as for instance in Nant Gwryd, and between Llyn Ogwen and Capel Curig. These may have possibly been formed by floating ice when the country was deeply submerged; but from the form of the valleys, it seems to us equally likely that they sometimes indicate a set of glaciers that existed before the deposition of the drift, which, (the cold still continuing) was afterwards deposited in the valleys during their submergence. If this were the case when the land subsequently emerged, the cold did not cease, and glaciers, ploughing through the narrower valleys which drained large and lofty areas of snow, cleared them of drift in the manner first suggested by Mr Darwin, in his Description of the glaciers of Cwm Idwal and Nant Francon.

We must add a few words about the appearance of the polish on rocks and the weathering of glaciated surfaces. In the Alps, when the glacier ice is freshly removed, the rock underneath, whether of limestone, gneiss, granite, or even quartz, though striated, often possesses the polish of a sheet of glass. In our own country, when the impervious covering of till has been taken away, the surfaces of limestones (as at North Berwick), though grooved and striated, are often beautifully smooth. In a country so low, this may have been due to the grating of icebergs. In other cases, as in some parts of Wales, when the turf and glacier debris is lifted, the underlying surfaces of slate still retain a perfect glassy polish, marked sometimes by flutings, and sometimes by numerous scratches as fine as if they had been made by the point of a diamond. After long exposure these finer markings disappear, and though the general rounded form perfectly remains, the surface becomes roughened, and the planes of the highly-inclined cleavage present on their edges a slightly serrated aspect. The deeper flutings, however, often for a long time remain, but even these at length disappear, though it is not for long after this has been effected that the general rounded form of the *roches moutonnées* is entirely obliterated. Phenomena of the same general nature are observable in the igneous uncleaved rocks over which a glacier may have passed. The original polished surface, on exposure, becomes roughened by atmospheric disintegration; but the general form remains to attest its glacial origin, and in no case is there any danger of the experienced eye confounding this with those forms produced by spherical decomposition about which so much used to be said by Von Buch, and latterly by the Messieurs Schlagintweit. Finally, in the long lapse of time, the air, water, and repeated frosts tell their tale, the rock splits at its joints, it crumbles, masses fall off, and it assumes an irregular and craggy outline altogether distinct from the glaciated surface produced by the long-continued passage of ice; and thus it happens, that on the very summit of some tower-like crag, the sides of which have been rent by the frosts of untold winters, the student of glacial phenomena sometimes finds yet intact the writing of the glacier, while below on its sides all trace of the ice-flood has long since disappeared. These things may seem almost incredible to those who are unaccustomed to read the records of many terrestrial revolutions in the rocks; but, nevertheless, of these extinct glaciers it is true, that just as a skilful antiquary, from the mere wrecks of some castle or abbey of the middle ages, can, in his mind's eye, conjure up the true semblance of what it was when entire, so the geologist, from the fragmentary signs before him, can truthfully restore the whole systems of glaciers that once filled the valleys of the Vosges, the Highlands, or of Wales.

It would be something could we form any idea of the years that have elapsed since, in these latter days of geological time, the glacial markings were made on the rocks. But of this we can have no approximate guess; and the only hint may be inferred from Sir Charles Lyell's remark that it probably took 30,000 years to excavate the deep ravine that lies below the Falls of Niagara, and that this was done since the deposition of certain fresh-water marls that lie above the cliffs, and which are of later date than the American *drift*.* There being no doubt that this drift was in general terms contemporaneous with our glacial period, and if Sir C. Lyell's calculation be correct, then the seemingly slight glacial markings on our rocks have endured for a like period—who can tell how much longer?—for no data exist by which we can estimate how long the marls were formed before the excavation of the ravine began, or, farther, how long a period elapsed between the close of the accumulation of the drift, and the commencement and deposition of the fresh-water strata. We may be sure that these passages consumed no mere minute fragment of time, for whole races of mammals were created, lived their appointed time on earth, and disappeared between the close of the drift and the commencement of the human epoch.

One interesting point still remains of this fascinating subject. Though the veteran Von Buch, in conversation, to the last denied that the glaciers of the Alps had ever been materially larger than at present, it is now almost universally admitted that many of them once extended down the valleys 20, 30, or even a greater number of miles beyond their present limits, and that they then were of much greater thickness. The same holds true of the glaciers of the Pyrenees and the Scandinavian chain,† and, according to Dr J. D. Hooker, of the glaciers of the Himalaya, which in places once descended to levels of only 9000 feet above the level of the sea, or 5000 feet below their present limits.‡ Was it during the presence of glaciers in the British isles and in the Vosges, or, in other words, during part of the Newer Pliocene epoch, that these glaciers attained their greatest magnitude? We believe it is susceptible of proof that this was the case.

Another important point to ascertain is the true nature of many of the superficial deposits that lie on the flanks of the Alps, and in some of the wider valleys and watersheds,—a good example of which occurs

* Manual, p. 145.
† Professor James D. Forbes's Travels in Norway.
‡ Himalayan Journal.

on the route between Meyringen and the Grindelwald by the Scheidegg Pass. There, near the base of the Wetterhorn, at heights between 4000 and 5000 feet above the sea, stretching to the south-west, is a broad, smooth slope, covered with comparatively small detritus, not dissimilar to the shell-bearing clays and stony beds which occur in some of the Welsh slopes, on the seaward flanks of the Snowdonian chain, at heights of from 1000 to 2000 feet above the sea. On the Alpine surface are scattered large limestone blocks from the Wetterhorn, arranged in rude lines. At lower levels, the upper and lower glaciers of the Grindelwald invade this territory; and in older times the glaciers have cleared the valley below of the drift-like detritus, just as in the Passes of Nant Francon and Llanberis the ancient glaciers swept out the drift, and left untouched the marine deposits that lie on the high grounds between Aber and the lower part of Nant Francon, from thence to Llyn Padarn, and on the slopes between Llyn Padarn and the river Ceunant. Are the deposits above the Grindelwald, and similar beds in other parts of the Alps, of marine origin, and were the blocks of limestone that lie on them arranged on or near an old sea margin by drift or pack ice? If so, perhaps they were deposited at the same time that the granite and gneiss blocks on the Jura, according to Playfair, were transported from the region of Mont Blanc, and that other boulders between the glacier of the Rhone and Martigny were borne westward and left on the mountain sides, when the Rhone above the Lake of Geneva was an arm of the sea, and glaciers descended to its level, according to the hypothesis of Sir Roderick Murchison.* Numerous blocks of granite and gneiss that lie on the Italian side of the Alps, scattered around the Lakes of Como and Lecco, were doubtless carried southward at the same period.† However this may be, it is much to be desired that geologists would search the drifts (if such they be) above the Grindelwald, and similar suspicious deposits for shells; and that if these were found, investigations were entered into to show the probable amount of depression that the Alps sustained during the glacial epoch.‡

We have already exceeded the limits we proposed to ourselves when this notice was commenced, otherwise we would fain make some remarks on the probable physical geography of the country through which flowed the river that deposited the Wealden and Purbeck strata; and also on the much vexed question of the denudation of the Weald itself, taken in connexion with other denudations of the Chalk and Oolites, of a like character but far larger in amount. Something more, too, might be profitably said of the Bunter and Permian rocks of Britain (subjects not yet clearly understood), and also on various more purely theoretical points, such as the anatomy (so to

* Geological Journal, vol. vi., p. 65.

† De La Beche's Manual, 1833, p. 195.

‡ Since the above was written, we have been informed that Mr Daniel Sharpe has produced a paper on this subject.

speak) of palæozoic volcanoes, the geological history of special areas of metamorphism, and the manner in which deep fissures or lodes have been filled with metalliferous and other more ordinary minerals, but for the present we must take leave of these subjects and of the book the perusal of which suggested them. The *Manual* itself requires no commendation of ours. The rapid editions that Sir Charles Lyell's *Elements* and *Principles* pass through are the best tests of their popularity, a popularity of the solid kind that makes his works essential to every student of geology, wherever the name of science is known.

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*Analytical View of Sir Isaac Newton's Principia.* By HENRY LORD BROUGHAM, F.R.S., Member of the National Institute of France and of the Royal Academy of Naples; and E. J. ROUTH, B.A., Fellow of St Peter's College, Cambridge.

We have have not forgot the fright we experienced two or three years ago, in turning up, on a friend's table, a little treatise on the Ellipse, *for the Use of Schools*, by His Grace the Duke of Somerset. Farewell to our occupation, thought we: who shall enter into the lists against such noble blood? Is it not enough that a prime minister has taken on himself the drudgery of correcting the press, for the life of a writer whose claim to national gratitude rests on nothing higher than the power of elevating sentimental verse almost into poetry, but that the House of Peers shall furnish treatises for the use of our little children? The shock soon subsided, the alarm wore off, and we have since learnt to view with complacency the competition which has thus arisen, believing that it has tended to exalt rather than to supplant the labours of our humblest compilers. Accordingly, when we took up the Analytical View, we experienced no pangs of jealousy; so far from it, that had Lord Brougham announced on the title-page his intention of giving lessons on the Principia at a reasonable fee, we verily believe we should have locked up our ferule for a couple of months, and taken a ride to the south, to get indoctrinated with deeper views of this, the noblest effort of the mind of man. Indeed, we have not given up the hope that we may yet do so; for we infer that, at any rate, one of the editors has had an experimental class of an unacademical kind, for the purpose of ascertaining how the work will answer as the basis of teaching. We are informed in the Introduction, that "two classes of readers may benefit by this Analytical View; those who only desire to become acquainted with the discoveries of Newton, and the history of the science, but without examining the reasoning; and those who