THE

SILURIAN SYSTEM,

FOUNDED ON

GEOLOGICAL RESEARCHES

IN THE COUNTIES OF

SALOP, HEREFORD, RADNOR, MONTGOMERY, CAERMARTHEN,
BRECON, PEMBROKE, MONMOUTH, GLOUCESTER,
WORCESTER, AND STAFFORD;

WITH

DESCRIPTIONS OF THE COAL-FIELDS AND OVERLYING FORMATIONS.

BY

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IN TWO PARTS.

PART I.

LONDON:
JOHN MURRAY, ALBEMARLE STREET.
1839.

CHAPTER XXXIX.

NORTHERN DRIFT (*continued*).

On the position of the great Bowlders which characterise the Northern Drift, and on the method of their transport.

THE northern drift, as distinguished by its materials and association with sea-shells of existing species, having been described, it still remains to inquire into the positions occupied by the great blocks or bowlders which form part of it, and to endeavour to explain *how* they could have been transported to the spots where they now lie[1].

Though of very general occurrence throughout the tract between the Cumbrian mountains and the parts of Shropshire, Staffordshire, and Worcestershire just described, the large granitic blocks abound in certain localities only. Thus, their great number on the hills near Preston and other parts of Lancashire, not far from the sources of their origin, has been adverted to; and the table land north-east of Liverpool may be further cited as richly strewed with them, sometimes of considerable size. In Cheshire they occur at intervals, but more as solitary bowlders than in heaps. In North Salop, on the contrary, and the adjoining parts of Staffordshire, they are found both isolated and in groups. On the northern face of Haughmond Hill and the north-western slopes of the Wrekin they are numerous, particularly at the former locality; while a few stray individuals extend southwards, lying on or near the surface of the other alluvia for a few miles south of Shrewsbury (Lyth Hill, Longden, Stapleton, &c.). These may be considered as short tassels prolonged from the edge of the fringe before described. The greater heaps, however, are lodged in Staffordshire, particularly in the district west of the Dudley and Wolverhampton coal-field. (See Map.) Large portions of the surface of the New Red Sandstone, between Bridgnorth on the west and Wolverhampton and Himley on the east, are so studded with these blocks as to be well worthy of a visit. In the tract extending from the hamlet of Trescot to the village of Trysull, in the south-western part of Staffordshire, their quantity and occasionally gigantic

[1] Mr. Greenough has marked upon his map the occurrence of these granitic bowlders in several inland places, nd Dr. Buckland has reasoned upon them in his Reliquiæ Diluvianæ. In certain districts where they were very numerous, they are fast disappearing through the labours of the Macadamites. The formation of good roads must, therefore, be admitted as a *vera causa* for their rapid disappearance in districts where other good materials are wanting.

dimensions (several tons in weight) may well excite surprise, seeing that they there occupy one of the most central districts of England. Here the farmer is incessantly labouring to clear the soil, either by burying them or by piling them up into walls or hedge banks, and his toil, like that of Sisyphus, seems interminable; for in many spots new "crops" of them, as it were, appear, as fast as the surface is relieved from its sterilizing burthen[1]. So great, indeed, is their abundance, that an observer, unacquainted with the region, would feel persuaded he was approaching the foot of some vast granitic range; and yet the source of their origin is one hundred and fifty miles distant! From this great central depôt, they are traceable into the estuary of the Severn in Worcestershire, till they appear as solitary bowlders, and finally are entirely replaced by gravel, in which small fragments of the same granite are intermixed with local detritus. (See p. 532.)

In this range, the blocks, as well as the shells and smaller gravel of which we have spoken, are found at all elevations from 50 to 400 and 500 feet above the sea. Their course has no relation whatever to the existing drainage of the country, for as they occur on the northern slope of the water-shed which separates the estuaries of the Mersey and the Severn, they have followed a direction quite opposed to the present line of drainage. Nor have the transverse, or east and west ridges and valleys, which form the present surface, been any obstacle to their progress from north to south, since the largest accumulations occur to the south of the crest which divides these estuaries.

Let us, therefore, endeavour to seek for a rational explanation of the method by which they may have been transported into such positions. In so doing we may first advert to the different theories already propounded to explain a phenomenon, which being very general in other parts of Europe, has given rise to much speculation. The earliest theory, usually called the "diluvial," supposed, that these blocks had been forced into their present positions by one or more tremendous inundations, passing over a subsoil which had been *dry land*. This theory was supported by able writers, who connected it with the account of the deluge recorded in the Scriptures, and thus gave it a great ascendency over the human mind. It is now, however, abandoned by almost every geologist. Independent of the physical improbability (may we say impossibility?) of the rise of waves sufficiently high and strong to propel these huge blocks across mountains and valleys, such an hypothesis has been shown to be inapplicable to large regions of the earth which have *never* been affected by any general rush of waters since their present configuration was assumed[2]. But, besides this, we have demonstrated, that in the region under review, not only are there no evidences

[1] I am indebted to Mr. Cotton of Claverly for directing my attention to many of these huge blocks in the environs of Abbotsford Hill. Seeing their great abundance in parts of the tract, and the difficulty of eradicating them, some of the farmers absolutely believe that they *grow* in the soil.

[2] Such as Siluria; Auvergne in France, &c. (See note, p. 511.)

of the existence of dry land anterior to the deposition of this drift, but that it contains marine shells of existing species, and has all the characters of submarine or shore deposits; in short, that it must have been spread out *beneath the sea*.

Another theory is, that these blocks, in common with the associated drifted materials, were transported by powerful currents, set in motion during the elevation of mountain chains. The geologists who have taken this view (which I also once adopted) have not sufficiently placed before us the probable condition of the physical geography of the country when these currents were in action. Without showing what portions of the present land were above and what below the sea, or what was the power of water under such conditions, they have only spoken generally of great debacles and abrading floods, thrown off upon the flanks of the upraised masses. Such causes may afford a true explanation in Alpine or mountainous regions where there are evidences of repeated violent action. The grooves on certain rocks of Scotland and other parts of the world appear also to prove that blocks have been driven along their surface in various directions by powerful *local* currents[1]. But although this theory may be applicable in such cases, it will not explain, in the region under review, the occurrence of *distantly* transported blocks, imbedded in *local* debris; for if currents sufficiently powerful to transport the blocks had prevailed, the local detritus and shells would have also been removed by the same action.

In our case, however, the blocks having certainly been deposited *under the sea*, and not transported over *previously dry land*, we get rid of much difficulty; but can we explain the phenomenon by the modern analogies of deltas and tidal currents? If we suppose a great delta, extending 60 or 80 miles southwards from the shores of the ancient Cumberland, and in which blocks of granite as well as other ancient rocks were commingled with the marine shells at the bottom of the sea, those who argue for the power of tidal currents may contend that, if a strait existed between England and Wales, the tide stream might have exercised considerable power in carrying materials, and that by comparison with straits in which tidal streams *now* flow, there might have been a preponderance of transporting force in *one* direction;—that as there can be no doubt, that all tidal streams have a stronger tendency to carry loose materials out to sea than they have to bring them back again, so the ancient tide streams, which from the distribution of materials have been supposed to flow and ebb in the straits of Malvern, may have had an effective transporting power from north to south; and lastly, that if the shore of the ancient Cumbria which skirted the trumpet-shaped arm of the sea extending into the straits of Malvern, formed a long inclined plane, a large portion

[1] For the details concerning the grooved and scratched surface of rocks see Colonel Imrie's account of the Campsey Hills, Trans. Wernerian Society, vol. ii. p. 35; Sir James Hall's memoir on similar phenomena in the neighbourhood of Edinburgh, Trans. Royal Soc. Ed., vol. vii.; also Dr. Buckland's commentary thereon, Reliquiæ Dil., p. 201 *et seq.*; and my notice of the scored surface of the sandstone of the oolitic series of Braambury Hill, Brora, Sutherlandshire, Trans. Geol. Soc., vol. ii. p. 257.

of the materials being derived from the southern end of that delta, would have been hurried along into the straits, strewing their bottom with a littoral deposit from the Cumbrian mountains. This explanation, suggested as a *possible* case[1], is attended with insurmountable difficulties in the one under consideration; for if we assume the delta to be only 50 miles in length (not a third of the distance to which the bowlders have been propelled), and that the slope of the delta did not exceed 3°, I am reminded by my friend Mr. Lonsdale that its southern end must then have lain at the depth of 13,000 feet below the level of the sea. The hypothesis of the sloping delta from the shores of Cumberland is, therefore, quite inadmissible. If this subject were fully entered upon, many other difficulties, as the occasional immersion of the blocks in fine sand, &c., might be suggested in inquiring how submarine currents of water can have impelled onwards these gigantic bowlders. It might also be objected that this ebbing and flowing of the tide is a complex question, barely within the limits of geological reasoning. If, indeed, it be assumed that the district occupied by water was open at each end, as I believe it was, then it is possible that the tides flowed in opposite directions; as in the Irish Channel, and to a much greater in the English. But I leave this abstruse point in the hands of those versed in the laws of dynamics, hoping that at some future time they may explain all the circumstances under which submarine currents may effect the distant transport of *large blocks*, or whether such transport is impossible.

A third theory refers the moving agent to ice, and originated, I believe, with Professor Esmarck of Christiania, from witnessing the conveyance of stones by icebergs during the thaw of glaciers, and their gradual advance upon adjoining plains. This theory, being confined to *subaerial* phenomena, is of course inadmissible in our *submarine* case. A new application of the same principle was suggested by M. Engelspach de L'arrivière[2], who from an observation near the mouth of the Niemen was led to believe, that icefloes sailing out from rivers into seas, may, from the specific lightness of the ice, have borne along many large blocks of stone and deposited them at great distances. This opinion, being founded on the observation of a large block of granite so circumstanced, is well worthy of consideration, particularly since the theory has been much improved by Mr. Lyell, who, combining this and other data, has shown that wherever icebergs and icefloes have existed, this method of transport is unquestionably a *vera causa*. The same reasoning may be applied to all those regions in which, from their physical features, we may be sure that the cold is, or has been, sufficiently intense[3].

[1] In a letter from the Rev. W. Whewell to myself, 1836, after my memoir on this subject was read before the Geological Society. This ingenious letter contains much additional matter, which may, I hope, appear hereafter in some work by Mr. Whewell, who having since been elected President of the Geological Society, will I trust show us to what extent physical science *can* be correctly applied towards explaining geological phenomena.

[2] Considérations sur les Blocs Erratiques. Bruxelles, 1831.

[3] See Charpentier and Venetz on the Glaciers and "Moraines" of the Alps. Professor Agassiz has also

Once let it be granted, that large frozen masses, like those now periodically liberated from the polar regions, were drifted to certain distances and in given directions by currents dependent on former configuration of the land, and we are furnished with an adequate agent; each icefloe as it dissolved, might have dropped its load of stones, at intervals, upon a submarine surface of gravel, sand, and shells. From the observations of Scoresby, Bayfield and others, we know that such operations are going on to a great extent in the Atlantic, floes being sometimes wafted to very southern latitudes before they are finally dissolved. This fact, indeed, was brought before the public more than a century ago by Bradley[1], who, having learned from seafaring men, that between our shores and the "Plantations," large islands of ice were sometimes met with, inferred, that the vapour arising from their dissolution, must have had a sensible influence upon the climate of England! Had geology been then a science, some Lyell might have seized upon this fact for the support of a wider induction than a meteorological theory.

But can we venture to adopt the icefloe hypothesis to explain the position of our Salopian bowlders? Have we a right to assume that the physical features of this region were formerly so different from the present, that ice may then have been formed in adequate quantities on the shores of Cumberland? I confess that on the first consideration I was disposed to reject such views as visionary, but reflection and reference to facts have led me to perceive, that many strong arguments may be employed for their adoption. In the first place, it might be said that even with the present amount of land and sea, the cold of our latitudes has at times been intense enough for the production of enormous masses of ice[2]. It might be argued that such frosts as those which congealed the Danube from top to bottom, which closed the Dardanelles, or rendered the Adriatic one sheet of ice, may have acted, in times long anterior to historic records, on the shores and rivers of Cumberland, Scotland, and Ireland; and that the ice islands set in motion at the termination of such frosts may have strewed their contents over the bottoms of adjacent seas. If, however, such causes be not deemed sufficient, the geologist may go much further in his endeavours to solve the problem. Knowing that great changes of sea and land *have* occurred within recent periods, and witnessing the mighty wreck of materials of the solid strata distributed on all sides, he may venture to suggest, that when England and Wales were separated, the distribution

recently expressed some peculiar opinions on the action of ice upon the Jura, &c. Cases purely subaerial, like these, can, however, have a collateral relation only to my submarine examples.

[1] "A Survey of ancient Husbandry and Gardening," Oct. Lond. 1725, by Richard Bradley, F.R.S., and Professor of Botany in the University of Cambridge.

[2] In the year 1709 all the rivers and lakes were frozen, and even the seas to several miles from the shore. The Adriatic Sea was quite frozen over, and even the coast of the Mediterranean about Genoa. In the year 1740 an ox was roasted on the Thames. In 1658 Charles X. of Sweden crossed the Little Belt with all his army and artillery, &c. For a full list of all the great frosts and excessive heats, see Edinburgh Review, vol. xxx. (No. lix.) p. 23 *et seq.*

of land and sea may have been such, as to have permitted the production of icebergs, which, being dislodged from the shores of Cumberland, might have been drifted into the straits of the sea then existing to the south of Bridgnorth.

If, however, we admit that icefloes or icebergs may have been the true method of transport, it is right to allude to an objection which has been raised, that the blocks in Shropshire (as in many other parts of the world) are generally so much rounded and worn, that they rather convey the impression of having been rolled under water, than of having been simply removed from their parent rocks in vessels of ice. Now, although this objection cannot be altogether obviated by replying, that modern atmospheric agency may have worn away their angles and scored their surfaces, (for we sometimes witness the same appearances when the bowlders are dug out from great depths beneath gravel, clay and sand) still the attrition of their surface may be well explained under any one of the following conditions. 1st. They may have been carried down by streams to the shores, and have been long bowldered there, *previous* to their insertion in the ice. 2ndly. They may have been fragments, which, falling from the adjacent rocks, were exposed to the action of water on the shores before their transport by ice. 3rdly. It is well worthy of remark, that granite is so prone to desquamation[1], that nearly all granitic chains are topped with *rounded* masses, which, though really *in situ*, have often the appearance of being bowlders; and these, if dislodged from cliffs and imbedded in icefloes, would at once present the appearance objected to, though they had *never* been rolled under water. Finally, it may be observed, that if transportation in ice be supposed, we can account rationally for the blocks occupying for the most part the surface or upper portions of the drift, for we know from modern analogies, cited by Captain Bayfield, that icefloes, in narrow bays or straits, are generally stranded on coasts or shallow shores.

Such were the arguments I employed to show how far the ice theory would account for the dispersion of erratic blocks over the central parts of England[2]. Others had put forth this theory in respect to fluviatile, lacustrine, and subaerial phenomena, and I applied it to the ancient condition of the region in question, when it *was permanently beneath the sea.* But still, in common with other geologists, I was unprepared with adequate data to show how such phenomena could have occurred in our latitudes during the period before the present, while geological evidence went rather to prove the prevalence of a former higher temperature[3]. No one, in short, had then the *means* of ac-

[1] See Macculloch on the Tors of Cornwall, Geol. Trans., Old Series, vol. ii. p. 66.

[2] The memoir containing these views was read before the Geological Society, in 1835, and was subsequently commented upon in Mr. Lyell's Anniversary address, Feb. 1836. (Proceedings of the Geological Society.)

[3] The erratic blocks on the surface of the earth are *so much larger* than any fragments found within the ancient strata, that some geologists have termed the epoch of their production "the block period," ("Période Clysmien" of Brongniart). It is quite manifest that as far as our present evidences teach us, the period n which these blocks were transported *differed essentially from any which preceded it,* and the difference can only be well accounted for by a prodigious change of climate. Geologists, therefore, naturally connect the absence of these

counting for the existence of ice in such latitudes, except by referring to the great vicissitudes of European climate within the range of modern history. Yet how inade-

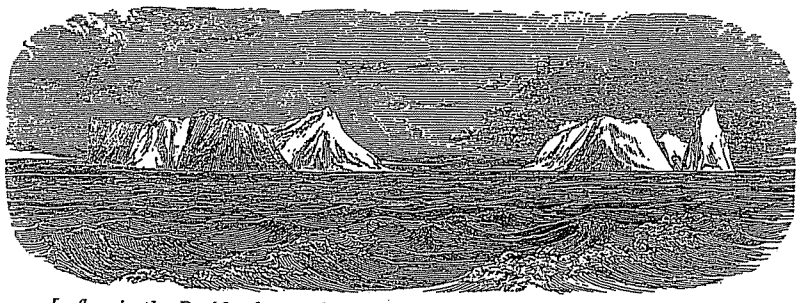
blocks in the older strata with the higher temperature which, from other independent reasons also, was then supposed to exist, and their presence in the modern æra with a diminished temperature. This accordance of geological data with the result of an icefloe hypothesis is further borne out by modern analogies; since, as far as our inquiries go, no far transported large blocks have yet been found on the surface of equatorial regions.

The preceding paragraphs in the text, including the first part of this note, were read to the Geological Society just as they are printed; and when I had no hope that the views they contain would have been so well sustained as they have since been by modern analogies. (See next page.) I still adhere to my belief, that there is yet no established case of far transported large bowlders in tropical regions; but from fresh sources of information I am led to suppose that the partial discovery of bowlders in such tracts, so far from weakening the icefloe hypothesis, would almost support it by evidence drawn from existing causes.

In 1836, Captain Octavius V. Harcourt, R.N., returning in the North Star from South America, met with a vast number of icefloes in the Pacific, in latitude 50°. Some of them were not less in size than two miles square and 250 to 300 feet above the water. It is remarkable that this phenomenon occurred from 85° west longitude, at a considerable distance from any land, to the meridian of Cape Pillar; while the immediate coasts of Chiloe and Cape Horn offered no trace of them. The winter was comparatively mild, which might indeed account for the liberation of such large masses of ice from the South Pole, and their being wafted into seas usually quite free from them. The number and size of these icefloes were truly astonishing (two of them as seen for a distance of three to four miles are represented in the wood-cut below), and Captain Harcourt had the greatest difficulty in so steering, during the long winter moonless nights of 18 hours, as to avoid shipwreck. Their course seemed to be from south-east to north-west, and they were met with through five degrees of latitude (50° to 55°), which would be *the exact position of England if transferred to the other hemisphere.* Their occurrence was accompanied by sudden changes of wind and violent tempests. (Abridged from a letter of Captain Harcourt to myself.)

In the 7th Volume of the Journal of the Royal Geographical Society icefloes are mentioned by Mr. Bennett (p. 212.) in latitude 47° south, and they have even been met with recently as high as 35° south latitude, the parallel of Bengal in our hemisphere.

The multitude of these icefloes sailing together for such a great distance from the source of their origin before they are dissolved, not only teaches us, that any stones of the polar region which they might be transporting, must now form part of submarine deposits, even in intertropical regions, but also explains how a vast number of such stones *might* be collocated in *one* tract very remote from the parent rock, as in the south of Staffordshire, p. 536 (*ante*). See Lyell's excellent illustration of this point, Principles of Geology, vol. iv. p. 267. According to this author the mass of ice below the level of the water in floating islands is seven or eight times greater than that above, and hence the islands here represented must have had a total altitude of from 2000 to 2500 feet! (See Scoresby's Voyage, p. 233.)



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Icefloes in the Pacific, from a drawing by Captain Octavius V. Harcourt, R.N.

quate was that cause to explain such widely spread effects! Doubtless, if the phenomena had been rare and confined to one part of Europe, a partial deviation from the ordinary course of nature might explain it; but how are we to reconcile the position of blocks which had been transported from Savoy to the Jura, or from Scandinavia to the plains of Prussia, with such a method of explanation? Notwithstanding the attempts to apply the iceberg theory generally in aid of the transport of submarine blocks (seeing that in northern latitudes it was a *vera causa*), still geologists were wholly unprovided with data to reconcile the former action of ice, in latitudes where it does not now occur, with a former condition of Europe favourable to tropical productions: and this argument was vigorously pressed home by the opponents of the theory. In this state of the subject, Mr. Charles Darwin, who accompanied Captain Fitz Roy during five years throughout the southern hemisphere, returned to Europe, with the knowledge of many novel facts bearing upon this and other geological questions. In his journal during the voyage of the Beagle about to be published, and to some pages of which I have had access, after giving examples in low latitudes in the southern hemisphere, he fairly establishes this proposition:—that an equable climate, probably a direct consequence of a large proportional area of water (a probable condition in the geological case under review) is at the same time favourable to the presence of tropical productions, and to a low limit of perpetual snow, and therefore to the descent of glaciers into the sea in latitudes as low as 46° 40′. (pp. 283—285.) Judging from these examples, he infers, that the dispersion of floating masses of ice, with included fragments of rocks, descending from the mountain chains of central Europe, where islands alone formerly prevailed (the case above supposed), might absolutely have been anticipated to have taken place during the period before the present. Referring my readers to the original observations of this clear and powerful reasoner for the details of the phenomena in the southern hemisphere, by which his inferences are supported, I will here quote his principal conclusion, drawn from the unanswerable facts, which he ingeniously applies to explain the transport of great bowlders.

"The circumstance of a luxuriant vegetation, with a tropical character so largely encroaching on the temperate zones, under the same kind of climate that allows of a limit of perpetual snow of little altitude and consequent descent of the glaciers into the sea is very important; because it has been argued, with great apparent truth, that as there is the strongest presumptive evidence of a gradual cooling down of the climate (or rather of a less favourable state for tropical productions) in Europe, it is most unphilosophical to imagine that *formerly* glaciers could have acted where they do not *now* occur. It may be asked, what are the circumstances in the southern hemisphere that produce such results? Must we not attribute them to the larger proportional area of water; and do not plain geological inferences compel us to allow, that during the epoch anterior to the present the northern hemisphere more closely approached to that condition than it now does? We are all so much better acquainted with the position of places in our

own than in any other quarter of the globe, that I will recapitulate what is actually taking place in the southern hemisphere[1], only transporting in imagination each part to a corresponding latitude in the north. On this supposition, in the southern provinces of France, magnificent forests, entwined by arborescent grapes, and the trees loaded with parasitical plants, would cover the face of the country. In the latitude of Mont Blanc, but on an island as far eastward as central Siberia, tree-ferns and parasitical *orchideæ* would thrive amidst the thick woods. Even as far north as central Denmark, humming-birds might be seen fluttering about delicate flowers, and parrots feeding amidst the evergreen woods with which the mountains would be clothed down to the water's edge. Nevertheless, the *southern part of Scotland* (only removed twice as far to the westward) would present an island, 'almost wholly covered with everlasting snow,' and having each bay terminated by ice-cliffs, from which great masses, yearly detached, would sometimes bear with them fragments of rocks. This island would only boast of one land bird, a little grass and moss; yet in the same latitude the sea might swarm with living creatures. A chain of mountains, which we will call the Cordillera, running north and south through the Alps (but having an altitude much inferior to the latter), would connect them with the central part of Denmark. Along this whole line nearly every deep sound would end in 'bold and astonishing glaciers.' In the Alps themselves (with their altitude reduced by about a half) we should find proofs of recent elevations, and occasionally terrible earthquakes would cause such masses of ice to be precipitated into the sea, that waves tearing all before them would keep together enormous fragments, and pile them up in the corners of the valleys. At other times, icebergs, 'charged with no inconsiderable blocks of granite[2],' would be floated from the flanks of Mont Blanc, and then stranded on the outlying islands of the Jura. Who then will deny the possibility of these things having actually taken place in Europe during a former period, and under circumstances known to be different from the present, when on merely looking to the *other hemisphere we see they are among the daily order of events?*" (p. 291 *et seq.*)

But Mr. Darwin is not satisfied with showing, that the coasts of former European islands were in all probability the seats of great icebergs; he pursues his argument further, and in common with other geologists points out the *absence* of erratic blocks in the intertropical regions (where glaciers and icebergs could not have acted) as a corollary of the great geological problem towards solving which he has done so much, by an appeal to existing nature[3]. The above observations, therefore, show, that *there are* conditions in which ice may be accumulated and become a motive power; and that such

[1] It is in the southern hemisphere that we find elephants, rhinoceroses, hippopotomuses and lions, as far south as latitude 34° and 35°. In South America the jaguar occurs in 42°, the puma in 53°.

[2] Captain P. King, R.N. uses these words when alluding to the case in Sir G. Eyre's Sound, which Mr. Darwin has more fully described from the information of Mr. Bynoe.

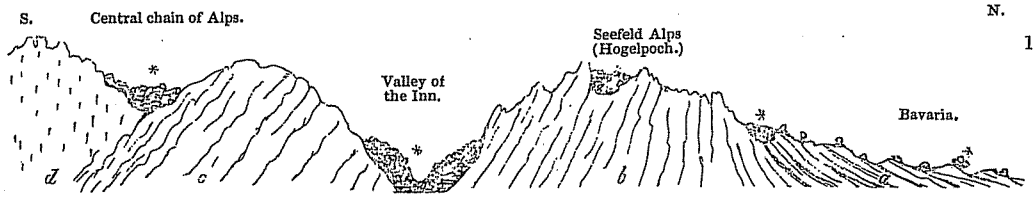
[3] See my note on this point, p. 541.

conditions *may* have existed in our latitudes when there was a very different proportion between land and water. Following up the important observations of Humboldt and Lyell, upon the influence of continental masses and great seas upon climate, Mr. Darwin materially adds to the cumulative proofs, that temperature is not dependent solely upon latitude.

Thus, the conditions of the difficult problem which we have to solve are now much more fully brought before us than in any former discussion of the subject. We have in running water a power, the extent of which has, however, yet to be worked out. We have also a *vera causa* in the icefloe, which, it appears to me, goes *much further* towards explaining the difficulty, than any hypothesis which has yet been framed; although it would, perhaps, be premature to assert that it completely settles the question, still less that such agency can be considered the only one by which bowlders may have been transported.

It still remains for us to say a few words on the present relative heights at which the bowlders occur, although, if their deposit by icefloes be admitted, much difficulty is obviated, as the bottom of a sea in which the bowlders were dropped, may have often been so full of inequalities, as to present, when desiccated, an outline similar to many of our undulating and even hilly countries. But the striking and sudden differences of altitude at which these blocks and shells are found, in the same district, seem to call for additional explanation. The difference of height between the top of Moel Tryfan, and the plains of Salop and Cheshire (1400 to 1600 feet), is almost too great to admit of the supposition that such was the submarine surface. If, indeed, we admit that in this district, such vast submarine inequalities existed, still we should have to account for others of much greater amount in foreign countries[1]; and, therefore, it is

[1] Illustrating the apparently inexplicable position of certain bowlders in relation to the *present* outlines of the earth's surface, I would cite one of many cases which have fallen under my observation in and upon the flanks of the Alps.



This wood-cut represents a transverse section across the Tyrolese mountains which flank the valley of the Inn west of Inspruck. To the south, the older transition rocks (*c*) are flanked by the granitic nucleus of the chain (*d*). To the north are the great masses of limestone (*b*) (crystalline and dolomitic), which representing our oolitic series and lias, attain heights of 6000 feet above the sea, and beyond them the lower hills of green sand (*a*) and tertiary deposits of Bavaria. In one of the loftiest combs of the Alpine limestone, called Hogelpoch, considerably above Seefeld, and at a height of at least 3000 feet above the valley of the Inn, is an accumulation (*) of blocks of gneiss, granite, porphyry, chlorite slate, &c., materials which can have been derived only from the central mountains (*c* and *d*), and from which they are now completely cut off by a deep valley. My present belief is, that there was a period in which the blocks in the valley and those on the summits of the

desirable to search for more valid reasons to explain the difference of levels. Geology furnishes us with these, in teaching us that our present lands have been irregularly raised from beneath the ocean[1]. Some regions have been heaved up in the form of great plateaux without many breaks; but the vastly larger proportion of the crust of the globe is absolutely starred through with rents (many examples have been cited in this work), by which beds once continuous have been snapped asunder, and subsequently moved up

limestone mountains, were deposited under water in the form of a delta, extending northwards from the central chain, during the formation of which the blocks overlying the limestone peaks were probably at no very different level from those now lying on the banks of the Inn.—That after the drift had been so deposited, powerful movements took place, heaving up the outer shores and raising the pre-existing bottom of the sea, estuary, or lake (as the case might be) to great heights, the blocks and loose materials being thus left at various elevations, and in the detached positions in which we now find them. Here, we have no occasion to *imagine* dislocations, for they teem in every mass of rock. The chasm in which the Inn flows, is indeed *one great line of fault*, and such are the contortions and dismemberments of the whole chain, that throughout more than 50 *miles* from east to west, the younger formations are thrown over and appear to dip under the older! But even with such evidences of mutation, I confess that in the year 1828, although I *then* believed that the phenomenon I am describing, could be explained only by movements of unequal elevation and depression, I was not prepared to go the length I now do in the solution of this problem, my present views being founded on the knowledge, *since* acquired in England, of the intermixture of sea shells of unquestionable modern species with erratic blocks. Now, although the rationale of icefloes, as above propounded, has rendered our appeal to catastrophes uncalled for in many cases, we cannot witness the scenes of dislocation in the Alps, and perceive that they are accompanied by the lodgement of bowlders derived from the same source at heights so different, without also employing such evidences of mutation to help us in part to solve these problems. If some of the greatest relative changes between the sea and land have taken place in our island within the modern period, the same may have also happened at a comparatively recent period in the Alps*.

[1] I could have strongly illustrated these views by an appeal to evidences of recent elevations of the shores of South America, but as this inquiry would lead me beyond the limits I have prescribed to myself, I must refer my readers to Lyell's Principles of Geology, or for details to the works of Mrs. Graham (now Lady Calcott), Mr. Caldcleugh, Dr. Meyen, and above all to the clear and unanswerable record of that distinguished navigator and precise observer, Captain Fitz Roy, R.N. In describing the effects of the last earthquake at Concepcion (Geographical Journal, vol. vi. p. 327.), Captain Fitz Roy has distinctly proved, that the island of Santa Maria was elevated from 9 to 10 feet, while the rest of the coast on the mainland was only raised from 2 to 4 feet; and thus we see that not only in the same epoch, but absolutely during the same minute, recent sea-shells lying in the same bed were placed at very different levels. This small measure explains the *modus operandi* as well as if the scale had been equal to that of the ancient phenomena under consideration.

The reader will have perceived in various parts of this work, that while I rejoice in what I would call the "Lyellian method" of testing geological phenomena by modern analogies, I do not believe in the doctrine, that the dislocations of the present day are produced by causes of the same degree of *intensity* as those of which geology affords the proofs. I must always be of opinion that, although they may belong to the same class, the geological catastrophe (such as the *overturning of a mountain chain*) and modern earthquake cannot be placed side by side, without our exclaiming "*sic parvis componere magna.*"

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* See observations by Professor Sedgwick and myself on the Eastern Alps, Geol. Trans. vol. iii. p. 415. The bowlders of Hogelpoch were observed by myself in a previous visit, but they form a part of the detritus referred to in our joint memoir.

and down to widely different levels. Is it not, therefore, a fair inference, that during the recent elevation of the continents and islands over which these bowlders are distributed, there must have been movements of very different degrees of intensity, at comparatively recent dates, affecting the different portions of the tracts in question? If partial elevations at some points and depressions at others, occurred during the desiccation of the bottom of the sea (and it is obvious such changes must have happened), many of the submarine valleys and hills must have thereby been much modified.

Adhering, therefore, to the prevalent belief of modern geologists, founded on a multitude of *well-recorded facts*, that the land has been repeatedly elevated and depressed in relation to the sea level, I confess my inability to imagine how such mutations can have been accomplished without involving, as a necessary result, the repeated fracturing of all the subjacent strata. In viewing the present surface, we are not to expect that the loose materials of the bed of the sea should, when elevated, exhibit lines of fault, as clearly and neatly defined as those impressed upon the solid strata which support them; the only memorials we could expect to find of the dismemberment of the loose aggregate, being what we now witness;—the separation and removal to various heights of gravel beds which were once continuous. For we must recollect, that under the view here adopted, the space between the elevated and stationary parts, or between those elevated and depressed, would always be exposed to the same action as a *sea beach*, and therefore such portions would be rounded off, and the final result would be the appearance of a covering spread more or less equably over the whole tract. Such elevations in throwing off large bodies of water must, it has been shown, have materially aided in the partial transport of many of the fragments.

Lastly, elevations to the extent we have now supposed, can hardly have affected so large a portion of our western shores, without producing a great effect on the relations of land and sea on the other coasts of the island; and as from collateral evidences we already know, that great part of our eastern shores was submerged at an equally modern period, because the same species of sea-shells are there also found in gravel, we may infer that, by whatever means accomplished, the estuaries of the Humber and the Thames, and the coasts of Devonshire and Cornwall, were desiccated during the same period as the plains of Shropshire and the estuaries of the Mersey and the Severn[1].

[1] See a memoir by Professor Sedgwick and myself on the raised beaches of Devon and Cornwall, Geological Proceedings, vol. ii. p. 441. Similar raised beaches, inclosing sea-shells of existing species, have been observed at various points along the eastern shores. See memoirs by Mr. W. Hamilton on the shores of Fife, Geological Proceedings, vol. ii. p. 180.; by Mr. Prestwich on the shores of Banffshire, Geological Transactions, vol. v. p. 139.; by Professor Phillips on the coast of Yorkshire; and by Mr. Smith, of Jordan Hill, Geol. Proceedings, vol. ii. p. 427., on the western shores of Scotland. The last-mentioned gentleman has very much enlarged our knowledge of this subject by very extensive collections and accurate determination of the species of shells. I may also mention a raised beach at Cranfield Point near Carlingford, Ireland, observed by Professor Sedgwick and myself, in company with Mr. Hamilton and Mr. W. D. Hull, in the summer of 1835, as its component parts and general aspect much too closely resemble the coarse and fine accumulations

These great mutations are, therefore, appealed to as the cause, by which in raising up large submarine tracts and uniting islands into continents, the climate of our region has been materially changed; while they satisfactorily explain to us why the agency now at work around us differs in so many respects from that of the period which preceded our own.

of Lancashire, Cheshire, and Shropshire to be passed by without notice on this occasion, particularly as this part of the coast of Ireland is precisely in the same latitude as the Cheshire and Salopian detritus.

111.

a and *b*. Vegetable mould, sand, and gravel, with shells similar to those found in the adjoining sea—18 feet above high water mark. The pebbles resemble shingle. *c*. Clay, with occasional coarse fragments of porphyry, limestone, granite, &c. *d*. Gravel as above repeated.

The late Major Patrickson described this raised beach in a memoir read before the Geological Society of Dublin. Similar beds of recent marine gravel have been observed in different parts of Ireland by Griffith and other observers.

[After the proof sheet of this chapter had passed from my hands, Mr. Lyell sent to me a letter from Capt. Bayfield, R.N. (now employed in surveying the coasts and rivers of our North American colonies), which so powerfully sustains the views I have adopted, concerning the transport of bowlders by ice, that an extract from this instructive and interesting letter will be printed in the Appendix.]

G.

Bowlders transported by Ice.

The chapters on superficial detritus were in the press when Mr. Lyell favoured me with the perusal of a most instructive letter from Captain Bayfield, R.N., now employed in surveying the coasts and rivers of our North American colonies, which so strikingly corroborates the views I have attempted to establish concerning the method by which our English bowlders and the associated shells have been deposited, that, with Mr. Lyell's permission, I annex an extract. After a graphic sketch of the geological features of the region, Captain Bayfield thus alludes to the case in question.

"The bed of the St. Lawrence below Lake St. Peters is full of immense bowlders of primary rocks, most of them (but not all) rolled or water-worn, or with their edges worn off by atmospheric agency, (for I do not believe that all the blocks which appear to be so, have been really water-worn). See pp. 540 *et seq.* These are principally derived from the Tertiary beds, for they abound in them, even among the shells, and at all levels; and as the terraces are worn away, the bowlders are left at the foot of the cliffs, and sticking out of sand and clay. *Torrents bring them down the steep water-courses at the melting of the snows; and when they reach the St. Lawrence, the ice moves them every spring.* I have seen a granite bowlder, 15 feet in length by 10 in width and depth, transported many yards along a meadow by this agent; and last spring I watched the lake ice (Lake St. Peter), which takes 2 or 3 days to pass Quebec every spring, and had the pleasure to observe several bowlders of considerable size, and many small stones, sand, earth, reeds and plants on their way down the river, drifting at a rate measurable by the excess of every ebb tide over the preceding flood. The latter flows $4\frac{3}{4}$ hours, at the rate of 3 knots; the former about $7\frac{1}{2}$ hours, at 4 knots. Any bowlders thus transported are liable to be dropped at various points along *the bed of the river,* as the ice gives way to the increasing temperature of the air and water in the spring of the year."

After showing how freshwater shells, seeds, plants, &c. are similarly transported and tranquilly deposited along with large blocks of stone, amid marine shells, Captain Bayfield gives practical illustrations of the power of the ice of one season in removing large bowlders and deep stakes, which he had caused to be placed in certain positions. These were entirely carried away and replaced by other bowlders, while in the same season a mass of granite, containing 1500 cubic feet, and which he had particularly marked, was transported several hundred yards from its observed position. Again, in speaking of the bowlders which occur in the younger Tertiary deposits, he says, "They are found in the cliffs at different levels, not resting upon each other, but as if they had been dropped there at widely different times, during a long period, in which a quiet deposition of clay, sand and gravel had been going on, and in which the various genera of testacea had lived and died. Some of the shells are of course broken, and some of the valves are separated, as is the case in the bottom of the present seam; but many have both valves together, although they separate when taken up, because the ligament no longer exists. All idea of these shells (together with the sand, clay and bowlders) having been drifted together into their present positions must be given up at once, when I state the fact, that the *Terebratulæ psittaceæ,* which you know are so fragile that the smallest stones would be sufficient to destroy them, if carried along with a moderate degree of violence by moving water, are found with their valves together, and their long and brittle teeth entire as when they were living."

"The whole of the facts, which I have neither time nor space to dwell upon in this letter, lead me to infer that these numerous erratic blocks, from whatever source originally derived, have been dropped from time to time (from ice floes) on the bed of the Tertiary sea."—Extract of a Letter from Captain Bayfield, R.N., to Mr. Lyell, November 1837.