Note.

The unsuccessful attempt made by Mr. C. E. Mathews and Herr E. von Fellenberg to reach the Silberhorn by the west arête took place on June 29, 1863 (*Alpine Journal*, i. 134); Herr von Fellenberg (with Herr K. Baedeker) succeeding in making the first ascent of the peak on August 4, 1863, from the plateau between the peak and the Wengern Jungfrau (*Alpine Journal*, i. 197). In the first volume of the *Jahrbuch* of the Swiss Alpine Club (for 1864), Herr von Fellenberg has given a full account of both expeditions (attempt, 326–335; ascent, 335–358). On June 29, 1863, the party started at 2 A.M. from the Stufenstein Alp, and at 11.10 A.M. reached the foot of the overhanging rocks at the west end of the western arête. Melchior Anderegg was unable to overcome this obstacle, and Herr von Fellenberg declares emphatically that the north and south sides of the arête could not be traversed, saying of the former (that actually scaled by Mr. King's party) that a 'terribly steep snow slope descended towards the very crevassed glacier far below.' The party was, therefore, forced to return at 12.30, leaving a flag and a bottle with their names. When on the summit on August 4, 1863, Herr von Fellenberg saw clearly the flag he had left on June 29, and says that the ridge between is so steep and rugged, and the little glacier basin so crevassed, that even if they had been able to scale the overhanging rocks (or 'Flühlein') the party would certainly have failed to force their way up to the Silberhorn (p. 350). Mr. King's ascent by the western arête has thus solved an Alpine puzzle which was tried in vain twenty-four years before. It would seem that there is no previously recorded instance of a paper having been found after twenty-four years' interval, the longest cases yet mentioned in these pages being twenty-three years (*Alpine Journal*, xii. 467; xiii. 129).

Herr von Fellenberg gives two diagrams of the western arête of the Silberhorn (pp. 332 and 347), with all the various points of the route indicated. They serve to make quite clear the route tried in 1863 and achieved in 1887.

The Growth and Sculpture of the Alps.*

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(The Tyndall Lectures for 1888, delivered at the Royal Institution, London.)

No. 1.

The geological history of the Alps, which is inseparable from the geological history of at least a large portion of Europe, is a far more complicated question than is generally imagined. Contrast a geological

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* Some introductory paragraphs are omitted in which the author drew attention to the diversity of opinion which still prevails in regard to the geological history of the Alps, and the field which, notwithstanding the atten-

map of this continent, blotched and spotted and streaked as it is with isolated groups of formations of all ages, from the very oldest to the most recent, with its mountain ranges past and present, its great, almost inland sea broken here and there by islands of no modern date, rising from comparatively deep water—contrast, I say, this diversity and seeming confusion with the attractive simplicity of the two Americas, which are only somewhat complicated in the neighbourhood of their Mediterranean—the Gulf of Mexico and the Caribbean Sea—and one begins to realise that the subject will not be easy.

In these lectures I must assume a slight knowledge of the leading facts and principles of geology, but shall avoid, as far as may be, technical details. The names and the order of succession of the strata are hung up to view to refresh the memory of those to whom these are not very familiar; and I must ask the more learned to forgive my avoidance of technical terms for the sake of those less fortunate than themselves.

About four years since I addressed a Friday evening audience in this room on 'The Building of the Alps.' What was then said bears upon the subject of these lectures, and more especially upon the present one. Hence, for the sake of completeness, I must venture occasionally to travel over old ground, though this, as far as may be, will be avoided, except where I wish to modify, or have need to amplify, my former statements. In regard to that lecture, I may say that, after four years of work in different regions, and two more visits to the Alps, planned expressly with a view of studying their geology, I have only some details to modify, while in regard to the leading principles, especially the more novel among them, I am prepared to speak more confidently and strongly than I could then venture to.

I purpose in these lectures to restrict myself to the geology of the Alps, but it is impossible to insulate them wholly from other mountain chains, or to separate it from the geology of at least a large part of Europe. To this, however, I shall only refer so far as may be absolutely necessary. But to dissociate the Alps from the Apennines and the Jura is impossible, from the Carpathians is not easy. They are closely connected with the ranges of the Dalmatian coast, with the basin of the Adriatic, and even with the great plain of the Po.

To say that a mountain chain is in intimate relation with a sea basin may seem at first sight a paradox, but it is none the less true. Perhaps it would be going too far to say 'without an ocean basin no mountain range,' but we may unhesitatingly assert that the one and

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tion bestowed upon them of late years, they still offer for research. He also said that, as this was the first of the courses of lectures instituted by the Royal Institution in honour of Professor Tyndall—a man so eminent, not only in science, but also as an explorer of the High Alps—the subject seemed especially appropriate. In conclusion, the author said, 'If in speaking I refer little to the work of others, this is not in order to pretend to originality in my own views. You are quite at liberty to suppose that everything in these lectures has been said by somebody, somewhere; only I shall state in them very little which I have not personally examined or independently investigated.' Here and there in the course of the lectures a few explanatory paragraphs are omitted.

the other in numerous cases are most closely connected, and the development of mountain ranges is facilitated by the existence at no great distance of deep seas, so that, as Dana once observed, 'the greater ocean basins are commonly bordered by the greater mountain chains.'

Such a chain as the Alps may be described as composed of a series of rock masses, in part at least deposited in successive layers, and then bent into wave-like folds, as a number of heavy carpets, laid one on another, would be, if their opposite ends were brought nearer together. These folds are sometimes comparatively gentle, sometimes exceedingly sharp. Occasionally the thrust is so powerful that the folds are bent over in the opposite direction; sometimes the rock masses are even broken under the strain, and the upper part of the fold slides forward over the lower. While these disturbances were in process, heat and cold, rain and rivers, snow-slide and glacier, in some cases also the waves of the sea, were sculpturing and transporting, so that the mountain peaks are in many cases only remnants of masses far more gigantic; that vast rocky wall, which rises so grandly against the sky, is a mere ruin of the huge bulwark which once guarded the Italian lowland.

We learn from maps and sections of the Alps * that there existed first a mass of crystalline rocks—granite and other igneous rocks, gneiss and schists, the age of which we will presently discuss—which formed a kind of floor or foundation; that this, about the beginning of the Secondary period, began to sink beneath the waters, and continued so to do till toward the middle of the Tertiary; successive masses of rock —sand, mud, and limestone—being spread out over the sinking region, until at last the downward motion ceased; then the thickened earth-crust was upheaved and folded, perhaps at more than one epoch, and eventually some of the older and harder beds were in places actually bent back and partly thrust over the newer and softer rocks which form the outermost zone of the Alps.

What were the physical causes of this great down-bending of the seemingly solid crust of the earth, of these subsequent strange deformations, this extraordinary and repeated folding and thrusting, which has bent rock masses the thickness of which may be measured by hundreds, even by thousands of feet, almost as easily as if they had only been Turkey carpets?

This is a question which I must pass over briefly, as its complete discussion would occupy too much time and lead me away from the main subject. Two explanations have been proposed: each dependent on changes in the volume of the earth's crust resulting from changes in its temperature.

The one more generally favoured asserts that the globe as a whole has from the first been gradually cooling by radiation, that its outer crust first became solid, and that, when the still semiliquid zone below

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* The lecture was illustrated by geological maps and by sections, taken more especially from Heim's *Mechanismus der Gebirgsbildung*, and the works of the Swiss Geological Survey. An admirable section (an extension of one by Heim) right across the Alps from near Zürich over the St. Gothard to near Como, will be found in Prestwich's *Geology*, vol. i. p. 334.

in its turn cooled and began to harden, this, as it and the inner nucleus contracted, dragged with it the already stiffened crust, and compelled it to crumple here and there so as to adapt itself to the altered conditions. Thus the mountain chains are the wrinkles on the face of mother earth, and prove that her youth has long since passed away.

The result of this contraction would be to subject the earth's crust to lateral thrusts, which would produce a kind of puckering, relatively elevating one zone and depressing another. The one part would now undergo denudation, the other become an area of deposit. Rigid as the crust may seem to be, rigid as the necessities of physical considerations may require it to be when subjected to strains for limited periods of time, there is much reason to think that the solid possesses a certain plasticity which causes it to yield to forces acting continuously for long periods of time; so that the denudation of material from one area and its deposition on another causes the former to continue rising, and the latter to sink down yet further. But at last there is an end to these gradual movements, which affect broad zones of surface. The crust—for what cause or causes we need not now inquire—becomes weakened along certain lines or narrower tracts. Here, then, a sharp puckering occurs; the strata, new and old, are folded together; long lines of fracture occur, especially along the axes of these folds; sometimes the lower beds are bent back over the newer, and the former are even pushed completely over the latter. Wonderful instances of similar movements, producing the most marvellous complications and the most deceptive arrangements of strata, have been discovered, and quite recently described in the conscientiously elaborate survey of the North-West Highlands of Scotland, which is still in progress.

Obviously the result of these corrugations has been to diminish greatly the breadth of the zone which they have affected. It is believed that the folding of the Ardennes may have reduced the area occupied by the strata when they lay flat by one half—from 50 or 60 miles to 25 or 30. The Appalachians are estimated as having been compressed from 153 to 65 miles, and the Alps themselves from about 202 to 130 miles.

It has, however, been urged that the diminution of the earth's radius, which these and other like contractions would require, is more than we are justified in assuming; and other solutions of the difficulty have been propounded, notably one recently advocated by Mr. Mellard Reade, who refers the elevation of mountain chains to expansion and contraction of portions of the earth's crust, due to variations of temperature, dependent on diverse causes, and he has demonstrated experimentally that, if the edges of a plate of metal be fastened down, and the temperature of the inner part be raised, flexures somewhat similar to those in mountain chains will be produced.

The controversy is one into which time does not permit me to enter, so I content myself with saying that, notwithstanding the difficulties involved—and difficulties there certainly are—the explanation first mentioned, that is the elevation of mountain chains by lateral pressure due to contraction of the portion of the globe below the more solid crust, appears to me the more simple and more in accordance with the results of observation. The idea that lateral pressure rather than vertical expansion has been the cause has been strongly confirmed by the experiments of Mr. H. M. Cadell. These experiments, of which a brief account has appeared in 'Nature,' * appear to me of the highest value; for he has actually succeeded in imitating some of the more remarkable complications existing in the Alps and in the Highlands of Scotland.

It is now time that we glance at the materials of the Alps, at the building-stones of which these mighty mountain walls are composed. Assuming the general order of succession exhibited in the sections before you to be correct, I must attempt to indicate briefly what physical facts bearing on the growth and development of this mountain region we can learn from a study of the rock masses.

We have first to deal with the foundation stones, as we may call them, though in many cases they tower above the strata of later date, which for long before the birth-throes of the present Alps reposed peacefully upon them as a solid and, seemingly, sure basement. They are crystalline rocks, generally very hard, the origin of which is often a matter of considerable doubt. Once, as we have said, buried deep below masses of sediment, they are now upreared high above the sea. Of these the grandest peaks—the central *massif* of Dauphiné, the pyramid of Monte Viso, the summits of the Pennine chain, the peaks of the attendant Graians, the crags that crown the central range of the Tyrol—are all composed.

Into this great crystalline series rocks of very diverse characters and mineral composition enter. Their origin and history is still a matter of dispute. . . . At present it is enough to say that no doubt a not unimportant portion of these rocks have solidified from a state of fusion, were once granites, dolerites, and the like, which however, owing to subsequent mechanical disturbances, have assumed the structure which we name foliation. There is also no doubt that a considerable number are of sedimentary origin, and that these, under the influence of agents not precisely known, but probably heat, water and pressure, have lost their original structure, have entered into new mineral combinations, so that they are now crystalline schists. There is another group of more uncertain origin. It is possible that they may be either igneous rocks which have undergone exceptional modification, or sedimentary rocks of which the like must be said. This only can be positively stated, that the modifications in them were not due to the forces which have upheaved the present Alpine chain, but that at a very remote epoch in their geological history they, like the group just named, had become what they are now, perfectly normal gneisses and schists. How far we can approximate to that epoch we shall see in a moment.

I have spoken of modifications produced by the action of mechanical forces. It is only of late years that we have realised how important these are as agents of change, or metamorphism, as it is often called.

* Vol. xxxvii. p. 488.

But its recognition, if I mistake not, has not been without drawbacks; for geologists are very prone to fall in love with a new idea at first sight, and are so captivated with the charms of Miss Hypothesis as to be forgetful of her weaknesses, and anxious to turn her straight off into Mrs. Theory. Such, I foresee, will be the case in regard to the new agent of change to which the pedantic name of dynamo-metamorphism has been affixed.

In regard then to these foundation stones, we confidently say that they are very old, that they exactly resemble rocks which in some cases are certainly older than the Cambrian group, and in no case can be proved newer than it; that they seem to exhibit a certain order of succession, those members which appear to lie lowest presenting a remarkable resemblance to rocks in America, Scotland, and other countries, which can be proved to be of enormous antiquity; that over these comes a series of gneisses and schists, of uncertain origin indeed, but often with much to suggest that they are metamorphosed sediments, and lastly a less coarsely crystalline series, clearly the newest of the three, commonly separated from the others (which where fully developed seem to pass insensibly one into the other), and which are beyond doubt mostly of sedimentary origin.

Now, when we come to examine these crystalline rocks, we find they have undergone structural modifications of great importance, long after they had assumed a crystalline condition and had become, whatever their origin, perfectly normal gneisses and schists; we can further see that subsequent to the assumption of the last-named character they were invaded by great masses of granite and other igneous rocks, and that these also have undergone structural modifications. Moreover, when we observe that these later and superinduced structures are directly related to the main trends of the existing ranges and folds, we are disposed to refer them, at any rate in part, to the set of earth movements which produced the present Alpine chain.

These structures are of great importance, because the distinction of them from those which were pre-existent is absolutely necessary for a right understanding of the history of the rocks. Pressure, acting on ordinary sediment, produces a fissile structure, which is called cleavage, and is distinctive of slates. This structure may be coincident with the original stratification of the rocks, but more commonly it is inclined to it, at a considerable, often at a very high, angle. The effects produced depend on a variety of causes, among these being the constitution and chemical composition of the rocks, besides, of course, the intensity of the pressure. Sometimes the lines of original stratification are rendered more conspicuous, sometimes they are curiously folded or distorted, sometimes even obliterated. Occasionally there is not only a mechanical, but also a chemical, change in the constituents of the rocks thus affected; unstable minerals enter into new combinations, and a rock of igneous origin may in certain cases set up to some extent a banded structure. It is, however, uncertain at present how far this process can be carried—in regard to it hypothesis extends far beyond the domain of proof, and some geologists are disposed to give very free play to the scientific imagination. In the case of sedimentary rocks, such as an ordinary clay, minute filmy minerals, such as mica, chlorite, &c., are produced, so that the rocks present some resemblance to a crystalline schist. This, however, is only superficial; so that, so far as I know, a practised observer has little difficulty in distinguishing one of these micaceous slates from a mica-schist.

In like way the gneisses and crystalline schists undergo modifications similar to those of the stratified rocks; the original mineral bands of the foliated rocks are intensified, contorted, ruptured, sometimes almost obliterated, as in the case of the slates; and here the nature of the rock seems especially favourable to chemical change, as a result of pressure; for new minerals appear to be produced more readily and on a somewhat larger scale than in most sediments, so that the foliation which follows on mechanical alteration in a crystalline rock is more conspicuous than in the former case. Still, as a rule, we can identify it even here; and this, which I propose to call cleavage-foliation, is distinguishable from that earlier foliation which, as it at any rate simulates stratification, I have called stratification-foliation. By these names I shall hereafter designate them.

Now, in most parts of the Alps we cannot (as I have said) attempt to give a date to the fundamental gneisses and schists, further than to say that they must be very old, and analogy suggests that they are older than the Cambrian. In the Eastern Alps, however, we come nearest to assigning an inferior limit to their possible age. On the northern face of the central chain is a band of the oldest rock which we can identify in the Alps. Commencing in the less elevated region south of Vienna, where the Noric Alps are shelving down towards the great plain of the Danube, this band can be traced practically without interruption to the neighbourhood of Innsbrück. Fossils are not common, but enough have been found to show that in the main it belongs to the Silurian period. From beneath this rise members of the series of crystalline schists. Now, although commonly these belong to the uppermost group of schists, and though just here and there an accidental similarity in colour, and to some extent in chemical composition, in the two, together with the effects of extreme pressure, constructive in the one, destructive—from its completely pulverising the constituents—in the other, occasionally cause local difficulties in drawing a line between them, yet, as a rule, the two series are perfectly distinct—the one is a cleaved sedimentary rock, the other a true schist. Hence the uppermost schists of the northern side of the Tyrol must be very much older than the Silurian rocks. But these schists are also represented south of the central range, and can be traced without a break to the watershed between the Inn and the Rhine. With little interruption we can follow schists substantially identical, so far as my personal knowledge goes, from the Glockner to the Viso, but I might say along the whole chain of the Alps. Hence it seems clear that the newest of our foundation series is much older than the Silurian period.

Many pages are now missing from the Alpine record: the next great group of which we have any representatives in the higher regions is the Carboniferous. Rocks of this era occur in parts of the Eastern, rarely in the Central, and rather more largely in the Western Alps.

The first I have barely seen, so I prefer to limit my remarks to the other two districts. The representatives of the Carboniferous era are commonly dark slaty rocks or quartzose grits; at the base occur not seldom coarse conglomerates or breccias; they sometimes contain fossils, usually plants. It is thus evident that these rocks in the main are of terrestrial or fresh-water origin. The coarser fragmental deposits suggest the action of streams flowing with considerable force, and thus the neighbourhood of an elevated land surface. The fragments themselves prove that, at any rate in Carboniferous ages, the crystalline rocks of the Alps were practically identical with those which rise up from beneath the later sedimentary deposits, and some of them indicate that even then a cleavage-foliation had been superimposed on a rock with a stratification-foliation.

Thus the Alps are not the modern upstarts which we sometimes consider them. They had ancestors at least respectable, though it must be admitted that the family went down in the world and for a long time was lost to sight.

The importance of these mountains of Carboniferous age will be brought into clearer relief as we continue the history of the region in the earlier stages of its submergence. There is, however, one point of interest to which I must draw attention, because it incidentally throws some light on the history of these ancient regions.

Near Le Freney in the valley of the Romanche troughs of Carboniferous rock are infolded in the old gneissic series. Now these troughs strike almost due N. and S., while the strike of the structures resulting from the Tertiary disturbances in this region is between N.N.E. and N.E., and the overlying Jurassic rocks are unconformable with them—indeed, may be said to pass sharply across their denuded edges—so that there must also have been important folding and denudation *after* the Carboniferous and *prior* to the Liassic age. Similar evidence is afforded by the sections about the valley of the Rhone between Martigny and St. Maurice, not to mention other districts.

We proceed now to the beginning of the great submergence, and here we must first examine the district of the Italian Tyrol. The cliffs which border the gorge of the Etsch or Adige between Klausen and Botzen, with their exquisite contrasts of red 'porphyry' and luxuriant vegetation, are becoming household words among travellers. The geology of this region has engaged for long the attention of German *savants*, among whom Baron Von Richthofen, so lately lost in the fulness of his powers, must never be forgotten. It has been explained to us in a lucid summary by our distinguished countryman, Professor Judd. These porphyries, and their associated but rather unfrequent tuffs, are the remnants of huge volcanos of (probably) Permian age. From them masses of lava, piled up in places to a thickness of 9,000 feet, but of comparatively moderate extent laterally, were ejected on either side of the present course of the Etsch, doubtless from more than one vent, and there is good reason to believe that other, though smaller, vents were opened at intervals westwards, at any rate to beyond the present Lake of Orta. We trace them eastwards to the neighbourhood of San Martino on the road to Primiero, where sedimentary rocks of Triassic age rest upon the crystalline schists.

Then began a long period of continuous and extensive subsidence. The craters of these volcanos were destroyed, their cones wasted. We find more or less completely overlying them a great series of beds, chiefly limestone or dolomite, which seem to have enveloped and entombed their lavas. They can be traced, as I will presently show, some distance to the west; they extend far away to the east. They continue practically undiminished in thickness until, north of the Pusterthal and the upper valley of the Drave, their foundation of schists and gneiss rises to form the central range of the Tyrol. Similar deposits of similar age compose the northern range from the neighbourhood of the Rhine about the Boden See far away to the east. Did this central range form an island in the Triassic sea, or were the sediments of that era once continuous across it? It is not easy to give a positive answer, but the comparative rarity of muddy deposits, and the almost complete absence of coarse sediment, make it probable that open water extended over the Eastern Alps, while the outliers which exist near the Brenner Pass suggest that the submergence was complete by the end of the Triassic period. But, inasmuch as the great Schlern dolomite, which belongs to the lower part of the Upper Trias (the Keuper of England), and beds equivalent to the Muschelkalk, and possibly to the Bunter, are often unrepresented in the central or northern range, it seems certain that the great highland district was at any rate not wholly submerged till late in the Trias, but that in the age of the Rhætic series, represented in England by rock only a few yards thick, but in the Eastern Alps by beds of limestone or dolomite, sometimes at least a couple of thousand feet thick, the older rocks had practically disappeared.

In the Central and Western Alps Triassic rocks are generally poorly developed and often entirely wanting, beds assigned to the Lias (as in Dauphiné) resting directly on the ancient crystalline rocks. Conglomerates or breccias sometimes occur at the base of them, but less extensively than we should have expected, so that the intermediate condition was probably a sea so studded with islands as to diminish the denuding force of the waves.

Now, inasmuch as the Trias and Rhætic are wholly wanting in parts of Central Switzerland and Dauphiné, and are represented by hardly less than 10,000 feet of rock in the Southern Tyrol, it is evident that either the level of the surface in the one region was some 10,000 feet higher than in the other at the beginning of the Trias, or else that if originally no great difference of level existed, the one region sank down far more rapidly than the other. The curious lenticular form of the Schlern dolomite, which is said to attain a maximum thickness of full 4,000 feet, and thins out in about twenty miles, seems to indicate the existence of a quiet land-locked basin in a region of slow submergence.

Some authors, indeed, have regarded the Schlern, the Langkofel, and other great peaks in this district as the remnants of *insular* coral reefs. This opinion, I think, is hardly tenable, but it is very possible that coral reefs and their detritus largely contributed to the formation of the above-named singular and now curiously picturesque masses of rock.

Thus were sealed up the volcanic vents of the preceding age, but not without a struggle. In more than one locality, submarine eruptions occurred, now represented by beds of volcanic ash, or by dykes and masses of basalt, dolerite, and even granite, which pierce into the cream-coloured dolomite. The chief centres of eruption were in the neighbourhood of Predazzo, where huge masses of igneous rock are found, showing that lavas of diverse mineral composition were successively discharged even at the same locality, and that very considerable volcanic cones must once have risen high above the coarsely crystalline rocks, which now form mountain masses about the glens of the Fassathal.

These eruptions, no doubt, occupied a long period of time, but they were certainly in full activity shortly before the close of the Trias, and do not, so far as I am aware, interrupt the continuity of the beds of the Rhætic series, while the Schlern dolomite is in many places pierced and rendered crystalline by their intrusion.

This, for a vast series of ages, so far as we can tell, was the last struggle. During the remainder of the Secondary period the earth's crust over the whole Alpine region appears to have been sinking slowly and generally uniformly downwards. Whether, on the site of some of the higher portions of the Alps, insular masses of craggy land still remained above water we have no means of knowing. But, on the whole, I am disposed to think that the submergence was complete and universal.

To this opinion I am inclined by the following considerations. Though there are now large tracts of crystalline rock without a trace of any Secondary deposits, which may well have formed islands, yet their relations with the latter rocks on their borders, and the fact that here and there they infold them as isolated masses, indicate that these beds formerly extended over a much wider area. We can, for instance, hardly doubt that the crystalline *massif* of Dauphiné, the peaks of which now rise full 13,000 feet above the sea, has been thrust completely through the dark slates, representative of the Lias. The latter are everywhere crumpled, contorted, bent back, around the edges of the protruded mass. Portions of them are uplifted high on its flanks—nay, one isolated patch still lingers 11,500 feet above the sea, to show the former wide extent of the newer rocks and the enormous flexures which they have undergone.

A glance also at the Western Alps, showing the Jurassic strata everywhere bordering the crystalline ridges, and occasionally infolded among them, as about Mont Blanc and in Dauphiné, not to mention other regions, suggests that they formerly extended unbroken across the existing ranges; nay, to the south-west of the Mont Blanc *massif*, the Secondary rocks are all but continuous from one side to the other, and the trough in the valley of Chamonix was doubtless once connected with the mass of secondary rock which forms the beautiful region south of the Lake of Geneva and sweeps across the Rhone to the

Bernese Oberland. This is demonstrated by the occurrence of some beds of this era, full 11,000 feet above the sea, still capping one of the pinnacles of the Aiguilles Rouges.

Again, another reason leading me to the same conclusion is the character of the beds themselves. Had the islands been of any importance, we should have expected that coarse fragmental materials would have been common in these Secondary rocks, and that the beds themselves would have exhibited much local variation. Now, conglomerates and breccias are much rarer than I should have anticipated. The crystalline rock in Dauphiné is overlain in places by black slate, as though nature had taken a besom and swept the whole land surface clean before she began to use it for a foundation; and in these Secondary deposits even sandstones are not common, slates, once fine mud, or limestones, being usual, and these maintain their character with little change over large areas.

The sediment, therefore, of which the Secondary rocks of the Alps are composed appears to me to have a distant and general rather than a local and variable origin, and to form part of an extensive series of continuous deposits. Indeed it is not easy to suggest a source for it. If for a moment we endeavour to picture the map of Europe in early Secondary ages, we see an ocean interrupted by many considerable islands. These for the most part consist of crystalline rock—granite, gneiss, schists, and the like—primeval masses which have overshadowed the morasses and lowlands of the Carboniferous epoch, which have been again modified by the folding and thrusting which closed that long period of subsidence and deposition. By these last movements, districts, fully comparable in extent with those of the Alps and the Caucasus, were profoundly modified, and in many regions the lately deposited masses of sandstone and carbonaceous mud were exposed to denudation. It is not impossible that the dark clays which in Western Europe often characterise the Jurassic series may owe their colour, at any rate in part, to the carbonaceous rocks of the Coal-measure age. At the beginning of the Secondary era there was a huge continental mass of land in the North-west of Europe, of which Brittany, Cornwall, portions of Ireland and the Scotch Highlands, and the Scandinavian peninsula are the more important relics; a tract of which the non-marine members of the British and German Trias are at once the grave and the monument—a tract which may have extended as far south as the Vosges and Schwarzwald, and northwards over many a mile of the Atlantic. The great 'Wald'—the wild forest region—of Baden and Bavaria, of Saxony and Bohemia, must have formed a part. The highlands of Auvergne and the Cevennes cannot have been much separated. Then, as we have said, there was sea over the district of the Eastern Alps. Northwards, westwards, and eastwards, that sea extended, till the mountain summits of the continental region were often reduced to steep and rugged islands. As Sardinia, Corsica, and the Balearic Isles now rise steeply from the Mediterranean, so rose the Vosges, the Schwarzwald, the Auvergne mountains, and other tracts of primeval land from the ancient ocean.

This great downward bend of the earth's crust seems to have affected a very large part of the present continent of Europe. The old continental districts were reduced in area, or converted into chains of islands. The islands were one by one submerged. During the Cretaceous age more than one tract (for example, the Saxon Switzerland) which had remained above water all the Jurassic age was submerged, and the pure white chalk of England and Northern France indicates that the sea in this area received but little detritus. This and the alternation of shale and limestone, common for instance in the English Jurassic, may be well explained by the struggle between land and sea. Where the rivers could bear their burden to within the reach of the ocean currents, the sea water for a long distance was charged with sediment, and shale or clay was deposited. Where a more rapid subsidence had converted the river-valleys into fjords and had fringed the land-masses by a protective chain of islands, the sediment was deposited (as now in Norway) in the inland glens, and the sea itself was clean.

Whence then came the sediment which forms so considerable a part of the Secondary series of the Alps, for the limestones themselves are ofter far from pure? To that question I cannot give a satisfactory answer. As I have said, the nature of the deposits indicates that we must look away from the Alpine area, and as there is no reason to infer the existence of any important land area to the south, we must, I suppose, look to the great northern continent which I have already mentioned. Still, if this be so, the ocean currents must have been of exceptional strength, for the débris in the Jurassic period must have been transported to unusual distances. But on this point we have not yet sufficient detailed information to enable us to do more than speculate. Careful tables of thicknesses of the deposits all along the Alpine area, and a study of their materials, may some day give us the power to speak more confidently.

There appear to have been fluctuations and even local upheavals during the Secondary era; for instance, the Cretaceous rocks are sometimes missing in Southern Dauphiné, Eocene succeeding to Jurassic, and there is a marked break in the Saltzkammergut between the Neocomean and the Cretaceous series, but subsidence continued generally over a large part of the district till near the end of the Eocene; for on the Diablerets and neighbouring peaks we can recognise strata, now elevated from ten to eleven thousand feet above the sea, which nearly correspond in age with the clays and sands of Bracklesham and of the New Forest, and with the nummulitic limestone from which Egyptian slaves constructed the pyramids. These local interruptions are indicated by pebble beds—though rarely—by the unconformity at the base of the Gosau beds (high up in the Cretaceous group) and by the Eocene lignite beds of Häring in the Northern Tyrol. Still subsidence was the rule. The most perplexing phenomenon is the occurrence of great blocks of granite in the Flysch (Late Eocene), as in the Habkeren Thal, north of the Lake of Thun. The locality to which these must be referred is unknown; they do not correspond with any Alpine rock, but they are so large that we can only explain their transport by floating masses of ice, such for instance as still bear the rocks of Arctic lands to latitudes quite as far to the south in the Atlantic.

By the end of the Eocene an era of change had commenced—change which has transformed the face of Europe—nay, of regions of far greater extent. Prior to this there were neither Alps, nor Pyrenees, nor Carpathians, neither Caucasus nor Himalaya—nay, I know not where to stop among the great mountain chains of Southern Asia. But restricting ourselves for the present to the Alps, we find the existing chain everywhere fringed with enormous masses of sandstone and puddingstone occasionally more than 7,000 feet thick, which to a very large extent were not deposited in the sea, but are the detritus and the spoil of mountain regions occupying in the main the position of the present Alps. The details of the Swiss Miocene, which are closely related to the physiography of the chain, must be reserved for the next lecture, so that I will now only say that all through the Miocene age the district between the Alps proper (the region of crystalline rocks, limestone, and slate) on the one side, and the Vosges and Schwarzwald on the other, was receiving detritus; the land sinking, especially parallel with the Alps, but the sea being on the whole driven back, until at last the newer material as well as the old began to be folded up, and the Miocene, like the Eocene, was closed by another period of mountain-making. The effects of this have been various. North of the Eastern Alps they have been comparatively slight, but they were considerable in the Western Alps, and at a maximum over the Swiss lowlands. There, as in the Rigi and the Speer, the deposits of the Miocene deltas have been uplifted some 6,000 feet above the sea, with which once they must have been nearly level, and for a very considerable distance the Eocene masses have been bent or thrust over their edges. The Alps, subject to minor modifications, were then left to the action of Nature's carving, to the heat and cold, rain and rivers, snowfall and glacier.

THE MUSTAGH PASS.

Its First Passage by a European Traveller.

The ordinary road from Cashmere to the Khanates of Central Asia, Kashgar and Yarkand, leads over the Karakoram Pass, 18,550 feet. It was this pass that was crossed by Sir Douglas Forsyth's mission, and on it Mr. Dalgleish was lately murdered. Some distance further W. in the same chain rises the great peak known as K 2, the second in height of mountains as yet measured, overlooking the ice-wilderness of the Baltoro Glacier, itself over thirty miles long,* and fed by numerous tributaries, each as large as the Mer de Glace. This greatest of glaciers in the temperate zone was visited and partially mapped many years ago by Colonel Godwin Austen, of the Indian Survey, who brought away many interesting sketches of its peaks, but failed to reach the passes

* The length of 61 miles, given in some geography books to the Central Asian glaciers, is got by unfair measurement and by disregarding watersheds, as if one measured the Aletsch Glacier from the Bell Alp to the lower end of the Grindelwald Glacier.