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ON THE CONNEXION OF

# GEOLOGY

WITH

## TERRESTRIAL MAGNETISM:

SHOWING

THE GENERAL POLARITY OF MATTER, THE MERIDIONAL STRUCTURE  
OF THE CRYSTALLINE ROCKS,

THEIR TRANSITIONS, MOVEMENTS AND DISLOCATIONS,

INCLUDING THE

SEDIMENTARY ROCKS, THE LAWS REGULATING THE DISTRIBUTION  
OF METALLIFEROUS DEPOSITS,

AND OTHER MAGNETIC PHENOMENA.

BY

EVAN HOPKINS, C.E., F.G.S.

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“Amid all the revolutions of the globe, the economy of Nature has been uniform, and her laws are the only things that have resisted the general movement. The rivers and the rocks, the seas and the continents, have been changed in all their parts; but the laws which direct those changes, and the rules to which they are subject, have remained invariably the same.”—*Playfair*.

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WITH TWENTY-FOUR PLATES.

LONDON:

RICHARD AND JOHN EDWARD TAYLOR,

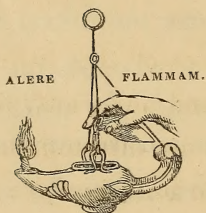
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1844.

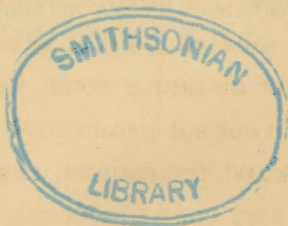


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## PREFACE.



THE principal object of this little work is to point out the general order and uniformity of rocks, and the mode in which minerals are disseminated and concentrated in them. There is no branch where there is so much capital expended without any established principle to guide us as mining—the opinion of a practical miner being often the only inducement to carry on a mine; and when two practical men differ, there is no data at present by which a third person can decide who is right. Both persons may be governed by the indications observed in their respective district, neither of which may be applicable to a mine in another locality.

With the view of obtaining some well-founded principle to guide us in our subterranean works, the Author, during several years' professional engagement in this pursuit, has paid very considerable attention to the subject, both in America and Europe: this brief sketch is the result of his investigations. The principle here brought

forward has not been assumed to account for a particular phenomenon, but has been *established by the facts*, and proved by several years' experience, so that its application will enable a person to predict the general nature of the crystalline rocks, metalliferous deposits, and dislocations of any mining district. With regard to the other points which the above principle leads to, there is no doubt they will be opposed by theoretical persons; however, this cannot interfere with the practical operations of the mining engineer; he may safely trust to the laws of terrestrial physics, and leave time to prove which has the best foundation. In conclusion, the Author hopes that his humble endeavours, combined with the local knowledge of practical men, will lead to new discoveries, avoid so much "*guess-work*" and unprofitable undertakings, and thus tend to render this branch of our national wealth more certain and prosperous than it has hitherto been.

February 1, 1844.

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AN  
OUTLINE OF GEOLOGY,  
SHOWING  
ITS CONNEXION WITH THE LAWS  
OF  
TERRESTRIAL MAGNETISM.

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INTRODUCTION.

ALTHOUGH geology has been brought, and now established as a distinct science, it must be admitted that the theories promulgated to account for the observed phenomena are in a most crude state—contrary to analogy, and not only unsupported by, but in direct opposition to, the evidence afforded by the phenomena themselves. We search in vain for any useful fundamental rules to guide us in subterraneous operations, even in a treatise professedly called *practical*, much less in those of a more theoretical character. Indeed the science may be considered at present as ‘Fossil Geology’ combined with Comparative Anatomy,—principally confined to the examination of the relics of the past entombed in the sedimentary rocks, which branch, being somewhat more enchanting, has monopolized nearly the whole attention and interest of this more generally useful science. If we refer to the descriptions of the *Primary* rocks, we find them so imperfect and so inapplicable to their general structure, and mixed so much with hypothetical ideas, that those who derive all their knowledge from books must imagine these rocks as confused igneous masses void of all order. Those who are practically acquainted with the subject have a very different opinion, and know that the crystalline rocks possess an harmonious symmetrical structure.

It is a very common remark in geological books, that great mistakes are committed in mining and other subterraneous works

owing to the want of a better acquaintance with the geological nature of rocks; yet no definite rules have ever been suggested to avoid the repetition of such errors. It has been triumphantly appealed to, as one important generalization among others established by geology for the aid of miners, that the proximity of pyrogenous and sedimentary rocks, and the changes thus superinduced upon the latter regulate the enrichment and productiveness of mineral veins. In this manner, it is said, that certainty and precision have been given to a knowledge which was before only vague and partial. It is not easy to comprehend the meaning, much less the application, of the above principle to mining, or any other works in rocks. There is scarcely a geological section furnished of the primary series in which the laminae of the crystalline slates are not confounded with the planes of the sedimentary strata; and also exhibiting veins with an overflow of melted matter, &c., showing volcanic effects, to explain phenomena with which they have no connexion. Every hornblendic vein is now called ancient lava; and igneous or volcanic rocks are terms of common occurrence. We shall endeavour to show that there is no foundation for assuming such an igneous element, and that the crystalline rocks and the veins are formed by polar forces according to geometrical laws, as uniform as any other physical phenomena of the material world.

This brief outline of the science is not brought forward with the view of showing the inconsistencies of the existing hypotheses to explain the facts, nor to gratify idle curiosity by entering into pure speculative questions, but to point out a general law, which is *simple* and *practically useful*, consistent with the general law of terrestrial physics, and which has been successfully applied for several years in mining and other geological operations.

Although the subject is confined here within narrow limits, and must necessarily be very imperfectly described, yet it is hoped that, by the aid of the accompanying illustrations, the general bearing of the *magnetical theory* will be comprehended, and found to rest on unquestionable data, without straining any facts, but simply following the legitimate consequences arising from cause and effect, proved by direct examination and experiment.



## CHAPTER I.

## ON THE POLARITY OF THE EARTH'S MAGNETISM.

PERSONS who have not paid attention to this interesting question, may consider this term as simply applied to magnetic needles, but we may observe that it is a property connected with *all* matter, and that it has an important influence on the general economy of nature. It is well known that if a magnetic bar be supported in such a manner as to have entire freedom of motion in a horizontal plane, it will, after a few oscillations, finally settle in a position directed more or less north and south. If disturbed from this situation and placed in any other direction, it will, as soon as it is again at liberty to move, resume its former position. The two ends are called its poles; the one which turns to the north being distinguished as the *north* and the other as the *south pole*; the tendency of the magnet to assume the above described position is called its polarity. On this property is founded the mariner's compass, which is of such essential use in navigation, and by the aid of which the mariner, however distant from land, amidst cloudy skies, or in the darkest nights, is enabled at all times to steer his course with certainty, and traverse in all directions the wide expanse of the ocean which separates the countries and continents of our globe. In exploring subterranean excavations, and, in a word, in all investigations which have reference to the meridian, its aid is equally available. When we reflect on the great benefit mankind has derived from the polarity of magnetism alone, and which has so much contributed to advance the civilization of the human race, it must necessarily create a desire to learn something of its general character.

It was considered for a long time that the only substance susceptible of magnetism was iron and its oxides, but recent discoveries have proved that there is no substance but which, under suitable circumstances, is capable of exhibiting unequivocal signs of the magnetic virtue, i. e. radial or lateral attraction, and the usual polar phenomena. The crystalline rocks, constituting the

solid surface of the globe, are more or less magnetic, and cause great variations in the direction of the magnetic needle; nor is the needle ever free from this combined influence.

It is well known, although not always taken into consideration, that the magnets were originally made out of a rock called a *loadstone*! a rock impregnated with iron in a state of oxide. All primary crystalline rocks containing iron and manganese will, with due delicacy, point north and south like the steel needles, *i. e.* in the exact direction in which they are found *in situ*, when fresh cut from the place where they were formed.

The above facts have been more or less proved by various experiments made in the equatorial regions.

Indeed, these effects have been more or less observed in every part of the world,—in the Straits of Magellan, along the whole range of the Andes, in Mexico, North America, the Arctic Regions, in Scotland, and in various parts of the continents of Europe and Asia. Not only is this influence of terrestrial magnetism observed in the solid substances which constitute the surface, but the atmosphere has been proved to be equally affected by it. This last phenomenon was observed by me on various occasions whilst making magnetical experiments in South America; and the same has been observed by various persons in Europe, and more especially when the aurora borealis makes its appearance; and, to make use of the happy term applied by Humboldt, there appears to be “magnetical storms,” probably arising from the equilibrium of the fluid being disturbed. They are very commonly observed before and during earthquakes in equatorial America.

The two hemispheres are represented in Plates IV. and V., on which will be observed the present average direction of the magnetic needles, according to Barlow’s ‘Magnetic Chart of Variations.’ It will be seen that, notwithstanding the numerous local disturbances which the needles must be subject to, they preserve a remarkable degree of uniformity from pole to pole; and when we reflect on the delicate nature of our instruments, and consider how slight an action will cause a deviation from the line of equilibrium, we should, *or ought to be*, astonished that their general direction is *so near* the true meridian, rather than it should *vary* a little from it.

It must be borne in mind that the magnetic meridians in the Plates only represent the present, and that these directions are perpetually varying to either side of the true meridian, within an arc of about  $15^\circ$  at the equator, and about  $60^\circ$  near the polar circle.

The direction of the magnetic needle in England about 250 years ago was  $11^\circ$  east of north, it is now about  $25^\circ$  west of north; it is constantly undergoing a slow oscillation.

The following Table shows the change which has taken place in London from the years 1576 to 1831\* :—

Years.	Variations.	Years.	Variations.
1576	11 15 0 Easterly.	1760	19 30 0 Westerly.
1580	11 17 0 "	1774	22 20 0 "
1622	6 12 0 "	1778	22 11 0 "
1634	4 5 0 "	1790	23 39 0 "
1657	No Variation.	1800	24 36 0 "
1662		1806	24 8 0 "
1666	0 34 0 Westerly.	1813	24 20 17 "
1670	2 6 0 "	1815	27 27 18 "
1672	2 30 0 "	1816	24 17 9 "
1700	9 40 0 "	1820	24 11 7 "
1720	13 0 0 "	1823	24 9 40 "
1740	16 10 0 "	1831	24 0 0 "

Besides the progressive changes in the direction of the needles, there are annual or periodical movements and daily oscillations constantly taking place in all parts where magnetic observations have been made. The dip of the needle, like the horizontal variation, has different values in different parts of the globe; on an average, being nothing or horizontal near the equator, and perpendicular to the horizon at the poles. Hence, if a magnetic needle were to be balanced at the equator, it would be found to decline from its horizon as we proceed from thence towards the poles; its average position forms a curve, called the 'Magnetic Curve,' from pole to pole, as shown in Plate IV.

On looking at the general direction of the magnetic curves and the magnetic meridians, we plainly observe that they tend

\* See Brewster's Treatise on Magnetism.

to converge at the poles ; notwithstanding their deflexions and undulations from various local disturbances, yet they preserve a remarkable degree of regularity. Numerous fruitless investigations have been made with the view of ascertaining the position of the magnetic pole, as if that must be a *mathematical point*.

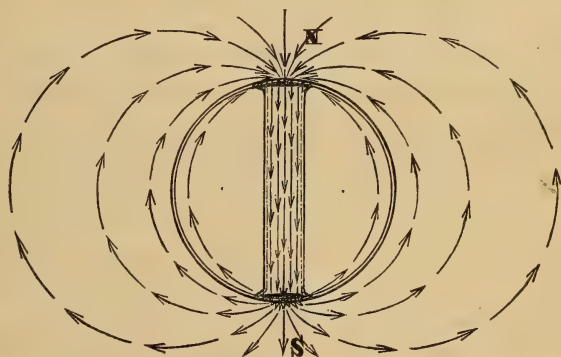
Any person who has had some experience with the action of fluids, whether water, air, or electric, converging towards or diverging from a central passage, must know that they cannot be forced into a *mathematical point*, there must be a limit to their compression or density ; nor can it be expected that every individual current should retain its exact radial course towards the focus, and much less when diverging from it. Hence, from analogy and observations, the narrowest limits that we can assign to the polar axis to which the magnetic currents converge and diverge are, perhaps, the areas bounded by the arctic and antarctic circles.

By taking these extensive spaces for the magnetic poles, we shall be relieved from entering into the useless and endless inquiries respecting late discoveries, and formulas which have been established or founded on them. The question is rendered simple, not requiring formulæ which profess great accuracy in points where the data of observation must be very uncertain. Although on an average the magnetic meridians, described in Plate IV., may be considered to approximate to the average direction at the present time, yet it must be kept in mind that a great proportion of the lines have been assumed ; however, they are sufficiently near for our present question.

Numerous observations have been made in the equatorial regions, indicating both east and west variations in the *same meridian* of only a few leagues in extent ; and numerous other experiments and observations may be quoted to prove that the direction of the needle does not necessarily point towards the centre of convergence of the individual current which moves it, but in the direction of the resultant, viz. the compound of the primary and local currents—the diagonal of the parallelogram of the two actions. The local disturbing force being a variable quantity subject to perpetual fluctuations, it follows as a consequence that the *variations* of the direction must be

uncertain, and therefore not within the power of any formulæ to know their periodical amount.

In the above, our observations have been principally confined to the magnetic needle; but as it is proved that all matter is more or less affected by the magnetic fluid or current, and since we cannot withhold our conviction, after tracing the curves which the needles form within, on, and above the earth, that the globe is a magnet, *i. e.* that its axis is magnetic; and according to the law of magnetism founded by direct experiment, the *North* end is the attractive and the *South* end is the repulsive, or in plainer language, that the magnetic fluid or currents move towards the north, enter into the axis, through which they pass, then issue out from the south pole and encircle the globe to complete their circuit (as indicated by the direction of the needles, and illustrated by the arrows in the following sketch);—we ought to be able to trace their effects on all substances within the limits of our observations.



If the earth be a magnet, as we have endeavoured to prove, it must produce the effects observed; if it be not a magnet, it possesses a property identical in its results to one; therefore all we require in our investigations is the knowledge of the law of these actions, as the *name* of the primary cause of the action cannot have a material influence on our researches. If we continue to call it *gravitation*, we must add to it a property which was not applied to it before, *viz.* polarity,—call it *magnetism*, and the term embraces all we require in astronomy as well as in geology.

Let us suppose a bar, having been made magnetic, to be placed

in the axis of an artificial globe, if iron filings be strewed carefully over it, the filings would become magnetic, and arrange themselves in curves like the magnetic needles on our globe, as shown in Plate I. The small magnetic ingredients do not converge to one mathematical point at each end of the bar, but to a space equal to the transverse section of the axis; and if this effect is produced by a current of subtle fluid, which may be conceived to emanate from one pole and to enter in at the other, penetrating the substance of the bar, and again to issue from its former outlet, as exhibited by the arrows in the above diagram, it is reasonable to suppose that the fluid will not be compressed more than the transverse size of the bar will require. Taking this simple principle of action as a guide, with its various consequences under different circumstances, we shall soon perceive that we not only account for the various phenomena of geology, but, in a word, *all* phenomena connected with terrestrial physics; and that we are enabled also to reason from the known to the unknown, and actually to predict facts before trial, not merely to satisfy curiosity, but questions of practical utility, especially in mining. Indeed, theories are not worthy of attention unless they can be fairly demonstrated and rendered practically useful.

The theory of gravitation was founded solely on the observed effects, and not from any knowledge of the cause; but this magnetical theory has been founded on both, and has the advantage of merging the whole into one simple system, which does not require any mysterious calculations to comprehend it, but only ordinary abilities with the exercise of common sense.

To proceed with our subject, let us consider a bar which has been rendered magnetic by the fluid entering into one end, and issuing out at the other, to be placed on a centre, or floating on water, we find that it will preserve its meridional position if left undisturbed; it is therefore manifest, that by some internal action the iron bar is rendered susceptible of allowing the fluid to pass through it *only in one direction, viz. from the south to the north end of the bar*. If we cut the magnetic bar into several pieces, what would be the result, supposing that by so doing we do not injure its magnetic susceptibility? Might we not reasonably expect the same phenomena in the separate parts

as when entire, viz. that the current would still preserve its definite direction through the separate pieces as when entire? Such is the fact; each portion of the fractured magnet is a magnet perfect in itself, *i. e.* each has a north and south end corresponding to their united position. Similar effects ensue from the subdivision of one of these fragments into any number, however great; and if reunited, by placing them together again in the same position, the result would be the same: that such would be the case is very evident, as the separation of the magnetic bar, provided it be effected without injuring its magnetic properties, only diminishes the length of the channels, not changing or altering the natural direction of the currents imparted to it originally.

A similar process of reasoning, derived from the same principle of action, will show that two similar poles must repel one another, and that two dissimilar poles must attract each other, owing to the tendency of the circulating currents to obtain a free passage.

The intensity of the action of the currents must be as their density; and if we assume that the whole of the circulating currents round the magnet, within a certain limit, are converged into the polar focus, their intensity must increase towards that point, inversely as the square of the distance; like any other fluid, air, water, or steam, which may converge to, or diverge from, a central passage. Consequently we can determine the resultants of the forces which may act upon a magnetic needle when its centre is situated in different directions relatively to the axis of another magnet; and what will be its movements, and what its final position of equilibrium. As the sketches exhibit the various effects, and as the correctness of the above is so easily proved by very simple experiments, we need not enter into any tedious details, but beg references to the Plates for ocular demonstration, which it is hoped will be found more clear and explanatory than any written description. Let us proceed to examine the effects of a magnet placed in a globe, as shown in Plate I.

In placing needles round this globe, we find them arranging themselves in the exact order which they keep on the terrestrial globe, both as to dip and direction; and as there is nothing to disturb them on the wooden globe, their positions in the curves

of convergence are uniform; their focus of convergence being equal to the transverse area of the magnetic axis at both ends.

We find in measuring the force along the magnetic curves, that it varies inversely as the distance; allowing for the influence of the earth's magnetism and tracing the effects in a horizontal plane, we obtain the following law, viz. *that the force varies inversely as the square of the distance from the surface of the ball in the equatorial plane, and also in the meridian from the poles towards the equator*; being the necessary consequences of the expansion and compression of the magnetic fluid surrounding it, as shown in the sketches. This is precisely the law of what is called gravitation, but the meridional variation towards the poles of the earth has been ascribed to the effect of a centrifugal force produced by the earth's rotation. The assumed centrifugal effect of the earth's rotation is also considered as the cause of the earth being an oblate spheroid. In the first place, a globe constituted and placed under similar conditions as our earth is, with its enveloping fluids, placed under the influence of centripetal and centrifugal forces *alone*, according to the well-known laws of physics, would not, nor could not produce the observed figure, much less the observed variation of attraction towards the poles. Its magnetism alone, without rotation, must necessarily compress the poles, and also cause the inverse law of intensity in the enveloping fluids.

In order to show further, that there is no necessity for a rotatory or a centrifugal force to cause, or at least to preserve an oblate spheroid in a similar body, let us take the moon for an example. She is an oblate spheroid, yet she does not rotate, i. e. *on an axis situated within her body*, because she always presents the same face towards the earth. Had the earth continued to present the same face towards the centre of its orbit, it could not rotate, yet we find a body similarly situated an oblate spheroid.

To return to our subject: we find that magnetism alone tends to form a sphere into an oblate figure, by the variable intensity of the currents on its surface, and that this effect is observed on our globe. If this be the primary agent by which all the substances of our globe are governed, we ought to be able to trace its effects according to the above principles of action, viz. circulating from south to north over the surface of our earth,



with a *force varying inversely as the square of the distance from the respective centres*. Commencing with the *atmosphere*.—If the globe be a magnet, we ought to observe at the poles some indications of the convergence of the air towards the poles, *i. e.* something similar to the inverted conical appearances which we observe in the ingredients at the poles of an artificial magnet, Plate I. It is true that the air is an invisible substance, yet, as it occasionally becomes saturated with visible fluids, it would, under such condition, with the advantage of reflected light, which may also be expected to vary according to the curves formed by the currents, show the phenomena of convergences. This fact we have in the aurora borealis and australis. These are the luminous appearances seen in the atmosphere connected with the poles of our earth, the general appearances of which correspond to the curves of convergence towards the poles. When these luminous phenomena display unusual brightness and activity, the magnetic needle is also found very fluctuating, both in dip and direction; and also the mercury in the barometer is subject to similar action; this coincidence of the variable movements indicates that they are produced by the same cause, *viz.* the disturbance of the equilibrium of the magnetic curves, or tension of the fluid.

The aurora is not the *cause* of the needle being disturbed, nor are its luminous rays required to produce a rise or fall of the mercury in the barometer; on the contrary, the whole phenomena appear to be the *effects* of the oscillating movements of the magnetic currents.

The mercury in the barometer, like the magnetic needle, fluctuates without being accompanied with a visible aurora. Probably the light is produced by a change in the constituent elements; but the light is not essential to prove the existence of the currents; nor is visibility necessary to produce undulations in such currents: such variations can only be ascertained by their effects.

That the barometer is subject to perpetual oscillation is a phenomenon so well known as not to require comment; but that the magnetic needle should be also subject to similar oscillations appears to those who have not paid attention to the subject somewhat ~~strange~~ However, the fact is, that the former is the effect

of the rise and fall, and the latter the horizontal movement of the same fluid; the former is governed by the curves of equal density, the latter by the meridional direction of the currents.

That there is a daily oscillation of the needle has been placed beyond a doubt by observations made with the most accurate instruments in almost every part of the world: the mean daily change amounts to about ten minutes. When the diurnal variation of the needle was first discovered, it was supposed to have only two changes in its movements during the day. About 7 A.M. its north end began to deviate to the west, and about 2 P.M. it reached its maximum westerly deviation. It then returned to the eastward to its first position, and remained stationary till it again resumed its westerly course in the following morning.

When magnetic observations became more accurate, it was found that the diurnal movement of the needle commences much earlier than 7 A.M.; but its motion is to the east. At half-past 7 A.M. in England it reaches its greatest easterly deviation, and then begins its movement to the west till 2 P.M. It then returns to the eastward till the evening, when it has again a slight westerly motion; and in the course of the night, or early in the morning, it reaches the point from which it set out twenty-four hours before\*.

Within the tropics the variations in the height of the mercury in the barometer are very uniform, subsiding about half an inch during the day, and rising again to its former height in the night. In the northern regions, such as Denmark, Iceland and Greenland, the diurnal variations are greater and less regular, in the height of the mercury as well as the direction and dip of the needle; but in advancing from the north to the equator the diurnal variations diminish. In the southern hemisphere the daily variation of the needle is in an opposite direction, the north end of the needle moving to the east at the same hours that it does to the west in the northern hemisphere.

To give an ocular illustration, we may conceive the magnetic current as a string from pole to pole: if the string be drawn from its meridional position at the equator, its relative direction or the angle formed between it and the meridian will be the same; but if we compare the direction on each side by look-

\* See Brewster's Treatise on Magnetism.

ing towards the north alone, we shall observe that the bend of the string will be—say north-west in the southern hemisphere and north-east in the northern. That such should be the natural consequences of such disturbances is too evident to require further explanation.

Besides these regular changes to which the needle and the mercury in the barometer are subject, they are often affected with sudden and extraordinary movements, to which Baron Humboldt has given the name of *magnetic hurricanes*, during which the needle often oscillates several degrees on each side of its mean position. The vibrating action of the needle during the appearance of the aurora is well known. It is also known that the luminous beams of the aurora are more or less parallel, or rather corresponding to the convergence of the dipping-needle; that the rainbow-like arches are seen on either side of the meridian; and that the beams perpendicular to the horizon are only those on the meridian. It has been found that on the days when the southern auroræ take place, the same phenomenon is observed also in the north: the one appears to be the cause of the other, and is therefore simultaneously produced, similar to the electric sparks seen at the poles of an artificial globe.

Although the aurora lights are generally accompanied with oscillations of the magnetic currents, it is not necessary that they should always be so affected, because the light may arise from a change in the density or property of the currents, and not from any changes in their directions. That there is magnetic matter in the atmosphere is indubitable, and that this matter is constantly acted upon by the currents cannot be doubted. However, it must not be expected that the variations are alike at all places, because the disturbances in the equilibrium of the magnetic currents are influenced by various causes of a local nature. Resembling the weather in this respect, these variations may differ at different places at the same instant of time.

The next point to be considered is the direction in which the magnetic currents move. If the currents, as we have previously stated, emanate from the south pole of the earth and enter into the north pole, we should expect somewhat different appearances in the south aurora compared with the north; because from the former they rise from an aqueous element, which must produce

a visible portion of vapour; and if so, the aurora will have the appearance of steam; whereas in the latter, as the currents descend from an aerial element, and are exposed to the effects of the sun, they must be drier. This difference has been observed by several navigators.

The southern aurora consists of long columns of clear white light, shooting up from the horizon, and gradually spreading over the whole sky. These columns are bent sideways at their upper extremities, and are in every respect similar to the northern lights, except in being always of a *whitish colour*, whereas the northern lights assume various tints, especially those of fiery and purple hue. The figure is identical—indeed exactly such as would be produced by the convergence, or *vice versá*, of the magnetic currents: and the difference in the colours is precisely what we should have been led to expect from the different nature of each pole. The saturated or hydrogenous nature of the currents coming from the south pole towards the north, will account for the observed peculiarity of the southern hemisphere in its general temperature, moisture, rains, the growth of vegetation, &c., as compared with that of the northern.

The great ocean of air which envelopes the planet we inhabit, and to which we are every instant beholden for supplying us with the elements of vitality, is governed by the magnetic currents. Whatever substances may be decomposed and converted into gases, and rise in the atmosphere, are again returned into the earth by means of the currents. Nothing can be destroyed; on the contrary, whatever substances we may consume, reduce, or decompose, become again, by means of the enveloping magnetic fluid, what they were before they existed, in the form of vegetable, stone or water, active agents in the business of the world, and main supports of vegetable and animal life, and are still susceptible of running again and again the same round, as circumstances may determine.

## CHAPTER II.

## THE IDENTITY OF MAGNETIC AND GALVANIC CURRENTS.

ALTHOUGH the sciences of magnetism, galvanism and electricity have been effectually blended, and proved by various experiments to be the effects of one primary cause, the direction of the magnetic currents compared with galvanic currents is considered different, *i. e.* that the magnetic currents move at right angles to those of galvanism. This idea has arisen from the effects of the *spiral* course in which the external current that envelopes the connecting wire of a battery moves towards the negative plate. For instance, if the connecting wire of a battery be placed in the meridian, having its negative plate attached to the north end and the positive plate to the south, the external current enveloping the wire will move northward towards the negative plate in a spiral form. On the upper side of the wire it moves towards the north-west, and on the under side towards the north-east; on the western side it moves downwards, and on the eastern side upwards. This spiral nature of the current produces motion in a circular direction round the wire, which is exhibited in various electro-magnetic machines. It is therefore very evident that the magnetic currents are not at right angles to those of galvanism. Supposing the intensity of the current causes the needle when held above the wire to deviate thirty degrees to the west, in placing it underneath the wire it will deviate thirty degrees to the east; taking the mean of the two, we find that the direction corresponds to that of the wire. That this is the fact is proved by making the experiment. It will therefore be observed, that the winding of a galvanic wire from east to west around an artificial globe, to illustrate the effect of the galvanic current on the magnetic needle, leads to very erroneous conclusions, by presenting the direction of one side of the spiral and not the under one.

The hypothesis of the magnetic currents being at right angles to the direction of the needles, must be admitted to have been

at best exceedingly strained and artificial, at variance with analogy of all other physical forces, and repugnant to our ideas of that simplicity which seems to pervade all the operations of the material world. All known forces, emanating from a certain point and exerted upon another point, act in the direction of the line joining these two points. Such is the effect of a stream of water on a substance exposed to its action, and on a vane by the wind, which always points in the direction of the current. The same law applies to electric and magnetic actions, in all the cases that belong exclusively to the one or to the other of these two classes of phenomena.

When two conducting wires, bent into helices, act upon one another, which they do in a manner that imitates very exactly the mutual action of two magnets, the action is called electrical, and is exerted in the lines of direction that join the acting points. The same is the case with two magnets in whatever position they may be placed. When the latter is exposed to the effects of the former, it indicates the spiral current above alluded to. All fluids, when forced through tubes by a great force, have a tendency to move in a spiral direction, as commonly observed in a funnel. However, if we take the mean of the direction of the spiral, we find that it corresponds to the direction of the wire; therefore we may safely consider that the magnetic needle, enveloped as it is in the great terrestrial magnetic fluid, indicates the direction of the currents.

We have now to prove that the currents move through the magnetic needle from south to north. In the battery we find that the currents of hydrogen move from the zinc to the silver plate, along or through the connecting wire. We find by experiments that the south pole of a magnet has a greater affinity for oxygen than the north pole. The difference in the oxidation of the south pole, compared with the north, is easily proved by various simple methods. All that is required is to place the ends of a magnet in water, and allow it to remain undisturbed for several days, and the fact is soon proved. A very powerful horse-shoe magnet will decompose water, and the oxidation will be observed to go on at the south pole, and the evolution of the hydrogen at the north pole: hence it is manifest that the currents move from the south pole to the north of the needle: the magnet

possesses the property of *filtering*, as it were, *the oxygen from the stream*, be that stream what it may, such is the effect and such the direction of the current.

Having so far shown that the magnetic and galvanic currents are identical, differing only in the degrees of intensity, the latter being somewhat confined to liquids, the former being equally active in the air, we shall proceed to trace the consequence of their action\*.

Before entering into the inquiry respecting the effects of the positive and negative poles of the great terrestrial battery on the surface of the earth, we shall first examine more in detail the action of Electro-magnetism, by experiments.

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### CHAPTER III.

#### ON THE REDUCTION OF METALS BY ELECTRO-MAGNETISM OR GALVANIC CURRENTS.

WHEN metals are observed in rocks or veins in their metallic state, which is of common occurrence in metalliferous districts, persons are too apt to think that such metals must have been produced by some intense heat, similar to that applied in smelting works. Such an idea arises more from the habit of our looking at metals as the production of our ordinary artificial process of reducing minerals, than to any cause that can be assigned for this being the only mode of their formation.

When we make a casting of any metal, even the most fusible, we find a great difficulty in getting it to take the exact impres-

\* Ritter asserted that a needle, composed of silver and zinc, had arranged itself in the magnetic meridian, *i. e.* the zinc towards the south and the silver towards the north, and was slightly attracted and repelled by the poles of the magnet: to effect this the air must be very moist. Generally speaking, such needles can only act when immersed in liquid. In the air the needle must be composed of such substances as will be capable of decomposing that element to indicate polarity. It is a singular fact that those rocks which contain manganese combined with iron ore are the most magnetic, and will preserve longer their polarity.

sion of the mould, owing to the great heat necessary to give the metal the required looseness and pliancy. The liquid metal has a considerable amount of cohesion, which tends to make it form into pretty large drops, like that observed in quicksilver; which drops cannot be separated into smaller, or reduced without great force. Consequently there may be openings or hollows in the mould into which the melted metal will not easily enter; and if these be very minute, it will be inadmissible. Besides, the substance which forms the mould must not only be capable of enduring a very high temperature, but sufficiently porous to allow the air to escape.

The native metals which are found in mineral deposits are often enclosed in quartz; but on whatever substances they may be, they present the exact impression, even the most minute cracks of the mould. Nor are the substances on which such metals are found always confined to those that resist intense heat; on the contrary, native copper and silver have been found deposited on timber, and decayed leaves in old mines. It is therefore very evident that the ordinary process by fusion is not capable of fulfilling the above conditions of the metals in the mines: but it is identical with those formed in the humid way by electro-magnetic action.

In speaking of metals, we should not forget that a great number of them are found not as solids, but in solution in the rocks. Indeed there is no rock *in situ* but is found more or less saturated with mineral waters.

*Iron* is abundant almost in all mineral waters.

*Copper* is found in solution in all the copper mines in Europe and America, and a large proportion of copper is obtained by the introduction of iron to precipitate the metal from its solvent.

Other metals are capable of being in solution as well as in their solid state.

*Platinum* remains in solution with one part of nitric to two of muriatic acid.

*Gold* is soluble in nitro-muriatic acid.

*Silver* is soluble in nitric acid.

*Nickel* dissolves in nitric acid.

*Zinc, Lead*, and in a word, all metals, are susceptible of remain-



ing in a soluble as well as a solid state ; therefore we should not consider that the metals must necessarily be solid in their original state. Indeed there is some difficulty in preserving some metals, especially iron and zinc, in their metallic state, in consequence of their great affinity for oxygen ; and those metals only which possess but little affinity for this element, such as platinum, gold, silver and copper, are found formed and preserved in rocks in their metallic state.

When we subject any metallic solution to the action of the magnetic current, the metal will be reduced, in different states, according to the strength of the solution and the intensity of the current.

In order to ascertain experimentally what are the circumstances which tend to produce these conditions, we have only to procure a galvanic battery and connect it with two platinum poles, which we place in a vessel to serve as the precipitating trough\*. In this trough we place a saturated solution of a metallic salt—for instance, copper—when on examination, if the battery possess but feeble power, we shall find that crystalline copper will be deposited ; if, however, we dilute this solution with twice, thrice, or four times its bulk of water, the metallic deposit will assume a very different aspect : it will then be aggregated in a flexible state, or a reguline deposit. If we now dilute this same solution to an infinitely greater extent, the metal will still be reduced, but in the form of a very fine black powder.

Almost all metallic solutions may be substituted for that of the sulphate of copper, and the experiment will show nearly the same result, namely, that the strength of the metallic solution influences the nature of the deposit.

If we examine the converse of the experiment, and take a solution of sulphate of copper, and use successively, first, one very small battery, then two or three batteries arranged in a series, and lastly, a very intense battery, we shall find that with this self-same solution we can obtain by these means, first, a crystalline, then a reguline, and subsequently a black deposit.

The above variable state in which minerals are deposited by

\* See Smee's excellent work on this subject, Second Edition, p. 113.

the battery is of very common occurrence in mineral veins ; and even the same vein presents large and small crystals, and often of variable composition, within a very small compass.

The application of the agency of fire to form such depositions, is not only a rude and clumsy hypothesis, but totally inconsistent with analogy, and contrary to facts : whereas a magnetic or galvanic current passing through solutions, if not the actual *modus operandi* of nature, is at all events capable of giving a rational solution, not merely of the mineral veins, but also of all the operations of nature disclosed by geology.

In order to understand how the metals are reduced from their solutions by the agency of a galvanic current, let us take a battery, and endeavour to discover the cause of the actions there going on.

In placing a plate of zinc in water, and allowing it to be immersed in it for a long period, it becomes coated with an oxide ; but if the water be diluted with sulphuric acid, the oxide will be dissolved, and the zinc will continue to present a clean surface to the oxygen of the water, until it is entirely dissolved, provided there be a sufficient supply of that element present.

The above chemical action is however comparatively feeble. This feebleness of action appears to arise from the want of another power to take away the hydrogen evolved during the decomposition of the water by the zinc. If we place another metal having a less affinity for oxygen than the zinc in the same vessel, and connect the two by a copper wire, the action is considerably increased, and the hydrogen evolved from the decomposition of the water is apparently conveyed from the zinc by means of the connecting wire, and finally escapes from the surface of the plate which forms the negative. And it has been experimentally proved that the greater the facilities by which the hydrogen is made to evolve from the negative plate, the greater is the action on the zinc or positive plate.

The positive plate may be considered as the fuel of the battery, and the connecting wire, with its negative plate, the flue and chimney of the battery. If we increase the draft of the chimney for the escape of the decomposed air, the greater is the supply of oxygen to the fuel ; if we break the connexion be-

tween the fire and chimney by shutting the flue, we check the combustion ; and such is the nature of the battery.

In order to increase the intensity of the battery Mr. Smee has introduced platinized silver, which possesses the singular properties of evolving, or rather liberating the hydrogen with great facility ; hence the draft is thus increased, and consequently the combustion of the zinc accelerated. 33195

Whatever may be the real origin of the current, it is very evident that its direction is from the positive to the negative plate, and that it is the positive plate alone which produces the action and causes the decomposition.

It is not necessary to enlarge on this subject here, as the reader may refer to Smee's admirable treatise on this interesting part of our inquiry. We shall only remark, that the metals in solution are reduced into their metallic state in the decomposing trough of the battery on the negative plate, *i. e.* the plate which evolves the hydrogen, and apparently contrary to the direction of the current.

But when we examine more minutely into the immediate cause of the reduction of the metal on the negative plate, we find that it is not produced directly by the current, but is the result of a secondary action ; thus a solution of copper being subjected to a voltaic current, the hydrogen in oozing out of the negative plate seizes upon the oxygen of the oxide of copper, and forms water, whilst the metallic copper is thrown down on the plate ; and as long as the strength of the metallic solution is kept up and remains in contact with the plate, the hydrogen issuing out will continue to liberate the metal from the oxygen, and the reduced mineral will present the appearance of a lateral growth from the plate.

Whilst the above action is going on, on the negative plate, a contrary effect is taking place on the positive. If the positive plate of the decomposing trough be copper, as is always the case in reducing copper solutions, the acidulated water in contact becomes decomposed by the oxygen uniting to the copper, the quantity of copper reduced at this plate being about equal to that forming on the opposite plate, and thus the strength of the solution is kept up.

Hence we observe that there is no real contrary current to

wards the negative plate; the effect being due to one constant direction in which the hydrogen moves, uniting with the oxygen at one pole, and becoming liberated from it at the other.

We have already observed that the nature of the reduced metal depends on the intensity of the current and the strength of the solution. If the current be very intense, causing the evolution of the hydrogen from the negative plate, it forms a fine black powder; if none evolves, the metal is generally thrown down in its crystalline state.

Mr. Smee observes, "that the quantity of electricity passing in a solution of copper curiously influences the state of the crystals, for there are two varieties of this deposit; one of which arises from a deficiency of quantity, relation to the strength of the solution, and in this state the new plate of metal is like an aggregation of sand, in fact like common sandstone, the particles having no more cohesion or consistence. In this state the plate of metal is in the utmost state of brittleness, and this, we must recollect, is produced by too small a quantity of electricity in a strong metallic solution. The second variety of the crystalline state of metals arises from a large quantity of electricity in relation to the size of the plate; thus, by using a very large positive pole, connected with a battery of feeble intensity, and by employing at the same time a strong solution, large crystals, possessing the utmost degree of hardness, will be thrown down."

Comparing these facts with those observed in metalliferous deposits, we find a very striking coincidence; and when we apply similar laws and orders of deposition to mineral veins, the problem of their formation is easily solved without having recourse to the igneous theory\*.

\* Mr. Fox has obtained an electro-type copper plate by the agency of these subterranean currents. He found their natural direction to be from south to north in Pennance mine. After a few days crystals were formed in the negative plate, but two months had nearly elapsed before the apparatus was removed from the circuit.

## CHAPTER IV.

## ON HEAT PRODUCED BY THE MAGNETIC OR GALVANIC FLUID.

THE next phenomenon which a battery displays is the power of heating substances according to the amount of current which is actually passing, and the resistance which they afford to its passage; and in this way the most infusible metals, as platinum, palladium, gold, copper, iron and steel, may be instantly melted.

Conducting liquids may be heated in a similar manner. This fact may be seen in a great variety of ways: dilute sulphuric acid may be made to boil in a siphon connecting two vessels, in which the poles of an extensive series of batteries are placed. Another mode of showing the same fact is to take a piece of string and moisten it with acid, connecting the extremities with the poles of a series of galvanic batteries, when it will begin to smoke, and become charred from the heat produced.

The next property which a battery displays is its power of igniting metallic or charcoal points when joined to the two ends of the battery, and held so that they barely touch; a light is then exhibited equal in brilliancy to that of a little sun. The spark seems to depend principally upon a combustion of fine particles of metal, and, when charcoal or hard gas coke is used, upon little points of it flying from one pole to the other; so that one pole wastes away and the other increases, till the flame becomes quite encased in a mass of carbonaceous matter. This flame is singularly repelled or attracted by a magnet held in its vicinity. Heat is, indeed, one of the effects of chemical action; and though we might by a fallacious reasoning be led to assert that chemical action is the effect of heat, a very slight examination will show the absolute futility of such reasoning. In fact, we have no heat of which the cause is known, but that which is derived from, and proportionate to, chemical action.

When we observe a body of water, we may with propriety state that it was derived from the ocean; but we could not be justified in attributing a similar origin to fire, or in stating that

substances, when issuing out of the rocks in a melted state, must be the produce of an incandescent nucleus. We have only three primary divisions, viz. solid, fluid and gaseous : we have no independent igneous elements ; the latter division is merely the effect of decomposition. Yet although this fact is so well known, the igneous theory is still pertinaciously adhered to.

The word heat generally implies the sensation which we experience on approaching a fire ; but in the sense it bears in physics, it denotes the cause, whatever it be, of that sensation, and of all the other phenomena which arise on the application of fire, or of any other heating media. We should be greatly deceived if we referred only to sensation as an indication of the presence of this cause. Many of those things which excite in our organs, and especially those of taste, a sensation of heat, owe this property to chemical stimulants, and not at all to their actual heat.

There are a number of chemical agents which, from their corroding, blackening, and dissolving or drying up the parts of some descriptions of bodies, and producing on them effects not generally unlike those produced by heat, are said, in loose and vulgar language, to burn them ; and this error has even become rooted into a prejudice, by the fact that some of these agents are capable of becoming actually and truly hot during their action on moist substances, by reason of their combination with the water which the latter contain.

Fire, or the combustion of inflammable bodies, is nothing more than a violent chemical action attending the combination of their ingredients with the oxygen of the air.

One of the arguments brought forward in support of the igneous theory, or central heat, is that it is found, by experiments in mines, that the heat increases with the depth, and that hot springs and mineral waters are found in all countries. Had this increased temperature proceeded from the radiation of an incandescent nucleus, we should have a more uniform variation as we descend. In South America, where a great number of experiments were made, the variations in the degrees of heat were not only very irregular and confined to particular patches in the rocks as we descended, but also in some instances the temperature was *found many degrees lower at a greater depth than near*

*to the surface.* This is easily accounted for by the variable nature of the chemical actions which are going on in the rocks. Parts of the rocks in deep mines, which are found intensely hot at one time, are at another time found at a very low temperature; and such is the nature of the heat observed in all mines.

That the intensity of action should be greater in depth generally than near the surface, is a reasonable supposition; but we have no proof of any intense decomposition or igneous effects taking place at those depths without the oxygen of the air or water being connected with such points. And if so, the decomposition of either element would be sufficient to account for any intense action taking place without having recourse to the hypothesis of central heat. All that we require to account for the observed geological phenomena is a current circulating within the crust of the globe, acting chemically and mechanically on those elements which form the external part.

It is the opinion of some very profound geologists, that the globe was originally in a state of igneous fusion, and that as this heated mass began gradually to cool, an exterior crust was formed, first very thin, and afterwards gradually increasing, until it attained its present thickness, which they calculate as amounting to sixty miles. During this process of gradual refrigeration, some portions of the crust cooled more rapidly than others, and the pressure on the interior igneous mass being unequal, the heated matter, or lava, burst through the thinner parts and caused high peaked mountains. The same cause they allege produces volcanoes.

According to this theory, we live upon a thin crust enclosing matter in a state of intense heat, which in particular districts agitates the earth in its pressure to escape, thus causing earthquakes, or occasionally bursting forth and producing volcanoes.

The arguments adduced for such a doctrine are the following:

*First.* That the form of the earth is just that which an *igneous liquid* mass would assume, if thrown into an orbit with a motion similar to that of the earth; as if an *aqueous liquid* under similar circumstances could not produce the same kind of figure.

*Second.* That it is found that heat increases with the depth in mines; thus inferring that there must be fire to produce heat; whereas it is proved by experiments that chemical action is the immediate cause of heat.

*Third.* They likewise argue, that the peculiar appearance of *lavas* all over the world indicates that they proceed from a common source. These indications are merely that of a rock *altered by a solvent*, and that solvent, be it igneous or aqueous, is governed by the laws of chemical action, and therefore no argument in support of central heat.

Finally, they contend that on no other hypothesis can we account for the change of climate indicated by the fossils. In another chapter we shall endeavour to show an ample cause for the latter.

Not only is the above doctrine of central heat unsupported by the arguments brought forward in its favour, but the consequence of such an igneous nucleus according to the laws which regulate the circulation of heat through fluid bodies, would be, that the crust of the earth, instead of increasing in thickness, would be *altogether melted*, even were it two hundred miles, much less sixty. (See Plate XX.) A cold crust and an incandescent nucleus are incompatible, and contrary to the known laws of terrestrial physics; yet it has been attempted to show by experiment and mathematical calculations that these are *necessary truths* in a body circumstanced as the earth really is.

It is without doubt one of the most dangerous errors in every science to attempt to allow mathematical refinement to usurp the place of careful experiment; and it would not be difficult to point out many instances of the injury which physical inquiry has sustained from the too-prevalent reliance upon the supposed power of mathematical investigations to alleviate the toil of inductive research; thus too often substituting the laws of geometry for those of physics, and leading the mind completely astray from the legitimate effects of the latter.

To make the hypothesis of an incandescent nucleus appear somewhat consistent, the following experiment is suggested:—  
 “If one end of a bar of metal, a few feet long, be plunged in the fire, while the other end is wrapped in a wet cloth, the one end may be ignited to any desired degree, while the other can be kept at any required temperature above a certain point, depending on the heating and cooling powers applied to the ends of the bar, its length, and the conducting and radiating powers of the metal. Instead of the metal bar, submit to the same heat a bar of stone or a rod of glass; in these cases, unless the bar be very



short, no cooling power at all is needed further than that of conduction and radiation from the surface of the bar, because of the extreme feebleness with which heat passes through its interior parts. What is the difficulty of applying this reasoning to the stony crust of the earth?" It is simply this, that heat is kept up by combustion, and that must be supplied with oxygen. Consequently that part exposed to the fire must necessarily consume and would finally decompose. Therefore a crust floating on an incandescent element under similar circumstances, as above described, could not increase, but would necessarily dissolve. The above bar should be placed on the fire *sideways*, to represent the assumed condition of the crust.

Such a doctrine deserves no serious attention, when we find that the observed phenomena are consistent with those produced by chemical actions. If we admit the existence of subterranean currents, and that these exert a slow decomposing power, like that of the voltaic battery, we have a sufficient power for our purpose. In the first place, we have a mechanical tension on the consolidated parts of the rocks, by the linear action of the currents passing through them; and should the intensity of the currents be very great, fractures would ensue, more or less at right angles to the direction of the force. These fractures would admit air and water, and thus produce intense heat, by the avidity with which the metallic nature of the bases of the earths and alkalis combines with the oxygen.

That nearly all the substances which constitute the crust of the globe are found *in solution* as well as solid, saturated throughout the rocks, and to such a degree sometimes as to issue out and form springs, is well known; therefore, judging from the violent effects on a small scale which we are able to produce by experiments, a heat would be engendered quite adequate to occasion all that takes place in volcanic eruptions. It is a fact, that nearly all active volcanic groups are within a short distance of the sea; and even those that are situated at a distance from it may be connected with subterraneous channels of water. It is also a well-known fact in South America that fish are commonly thrown out of the crater, and some of the eruptions consist entirely of mud or muddy water, thus giving a still greater proof of their origin. The sudden fracture, as well as the sudden expansion of the gases, would produce a vibratory jar, which,

being propagated in undulations through the rocks or external crust, would give rise to superficial oscillations, and thus cause earthquakes.

We shall note here a singular fact connected with the earthquakes of South America, viz. during nine years' observations made by the writer; the oscillations were from *east to west*, whilst the directions of their disturbances, and the rumbling noise which generally accompanies them, were from *south to north*. The former were generally confined to comparatively narrow limits, whilst the latter extended often from Chili to central America.

This meridional action of the subterranean currents from south to north is not confined to South America, but extends to the northern hemisphere. And it appears from numerous observations made on the magnetic currents, that the power which governs earthquakes and magnetic currents is the same. The mean direction of the latter in South America corresponds to the average direction of the subterranean disturbances.

## CHAPTER V.

TERRESTRIAL MAGNETISM, OR THE EFFECTS OF THE POSITIVE AND NEGATIVE POLES OF THE GLOBE ON ALL SUBSTANCES WITHIN THE LIMITS OF THEIR ACTIONS.

FROM a consideration of the general facts that have been stated with respect to the effects of the galvanic current and its identity with magnetism, it will be sufficiently evident that the earth acts upon magnetized bodies in the same way as if it were itself a magnetic battery; or rather, as if it contained within itself a powerful magnet or battery lying in a position coinciding with its axis of rotation.

In order to make the above to agree with the facts as indicated by the needle and other bodies possessing the property of polarity, we must assume that the north pole of the earth is the positive one, as the currents are moving towards it, therefore the pole of decomposition, and the south the negative pole, *i. e.* the pole of recomposition. Provided these poles be connected

by a conducting fluid an action would ensue ; and in consequence of the oxidation going on at the north pole there would be a tendency in the conducting element to move towards it.

The ocean may be considered as the conducting element, its composition being peculiarly applicable for the purpose. The most general component parts of the sea, in addition to pure water, are muriatic acid, sulphuric acid, fixed mineral alkali, magnesia, sulphate of lime, and various other substances. We also know that the ocean reaches from pole to pole.

On reference to the observations made on the general currents of the ocean, we find the following :—

The principal currents of the Pacific, Atlantic and Indian oceans proceed from the south pole in a north-westerly direction towards the north. These currents are subject to numerous modifications, in consequence of the obstacles presented by the land to its free passage. The eastern coast of South America, and the western coast of Africa form the boundary to the Atlantic ocean, and the general movement of the ocean between the above is in a north-west direction, until it enters amongst the West India Islands and the Gulf of Mexico ; from which point it turns towards the north and north-east near Newfoundland. In the Pacific ocean there is a similar northward current.

Another interesting question connected with these general northward currents is the fact, that within the Polar region the fruit of trees which belong to the American torrid zone is every year deposited on the western coasts of Ireland and Norway ; and on the shores of the Hebrides are collected seeds of several plants the growth of Jamaica, Cuba, and the neighbouring continent. The most striking circumstance, perhaps, is that of the wreck of an English vessel, burnt near Jamaica, having been found on the coast of Scotland. From the account of Captain Parry, it appears that there is also a great quantity of timber cast by the sea upon the northern coast of Spitzbergen. Timber is found floating in large quantities in the north polar seas, and much of which is thrown ashore on the northern side of Iceland ; some of which appears to be of the growth of Mexico and Brazil. This question has engaged a good deal of attention, and has been considered difficult to explain ; but by admitting the general northward tendency of the ocean the question is easily solved.

Ice is fallen in with much sooner in sailing towards the south than it is in approaching the north pole. The dry lands or the large continents are more or less pointed towards the south, whereas the northern parts are more or less ragged and crowded about the northern pole; in a word, all observed facts tend to prove that the ocean moves from the south pole towards the north. (Plate V.)

If, then, such an action is actually going on in the great terrestrial battery, its effects will not be confined to that of the ocean, but will also produce corresponding effects on the solid and semi-fluid part of the earth. Such an effect is apparent in the meridional lamination of the crystalline rocks, as shown in Plates IV. and V.

In South America we find the whole region laminated in a north and south direction, subject of course to great contortions from various local disturbances. This lamination forms those kind of rocks known by the name of gneiss and schistose, being in fact a modification of the granitic base, produced by the polar laminating action, and not, as it is erroneously considered, the result of a mechanical sedimentary action. The planes of these meridional laminations are generally more or less vertical, and are often seen cutting through sedimentary beds at right angles to the seams of deposition, and thus showing their independent and subsequent origin. Nor is this meridional structure confined to South America, but extends to the north, subject of course to great bends from numerous mechanical resistances.

It may be considered strange that such an universal structure has escaped attention, and that it has not ere this been discovered. The isolated facts have been long known, but not properly used, and the laminated structure has been, and continues to be, confounded with those planes resulting from mechanical deposition. As we have already noted, the granitic gneiss and the schistose, which are commonly represented in geological sections as sedimentary beds resting on one another, are the result of a crystalline action modifying the granitic mass in the direction of the lamination, which structure is generally formed in a more or less vertical position as commonly seen when not disturbed.

“Since the year 1792,” says Humboldt in his treatise on Rocks,

“I have been attentive to the parallelism of beds. Residing on mountains of stratified rocks, where this phenomenon is constant, examining the direction and dip of primitive and transition beds, from the coast of Genoa across the chain of the Bochetta, the plains of Lombardy, the Alps of St. Gothard, the table-land of Suabia, the mountains of Baireuth, and the plains of Northern Germany, I have been struck, if not with the constancy, at least with the extreme frequency of the directions from south-west to north-east. This inquiry, which I thought would lead naturalists to the discovery of a great law of nature, at that time interested me so much, that it became one of the principal reasons for my voyage to the equator. When I arrived on the coast of Venezuela and passed over the lofty littoral chain and the mountains of granite-gneiss that stretch from the Lower Oronoco to the basin of the Rio Negro and the Amazon, I recognized again the most surprising parallelism in the direction of the beds; that direction was still north-east.”

Unfortunately, in consequence of Werner's theory, Humboldt wrote the above under the impression that the gneiss and schistose rocks were similar to sedimentary beds; hence he confounds the lamination of the former with the divisional planes of the latter.

“When we examine,” says M. Boué, “with a compass the position of mineral masses in Scotland, and endeavour to stop at general facts, we perceive that the direction of the beds is *constant*, and corresponds with that of the chains from south-west to north-east, but that the dip varies according to local circumstances.”

According to Von Buch and other continental geologists, the directions of the lamination of the crystalline rocks in Sweden and Finland are from south to north, varying occasionally towards the east. In Mexico the laminated structure is principally towards the north-west; but in the plains it is frequently found due north and north-east. In the United States its general direction is similar to that of South America, *i. e.* from south to north, but presenting numerous contortions, and thus causing local variations in the direction, either towards the east or west, according to the nature of the local resistance.

“The direction of primitive and transition beds” (gneiss and

schist), says Humboldt, "is not a trifling phenomenon of locality, but, on the contrary, a phenomenon independent of the direction of secondary chains, their branchings, and the sinuosity of their valleys; a phenomenon of which the cause has acted, at immense distances, in a uniform manner, for instance in the ancient continent, between the  $43^{\circ}$  and  $57^{\circ}$  of latitude, from Scotland as far as the confines of Asia."

Hence it will be observed that the universality of this structure has not escaped attention.

Dr. M'Culloch, in his description of the Western Islands of Scotland, remarks on the striking uniformity of the beds of gneiss and schist being more or less in a north-east direction. In cutting any of these beds, as they are called, in an east and west direction, *i. e.* from the eastern to the western coast of Scotland, the lamina would be intersected transversely, and on examination the planes would be found more or less vertical, sometimes leaning to the east and sometimes to the west: any east and west section of considerable length would be found the same. It must be understood, however, that the above remark is confined to the average, because numerous bends and contortions of very considerable extent are frequent in this fundamental structure, and are susceptible of constant changes from the effects of chemical action going on in it.

On the eastern coast, between Waterford and Dublin, the more ancient lamination presents a mean average direction towards the north-east, but is also intersected at various points by a comparatively recent lamination in a north-west direction. It is at these intersections of the old and new lamina that the metalliferous deposits of Ireland are principally found. In the Barony of Bantry the old laminated structure is much contorted and dislocated.

In North Wales and the northern part of England similar oblique intersections of the old and new lamina are observed. The most recent lamination of Cornwall is nearly in the direction of the magnetic needle, and corresponding to that of Wicklow.

The above observations are not founded merely on a superficial survey of these districts, but on a laborious investigation under ground, as well as on the surface. Indeed, without studying

the structure of rocks *beneath the surface*, where chemical actions are observed in operation, and various crystals constantly forming, it is not possible to arrive at anything like a correct knowledge of the law which governs the superficies of our globe.

In Auvergne the laminae of the gneiss and schist run nearly in a direction from south to north, and dip to the west, that is, when viewed on a great scale, for when examined more partially the ordinary exceptions occur. In short, the continent of Europe exhibits this uniformity of structure throughout.

In the United States of America we find the same meridional structure. In Virginia the gneiss, talcose and chlorite slates run north and south, leaning from the perpendicular towards the west. The Boston railway exhibits, by its numerous cuttings in an east and west direction, the general verticality and meridional structure of the schistose rocks for several miles in length.

Along the north coast of South America, in the Carribean Sea and the West India Islands, the same structure prevails; and was minutely examined by the author, from east to west across the three great branches of the Cordilleras, between the latitudes of 4 and 6 degrees north.

In an admirable essay published on this subject by Professor Sedgwick, we find the following observations:—

“In that variety of slate which is used for roofing, the structure of the rock has been so modified that the traces of its original deposition are quite obliterated; and this remark does not apply merely to single quarries, but sometimes to whole mountains . . . . In the Welsh slate-rocks we see the cleavage planes preserving an almost geometrical parallelism, while they pass through contorted strata of hard slate, obviously of sedimentary origin . . . . Crystalline forces have re-arranged whole mountain masses of them, producing a beautiful crystalline cleavage, passing alike through all the strata . . . . And again, through all this region, whatever be the contortions of the rocks, the planes of cleavage pass on, generally without deviation, running in parallel lines from one end to the other, and inclining at a great angle to the west . . . . Without considering the crystalline flakes along the planes of cleavage, which prove that crystalline action has modified the whole mass, we may affirm that no retreat of parts, no contraction in dimensions, in passing to a solid state, can

explain such phenomena as these. They appear to me only resolvable on the supposition that crystalline or *polar forces* acted on the whole mass in given directions and with adequate power."

In the Geological Report of Cornwall and Devon, Sir H. de la Beche remarks,—

"When we regard the prevalence of the great divisional planes in particular directions crossed by others nearly at right angles to them, producing solids to a certain extent symmetrical, and consider the mineral modifications which the sedimentary beds have generally undergone since they were deposited, we are led to suspect not only that the lamination planes, commonly termed cleavage, are, as has been supposed by some authors, due to *polar forces*, but also that the great divisional planes have been equally caused by them, as has been considered probable by others." "Although the direction of the present magnetic meridian in the district may be merely temporary, and the proximation of so many great divisional planes to it therefore accidental, still their great prevalence, both in the igneous (crystalline) rocks and sedimentary deposits, in that direction, leads us to suppose that *polar forces* may have considerably governed the arrangements of the component matter of the rocks they traverse during consolidation . . . . If we require a constant tendency of such *polar forces* to arrange the component matter of rocks during consolidation in given areas, we can the more readily account for the frequency of nearly similar directions in the great divisional planes of rocks of different ages."

These observations are quoted here merely to show the striking coincidence of independent investigations with which the writer was totally unacquainted during his researches in America; but they clearly prove the universality of the *polar lamination*.

During a recent examination of the metalliferous deposits and primary rocks of England and Ireland, we found the old lamination of the United Kingdom, on an average, a few degrees east of north, and the new lamination intersecting it obliquely, in a direction approaching the present magnetic meridian. See Plate IX. The same kind of polar structure has been observed in coal beds in all countries.

The meridional lamination has been observed from Morocco, in



the north of Africa, to the most northern parts of Europe ; therefore the crystalline crust of the earth does not consist of confused shapeless masses, resulting from igneous eruptions, but possesses a structure and arrangement of parts as regular and uniform as any other natural production. It has but one general grain, by which any of the masses will split, and that is from pole to pole, as represented in Plates IV. and V. This meridional grain is produced by the polar arrangement of the crystals in the granitic base causing more or less vertical sheets or plates of mica, talc, chlorite, &c., the influence of which, together with the constant circulation of the polar currents in the direction of the planes, extends to the sedimentary beds, and thus the whole of the surface becomes uniformly cleaved.

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## CHAPTER VI.

### ON THE GENERAL CHARACTER OF THE CRYSTALLINE ROCKS CALLED "PRIMARY."

THE first remarkable fact that presents itself to our notice on examining the nature of these rocks is, that they contain a very considerable proportion of water, and are often found in depth as soft as clay. Nothing is more common than springs, a great number of which are daily forming incrustations of mineral matter by precipitation. In New Granada great streams of siliceous and calcareous matter are seen issuing out of the rocks and forming large deposits. When the calcareous solvent happens to predominate, the silica becomes aggregated into small lumps, like flints in chalk, and when equal they form distinct beds. In mines and caverns mineral springs are very abundant, and numerous crystals are constantly forming, according to the strength of the mineral solvents. A crystal thus produced may with propriety be called "primary," as it is formed from a primary element, like a crystal of salt from the sea, into a definite form, according to exact laws ; and the powder of such a crystal reconsolidated by any cement may be called a "secondary" or "sedimentary" formation. Therefore the terms "primary" and

“sedimentary” rocks used here, are to be considered in the same sense, having no reference whatever to the time of their formation. With regard to the interior of the globe below the “primary base,” nothing can be determined from immediate observation, nor is the question essential to our inquiry. Were we to speculate on this subject, we should consider it filled with hydrogen gas, from the fact of its surface being principally composed of water: be this as it may, there is no reason to suppose it to consist of an igneous fluid; we cannot conceive the existence of such an element in a quiescent state. This point cannot be too much insisted upon, as geologists have assumed such an agent, and consequently *all* crystalline rocks are called igneous.

In our investigation of phenomena dependent on natural causes, certain laws of reasoning should inviolably be adhered to. First, no cause should be adduced whose existence is not proved either by its effects or by a true process of induction. Secondly, no effect should be attributed to a cause whose *known* powers are inadequate to its production. Thirdly, no powers should be ascribed to an assumed cause but those that it is known to possess according to the laws of terrestrial physics. To these rules we mean strictly to conform, in which conformity rest the merits of our argument in support of the effects of terrestrial magnetism to account for all geological phenomena.

In the first place, we have no proof of the existence of an igneous element. Granting its existence, it could not produce a solid, but merely the melting of a substance already formed; therefore there is nothing gained by such an assumed agent. Besides, it is extremely difficult to produce crystals from fusion, and those which are imperfectly formed are produced when in the act of *sublimation*. Siliceous and calcareous crystals have often been formed by art in the moist way, but never by igneous fusion. The crystals forming the primary base could never be imitated by fusion, even though every other necessary circumstance should concur, especially those with or without an intermediate prism, terminating with pointed pyramids at both ends, as those of quartz and calcareous spar. Even those rocks called ancient lava, such as basalt, trap, &c., are of the same aqueous composition as any other rock, their pores being always filled

with mineral salts. There is not a single case to support an igneous doctrine; whereas by means of the natural solutions and the polar current, we can, not only account for, but imitate the natural productions. There is scarcely a substance known but what is either found naturally in solution, or may be dissolved in an aqueous menstruum. The apparent insolubility of quartz has given rise to some of the difficulties which have embarrassed geologists; but as silica is found in that state in the primary base, we need not trouble ourselves with the question how quartz may be redissolved.

We shall consider the ocean as the primary menstruum from pole to pole,—a compound of all the elements in solution through which the magnetic currents circulate. From analogy and by experiment, crystallization would commence at the negative pole, and would continue to form until its growth would extend to the positive pole in meridional lines, thus producing the polar grain or lamination explained in the previous chapter. In the primary rocks we recognise in every crystal the action of the constant and undeviating laws of the polar force and chemical affinity, giving to the mass a regular grain, and to every crystal a definite form and composition. Hence the above may be considered an experimental and natural truth.

The elementary substances entering into the composition of the primary rocks may on an average be considered the following:—

Silica,	Iron,
Aluminum,	Manganese,
Magnesia,	Fluoric acid,
Potash,	Carbonic acid,
Soda,	Water.
Lime,	

These are united with variable proportions of the gases, hydrogen, oxygen, chlorine, &c. The compound consists of the above in a state of fluids, semifluids and solids, being an aggregation of the separate elements in different states of crystallization.

Silica forms . . . . .	Quartz.
Silica, alumina, lime and potash . . . .	Felspar.
Silica, alumina, potash and iron . . . .	Mica.
Silica, magnesia and potash . . . . .	Talc.
Silica, alumina, magnesia and iron . . . .	Chlorite.

Silica, alumina, magnesia, lime and iron . . . . .	Hornblende.
Silica, alumina, magnesia, potash and iron . . . . .	Schorl.
Lime and carbonic acid . . . . .	Carbonate of lime.

Besides the above compound ingredients, there are also disseminated in the primary mass all the known mineral substances; these may likewise be compounds, of which hydrogen forms a part.

*Granite* may be considered as the fundamental crystalline base, a compound of the above ingredients in variable proportions. Numerous appellations have been from time to time suggested for the different kinds of granites, but it is very evident that such distinctions cannot be established, inasmuch as the variety of crystals constituting the granitic masses are very irregularly disseminated, and possess no distinct lines of demarcation. However, in order to have some idea of their variable character, the following may be enumerated as very common compounds in Europe and America:—

Micaceous granite . . . . .	Mica predominating.
Chloritic „ . . . . .	Chlorite „
Talcose „ . . . . .	Talc „
Hornblendic „ . . . . .	Hornblende „
Quartzose „ . . . . .	Quartz „
Felspathic „ . . . . .	Felspar „
Porphyritic „ . . . . .	Felspar in excess with crystals of felspar in a base.

Felspar in general constitutes by far the largest part of granite: it is often in a soft and fluid state, and in small and large grains.

The following varieties of granitic rocks are often associated in the same mountain mass, and may be regarded as contemporaneously formed, accidentally modified by an admixture of different ingredients:—

Common granite; the felspar white or red, composed of quartz, felspar and mica.

Chloritic granite; quartz, felspar and chlorite.

Felspathic granite, in which felspar is the principal ingredient, and the quartz, and particularly the mica, very rare, with large crystals of felspar.

In these masses are veins of the predominating substances of the enclosing rocks.

The granite being the fundamental base, or the crystalline shell of the globe, its thickness is not known. It has a polar structure, and when the quantity of mica is considerable, granite divides into parallel plates, or in other words becomes laminated, and exhibits the meridional structure explained above.

*Gneiss* is the laminated part of the granitic base, the same identical mass; the distinction being produced by the ingredients tending to arrange themselves in parallel plates; quartz follows quartz, felspar follows felspar, and mica follows mica. (See Plate VI.)

As this crystalline arrangement and lamination of the fundamental base is produced by the continual circulating action of the magnetic currents through the semifluid mass, the transition of the crystalline aggregation to the laminated structure is necessarily insensible; the action being like a simultaneous growth of the granite northward. Hence a micaceous granite produces micaceous gneiss, chloritic granite chloritic gneiss, &c.

*Schist, or Crystalline Slate.*—This variety forms the termination of the granitic base, the branches and leaves, as it were, of the great granitic trunks. The mica granite passes first into gneiss, and the latter into mica schist by an almost imperceptible gradation. This rock has been represented as stratified by a mistake in confounding the stratified with the laminated structure. (See Plate XVI.) It is the final decomposition of the felspar that distinguishes slate or schist from gneiss. (Plate VI.)

It will therefore be observed that the primary crystalline, from the granite to the schist, belongs to one formation, and is essentially composed of the same minerals, variously modified by the polar force, and passes by insensible gradation from the base to the final slaty structure in a more or less vertical and meridional direction; but subject to constant changes and disturbances from local causes.

These rocks are very extensively developed in South America, and may be traced from Chili to the Caribbean sea. A section was taken across the three Cordilleras, where the rocks were seen cut by ravines upwards of 2000 feet deep, thus exhibiting natural sections, and showing the nature of their transition vertically

as well as horizontally; the minute, and very laborious investigation of which is the foundation of the present observations. The crystalline series in Europe falls into insignificance when compared with those of America, and it is in such extensive areas that the real character of the crystalline base can be clearly ascertained.

Besides the regular transition of the crystalline base into slate, there are also veins formed, interlaminated in the mass. Should the base contain a large proportion of magnesia and talc, veins of serpentine rocks will be formed; should the granite predominate in silica, quartz veins will be found very abundant.

The felspathic granite never produces slate for the want of mica, therefore it is generally covered by a massive rock which is erroneously called clay-slate. Should hornblende and lime be disseminated in a felspathic base, hornblende, basaltic, trap, and greenstone veins are formed; and as carbonic acid is generally combined with the ingredients, this compound base produces great disturbances in the superincumbent masses; it is the most restless base of the whole of the above compounds. However, we must always bear in mind that there is no granitic base *in situ* actually dormant; these are constantly acted upon by the polar current, with variable degrees of intensity. The porphyritic granite is the richest base for producing minerals in Chili, Peru, Quito, New Granada, Mexico, England and Germany. The quartzose granite is the most unproductive.

When the granite forms a moist massive base it is seldom deficient in mineral salts, but when comparatively dry, with a distinct crystalline grain, it is generally poor in mineral. These are the primary points to be first considered in making a survey of a mineral district.

The metalliferous parts of Cornwall have a porphyritic granite, which on the surface is partially decomposed, forming patches of dark masses of the same substance; the intermediate part (forming the transition) is called "elvan," being a fine grain porphyry.

The transition of the granite into the slate is very irregular, owing to the excess of felspar and the want of mica: this is also the cause of the series not possessing the uniform cleavage structure seen in America and other places. However, there are a

few meridional channels intersecting Cornwall, presenting the usual phenomena of the vertical polar cleavage, and cleaving the superincumbent beds, which may be seen at the United Hills, St. Agnes, and various other parts of the northern coast. The interlamination of the granite, porphyry, and slate, and the common northward transition, may be seen at Dolcoath, and along the whole range of the Carn Brea granite on the north side.

The gradation of granite into gneiss, and gneiss into mica and clay slates, may be seen in Wicklow, and also in the western part of Scotland. The Irish crystalline series may be considered as the southern extremity of those of Scotland. It has been conjectured that the slates of the western part of North Wales formed the eastern edges of those seen in Wicklow; this idea originated from the mistaken notion that primary schist were sedimentary beds. The Wicklow and North Wales crystalline slates are two independent meridional series. (Plate IX.)

A variety of talcose, micaceous and chloritic schists may be seen near Holyhead and on the south-west coast of Carnarvon, possessing that fibrous structure and silky striated and shining lustre in the planes of the laminæ or meridional cleavage, so peculiar to all the crystalline rocks.

To enumerate the localities of the primary series would be an endless task; therefore we must refer to other works, and confine ourselves to the mode of their formation and general structure. As the action in the primary base is constant, like a series of channels growing northward, with their pores and cleavages full of mineral solutions, subject to variable tensions, fractures, &c., the structure of the compound becomes occasionally very complicated, by which cause the phenomena of heaves, splits, veins, &c. are produced.

*Metalliferous rocks.*—These are channels of rocks in which minerals are so abundantly disseminated that the whole masses are worked like quarries. In the silver mines of Mariquita native silver is commonly found in flakes, like mica in the laminæ of the schist, in channels of ground of about twenty-four feet wide, of course in the meridian, like the formation of the rock itself; and these metalliferous channels are quarried for silver. In the same neighbourhood the argentiferous channels are very numerous.

At Ibague, copper is found under similar circumstances in a

clay-slate formation ; also lead and iron pyrites, disseminated in porphyritic rocks in the same locality.

Gold is principally found as a superficial efflorescence on the face of rocks and in cavities, seldom or never in a close grain or compact rock. It is found in the Brazils, Chili and New Granada, in the tender part of porphyry and clay-slate. It is the destruction or waste of these friable rocks that produces the rich alluvial soil of America.

The porphyry of Cornwall contains nests of yellow copper ore varying from a few ounces to several tons' weight. In North Wales and Cumberland similar metalliferous rocks are common ; they are also very abundant in Ireland.

*Moss copper* is well known to miners : it is the produce of a metalliferous rock, out of which it vegetates like common moss. Gold, silver, pyrites, lead, and indeed all metals, may be seen occasionally growing out of rocks where the situation and circumstances are favourable for their formation.

The minerals are found in the rocks in solution as common as in the solid, indeed it is the state in which we consider them to be previous to their crystallization. All rocks are more or less impregnated with mineral solvents. The cupreous springs are very abundant in Chili, Peru, New Granada, Cuba and New Brunswick : they are to be seen also in Ireland, Anglesea, Spain and Hungary. The copper in solution is obtained by precipitating it by means of iron. The bog-iron ore is of similar origin, and is formed precisely in the same manner as the calcareous and siliceous tuffa.



## CHAPTER VII.

ON THE ORDER OF THE SPLITS, FRACTURES AND DISLOCATIONS IN THE PRIMARY ROCKS, INCLUDING THE SUPERINCUMBENT SEDIMENTARY MASSES.

ACCORDING to the meridional structure of the globe described in the preceding chapters, the general appearance of the surface may be compared to the grain of a fruit; such for instance as an orange or melon, having a grain from pole to pole. Indeed, when we look at the moon through a telescope, and especially in the clear atmosphere of the tropics, she also presents such an appearance. We observe numerous luminous rays radiating from the pole facing the south, which are seen diverging towards her equator, some of which extend to the northern edge\*. Probably the external part of all fruits, possessing two opposite poles, is formed in the same manner as the crystalline shell of our globe.

This meridional action, producing the crystallization, fibrous and laminated structure of the consolidated masses, must necessarily cause a very considerable tensional strain. Let us, for example, suppose a given area were undergoing elongation by the polar force; should any part of the mass not possess sufficient tenacity to allow it to extend, fractures would ensue, and those would take place more or less transversely to the direction of the force; the nature and number of these ruptures would depend on the variable state of the mass. Should the rock contain subordinate channels of unequal elasticity and variable width, splits would occur longitudinally or diagonally to the grain, according to the direction of the least resistance. That the rocks are elastic and subject to undulating motions, capable of being elongated, and not, as is too commonly supposed, a rigid incompressible mass, is a fact which we need not further insist upon. We have therefore the following series of lines as a necessary

\* The bright polar *focus* is considered a *volcano* by the Plutonists, and the radiating rays streams of *lava*; it requires no ordinary stretch of the imagination to suppose such conditions without causing some awful catastrophes.

consequence of the polar action, viz. meridional grain or laminæ, splits, and transverse or east and west fractures. Besides these, numerous smaller fractures must occur according to circumstances; but as they are of minor importance and of a local character, we need not take them into consideration.

We have already shown that the polar grain is universally observed; the east and west fractures intersecting this structure are seen in the Brazils and Chili, forming immense veins of quartz. In Peru and Quito they are very abundant. In New Granada, on the western Cordillera, which is principally formed of porphyritic granite, the east and west fractures are very numerous, and are generally filled with quartz and auriferous pyrites, being the principal metalliferous solvents of this chain.

The central Cordillera is very schistose, thus possessing great tenacity and capable of being elongated; consequently the transverse fractures are but few, and confined to subordinate granular channels: the longitudinal and diagonal splits are of ordinary occurrence, the sides are commonly grooved and highly polished by friction caused by the meridional movements of the parallel masses. The hornblendic, calcareous and talco-magnesian varieties are found extremely active in the above series. The eastern Cordillera is very quartzose, therefore the east and west fractures are very numerous, and are intersected by a few polar splits, with striated and polished sides. In Mexico the porphyritic variety predominates, and the meridional splits are consequently intersected by a great number of fractures. (See Plate VII.) In Cuba and the other large islands of the West Indies the same phenomena are observed. In the southern departments of the United States, and especially at Virginia, the polar splits predominate. These splits have cleaved the coal beds of Blackheath into longitudinal fragments, causing great disorder in their position. (See Plate XVI.) In Cornwall they are very numerous; the splits are known by the names of *flucan* and *cross courses* (Plate VIII.), and the transverse fractures are called *lodes*. It is in the fractures that the mineral wealth of this county is found.

The great polar splits of Cornwall and Devon extend across the Bristol Channel to Wales, and have cut the coal fields and all the sedimentary rocks of the province into meridional strips.

The same kinds of splits and fractures are seen throughout England, Scotland and Ireland, and have broken the great sedimentary beds into various fragments of a somewhat rhomboidal form, according to the oblique angles of the splits. (Plate IX.)

On the continent of Europe similar series have been observed, especially in Tangiers, Spain, France, Germany, Hungary and Sweden; we need not detail them, but beg reference to works describing each district.

These splits and fractures, and their being in continual motion by the constant action of the polar force, produce great disorder in the general structure, and cause dislocations in the order of the masses (called *heaves* by the miners). These are the effects of the horizontal or diagonal motion of the individual strips of rocks between the splits from their original position. The great *heaves* are produced by the northward action of the rocks between the polar splits; the *slides* observed in the east and west fractures are few, and generally insignificant; they are the effect of wedges of rocks squeezed between great splits. (Plate X.)

These dislocations have created great discussions, and have caused very opposite opinions, owing principally to the impossibility of restoring the continuity of *all* the fractures on both sides of the splits. A very little reflection must show that such an agreement in *all* the fractures could not be expected. In the first place, the ruptures across the splits would necessarily take place in the direction of the least resistance, be that in a direct line or not; it does not follow that it should be straight across the split. If, again, we consider that the rocks are exposed to the continual action of the polar current, and therefore subject to a slow movement northward, there would necessarily be fractures taking place periodically in the same masses, *i. e.* when the "heaves" are only 1, 10, 20, 30, 50 feet; how then would it be possible to restore the continuity of the whole series of fractures? It is well known, and can be proved, that the fractures have occurred at different periods. It is like attempting to refit pieces of ice, after having been broken and subjected to repeated movements and reunited again by repeated freezing, as to try to restore dislocated masses of rocks in the primary base.

When we consider the semifluid nature of the masses, and their permitting a continual molecular action through their pores in the

meridian direction, like the current of sap in a living tree, we need not be surprised that the wall of the fractures, cannot always be refitted; their ruptured sides are altered by the chemical action in a very short time; the southern parts of which are often seen penetrating into the northern by a new cleavage formed subsequently to the filling of the cracks, as represented in Plate XI.

Miners are well aware that the sides of veins often bulge out in defiance of all mechanical resistance: it requires a considerable practical knowledge to keep them open to extract the mineral, particularly in very wet ground. When the *splits* happen to be in a *north-west direction*, the masses of rocks on the *western side* are generally forced *northward* more than those on the eastern side: if the *splits* be towards the *north-east*, the *contrary effect* takes place; that is, in real *heaves*, because a great number are called "heaves" that are only apparent. (Plate XII.) In Cornwall the majority of the *splits* are north-west, as described in Plate VIII.: consequently all the principal "*heaves*" of the country are to the right, the western masses having shifted northward more than the eastern. The red sandstone and carbonaceous series, intersected by a split near Tiverton in Devon, has been shifted northward on the western side nearly half a mile. In the vicinity of Tavistock and Callington similar northward movements are observed. There is another great northward "heave" near Redruth, produced by the great cross course traversing the North Downs. The direction of the "heaves" is generally expressed by *right* and *left*, because the same expression serves on approaching them on either side. Some suppose that the nature of "heaves" depends on the direction and inclination of the mineral veins or transverse fractures; but this is a mistake: the movements of the masses are quite independent of the cracks, and would be the same had they not existed. Nor does it follow that the dislocated veins should be always "heaved" on the side of the obtuse angle, as generally supposed, because this depends on the angle of the fracture itself. (Plate X.)

The cause of the above order in the dislocated masses is made manifest when we examine the nature of the mechanical disturbance. Admitting the magnetic force to act in the meridian, the direction of the *oblique splits* destroys the parallelism or uniformity of the polar forces; consequently the masses presenting

the largest transverse bases to the south will be propelled northward at a greater rate than the others. (Plate XII.)

Having lately made a very extensive investigation of the principal mines of Cornwall, Wales and Ireland, with a view of instituting a comparison between them and those of America, this part of our subject was carefully attended to, and the result has fully confirmed our previous opinion that the greater number of the veins on the large scale have been "heaved" and filled simultaneously. The splits, generally speaking, are older than the transverse fractures. The mines of Flintshire are referred to as one instance out of hundreds which may be mentioned, where the transverse cracks are confined within the limits of the meridional strips. The cause of the meridional splits intersecting the east and west cracks is not from their being of a more recent origin, but owing to one series being subject to perpetual longitudinal movements, and the other to transverse actions.

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## CHAPTER VIII.

### MINERAL VEINS, THEIR MODE OF FILLING, AND THE GENERAL CHARACTER OF THEIR CONTENTS.

BESIDES the conflicting opinions respecting the origin of mineral veins, much confusion has also arisen from the very loose signification which is given by miners to the term *vein* or *lode*, which they apply, in fact, to almost any species of mineral deposit which affords a foundation for mining operations, however widely it may differ from the definition of these terms in a mechanical sense. To avoid this confusion, and to render the opinion which is here maintained respecting their origin more clear, we shall distinguish them by *veins of fractures* and *split veins*; the former being more or less east and west, and the latter north and south: transverse fractures and meridional splits are to be considered as identical. We must always bear in mind the fact, that the rocks are more or less strongly saturated with minerals in solution, in a state favourable to chemical action, and having a free motion through the pores of the rocks in obe-

dience to the polar force. Those who may wish to know whether this is a known fact in England may consult the numerous experiments of Mr. Fox, who has proved the existence of the subterranean currents and mineral salts in Cornwall by repeated experiments. Indeed, to doubt this is equal to doubting the meridional action of the magnetic needle; the latter is the effect of the same power.

We have already observed that the meridional channels of rocks contain different kinds of minerals, the fractures intersecting which form what are called lodes or mineral veins; we shall now consider the nature of their contents.

### *The Filling of Veins.*

Agreeably to the preceding observations, we should naturally conclude, that if fissures be formed in a rock of any given chemical composition, the pores of such a rock being filled with solvents, the fissures traversing it would contain the predominating mineral substance: hence we should find in limestone, veins filled with carbonate of lime; in siliceous rocks, veins of quartz; in hornblendic granite or slate, veins of hornblende, &c.: consequently those veins which may intersect a series of rocks varying in their chemical composition, would be filled with a corresponding variety of minerals. Should the laminae or pores of any given channel of rock be more strongly saturated with mineral salts than another, the traversing crack, or a series of cracks, would be found to contain rich deposits opposite to, and within the limits of such a channel. This variation in the contents of the bounding rocks produces a corresponding variation in the fissure: hence the cause why the minerals are formed in isolated masses (called "bunches"), a well-known fact in every mining district. (Plate XV.) The reality of the dependence of the masses of metallic ores in a continuous vein upon the qualities of the bounding rocks, is very perfectly demonstrated by facts long known in England.

Some veins of fracture change so much in their horizontal direction as to be considered in one part a *tin* lode and in another a *copper* lode. This is particularly the case with Chase-water lode, which at Wheal Daniel is called a tin lode, at Chase-water mine a tin and copper lode, and at Treskerby a copper lode.

The nature of the minerals and the accompanying matrix changes with the changes of the rocks intersected by the fracture. In South America the veins of fractures are also often found,—in one part auriferous, in another argentiferous, again cupriferous, according to the metalliferous character of the bounding rocks (Pamplona, Ibaguë).

The changes in the contents of fissures, when traversing sedimentary rocks, are equally striking. The mining districts of Aldstone Moor, Teesdale, Swaledale, &c., consist of sedimentary beds of shales, grits and limestones, traversed by fractures; the minerals in the fissures are chiefly found opposite the limestone beds, which in the above district are the most metalliferous. (Plate XV. fig. 3.) The ore is more abundant in the limestone than in the gritstone, and in the shale ore seldom occurs. The matrix of the vein as it passes through the gritstone is often sulphate of barytes; but when it enters the limestone it changes to carbonate of barytes. When the rock on one side of a vein is thrown up or down considerably, so as to bring a stratum of limestone opposite a stratum of sandstone, or when the walls of the vein are of two different kinds of stone, the vein is never so productive in ore as when both sides of the vein are of the same kind. The connexion of the opposite beds of limestone appears essential to keep up the crystallising action, and consequently the accumulations of the useful metals from side to side within the fracture. When the strata are but slightly shifted, the component parts, or the elements of each stratum, connect the opposite walls obliquely: sometimes the shales cut through the veins from side to side; thus the transverse section of the contents of the fracture exhibits the order of the sedimentary demarcations of the bounding rocks, as shown in Plate XV. This important fact alone is sufficient to invalidate the idea of veins having been filled from above or below; and proves very clearly that the veins of fractures have been forced open and filled gradually by a lateral crystallization from the bounding rocks.

In Derbyshire the beds of metalliferous limestone are interstratified by hornblendic rocks, called toadstones. When a vein of lead is worked through the first limestone down to the toadstone, it ceases to contain any ore, and often entirely disappears: on sinking through the toadstone to the second limestone the

ore is found again, but is cut off by a lower bed of toadstone, under which it appears again in the third limestone. In some situations, where the beds of limestone are divided by seams of clay, they cut off the contents of the vein as effectually as the toadstone. (Plate XV.)

With regard to the metalliferous beds or channels of rocks, it matters not of what variety they are, provided they be good conductors and well charged with metallic solutions. The changes in the contents of veins intersecting the more or less vertical channels of the crystalline rocks are similar to those observed in the sedimentary rocks.

The mining districts of Gwennap, Redruth and Camborne (Plate VIII.), consist of crystalline channels of clay-slate, porphyry, greenstone, granite, &c. When the lodes intersect the pale-blue massive clay-slate, they are generally productive in copper, and tin in the chloritic variety. When the channels dip towards the east or the west, the bunches of ore dip in the same direction. If the channels of ground be very dry and of a close crystalline grain, they seldom produce minerals. The metalliferous character of the channels depends principally on a primary porphyritic and moist base; this kind of rock appears to be the richest soil, as it were, for the production of minerals. These crystalline channels of rocks being more or less in the meridian, as we have already explained in a previous chapter, and the fractures called lodes intersecting them from east to west (Plates VII. and VIII.), each fracture will contain similar deposits of mineral in the same meridian, or in a line approaching to it, as illustrated in Plate XV.: hence the miner's old rule in Cornwall, *parallel lodes produce parallel bunches*. This is an established fact in all mining districts; but it must be remembered that the rule cannot hold good in split veins. The east and west cracks being across the meridional grain, are exposed to the whole crystallising action of the series, whereas split veins between the channels can only receive such solvents as may pass longitudinally through them: this is also the cause of the contents of the two classes of veins exhibiting a different structure, viz. the east and west from side to side, and the splits in longitudinal plates. (Plate X.)

In order to exhibit the mode of filling, and the formation of



different crystals in the same fracture, place a mass of clay-slate between the poles of a battery, immersed in a metallic solution ; it will be seen that the currents pass *only* in the direction of the *cleavage* : if the slate be broken across, so as to represent veins of fractures, crystals will be observed to grow in each fracture transversely, *i. e.* in the direction of the cleavage planes\*. If two or more metals be combined in the solution, and the current be very feeble, only one of the metals will be formed in each crack at a time : should the current be increased beyond that required for the decomposition of one of the metallic salts, the others will be reduced proportionably and accordingly to their relative ease of decomposition. The intensity of the current and the proportion of the metallic salts may vary periodically, which may account for the variety of crystals irregularly grouped together in the same vein and at the very same spot. When the intensity of the currents is very feeble the crystals are large, and when greater than sufficient to reduce the metallic salts, hydrogen will evolve and the metals will be precipitated in a massive powder. Hence, when minerals are found in their metallic state and in large crystals, they indicate feeble currents, and consequently unfavourable for the production of large quantities in such veins. The most favourable indications for rich deposits are strong solutions of minerals, dammed by fluccans or clayey veins, so that the excess may ooze out on the surface, forming hydrous oxides and sulphates. The amount of deposition in each fracture depends on the mechanical position, as illustrated in Plate XIV. The most favourable position of a fracture for the accumulation of minerals is at right angles to the grain of the district, and slightly dipping northward ; the unfavourable frac-

\* We have already insisted that cleavage planes are formed *in the direction of the currents from pole to pole*. Experiments have been made with the view of imitating these crystalline planes, by placing a mass of clay between the poles of a battery, and it has been supposed that the small transverse *fissures* produced by the tension represent the phenomenon of cleavage. A very slight examination will show the distinction between them. Those who may feel disposed to imitate real polar laminæ must furnish each pole with a piece of laminated rock ; without this preparation cleavage planes cannot be produced by artificial means. A mass of clay jammed between the walls in a vein of fracture will be cleaved across by the natural magnetic currents in a very few years. It is this constant cleaving action which is the cause of veins becoming obliterated, as represented in Plate XI.

ture is, that dipping southward at a flat angle under a heavy hill. In a series of parallel fractures the bunches of mineral will be found in a more or less meridional direction (Plates VII. and VIII.), on the south somewhat deep, and on the north shallow deposits. This rise of the metalliferous currents varies in South America from  $10^{\circ}$  to  $20^{\circ}$  from the horizon. In Mexico the richer bunches of minerals are found in the parts where the fissures intersect the moist porphyritic varieties of clay-slates. (Plate VII.) In New Grenada, Peru, Chili and the Brazils, similar channels of rocks are equally productive. In a word, every mining district have their conducting metalliferous channels, and the whole accumulated evidence obtained in all parts of the world clearly proves the fact, that the contents of the veins of fractures depend on the character of the rocks they traverse, as represented in the sketches.

It is of great importance to bear this fact in mind, because veins which have been particularly rich at one place have led persons to suppose that the continuation of the same fracture must lead to more riches, although such a fracture may intersect barren rocks. Every mining establishment ought to be in possession of the general bearing and undulations of their respective metalliferous channels, without which the work must be attended with great risks: guess work, "*where it is there it is,*" is an extremely bad principle to go by, even with a good practical miner; but when exposed to the changes of agents, inexperience, &c., the consequence may be easily conceived. After great expense has been incurred in carrying on works through unproductive rocks, mines have frequently been abandoned, when within a few feet of rewarding our search, for the want of knowing the width and positions of the barren and rich channels of ground. On the other hand, in prosecuting works of discovery in a direction where no metalliferous channels exist, mines have been carried on at a considerable loss, simply because the vein happens to be in the same direction as another more productive. Of all speculative employments, mining has been, and continues to be, for the want of a well-founded principle, the most uncertain; experience and ingenuity being frequently and completely defeated, although the miner has been continually led to suppose himself on the point of meeting a good course of ore; while from veins,

which men of equal ability have abandoned, large profits have afterwards been realized. Therefore the theory of the formation of mineral veins, and the rules which lead to the discovery of the richer deposits, are objects of much greater national importance than is generally supposed. It is essential to the interest of every mining proprietor to know the general character of the local dissemination of the minerals in the district, and indispensable to his forming a correct judgement on the mode of working adopted by the practical miner.

The metalliferous deposits are subject to be decomposed and recomposed periodically, according to the nature of the local changes. In some situations it is possible that veins may change their character in a comparatively short period, so as to be rich at one time and poor at another, especially if kept full of water.

Numerous instances may be mentioned where old workings have been partially filled with a fresh crop of minerals, and also where minerals have been decomposed and disappeared. After the production of some crystals these are again decomposed by new elements; and thus we find crystals have disappeared after having once served as nuclei for others to be deposited upon.

A kind of efflorescence of gold, blende and pyrites have been found formed on the walls in old workings in the mines of Marmato in New Grenada. Gold washings are often abandoned, and the very same sand becomes again sufficiently rich to be re-washed, if situated immediately on a primary rock. Capillary gold, silver and copper have been found formed in old workings near Ibague, subsequently to the mines having been worked by the Aborigines. Native copper has been found formed on the timber in the Wicklow mines.

Mr. W. Forster states, that at Wolfclough mine, in the county of Durham, which was closed for more than twenty years, and opened again, needles of white lead ore were observed projecting from the *sides* of the veins, more than two inches in length, being equal to a vein two inches wide.

D'Aubuisson observes, that in the mines near Pontgibaud, ferruginous and calcareous deposits are now effected in the open spaces left in the mines; so that if after working out the lode the galleries be left shut, and filled with the solutions of the bounding rocks during a long series of years, new workings

could be carried on upon the new deposits. The rubbish left in old workings becomes often cemented by mineral salts, which sometimes crystallize in the crevices, so as to render it worth working over again in the course of a very few years. In the mines of Hanover a leather thong suspended from the roof of a mine was found coated with silver ore, and also native silver and vitreous ore coating the wooden supports of a mine which had been under water for several years.

These chemical actions, governed by the subterranean polar currents, continue to fill every fissure or vacuity with crystals, the growth of which swells open the cracks, and thus causes new fractures and dislocations, according to the variable nature of the containing rocks, and the amount of resistance. This gradual opening of the veins with the growth of the crystals from the *sides* accounts for the isolated masses of the bounding rocks found in veins (Plate XIII.), which could not possibly occur had they been open fractures. Indeed the hypotheses supposing mineral veins to have been *filled by solution from above*, or that of the *injection of igneous matter into an open fissure from below*, are so crude and irreconcilable with the nature of their contents that they do not deserve our attention: the facts brought forward fully justify the conclusion that *all* veins, whether they be mineral or not, have been formed and filled on the same principle of polar action as above described. In the east and west, or transverse fissures, the crystals are formed from side to side, and in the splits, longitudinally, in parallel plates, as shown in Plate X. The bunches of mineral in the splits are in diagonal and longitudinal shoots. (Plate XV.)

#### *Roots and Branches of Mineral Veins.*

The meeting of a number of small veins either in depth or in a horizontal direction is favourable for the accumulation of minerals. Plate XVIII. represents a plan of a split vein in New Grenada containing silver ores; the *feeders* or *roots*, and the *northern branches*, are laid down according to the manner in which the mineral concentrated and dispersed northward. Many are called feeders by miners which in reality have had the contrary effect.

The feeders of the east and west veins, like those of the splits,

are on the south side; the branches seen on the opposite side have, generally speaking, allowed the mineral to escape from the veins. An oblique fissure on the south side, called a *caunter*, formed contemporaneously with an east and west vein, produces the same effect as the small oblique branches, viz. enriching one part of the east and west fracture at the expense of another: the lode north of the oblique vein would be found comparatively poor. These facts may be observed in Cornwall in various parts, and particularly in the mines of Dolcoath, Tin Croft, and North Roskear.

The feeders or roots of the split veins may be seen in the mines of St. Just, the bunches of mineral depending entirely upon them; the principal being those coming in from the granite in a S.S.E. direction, and forming diagonal shoots of ore from their junction northward, as represented in Plate XV. The tin ore formation in the St. Ives consols may be described as a number of large roots coming in from the south-east, converging into one grand trunk, and growing northward at an angle of about eight degrees from the horizon, surrounded by the granite. A similar split vein may be also seen on the banks of the Tamar, having the principal feeding veins or roots on the south-east side, in tender ground under the bed of the river. Split veins, cross courses, &c. are not productive without the feeders, the latter being the only means by which the contents of the bordering rocks can be brought into them.

The split veins of all mining districts are of the same nature; therefore as these effects are matters of fact, and easily referred to, we shall not enter into further details. All split veins, be they quartz, carbonate of lime, hornblende, or any other, have been formed in the same manner, and consequently the contents are arranged in longitudinal plates.

*The influence of the impermeable Splits on the accumulation of the Minerals in the Transverse Fractures.*

Independent of the "bunches" of mineral being found corresponding to certain channels, the amount of the deposits in the fissures is considerably influenced according to the position of the intersecting splits. (Plate XVII.)

That veins of fractures are enriched near their intersection by cross-courses, fluccans, faults, &c., is a fact well known in Cornwall, North Wales, and the North of England; the same fact is also observed in Germany, in Mexico and South America: the evidence for which is very clear, inasmuch as the bunches of mineral are sometimes found confined to one side of the splits, as represented in the Plate. This well-known fact is another proof of the east and west fractures having been filled *subsequently* to, or *contemporaneously* with, the formation of the splits.

These accumulations of minerals appear to have been produced by the splits having been filled with substances impervious to water, the metallic solutions being thus retained entirely on their respective sides; and when one side happens to be more strongly impregnated than the other, the quantity of minerals formed in the transverse fissures will be found in the same relative proportion. The sketches in Plate XVII., illustrating these kind of accumulations, have been taken from mines in America and Europe; therefore they may be considered as real sections, to which we beg reference for a more clear idea of this interesting part of our inquiry.

The *impermeable* porphyritic channels have the same influence on the deposits of minerals as the cross-courses, or meridional splits, *i. e.* they dam up and retain the metalliferous solutions on one side, and thus produce large accumulations. In South Roskear, Tin Croft, and some other mines in Cornwall, the mineral is found almost entirely confined to one side of their intersecting cross-courses and hornblende veins. One of the most noted examples of this fact, mentioned in the Geological Report of Cornwall, is that of Wheal Alfred, near Guinear. The elvan vein, Plate XVII. fig. 1, runs from south-west to north-east; the lode intersects it obliquely; while in the slate, on the eastern side, it contained mineral; but on approaching the elvan it became much richer, and yielded sufficient ore to afford a profit of £140,000. After quitting the elvan on the western side the lode became poor, and eventually the mine was abandoned as unproductive. The arrows in the sketch represent the nature of the accumulation on one side of the elvan, and the apparent cause of the poverty on the other. Viewing the subject on a

large scale, the accumulations produced by impermeable veins will be found according to the following order :—

When the splits or veins run from south-west to north-east the “ bunches ” will be found principally on the *eastern side*; if the splits run from south-east to north-west the deposits will be found on the *western side*, being the natural consequences of the oblique mechanical interruptions of the solvents transmitted through the grain of the rocks by means of the magnetic currents. Numerous minor variations must necessarily occur from the effects of local causes; but we need not describe them, as we hope that the principle here laid down will be found sufficient for the guidance of the practical miner.

### *Recapitulation.*

In the preceding observations we have endeavoured to reduce to order and system those vague indications applied by miners to guide them in their subterranean operations, and concentrate those scattered rays of information which have been obtained by long experience, but have been hitherto so much diffused as to lose their value.

*First.* We have shown that the cleavage planes are not mere local phenomena, but an universal structure—a polar grain, formed uniformly more or less vertically from pole to pole, caused by a subterranean molecular action, or the circulation of the magnetic currents from south to north.

*Secondly.* That the crystallization and meridional structure of the primary base, from aqueous solutions of the elementary substances, have been, and continue to be, formed by the constant action of the currents of terrestrial magnetism from south to north.

*Thirdly.* The order of the splits, and transverse fractures in the crystalline crust of the earth, is caused by the magnetic tension; with the progressive opening and filling of the ruptures by the moving solvents in the intersecting rocks, according to the nature of their respective contents.

*Fourthly.* We have also exhibited the order of the dislocations, or “ heaves,” and the influence of the impermeable splits on the contents of the fractures. The more closely and minute the investigation is made, the more convincing is the result;

therefore this general principle may be safely applied to any mining district, be it in America or Europe, and it is so simple that it requires no other aid than the magnetic needle, the knowledge of the local grain or laminae of the district, its metalliferous channels and configuration, to enable a person to know where the minerals have been principally deposited, and where scarcity of minerals prevails. This principle, that is, the laws of terrestrial magnetism, is therefore obviously of vast importance to the practical miner, and the elucidation of the subject to the furthest practical extent is the greatest desideratum which now remains in the art of mining, since the operations carried on for the discovery of the deposits of ore contained in mineral veins, not only constitute one of the heaviest expenses of mines, but it is the vague and precarious result of these trials which chiefly stamps the proverbial character of hazard and uncertainty which is attached to the pursuit. We therefore trust that the above outline will tend to simplify this interesting subject, and remove that embarrassment and complexity which have hitherto impeded the progress of this department of geological science.

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## CHAPTER IX.

### QUICKSILVER DEPOSITS.

IN the mines of Bavaria this metal exists in a variegated sandstone resting on slate. It occurs in transverse fractures intersecting *meridional channels* of ground, which are nearly perpendicular.

The ores of Cinnabar in the mines of Idria are inclosed in friable talcose rock, interlaminating in small veins in *meridional channels*.

In Peru the quicksilver is found like the silver ore, principally in the laminae of the *meridional channels*. It will therefore be observed that *all* metals are similarly transmitted or deposited in rocks.



*Saliferous Deposits.*

No satisfactory hypothesis has yet been advanced to account for the occurrence of rock-salt (muriate of soda)\*. Some have endeavoured to maintain that it was deposited by the ocean like the sedimentary rocks. The strata above the salt contains organic remains, as do also those below, but the salt contains none. The entire absence of marine exuviae from the strata of salt shows that such rocks could not have been deposited *in* the sea; and it would be difficult to conceive how such a very soluble substance could crystallize in a large body of water like the sea. Others think that it was produced by heat. Not only are salt rocks always found impregnated with water, but they sometimes inclose substances incompatible with the action of heat.

Crystals of salts can only be produced from aqueous solvents, and although heat is employed to expedite the process in artificial works, it is not essential for the formation of the crystals, as a crystalline mass formed from solution is effected by polar action alone at common temperature. When salts are crystallized, they frequently retain a portion of the solvent not mechanically mixed with them, but as an essential component, to which their regularity of figure and colour is in some instances referrible. Thus *Glauber's salt* contains a great quantity of water, and crystallizes in six-sided prisms, transparent and beautiful; expose them to heat, the water of crystallization flies off, the crystals lose their shape, and crumble down into white powder. Crystals of *gypsum* are of glossy transparency, and of regular figure; this is due to water: heat them, they crumble into a white powder, well known as plaster of Paris. Such is the aqueous nature of all natural crystals as well as salts; hence we have abundant reason for assuming that crystalline masses have been gradually formed out of aqueous solutions of the substances permeating the rocks.

It was once supposed that the deposit of salt, or muriate of soda, was confined to a particular series in the order of the sedimentary rocks; but the fact is, that salt springs are found to

\* *Salt*, in the common acceptation of the word, implies culinary salt; but it denotes a variety of substances, totally distinct from common salt. Thus *marble* is a salt; so is *pearlash*, *blue vitriol* and plaster of Paris.

issue out from all kinds of formations, from the granite upwards, in different parts of the world, and become gradually crystallized and consolidated in any rock which may be of a loose and porous nature, and not heavily pressed. The deposits of rock-salt and the springs of muriate of soda in the eastern Cordillera, succeed each other from Pinceima on the south to the Llanos de Meta on the north, a distance of about 200 miles in the same linear direction. All the known salt springs in South America are found in bands more or less meridional.

When the salt does not form beds it is found interwoven in clay, that is, in small veins, like white carbonate of lime veins in a black limestone. The fibres of salt are found perpendicular to the sides of the cracks, like the quartz in veins of fractures. In the splits and horizontal seams the salt is generally divided into thin parallel plates, varied in colour, sinuous, and similar to the general appearance of quartz and other substances in meridional and horizontal veins.

Salt springs issue from the micaceous schist on the western side of the plains of Mariquita, from the porphyry of the western Cordillera near Supia, and apparently from the fissures in the granite in Autioquia. Near Lima, rock-salt is pierced through by veins of porphyry. The direction of the subterranean salt springs, like that of all mineral solutions, is independent of the inequalities of the surface, and may be traced for miles in meridional bands. In England we find the saline springs similarly situated. We may consider Dudley, in Worcestershire, as the northern part, and the mineral waters of Cheltenham as the southern; all the brine springs are situated in the intermediate space, and almost in a *north and south direction*.

Hence we have only to apply the polar force, in connexion with solutions, to account for the formation of salt like all other subterranean products. The natural process is constantly going on under ground without the aid of heat, at least in the sense in which this much-abused chemical phenomenon is employed in geological theories.

What we have stated above respecting the formation of salts from saline solutions, and the gradual formation of veins and horizontal masses by the hydrostatic power of the solutions, and the force of the crystallizing power of the substances, equally

applies to veins called dykes, hornblendic seams interstratified in sedimentary beds; such as the Whin sill of the North of England, veins of carbonate of lime, &c., that is, they are forced into the joints in an aqueous state subsequently to the formation of the inclosing beds.

A very interesting article on this subject appeared in the Mining Journal, which appears to have been written by a practical person who had examined such a formation near Wolverhampton: the following is an extract:—

“Some geologists not only maintain that the trap rocks which are interstratified amongst the beds of the carboniferous rocks of England were forced into their present positions in an igneous state, but they also point out the centres of eruption from which they were injected into the coal measures. Several such centres of eruption had been long pointed out in the Wolverhampton district; but, like numbers of other questionable points on this subject, persons seldom take the trouble of contradicting them, by giving a *bonâ fide* representation of the facts, to check the progress of such igneous absurdities.

“The occurrence of the large masses of green rock, called ‘trap,’ at Pouk Hill, the Nechells, and other localities in the Wolverhampton district, is not owing to these points being centres of eruption, but simply to the bed of greenstone (which is hornblendic) throwing off branches from its upper surface, which branches in parts are exposed on the surface; the under part of the above bed of trap maintaining its position unchanged, and the coal measures ranging underneath it, in a comparatively undisturbed state, as observed in the workings below, showing very clear that the disturbance in the district is confined to the upper part of the series, and proceeding solely from the action of the bed alone upwards, and not from an igneous intrusion from below.

“This trap, or hornblendic bed, is always moist, and in parts as soft as clay; and when this happens to be the case, the disturbance appears to be greatest, and the beds in contact are often seen fractured, and saturated with mineral water, and the cracks filled with calcareous and siliceous spar proceeding from the large bed of trap,—and, as the upper beds present the least resistance to the swelling or apparent increasing power of this rock, the fractures and veins are formed upwards, and bear the same

analogy or relation to it as the larger masses do, and similar to the veins usually observed in slate-works when resting on granite. These branches appear as if they had been squeezed or forced up from the trap bed by the pressure of the superincumbent beds upon it, similar to what would take place in a bed of soft clay confined, if covered by a layer of stones; the clay would be forced up between the joints, and such are what are called centres of eruption in the above coal district. Where the coal happens to be in contact with the above rock, it is more or less impregnated with substances corresponding to it, and always saturated with mineral waters, which coal, when dry, presents a somewhat reddish and greyish appearance, vulgarly called 'burnt coal;' but absolute fusion had no more to do with this change in the character of the coal in contact than it has to do with any other slow chemical saturation by the humid way.

"The following quotation from a recent work on this subject will give some idea how the volcanic action is pushed beyond its natural limits to explain phenomena with which it either has none, or, at best, very little connexion; and it will also exhibit the kind of reasoning, called 'a strict process of induction,' by which the igneous theory is established:—"The modes in which trap rocks, and, in fact, all the primary rocks occur, strongly countenance the idea of injection from below; and their occasional striking resemblance to the products of existing volcanoes shows that the agency by which they were produced was that of subterraneous heat, and therefore closely resembling, if not identical with, volcanic action. One or two decisive facts in support of these views may not be misplaced. When dykes or masses of basalt or trap come in contact with beds of coal, the coal in its vicinity is generally found to be converted into coke or cinder, clearly proving, that when the basalt assumed its present position, it must have been in an intensely heated state; and as it now occurs, completely filling the cracks, &c., in the coal strata, there can be no doubt that when ejected from below it was in a state of actual fusion. Were further proof needed that such is the origin of basalt or trap rocks, it would be furnished by the fact, that this rock often resembles lavas, not merely in its external texture, but in actual composition. We have thus clearly established the igneous origin of this class of

rocks ; and it is sufficient to observe, that by equally satisfactory, though, perhaps, less self-evident reasoning, the same origin may be ascribed to all the rest. In this manner it will be seen that by a strict process of inductive reasoning, we are enabled to arrive at conclusions no less interesting than important with regard to the nature of those powerful agents,' &c. &c.

“ Such are the reasonings by which it has been concluded that the above rocks are of an igneous origin, which, forsooth, is called a *strict process of induction* ! Fortunately for our underground operations, our practical men laugh at such absurdities, and are guided by better reasoning, founded on daily experience ; but it is on young men, such as surveyors, &c., who have been taught such doctrines in the academies, and are too often placed in responsible posts, where such ideas lead to bad results, and who are under the impression that every vein or rock of what they call trap is the relic of a former volcano,” &c. &c.

One of the most usual effects of heat upon limestone is to deprive it of its carbonic acid and reduce it into a white powder. We know of no instance of lime having been reconverted into a crystalline limestone by heat. Chalk, when intersected by veins of any substance containing carbonic acid, is partially converted into marble by the impregnation or absorption of the acid from the veins. One of the most direct objections to the supposed igneous rocks was first drawn from the appearances of the calcareous strata in contact with basalt ; but the assumed igneous element, with its effects, appears by its supporters to possess extraordinary properties,—remaining unaffected *in* water as well as in the air, hot or *cold*, according to circumstances ; capable of converting limestone into lime, or lime into limestone, as they may feel disposed to apply it, and totally uncontrolled by any fixed principle or the known laws of heat. Much has been written against the theoretical deductions of Werner ; but however inconsistent they were, those which have been founded on the assumed igneous agency are much more arbitrarily drawn, most irregularly applied, and totally irreconcilable with the observed phenomena, and have tended quite as much as the dogmas of our predecessors to bring the geological science into dispute.

Those who feel an interest in this subject, *i. e.* the contact of hornblende veins with limestone, coal, &c., may examine the

dykes in Anglesea, Newcastle, and Durham; they afford abundant evidence of their aqueous nature and growth from a semi-fluid base, and the effects at the points of contact are such as would naturally take place by dissimilar substances in a moist state, subject to a slow chemical action.

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## CHAPTER X.

### POLARITY OF EARTHQUAKES.

IF any persons should be more in favour of the igneous theory than others, it might be supposed that they would be those accustomed to earthquakes and volcanic actions; however, nine years' residence on the Andes has produced on the writer, as will be observed, the very contrary impression. As we have already stated, one striking peculiarity in the American earthquakes is their meridional action from south to north. The shock of the earthquake of Chili in 1822 was felt simultaneously throughout a space of 1200 miles, from south to north; the lateral oscillations being confined to narrow bands. The following are a few registered by the author:—

1834. Jan. 20.—Violent shock from Chili to St. Martha in a more or less meridional direction; caused great damage in the line of its maximum force. Its meridional disturbances were felt over a space of 1500 miles of linear measurement; but the transverse oscillations scarcely extended over 200 miles on land.

1835. Feb. 20.—Ditto, a great number, and continued more or less daily until the month of March.

1836. Jan. 4.—Slight shock from the south.

Jan. 8.—Ditto.

On the central Cordillera, from four to five shocks almost daily, from the 1st to the 15th.

1837. Nov. 10.—A shock from the S.S.W., accompanied by subterranean thunder, after heavy rains.

Nov. 27.—Ditto, after a few days intense heat.

1838. June 19.—Two violent shocks; no oscillations; the ground appeared to heave up.

1838. Aug. 9.—Sounds heard in the mines, passing in the direction of the cleavage from south to north; no oscillations; the magnetic needle much affected.

Aug. 11.—Shock accompanied by a very loud explosion, apparently from the volcanic vent of the Paramo de Ruez.

1839. May 28.—A severe shock, continued for nearly a minute.

Sept. 21.—Ditto.

Sept. 22.—Ditto.

Sept. 28.—Ditto.

All in the usual direction, from south to north.

Oct. 15.—A great number of shocks during the last few days. The quantity of rain fallen last month exceeds that of any month in the last three years, viz.  $15\frac{1}{2}$  inches.

Natives consider earthquakes to follow the extremes of wet or hot weather.

Nov. 28.—Ditto.

Dec. 13.—Three very violent shocks from the S.S.W. to N.N.E.

1840. Jan. 2.—Strong shocks from the south.

June 12.—Ditto, the oscillations confined to very narrow limits.

Aug. 22.—A sharp shock from the south.

Dec. 11.—A severe shock from the south, lasted fifty seconds; several houses thrown down in Antioquia in its line of bearing.

1841. Mar. 12.—Slight shocks from the usual direction.

Mar. 19.—Ditto.

June 1.—Ditto; the magnetic needle much affected.

Sept. 8.—A severe shock.

Sept. 14.—A slight shock.

Sept. 30.—Ditto.

The whole of the above, without exception, were from south to north, and oscillating from east to west. It will therefore be observed that earthquakes are subject to laws of action as uniform as other natural phenomena.

In 1797, the district around the volcano of Tunguragua in Quito, during one of the great meridional shocks, experienced an undulating movement which lasted four minutes. At the

foot of the Paramo the earth was rent open, and streams of water and foetid mud with fish poured out, overflowing and wasting everything. During several of the eruptions which have taken place since the year 1822, on the western coast of Chili, some were seen which were followed by great whirlpools, as if the sea was pouring into cavities of the earth. The volcanoes of Nicaragua, in Guatemala, during their activity, are commonly attended by whirlpools. Had there been such an igneous nucleus as the one assumed by the plutonists, covered only by a thin crust, what would be the consequence when the sea happens to pour into it? There would certainly follow some awful catastrophe; but we are happy to state no such convulsions have occurred. Aqueous products and muddy matter are more common than lava or melted rocks; and we find that they generally contain putrid fish of the adjoining sea or lakes, as the case may be. Hence, if we take the products, their effects, and linear actions into consideration, we have strong evidences in favour of considering the whole phenomena due to electro-magnetic action.

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## CHAPTER XI.

THE NORTHWARD AND UNDULATING MOVEMENT OF THE EARTH'S SURFACE *EN MASSE*, BY THE CONSTANT CIRCULATING ACTION OF THE MAGNETIC CURRENTS.

FROM the apparent quiet and regular succession of natural events to which we are accustomed, and the repugnance we feel to the idea that it is possible for the common course of nature to change the general appearance of the surface without causing interruptions, we might, without due investigation, almost persuade ourselves that the physical features and conditions of the globe possess an unchangeable character. Indeed the general phenomena of nature which are daily before our eyes, are often those which are considered the least attentively. In looking at an extensive forest for a hundred years, it would appear to a superficial observer that he was viewing the same identical substances all the time, yet there is no truth more certain than that the whole, or



nearly so, would entirely change in the interim. Continents are changing their physical aspects and configurations—emerged and submerged from the level of the ocean, and moving in masses, unobserved by the millions of animated beings who have their existence on them. Generation after generation disappears while others are taking their places, and so gradually and imperceptibly are these effected, that without reflecting a little, and comparing the past with the present, we almost look at things as if they had been always in the same state. So familiar and reconciled we become to the altered condition, that the past is soon forgotten, and man, who is linked to these renovating laws of nature, too often forgets his final destiny.

That the dry land does not possess that fixity of position, or that it is not a solid and immovable mass attached to a solid globe, as formerly supposed, is now well known; and the earthquakes of South America abundantly testify that the surface is a flexible crystalline compound floating on some more dense fluid, and subject to perpetual movements. There have been very opposite opinions entertained respecting the effects of the earthquakes on the coast of Chili. Some maintain that the coast was permanently raised at various points during the earthquakes of 1822–34–35, &c.; others oppose such statements by very circumstantial evidence; yet both parties agree that the coast is at present at a higher relative position at various points than it was formerly. That such a disparity should occur in observations made by parties who were living on the spot is somewhat singular, and shows how cautious we should be in drawing conclusions on observations made by a hasty survey. The cause of the above conflicting opinions is simply this: the whole western coast is gradually rising, from Terra del Fuego to central America, and so insensible is the action that it is effected unobserved, until an earthquake draws attention to the changes, when the whole is immediately attributed to that phenomenon by those who may not have attended to the exact height of the sea previous to the shock. That the earthquakes do occasionally cause undulations in the coast there can be no doubt, but they are comparatively insignificant to the great changes effected by the silent operations of nature. The electro-magnetic tension is sometimes so great in the Chilian range as to cause immense transverse

fractures and meridional splits, from which water is sometimes seen bursting out.

With regard to lands being gradually elevated and depressed unaccompanied by earthquakes, Professor Lyell has abundantly proved in his 'Principles of Geology,' and has also made very lucid observations on this part of our subject. The coast of Brazil is subject to changes like the Chilian coast, although earthquakes are seldom felt there; but we have more satisfactory proofs in the gradual sinking of the western coast of Greenland, and the equally slow and gradual movement taking place throughout a large part of Sweden and Finland, and a number of other parts in the northern hemisphere, where earthquakes are seldom felt. How much more satisfactory and consistent with the ordinary laws of nature is it to regard these grand operations as regular and necessary effects of great and general causes of the action of terrestrial magnetism, than to suppose them as resulting from series of convulsions and catastrophes, regulated by no laws, and reducible to no fixed principles!

In making comparisons between the ancient latitudes of twelve places in South America with recent observations, we find an average difference amounting to about twenty minutes in favour of a more northerly position. Humboldt took the latitude of Mariquita about forty years ago, and made it  $5^{\circ} 13' 0''$  north. The author continued a series of observations in the same neighbourhood, and connected the above point with others by trigonometrical measurements: the latitude of the same spot is now  $5^{\circ} 25' 30''$ . The observations were not confined to a star or the sun alone, but taken from various celestial points, with their complementary angles, by fixed theodolites, a sextant, and a repeating circle. Similar observations were made at other points. It is therefore concluded that South America is not only subject to vertical undulations, but also to a *horizontal* movement *en masse* northward, amounting to at least ten seconds per annum. However, we shall not dwell on this fact, but shall refer to other evidences, as being more substantial and satisfactory proofs of the northerly movement of the earth's surface. It is the necessary consequence of the action of the polar force, which may be proved by an artificial globe having an electro-magnetic axis, placed horizontally in a fluid containing salts: the masses formed

at the negative pole will be found propelled as they are formed toward the opposite pole.

Granting these mutations in the southern hemisphere, it may be said that they cannot have been going on during the last thousand years in the northern hemisphere, otherwise they would have been detected by astronomers, as the latitudes of places must have varied.

Let us examine what were the actual appearances of the islands and continents, with their respective positions in the time of Ptolemy. In comparing Ptolemy's observations with the present we recognize great discordance. Even at the beginning of the last century the position of places could not be depended upon within 20 minutes. Let us suppose that the position of a place was known a hundred years ago, and that it was situated exactly in the equator; in comparing the same point at distant intervals of time with the same celestial objects, we find a difference amounting to a measurable quantity; and this difference is proved by astronomical observations to be in one direction. Consequently, in order to denote the latitude, or rather to preserve it in the same relative spot, the position of the celestial objects must be altered. This change is called the precession of the equinoxes. To account for this movement it has been assumed that the axis of the globe is continually altering its relative angular position in space, which apparent movement during the historic period has been *northward*. The amount of this motion, by which the equinox appears to travel, is 50 seconds per annum, producing a change along the meridian of about nineteen seconds. This relative change destroys, in the lapse of a moderate number of years, the arrangement of the catalogues of stars, and makes it necessary to reconstruct them. Since the formation of the earliest catalogues on record the place of the equinox has retrograded about 30 degrees.

When the above hypothesis of the precession was propounded, the earth's surface was considered as a fixed and immoveable mass. So little was known of the phenomena of geology, magnetism, &c., that they were not consulted; hence a change of the whole globe appeared necessary to account for the observed variation. The cause of such a movement has been attempted to be explained by the assumed geometrical forces. It would be

easy to analyse the hypothesis, but as we have questioned the very foundation of the principle on which it is founded, we need not dwell on it here, but simply state, that the movement of the surface of the globe northward accounts for the above effect in a more convincing manner, and more free from intricate computations, than the *geometrical physics* now used in astronomy. Besides, the supporters of the theory leave a residual phenomenon equal to about ten seconds unaccounted for, and another movement in the ecliptic; hence we have abundant proofs by celestial observations of terrestrial changes in a northerly direction. It may be argued, that if the masses of dry land, which are now situated near the north pole, containing organic remains belonging to the tropics, have been propelled there by such a slow northward action, it must take some thousands of years since they were in the torrid zone more than we admit according to our chronology, supposing the relics are the remains of those given to man. There is no proof that they are not the relics of those given to man, and we have abundant evidence of the fossils of the existing organic beings being found with those which have become extinct; therefore no line of separation can be legitimately drawn between them. With respect to our chronology, it is not well defined, *i. e.* not a demonstrable quantity; it is a mean of a compound composed of uncertain quantities, therefore necessarily an uncertain amount. Not one of the chronological records was considered sufficiently certain to be adopted—the Egyptian and Chinese were left out—therefore it is useless to enter into this question; besides, it matters not to our creed whether the globe was created 7000 years or 30,000 years ago; time cannot make any difference in a faith which is founded on too firm a foundation to be shaken.

Plato says that the world changes its superficies in every respect; that the heavens and the stars appear to change and reverse their movement by time, in such way as that the east appears to become the west; we find also the Egyptian priests acquainting Herodotus, that from the commencement of the dynasty of their kings (which according to their computation extended to more than 11,000 years) the sun had apparently changed his course in the heavens four times.

We can easily conceive that a country like Australia, which is

now south of the tropics, if brought up to the northern hemisphere, would cause the sun to appear to rise on the left instead of, as in the former situation, on the right: probably such effect was the origin of the above notion of the Egyptian priests.

The observations of the ancient philosophers have been lost in the lapse of ages; however, we have great advantages in our present investigations; the records of the past have been laid down and preserved by a power beyond the reach of human control: we may recall the past and anticipate the future by means quite independent of the conflicting and imperfect evidences of human record.

With regard to the actual time since the creation of the system, it is a question so totally beyond our reach, that it is as useless as it is unreasonable for us as finite beings to enter upon the subject; all that we can legitimately speculate upon is the nature of the dry crust we call land. The comparatively recent origin of the existing organized beings appears abundantly evident, and there is a still more decided proof that the whole of the present dry land as it becomes oxidated at the north pole, will come to an end; and unless a corresponding dry land continue to rise from the southern hemisphere, towards which the living system may retrograde, the world must come to an end, independent of the existence of the globe itself as a body in space.

There are many philosophers who admit in its full extent the doctrine of final causes as evinced in the structure of a plant or an animal; or, in other words, who readily grant that all the various parts and organs conduce to one definite purpose; yet they are reluctant to allow that the earth itself is under any other guidance than an irregular and confused igneous element. We have no reason to suppose that the laws which govern the whole body of our planet are not directed by the same wisdom as that displayed in the external world. Every part of the surface of the globe is adapted to the wants of man, and the inferior creation by which he is surrounded; it is not the result of chance, or of any imaginable fortuitous circumstances, but the production of a season,—it has its beginning and ending, like animated nature.

## CHAPTER XII.

THE NORTHWARD MOVEMENT OF THE SURFACE PROVED BY THE CLIMATE OF THE LAND IN THE NORTHERN HEMISPHERE GETTING COLDER.

WE have evidences of the northern movement of the surface in the changes of the temperature of the northern hemisphere.

Within the limits of the historic records we have abundant proofs of the climate of Europe getting gradually colder, and that the inhabitants of the north are continually retrograding southward. The first settlers in Iceland found extensive districts of that now dreary country covered with forests of birch and fir. They were also able to cultivate barley and other grain. At present the whole island is a naked desert, the native woods have totally disappeared, and the Icelanders have long since relinquished, for good reasons, the practice of growing corn. The relics of the past in this island are few, but sufficient to prove its former habitable state. One of the most remarkable circumstances attending the discovery of Iceland is, that relics were found there which showed that it had been *previously* inhabited. The nature of these relics, which consisted of bells, wooden crosses, and books in the Irish character, induced the Norwegians to believe that those prior inhabitants were Christians either from Scotland or from Ireland.

The most ancient of the Icelandic chronicles are not contented with mentioning the vestiges of former inhabitants, they distinctly state that there were actual settlements on the island previous to the Norwegian emigration\*.

They name Kirkinbui, one of the *warm* and *fertile valleys* that occur on the southern coast, as the residence of those *papæ*, as they called strangers, who deserted the island, it is added, from their aversion to the pagan colonists.

Greenland, according to most of the Icelandic histories, was discovered in 982, and peopled four years later. But there

\* Lardner's Cyclopædia, Maritime Discovery, vol. i. p. 216.

exist letters patent of Louis the Debonaire in 834, and a bull of Gregory IV. in 835, which confers on the church of Hamburg, among other privileges, that of converting the heathen in Iceland and in Greenland.

The new settlers in Greenland had their bishops from Europe, and continued their intercourse with the parent state of Norway till the year 1418. The colony paid to the pope an annual tribute of 2600 pounds weight of walrus' teeth, as tithe and Peter's pence. The dreadful pestilence, called the *black death*, which in the middle of the fourteenth century depopulated all Europe, extended its ravages to Greenland. The colony was, from this and the increased severity of the climate, enfeebled, and soon after disappeared from history.

There was a country called Vinland within a few days' sail of Greenland, watered with rivers yielding abundance of fine salmon, on the banks of which were trees loaded with agreeable fruits, the temperature delicious, and the soil very fertile. Amongst the fruits were found grapes, which was the cause of their naming it the *land of wine*.

It is impossible to shake the authenticity of the above circumstantial accounts of the Northmen; and it is likewise difficult to acknowledge their genuine character without admitting at the same time that Vinland was in Newfoundland. Wine was made from grapes which grew formerly in the open fields of England and the north of France, and there are ample proofs of a similar reduction of mean temperature in other parts of the continents of Europe and in North America. It is in the *northern* regions that we find relics of man and his works, and probably the greater part have disappeared, owing to the rapid destruction and oxidation of the land at this pole.

According to a recent account, several subterranean stone labyrinths have been discovered in Lapland, Nova Zembla, and some of the islands lying near the coasts of Finland, particularly in Wiez, which is all desert, called by the natives Babylons\*. Arabian coins are found in many parts of Russia, along the Volga, and northward even as far as the White Sea, all of which are of a date anterior to 1010†.

\* Athenæum, part 190.

† Lardner's Cyclopædia, Maritime Discovery, vol. i. p. 169.

When we descend below the surface and examine the remains of the organic system now inclosed in the rocks, the proofs of the change of climate is much more decisive, and free from all the doubts arising from imperfect history. So striking has been the general northward action on the surface, that such effects have been long observed. Kirwan stated, that in the northern latitudes beyond  $55^{\circ}$  we find the animal spoils of the southern countries and the marine exuviæ of the southern seas; but in the southern latitudes we find no remains of animals, vegetables, or shells belonging to the northern, but those only belonging to the neighbouring seas. Subsequent surveys have proved the above remark to be a fact. It is now fully admitted that the sedimentary rocks of the northern hemisphere were, at a former period, or during their deposition, exposed to a much hotter climate than they are at present. In the superficial deposits of sand, gravel and loam, strewed over all parts of Europe, remains of Mammalia are discovered, among which are those of the elephant, rhinoceros, hippopotamus, bear, hyæna, lion, tiger, crocodiles, and others, consisting of genera now confined to the tropics.

Professor Lindley justly remarks, that it is an important fact, "that at the period of the deposit of the Lias the vegetation was similar to that of the *southern hemisphere*, not alone in the simple fact of the presence of Cycadææ, but that the pines were also of the nature of species now found *only* to the *south of the equator*. Of the four recent species of Araucaria at present known, one is found on the east coast of New Holland, another in Norfolk Island, a third in Brazil, and the fourth in Chili\*." "With regard to the degree of analogy which the productions of different regions may be found to present," says Professor Phillips, "with the fossil reliquiæ of the lower series of rocks, we are not aware that any investigations are on record; and yet it is impossible to turn to Australia without a suspicion that the productions of that region have more than the average resemblance to the primæval fauna and flora now found entombed" in the northern hemisphere. In the coal deposits the proofs are equally striking that they were deposited in a climate like the southern hemisphere,

\* Foss. Flora, vol. xi. p. 21.



and that no coal except a recent formation of lignite is found from the tropics southward ; in a word, the whole of the deposits of the southern hemisphere are comparatively recent, whereas those of the northern are more or less ancient.

“ It is not merely by reasoning from analogy that we are led to infer a diminution of temperature in the climate of the lands now situated in the northern hemisphere ; there are direct proofs in confirmation of the same doctrine,” says Professor Lyell, “ in the only countries hitherto investigated by expert geologists where we could meet with such proofs. It is not in England or Northern France, but around the borders of the Mediterranean, from the South of Spain to Calabria, and in the islands of the Mediterranean, that we must look for conclusive evidence on this question ; for it is not in strata where the organic remains belong to extinct species, but where living species abound in a fossil state, that a theory of climate can be subjected to the *experimentum crucis*. The fossils of the Subapennine hills, and their living analogues from the tropics, correspond in size ; but the individuals of the same species from the Mediterranean are dwarfish, and appear degenerate and stunted in their growth, for want of conditions which the Indian Ocean still supplies. This evidence is not neutralized by any facts of a conflicting character ; such, for instance, as the association, in the same group, of individuals referrible to species now confined to the arctic regions. Whenever any of the fossil shells are identified with living species at or near the equator, it is not in the Northern Ocean, but in the Southern that they must be sought.”

When geologists assumed an igneous globe undergoing refrigeration, to account for the former high temperature of the northern hemisphere, they imagined that the southern hemisphere indicated the same kind of change, *i. e.* from hot to cold ; but it will be observed that the changes are quite the reverse. The sedimentary beds of equatorial America contain shells analogous, and some identical, to those found only in the south temperate zone, and none indigenous to the seas of the northern hemisphere. Those who may prefer the doctrine of a cooling globe to account for the phenomena, are placed in the dilemma of making the globe hot only in the northern hemisphere and colder at the tropics than at present to agree with the observed facts.

The variable temperature on the surface of the globe is pro-

duced by solar radiation in connexion with the modifying effects of the atmosphere: we have no reason to suppose that climate has ever been governed by any other source of heat. In order to understand the general nature of the present climates from pole to pole, let a convex lens be exposed to the rays of the sun, the rays will be concentrated into the focus, and cause intense heat; the degree of heat depends on the number of rays collected and concentrated into the focus. If we expose a small point to this focus it would be intensely heated; but if, instead of a point, we place a large body in the focus, the heat would be diminished, and the nearer we approach the lens the less the heat.

Our globe occupies the focus of the atmospheric lens, illustrated in Plate XX., and thus prevents the concentration of the sun's rays into one point. In the equatorial region, when the sun is in the zenith, if we ascend to the height of 20,000 feet, instead of finding it hotter as we rise, we get into colder regions, *i. e.* perpetual snow. Hence it follows that one planet may be near the sun, and another placed at the confines of the solar system, and yet both possessing equal temperature on their surfaces, by proportioning the diameter of their atmospheric lenses to that of their respective bodies. Therefore to say that Venus *must* be intensely hot and that Saturn is in the region of eternal snow, is a mere assumption, unsupported by analogy. Some attempts have been made to show how the globe may have become hot and cold by its probable exposure to the effects of intense stellar radiation in passing through the milky way; but such speculations are flights of the fancy, and unworthy of attention. There has been too much dependence placed on celestial observations already for the progress of geology. If we would speculate to any purpose on a former state of our globe, and on the succession of events which from time to time have changed the condition and form of its surface, we must confine our principal inquiries to the results or effects of terrestrial physics, and not attempt to solve the problems by reference to celestial objects; for if we differ so materially on those points which we can handle, it is not probable that we could decide by referring to objects so much beyond our reach.

We shall give a few examples of some points used by geologists for their guidance in theoretical researches, founded on

astronomical observations, which are not only doubtful, but proved incorrect. It is said that the moon turns on her own axis, because she is an oblate spheroid, notwithstanding that she always presents the same face towards the earth. That a body revolving round a centre, and continuing to present *the same face to that centre*, should rotate on an axis situated parallel to the revolving axis, is physically impossible. Yet it is maintained, and absolutely stated in our astronomical works, that the moon rotates on her axis.

There is another idea propagated respecting this body, viz. that she has no atmosphere, because we do not observe any refraction during the occultations of the stars. If the moon is enveloped in an atmosphere, the angle of refraction would be between the moon and the star, and that would, on impinging on the moon's surface, be reflected towards the earth. If a ray of light be successively transmitted through several transparent media having different refracting powers on one side, and reflected so as to pass through similar media on the other side, its emergence from the last of these media will take a direction parallel to that which it had when incident upon the first of them. In this case the several refractions which the ray suffers in passing through the media on the one side is compensated and neutralised on the other, so as to produce, on the whole, no deflection of the ray from its original course. "The angle of incidence is equal to the angle of reflection." The reason why we observe the refraction of the rays in our atmosphere is, because we are exposed to *one* angle only, *i. e.* that of refraction, owing to our being *within* the spherical media. Yet we are told the moon has no atmosphere, because she does not show signs of refraction, notwithstanding the contrary evidences proved by the halo which this body often exhibits. Persons have attempted to describe the geological features of the moon! If the above simple questions are in such a confused state, and so easily demonstrated at a distance by the aid of mathematics, what are we to expect from the geology of the moon? Unless geologists can procure more substantial data than those obtained from celestial observations, it is not very probable that the science can improve; and much less when fettered by other incompatible laws, which have taken too deep a root to be very easily eradicated.

The changes of climate have been attributed by some to a

greater eccentricity of the orbit formerly than it is at present. But even the eccentricity of the orbit is a doubtful question; the only proof brought forward that the orbit is excentric is the variable diameter of the sun. The atmospheric lens not only refracts the rays when not in the direction of the radius, *i. e.* in the zenith, but also augments the size of bodies, such as the sun, the maximum size being in the horizon and the minimum in the zenith. According to a series of observations made by the author for nine years within the tropics, the sun's *apparent* diameter is throughout the year the *same* when measured in the zenith; therefore its observed variable diameter is an *optical deception*, and not from any excentricity of the orbit. That this is the case must be well known to those who have taken observations in the southern hemisphere with delicate instruments, and especially when the diameter of the sun formed an important amount in the measurement\*.

To return from this digression, we find that the variable nature of climates from pole to pole arises principally from the obliquity of the rays and the height from the sea, and not from internal heat;

\* Santa Ana, N.L.  $5^{\circ} 10' 0''$ . The sun's diameter, according to direct observations taken in the meridian from the south tropic to the north.

South tropic .....	< $61^{\circ} 22' 37''$ altitude.	31' 30'' diameter.
Equator .....	84 50 0     „	30 45     „
Zenith .....	90 0 0     „	30 36     „
North tropic .....	71 35 20     „	31 12     „

The following measurements exhibit the apparent variation of the sun's diameter in the plane of the orbit during its daily apparent path, from the rising to the setting; the latitude of observations and the sun's declination being equal.

	Diameter.			Diameter.	
The sun rising < $0^{\circ}$	32' 55''		Noon S. in zenith < $90^{\circ}$	30' 36''	
„            15	32 35		„            75	31 2	
„            30	32 18		„            60	31 30	
„            45	31 55		„            45	31 50	
„            60	31 32		„            30	32 15	
„            75	31 6		„            15	32 32	
			The sun setting ...	0	32 51

If it is maintained that the orbit is an ellipse, because the sun appears larger at a lower altitude in December than in June at a higher elevation; on equally good data we may state that its diurnal path is an ellipse, and that our approach to the sun morning and evening is compensated by the obliquity of the rays and greater velocity, thus forgetting the consequence of such deductions at those places under the sun in the opposite hemisphere. When Kepler established the excentricity of the earth's orbit little was known of refraction.

therefore we can only account for the changes of climate indicated by the organic remains by changes in the relative position of the dry land and the sun's rays.

Professor Lyell suggested that the changes in the position of land and sea may have given rise to the vicissitudes in climate. The Professor does not bring proofs of more than a mere rise and fall of land from the level of the ocean, which could not furnish us with tropical heat in the arctic regions, therefore he assumes the possibility of geographical changes, such as the shifting of land from the southern hemisphere to the northern, to reconcile the effects with the facts. "However constant," says the same author, "may be the relative proportion of sea and land, we know that there are constantly some small variations in their respective geographical positions, and that in every century the land is in some parts raised and in others depressed. By these ceaseless changes the configuration of the earth's surface has been remodeled again and again since it was the habitation of organic beings, and the bed of the ocean has been lifted up to the height of some of the loftiest mountains. The imagination is apt to take alarm when called upon to admit the formation of such irregularities in the crust of the earth after it had once become the habitation of living creatures; but, if time be allowed, the operation need not subvert the ordinary repose of nature, and the result is in a general view insignificant, if we consider how slightly the highest mountain chains cause our globe to differ from a perfect sphere. Chimboraga, though it rises to more than 21,000 feet above the sea, would be represented, on a globe of about six feet diameter, by a grain of sand less than one-twentieth of an inch in thickness."

Let us consider what would be the nature of the deposition in a large tract of land like Australia, supposing it gradually floated from its present position to the north polar region. Here and near it, tree ferns, Cycadææ, Araucariæ, Cassiarinæ grow upon the land: corals and sponges abound on the coast even of Van Diemen's Land; also Trigonias, Cerithium, Isocardia, a Cardium like *C. hillarium* of the greensand, and quadrupeds of the peculiar marsupial races, to which the Stonesfield animal is referred by Cuvier. These would be deposited, and their place would become gradually occupied by others as it approached the equator, where it would be inhabited by a different variety.

These would again disappear on the arrival of the land in the north, and their place would be taken by others. The contents of the deposition, supposing the land undulated above and below the level of the sea during its movement from the south to the north, would represent the order of deposition and organic remains similar to those now found in the rocks of the northern hemisphere.

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### CHAPTER XIII.

#### THE DIVISION OF THE SURFACE OF THE GLOBE INTO ZONES OF DEPOSITION.

IF, as we have endeavoured to establish, the sedimentary rocks have been deposited in different zones during the movement of the surface from the south pole towards the north, we may distinguish their respective zones of deposition in the following order:—

Zones.	Deposits.
No. 1. South frigid . .	The most ancient:—Cambrian and Silurian.
2. South temperate . .	The Carboniferous, or great coal formation.
3. South tropic . .	Oolitic, or Saurian group.
4. North tropic . .	Cretaceous, & tertiary of Europe.
5. North temperate . .	Alluvial deposits of Europe.

1. Commencing with the most ancient deposits, we find *Orthoceratite*, *Trilobite*, and other marine relics, but scarcely any land plants. That this ancient deposit should not contain land plants is not surprizing. The newly-discovered countries within the south frigid zone, although placed in latitudes in which herds of wild herbivorous animals are met with in the northern hemisphere, nay, where man himself exists, are most wintry in their aspect, almost entirely covered with ice and snow even in summer, and completely destitute of animal life and vegetation.

The living representatives of the fossils have not yet been identified; but according to Dr. Buckland, the nearest approach

among living animals to the external form of Trilobites is that afforded by the genus *Serolis* in the class Crustacea. The genus *Serolis* inhabits the Straits of Magellan and the coast of Patagonia. The beach is often seen covered with them dead; they are found alive only by dredging in deep water. This region is but little known, but the above approximation is sufficient for our present purpose. All the deposits found within this region are comparatively recent, containing organic remains of those only which inhabit the bordering sea.

## 2. *South temperate deposits, or Carboniferous groups.*

The forms of life buried in this system of strata are exceedingly numerous and varied, and generally in an excellent state of preservation, allowing of a most strict comparison with existing types. They consist of many races of plants, abundance of Zoophyta, with multitudes of Mollusca, Crustacea and Fishes. The plants are in some respects very similar to existing races, as the large group of ferns generally, the Equiseta, Lycopodiaceæ, Araucaria, Cycadeæ, Coniferæ, &c. The remains of these plants are often abundant in coal-seams. The coal plants of North America are for the most part identical with those of Europe, and all belong to the same genera. Specimens from Greenland are referrible to ferns, analogous to those of our European coal mines. The fossil plants brought from Melville Island warrant similar conclusions. The coal formation of Bogota, which is situated within 4° north of the equator, at an elevation of about 8000 feet above the level of the sea, contains the same kind of plants—arborescent ferns, and Lycopodiaceæ of the same species as those now growing in the southern hemisphere. The living representatives of the above are found in New Holland, New Zealand, Brazils, Chili, and various islands within the south temperate zone. Not a single species of Cycadeæ is known to grow in the north temperate region; their principal localities are equinoctial America, and southward of that part, the Cape of Good Hope, Madagascar, India, the Molucca Islands and New Holland.

The enlarged size of the arborescent ferns depend not only on a warm temperature, but also on a shady and moist place. Within the tropics they are found at an elevation of about 4000 feet above the sea, from twenty to thirty feet high, flourishing

only in shady parts of great humidity. It is in the south temperate zone of America that the ferns approach to the magnitude of those found in the European coal formation. Trees grow in this region to a very large size, and the shrubs and smaller plants become particularly luxuriant and productive. Much alluvial matter, saturated with calcareous and siliceous solutions, is carried down the valleys, blended with decomposed vegetation, and forming immense deposits. Springs of bitumen are also very abundant, and form very extensive beds.

Were persons a little more acquainted with this prolific region, and possessed more information respecting the great deposits of calcareous, siliceous, bitumen beds, &c. which are now forming and consolidating in a short period, they would not be quite so extravagant in their calculations on the time necessary to form the coal formation\*. Small beds of lignites are formed within the tropics in less than one hundred years in favourable situations, and more especially in the neighbourhood of bituminous springs. Owing to the great warmth, rich and soft nature of the soil, tender plants flourish through the long winters of Patagonia. The humidity of the air near the Straits of Magellan is very great, yet there is great warmth in the sea and in the soil.

There is no well-authenticated instance of the remains of a saurian animal having been found in a member of the carboniferous series of England; nor have the bones of any terrestrial mammalia been discovered†. Their absence has been regarded by some as corroborating the theory of the non-existence of the higher orders of animals in the earlier ages, but the circumstance is owing to the geographical position of the zone; the general character of this division of our globe being a profusion of vegetation, and land almost destitute of quadrupeds. “Kerguelen’s land, which is of no inconsiderable size, placed in lat. 49° 20’ south, and also the groups of fertile islands in the Pacific Ocean, contain no quadrupeds, except such as appear to have been conveyed there by man. Even the islands of New Zea-

\* It has been calculated that the coal series of Newcastle, with its accompanying strata, must have required for its production a period of at least 200,000 years.

† Traces of reptiles have been found in other countries.



land, which may be compared to Ireland and Scotland in dimensions, appear to possess no indigenous quadrupeds except the bat; and this becomes the more striking when we recollect that the northern extremity of New Zealand stretches to latitude  $34^{\circ}$ , where the warmth of the climate must greatly favour the prolific development of organic life\*.”

Australia is exceedingly deficient in Saurians and other terrestrial quadrupeds. Hence the contents of the carboniferous group accord well with the prevalence of such a state of things in the southern hemisphere during their respective depositions.

We cannot expect to find any large coal formation south of the tropics, but mere beds of lignites; because should there be any forming it would be below the level of the sea, and not yet sufficiently consolidated to make good coal. The coal formation of Australia is a similar new formation. “In the inlet of Awaaba, in  $33^{\circ}$  south latitude, is a formation of conglomerate and sandstone, with subordinate beds of lignite, which extends from the Hunter river southwards towards Brisbane water. The lignite constitutes the so-called Australian coal †.”

Tree ferns, which require abundance of moisture and an equalization of the seasons, are found in Van Diemen’s Land in south latitude  $42^{\circ}$ , and in New Zealand in south latitude  $45^{\circ}$ . The orchideous parasites also advance to the  $42^{\circ}$  south latitude.

Before concluding this part of our inquiry, we shall make a few observations on the supposed predominance of carbonic acid in the atmosphere during the deposition of the coal-beds. The researches of M. A. Brongniart on fossil plants led him to conclude that during the early period, when the plants entombed in the coal-measures of the northern hemisphere flourished, the atmosphere was more charged with carbonic acid than at present, aiding, it is said, the development of the gigantic species seen in the coal, and also protecting them when dead from being so readily decomposed by the atmosphere.

It is difficult to conceive how the idea of plants obtaining their carbon from *the atmosphere* originated, when it is a well-known fact that it is obtained from the soil. No such atmosphere exists in the southern hemisphere, nor within the tropics,

\* Lyell, Principles of Geology, vol. i. p. 199.

† Geological Proceedings, March 8th, 1843.

yet those magnificent trees above alluded to grow there; but the soil is strongly impregnated with carbonic acid. It is more or less saturated in all soils, and without it vegetation cannot thrive, as it feeds the plants by means of the *roots*, and not by the *leaves*. The function of the leaves is to evolve the gases, *i. e.* they form the negative plates to the currents of sap in the living plants. Had there not been a provision to take the carbonic acid away from the atmosphere we could not exist; indeed it is the *absence* of it from the air that preserves the vital principle. The purer the air is at the leaves, with a due proportion of moisture, the more healthy is vegetable life\*.

Probably our coal-beds may be as much due to the combination of carbonic acid and hydrogen forming bitumen, as they are to decomposed vegetation. We have abundant facts to prove that plants are as liable to become silicified as to be converted into coal; and there are also proofs of beds of lignites forming from bituminous substances, near the roots of living plants, within the tropics.

We shall not enter into a description of the probable mode of deposition of the carboniferous series, because this has been well explained in all geological works; but we may note in conclusion, that the coal basins appear to be principally lacustrine deposits, where bitumen, mud, sand, and decomposed vegetable matter may have accumulated, such as we now see forming within the tropics and in the southern hemisphere.

3. *South Tropical Zone. The system of rocks between the carboniferous strata and the chalk, containing a large proportion of gigantic amphibious Saurians.*

The oolitic group may be considered as representing this division of the series. The remains of plants, Zoophyta, Mollusca, Articulosa, and vertebral animals belonging to the oolitic system,

\* The respiration which takes place at the leaves has been found to vitiate the atmosphere, and more especially at night; the sun's rays appear to restore the purity of the air. An atmosphere containing 60 per cent. of carbonic acid gas has been found destructive of vegetable life; the doses become less prejudicial as they are diminished. Any addition, however small, of this gas to common air, if placed in the shade so as not to be neutralized by the sun's rays, has been found prejudicial to plants.

are very numerous. The most characteristic of the plants are the group of Cycadeæ, of which stems in the isle of Portland, and leaves and fruit in Yorkshire, show considerable analogy to the existing forms of the tribe at the Cape of Good Hope, in India and Australia.

The sponges resemble those of New Holland. Among the Saurians, those which frequented the water predominate in number, but the largest forms were terrestrial (Iguanodon, Megalosaurus). It is interesting to know that the earliest Mammalia, of which we have yet any trace, were of the marsupial division now almost characteristic of Australia, the country where yet remain the *Trigonia*, *Cerithium*, *Isocardia*, *Zamia*, tree-fern, and other forms of life so analogous to those of the oolitic periods. During the deposition of the European formation the rivers and shores were inhabited by Saurians more or less amphibious, while the sea was full of forms of Zoophyta, Mollusca, Articulosa and Fishes.

Within the south tropical zone we find a similar scene of organic life in the seas, lagoons, and on land enjoying their limited existence. Here the rivers, such as the Amazon and its shores, are watched by amphibious Saurians, the living representatives of the *Megalosaurus* and *Iguanodon*. Although the identical species have become extinct, yet the alligator, crocodile, gavial, and the bavian of South America (the latter was seen by the writer in the lagoons of equatorial America, having a head like an iguana and a body like a crocodile), are sufficient to show the correspondence of this zone to the fossils of the oolitic group.

When we consider the myriads of reptiles which inhabit this zone, it is not surprising that their relics should be found in sediments within their own element; nor is it to be wondered at that no traces of man and his works have been found in such deposits. There are regions at present in the Indian and Pacific Oceans co-extensive in area with the continents of Europe and North America, where we might dredge the bottom and draw up thousands of shells and corals without obtaining one bone of a land quadruped. The casualties must always be rare by which land quadrupeds are swept by rivers far out into the open sea, and still rarer the contingency of such a floating body not being devoured by sharks or other predaceous fish. If the carcass

should escape and happen to sink where sediment was in the act of accumulating, and if the numerous causes of subsequent disintegration should not efface all traces of the body, is it not contrary to all calculation of chances that we should hit upon the exact spot? Can we expect for a moment, when we have only succeeded amidst several thousand fragments of corals and shells in finding a few bones of aquatic or amphibious animals, that we should meet with a single skeleton of an inhabitant of the land? Are we then warranted in supposing that man was not an inhabitant of this world during the deposition of the oolitic group? In the first place, the southern hemisphere is even at present but thinly inhabited, and if perchance a man be carried into the rivers, he would soon be devoured amongst such a profusion of carnivorous reptiles. As to the works of man within this zone, even at the present advanced state of civilization, they consist of such materials that their remains would be undistinguishable from the wrecks of the forest. Therefore we have no proof that man was not an inhabitant of this world during the deposition of the series in question.

Let us take as an example the banks and lagoons of the Amazon, which are swarming with reptiles, and consider the nature of the deposits forming at the mouth of this immense river. The inhabitants of the country are principally roving Indians, living in bamboo huts; probably we should not be far wrong in stating, that for every man there are within this region 10,000 amphibious animals. Again, for every man, or his relics, which may be carried into the deposits of the river and escape being devoured, there will be deposited 100,000 amphibious reptiles: is it then to be wondered at that man or his works have not been discovered in the deposits of the saurian zone, much less during past æras, before the world became so thickly populated as it is at present? Besides, the deposits in question have been but very partially explored,—merely the edges of the strata.

Marine animal life was exceedingly abundant during the deposition of the older oolitic group now found in Europe; some beds seem composed of little else than the remains of shells and corals. A very striking zoological feature of this group is the immense abundance of Ammonites and Belemnites which must have existed previous to, and during not only the deposition of

the European group, but also when the most recent equivalent of the same group was formed, as now seen near the equator.

It would far exceed our limits to enter into the general comparison which might be made, even to minute details, of the living representatives and the depositions of the river Amazon, and other parts within the south tropical zone, with the fossils and deposits of the oolitic group; and as it only forms but a mere link in our chain of argument in support of the northward movement of the surface, we must content ourselves with a general glance. If this system of deposits was formed within the south tropical zone, and should they be visible at the equator, they must be very superficial, and in a very unconsolidated state as compared with the European. The equivalent of the European oolitic group in equinoctial America, from the Amazon to the Orinoco, and on the plains and table-lands of New Grenada, is an immense mass of alternate beds of fine-grained quartzose sandstone and conglomerates, containing Ammonites, Belemnites, and a variety of other marine shells, together with species of fossil plants of the Cycadeæ, Coniferæ, &c.; and on the superficial, arenaceous and unconsolidated part of the same series are found immense bones, considered to be the remains of the Mastodon. These bones are very abundant in the province of Nieva, amongst which are those of the alligator.

In New Grenada this series of sandstone is stratified in layers more or less horizontal; a great number of the thinner and upper seams are composed of decayed leaves and impressions of plants the same as those now growing on the spot. On the plains of Mariquita and Nieva are immense isolated terraces presenting beautiful sections of 2000 feet high; and also on the plains of Bogota, resting on the coal formation of that district; whilst on the west this formation rests immediately on the crystalline schists of the central Cordillera. The elevation of this part of South America from the level of the sea (which appears to have been comparatively recent) was extremely uniform, and about 3000 feet. According to the theory here brought forward, it was not a mere vertical rise, but a diagonal movement from the south. There are but few beds of the oolitic group sufficiently consolidated for building stones, and those that are so employed are much softer than the common freestone. Stems of soft plants are commonly found, as black as jet, in the harder beds.

In examining recent deposits within the tropics, we often find the accumulations of only a particular variety of plants : and it is remarkable that some plants which are common in the neighbourhood are yet absent in the deposits. Some appear more susceptible to rapid decay than others ; hence it follows that if a series of beds should be found to contain only a particular class of plants, it is no reason but that other kinds grew, not only in the region but within the district. We note these facts in order to guard against the too hasty conclusions of supposing that the fossils always represent the real character, number and variety, of the living organic system during their deposition.

4. *North Tropical Zone.—The European, Cretaceous and Tertiary Deposits.*

Although the English sedimentary rocks are divided into distinct groups, it is not a natural and definite subdivision, but depending entirely on local circumstances. A perfect transition from one bed into another is of more common occurrence in nature than distinct separation. We have no cretaceous equivalent in the equatorial zone ; nor can we expect to find such a deposit, if as we suppose, this is a marine formation, formed in that part of the globe. No remains of mammiferous animals have been discovered in the cretaceous series of England, and the exuviæ of reptiles are by no means common, showing that the deposit was formed somewhat distant from dry lands. The remains of a crocodile have, however, been found in the chalk of Meudon, and the exuviæ of a large reptile, the Mososaurus, at Maestricht. The remains of fish are not so rare. The supracretaceous deposits are commonly termed tertiary, which denomination is exceedingly objectionable and inapplicable, as it implies that there were three classes of rocks possessing marked characteristic distinctions, and that the deposits above the chalk constituted the third of such classes\*. We should rather consider, that as other groups pass into each other in one place, while there is evidently a geological break between them in another, that the like should happen with respect to the cretaceous and supracretaceous groups.

In examining the deposits which are now forming within the tropical region, we often find a great number of beds containing

\* De la Beche's Geological Researches, p. 355.

only marine and freshwater organic remains, and it is but in very few instances that we can detect traces of terrestrial creatures. In some parts, large deposits of carbonate of lime are seen, with scarcely any organic remains, although forming at the same time as those deposits in which they are very abundant. Those persons who confide in what are hastily called general views, and believe in the gradual change and sequence of organic life on the globe, and picture to themselves the early land and sea as tenanted only by what they find in the sedimentary deposits of a particular region, from what they consider simple forms of life to a more complicated, till man, as they say, was at last awakened to the supremacy of creation,—would receive a useful lesson on the banks of the river Magdalena and the lagoons of Santa Martha; they would soon be satisfied that the few fossil birds and quadrupeds of Stonesfield, and other places, are not anomalies so puzzling as they were once considered. How can we expect to find the whole variety of the living system in such deposits? It is as unreasonable as the general views which have been established on their absence.

Although there have been actually found, not only the bones of quadrupeds, and various terrestrial animals, but also those of man, amongst those of the extinct animals, in caves, &c., and also in a fossil state in the calcareous deposits of Guadaloupe, yet so obstinate is the adherence to the supposed recent origin of man, as compared with the organic remains of the sedimentary rocks, that such discoveries are not considered sufficient to prove their coexistence. Various species of monkeys have been found under similar circumstances, which were at one time considered of the same recent origin; even this must show the inconsistency of the hypothesis.

In the red sandstone, which occupies nearly the same geological position as the cretaceous group, in Dumfriesshire in Scotland, and Massachusetts in North America, we find the impressions of the feet of birds, and the foot-marks of tortoises. On the present *soft sand banks* of the river Magdalena, between Mompox and Morales, the writer saw impressions of foot-marks of birds of a most gigantic size,—feet measuring about fourteen inches long and eight inches wide, having three claws, and the steps four feet; amongst which were also those of tortoises, and various

other animals well known on the banks of the river. Although the bird itself has not been seen, there can be no doubt of its existence, as the impression was found in the *soft* bank in the middle of the river, which a heavy storm would obliterate, amongst other well-known species. The trees in the *dirt-bed* in the neighbourhood of Weymouth stand in or rest upon the soil in which they grew; consequently their submersion beneath the water in which the Purbeck beds were formed, and which now cover them, must have been gradual and unaccompanied by a rush of waters. Such is the case in the present formation of their equivalent in the lagoons of Santa Martha, where the trees are growing in shallow water, subject to slight oscillations above and below the level of the sea. Sometimes the salt water prevails, and the sediment becomes thickly covered with marine shells: during the great floods pouring down the Magdalena, carrying with it immense forests and the debris of rocks, the lagoons become again covered with freshwater and terrestrial organic remains. Thus, by variable seasons, and by the slow oscillation of the land by subterranean forces acting for a long period, the variable sedimentary beds are formed, such as we now see them when exposed to view. Lacustrine deposits of the same period may present very different characters, depending on the nature of the locality in which they may be formed: for instance, the lagoons of the Orinoco may contain a very different series of organic remains, as compared with those of the Magdalena; hence formations may be of the same age and the same zone, yet different in degrees of induration and organic contents, as well as in the relative geological position. Viewed generally over a considerable area, the rock called chalk is based either upon an arenaceous or argillaceous deposit. As we cannot expect uniformity in the distribution of detritus, unless under conditions which could scarcely ever obtain, we should anticipate that sands would predominate over one part of the area and mud or silt over another, as we now find to be the case in the present deposits forming within the tropics. The white variety may probably have resulted from the precipitation of carbonate of lime from solution in water, in a favourable locality, suitable for the reception of calcareous springs.

The supracretaceous group of Europe completes the great sedi-



mentary system of rocks; during the deposition of which it has been supposed man came into existence, simply because his remains are principally found in the superficial part of the series. These rocks constitute a large proportion of the dry land of Europe; and there are abundant evidences that they are, comparatively speaking, of recent origin, and that a great portion of the dry lands now forming Europe and Asia, have been raised from the sea since they were exposed to a hotter climate. The chalk of Europe, the oolite of the tropics, and the coal formation of the south temperate, may be all of the same age; hence it will be observed that the present mode of distinguishing these rocks is only applicable in certain localities, in the same parallels of latitude.

Sir H. De la Beche very justly remarks that "classifications entirely founded on organic remains are at all times liable to be erroneous, if contemporaneous deposition be thence inferred as a necessary consequence, as we have had occasion to observe; they therefore may be considered as doubly liable to error when employed in proving contemporaneous origin in such rocks as those of the supracretaceous period."

Palms and crocodiles are found in these deposits, analogous if not identical to those now found in Africa and in the neighbourhood of the Nile. That a great number of organic beings should have become extinct during such great oscillations of the earth's surface is a very natural supposition; it is more surprising that so many of the grand stock should have been preserved amongst the numberless vicissitudes of climates, and the separation of continents into islands, and *vice versa*.

The last group of sedimentary beds pass so insensibly into the superficial alluvial deposits that no line of demarcation can be drawn; we shall therefore close this subject by observing, that the alluvial and loose accumulation of sands, &c. covering the indurated sedimentary beds in Europe, contain principally organic remains belonging, or indigenous, to the zone in which they are now found. As this part of the subject is so well described in almost all geological works, we must beg reference to them, trusting that the outline we have given here is sufficient to show the agreement in the order of the sedimentary rocks with the action of the northerly movement of the magnetic

currents, and that this prime mover, which controls our planet, is equally available to guide us in our researches in sedimentary rocks as it is in the fundamental series and mineral deposits.

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## CHAPTER XIV.

### ON THE GENERAL NATURE OF THE DISTRIBUTION OF HEAT OVER THE SURFACE OF THE GLOBE, AND THE ZONES OF EQUAL TEMPERATURE.

IN order to avoid misconception with respect to the zones, and not to suppose that they are considered here as parallel bands, such as those mathematically drawn on our artificial globes, we introduce these observations to explain their general character, and their influence on the organic system.

It is now well ascertained that zones of equal warmth, both in the atmosphere and in the waters of the ocean, are neither parallel to the equator nor to each other. It is also known that the *mean* annual temperature may be the same in two places which enjoy very different climates, for the seasons may be nearly uniform or violently contrasted, so that the lines of equal winter temperature do not coincide with those of equal annual heat. The deviations of all these lines from the same parallel of latitude are determined by a multitude of circumstances, among the principal of which are the position, direction and elevation of the continents and islands, the position and depths of the sea, and the direction of currents and of winds.

The amount of the immediate solar heat depends upon the position of the sun in the ecliptic, the direction in which the sun's rays strike the earth, and the variable degrees of intensity occasioned by the atmospheric lens, illustrated in Plate XX. In proceeding from the equator towards either of the poles, without altering our height above the level of the sea, we must travel a great distance before we find the mean annual temperature reduced even a few degrees; but by increasing our elevation, a rapid change of temperature will be experienced, till we arrive

at the point where constant frost prevails, *i. e.* the curve of congelation. (See Plate.) The annexed table shows the relative height of this curve in different latitudes from the level of the sea :—

Latitude.	Height of Curve of Congelation.	Mean temperature at the level of the sea.
0	16,000	84·2 Fahr.
10	15,600	82·6
20	14,500	78·1
30	12,600	71·1
40	10,000	62·6
50	6,900	53·6
60	3,900	45·0
70	1,000	38·1
80	0	32·0

What we have stated above respecting the variable temperature of the sub-aërial zones according to the heights, we have every reason to suppose is applicable to similar sub-aqueous zones of variable temperature from the level of the sea downwards. At the equator, commencing from the level of the sea upwards, we have the following :—

Mean temperature.

Level of the sea 84°.

4,000 feet high	70°	descending to the level of the sea in	30° lat.
8,000	62	”	40
12,000	44	”	60
16,000	32	”	80

From the level of the sea downwards the temperature decreases in a similar manner, but the actual variations of temperature in the sub-aqueous zones are not known. All that is positively ascertained is, that within the tropics the ocean is found to be getting colder as we descend.

According to the concentrated rays, the heat of the sun ought to increase in depth, and such would be the case in an empty space; but liquids conduct heat very imperfectly downwards. A thermometer let down a few feet below the surface of a pond or of the sea, would, on being drawn up, indicate a lower temperature than that of the surface water; for the latter, heated by the rays of the sun, would communicate by conduction little or

no heat to the water below. Indeed it can be proved by experiment, that water does not transmit heat downwards by conduction ; whereas, in applying heat underneath instead of to the surface, it is easily transmitted. Had the globe contained an igneous nucleus, whatever might be the bad conducting quality of the crystalline shell, it would be heated, and that heat would be communicated to the ocean, and an ebullition would be produced sufficiently strong, if not to cause evaporation of the ocean, at least to prevent the formation of ice at the poles, and the heat would increase as we descend. The observed facts are quite the reverse. It is very probable that the ocean at a certain depth possesses a constant temperature, and according to observations made in the polar regions on the temperature of the ocean under the ice at the depth of 100 fathoms, we may consider it about  $45^{\circ}$  Fahr. We may appeal to observations for proof that it is at the surface of the globe the greatest variations of temperature take place, and from this surface they diminish as we ascend into the air or descend into the ocean, till in each direction they terminate at an invariable temperature, where the solar radiant heat becomes insensible ; and it is within these zones of variable temperature that the animal and vegetable kingdoms are bounded.

According to the above, we find that in sailing from the south pole to the north we are exposed to zones of variable temperature : commencing at  $32^{\circ}$  Fahr., and on arriving at the equator, it amounts to  $84^{\circ}2$ , and becomes reduced again as we approach the north pole to  $32^{\circ}$ . If, instead of sailing on the ocean, we sail through the air at the elevation of the above curve, we should be constantly exposed to the low temperature of  $32^{\circ}$ . The variable height of the land between the level of the sea and the curve of congelation must therefore vary the climate of the different zones, independent of their latitudes. Within the tropics we may obtain any temperature from  $84^{\circ}2$  to  $32^{\circ}$ , by regulating our elevation ; but in the frigid zone we are limited for the want of direct rays, and cannot obtain a mean temperature above  $50^{\circ}$  by depression, or by any other means we may choose to adopt ; consequently no changes in the relative position of land and sea can produce a tropical climate in the polar zone. The aspect of a country has an influence upon its climate, for this reason, that the angle at which the sun's rays strike the ground, and conse-

quently the power of those rays in heating it, varies with the exposure of the soil relatively to the sun. Countries in the northern hemisphere will be rendered warmer by having large tracts of low land to the south and sea to the north, and cooler when the relative position of these two is reversed. This fact is exemplified by a comparison of the climate of Europe with that of America and Asia. The western parts of the old continent derive considerable warmth from Africa. On the contrary, the north-eastern extremity of Asia experiences in the same latitude extreme cold; for it has land on the north between the sixtieth and seventieth parallel, while to the south it is separated from the equator by the North Pacific. The whole of Europe, compared with the eastern parts of America and Asia, has an insular climate. If lines be drawn round the globe through all those places which have the same winter temperature, they are found to deviate from the terrestrial parallels much more than the lines of equal mean temperature.

When we compare the climate of the northern and southern hemispheres we find a great difference in the corresponding parallels. There is no accurate information as to the mean temperature of any place beyond  $50^{\circ}$  of south latitude; but there is every reason to suppose that it differs considerably from that of places in the same degree of north latitude. In Sandwich land, according to Cook, in  $59^{\circ}$  of south latitude, the perpetual snow and ice reach to the sea beach; and in the island of Georgia, which is in  $54^{\circ}$  of south latitude, the line of perpetual snow descends to the level of the ocean. We therefore observe that latitude is one only of many powerful causes which determine the climate of particular regions of the globe. The coldness of the southern hemisphere in countries situated under similar circumstances as those in the north, has frequently been attributed to a cause quite inadequate to explain it, namely that of the sun being a shorter time (said to be  $7\frac{3}{4}$  days) on the south than on the north side of the equator. As the variable diameter and velocity of the sun has been already alluded to as optical deceptions, we need not dwell on the inadequacy of such an hypothesis to account for the difference, but simply state, that we believe the lower degrees of temperature of the southern zones as compared to those of the north, placed under equal circumstances,

arise from the northerly movement of the ocean. Ice has been seen floating in the southern hemisphere between latitudes  $36^{\circ}$  and  $39^{\circ}$ .

Having thus noticed the subject of temperature, it will be proper to advert to the amount of moisture which the atmosphere contains in different parts of the globe. In the temperate zone, with a mean temperature of  $52\frac{1}{4}^{\circ}$ , the annual evaporation has been found to be between thirty-six and thirty-seven inches. At Cumana, on the coast of South America (north lat.  $10\frac{1}{2}^{\circ}$ ), with a mean temperature of  $81\cdot86$  degrees, it was ascertained to be more than 100 inches in the course of the year; at Guadaloupe, in the West Indies, it has been observed to amount to ninety-seven inches. The average yearly quantity of rain is greatest within the tropics, and it seems to diminish the further we recede from the equator. In general much more rain falls in mountainous countries covered with extensive forests than in those where wood is less abundant. The following shows the quantity of rain fallen at Marmato, on the western Cordillera, latitude  $6^{\circ} 28'$  north, elevation above the level of the sea 4836 feet, mean temperature about  $68^{\circ}$ , from the year 1833 to 1841 inclusive.

	1833.	1834.	1835.	1836.	1837.
	Ins.	Ins.	Ins.	Ins.	Ins.
Jan. to March...	15·15	5·15	25·14	23·3	8·1
April to June...	24·3	29·6	34·6	39·4	23·9
July to Sept. ...	2·0	12·9	21·2	18·3	18·1
Oct. to Dec. ...	17·8	24·12	36·14	28·10	31·16
	59·6	72·2	127·16	99·0	81·7
	1838.	1839.	1840.	1841.	
	Ins.	Ins.	Ins.	Ins.	
Jan. to March...	21·10	10·16	18·3	12·3	
April to June...	41·18	28·0	22·0	26·2	
July to Sept. ...	19·0	23·16	9·3	16·35	
Oct. to Dec. ...	31·0	31·18	14·17	32·2	
	113·8	94·10	64·3	87·2	

It must not, however, be imagined that the climate of all hot countries is characterized by such abundant rains; for there are many which from one year to another are either almost or

entirely destitute of rain. This is the case along an extent of several hundred miles of the coast of Peru, and many other parts. At Cumana, on the north coast of South America, the annual quantity of rain is scarcely 10 inches ; and there are other places on the shores of that continent where none falls for several years, but where, nevertheless, vegetation is exceedingly luxuriant, owing to the humidity of the atmosphere.

In Santa Ana, on the central Cordillera, at an elevation of 3648 feet above the level of the sea, mean temperature  $75^{\circ}$ , latitude  $5^{\circ} 10'$  north, no rain falls for months together, yet the air is so strongly saturated that vegetation (excepting the plains below) flourish in their usual luxuriance. In the torrid zone, generally, the temperature ranges within comparatively small limits, and the various phenomena of the atmosphere occur from one year to another with a regular and uniform succession unknown in this part of the world : the *dry* and *rainy* seasons are the divisions of the year, depending on the position of the sun and elevation.

The subject of climate is in itself highly interesting ; but it becomes still more so when we extend our view, and consider its effects upon the numerous animal and vegetable tribes which are dispersed over the earth, and compare them with those of the past, which are now entombed in our rocks.

Every climate, as we pass from the plains just raised above the level of the ocean to the curve of congelation, has its peculiar vegetation. At the equator palms flourish within the zone, varying from  $80^{\circ}$  to  $70^{\circ}$  of mean annual temperature ; but on ascending to the elevation of 4000 feet above the level of the sea, to a mean temperature below  $70^{\circ}$ , they almost cease to grow ; however, a few isolated groups of particular species continue to flourish at a higher elevation in New Grenada. On ascending to the elevation of about 5000 feet the arborescent ferns cease to grow, and in the next zone (above) the vegetable tribe of the hot region disappears, and new varieties make their appearance, such as the oak, firs, and several others common in the temperate zones. Near the equator the oak grows at an elevation of 9200 feet above the level of the sea, and never descends lower than 5500 feet. It therefore follows that if the whole of the land within the tropics were to be elevated to 8000

feet all the tropical plants would disappear, as there would be only a temperate zone within the tropics; if, on the contrary, the land was depressed so as to be entirely below 3000 feet, or say mean temperature  $75^{\circ}$ , there would be only the productions of the hot regions: therefore the oscillations of the land must considerably influence the width and parallelism of the zones. In the former there would be no tropical band on dry land, and in the latter case it would be much augmented; consequently they can never be definitely marked, or permanently preserve their parallelism.

When we compare the productions of the southern hemisphere with the north, in corresponding zones of equal mean temperature, we find a great difference. Among the tallest of living trees the Norfolk Island pine is found in south latitude  $30^{\circ}$ , but is not known in the north temperate zone. Tree ferns, which require abundance of moisture, as well as equalization of heat, are found in Van Diemen's Land and New Zealand in south latitude  $45^{\circ}$ : there are none in a corresponding latitude in the northern hemisphere. The distribution of plants cannot therefore be explained solely by the influence of climate, for it frequently happens that similar climates are found in different parts of the globe without identity of productions.

In ascending from the vegetable to the animal world, and from one rank of animal existence to another, the most admirable order is manifest. Each description of zoophyte has its place of residence determined by the temperature and nourishment required for its support. The zones of depth below the level of the sea may be governed by a law similar to those above.

Professor E. Forbes, in his admirable observations on the Mollusca and Radiata of the *Ægean* Sea, states, "It was found to be a law, that the extent of the range of a species in depth is correspondent with the extent of its geographical distribution. On the other hand, species having a very limited range in depth were found to be either peculiar Mediterranean forms, or such as are extremely rare in the *Ægean*, but abundant in more northern seas. The Testacea of the *Ægean* are for the most part dwarfs, as compared with their analogues in the ocean, and the number of Medusæ and Zoophytes are comparatively small. Below the fourth region in depth the number of animals dimi-



nishes as we descend, until, in the lowest part of the eighth region, the number of Testacea was found to be only eight, indicating a zero in the distribution of animal life at probably about 300 fathoms.

“ In the upper regions the more southern forms prevailed, whilst those of the lower zones presented a northern character, indicating a probable law, that in the distribution of marine animals regions of depth are equivalent to parallels of latitude.

“ Any oscillations of level, however slight, would produce alternations of strata containing distinct groups of organic beings with others void of such ; and partial alternations of marine and freshwater beds would be formed, a phenomenon now in progress on the coasts of Asia Minor. All this would occur without convulsions or violent catastrophes of any kind. Changes of level, however slight, might cause the extinction of whole genera of animals and plants, of which only such as hard parts would be preserved. Were the present sea-bottom of the *Ægean* to be upheaved, whole classes of animals would disappear and leave not a trace behind to assure the future geologist of their having existed\*.”

With respect to *fishes*, it is probable that every basin of the ocean has its particular tribes ; while indeed the regions which some inhabit are well known. The most remarkable species of fish are met with in the torrid zone and its vicinity. Here the *lizard tribe*, under the various names of crocodiles, gavials, alligators, and bavilla, attain to an immense growth ; but each variety, although within the same zone, is confined to particular regions, as the crocodile of the Nile and the alligator of the Orinoco.

When we consider terrestrial animals, but more especially those that are wild, we may divide the earth into a number of zoological regions or provinces, each of which, in the same individual zone, is the residence of a distinct set. The first of these provinces, if we commence from the north, is the arctic region, which contains the white bear, the rein deer, the arctic fox, and other tribes common to both of the great continents. The northern temperate zone is divided by the ocean into two great districts. The same tribes are found to be spread from

\* Athenæum, No. 830.

the western to the eastern parts of the old continent; but the quadrupeds which inhabit the temperate climate of America are peculiar races. The equatorial region contains three extensive tracts widely separated from each other by sea: each of the three tracts has a distinct nation of quadrupeds. The large region of Australia forms another zoological province, in which are contained many indigenous tribes of a very singular description; and lastly, the southern extremities of America and Africa are each distinguished by the possession of peculiar races.

Of these several provinces into which the animal world admits of division, none has so remarkable a stock of animals as Australia. It possesses several entire genera of quadrupeds which have been discovered in no other part of the world. One remarkable tribe is the *Marsupial*, which term comprises such as produce their young in an immature state, and keep them for a time attached to their bodies, chiefly in abdominal *bags*, given them by nature for that purpose. The *opossum* is peculiar to the southern hemisphere, and is very common in the lofty forests of America. We behold in every region striking instances of the structure of animals being fitted to the general nature of the country in which they reside.

If we take a general view of the zones of equal temperature, both above and below the level of the sea, and consider that each has its peculiar vegetation, and again, that each zone is furnished with different groups of animals adapted to its temperature and general production, we can easily conceive that a very slight oscillation of land and sea would cause the extinction of whole genera of animals and plants, and that those bands of variable temperature, from the equator to the poles, can never be expected to be parallel to the equator, but always to present great undulations according to the relative position and height of the dry land and the bottom of the sea. Therefore, in tracing the general effects of the northerly movement of the surfaces, and comparing the effects with existing nature, we must take all the above questions on the modifying causes of temperature and variable distribution of vegetables and animals into consideration, and not be limited to the mathematical zones of geography.

In closing this chapter, we may note, that various calculations

have been made with the view of ascertaining the mean depth of the sea; this is a mathematical refinement which cannot be supported by physics. We may as well attempt to find the mean height of the dry land above the level of the sea by centrifugal forces, &c.\* However, our present question is that of observation, and need not be mixed with geometrical analysis; and we recommend the reader to refer to actual facts, and judge for himself.

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## CHAPTER XV.

### ON THE POSITIONS, UNDULATIONS, CONTORTIONS AND FRACTURES OF THE SEDIMENTARY ROCKS.

THAT disturbing forces have acted on the sedimentary rocks during and after their formation, is abundantly proved by their general appearance in all parts of the world. We have shown that the surface of the dry land has been cleaved, fractured and dislocated, and that there is scarcely an area of a few square miles which does not bear marks of having been acted on by subterranean forces. Since this is the case with the fundamental crystalline base, it is reasonable to suppose that the sedimentary beds deposited on it would be similarly affected; not simply by the periodical and sudden effects of earthquakes, but by the quiet and insensible slow action of the magnetic currents, perpetually altering the plane of the beds by numerous undulations and different relative positions; so that a series may commence to be deposited on a concave, half formed on a level plane, and completed on a convex surface; sometimes receiving the elements on the one side, and again on the other, according to the nature, amount and continuity of the subterranean forces.

Suppose, for instance, we find a series of rocks in the north-

\* Persons who have been led to suppose, by the established geometrical theory of the 'Principia,' that at the equator centrifugal and centripetal forces are equal, and that the trade-winds sweep over the zone with great force always in one direction, &c., may probably be surprised when informed that such is not the case.

ern hemisphere, containing in the ascending order, first, beds with organic remains belonging to the south temperate zone; another series of beds inclosing marine and terrestrial animals corresponding to those of the tropics resting on them; and again, beds of marine and freshwater shells alternating, similar to those now living in the northern hemisphere, completing the series: such a formation would show that the beds must have undergone a considerable oscillation since the commencement of their deposition. The whole series, in moving from zone to zone, would be governed by the local nature of the base on which it rested, and would necessarily conform to all the changes which may periodically occur in the inferior bed. One of the most satisfactory results arrived at in the study of the sedimentary rocks, is the certainty that the subterranean movements of the solid crust of the globe, to which the deranged positions of the strata are owing, were not all of the same date, but that some mountain ridges and some lines and points of stratified rocks had been bent and disturbed before others were formed.

Let us suppose a coal formation to be now forming near the mouth of the Rio de la Plata, and the movement *en masse* northward to be 20 seconds per annum, it would take 2200 years to arrive within the tropic of Capricorn; during this period there would be very considerable changes in the configuration of the land; and when we consider the longitudinal extent of the movement, say about 750 miles, we need not be surprised that the mass should happen to be much contorted and elevated or depressed a few thousand feet from its former relative position. From the tropic of Capricorn to the equator the sedimentary mass may remain above the level of the sea and form the habitation of the organic beings confined to that part of the earth, whilst another mass of the same age may still remain under water. From the equator to the tropic of Cancer it may become again submerged below the level of the sea, and thus receive additional layers of sedimentary beds; on its emergence from the sea in the northern hemisphere, it would present an undulated compound, containing a different series of organic remains belonging to distinct zones, with one strong line of demarcation, showing the absence of the beds belonging

to the south tropical zone, arising from its being then above the sea level. It will, therefore, be observed, that although the sedimentary series of rocks are commonly described as if they were regularly built on each other in the following order, Cambrian, Silurian, Coal formation, Lias, Oolite and Chalk, with a series of beds called Tertiary, they are never found so complete in nature. It is true that the order of the beds is never found inverted, yet a great number are always absent, and their respective development varies considerably in different localities. England contains almost all the series from the south frigid to the north temperate, but not piled on one another, as described in the usual geological sections, but overlapping at the edges at different extremities of each other, thus showing that although some parts were constantly under the sea receiving new deposits, they were not always the same, but alternately changing according to circumstances. By reading some geological works it may be supposed that the earth was once actually covered by all the variety of beds, like the concentric coats of an onion; but such an idea is very erroneous, because it is abundantly evident that the depositions were extremely local.

In order to give a more general idea, and comprehend the relations of superposition of the sedimentary rocks, as actually observed in the different zones from south to north, and to show that although the order is never inverted, the beds are often wanting, and seldom seen in their complete numerical order, we shall enumerate the series in the following manner:—

Deposits.	Contents.	Geological names.
1. South frigid zone.	Trilobite, Orthocerata, &c.	Cambrian and Silurian.
2. South temperate.	Terebratula, Producta, Encrinure, Spirifer, &c.	The great coal formation.
3. South tropic.	Ammonites, Belemnites, Gryphites, &c.	Oolite.
4. North tropic.	Echinus, Fusus, Pecten, &c.	Chalk and clay.

1. Commencing our examination south in Patagonia, we find, by a transverse section from Rio Santa Cruz to the base of the Cordilleras, and another on the Rio Negro, that the whole sedi-



not be found under No. 2, nor any other in the inverted order. A deposit may be of the same age and belonging to the same zone, that is, exactly equivalent to another, and yet differ both in lithological and zoological character, and thus cannot be determined without the aid of the inferior and superior beds.

During a late survey in Ireland the writer saw pits being sunk in No. 1 in search of No. 2 (coal) on the eastern side of the Wicklow mountains; although no fossil could be detected in No. 1 to prove that coal could not exist below, yet the structure of the beds, and their lamination, enclosing veins of quartz and pyrites, were sufficient to show, not only their contact with the primary base, but their actual transition: it was like cutting into the body of a tree in search of the bark. When the upper series of the sedimentary beds are much developed the lower are seldom found underneath, and *vice versa*; it is essential to bear this fact in mind when making trials for coal below the Chalk, Oolite, &c., as a thick seam of coal could not exist, even had it been originally deposited in the spot, under such a pressure as would be produced by a *complete set* of the superincumbent series; therefore those who have studied geology from theoretical sections must modify their ideas on this point.

It is a very common observation in geological works, "that we can, by the aid of geology, see as it were into the interior thirty miles or more; for Pallas had described, in the peninsula of Tauris, a series of parallel strata as regular as the leaves of a book, inclined at an angle of  $45^{\circ}$  to the horizon, and exposed in a continuous section eighty-six English miles long." The above series is a *laminated crystalline rock*, and not *sedimentary beds*. In South America, we may see sections of such a series for upwards of 300 miles in extent, in an east and west direction, exhibiting such inclined planes. To deduce the thickness of the earth's crust by the planes of lamination, is like calculating the depth of a transverse section of a tree by the *medullary rays* instead of the *concentric rings*.

The more recent deposits must necessarily be less contorted and fractured as a whole than those which are more ancient, on account of their being subject to less disturbances, and not so compact: the fractures and dislocations visible on the surface of any series of rocks would not afford a just estimate of the amount

of disturbances to which that particular part of the earth's surface has been subjected. Extensive ranges of country often have the beds of rock of which they are composed thrown into particular lines of direction. Such lines, when considered in the usual manner with reference to our general ideas of distance, appear of considerable length; but when viewed, as they should be, in connexion with the whole superficies of our spheroid, a large proportion of them lose their apparent importance: many of them are then seen to be so short, that the cracks or elevations of strata by which they are marked may readily be conceived to have been effected by comparatively small intensities of force. It is a want of due attention to the relative proportions of the radius of the earth to the height of mountains and the undulations of strata, which is probably the cause of such disturbances being considered as the result of forces so tremendous as those arising from an igneous nucleus and a broken shell. (See Plate XX.) Most gigantic and awful igneous forces are now commonly brought forward to account for disturbances which could be effected by an ordinary hydrostatic press connected with a subterranean sheet of water.

The gradual northerly crystalline action of the Dartmoor granite tilting the southern edges of the strata of North Devon has been ascribed to an igneous eruption. It is a singular fact that the sedimentary beds are principally tilted on the *southern edges* in Europe and America, indicating very forcibly the effects of a northerly action.

When we minutely examine the faults in coal-fields, we have abundant proofs that they were not the effect of volcanic convulsions or earthquakes, but the result of a quiet, uniform operation of nature. Movements, fractures and dislocations, of such order, regularity and extent as we find in the whole masses of rocks constituting the surface of the globe, require a corresponding, slow, regular and powerful acting cause, such as that which we find in the operations of terrestrial magnetism. Volcanoes and earthquakes are merely secondary forces, *i. e.* the effects of the subterranean currents; therefore even the local and irregular effects from these actions must be classed under the same natural operation as those above alluded to. It is anything but desirable to have constant recourse to great forces in explaining



geological phenomena, when the exertion of a comparatively feeble power will afford sufficient explanation. We very commonly observe in coal works, when the workings happen to be very extensive, the lower beds swelling upwards, and sometimes the upper bulging downwards until they meet, without producing a single crack; here we have contortions of solid rocks by a slow action, without those awful subterranean disturbances and igneous matter to soften rocks, which some geologists are so fond of contemplating. The mere elevation and contortion of mountain masses can be produced by a slow force as well as by other means; and the examination of these upraised mountains shows that the effects could not be produced by one great and instantaneous action. Contortion requires that the rocks should be in a yielding state, and that the particles be capable of a certain movement among each other, so that in applying force no absolute fracture would occur. Were we to attempt to bend a bed of limestone by one instantaneous action, the probability would be that it would immediately break; but if we gradually apply pressure, so slow as to afford time for the constituent particles to adapt themselves to the change, the bed may be subjected to any degree of contortion without fractures while *in situ*; where it is always saturated with carbonic acid and the usual natural solvents. The volcanic forces are insignificant compared with the apparent feeble force of magnetism; it is like the effect of a blow from a sledge on a sheet of ice on a pond, compared with those effects which would be produced by water if confined and connected with a hydrostatic press; the former would exhibit a great break in one individual spot, but the latter would fracture and bend the ice throughout by a slow and insensible action. The disturbances thus produced on the ice would be greater than those observed in the crust of the earth, when viewed in their relative proportions.

When we consider that rocks have been liable to be contorted from the time they were in a state of mud to their consolidated state, we can easily conceive why they should present such bends as we now find in them. The extent to which the particles of various rocks, saturated with water as they always are in nature, may be compelled to move among each other by great pressure, has never been sufficiently considered. Indeed rocks

have been viewed too much in the sense of dry, hard and inert, instead of active and moist masses : an absolute dry and compact rock would be a phenomenon in nature, *i. e.* an extraordinary exception to the usual natural production.

It is exceedingly difficult to expel moisture from rocks, and when expelled the difference in weight is found very considerable. Limestones contain a great quantity of water, and are sometimes found at great depths very soft ; and often, by means of the weight of the superincumbent beds, force a great proportion of their soft parts into the joints of the bounding beds. Sometimes limestone beds and hornblende veins have been thus introduced between the planes of sedimentary beds. As this part of the subject has been anticipated by the observations made on the nature of the crystalline rocks, we need not extend them here ; we shall conclude by stating that stratified rocks are not homogeneous inflexible dry and solid masses, on the contrary they are composed of numerous moist and pliable sheets, capable of extension and compression, and easily twisted and bent under pressure.

We have already alluded to the effects of cleavage, *i. e.* that all the sedimentary rocks are liable to be cleaved by the primary base\* : this is particularly the case with coal, and which greatly facilitates the extraction of the coal-seams. Parallel to the stratification of the seam are, first, the *partings* ; intersecting these, in a more or less vertical position, are the *polar cleavages* : these last separations are sometimes called *backs* or *slines*, or *bright heads*, from the coals separating at these cleavages with clean and highly polished surfaces, except when, as often happens, the complanatory lustre is covered with a rusty-looking scale, or with the well-known white sparry concretion, consisting for the most part of carbonate of lime, derived from the infiltration of the solutions of the bounding beds ; besides these fissures, there are others passing nearly at right angles to the planes of cleavage, fractured divisions, and appropriately denominated *cutters* : so that by means of this compound system of natural series of lines,

\* Attempts have been made to distinguish sedimentary beds by the cleavage alone, but this is no guide, because *any bed* or *compact soil* even is liable to be cleaved by the primary in favourable localities. In New Grenada the soil is often found cleaved subsequently to the growth of the oldest trees.

the coal, under favourable circumstances, easily breaks down in parallelepipedal masses.

### *Faults.*

In Chapter VII., on Dislocations, &c., our observations were principally confined to horizontal and diagonal movements; but in sedimentary or more or less horizontal beds, these kinds of disturbances are not so much felt as the vertical displacements called "faults." They are first produced by the splits and transverse fractures of the primary base, as already explained. The north and south lines are called *main faults*, and the east and west *cross faults*. When the strata rest on a semifluid base, such as beds of clay and moist carbonate of lime, the divisional planes disturb the uniformity of the pressure, consequently the isolated masses will gradually subside or elevate according to the angle in which they are separated. The most simple and frequent case of faults is represented in Plate XXI. Let us consider what would be the consequence of the oblique separations of the series of beds in Fig. 1, supposing they rested on a soft stratum. According to the laws of statics, the pressure will increase as the lower area of the masses becomes less than the upper, and *vice versa*: the weight divided by the area will give the amount of each, therefore the *wedges will sink* and the *parts between them rise* to restore the equilibrium of the pressure on the semifluid base, as illustrated in Fig. 2. The planes or joints, when they are found in contact, are often seen grooved and polished by the friction or the rubbing of one side against the other: and as the direction of the action must necessarily depend on local variations, the polished striæ are not always parallel, but commonly curved and irregular. Sometimes the beds are separated vertically upwards of 1000 feet, yet the masses of the uplifted and depressed strata do not present such irregularity on the surface; the action having been so extremely slow, that the upper parts have been modified and obliterated by atmospheric and aqueous causes; during the displacement therefore we only see the wreck of the elevated masses in the shape of sand, clay, &c., and the greater part of this washed away.

It has been supposed that even these "faults" were the result of violent mechanical convulsions produced by volcanoes, but

such notions have arisen from the want of a more practical knowledge of the general appearance and order of the disturbed strata. Sometimes "faults" are filled with clay and various other substances from the base below, or from the softer interstratified seams by means of the pressure; these clay veins are impermeable, and consequently the water percolating in each mass is retained by these natural dams, which is of great advantage to the independent workings of coal districts. The coal on one side of a fault is often different from that on the other side; sometimes losing its bituminous quality and becoming impregnated with other elements. Occasionally a perfect transition may be observed from anthracite to bituminous coal, the modifying cause being from the former to the latter. Not only is the water separated by the "faults," but also the subterranean gases, the local accumulation of which is much influenced by the angular position of the "faults" and dip of the beds. This interesting question deserves a separate investigation in connexion with the best mode of ventilation, or practical means of neutralizing the disastrous effects of these dangerous elements, which the coal miner has to encounter: we shall leave it to those who may have the opportunity of making the necessary examination.

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## CHAPTER XVI.

### GENERAL OBSERVATIONS.

IF we now take a general view of the effects of terrestrial magnetism in combination with other secondary agencies really existing, we find a sufficient natural cause to explain all the characteristic changes which have been observed in the earth's condition, in the degree, combination and sequence which actually belong to them. Each of the phenomena, taken singly, is capable of demonstration in all its details of circumstances by the operations of terrestrial magnetism in connexion with some special branch of natural science.

*First.* We have ample proofs of the existence of the magnetic

fluid enveloping our globe, and that it has two points of convergence, which we call poles; that this fluid has a motion from the south to the north pole, and has an influence on all matter, causing all bodies to fall towards the earth, which we call attraction of gravitation, and also tends to cause bodies to arrange themselves in a meridional direction, called polarity, as shown by the magnetic needle; and that the latter action tends to propel all matter northward; and finally, that it acts both mechanically and chemically on all matter.

*Secondly.* This northerly movement is observed in the ocean, which is found to carry all substances that happen to float in it from the south to the northern regions.

*Thirdly.* The grain of the primary crystalline presents a polar structure in all parts of the world, thus showing the universality of the action. The modification in the transitions of the different rocks, the elongation, fractures and dislocations, show the general northerly movement of the whole surface.

*Fourthly.* Volcanoes and earthquakes appear to be the effects of the chemical action and meridional force of the magnetic currents.

*Fifthly.* The formation of mineral veins, their general character, order, and numerous dislocations prove the action of a polar force; the constant operation of which is essential to account for the observed subterranean phenomena.

*Sixthly.* This northerly movement co-exists with the formation of our globe; it is the increased density of the currents at the poles which is the cause of its oblate figure; and it perpetually changes the surface of the earth, by bringing the consolidated masses, as they are formed in the southern hemisphere and other parts of the globe, towards the north pole, and thus exposing them to the temperature of different zones; consequently we find the relics of the southern in the northern hemisphere. Such series of beds are never found in the south, nor is the order of the deposits ever seen inverted. Therefore we have no need to invent strange hypotheses to account for the observed facts, but simply apply the natural operations of nature, *i. e.* the prime mover of terrestrial physics—magnetism, to guide us in our geological researches.

If, then, this power is so extensive, and embraces that effect

which we call gravitation, its operations are not confined to the surface of our globe, but must extend to the whole solar system; and if all space is filled with the magnetic fluids of the different celestial bodies according to their respective magnitudes, their movements must be explained differently to the commonly received hypothesis; because a resisting medium is incompatible with the Newtonian philosophy, and a perfect void is indispensable to the assumed geometrical movements demonstrated in the 'Principia.'

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## CHAPTER XVII.

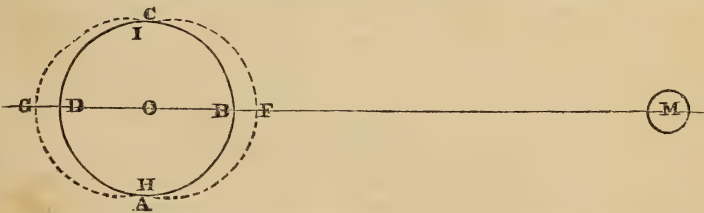
### UNIVERSAL MAGNETISM.

WITH regard to the absolute diameter of the terrestrial magnetic fluid, there is no definite data by which we can ascertain it; but from the apparent influence of the moon on the surface of the earth, together with her orbital motion round the globe, we have reason to suppose that it extends to the orbit of the moon. Within the tropics we have striking evidences of the influence the changes of the moon have on the growth of vegetation. From the new moon to the full there is a very intense action of the sap, accompanied by a great evolution of hydrogen from the leaves; and so strongly saturated are the trees during these periods throughout the year, that if cut and used for any purpose they would become rotten and useless in the course of a very few months. During the latter period of the change, viz. from the full to the new moon, there is a temporary suspension in the action of the sap, the woody substance becomes consolidated and is rendered fit for cutting. So much is this the case, that we find it rigidly attended to, from the making of a common fence to that of the largest works. It does not follow, that if a tree should contain 100 rings that it is a hundred years old; because *within the tropics* there are *monthly* rings, formed by the expansion of the external part of the trunk during the *rise* of the sap, and not, as has been supposed, by a mechanical return of the superfluous sap from the branches downwards between the trunk and the bark. A bamboo of three

years' growth contains about thirty-six knots; each shoots out monthly, like the extension of a telescope. The central pith, or heart of the trees, varies from the centre according to the angle of the hill on which they grow, the roots being generally more extended from the trunk down the hill than they are on the upper side, and consequently feeding stronger: the transverse sections of the trees on such declivities exhibit elliptical rings, very wide on the side of the strong roots, and diminish to mere lines on the opposite side, as shown in the following sketch.



That the moon has an influence on the ocean is a fact well known, although not such as is usually represented according to the established theory of the tides. It is said "that the moon attracts the ocean; that is, when any part of the surface of the sea is turned towards the moon the water is drawn towards it, and raised into a tide, which falls again when the place is turned away from the moon. The water rises to the same extent on the side opposite the moon; so that there is always high water on the two opposite sides of the globe at the same time. Let A B C D represent the earth, and M the moon, and let the surface at B next the moon, and that at D, opposite, consist of water."



It is said, "as the force of attraction is greater in proportion to nearness, and less in proportion to distance, the moon will exert her greatest influence in the waters at B, which accordingly will be drawn towards the moon to F, and their surface will form the dotted curve. The waters on the opposite side being further from the moon than the earth, the moon will attract it

more strongly than the waters. The earth, therefore, will be drawn away from these waters; and they *being left at a distance* somewhat greater than the usual surface, will appear to have risen from D to G." If the moon be capable of attracting the water at B, and the *whole bulk of the globe besides*, what keeps the water up at G? Surely the little covering at D would follow, if not withheld by some external power not noticed in the demonstration, and especially when the sun and moon are in conjunction. It may be argued that Laplace and other astronomers have established the consistency of such a doctrine: as all the complicated and intricate analysis used rests on the truth of the conjectures or assumptions made for procuring the possible application of the fundamental equations the argument is of little avail. Had such tides existed at the equator, proportionably to the supposed attractive curve, in the ratio of the length of the ordinates, according to the geometrical degrees of intensity, the Low Countries would be completely inundated; but the fact is, there are no such tides at the equator, at least on the coasts of South America, in the Pacific, nor in the Atlantic. The tides there and in the West Indies are comparatively insignificant, amounting only to a few feet. However, although we are not able to describe the exact mode by which the electromagnetic action of the moon operates on the surface of our globe, yet we have abundant proofs of the existence of a physical connexion between the two bodies. It is equally evident that there is a connexion between the variable changes of the moon and the weather, and this has been calculated upon from time immemorial, especially within the tropics.

If, then, the aërial ocean, combined with the magnetic fluid, extend to the moon, we may presume from analogy that the satellite floats upon it, and may possibly be carried round the earth by means of a circular current, similar to that of the trade-wind; and that the planets may be sustained and revolve round the sun on the same principle, as they all circulate round that body in the same direction. The sun rotates on an axis nearly perpendicular to the orbit. In round numbers, fourteen rotations of the sun imparts one orbital revolution to the earth; twenty-eight rotations of the earth impart one orbital revolution to the moon, and all in the same direction, *i. e.* from west to east. Here, then,



we have an analogy with what we see produced by circular motion of fluids, moving in one definite direction by a prime mover; the slower and more majestic movement corresponding with greater dimensions of machinery, and thus impressing on us the prevalence of an harmonious law of action and circular movements, and not mere accidental compound of forces produced by the casual meeting of two forces arbitrarily assumed. We know that bodies may be sustained at any elevation in the air, as well as in the ocean, by adjusting their densities to that of the stratum of fluid in which they may be placed; and that such bodies, like the balloon in the air, or a vessel on the ocean, would continue to revolve uniformly round the earth by a circular current. This is consistent with our daily experience, and according to the well-known laws of nature. No one would presume to say that the clouds are retained in their positions by means of centrifugal forces, and that they would fall towards the earth if such forces were removed. As nature is considered always conformable to herself, we have no right to assume powers different from those that exist; therefore we have no reason to suppose that the moon is retained at her respective distance from the earth by a power different from that which retains the clouds. The moon, as well as the earth, may be filled with hydrogen, or with still lighter gas for aught we know to the contrary, and which is an opinion infinitely more probable than that of its being filled with igneous matter; consequently a shell containing such a gas enveloped with an atmospheric fluid, kept together by the magnetic attraction, would render the moon sufficiently buoyant to float on the external part of the terrestrial fluid.

*On the established Laws of Motion as applied to the Heavenly Bodies.*

It is said that celestial bodies are not sustained in their orbits like those we observe in terrestrial physics; they have laws of motion peculiar to themselves, which have been assumed and blended with the laws of geometry. Indeed, so far as physics are concerned, it matters not much what hypothesis may be adopted in astronomical phenomena, provided our calculations be founded on uniform spaces, velocities, &c., as the whole are reduced to the laws of proportion which subsist between sines

and cosines, and not in the least depending on real physics. Admitting in the abstract that such a space as a perfect void existed (which is not the case, according to astronomers themselves), a body placed in it would remain for ever at rest; let us then suppose the body to be put in motion by an external force; not a vital principle, nor means of generating a force, but one impulsive action: what would be the consequence according to the established laws of nature founded on experience? According to terrestrial physics, experience and analogy, all forces depend more or less on the expansion of a power previously concentrated: for instance, a boiler full of steam (or any other gas) is a power, but cannot produce any action without expansion; but immediately on allowing it to expand it will produce effects proportionable to its density, the force of which, if not supplied by some generating power, will diminish inversely as the cube of the volume increases. The ultimate extent of the expanding power need not be considered, but its variable force and velocity; these are the questions at issue.

We know, and it has been proved experimentally, that an impulsive force, limited in its amount, has an evanescent quality, and consequently any body or point carried by it commences with a maximum force and velocity; it cannot describe equal spaces in equal times; "like causes produce like effects, or, in similar circumstances, similar consequences ensue;" the force must therefore diminish, and consequently the velocity, inversely as the volume increases, until it finally arrives at a state of rest, *i. e.* a state of equilibrium between the limited impulsive power imparted and the actual effect produced. Indeed engineers are so much accustomed to the above law of forces that it requires but little comment.

When a ball is discharged, it is not the mere resistance of the air and the earth's attraction that destroy its rectilinear velocity and brings it into a state of rest, but it is the evanescent quality of that power which had put it in motion: the resisting medium and the attraction of the earth only diminish the extent of its path. According to the doctrine of gravitation, neither the radial attraction of the planets, nor a resisting medium, can destroy the impulsive effect: these obstructions are considered to exist in the planetary system, and indeed are applied in calcula-

ting the motions of the comets. Had such a doctrine of the laws of motion been founded on facts or correct data, we should have no difficulty in effecting a perpetual motion. The late proposed aërial machine, although it did not possess a single element fit for the purpose intended, was yet founded on the principle of motion promulgated by the Newtonian doctrine,—to be projected into the air by one impulsive action, so as to acquire a certain velocity, with which, it is said, it would be capable of retaining itself at a certain elevation, and continue to describe equal spaces in equal times.

The following extract from a standard work on astronomy, written by one of the first philosophers of the day, will at once show on what foundation the orbital motions of the ‘Principia’ are based, and how geometrical curves and the paths of projectiles have been confounded.

“All bodies with which we are acquainted, when raised into the air and quietly abandoned, descend to the earth’s surface in lines perpendicular to it. They are therefore urged thereto by a force or effort, which we term *gravity*, and whose tendency or direction, as universal experience teaches, is towards the earth’s centre; or rather, to speak strictly, with reference to its spheroidal figure, perpendicular to the surface of still water. (See Plate I.) But if we cast a body obliquely into the air, this tendency, though not extinguished or diminished, is materially modified in its ultimate effect. The upward impetus we give the stone is, it is true, after a time destroyed, and a downward one communicated to it, which ultimately brings it to the surface, where it is opposed in its further progress and brought to rest. But all the while it has been continually deflected or bent aside from its rectilinear progress, and made to describe a curved line concave to the earth’s centre, and having a *highest point, vertex or apogee*, just as the moon has in its orbit, where the direction of its motion is perpendicular to the radius. When the stone which we fling obliquely upwards meets and is stopped in its descent by the earth’s surface, its motion is not towards the centre, but inclined to the earth’s radius *at the same angle as when it quitted our hand*. As we are sure that, if not stopped by the resistance of the earth, it would continue to descend, and that *obliquely*, what presumption, we may ask, is there that it

would ever reach the centre, to which its motion, in no part of its visible course, was ever directed? ”

If it is true, that a body thrown up at a certain angle, say  $45^\circ$ , will descend again at an angle of  $45^\circ$ , it follows that if thrown sufficiently high it would escape the earth altogether, and possibly revolve round it : but what is the *fact* ? It is, that bodies *do not* return at the *same angle*. Suppose a stone was thrown up at an angle of  $45^\circ$  with a force which would carry it to an elevation of 500 yards, it would on its near approach to the earth descend almost *perpendicular*. It commences with its maximum angular force, which exceeds that of the radial attraction of the earth proportionably to the sides of the parallelogram of which its path is a compound ; at its greatest elevation the radial attraction and the impulsive force are in a state of equilibrium ; as the latter rapidly decays, the former being constant and accumulating, the stone returns, and the angular or tangential force becomes evanescent, until at length the stone is left to the sole action of the radial attraction of the earth, and therefore must proceed towards the centre. Those who may not feel disposed to prove the above mathematically, or who may prefer having an ocular demonstration of the fact, may have an illustration in the path of a stream of water forced by a strong pump at a given angle, when it will be observed that the curve of the stream of water, instead of forming the same angle at each extremity, will be very different.

We shall now proceed with the extract, to show the consequence which follows from the assumed proposition.

“What reason,” it is said, “have we to believe that it might not rather circulate round it, as the moon does round the earth, returning again to the point it set out from, after completing an elliptic orbit, of which the centre occupies the lower focus ? And if so, is it not reasonable to imagine that the same force deflects the *moon* at every instant from the tangent of her orbit, and keeps her in the elliptic path, &c.? . . . It is on such an argument that Newton is understood to have rested his law of gravitation.”

That the moon is retained in a circular path round the earth by the earth’s radial attraction, in the same manner as a balloon is retained at a certain elevation by means of the intermediate

fluids, no one will question; but that it should be retained there by a *projectile force*, is contrary to analogy, and cannot be demonstrated.

If, then, we find that a body put in motion by one impulsive action must ultimately come into a state of rest without any resisting medium, how much sooner must it exhaust its force if opposed by other forces, and especially if the latter should be constant! A straight line divided into equal parts is one thing, but to produce a force to describe such parts in equal times is another; the former is controlled by the laws of geometry, the latter by the laws of physics. This is the secret link which has been used to preserve the curvilinear doctrine of gravitation; without which tie it could not stand, and must be well known to those who have studied the 'Principia.' Is *this* a legitimate connexion?

We may observe that it was once proposed as a prize question by the Academy of Sciences at Berlin, to determine whether the laws of motion were necessary or accidental; that is, whether they were to be considered as mathematical or as physical truths. An attempt was made to deduce them from a metaphysical principle of the minimum of action in a very complicated and fanciful nature, the intricacy of which only tended to envelope the subject in still greater obscurity than is found in the 'Principia;' while the fundamental laws of motion are easily demonstrable from the simplest physical truths.

Besides the disagreement which exists between the rectilinear motions of the 'Principia' and those of terrestrial physics, there is another point connected with the composition of two forces, viz. the compound of the tangential and centripetal forces. We find that the diagonal of the parallelogram of two forces represents the magnitude and direction of the compound; but we must always bear in mind the distinction which exists between *statics* and *dynamics*. In the former it matters not how the sides of the parallelogram are accumulated, whether slow or quick, by small quantities or by large quantities; as long as the amount of the forces is represented by the length of the sides, a straight diagonal will represent the compound when in a state of equilibrium. The laws of dynamics are not confined to the extreme limits or the mere gross amount of the forces, but they

embrace also the nature of their accumulation ; we have to analyse the component parts and consider them in connexion with space and time. Speaking *geometrically*, the sides of the parallelogram may be of equal length, and therefore contain an equal number of parts ; but that is no reason that such parts should be described in the same time. Time is another element, and independent, having no necessary connexion with pure geometry ; it belongs to physics, and if we combine them we must do it legitimately. The laws of one are definite and unalterable, whilst the other may be modified according to circumstances. If we describe a circle, we find it in its usual exact proportion ; if we apply motion and time to describe a circle, we must adopt them for it, *i. e.* according to their own peculiar properties, and not *solely* by geometry. We are told that the planets are retained in their orbits simply by means of two forces, the tangential and centripetal ; and that if one of the two forces were taken away, these bodies would be either carried off in a tangential direction, or fall to the focus of the centripetal action. If a body put in motion by an uniform force in one definite direction be met by another body moving at right angles to it by a similar uniform force, they will form a compound at the point of contact, which will be equal to the diagonal of the parallelogram of the two forces, in direction and magnitude, and as their respective forces were uniform, the compound will be uniform and straight. (See Plate XXIV.)

Suppose the body set in motion by an impulsive or a variable force be met by an uniform force, the diagonal will be described by a variable velocity, and in a curvilinear direction. If the two forces be variable in the same ratio, the diagonal of the parallelogram will be straight, but described by a variable motion. If we require the compound to form a circle, and to be described in equal times and spaces, if the radius and velocities are to remain constant quantities, the centrifugal and centripetal must be constantly equal ; but in order to form the circle the tangential must possess the power of *perpetually changing its direction*, in a word, a *circular motion* ; without this the orbit cannot be described by the compound.

It must not be forgotten that an arc, although bounded by the same extreme limits in a parallelogram, however small it may

be reduced, cannot be considered as a straight line. Any attempt of making rectilinear and curvilinear figures equivalent by reduction, must be considered as merely merging into indivisibles and inadmissibles, if there be any truth in the laws of geometry. Indeed the question on the condition of forces necessary to produce given effects is clear and divested of all metaphysical obscurities, not requiring the differential calculus, and other methods of geometrical analysis that are so objectionable in their logic and conclusions. All we require to account for the moon being retained in her orbit, and the planets again in the atmosphere of the sun, and all moving in one definite direction, is the admission of magnetism, *i. e.* that mysterious power which we *know* to exist, circulating from pole to pole of every individual body, with a power varying inversely as the square of the distance, rendering the respective compounds or fluids of each body of variable density; and this again accompanied by an equatorial current or circular motion.

The application of the Newtonian laws of motion to the comets is still less satisfactory than it is to the planetary bodies. The comets appear to be gaseous bodies as rare as vapour; yet it is assumed that bodies so light move round the sun, and pass through the dense atmosphere of the latter by means of tangential and centripetal forces. Conceive a body, say a feather, to be drawn from a distance by means of a radial power increasing in force as the distance diminishes, and that it should arrive at the focus of the radial power, that the said feather should turn round such a focus, and move again from it, simply by means of the velocity generated in moving towards it, and thus continue to circulate in an elongated ellipsis round the centre: it is contrary to all analogy. If we apply magnetism, and assume that the sun is governed by a similar power, we have no difficulty in explaining the nature of the motion of comets. According to the laws of magnetism, a combination of magnetic globes in a state of equilibrium will have their respective poles dissimilar, *i. e.* the north end of one corresponding to the south end of the other, as described in Plate II. Hence it follows that the pole of the moon corresponding to our south pole must be the attractive, and that the pole of the sun corresponding to our north pole must be the repulsive. If we now suppose a comet a luminous

vapour, like the aurora borealis, moving by the polar currents of the sun, it would necessarily move nearly at right angles to the orbit; such are their paths. If, again, we consider them as mere magnetic sparks, they must be conveyed by the polar current to the attractive pole, and issue out again at the negative pole, and thus continue their circular motion from and to the axis of the sun by the magnetic currents. The light of the sun is too intense to examine minutely the effects of these bodies near it; probably in passing through the axis they present the appearance of a solar aurora borealis and australis.

The following description in Sir J. Herschel's 'Astronomy' is interesting:—

“ Their variations in apparent size during the time they continue visible, are no less remarkable than those of their velocity: sometimes they make their first appearance as faint and slow moving objects, with little or no tail; but by degrees accelerate, enlarge, and throw out from them this appendage, which increases in length and brightness till they approach the sun and are lost in its beams; after a time they again emerge on the other side, receding from the sun with a velocity at first rapid, but gradually decaying. It is after thus passing the sun, and not till then, that they shine forth in all their splendour, and that their tails acquire their greatest length and development, thus indicating plainly the action of the sun as the exciting cause of that extraordinary emanation.”

A singular circumstance has been remarked respecting the change of dimensions of the comet of Encke in its progress to and from the sun, viz. that the real diameter of the visible nebulosity undergoes a rapid *contraction* as it *approaches*, and an equally rapid *dilatation* as it *recedes* from the sun, owing probably to its passage through the axis. Cometary bodies may appear, in looking at them in the heavens, irregular and capricious in their paths; but a careful observation will show that they uniformly move to the same pole and emerge from the opposite. They may also pass through the axis of the planets in a similar manner, thus producing the phenomena of the aurora borealis and australis. (See Plate III.)

To conclude, we may reasonably consider that by this power the stability of the solar system is maintained, and the form of



the celestial bodies shows that it is an active agent in each. Nor is this universal power necessarily confined to our own system, but probably extends as far as telescopic vision can determine in the immensity of the works of the creation. This wonderful power is present in all things visible and invisible, like a mysterious and universal spirit controlling the vast works of the universe. Yet although so vast and so various in its effects, its laws of action are so simple as to be within the reach of our comprehension. It is like a wheel within a wheel working myriads of other wheels within its sphere of action ; we find it in the minutest microscopic crystal, in the aggregation of crystals which constitute a continent, in a word, in our globe bodily ; this again governed by the magnetism of the sun, and probably the sun by a still larger body, until we are lost in its immensity. Although the harmony and uniformity of the system may be thus preserved for ever, exhibiting no change, no beginning nor ending, yet we find in our terrestrial habitation, *i. e.* the earth, the seat of man, traces of beginning and ending : the spot on which we have our existence will by the same harmonious law of nature, independent of the globe itself, ultimately decay, and be reduced to its primary elements at the north pole. Great Britain, and other countries which are situated in the same parallel, will in a very few thousand years disappear from the surface of the globe, and other more southerly lands will take their place. Hence geology is not that crude, inconsistent and useless science which some have imagined it to be ; on the contrary, it cannot be surpassed in its utility nor in the sublimity of its objects : not only is it next to astronomy, but it also forms part of one and the same system of physical operations ; and besides, it instructs us “that we are placed in a part of a scheme—not a fixed but progressive one—every way incomprehensible ; incomprehensible in a measure equally with respect to what has been, what now is, and what shall be hereafter.”

## CHAPTER XVIII.

## ON THE GENERAL APPLICATION OF THE LAWS OF TERRESTRIAL MAGNETISM.

NOTWITHSTANDING the existence of magnetism has been so long known, and turned to account in navigation and general surveying, and has been the subject of numerous experiments and theories, the application of this principle, beyond that of the above, has been of a nature purely local, confined to mere toys, and never has been duly considered in the magnitude of its effects and universal character. A detail of all the various useful application of which this universal principle is susceptible, would occupy volumes, as it embraces all phenomena now classed under the head of gravitation; it has an intimate connexion with our proceedings, and we are always under the immediate dominion of its laws, which laws are found permanent, consistent, intelligible, and discoverable with only a moderate degree of research. Hence, since it is certain that such a principle exists, it is manifestly of the utmost importance to study its laws and to know how to apply them, were it for no other reason than to enable us in all we undertake to have at least the laws on our side, so as to avoid struggling in vain against difficulties opposed to us by natural causes.

It is the variation in the density of the enveloping magnetic fluid which is the cause of pendulums of equal length varying in the number of their oscillations in a given time in different latitudes; and in order to make them keep correct time, it is necessary to vary the lengths respectively according to the variation in the intensity of the radial attraction in each latitude. We find also that the zones of equal density in the atmosphere are not at equal heights in different latitudes, and therefore in making barometrical measurements the formulæ should be made to correspond to the variation in each latitude.

The *polarity* of terrestrial magnetism is the mariner's faithful guide when enveloped in darkness on the boundless ocean; and he knows that if masses of iron should be placed near the magnetic needle it becomes disturbed and rendered useless. The

knowledge of the cause of such disturbances for its safe application is as essential as that of the principle itself; and still more so, as it will protect its possessor from being misled by inventions which pretend to neutralize the effects of local attraction. The law of magnetic action will show what is within the limits of possibility and what is not; and that the less the natural current is disturbed, the more correct must be the indication of the needle.

3 3 1 9 5

We are to consider magnetism as a stream of subtle fluid constantly moving from south to north; should it be disturbed from its natural course, nothing short of the removal of such disturbances can give its true direction. The author made several experiments on this subject during his voyage from South America to England; therefore he speaks from experience, as well as from deductions founded on experiments. The most important points to be attended to are the following: to make the needles in the best form for retaining their magnetism, and in such a manner as to allow the currents to enter and issue out at two points diametrically opposite, and that the current may pass through without being interrupted by a dissimilar metal; and to place such needles in situations sufficiently distant from local disturbances.

#### *Variations.*

The charts of magnetic curves of variation are drawn at present in a manner that tends to mislead persons. Instead of laying down the direction of the needles as they would naturally appear when left to the sole control of the magnetic stream in their undulating meridional lines, they are marked in the most confused manner with irregular inflections of curves, indicating a total want of symmetry, and thus complicating the question of variation by lines which have no necessary connexion, productive of no advantage, but of much real injury to the problem itself. On reference to a chart, it will be observed that it contains two distinct lines, which are called lines of no variation; the western passing in a north-west direction from the South Atlantic Ocean to a point *called* the magnetic pole, round which a series of lines are drawn, having the appearance of a general convergence towards it, which on a superficial inspection leads to the idea that they represent the actual direction of the horizontal

needle, which is by no means the case: the eastern line of no variation is much more irregular, being full of loops and inflexions: it begins in latitude  $60^{\circ}$  south, below New Holland, crosses that island through its centre, and extends through the Indian Archipelago with double sinuosity, so as to cross the equator three times: it then stretches along the coast of China, making a semicircular sweep to the west till it reaches the latitude of  $71^{\circ}$ , where it descends again to the south, and returns northwards with a great semicircular bend, which terminates in the White Sea. In the Pacific Ocean we find elongated ovals described; what the centre of such ovals intends to represent it is difficult to imagine. Such is the confused manner in which the direction and variation of the magnetic needle are represented. If the chart were compared with Plates IV. and V., on which the same magnetic meridians are indicated by the arrows, it would scarcely be believed that they represented the same phenomena. It is to be hoped, for the sake of mariners as well as for the progress of science, that the lines will be shown in their simple natural state, and not confuse the phenomena with unmeaning lines, to suit formulæ which can never be of any utility.

#### *Rocks.*

We have shown how essential is the knowledge of the principle, not only for surveying lands, but for studying the structure of rocks, their modifications, disturbances and general character. By knowing the nature of the formation, the growth as it were of a series of crystalline rocks, their grain, and the laws of action by which they are controlled, we are enabled, first, to make a systematic examination, and the results must be more definite and satisfactory than it possibly can be without any rule or order. In the proper selection of building materials, it will teach us that rocks of the same nature are very different in structure, composition and durability, according to their geological position and the variable state of the compound. Like timber, so it is with stone; it is not equally durable in all situations, nor equally compact *in situ*.

#### *Mining.*

To the mine captain this grand law of nature has been of important service in carrying on his subterranean operations, but

its further application in directing him how to make new discoveries renders it of inestimable value. It not only shows the rocks in which mineral wealth is most likely to be contained, but also those particular portions of them where the greatest degree of remuneration may be expected. By this principle the great laws which regulate the distribution of mineral veins, and the arrangement of their subterranean treasures, are established. The apparent and real "heaves" may be distinguished, and all description of displacement can be ascertained on the same mechanical principles.

When the existence of subterranean electric currents was first discovered by Mr. Fox in Cornwall, it was naturally anticipated that they would afford some useful indications as to the relative quantities of ore in different veins, and also as to the directions in which they would be most productive. But on applying the necessary apparatus, we find it very uncertain in its indications; local action is often produced so as to cause the currents to move in all directions; hence, although the principle is unquestionable, the mode of applying it to useful purposes is very defective. Since we know that magnetic currents are the same, and governed by the same identical power, all difficulties in the application are removed, and the needle will always indicate the true direction, free from the effects of local chemical action, and in places where no mineral is visible. Indeed the knowledge of the effects, in a limited and local form, is often perfectly and accurately known to many, but more especially to the intelligent mining captains of Cornwall, whose extensive experience has naturally led them to an acquaintance with the nature and distribution of the great mineral masses in that county. To give consistency to the scattered elements thus acquired, to show the mode in which they are connected, has been the main object of this outline, and it is hoped that mining will be benefited by it. It will show that parallelism of bunches depends on the angular position of the lodes, and that it is an effect arising from a primary cause. The miner complains that the rapid progress of geology, and the geological surveys by eminent geologists, have thrown no light on their operations, and that hitherto geology is more indebted to mining than mining to geology. However, such is not the case with magnetism; its

aid has been already almost indispensable, and the manner in which it is now brought forward in connexion with geological phenomena will not only guide mining operations, but elevate geological science from the mere study of fossil shells, &c., to that of the sublime in magnitude, utility and moral good.

A geological investigation has been recently undertaken by the author in Ireland to determine the following points for certain parties; viz. first, whether limestone existed in a certain locality or not, where stones had been found, and a considerable sum offered for the undiscovered limestone; secondly, to ascertain whether mineral could be expected in a place which was considered, but somewhat vaguely, parallel to a neighbouring rich mine; and, thirdly, if coal existed in a certain place where workings were actually carried on in search of it. No miner, with all his practical experience, and aided with the present state of geological science, could determine the above points with any degree of satisfaction, without considerable time, labour and expense; but, by the assistance and proper application of the above principle, the questions were not only decided in a few days, but in such a manner as to remove all doubts in the minds of the interested parties. Our geological maps are very useful to persons in a new district, to give a general idea of the formation, but they are of little assistance in the investigation of the details; in order to make them of use to mining operations generally, a systematic survey should be made of the laminae, faults, fractures, metalliferous rocks, &c. in England and Ireland, expressly confined to this object; this would not only be of great importance to mining, but of national benefit.

#### *General Engineering.*

The application of this principle to engineering is so obvious as scarcely to require comment. No work of any magnitude can be undertaken in which excavations, cuttings, tunnelling are not necessary; and these operations generally constitute the most formidable items of expense, and depend entirely on local circumstances, such as the structure of the rocks, compactness, fractures, faults, &c., which, without some knowledge of them, can never be properly appreciated or understood. Indeed the ap-

plications of the principle are so great that it would exceed our limits to describe them; we only wish to point out the fundamental laws, and leave their local application to the judgement and ingenuity of the engineer.

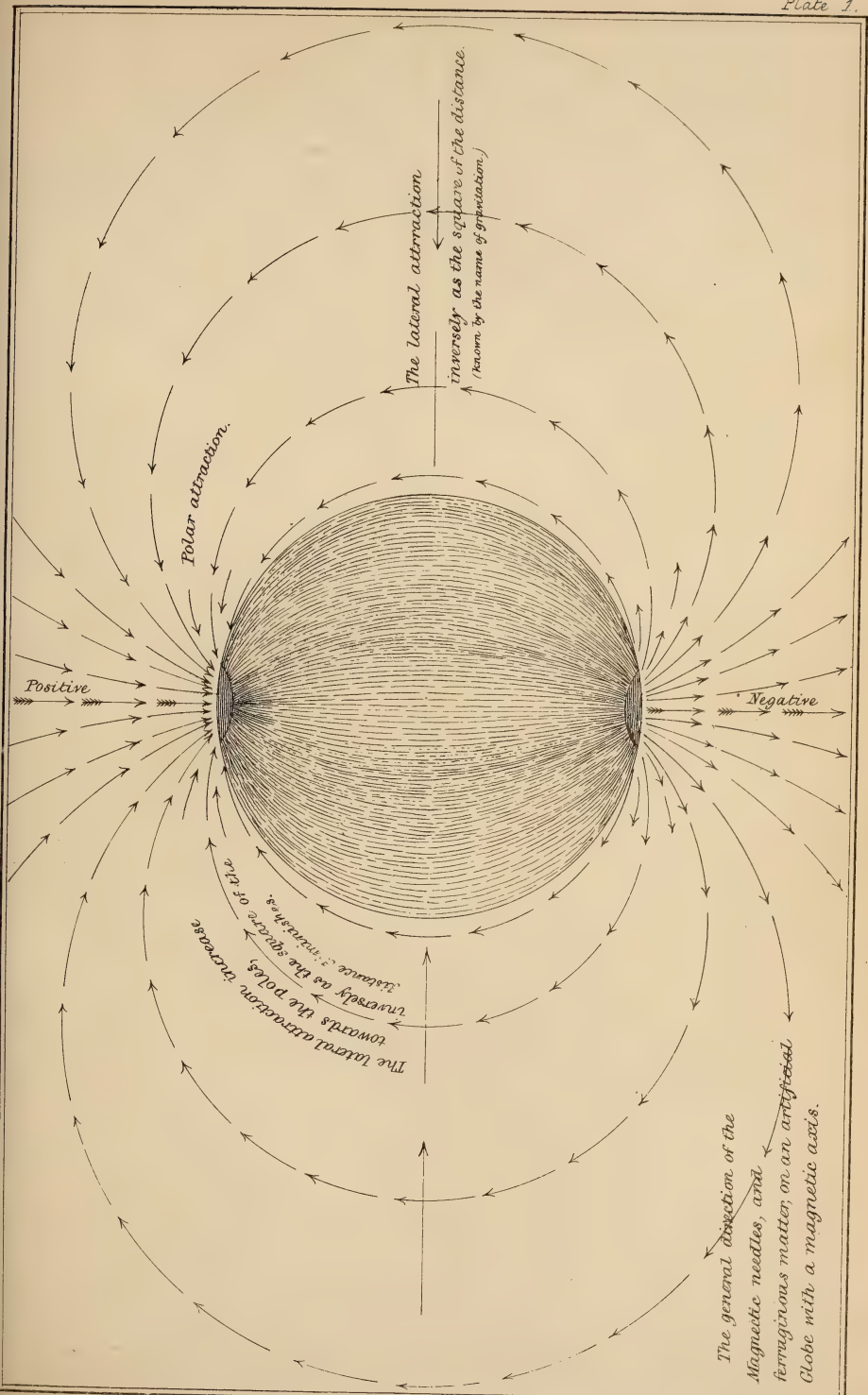
*Conclusion.*

Besides geological dynamics, this inquiry leads to the true laws of terrestrial physics, showing what is possible and what is not. What an amount of ingenuity, labour and expense have been thrown away on the pursuit of the perpetual motion, which might have been turned to better use if the simplest laws of terrestrial physics had been consulted instead of mere geometry, *i. e.* that no motion can take place and continue without the presence of an active principle! It is time to remove some of the mist which has so long enveloped physical science, and sweep off some of those intricate calculations which have obstructed the path, and make it easy and clear to all. "Natural philosophy may thus become regarded as it ought to be, a fountain of intellectual recreation capable of being enjoyed by all, to the injury of no one; on the contrary, adding to the practical aid and advantages of our fellow-creatures, cherishing an unbounded spirit of inquiry, free from all prejudices, and open to every impression of a higher order, and affording at all times the purest earthly happiness of which human nature is susceptible."

THE END.







Positive

Negative

Polar attraction.

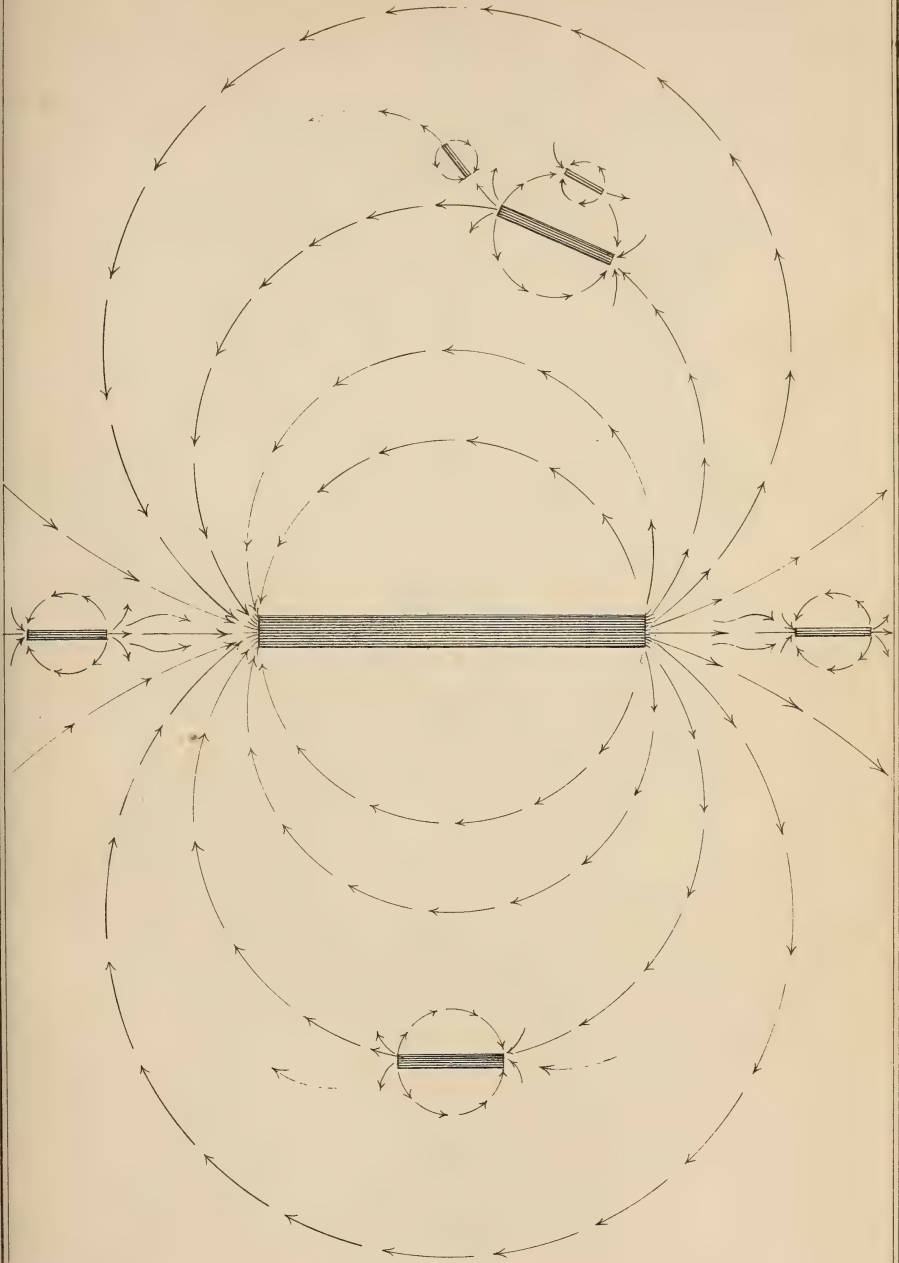
The lateral attraction  
inversely as the square of the distance.  
(known by the name of gravitation.)

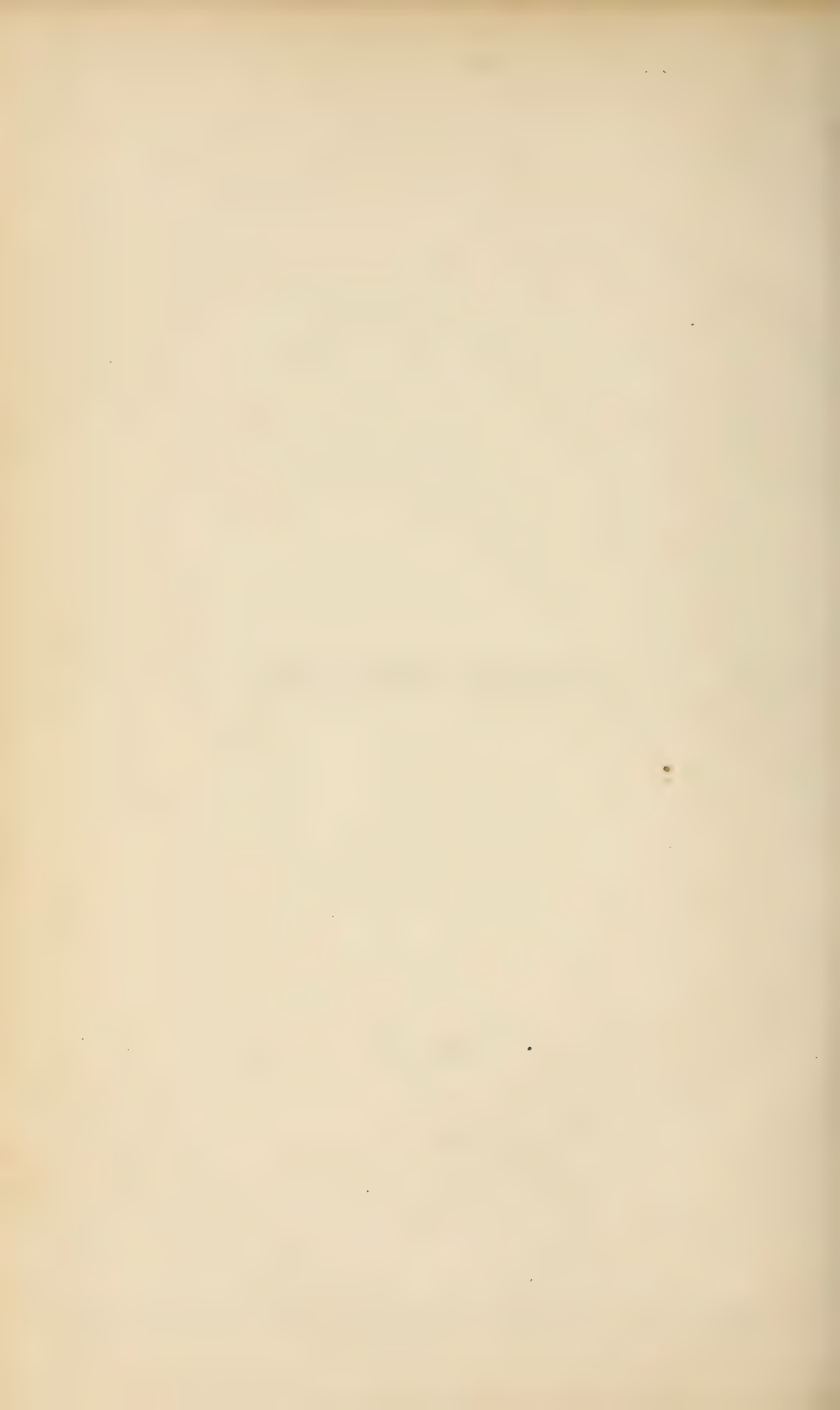
The lateral attraction increases  
towards the poles,  
inversely as the square of the  
distance, etc.

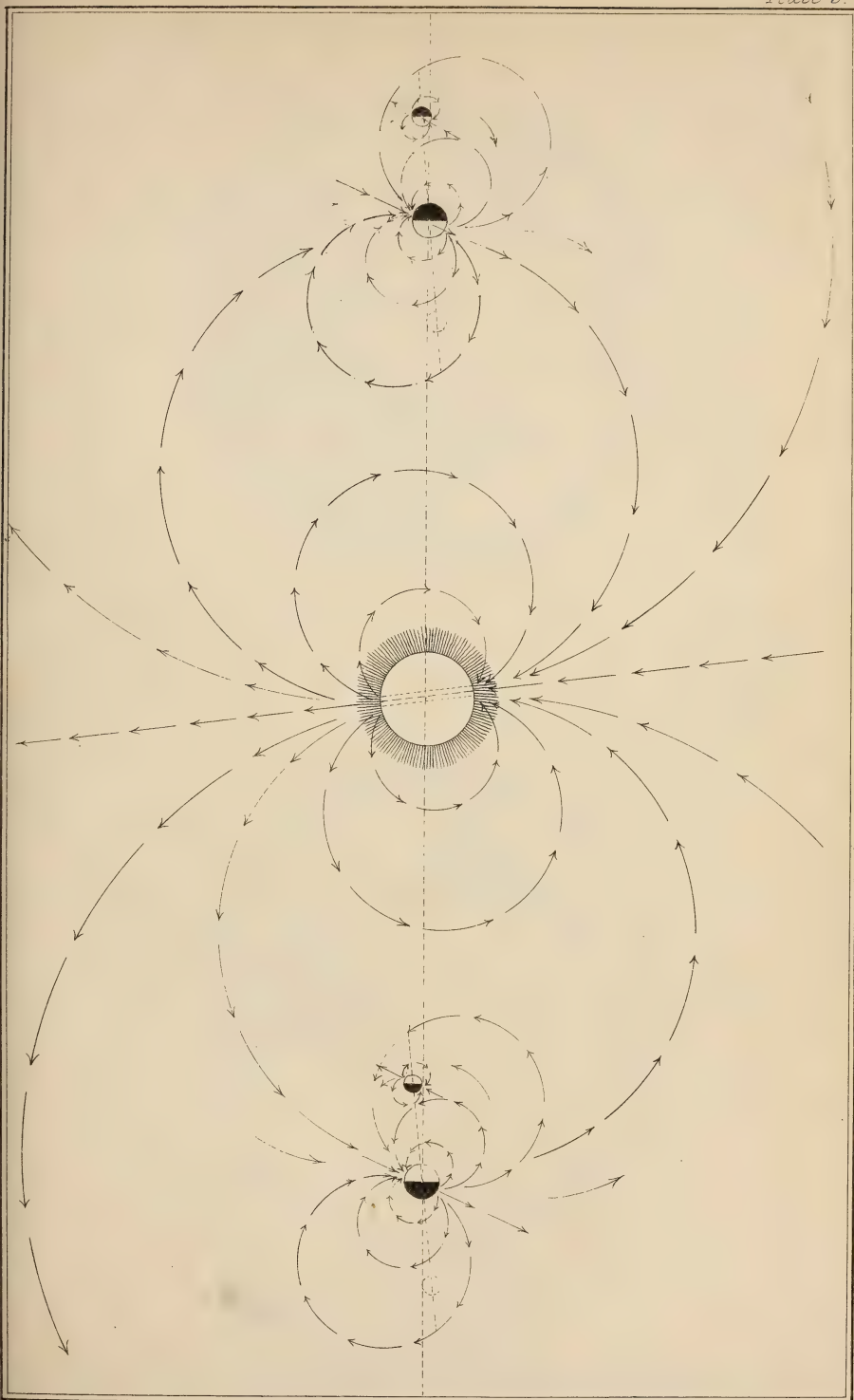
The general direction of the  
Magnetic needles, and  
ferruginous matter, on an artificial  
Globe with a magnetic axis.



Magnetic Bars.





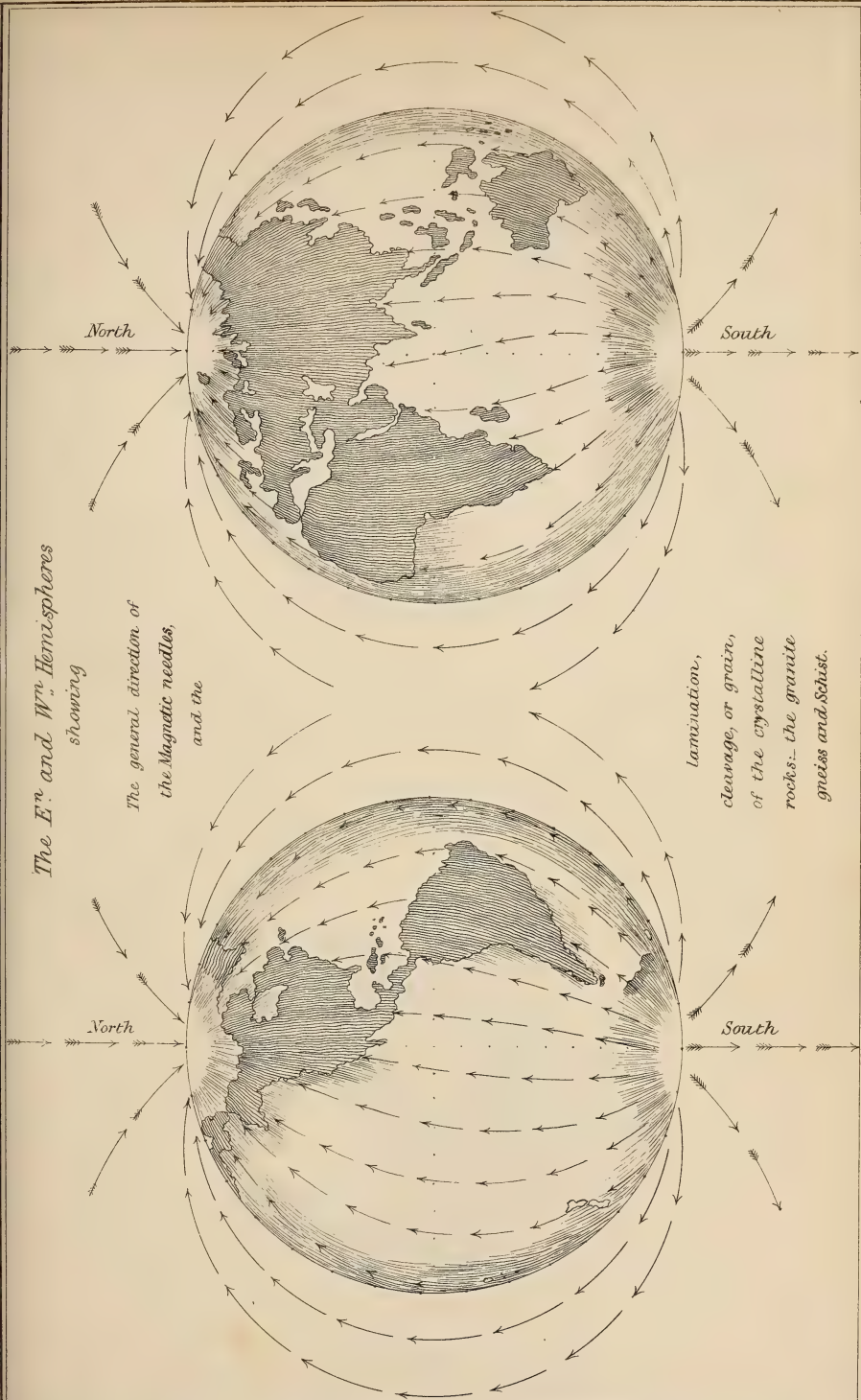




The E<sup>n</sup> and W<sup>n</sup> Hemispheres  
showing

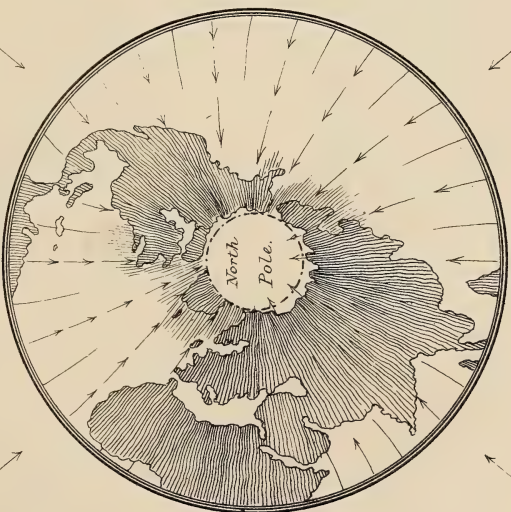
The general direction of  
the Magnetic needles,  
and the

lamination,  
cleavage, or grain,  
of the crystalline  
rocks: the granite  
gneiss and Schist.



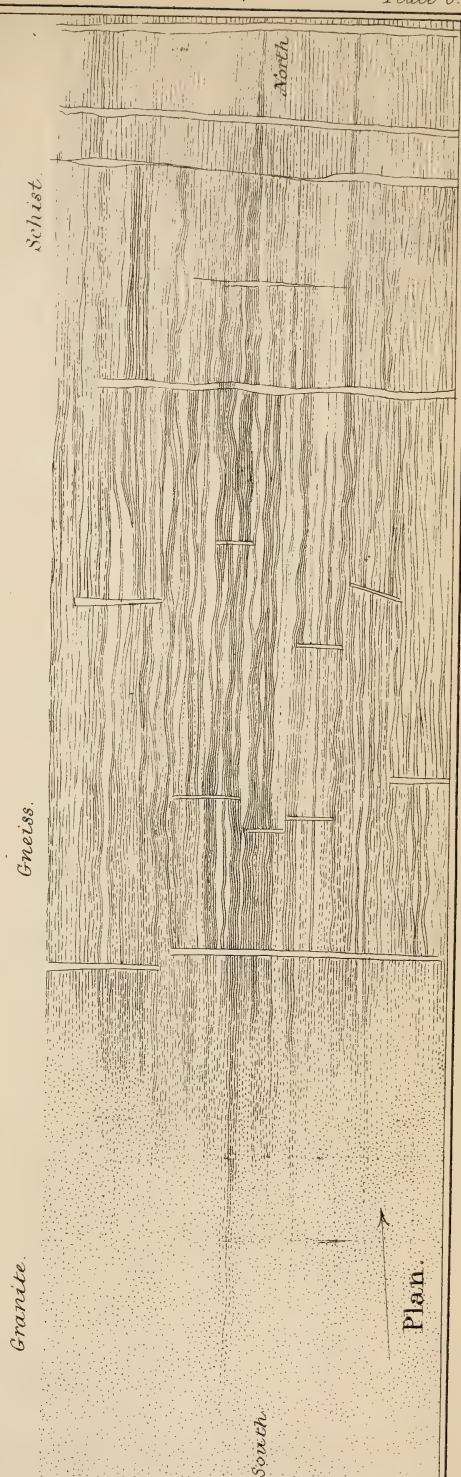
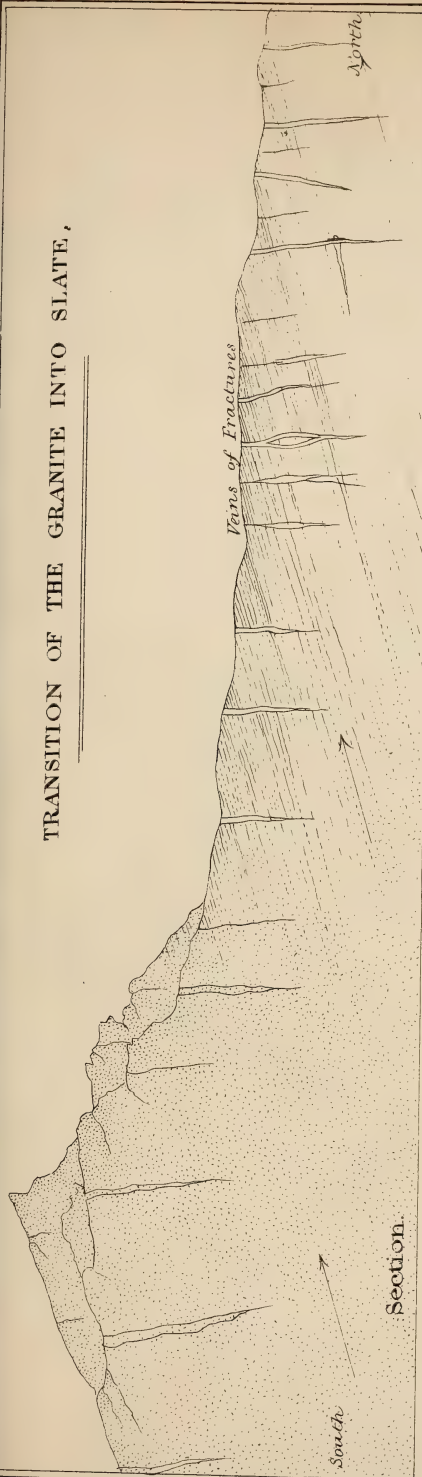




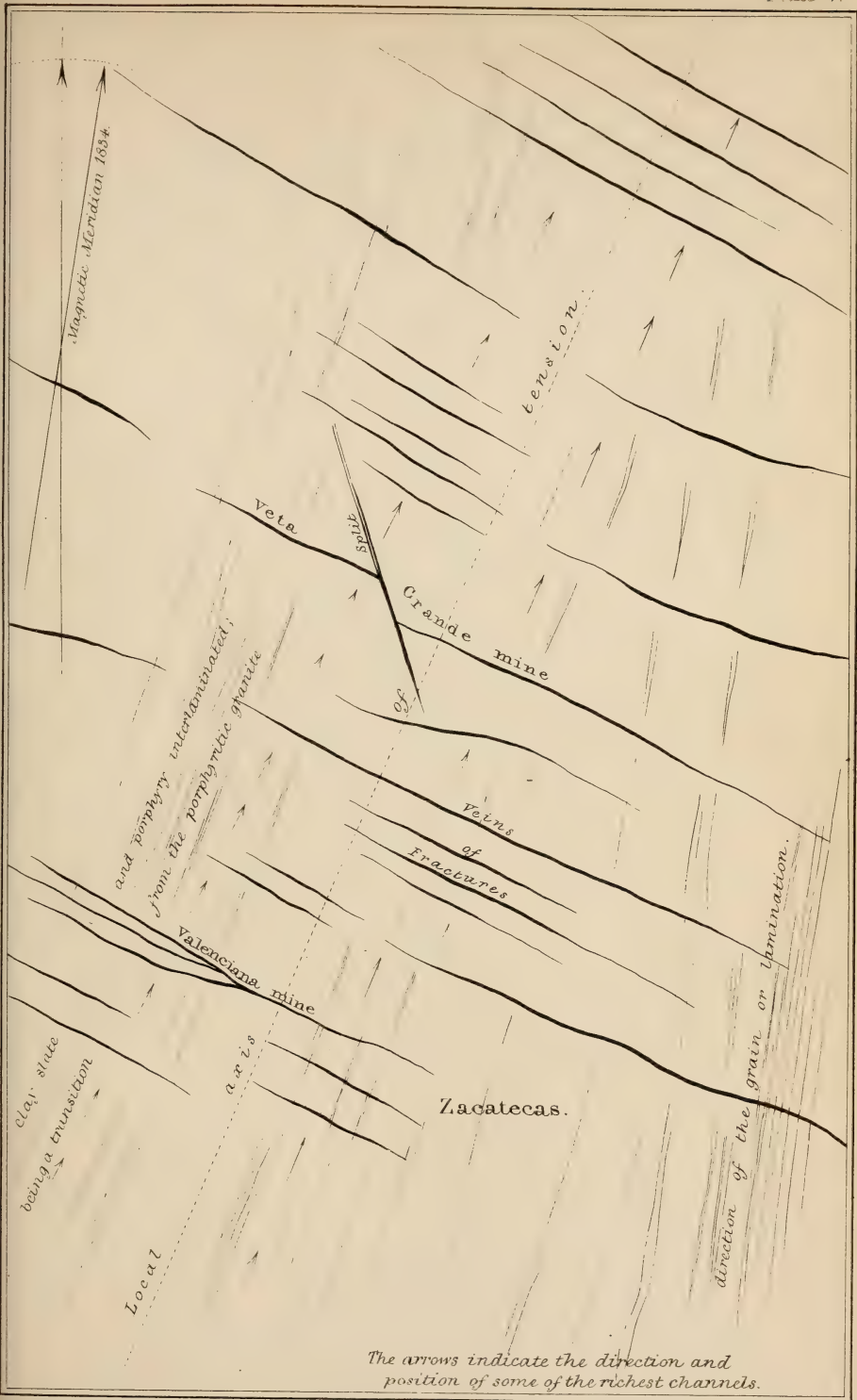




TRANSITION OF THE GRANITE INTO SLATE,

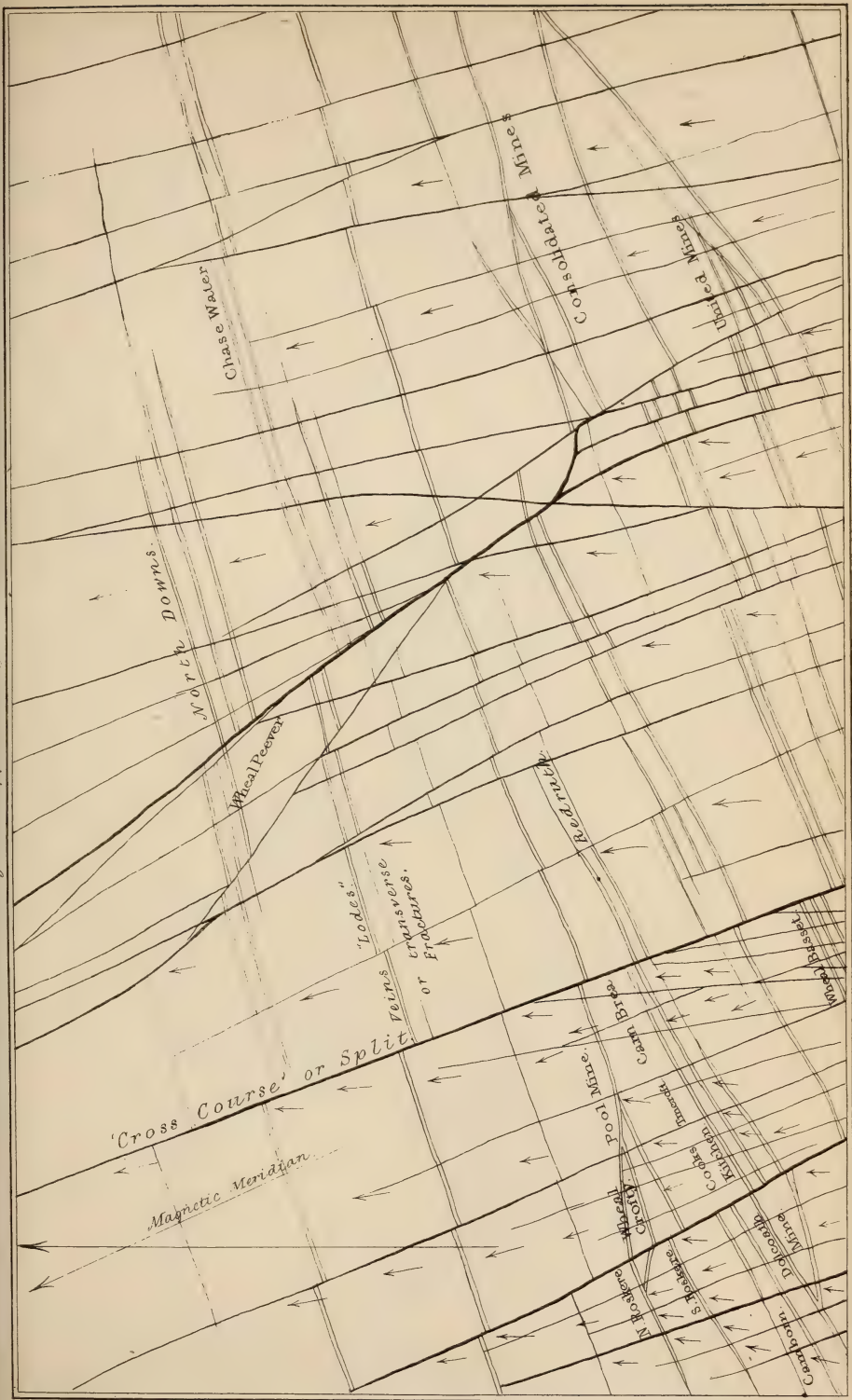








The 'bunches of ore' approaching the surface northward.



The arrows indicate the direction of the metalliferous currents. The 'bunches of ore' comparatively deep Southward.





Arc of Variation

British Islands.

Average direction of the recent cleavage

dir. of the recent fractures

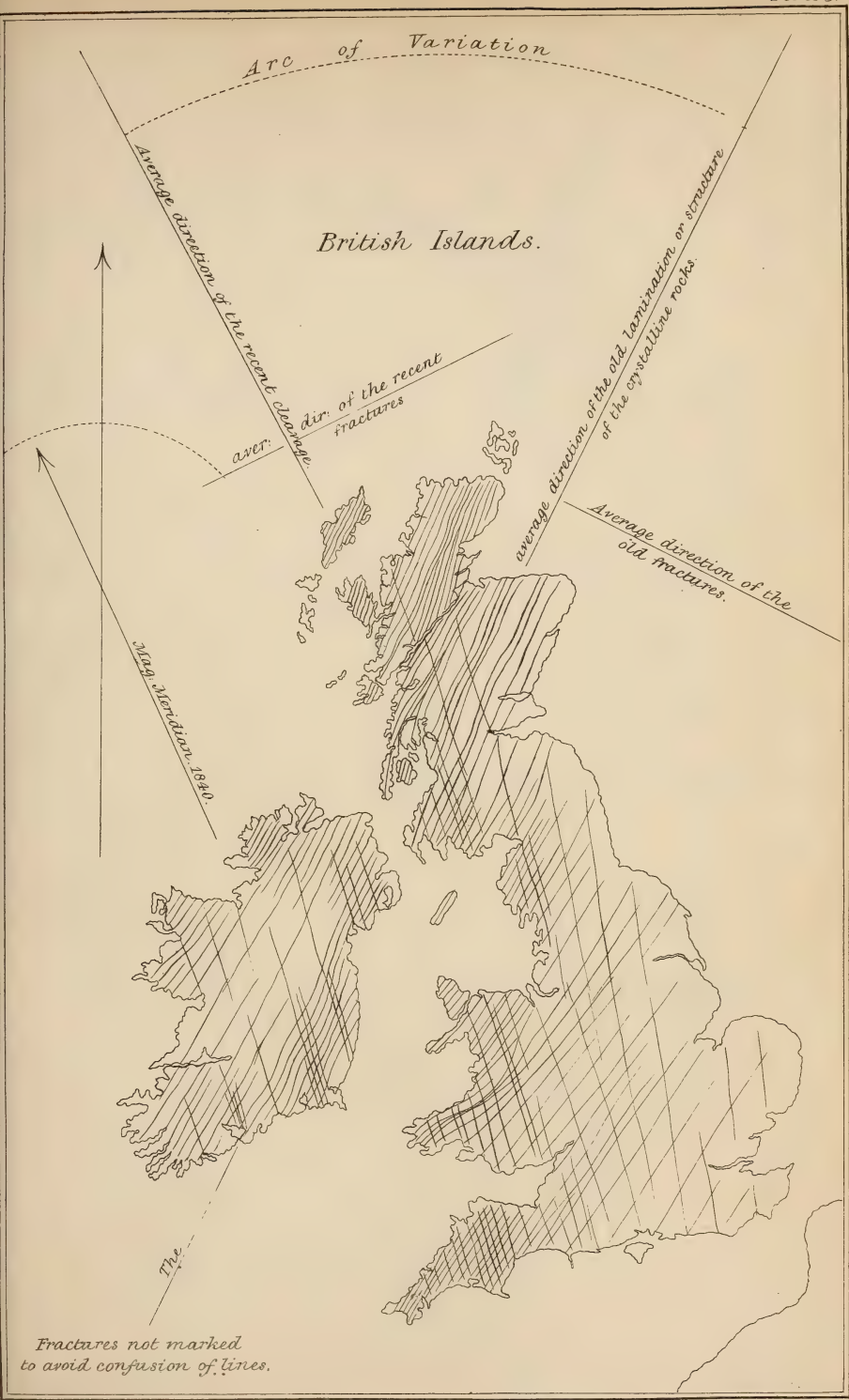
average direction of the old lamination or structure of the crystalline rocks.

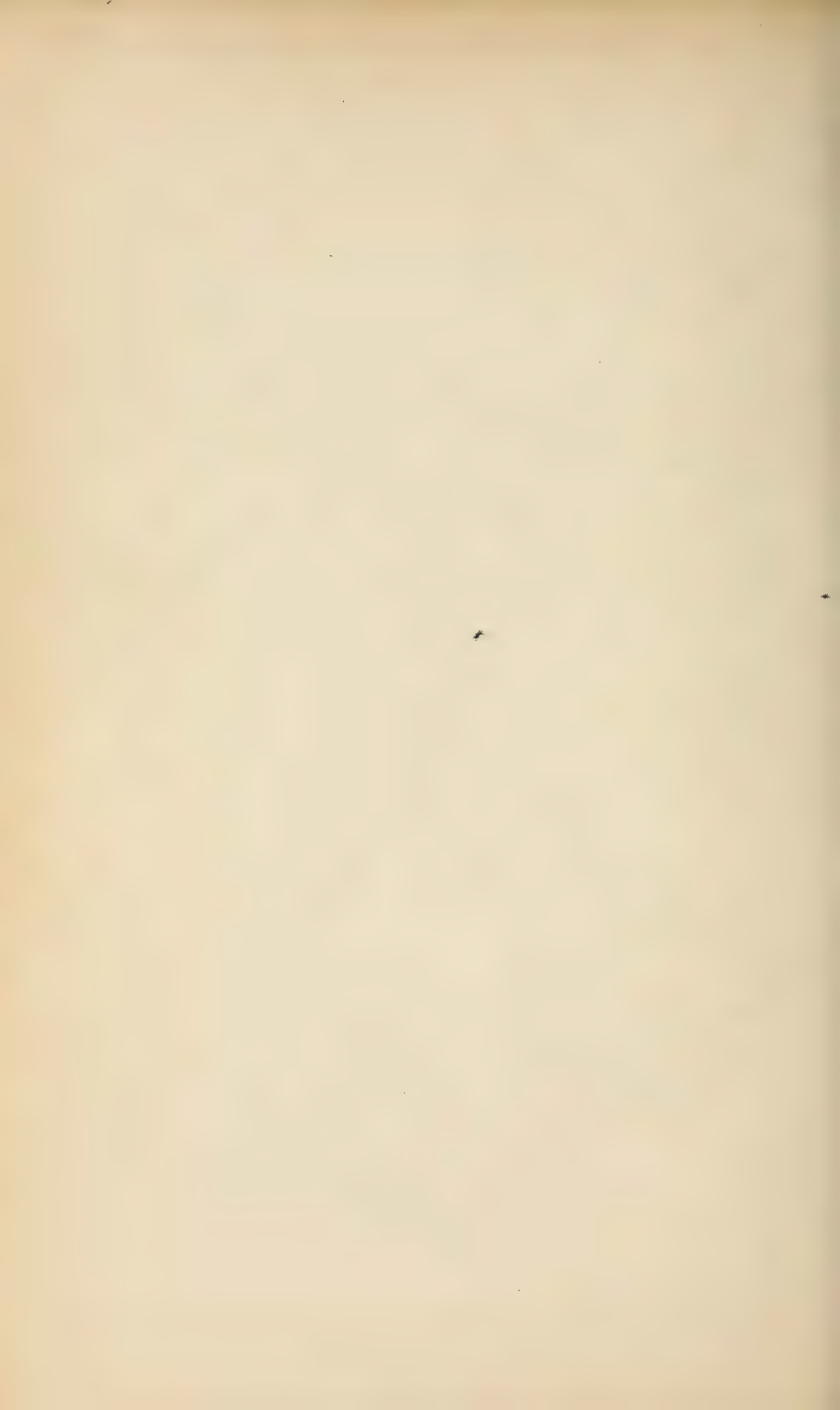
Average direction of the old fractures.

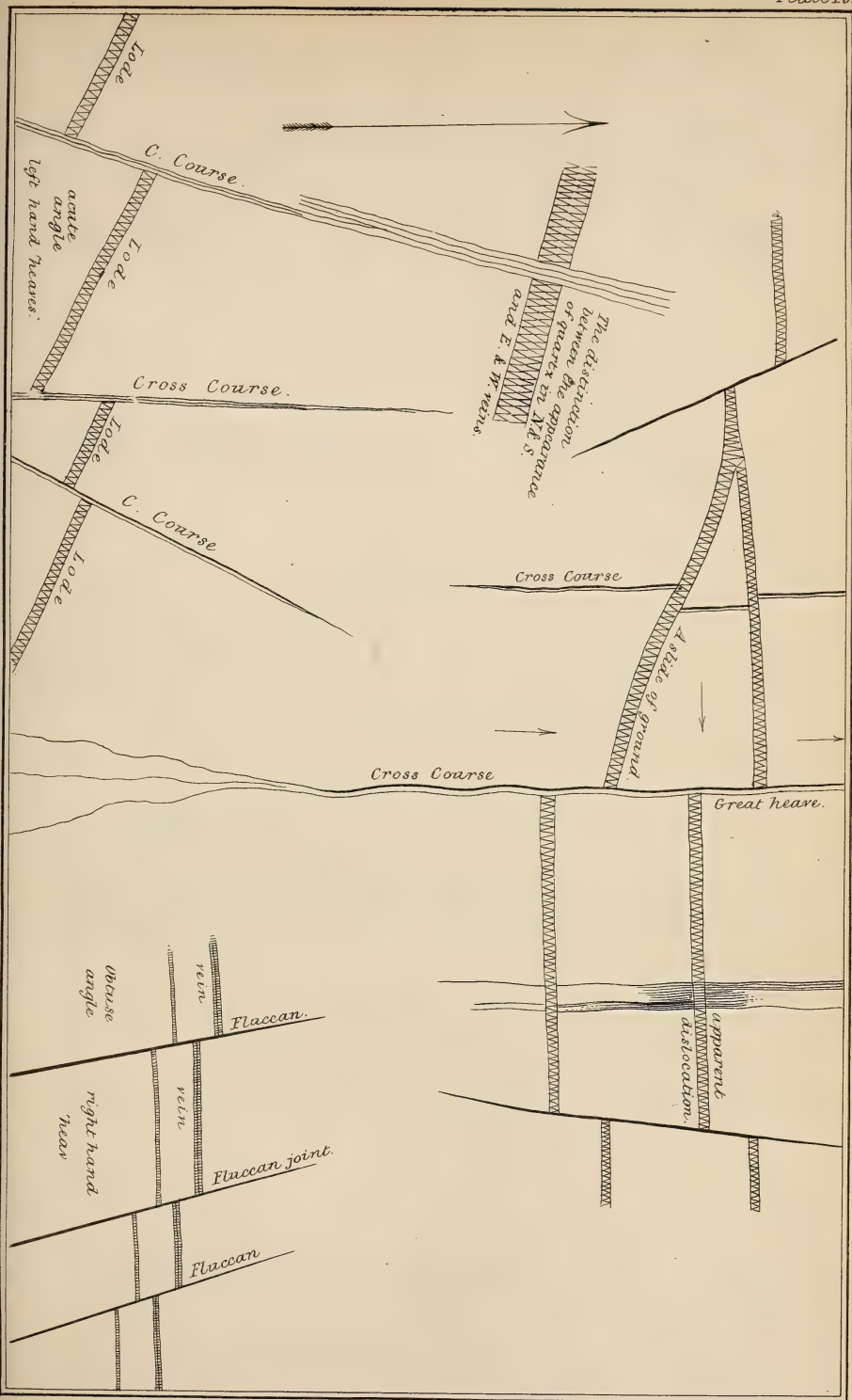
Magn. Meridian, 1840.

The

Fractures not marked to avoid confusion of lines.



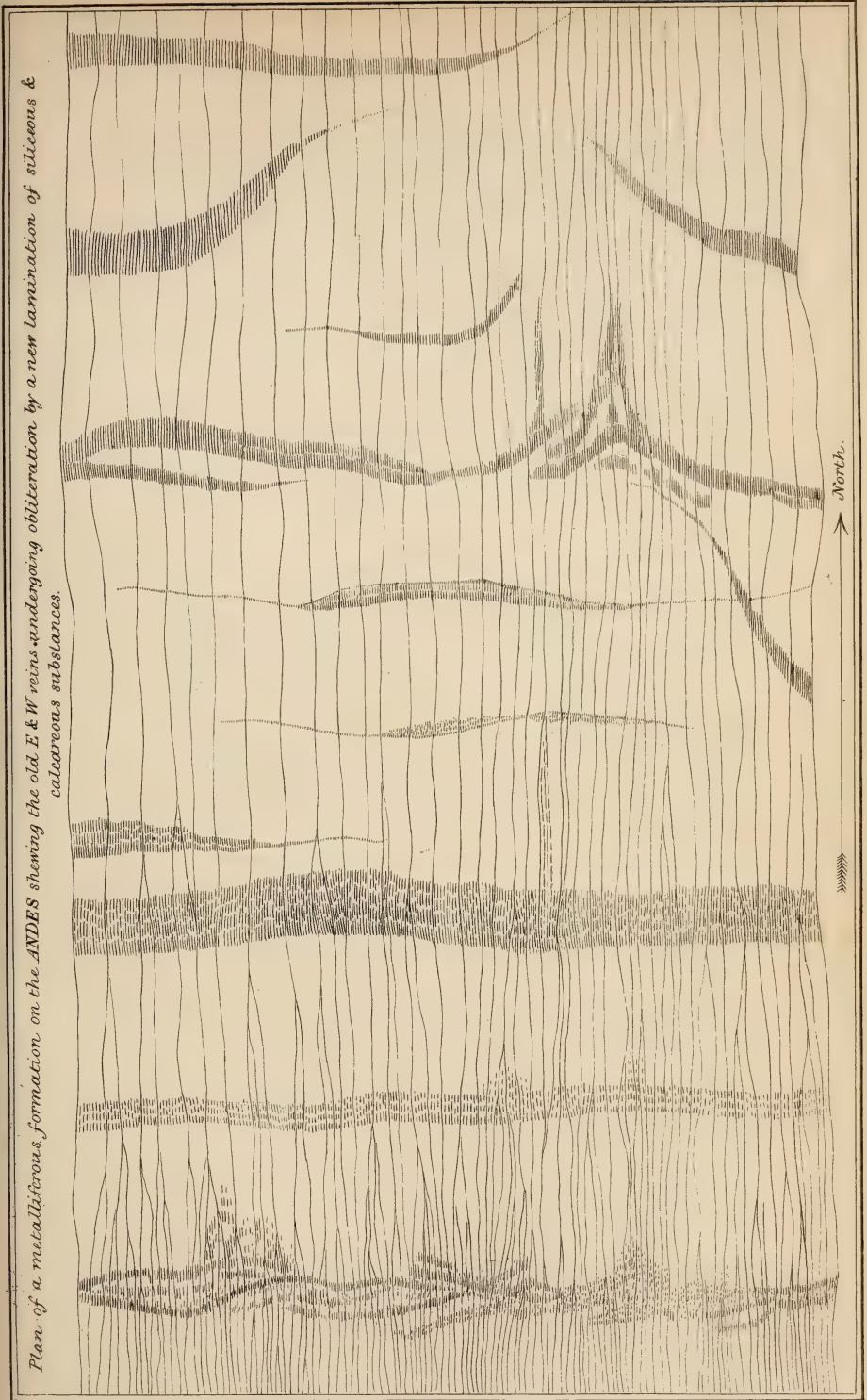






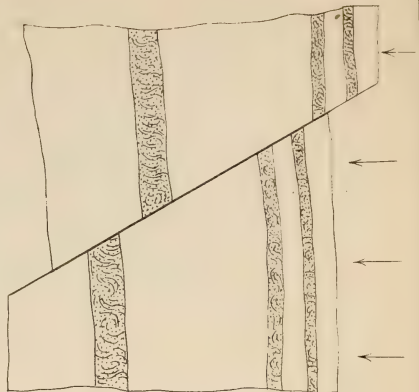
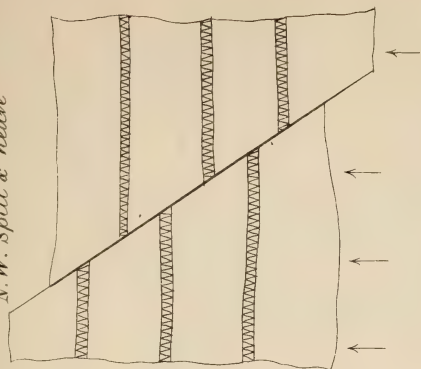
Plan of a metalliferous formation on the ANDES showing the old E & W veins undergoing obliteration by a new lamination of siliceous & calcareous substances.

North. ↑

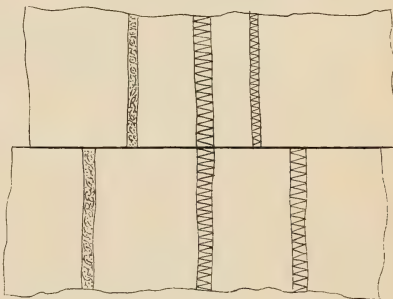
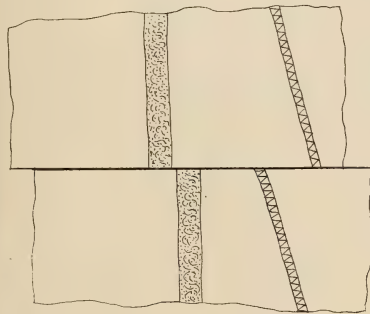




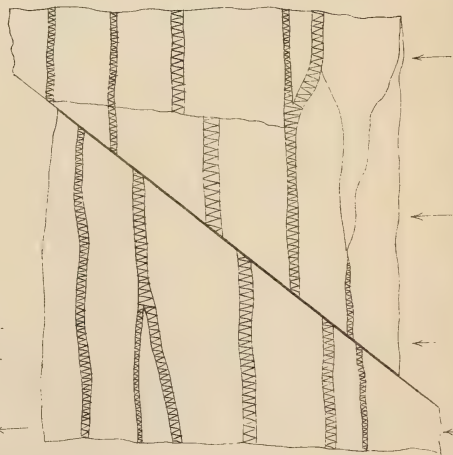
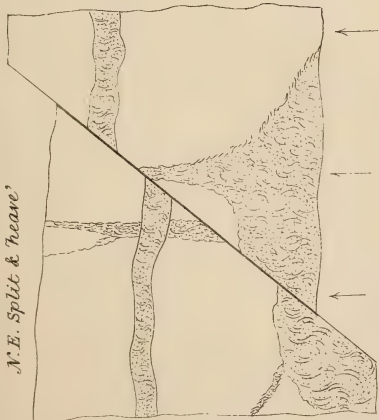
N. W. Split & heave'



Meridional split.



N. E. Split & heave'

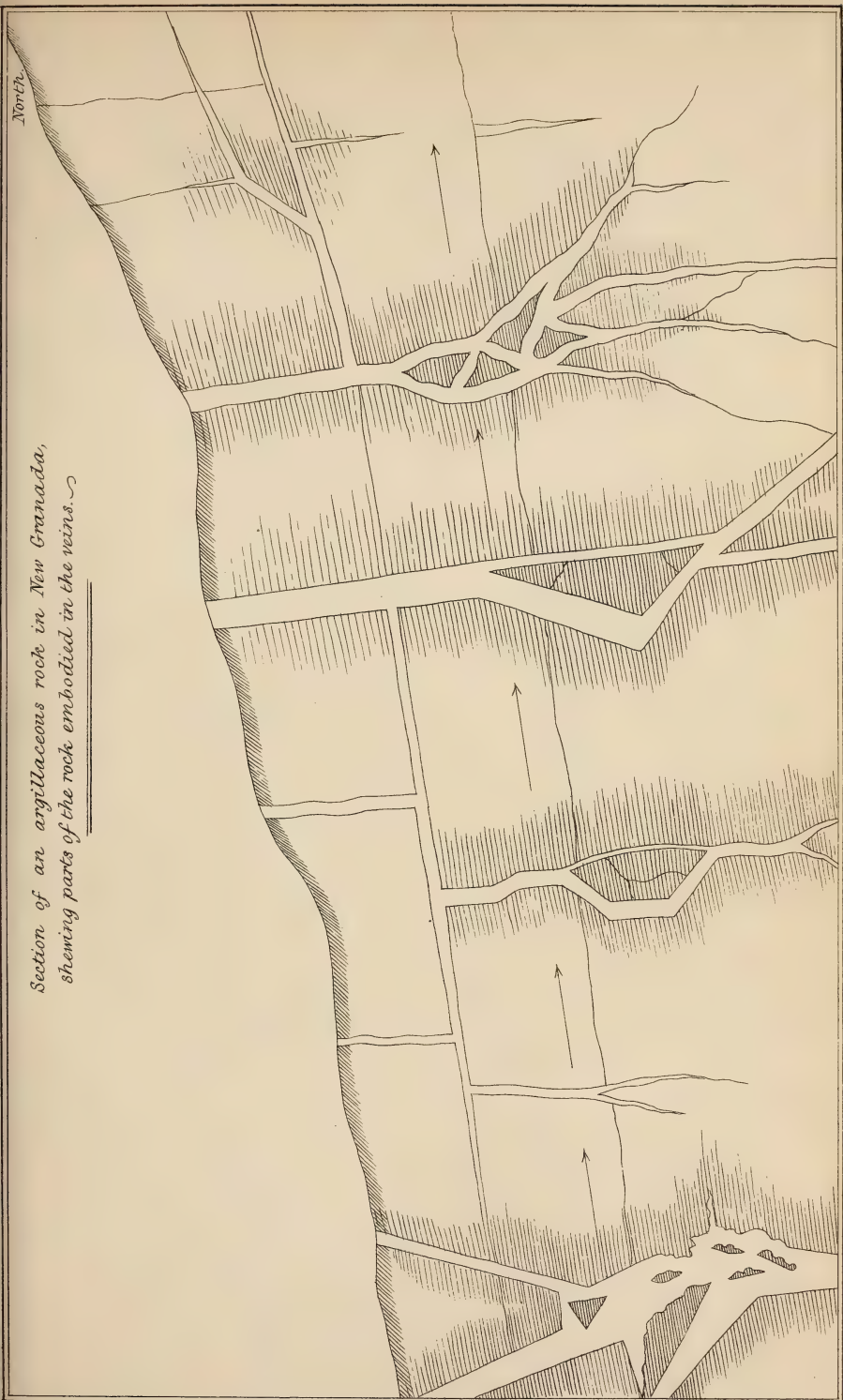






North

Section of an argillaceous rock in New Granada,  
showing parts of the rock embodied in the veins.



E. Hopkins, del

J. Basire, lith.

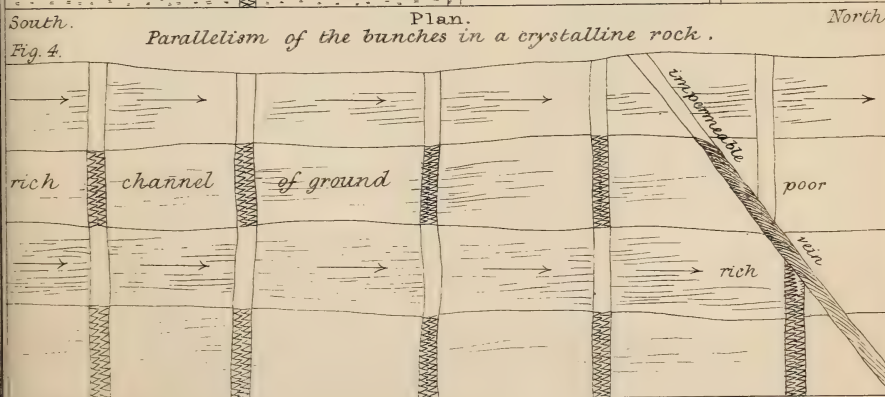
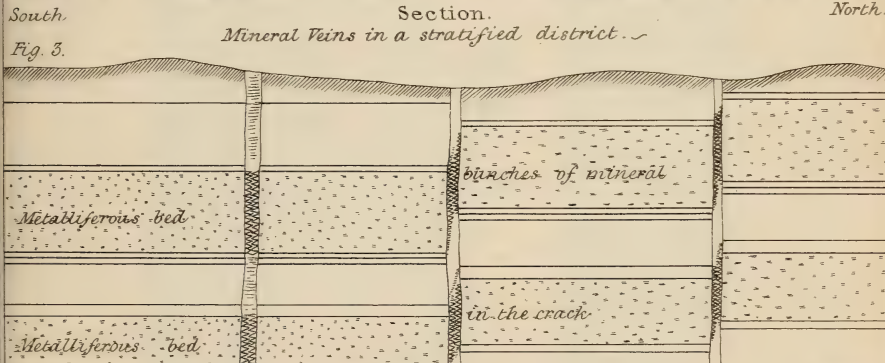
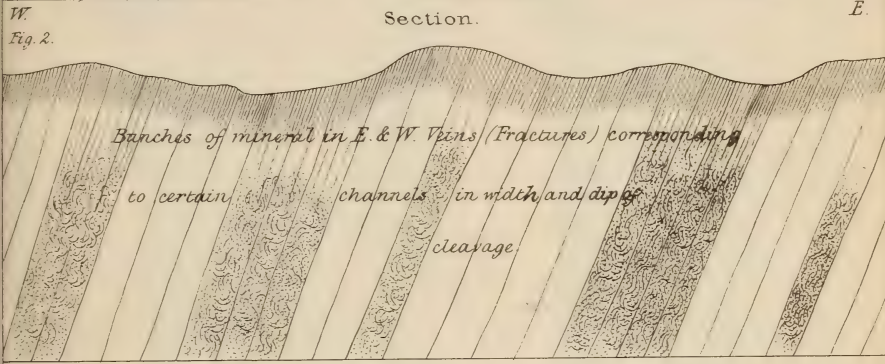
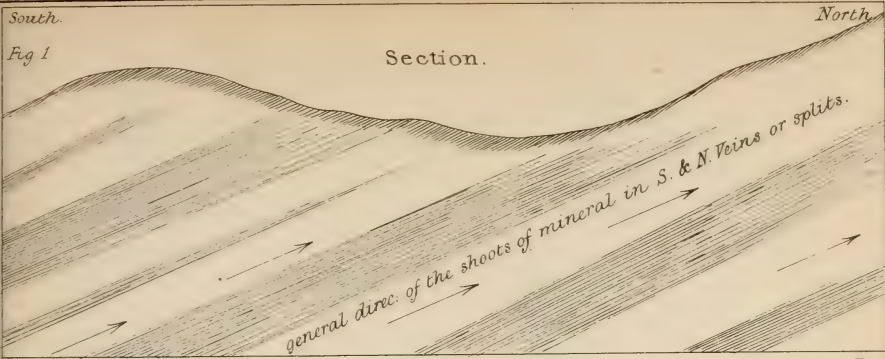


Sections to illustrate the relative position of mineral veins (E. & W.) with their bunches of mineral.



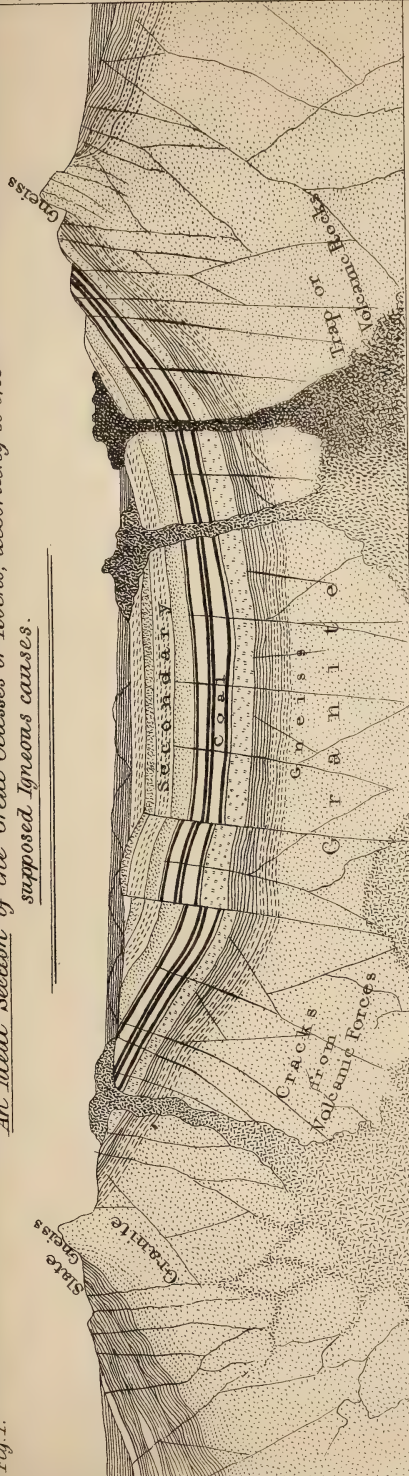
South







*An Ideal Section of the Great Classes of Rocks, according to the supposed Igneous causes.*



*A Real Section, or the exact appearance of a similar series, in an E. W. direction.*

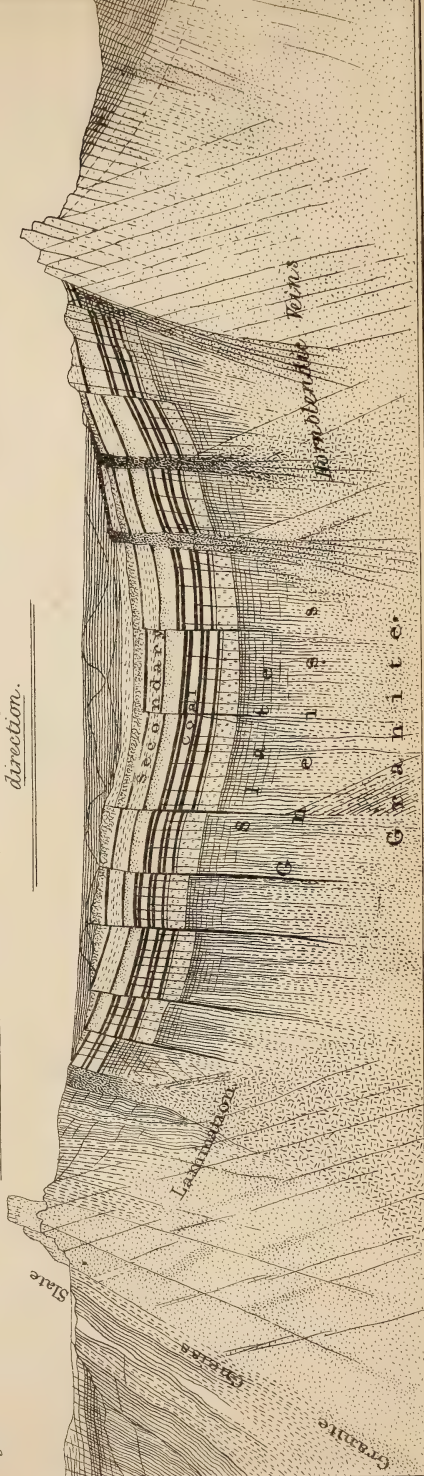


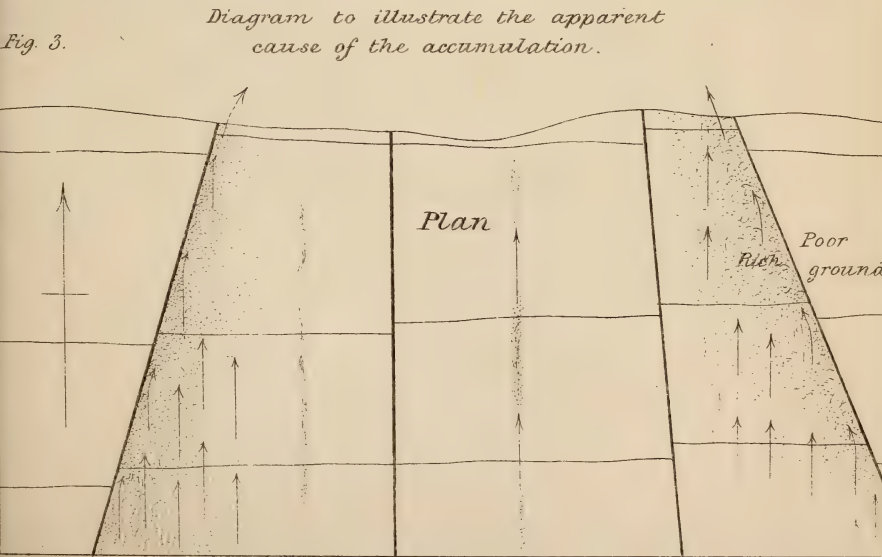
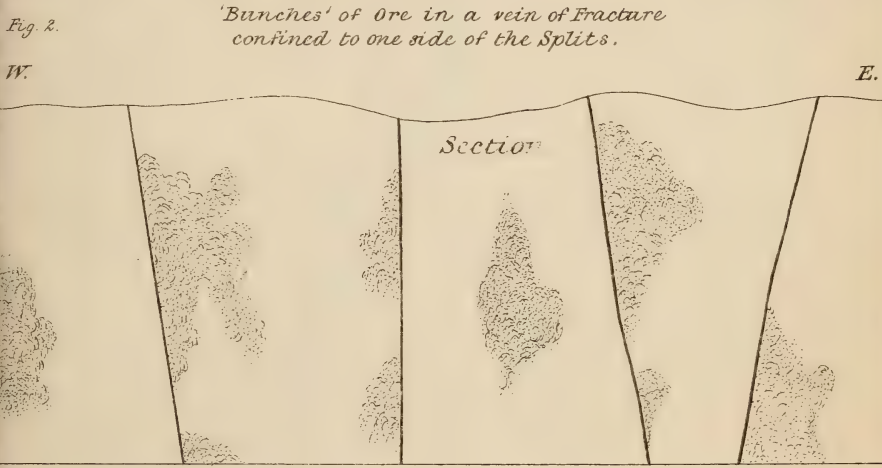
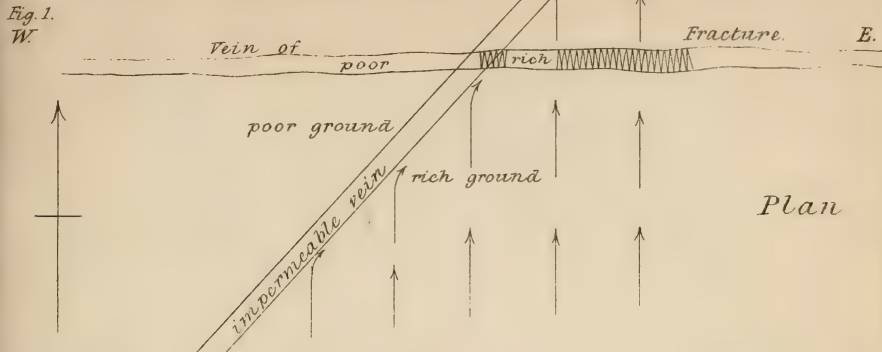
Fig. 1.

Fig. 2.



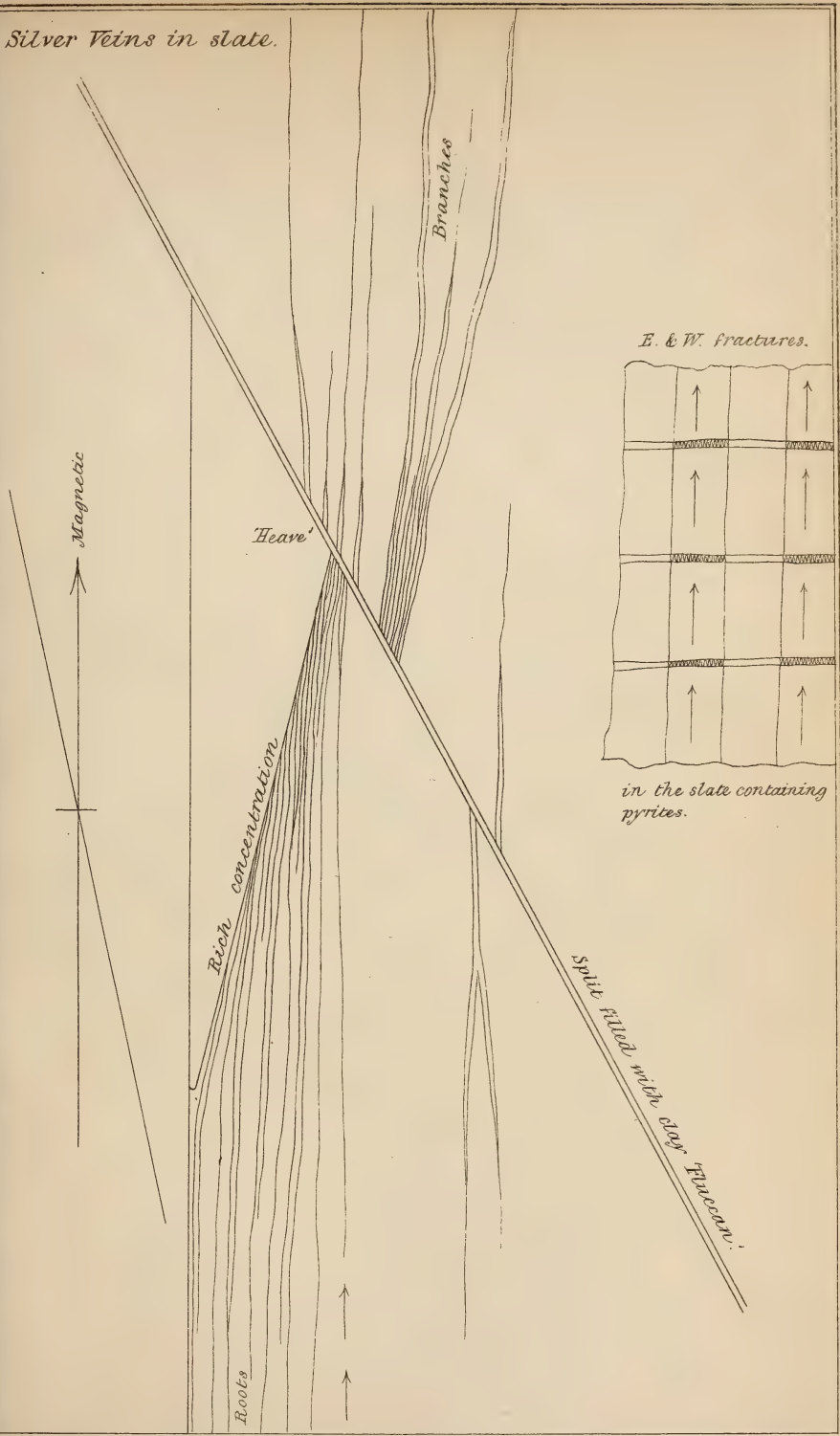


Influence of the impermeable Splits on the accumulation of Minerals.





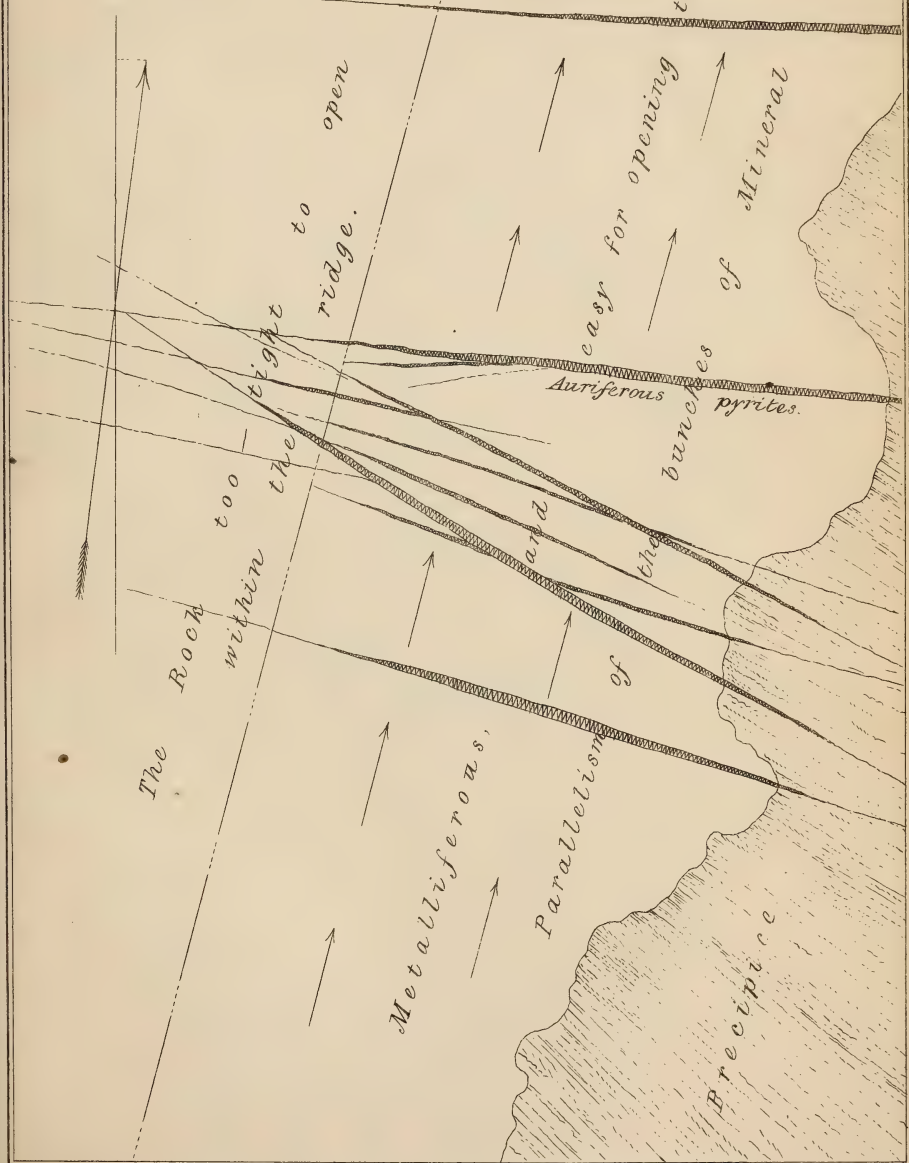
Silver Veins in slate.

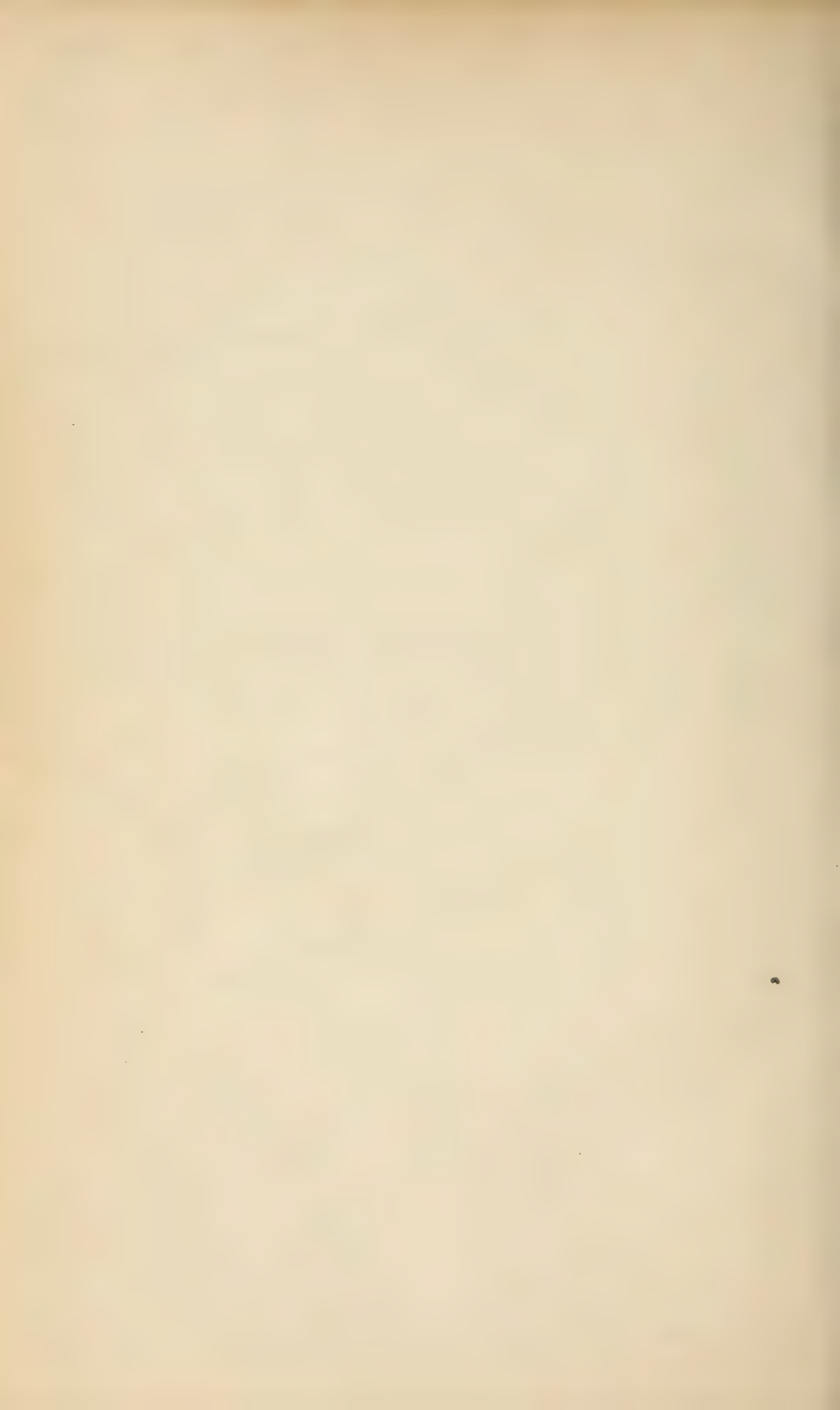


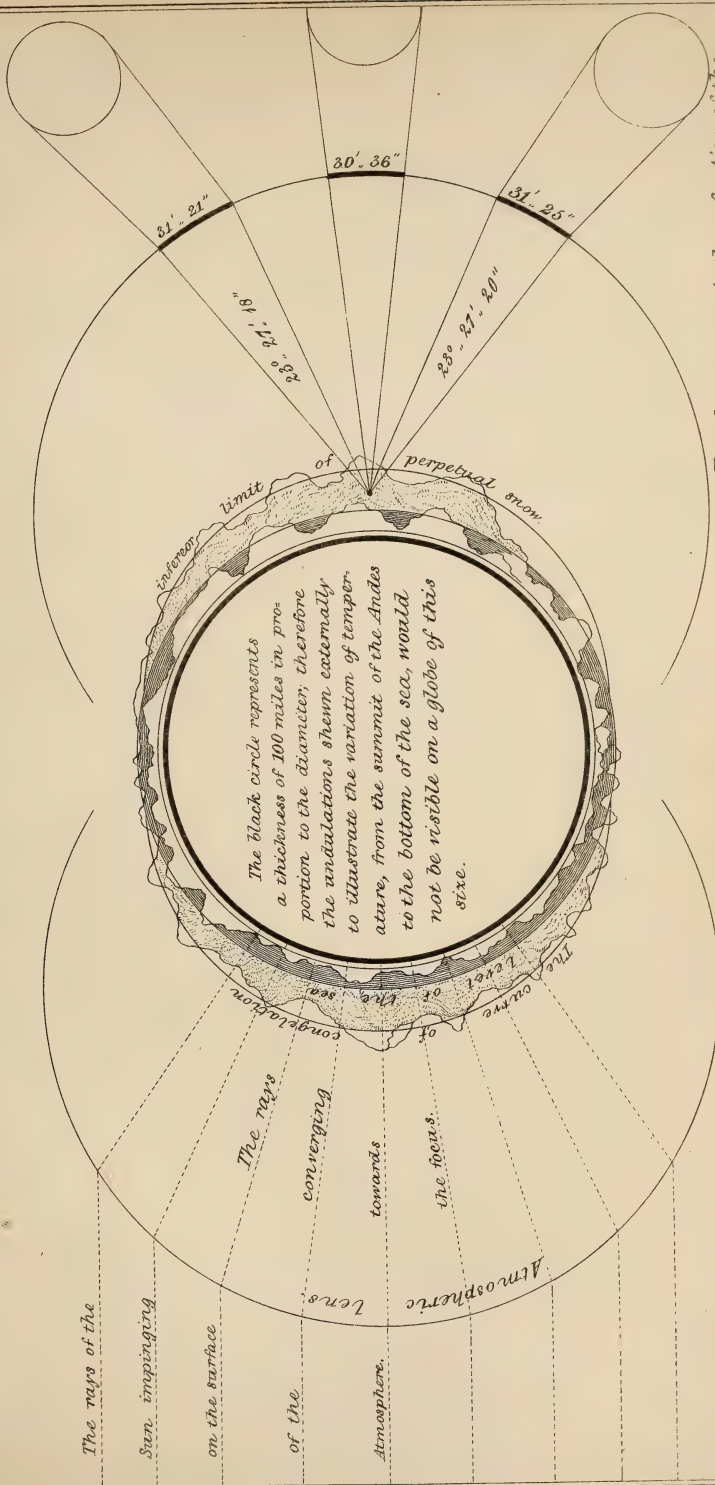


GOLD MINES  
on the  
W<sup>N</sup> CORDILLERA.

Veins of Fractures  
in  
Hornblende Porphyry.







The above represents the refraction of the sun's rays, and the apparent augmentation of the diameter, according to observations made near the equator from the S. tropic, to the N. tropic.

The black circle represents a thickness of 100 miles in proportion to the diameter, therefore the undulations shown externally to illustrate the variation of temperature, from the summit of the Andes to the bottom of the sea, would not be visible on a globe of this size.

The rays of the

Sun impinging

on the surface

of the

atmosphere.

The rays converging towards the focus.

Atmospheric lens.

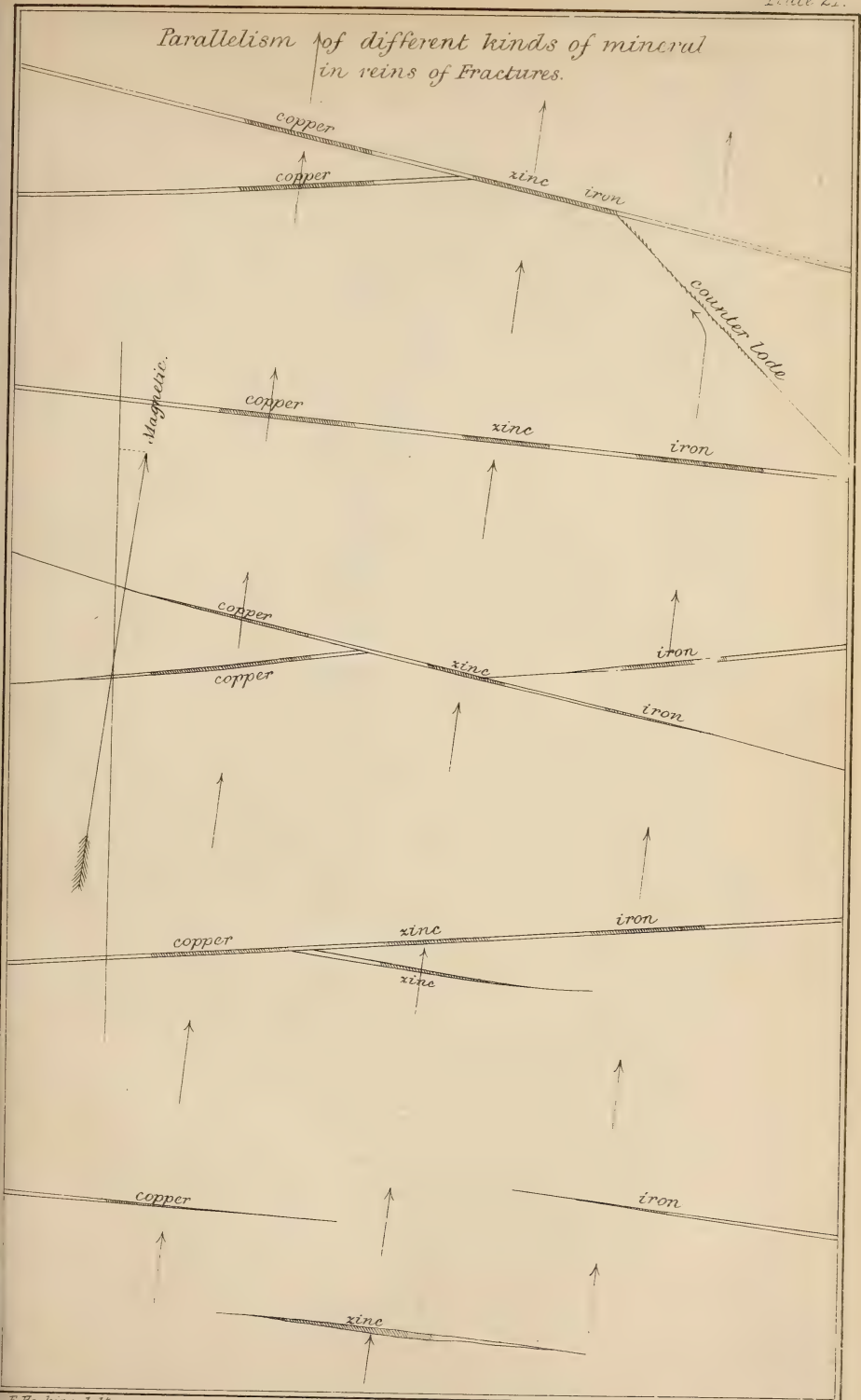
The curve of the level of the sea

inferior limit of perpetual snow





Parallelism of different kinds of mineral  
in veins of Fractures.





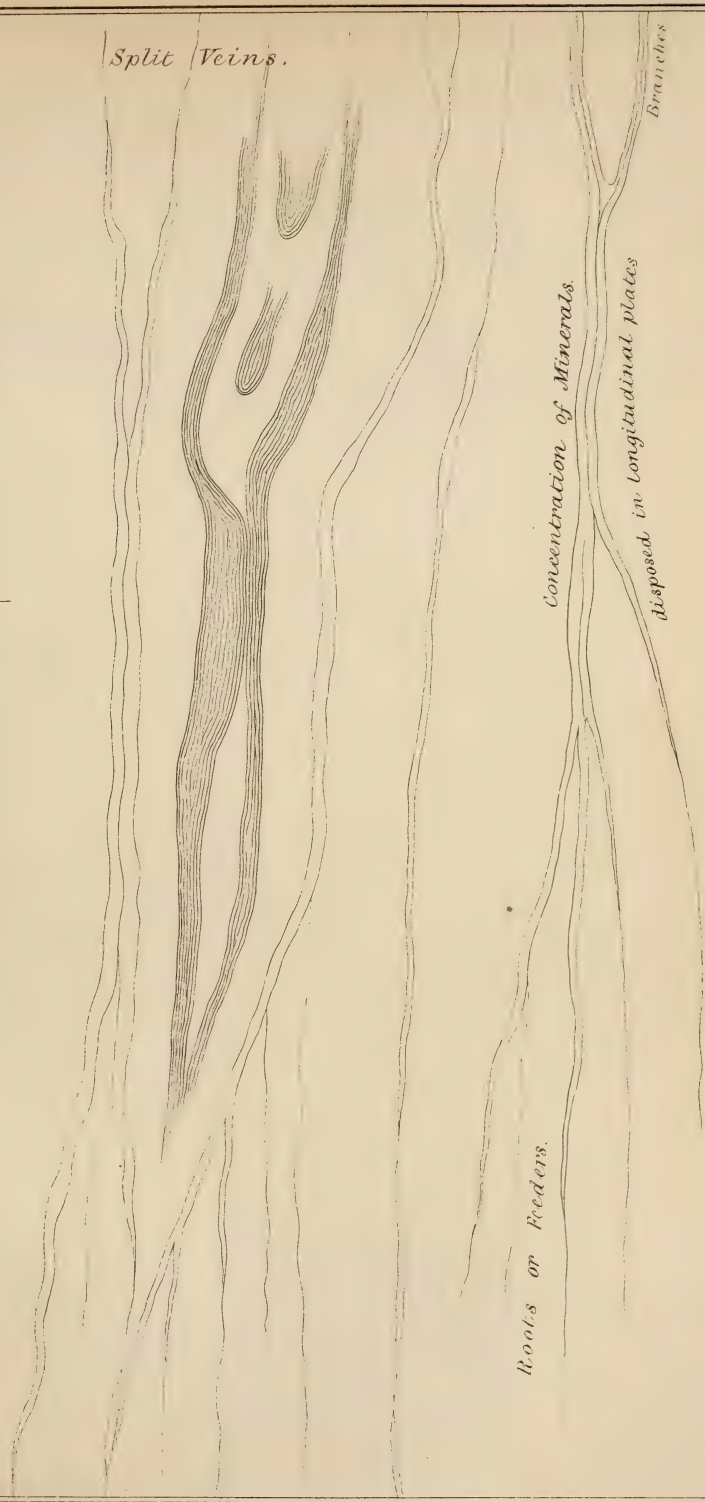
Split Veins.

Branches

Concentration of Minerals

disposed in longitudinal plates

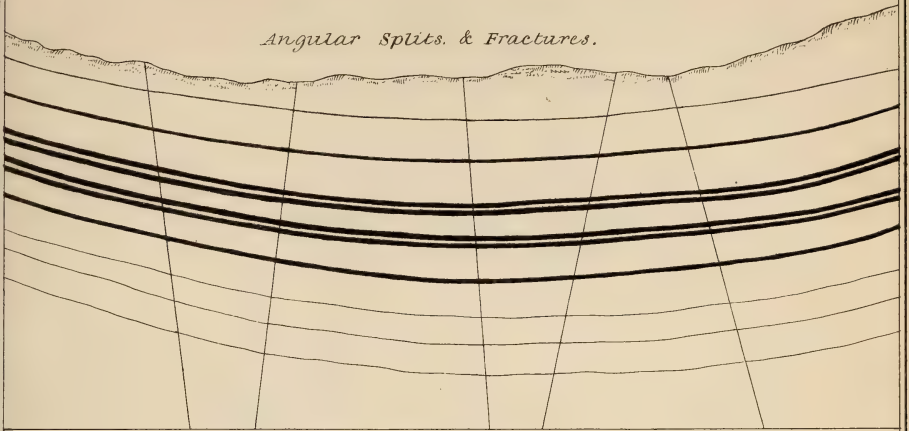
Roots or Feeders.



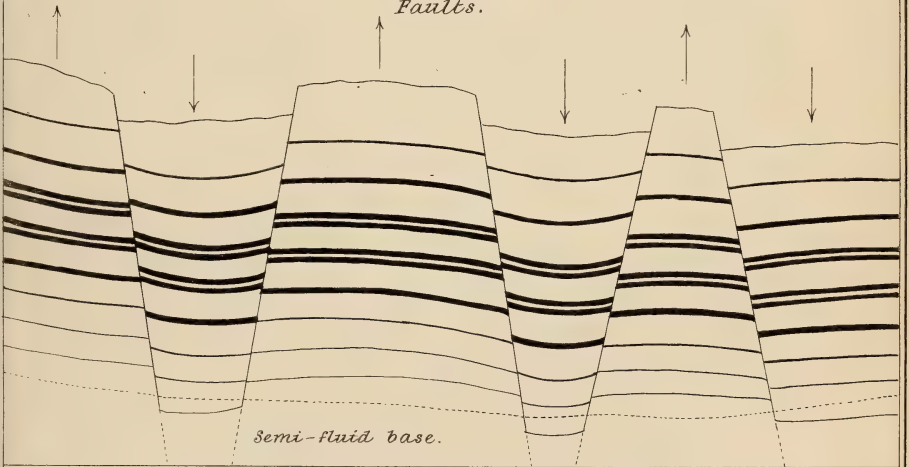


' FAULTS IN COAL BEDS .

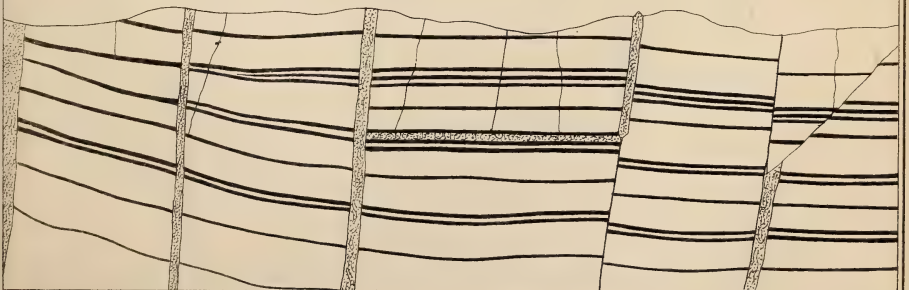
*Angular Splits. & Fractures.*



*Subsidence and Elevation of the separate parts according to the angles of the Faults.*



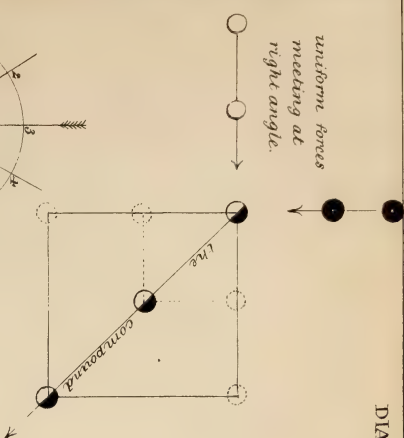
*Soft clay beds forced into the joints. 'Dykes'*



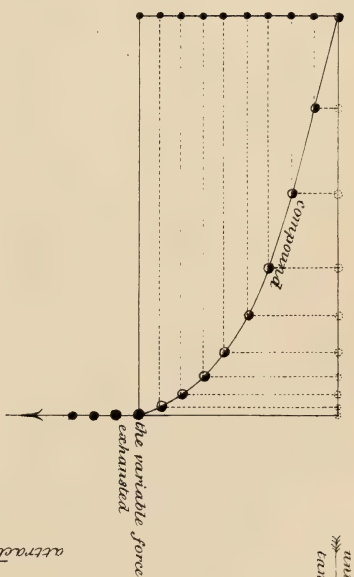


DIAGRAMS ILLUSTRATING THE COMPOSITION OF FORCES.

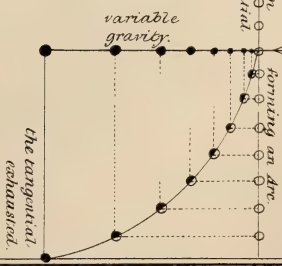
uniform forces meeting at right angle.



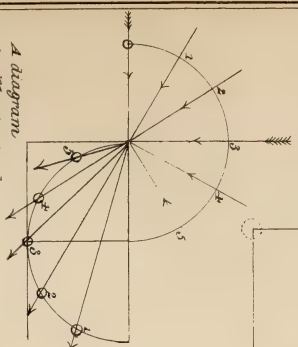
variable uniform



uniform tangential forming an Arc



A diagram to illustrate the composition of forces

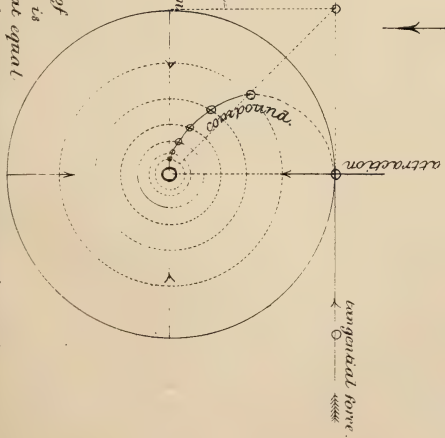


A body to describe a circle must have a central force equal to the centripetal force.



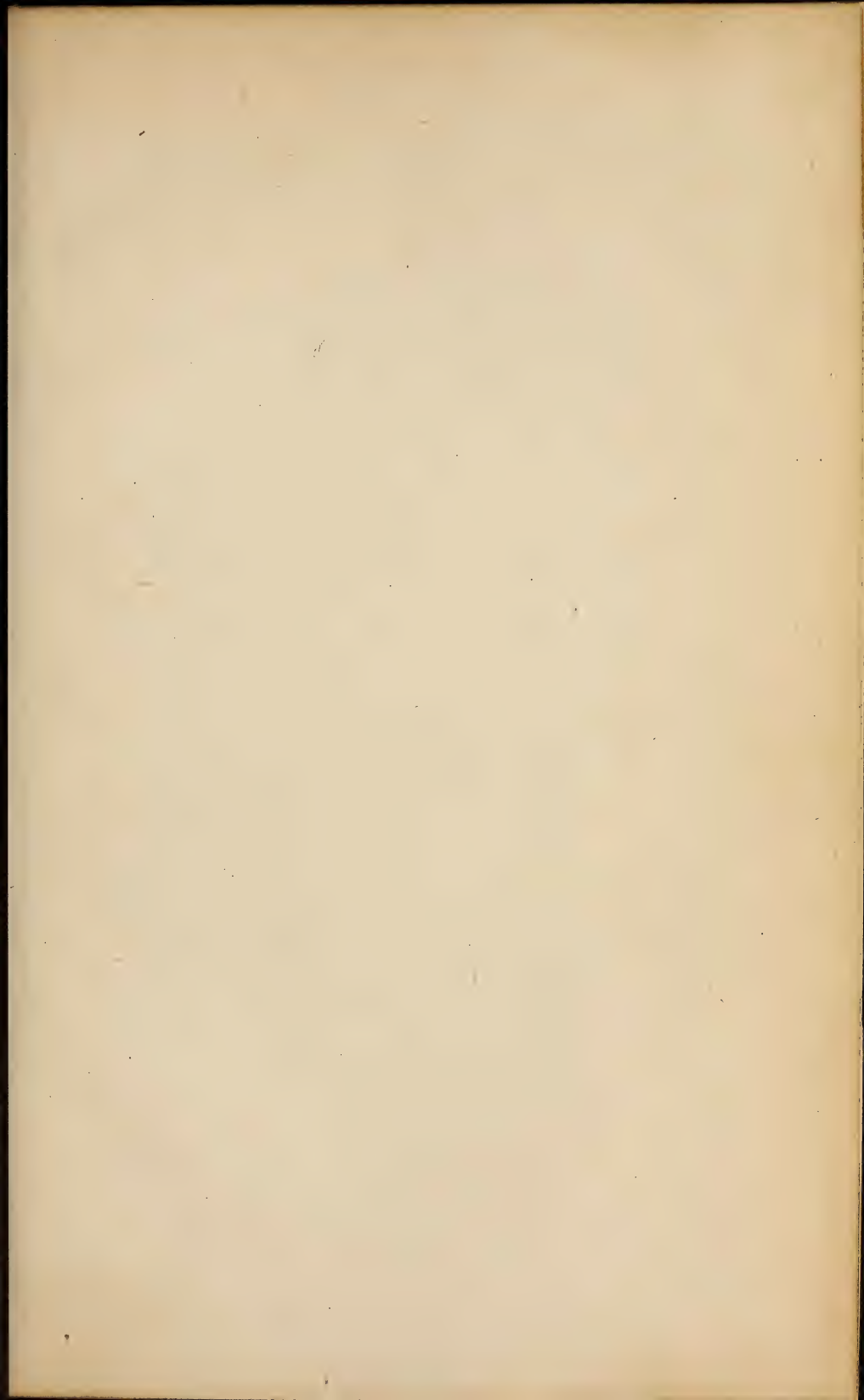
A central force will not admit of a rectangular parallelogram

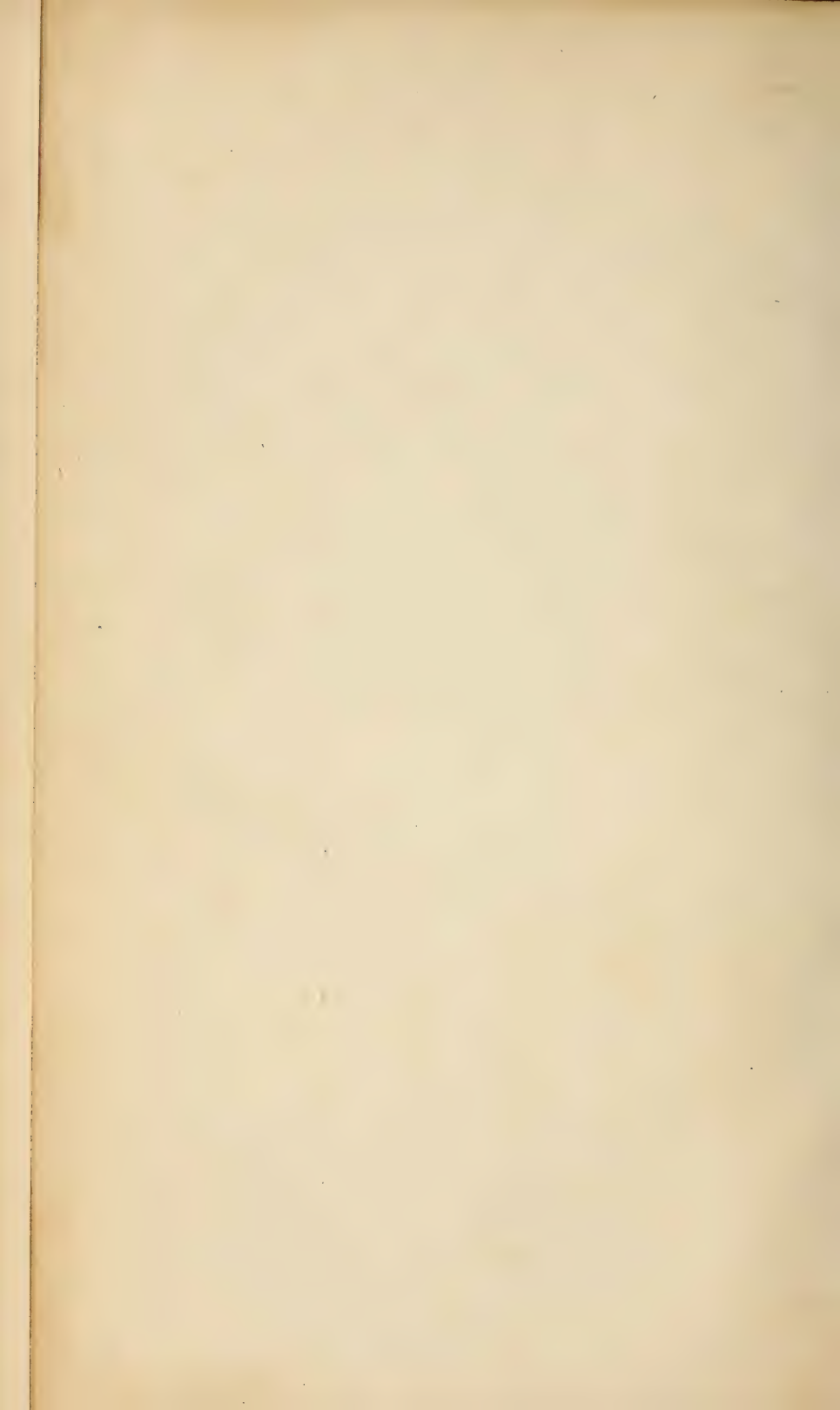
The force of attraction is uniform at equal distance from the centre... increasing inwards.

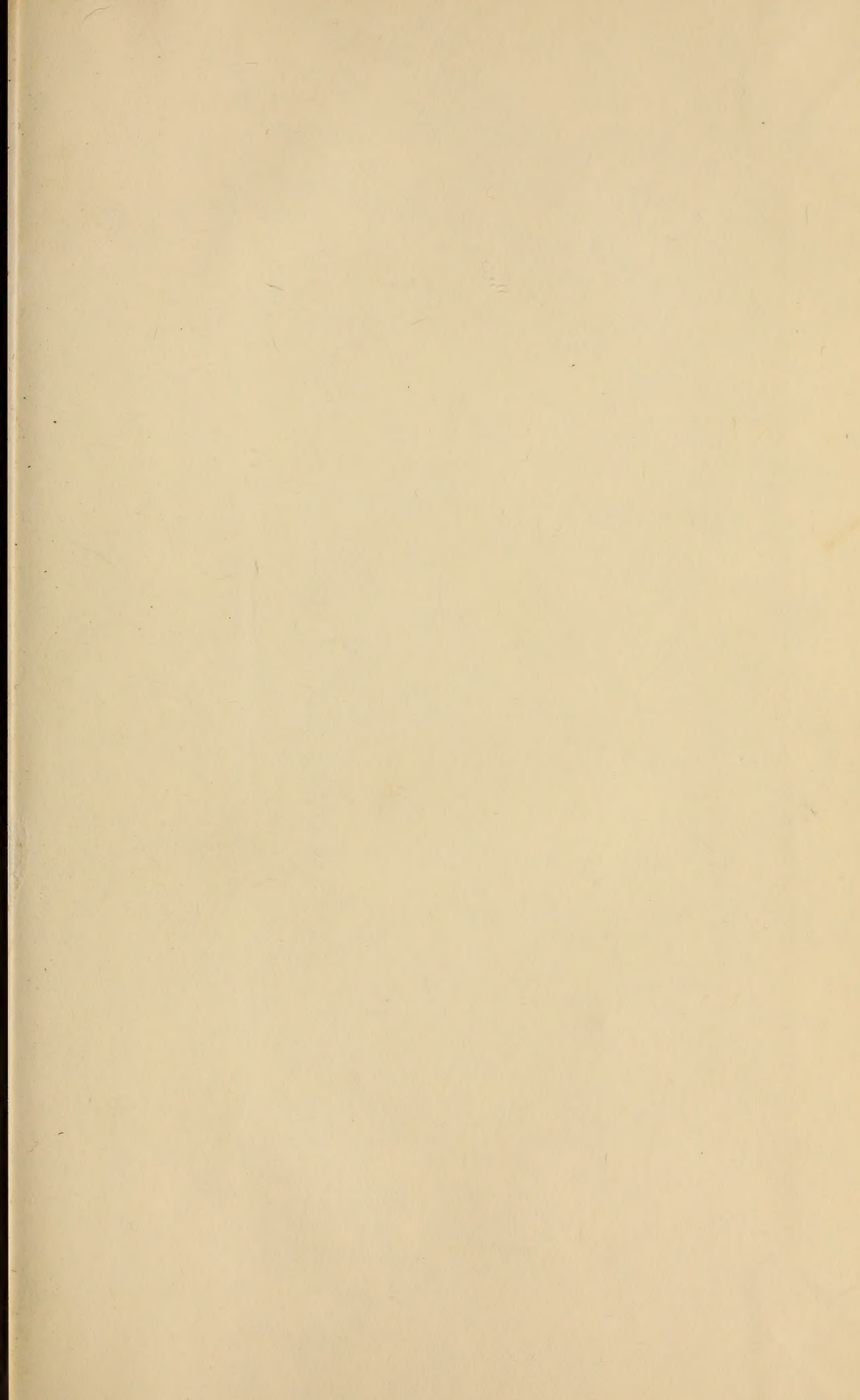
















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On the connexion of geology with terrest