# OUTLINES

OF

# GEONOMY:

A TREATISE ON THE

PHYSICAL LAWS OF THE EARTH

AND THE

CREATION OF THE CONTINENTS.

FOUNDED UPON RECENT DISCOVERIES.

BY

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ELECTROTYPED AT THE
BOSTON STEREOTYPE FOUNDRY.

# DIAGRAM MAP OF THE WORLD.

# PREFACE.

In submitting this outline of a novel system of geonomy, and asking that it may be admitted into the confederation of recognized sciences, to occupy, at once, the place of geology and physical geography, I am conscious that I render myself liable to be charged with egotism; and if it shall be found, upon a proper investigation, that what I deem to be new and important discoveries are merely erroneous fancies, I shall abandon all defence, and throw myself upon the mercy of the public. If, on the contrary, it shall appear that I am not mistaken in regard to the essential principles of the new form of science which I propose to introduce, I shall hope and expect that the faults and errors that accompany the truths will be looked upon with a lenient eye, and attributed in a great measure to the numerous disadvantages under which the author has labored.

This little book is designed merely as the forerunner of a larger volume, which will be presented to the public hereafter. In the mean time, I would respectfully solicit from the friends of science the communication of any facts or suggestions which may be useful in bringing the geonomic system nearer to perfection. A wilderness of details is yet unexplored. Even in preparing this meagre outline, I have been painfully sensible of the want of correct information; but I am tempted to hide my own deficiencies behind the reflection that no one individual is at present capable of doing full justice to a theme so vast and comprehensive in its general outlines, and at the same time so rich and varied in its minor features. It is worthy of the united labors of all the scientific minds of all countries; and to them I earnestly commend it.

The Hon. L. Chandler Ball is the only person whom I have consulted during this investigation; and it is proper that I should publicly acknowledge the obligations which I am under for his valuable assistance and his friendly criticisms. While travelling a short distance with him among the lower ridges of the northern part of the Alleghanies, he pointed out the necessity of modifying my views in such a way as to account for the peculiar and frequent, but gentle, rocky undulations that abound among the most ancient stratified formations. I was thus led to new researches, which resulted in the important conclusion, that when the first mountains were made, the earth's crust was much thinner and more flexible, and admitted of being more readily bent into small folds than when it became colder and thicker. This enables us to understand the reason of the fact that mountains have been raised progressively higher, and oceans depressed lower, from the earliest to the latest geologic ages.

I have purposely avoided all scientific questions which are connected with theological controversies, and confined myself strictly to the subject before me; but it is proper in this place to remark, that geonomy furnishes additional evidence that the operations of nature are dependent upon universal laws which, "in the beginning" of time, were made by Him who "weighs the mountains in the scales and the hills in the balances."

We have every reason to conclude that, should another world precisely like this be now launched into its orbit, under the same astronomical circumstances as the earth was, the creative laws would reproduce or repeat all the forms of this earth, and in exactly the same order, upon the surface of the new planet; but it by no means follows that the divine Being has not reserved to himself the power of modifying, or even reversing, his laws, to adapt them to special circumstances. It ill becomes short-lived and frail beings like us to set bounds to the discretionary power of the supreme Ruler of the universe. Let us rather manifest our gratitude for the faculties which he has bestowed upon us by using them to learn and to obey his laws.

J. STANLEY GRIMES.

LANSINGBURGH, N. Y., *November*, 1857.

# EXPLANATION OF THE DIAGRAM MAP.

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The map is drawn on Mercator's projection, which, though convenient when we wish to show the whole earth at one view, is not strictly correct, because it represents the diameter of the earth from east to west as if it were as great at the poles as it is at the equator; whereas, in reality, it grows continually smaller from the equator to the poles, as it is represented on maps with the globular projection.

Arrows are drawn on the map, following each other along a dotted line, so as to represent the normal elliptical currents, circulating independently of each other, and covering the surface of the whole earth, except a few angular inter-elliptical spaces, the principal of which are South America, Africa, Australia, Greenland, Kamschatka, Alaska, Mexico, and India.

The arrows on the *land* are designed to represent the courses of the ancient currents of water which circulated over the land before it was elevated from the bottom of the sea to its present situation. The principal mountain ranges of the earth are parallel to these ellipses, as any one can perceive by comparing a good atlas with the diagram.

The arrows on the *water* represent, though in a general manner only, the courses which the present ocean currents originally and normally pursued. I have not attempted, in this diagram, to give all the subordinate currents as they now circulate, in gulfs, and bays, and among islands, nor in all places where the partial drainage of the continents has caused counter currents to overflow from inland seas, and disturb the normal directions of the main currents.

In the North Atlantic, I have represented the course of the Gulf Stream as if it were directly north-east from Florida to Spitzbergen; and analogy, as well as the general forms of the land, indicates that this was the direction in which it did run before the upheaval of the more southern parts of the North American continent. That event forced the remaining inland seas to find an outlet to the east through Davis's Strait, elevated the Grand Banks, and deflected the Gulf Stream more to the east, across the ocean, to the European side. There the main current of the stream is divided into several abnormal branches.

The arrows in the North Atlantic and Baffin's Bay that are not in a range with the dotted lines are intended to represent the irregular branches, and also the course, of the main current from Newfoundland to Europe.

The arrows represent all currents as running westerly in the tropical, and easterly in the polar, regions, and north and south between; and any good atlas will show that the mountains curve in accordance with the curves of the currents.

The object of this diagram is to illustrate the *principle* of oceanic ellipses and their relations to mountain ranges, and not to instruct in the details; this may be done, hereafter, in a larger work, with proper illustrations.

If ellipses are to be introduced into geographical science, it will be convenient for reference to divide each ellipse into eight segments, commencing at the equator, and following the courses of the currents as indicated by the arrows. The eight segments would be named and numbered as follows: 1. The mid-line, or equatorial segment; 2. The west mid-line segment, being that eighth which is between the mid-line segment and the western segment; 3. The western segment; 4. The west polar segment, being that eighth which is between the western and the polar segments; 5. The polar segment; 6. The east polar segment; 7. The eastern segment; 8. The east mid-line segment.

If the above arrangement were adopted, it would, in practice, only be necessary to refer to the *number* of the segment in order to be understood. This plan would be found very useful when comparing the facts and details of one ellipse with those of another. Thus, in comparing the Asiatic ellipse with the North American, we could say that the eighth segment of one is occupied by the Anglo-Americans, and of the other by the Chinese. It would also be convenient in describing or in referring to a place. Thus we could say that the Aral Sea is near the second segment of Asia.

Two of the ellipses on the map — one in each hemisphere — are numbered, to show the manner in which they may *all* be numbered in accordance with the above plan.

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# OUTLINES OF GEONOMY.

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## INTRODUCTION.

Geonomy is a science which relates to the physical laws of the earth, and includes all the essential facts of geology and physical geography.

In this treatise those facts are mostly accounted for upon the theory that the weight of the atmosphere, the ocean, and the stratified deposits, pressing unequally upon the granite crust of the earth, causes it to sink unequally, and by reaction produces upward movements of the lava and of the land, and gives birth to earthquakes, volcanoes, mountains, and continents.

The term *geonomy* is derived from two Greek words, —*ge*, the earth, and *nomos*, a law,—and is analogous to the term *astronomy*, which is from *astron*, a star, and *nomos*.

*Geography* literally signifies a description of the earth; but it is commonly applied to the surface only.

*Geology* signifies a discourse concerning the earth; it is, however, limited by usage to an explanation of the structure and origin of rocks and fossils, and cannot conveniently be made to include physical geography.

I have adopted the term *geonomy*, because there is no other word, of equivalent meaning, now in use in this country, and because it appears to be perfectly appropriate. It implies that we are not only acquainted with many facts concerning the structure and natural history of the earth, but, also, that we have at length arrived at a knowledge of the great principles and laws of nature, which, under the same circumstances, must always produce similar terrestrial phenomena and forms. Nearly all the natural sciences may be regarded as subordinate to geonomy, and as each furnishing contributions to enable us to understand the complicated nature of the planet on the surface of which we live.

In order to render the subject more clear and intelligible, I have introduced a brief preliminary section, containing a summary view of the most essential points, expressed in concise terms, and arranged in a natural order.

## SECTION I.

### SUMMARY OF THE PRINCIPLES OF GEONOMY.

THE following is a summary of the distinct principles of geonomy, which, when properly applied, enable us to solve most of the difficult problems of physical geography and geology.

1. The effect of centrifugal force is to flatten the earth at the poles and enlarge it at the equator, so as to make the equatorial diameter about twenty-six miles greater than the polar diameter.

2. The combined effects of centrifugal force and of gravitation, are to continually maintain the spheroidal form of the earth, and to resist all forces that tend to disturb the equilibrium thus established.

3. As far as we know, the heaviest substances and strata are nearest to the centre of the earth, and the lightest occupy the circumference; and all substances have a constant tendency to move towards or from the centre of the earth, until they reach the places assigned them by gravity. The result is, that all substances of equal specific gravity tend to occupy equal distances from the centre, and to each constitute a special spheroidal layer or shell around the earth.

4. If centrifugal force and gravity had been left to arrange the substances that compose the earth without

the interference of any other agent, the surface of the earth would have presented a uniform appearance, and the atmosphere and ocean would have been of equal depth over the surface of all parts of the earth; there would have been no winds, nor waves, nor currents; no mountains nor valleys; no vegetable nor animal life; nor any motion whatever, except that produced daily by the tidal influences of the sun and moon.

5. All the phenomena of geology and physical geography, all the innumerable forms of earth, — mountains, valleys, rivers, oceans, — and all the varied manifestations of life, beauty, and intelligence upon our planet, are directly dependent upon the disturbance which the unequal distribution of the sun's rays produces in the equilibrium of the atmosphere and the ocean.

## THE ATMOSPHERE.

6. The atmosphere is the outer layer of the earth's substances, and being the most volatile, has its balance most easily disturbed by heat, and consequently it reacts with proportionate facility to recover its balance.

The heaviest and densest layers of the atmosphere occupy the space nearest to the surface of the earth, and the lightest layers occupy the spaces which are highest, and are supposed to be about fifty miles above the earth. Between the lowest and highest parts of the atmosphere there is a regular gradation of density and weight, the air becoming less and less dense from the bottom to the top.

7. Let us assume that the atmosphere is normally

composed of fifty distinct layers of air, each of which is of a different degree of density from the other, and is one mile in depth. If the lowest layer becomes expanded by heat, so that its density is only equal to that of the tenth layer, the lowest layer will immediately rise and mingle with the air of the tenth, and allow the second layer to subside to the surface of the earth.

If the expansion of air by heat at the surface of the earth was the same in all places, from the equator to the poles, the equalizing movement would be merely upward and downward; otherwise it would be horizontal, and constitute what is commonly called a *wind*.

8. The rays of the sun's heat penetrate through the atmosphere without expanding it much, but after striking the earth, are reflected again into the atmosphere, and cause an expansion of the lowest layers only: this expansion is greatest at the equator, and is gradually less as we proceed to the poles.

9. The reason why the direct rays of the sun expand the upper layers of the atmosphere less than they do the lower is that, from some unknown cause, the direct rays of the sun have more penetrating power and less heating power than the reflected rays do, and consequently the rays pass from the sun directly through the atmosphere to the earth without being obstructed by the air; but when the rays rebound from the earth, they have not penetrating power sufficient to expand any part of the atmosphere except the lower layers.

10. The celestial space through which the earth is moving is many degrees colder than the earth is even at

the poles; consequently, however hot or expanded the lower layers of the atmosphere may become at the equator, they can perfectly recover their density without leaving the tropics, by merely rising to the upper regions.

11. On each side of the equator there is a column of hot and expanded air continually rising and swelling the atmosphere, so as to make it about four miles higher at the equator than at any other part of the earth. When the expanded air reaches a sufficient elevation, it becomes chilled and condensed, so that it is heavier than when it left the surface; of course it immediately begins to fall. Being crowded by the rising and overflowing column of air near the equator, it slides down an inclined plane, poleward, and reaches the surface of the earth at about the thirtieth degree of latitude from the equator. Perhaps it would be more correct if we should say that near the thirtieth degree the condensing column from the upper regions of the equator is resisted by the dry cold air beyond the tropics, and prevented from moving farther poleward in the upper regions; therefore it continues gradually to sink, and by its weight presses upon the lower strata, so as to cause a movement towards and from the poles at the surface of the earth; just as the pressing of a heavy body into the middle of a trough of water causes a movement of the water towards both ends of the trough.

In accordance with this theory is the fact, that the wind is constantly blowing towards the equator from near the thirtieth degree of north and south latitude, and on the contrary it is almost continually blowing towards the poles beyond the thirtieth degree.

It is also in accordance with the fact, that the barometer indicates that the weight of the atmosphere is greater near the thirtieth degree than in any other part of the earth.

### THE OCEAN.

12. There would be no movements of the ocean in a north and south direction, were it not for the unequal distribution of the sun's rays on the surface of the earth. The tides cause a daily movement of the waters east and west; but with this exception all the currents of the ocean are caused, like the currents of the atmosphere, by the disturbance of the equilibrium produced by the sun's heat.

The heat of the sun, all else equal, being greatest at the equator, and becoming gradually less to the poles, the waters of the ocean are, of course, more expanded at the surface the nearer they are to the equator; and on the contrary, they are more chilled and condensed at the surface the nearer they are to the poles. The consequence of this state of things is, that there is a continual movement going on, between the tropical and polar waters, to restore the equilibrium, which is thus continually being disturbed.

13. Supposing the depth of the water to be equal over the surface of the whole earth, and the bed of the ocean to be smooth, so that there should be no inequalities nor shores to interfere with the natural direction of the waters, what course would the currents pursue? Would the condensed polar waters move in a mass towards the equator, and the expanded tropical waters move in a

mass to meet them near the thirtieth degree of latitude, as the winds meet? Is there any law which would separate the poleward currents from those which are moving towards the equator, and force each to turn aside, avoid an encounter, and choose a separate path for itself? It is a law of nature that opposing forces, under such circumstances, shall tend to compromise, and form a circuit which is generally of an elliptical or oval form. The planetary bodies, which were in motion long before the ocean waters were, had already set the example of obedience to the law of elliptical motion.

14. Assuming, then, that the current from the pole to the equator constituted half of a circuit, and the current from the equator to the pole the other half of it, what natural laws are there that would impose upon this circuit a definite length, breadth, and form, and restrict the number of distinct circuits? The poles of the earth are but two central points. Several currents, therefore, which go to and from one of the poles without crossing each other must necessarily form acute angles at the pole; and furthermore, the currents which go from the pole must be continuations of those which go to it.

15. The currents that primitively moved towards the equator, instead of converging to a point, as at the pole, must have diverged and become widely separated from each other. The earth being twenty-four thousand miles in circumference, if there were but three equidistant currents that run to the equator, they must have been eight thousand miles apart when they reached there; and as the distance to the pole is but six thousand

miles, the three primitive ellipses of each hemisphere had their longer diameters from east to west.

16. Let us suppose that the first ocean currents were thus arranged, and that each hemisphere was divided into three elliptical circuits; what natural laws would govern and limit these circuits? Before answering this, let us define an ellipse.

An ellipse, or ellipsis, differs from a circle in being longer than it is wide. The most distant extremities of an ellipse are called *apsides*. The terrestrial ellipses at the present time each have one apsis near the equator, and the other near the arctic or the antarctic circle. The waters of each distinct oceanic basin run in an ellipse from the equator along the western part of the ocean towards the pole, and from the polar region along the eastern part of the ocean to the equator. When the primitive currents of water moved from the pole towards the equator, the rotatory motion of the earth must have given them a westward tendency, so that they reached the equator at least two thousand miles farther to the west than if they had moved in a direct line.

When the water of the current arrived at the equator, if it was not yet sufficiently expanded by heat to overflow towards the pole, it moved westward along in the tropics, until it became sufficiently expanded. Let us suppose that it moved along the equator two thousand miles before it turned towards the pole; it would afterwards naturally move at least two thousand miles farther before it would cease to tend towards the west in any degree, and by this time it would be nearly one third of its way from the equator to the pole. During the remaining two thirds of its journey, the rotation of the earth would curve it in an easterly direction.

17. The causes that move the water in a northern and southern direction are obvious enough, and so are those that bring the currents together at the poles; but the causes that operate at the equator to send the current eight thousand miles in a western direction require to be further considered. *First:* the rotatory motion of the earth gives all currents which are moving towards the equator a western tendency, which is greater the nearer they approach to the equator. *Second:* a current which embraces one third of the waters of the earth must be very broad, and must require considerable room to turn in, and but a short segment of it would actually touch the equator before it would turn again towards the pole, gradually curving, until it moved in an easterly direction. *Third:* It must be evident that the larger the body of water which required warming, the longer must be the space which it would occupy parallel with the equator; and it must be equally evident that when the water near the equator is warmed to a certain degree, it must turn towards the pole; and this fact limits the size of ellipses, and prevents the equatorial waters from moving in a continuous stream around the earth. *Fourth:* the current from the pole must strike the equator at a certain point, and after moving a certain distance, leave the equator at another more western point, in order to return to the pole; the distance between these two points will depend principally upon the distance to the pole, the depth of the water, and the

difference of temperature between the tropic and the pole; but one thing is demonstrable, and that is, that an ellipse of waters can move no farther westerly along the equator than is necessary to acquire a certain degree of warmth.

18. If the southern hemisphere was originally divided into only three ellipses, as appearances now indicate that it was, the reasons given above are sufficient to account for the fact; and if the northern hemisphere contains evidences of having been divided into six ellipses, it will naturally be accounted for by supposing that its three original ellipses were each divided, as the continents gradually rose and limited the area in which the waters moved.

## MOUNTAINS AND CONTINENTS.

19. It appears that the principal ranges of mountains were originally the boundaries and divisions between the great oceanic ellipses. In the southern hemisphere, from the north and south mountain ranges of Africa to the mountains which run north and south in South America, there was originally one ellipse, which was bounded east and west by those mountains; and even now this may be geonomically considered as one basin. From the north and south mountain ranges of South America to the north and south mountains of eastern Australia there was another very similar ellipse. From the north and south ranges on the western coast of Australia to the north and south ranges of Africa was a third ellipse. These three great ellipses, or basins, now constitute the three great oceans of the

southern hemisphere, namely, the South Atlantic, the South Pacific, and the Indian Ocean; and they are separated from each other by three analogous elevations of land, namely, Africa, South America, and Australia. These three elevations originally divided the southern hemisphere into three nearly equal parts.

In the space between the southern shore of Australia and the antarctic continent, the forms of the land indicate that there is a small independent ellipse; but we know nothing concerning the directions of the currents there, and this region must therefore be put down as doubtful. There are also some evidences of a distinct ellipse between New Zealand and Australia; but as both of these last mentioned are doubtful in the present state of our knowledge, and as, if they do exist, they are the consequences of a derangement of the primitive ellipses, produced by the elevation of so much land above the sea, I will leave them out of the account in this place, and speak of the southern hemisphere as possessing only three great oceanic basins.

In the northern hemisphere the equivalent of the Indian Ocean is the continent of Asia; the equivalent of the South Atlantic basin, including a large part of Africa, and of South America, is found in Europe, the North Atlantic, and North America; the North and South Pacific Oceans balance each other. The northern hemisphere is in six ellipses, as follows:—

*First.* Asia extends from the Aldan Mountains to the Oural Mountains, and originally constituted a distinct submarine ellipse.

*Second.* Europe extends from the Ourals to the

Scandinavians, and though small, has the undoubted marks of a separate ellipse.

*Third.* The North Atlantic constitutes a model and well-known ellipse called "the Gulf Stream."

*Fourth.* North America was once overflowed by an ellipse of the ocean extending from the Appalachians to the Rocky Mountains.

*Fifth.* There is an imperfect ellipse now in the process of draining, and rising in the north-west part of North America, between the Rocky Mountains, the peninsula of Alaska, and the Sandwich Islands.

*Sixth.* An oceanic ellipse evidently exists between Alaska and China, which I will denominate the north-west Pacific ellipse.

20. A demonstrable parallelism exists between the normal currents of the ocean and the principal ranges of mountains, which renders it evident that there is a necessary connection between the two classes of phenomena that may rationally be accounted for as follows: —

21. When the earth was first formed, its surface was too hot to allow the waters to remain upon it; but the ocean then existed in the form of vapor circulating in the atmosphere around the solid earth. Under these circumstances, there was nothing to prevent the earth from assuming a spheroidal form, without any irregularities upon its surface; it had neither mountains nor valleys, and it would have remained in this regular and smooth condition, had not the gradual radiation of heat into the celestial spaces caused the formation around the earth of a shell or crust of cooled lava, upon the surface

of which the condensed vapors fell, to constitute the ocean.

22. As soon as the ocean had covered the earth, and the difference of temperature between the equator and the poles began to operate, there would immediately commence a movement of currents from the poles to the equator, and back again, to restore the equilibrium.

23. The paths pursued by the ocean currents soon became heaped with a heavy mass of detritus, — gravel and sediment, — which was precipitated and deposited there.

24. When water runs the most rapidly, it becomes the most heavily charged with sediment; and when it runs the most slowly, it drops the particles of sediment the most copiously.

25. There are some substances that are held in solution by cold water, but which are immediately precipitated and deposited at the bottom when the water becomes warmed. This is the case with lime, especially when the water contains considerable carbonic acid.

26. When, by the regular operation of the currents, a series of strata was formed along the course and direction of the current, especially in the young and tender condition of the earth's primitive crust, its weight caused a subsidence of the crust proportionate to the quantity of the sediment accumulated in one place.

27. It would be impossible for such a subsidence of a long ridge of strata to take place without producing a corresponding elevation parallel to the line of subsidence, and also parallel to the course of the current.

28. When two parallel currents run in opposite

directions so near to each other as to somewhat interfere and moderate each other's movements, the effect is to cause an uncommon precipitation of sediment at the points of mutual contact, and consequently at such points a subsidence and elevation would be most likely to take place, the effect of which would be to place a ridge, or line of elevation, between the two currents that would prevent their further interference with each other. Each current afterwards, instead of impinging against another current, would impinge against its own shore or side of the elevated ridge, and impress it with its own character, curve, and direction.

29. If the elevation extends north and south, and is very long, it has its eastern side concave at the end which is towards the pole, and convex at the eastern side of the other end. Its western side will be the reverse of this; that is to say, the end which is towards the pole will be convex, while that which is towards the equator will be concave. The mountains and shores of the western part of North America are a good illustration.

30. All normal oceanic currents invariably run *from* the pole on the *western* sides of elevations, and all normal currents that run *towards* the pole, take the *eastern* sides; and this fact, together with the fact that the rotatory motion of the earth causes poleward currents to curve to the east when nearing the poles, and those moving towards the equator to curve to the west, is a sufficient explanation of the difference in the curves of mountains at their northern and southern extremities.

## EARTHQUAKES.

31. When two currents are running, one on each side of a ridge, a subsidence will be most likely to take place on the side which borders the larger body of water; because that side will be likely to gather and deposit the largest and heaviest body of detritus.

32. When a subsidence takes place on one side of a ridge, it produces an elevation on the opposite side, by crowding the subjacent lava upward, under the crust of the opposite side, and sometimes causing it to gush out and overflow towards the side which has subsided. This explains the phenomena which are known in geology under the name of *faults*. It also explains the fact that mountains generally have their crests inclined towards their most abrupt slopes, and are, in some instances, even folded over.

33. The side of the ridge which has proved its superiority of weight by subsiding once, seldom loses the advantage thus gained over its opponent. The waters on both sides of the ridge retreat from the ridge to an extent proportionate to the degree of the elevation, but the waters on the side which sinks deepest retire the shortest distance; and under the operation of the same causes, another stratified formation of detritus and sediment is deposited, parallel, or nearly so, with the first, which is of the same weight; but this fails to produce a subsidence, for the reason that in the mean time the crust of the earth has grown cooler, thicker, and stronger. The subsidence is therefore postponed until sufficient rëenforcements of sediment arrive. At length the

shell gives way, and goes down with a force proportioned to its weight, and raises a corresponding elevation, as much higher than the first elevation as the force which produced it was greater. A third, a fourth, and a fifth formation are afterwards deposited, each of which is heavier than its predecessor, and consequently produces a deeper subsidence and a greater elevation. The highest mountains on the earth should by this law be the product of the latest general catastrophe, and raised parallel to several ranges of minor mountains in the interior, whose elevation should be found to be continually less, and the dislocations of the crust less violent, as we approach the locality of the original subsidence.

34. The rule that the larger ocean produces the greater subsidence holds true not only in reference to different mountains when compared with each other, but also when applied to different sections of the same mountain range. Those parts of a mountain range will be found to be the highest which are contiguous to the largest mass of waters.

Those mountains that terminate in deep water are generally promontories, and owe their elevations to the subsidences which have taken place around them. For the same reason the mountains near the poles are not as high as those nearer the tropics, because the ocean there is necessarily contracted for want of space. In accordance with these principles it will be found that the ocean is generally deepest, and its diameter greatest, opposite the highest mountains.

35. The heavy metals are probably situated immediately beneath the lava or melted granite which is

beneath the earth's crust; and they are more likely to be found, not in the highest mountains, but where the greatest subsidences and elevations have been made *at one movement;* for the reason that *such* a movement would stir the melted masses which are beneath the crust to a greater depth, and, by reaction, send the heavier metals up to greater heights and in larger quantities.

36. The first formation of rock upon the earth was produced by the cooling and hardening of the lava. The lava consists of the lightest known metals and metalloids combined with oxygen; and it is to be presumed that the reason why the crust is composed of these light metals is, because they were floating upon the melted metallic surface of the primitive earth, and were thus brought into contact with the atmosphere, so as to become oxidized and cooled to form the crust.

37. The next formation was *gneiss*, and is composed of the worn and broken fragments of granite. During the accumulation of this and the following formation, the surface of the earth was probably in continual agitation, in consequence of the strife which was taking place between the hot lava below the thin crust and the moisture which was condensing from the atmosphere above it. This is evident not only from the nature of things, but also from the contorted appearance of the strata in the rocks themselves.

38. The next rocky formation is called mica schist, and is a species of slate, in which mica abounds, and was apparently formed by sediment falling from the water among the lighter portions of the gneiss. Above this

are clay slates, and sandstones of a more fine and regular formation, indicating that a more quiet ocean prevailed.

39. The next important circumstance in a geonomic point of view, in the progress of the formations, is the abundance of red sandstone, which indicates that subsidences had taken place deep enough to send up a large quantity of iron by their reactions, and that oxides of the iron had tinged the sandstones with a brownish red color.

40. Above the old red sandstones is deposited an immense quantity of limestone, which was probably formed in hot and shallow seas, by the precipitation of lime from solution in cold water. Cold water, which contains considerable carbonic acid, is capable of holding a large quantity of lime in solution, the carbonic acid being absorbed from the atmosphere, and the lime being dissolved from the rocks at the bottom of the sea. When this solution was borne by the currents from the deep cold waters to the shallower and warmer seas, the increase of heat caused a precipitation of the lime to the bottom, which, accumulating gradually for indefinite ages, produced the limestones of the carboniferous formation.

41. Immediately above these carboniferous limestones are the beds of coal which now supply fuel to man. These were formed in the lowlands of an archipelago, where, in consequence of the flexible condition of the earth's rising crust, there were alternate, and sometimes, perhaps, annual subsidences and elevations, which brought the same area to the surface, and allowed a

growth of vegetation upon it, and then sunk it so far as to allow a formation of limestone and detritus to be made above the coal. Being again raised to the surface, a new layer of coal was added. This carboniferous formation was brought to an end by a series of general and enormous subsidences and elevations, which raised still more iron from below the crust, and produced the new red sandstone formation.

42. The next fact to be noticed is, that above the coal and lime, in the new red sandstone, is the saliferous formation ; that is to say, there is evidence of the commencement of plains of land containing salt lakes or lagoons within their bosoms, from which the fresh water gradually evaporated, as the land rose, leaving rock salt, gypsum, and magnesian stone, deposited and accumulated in the beds where they are now found.

43. Above the saliferous formation are the lias, the oölitic, the cretaceous, the tertiary, the drift, and the present alluvial formations, all of which unite in furnishing satisfactory proofs that, 1st, the present dry lands were sometimes elevated gradually and quietly without sudden convulsions, in a way which it would appear can be most easily explained by supposing that the elevation was caused by the gradual subsidence of the beds of the surrounding oceans crowding the subjacent lava up under the rising continents, and producing earthquakes and volcanoes occasionally, in consequence of local interruptions of the general gradual progress downward in one direction, and upward in another.

2d. That the most remarkable convulsions and elevations followed, in many instances, after a very long period of quiet and gradual accumulations of stratified deposits of sediment and detritus.

3d. That the dislocations of the crust almost invariably took place in a line parallel with the line in which the strata were deposited, and also in a line parallel with the course which the ocean's currents must naturally have pursued.

4th. The formations which were the last that were deposited in the sea before the present time, namely, the tertiary, are found tilted up from their original places around the *highest* mountains, while around the lower class of elevations they are seldom disturbed; thus demonstrating that the latest elevations are the highest, and were caused by the latest subsidences of the ocean's bed.

44. In some cases, it is very likely that local subsidences and elevations took place in consequence of the general disturbance of the crust over a large area. A local accumulation which would be insufficient to break the crust by its weight when the earth was quiet, would subside if the earth were shaken in that region. Not only so, if a large region were forced upward by the pressure of a vast and extensive mass of lava, the localities where the crust was thinnest and least loaded with strata, would be likely to rise highest, and leave the places lower, where the strata were thickest and heaviest. The appearances in some mountainous regions seem to suggest this explanation.

It is a demonstrable fact in geology, that the convulsions, as they are called, have been continually less frequent and more violent, from the time of the deposition of the first and lowest strata ; the hills have also become continually higher and the oceans deeper.

45. When the most modern stratified rocks are found but slightly disturbed, and yet much elevated, it is generally near the sea shore, and their elevation in such cases is owing not to the dislocation of the crust so much as to the gradual and general subsidence of the neighboring seas, and the equally gradual elevation of the whole mass of land which borders upon the ocean.

It has for a long time been known that there is a distinction between earthquakes, volcanic eruptions, the sudden elevation of mountain ridges, and the gradual elevation of continents and peninsulas ; but the causes of neither have been understood. Earthquakes are caused by subsidences which produce movements of lava beneath the crust of the earth. Volcanoes are the eruptions of lava through orifices in the crust. Continental elevations are caused by the gradual subsidence of the ocean, producing unobserved reactions upon the masses of higher land.

## PHYSICAL GEOGRAPHY.

46. The mountains of the same hemisphere, that are parallel to each other, possess the same relations to the ocean currents ; and wherever similar forms of mountains, islands, peninsulas, plateaus, or lakes are repeated, it will be found that they are always the results of analogous movements of different currents.

It will also be found that when the forms of different lands approximate to each other, but are yet, in many respects, unlike, the forming currents equally approximated and equally varied in their conditions and directions when the lands were created.

47. When the forms of different lands greatly resemble each other, but one land is much more diminutive than the other, it will be found that the smaller land was produced by currents analogous in direction, but proportionally as much inferior in size as the land is. As illustrations, we may study the analogies of the currents and terrestrial forms of the three continents of the southern hemisphere — South America, Africa, and Australia. We here find similar ocean currents associated with strikingly similar forms of land.

48. In the northern hemisphere we have a series of three ellipses, Asia, Europe, and the North Atlantic, repeated in every thing essential by the next series, namely, North America, North-west America, and the North-west Pacific.

Let us make two columns, and put opposite each other the names of those places that are analogous, and, as it were, repetitions of each other in the two series of continents.

| | |
|---|---|
| Kamschatka, | Greenland. |
| Okotsk Sea, | Baffin's Bay. |
| Japan, | Newfoundland. |
| China, | United States. |
| Siam, | Florida. |
| Bengal Bay, | Gulf of Mexico. |
| Sumatra and Java, | Central America. |
| Borneo and Celebes, | Cuba and Jamaica. |
| Peling and Nanling Mountains, | Appalachians. |
| India, | Mexico. |

| | |
|---|---|
| Plateau of Thibet, . . . | Plateau of California. |
| The Oural Mountains, . . | The Rocky Mountains. |
| The Peninsula of Arabia, . . | The Peninsula of California. |
| The Persian Gulf, . . . | The Gulf of California. |
| Europe, . . . . | North-west America. |
| Scandinavia, . . . | Alaska. |
| Iceland Channel, . . . | Behring's Strait. |
| North-west part of the Atlantic, . | North-west Pacific. |

If we compare Europe with North America, we find that Italy corresponds with Panama. The semicircle of the Alps corresponds with the semicircular form of the shores around the Mexican Gulf. We must not allow ourselves to be deceived by the greater elevation of the Alps, for in geonomy the degree of elevation is of minor importance, when the analogy of forms and their relation to currents are in question. In all the preceding instances which have been given of analogous forms of land, it will be found that, as far as we know or can judge, the direction of the currents was also analogous.

49. There is not a land upon the earth, neither island, peninsula, nor continent, the known form of which is such as to contradict the geonomic theory here proposed.

In those instances where counter currents prevail from temporary and local causes, the directions of the land are found reversed. This is believed to be the case with the Massachusetts capes, that were formed under the influence of the cold current from Baffin's Bay, which is probably a relic of the ancient North American ellipse.

50. There are a great many ridges of small hills in the interior of almost every country, the formation of

which can only be understood by considering the condition of the earth at the time when they were made; most of them are composed of the earliest deposited stratified rocks. They contain evidence of having once formed a part of the ocean's bed, at a period when the crust of the earth was warm and thin, and easily bent by the weight of small masses of detritus and sediment. They were, in fact, the first created hills. In most instances their highest points are unbroken by the protrusion of lava, for powerful volcanoes had not yet burst forth. It is interesting to study these ancient ocean beds, and determine by observation the particular valleys or plains, the depressions of which produced the particular elevations.

51. The principles of geonomy, when applied to other planetary bodies, indicate the existence of fluids, which circulate upon their surfaces in ellipses, the forms and sizes of which are modified by astronomic conditions peculiar to each; but the directions and curves of the currents can be determined with great accuracy by the elevations which they have been instrumental in producing.

## SECTION II.

### EQUILIBRIUM OF THE EARTH.

It is the opinion of many distinguished modern philosophers that the solid materials which constitute the earth, were at one time so much expanded by heat that they were in a melted and liquid state; that the whole world was but a revolving ball of fluid and liquid substances, which occupied much more space than the earth does at present.

It is estimated that the temperature of the space through which the planets of our solar system are moving, is not less than sixty degrees of Fahrenheit's thermometer below zero; and we know that the line of perpetual frost at the equator is only fifteen thousand feet above the level of the sea.

It is conjectured by some astronomers that our solar system is only a small segment of a vast circle of systems revolving around a common centre; and they suggest it as possible that in one part of the circle, the planets are all melted by the intense heat of the space through which they are passing, and that in another part they are congealed by the intense cold. This, however, is mere speculation, concerning a question which cannot be settled by observation nor experiment. But we have satisfactory evidence that, whatever may be the remote causes, the fact is, the surface of the earth was formerly in a melted condition, so that each substance was at liberty to move to the place assigned to it by gravitation. We are also satisfied that the surface of the earth has been gradually cooling; and that, consequently, its external substances have been condensing. When the surface of the whole earth was in a melted state, many of the substances which now exist in the condition of fluids or solids must have been gases or vapors. The waters which now constitute the sea, were then in the atmosphere, mingled with vapors of sulphur, phosphorus, iodine, and many other things which are now only found in the natural state as solid substances.

What a splendid subject have we here for the contemplation of a chemical philosopher! It is his province to determine the effects of different degrees of heat upon the specific gravities of the various substances which mingled in that chaos of terrestrial elements. There were no solids then at the earth's surface. Metals and metalloids were in a liquid state; all else was vaporous. When the condensing process began, what substances first fell from the atmosphere upon the earth? Was it a rain of sulphur, phosphorus, iodine, and chlorine, in combination with oxygen; and then a rain of acidulated water; then water more pure; until the whole ocean fell from the atmosphere upon the solid surface, and enveloped the earth in a blue and waving robe, to protect it from the scorching rays of the sun above, and the more powerful heat of the metallic ocean below?

The astronomical position of the earth, and its relation to the sun, are such that the tropical regions receive a constant flood of heat, while the poles are supplied scantily and alternately; the consequence must have been, in the original formation of the earth's crust, that the condensation and precipitation of substances at the poles must have been much more copious than in the tropics, and dry land would therefore be more likely to appear at the poles first, while water would be accumulated near the equator. The continents did probably all commence rising in the polar regions, and gradually extend towards the equator.

The fact is noticed and commented on by all physical geographers, that much the larger part of the dry land is in the northern hemisphere; though I am not aware that any suggestion has ever been made concerning the cause of this apparent violation of the laws of equilibrium. As the earth revolves, steadily, upon its axis, gravitation tends to make the two hemispheres equal in every respect; and there can be little doubt that the inequality which apparently exists has been produced by some cause which acted upon one hemisphere more powerfully than upon the other. Was it the unequal distribution of heat to the two hemispheres? Did some apparent accident in the beginning elevate a little more land in the north, and thus give it an advantage which, from its very nature, would increase indefinitely? Or, may the predominance of northern lands and southern waters be attributed to the precession of the equinoxes?

Every elementary work on astronomy contains an explanation of the principles involved in the precession; and it is sufficient here to state the result, which is, that during a period of about ten thousand years, the spring and summer in the northern hemisphere is about seven and three fourth days longer than in the southern, and this is followed by an equal period in which the spring and summer in the southern hemisphere is the longer.

At the present time the longer summer and shorter winter is in the north, and will continue here about four thousand years to come, when it will be transferred to the southern hemisphere. Herschel calculated that the precession would make no difference in the absolute amount of light and heat received, but that it would be the same in both hemispheres, the greater proximity of the earth to the sun in perihelion compensating for its shorter time; but Humboldt justly remarks in substance that a winter longer by seven and three quarter days will occasion a loss of heat by radiation which is not fully compensated; and therefore the greater degree of cold which is well known to exist in the southern hemisphere than in the northern, at the present time, may be in part, at least, if not wholly, attributed to this cause.

Sir Charles Lyell, in his Principles of Geology, vol. i. p. 121, adopts the same view of the subject. He says, "Perhaps no very sensible effect may be produced by this source of disturbance; yet the geologist should bear in mind that to a certain extent it operates alternately on each of the two hemispheres for a period of upwards of ten thousand years, dividing unequally the times during which the annual supply of solar light and heat is received. This cause may sometimes tend to counterbalance inequalities of temperature resulting from other far more influential circumstances; but, on the other hand, it must sometimes tend to increase the extreme of deviation arising from particular combinations of causes. But whatever may be at present the inferiority of heat in the temperate and frigid zones south of the line, it is quite evident that the cold would be far more intense if there happened, instead of open sea, to be tracts of elevated land between the fifty-fifth and seventieth parallel; and, on the other hand, the cold would be moderated if there was more land between the line and forty-fifth degree of south latitude."

If we multiply ten thousand years by seven and three fourth days, we find that it amounts, in the aggregate, to about two hundred and twelve years; now, it is evident that if we could have two hundred and twelve years of *constant* winter in the southern hemisphere, and summer in the northern, the currents would, during all that time, bring to the north the detritus of lands, which the cold tempests and the frosts would naturally break up in the south; and we should expect to see a predominance of dry land in the north. Instead of having the whole two hundred and twelve years of southern winter at once, we have it equally divided between ten thousand years, so that each year the south receives but about seven and three fourth days of colder weather: this makes no difference in the aggregate effects. It will, doubtless, be suggested by some critical readers that the land gained to one hemisphere by the precession during a period of ten thousand years must be lost during the following period; but this does not necessarily follow. Before we come to such a conclusion we should consider all the possible effects that the precession of the equinoxes might have produced, not only upon the movements of the waters, but upon the precipitation of substances held in solution by the waters, and also upon the cooling of the crust of the earth during the earlier ages of creation; we should also consider whether the disturbance of equilibrium produced during one period might not, by a change of circumstances, have been increased during the next, instead of being compensated and balanced. Furthermore, we should consider whether the stage of creation at which the earth had arrived in the commencement of a particular period may not have been such that a slight increase of heat in one hemisphere would produce effects which could not be compensated during a large number of succeeding cycles. Is it not possible that the greater weight and pressure of the more condensed atmosphere in the colder southern hemisphere may have depressed the earth's crust when it was very young and delicate, and thus forced a portion of the subjacent lava to escape into the northern hemisphere?

It is frequently said that continents grow broader towards the north pole; but this is only apparently so. The currents of the whole northern hemisphere tend to converge to the north pole; the lands, of course, do the same; and the consequence is, that the arctic circle is mostly occupied by land; but the distance around the earth at the arctic circle is so small that it does not require such broad lands to fill the whole space as it does nearer the equator.

The greatest part of the ocean waters in the northern hemisphere move north as far as Iceland or Behring's Strait, and south to the north part of South America; half way between these, near the fortieth degree of north latitude, the lands are broadest, highest, and most productive. Follow the fortieth degree around the artificial globe, and we shall pass near the regions most celebrated in human history, at the same time that we are traversing the most extended dry lands on the earth. From this it appears that the lands are broadest in the middle of the ellipses.

In reflecting upon the subject of the predominance of the northern lands and the southern waters, the following hypothetical explanation has occurred to me: —

It being admitted that the earth has been, during indefinite ages, contracting its dimensions in consequence of the gradual radiation and loss of its original heat, and it being a natural law that, under such circumstances, the centrifugal force increases, and causes a greater bulging at the equator and a flattening at the poles, — if, when the crust of the earth was first hardened, it resisted the flattening tendency at the south pole, and yielded to it at the north, the effect would be to produce precisely such a predominance of land in the north and of water in the south as actually exists.

The precession of the equinoxes may have been a cause of the more rapid cooling and hardening of one pole than the other.

If, after this inequality was produced, whatever was the cause, the ocean currents commenced moving between the equator and the poles in both hemispheres alike, the result would be, that the northern hemisphere, having shallower seas, would have its crust most worn and elevated in some places, and depressed by the weight of detritus in other places, so that its land would be the first to rise above the level of the ocean. That part which rose in arctic regions would be broken up by frost, and form detritus to swell the bulk of lands between the arctic and the tropics, where we actually find the lands most elevated and broad. The lands at the south pole, not being so much depressed, would form an antarctic continent, and between the antarctic circle and the tropic of Capricorn would be the great bulk of the ocean, gathered, and, as it were, clinging there, upon one side of the earth, to preserve its equilibrium. These are curious and complicated questions of dynamical geonomy, which I will not pursue farther at present, as they are not necessarily connected with my main argument, though as subordinate matters they are highly interesting.

The natural laws of equilibrium must necessarily *tend* to make the two hemispheres of the earth equal, and if the partial distribution of heat, or refrigeration of the earth, produces a temporary external inequality of the hemispheres, there will be a tendency of the fluids, both above and below the crust, to move, and ultimately to restore the equilibrium. We know that the atmosphere and aqueous fluid do actually more for this purpose, but we have not hitherto regarded earthquakes as the results of movements of the lava to accomplish the same object; I have no doubt, however, that such is the fact.

As soon as the primitive ocean covered the earth, and the polar regions became colder than the tropics, a circulation of winds and waters commenced to restore the equilibrium, which has been continually disturbed by the differences of temperature.

I have no doubt that the actual amount of matter in one hemisphere of the globe is continually the same as that in the other; or, if, through any apparent accident, one hemisphere should temporarily get the advantage, a movement of the air, the water, or the lava immediately begins to restore the balance. If, in consequence of the more rapid cooling of the southern hemisphere, from astronomic causes, there should be, for a series of years, a greater amount of precipitation of substances from an aeriform or a liquid state to a solid state, it might, in the early and nascent condition of the planet, produce a greater subsidence of its young and tender crust, between the equator and the antarctic circle, than what took place in a corresponding region of the northern hemisphere during the same period. This general subsidence of the whole southern hemisphere would, of course, cause a movement of the subjacent lava to the south pole, and across the mid-line of the earth, into the northern hemisphere; and thus, though the southern seas would be larger and the northern lands higher, the relative quantities of matter would be the same in each hemisphere.

The tendency of the two hemispheres to keep in equilibrium seems to be indicated by the symmetry which is to be observed in the ocean currents of the two opposite hemispheres. This is especially apparent in the

Mozambique current being originally antagonized by a current of which the Red Sea is a relic. So also the normal current that flows to the equator along the west coast of Africa, appears to be antagonized by the European current that flows along the eastern part of the Atlantic, to meet, and, as it were, to balance the African current at the western point of South America, near Cape St. Roque; here the two currents separate again, like two limbs proceeding from one vertebra, and each pursues an analogous course to the opposite poles. From the poles again, a little farther west, we find two currents moving towards the equator, meeting a little at the west of Panama, and moving onward together, until the laws of equilibrium require them to part and move towards the polar extremities of the earth; one current impinging, as it goes, upon the eastern coast of Asia, and the other upon the eastern coast of Australia. Looking now a little farther west, we find a current in the Indian Ocean, moving along the western coast of Australia to the equator, and then turning again towards the pole; a part or branch of it running through the Mozambique Channel, the other branch going to the east of Madagascar. In the opposite hemisphere, the mountains of Asia are enduring witnesses, that a current once moved on the western side of the Aldan Mountains to the tropics, turned west and north-west on the northern side of the Himalayas and the Hindoo Kosh, and returned north by the east side of the Oural, seventeen hundred miles, to the Frozen Sea. In fact, we have, in the Asiatic ellipse, the counterpart of the Indian Ocean ellipse. I do not wish to be understood that the ocean currents in the two hemispheres are all *now* symmetrical, but that it is evident that they originally were so when the land was all beneath the sea, and even now they are as symmetrical as the inequalities of the land will permit them to be.

The idea has been advanced by some theorists, that geological phenomena may be explained by supposing that the axis of the earth has been changed, so that what are now the poles were formerly the tropical regions; and distinguished astronomers have been at the pains to show that such could not have been the case; but when the fact is established and admitted that the mountains are produced by currents that run between the poles and the equator, we need look no farther for proof that the poles have remained unchanged. May we not hope that in the future progress of discovery, we may yet find, in the physical constitution of the earth, some marks produced by astronomic cycles or changes, such as the precession of the equinoxes, and thus connect astronomical and geological periods.

## SECTION III.

### ELLIPTICAL PATHS OF THE CURRENTS.

THE tendency of the waters of the ocean is to run in irregular oval currents, or elliptical circuits.

The currents appear to be, at present, divided into seven great ellipses, as follows : —

1. The ellipse which circulates in the north-east part of the Pacific, a part of which is elevated and drained so as to constitute the North-west American ellipse of land : let us name this the Vancouver ellipse.

2. The Siam or North-west Pacific ellipse, which washes the shores of China.

3. The North Atlantic, or Gulf Stream ellipse.

4. The South Atlantic ellipse.

5. The Indian Ocean ellipse.

6, 7. The Chili or South Pacific ellipse, which is probably divided into two submarine ellipses of land. According to Lieutenant Maury, the South Pacific is divided into two parts by currents which run in a north and south direction, between South America and Australia.

Judging by the forms of the land, I presume that there is a small ellipse which circulates between the southern shore of Australia and the antarctic continent. This can only be determined with certainty by a future survey of this region.

The analogy of the sea between New Zealand and Australia to the South Atlantic leads me to suspect that

5

there is also a small ellipse circulating in the New Zealand Sea.

If these two small ellipses do exist in the vicinity of Australia, it is because the lands in that region are rising and interfering with the regular operations of the large primitive ellipses.

It seems to me that I can trace an analogy to the North and South Atlantic Ocean, on a diminutive scale, in the channel that extends from Behring's Strait to the antarctic continent, along the eastern coasts of Asia and Australia, and I cannot help fancying that continents analogous to Europe and Africa are now in the process of forming and rising in the North and South Pacific; the South-east Pacific being the representative or repetition of the Indian Ocean, — the waters between New Zealand and Australia repetitions of the South Atlantic, — and the waters between Behring's Strait and Siam repetitions of the North Atlantic; but these speculations must be postponed for the present.

To the above-mentioned ellipses must be added three oceanic ellipses which have been drained, but whose mountain ranges show plainly the directions in which the currents which created them formerly circulated; they are Asia, Europe, and North America; and perhaps we should reckon North-west America as an ellipse, about one fourth drained.

Subordinate ellipses, or circular currents, appear to be generated in small land-locked seas, bays, and gulfs, by offsets from the great ellipses; thus, in the Gulf of Mexico there is a distinct ellipse, produced by the water entering through the Caribbean Sea, and passing out again through the Florida Channel. This sub-ellipse is generally considered as the principal instigator of the Gulf Stream; but the waters of the Atlantic would circulate in an ellipse, just as they do now, if the Gulf of Mexico and the Caribbean Sea were both entirely closed. The circulation in the Gulf of Mexico, instead of being a necessary part of the North Atlantic circulation, is merely an unessential addition to it. The same may be said of the still greater sub-ellipse, which sets from the North-east Pacific into Bengal Bay, through the Indian Archipelago. The Gulf Stream is here repeated on a larger scale, in every respect; not only so, the whole coast, from India to Alaska, is constituted of repetitions of peninsulas and gulfs, produced by the current entering on one side of an inland sea, and passing out on the other side, thus constituting a remarkable series of sub-ellipses. I have no doubt that the cause of many currents of the deep sea, which have hitherto seemed mysterious, will be perfectly plain when the bottom of the ocean is well known, and the elliptical circulation understood.

Lieutenant Maury very modestly remarks, "There are also about the equator in this ocean (the Pacific) some curious currents which I do not understand, and as to which observations are not sufficient yet to afford a proper explanation or description. There are many of them, some of which, at times, run with great force. On a voyage from the Society to the Sandwich Islands, I encountered one running at the rate of ninety-six miles a day." I have a sanguine hope, amounting to a confident expectation that when the elliptical theory is applied to those currents, they will be readily understood, after a more particular survey of them has been made by the distinguished head of our National Observatory, aided by the numerous ship-masters, who report their observations to him.

## EFFECTS OF THE EARTH'S ROTATION.

We may enumerate six different causes which are constantly tending to move the waters, or to modify their motions.

1. The tides cause a flow twice a day towards the west, which is each time followed by an ebbing reaction eastward.

2. The earth, as it moves upon its axis from west to east, successively presents its different parts to the heat and light, and other influences of the sun and moon.

3. The evaporation of water from one part of the earth, which falls in rain or snow in another, and then flows back again.

4. The winds which blow upon the surface of the waters and warm or cool them, and also force them to move temporarily in the same direction.

5. The inequalities of temperature between the polar and the tropical regions is the principal cause of ocean currents.

6. The rotatory motion of the earth, communicating itself to the waters of the ocean, causing currents that are moving towards the equator to incline westward, and those moving towards either pole to incline eastward. Let me explain this more particularly. As the

earth revolves upon its axis, the particles of water, air, or any other substances which are near the pole, have but a short distance to travel to go entirely around the earth ; or, if they remain still, and are carried around by the rotation of the earth, they have to proceed but a short distance before they complete the circuit.

At a greater distance from the pole the journey around it is longer, and at the equator the circumference is twenty-four thousand miles. In other words, all the substances on the surface of the earth at the equator are carried twenty-four thousand miles every time that the earth revolves ; and the distance around decreases continually as they approach the pole. When any substance moves from a part of the earth which is farther from the pole to one that is nearer, it carries with it a momentum, or tendency to motion, greater than it finds among similar substances there, and, of course, it moves eastwardly faster than the others do. For this reason a current in the ocean that would otherwise flow directly poleward from the equator, actually curves several degrees eastwardly ; on the other hand, currents which otherwise would move from the poles directly to the equator, are made to curve westwardly.

The same fact may be stated thus : When the waters of the polar region move in currents towards the equator, they are not permitted to proceed due north or south, but are made to curve so as to reach the equator several degrees west of the place from whence they set out ; on the contrary, a current going from the equator is not permitted to proceed to the pole in a direct line, but the rotation of the earth forces it out of its course, and causes it to terminate its journey several degrees farther to the east than the place from whence it started. This modifying effect of the earth's rotatory motion upon the currents, to and from the tropics, is the key to many important facts in geonomy.

## EQUATORIAL CURRENTS.

Writers on physical geography have much to say about "the great equatorial current;" but it will be perceived, that what appears to be one current consists of the tropical segments of all the elliptical currents. Each great oceanic ellipse has one of its extremities, or apsides, in the tropical and the other in the polar region; any one, therefore, unacquainted with these principles, would naturally be led, by mere practical facts, to suppose that there is one continuous current of water tending to make its way along the equator, in a westward direction, entirely around the earth. That this is not the case, however, we might presume — independently of geonomic considerations — from the geographical arrangement of the two Americas, which renders such an equatorial flow impossible. The only place where the waters can escape westwardly from the Atlantic or from the Polar Sea, is through Behring's Strait, or around Cape Horn; and at both these points the fact is that, as far as we know, there is as much water passes to the east as to the west, and probably there is more; thus proving that there is no such tendency to a continuous equatorial westward flow as is commonly supposed to exist. Depend upon it, if there were any necessity for such a flow, the Isthmus of Panama or of Suez would never have existed ; or if they had, they would have long since been swept away by the "great equatorial current." If correct notions had been more prevalent concerning the design or causes of the ocean's movements, the idea would never have been entertained of such a continuous westward current. The truth seems to be, that water flows westwardly along the equator until it acquires a certain degree of warmth, and then it turns off in an easterly curve, poleward, where it parts with its caloric, and returns to the tropics again by a westerly curve ; the two currents together constituting a circuit of an elliptical form, the equatorial portion of which moves westward, and the polar segment eastward.

The reason why water flows from the tropics when it is heated, is, because heat expands it and causes it to occupy more space than when cold. In order to find more space, that part of it which is nearest the surface flows towards the poles, and in doing so passes over the surface of the intervening waters. It gradually parts with its heat as it proceeds, but is enabled to continue its course because it is constantly arriving in colder and colder regions, so that its relative superiority of warmth is still maintained. While it is in this superficial situation, it is continually losing a part of its substance by evaporation. That portion which evaporates leaves all its salt behind ; the remainder, therefore, becomes ultimately so much heavier than equal quantities of fresher waters of the same temperature, it consequently sinks below the surface, occupying an intermediate position, with the fresher ice water of the poles flowing over it, and the colder and heavier water flowing beneath it towards the tropics; but it continues its own course poleward, freshening, cooling, and sinking, until it becomes assimilated to the deep polar waters; then it turns again, gradually warming, and swelling, and rising, until it overflows again, under the influence of the tropical sun. From this statement it will be perceived that water only flows westward and tropicward until it becomes sufficiently warmed, and it only flows poleward and eastward until it becomes sufficiently cold and condensed.

It will also be apparent that we may with quite as much propriety speak of a continuous eastward polar flow of waters as of a westward equatorial flow; for there is near the north pole, and also near the south pole, a tendency of the waters eastward in each ellipse, while near the equator the waters of each ellipse tend westward. This will be understood at once from an inspection of the diagram map. It will be seen that there is really a tendency in the poleward currents, near the fortieth degree of latitude in each hemisphere, to flow eastward, and also, in currents from the pole, a tendency, between the fortieth degree and the equator, to flow westward, and that the effect of these two tendencies is to produce ellipses.

The whole proceeding might be experimentally illustrated by filling a trough with water, putting in blocks of ice at both extremities, and then letting a heated stove pipe pass over the water at right angles to the long diameter of the trough. As the water in the middle of the trough became heated, it would flow towards the icy extremities, and after becoming cooled, would return again. If the water in the trough contained considerable sediment, it would be deposited at the bottom, in the track of the currents; but the forms which the detritus would assume at the bottom would not be elliptical, as they are in the ocean, for the reason that there would not be in the trough any movement to represent the eastward and westward currents of the sea; and the detritus would, therefore, be deposited in the same straight line, both in moving to and from the centre.

If, instead of such a trough as I have described, we take a very large, circular caldron of water, and put ice into an upright cylinder in its centre, to represent the north polar region, and then put a hollow rim of sheet iron, filled with coals, around the rim of the caldron, to represent the equator, and if now we make it revolve, we shall have a very good representation of the northern hemisphere of the earth and its currents.

Under these circumstances the sediment in the water will be deposited in a series of ellipses, with their long diameters extending from the warm circumference to the cold centre precisely like the directions of the ocean currents, and of the mountain ranges. The cold water will flow from the polar centre to the outer or equatorial edge in a curve, the convexity of which will be in the direction in which the caldron is turning; but in returning to the polar centre, the curve will be convex in the opposite direction. Theoretically it may at first seem that the curve to the pole should be precisely as the one from it; and it would be so, all else equal; but it is deflected westward, after it begins to move from the tropics, by the opposite current, which is continually warming, swelling, and rising beneath it, and, as it were, crowding it over westward, until it has performed half its journey to the pole; then, however, it does move eastwardly, until it completes the circuit.

It should be considered that all lines proceeding north from the equator necessarily come together at the pole. A current, therefore, which moves to the tropics, and then proceeds a given distance westward before it returns, will, of course, have made a complete elliptical circuit, when it has reached the pole again.

## THE GULF STREAM.

The Gulf Stream is a name given to a current, or, rather, a succession of independent currents, which were formerly regarded as one, and were described as follows: "Running from the Indian Ocean around Good Hope, into the South Atlantic, and following the western coast of Africa until it reaches the most western point, it crosses the Atlantic to the most eastern point of South America, where it becomes divided into two branches, one of which runs south along the eastern coast of South America to Patagonia; the other runs along the north-east coast of South America, enters the Caribbean Sea, and passes through the Gulf of Mexico, around which it circulates, and passes out between Florida and Cuba, and proceeding along the eastern coast of North America as far as Nantucket, it then turns eastward, and crosses the Atlantic to the coasts of England and Norway."

Later discoveries, and especially the valuable researches of Lieutenant Maury, have continually tended to the conclusion that each ocean has a circulation independent of the others; that there are, in fact, as many Gulf Streams as there are distinct oceans.

The Gulf of Mexico is the most western part of the Atlantic ellipse of waters. When we reflect that the waters, in all ellipses, run west in the tropics until they become sufficiently heated, and then turn north-east, we can understand why the Gulf of Mexico extends so far west; why the waters there are warmer than in any other part of the Atlantic; and why, when they leave there, they move north and east until they reach the north of Scandinavia.

We can also understand why, on the south-eastern coast of Asia, the currents and lands are so strictly analogous to those of the south-eastern coast of North America; why the Bay of Bengal is situated, in relation to the currents, precisely as the Gulf of Mexico is. In studying the Mediterranean and Caspian Seas, we can also perceive that they were formerly situated, in relation to the western currents, just as the Bengal Bay and the Mexican Gulf are now.

Hereafter the "Gulf Stream" must be confined to the North Atlantic Ocean; and if it receives the excess of water that is forced into it from the other oceans, the circumstance must not be misinterpreted. The truth is, that the Atlantic Ocean would have the same elliptical circulation if it were walled up so that no other ocean could communicate with it. The probability is, that, so far is it from being in any degree dependent upon the Indian Ocean or the South Atlantic, they rather tend to derange its normal circulation, and force it to extend its operations farther north than it otherwise would.

The North Atlantic Gulf Stream, or ellipse, is better known than any other, and may serve as a model or type of all the others. Any one who objects to this is bound to give some good reason why the waters in this particular ocean should circulate on different principles, or in a different manner, from other oceans. It is commonly said that the Gulf Stream has its head or focus in the Gulf of Mexico; but it may as well be said to have its focus in the White Sea. The fact is, that it has two foci — one at its second or south-west segment, in the Gulf of Mexico, and the other at its sixth or north-east segment, in the Frozen Ocean. The same is true of all ellipses; they have their two extremes of cold and heat at their second and sixth segments, and between these two segments the currents continually circulate.

If we make a tin trough three inches in diameter, and arrange it in an elliptical or circular form, the ellipse being twelve feet in its long diameter, and if now we fill it with water, and put one apsis or extremity of the ellipse upon ice, and the other upon fire, we shall see a circulation immediately commence between these two extremities of the elliptical trough. This is precisely the predicament in which the waters of the Atlantic are placed, so far as the *causes* of the circulation are concerned; and this ocean is in no respect different from the other oceans; they enjoy no exemption from the operation of the natural laws that force the Atlantic

Gulf Stream to circulate elliptically. Each of them has its second segment filled with warm water, and its sixth with cold. What, then, is to prevent a circulation from taking place?

I have no doubt whatever that the ellipses all run in a manner perfectly analogous to the North Atlantic Gulf Stream: all the known facts tend to prove this. The Indian Ocean ellipse runs south, along the east coast of Africa, and then most of it turns east and crosses the southern part of the Indian Ocean, and then turns north again before reaching Australia, and, passing around north-west, and then south-west, through the Arabian Sea, again moves south along the east of Africa. That an abnormal current runs from the Indian Ocean around the Cape of Good Hope is unquestioned; but it must not be confounded with the great normal ellipses which move in obedience to the same natural law that produces the *North Atlantic* Gulf Stream.

It is fortunate for me that the very latest observations establish the fact that there is a current moving east across the southern part of both the South Atlantic and the Indian Oceans.

Lieutenant Maury is superintendent of the National Observatory, and has for a long time been engaged in collecting from the reports of ship-masters whatever important facts they observed during their voyages. He says, "The most unexpected discovery of all is that of the warm flow along the west coast of South Africa, its junction with the Lagullas current, called, higher up, the Mozambique, and then their starting off as one stream to the southward. The prevalent opinion used to be that the Lagullas current, which has its genesis in the Red Sea, doubled the Cape of Good Hope, and then joined the great equatorial current of the Atlantic, to feed the Gulf Stream ; but my excellent friend, Lieutenant Marin Jansen, of the Dutch navy, suggested that this was probably not the case. This induced a special investigation, and I found it as he suggested. Captain N. B. Grant, in the admirably well kept log of his voyage from New York to Australia, found this current remarkably developed. He was astonished at the temperature of its waters, and did not know how to account for such a body of warm water in such a place. Being in longitude fourteen degrees east, and latitude thirty-nine degrees south, he thus writes in his abstract log : —

"'That there is a current setting to the eastward across the South Atlantic and Indian Ocean is, I believe, admitted by all navigators. The prevailing westerly winds seem to offer a sufficient (?) reason for the existence of such a current, and the almost constant south-east swell would naturally give it a northerly direction.'"

The observations of Lieutenant Jansen exactly agree with my views concerning the Lagullas current ; that is to say, it is merely an overflow of warm water from the Indian Ocean into the South Atlantic, which, after being thus diverted from its normal course, resumes it again after it gets into the South Atlantic, and runs to the south and south-east to mingle with the cold waters of the antarctic regions.

The current that runs east across the southern part of the South Pacific to connect with what is called the Humboldt current on the west coast of South America, is commonly considered abnormal, and attributed to the winds; and so, indeed, are all the eastern currents in the southern hemisphere; but the law of rotatory motion *demands* that they should run precisely as Lieutenant Maury's latest charts indicate that they do run. That the winds add to the vigor of their flow is very likely; but they would still continue to flow in the same direction even if the wind blew the other way. Who can believe that the Gulf Stream could be made constantly to reverse its course by the mere force of the wind, when icebergs are annually seen to move hundreds of miles against winds and tides, and a surface current, and only because they are impelled by a powerful deep current, which is perfectly protected from the influence of the winds?

Lieutenant Maury, in his Physical Geography of the Sea, p. 166, says, "I have, I believe, discovered the existence of a warm current from the intertropical regions of the Pacific, midway between the American coast and the shore lines of Australia."

If this discovery is confirmed by future observers, as I think it will be, there must also be a deeper and colder current a little to the west of Maury's current, which runs in the opposite direction. Maury's current must be the complement or western half of an ellipse of which Humboldt's current is the eastern half. Humboldt's current runs from the antarctic coast north-east until it strikes the west coast of South America; it proceeds to the equator, and then turns west, and, according to Lieutenant Maury, it does not reach Australia, but turns towards the south when it gets about half way there. If this be so, then there must be two ellipses between Australia and South America.

I have explained sufficiently that the natural course of the ocean currents is to move in ellipses whose number, size, and form depend upon the relative temperature and distance of the equator and the poles. I have also explained the effect of the rotatory motion of the earth in causing all the normal currents of both hemispheres to move in a westward direction when at or near the equator, and in an easterly direction when approaching either of the poles. I have shown that what I denominate the normal currents are simply the results of the laws of expansion, condensation, gravitation, and rotation; that this is true, not only of their rapidity, but of their directions, their distances, and their curves, and that the same law of equilibrium which produces the Gulf Stream in the North Atlantic Ocean produces analogous circuits in every other ocean. It follows, from the foregoing, that if we find a current actually proceeding in a direction contrary to the normal currents, there must be some special and extraordinary cause which has operated to force the waters from their primitive course. Originally there was nothing to prevent the currents from moving in normal and regular ellipses in all cases; but when the land became elevated in some places, and depressed in others, the regularity of the currents was continually liable to be interfered with. When Asia, Europe, and North America became drained and elevated, the water that formerly constituted the ellipses that circulated over them was forced to circulate in the remaining ellipses. Where one of the oceanic ellipses is land-locked, as the Indian Ocean is, an excess of water poured into it causes an overflow, such as that which takes place at the Cape of Good Hope, where an abnormal current flows westward into the South Atlantic from the Indian Ocean.

If the Indian Ocean had several channels through Asia and Europe, as it formerly had, with which to communicate with the Arctic, there would be no "Lagullas current" intruding from the Indian Ocean ellipse into that of the Atlantic; but after Asia was elevated, the waters of the Arabian Sea had no means of communicating with their own natural polar regions in the Arctic, and they therefore forced their way south through the Mozambique Channel, with great rapidity, and, passing around Good Hope, entered the Atlantic, and flowed north along the western coast of Africa, in company with the normal South Atlantic current, from the Antarctic Seas. The probability is, that what is called "the Lagullas Bank," which is supposed to deflect the Mozambique current to the west, was created originally by the normal current that proceeded easterly from Good Hope, and that this bank was modified by the Lagullas current when the northern channels to the Arctic were obstructed, and the Arabian waters forced through the Mozambique Channel.

To illustrate: Suppose that the bed of the North Atlantic should become elevated as far to the south as the thirtieth degree of north latitude, so that railroads could be built along the northern shore, from Spain to Florida, via Bermuda; would there not be an enormous overflow of heated waters to the south, which would manifest itself in producing a powerful current west around Cape Horn, analogous to the present Lagullas current, which flows west around Good Hope?

It appears that there is annually an excess of water forced into the North Atlantic, in consequence of the peculiar land-locked condition of the Indian Ocean. Besides this, the shores of the Atlantic are continually extending, and contracting the bounds of the ocean; the consequence is, that a large quantity of water is forced from the southern hemisphere, across the mid-line, into the Gulf of Mexico, and from thence into the Arctic Ocean, as far as Spitzbergen and Nova Zembla.

I have no idea that the Gulf Stream would extend so far north, were it not for the overflow of the Indian Ocean and the narrowness of the Atlantic. We have a proof of this in the fact that the North Pacific does not extend beyond Behring's Strait. Why should the Atlantic Ocean extend its normal circulation farther north than the Pacific, unless for the reasons here given? It is further to be observed, that the ancient North American ellipse is nearly extinct, and that Hudson's Sea and Baffin's Bay are its relics. These vast seas receive warm waters from the Atlantic, and perhaps some through Behring's Strait; and in return they pour a cold current into the Atlantic, to chill the Gulf Stream, and deflect it east from the Banks of Newfoundland and the New England coast. Being thus forced to move more easterly than it otherwise would, the warm Gulf Stream crosses to the other side of the Atlantic, and there separates into several sub-currents, or branches; — one moves along the coast of Norway to North Cape; it then turns south, touching Spitzbergen, and passes between Greenland and Iceland. Another branch (supposed by some to be the same) moves from the North Atlantic, by the western coast of Greenland, to the head of Baffin's Bay, then crosses over to the north-eastern coast of America, and returns to the Atlantic, where a branch of it crowds itself between the Labrador and New England shores and the Gulf Stream, and manifests its power by forming several bays, with their mouths towards the north-east, while those on the same line of coast, which are formed by the Gulf Stream, have their mouths towards the south-east.

The Banks of Newfoundland must be regarded as the product of the Gulf Stream on one side, and the Baffin's Bay current on the other. It appears that a subsidence has taken place in the bed of the Gulf Stream, just south of the bank; for on that side it is very steep, and on the north side the slope is gentle.

A process analogous to this is going on in the North Pacific, where the warm stream from the south contends with the cold waters of Behring's Sea, and between them the Aleutian chain of volcanic islands is rising. Kamschatka and the Kurile chain are formed in the same way by the opposition of the cold stream from the Okotsk Sea to the warm stream from the south. The same is true of the Japan Sea and the island chain at the east of it. These islands in the Pacific are eminently volcanic, and in this respect they differ from Newfoundland at present; but I will venture the prediction that volcanoes will yet rise and illuminate the ocean not far from the line marked out for the transatlantic telegraph, and the whole north-western coast of Europe, Portugal, Britain, Scandinavia, and Iceland will be racked with convulsions which will leave them much higher, and their centres farther from their shores, than they are at the present time.

The northern ocean once flowed from the mountains of China to those of California, enclosed by a chain of low islands or submarine mountains, which extended from Behring's Strait south-westward to India, then west to Mexico, and then north-west to Behring's Strait again, constituting one vast compound ellipse, which is now subdivided into Asia, Europe, the North Atlantic, and North America. Formerly all parts of the northern tropical region were in direct communication with the Arctic Ocean, the intermediate land being merely groups of islands; but gradually the Arctic has become a solitary and frozen inland sea, and the tropical waters are excluded except through the long, deep, and narrow channel of the Atlantic. As for Behring's Strait, it is only about twenty miles wide, and has a bar at its entrance, which indicates that it is becoming entirely closed. Not only so, the detritus that was wont to pass through it is now gathering near by, in the Pacific Ocean, and by its weight raising the semicircular chain of the Aleutian volcanic islands, to more effectually separate the Arctic from the Pacific and the tropics. The north part of the Atlantic is now little more than a channel of communication between the Arctic and the other oceans. This channel has been becoming narrower for many geologic ages, and will finally be entirely closed. To be convinced of this, we have only to study the positions, and what can be learned of the history of the volcanic islands and shores which are continually encroaching upon it in the Iceland Sea. Norway and Sweden are constantly rising, especially in the northern parts. The Faroe Islands, between Britain and Iceland, abound in volcanoes, which continue to increase and rise, causing the dry lands to expand and blaze, as if in defiance of the deathly cold and the terrible tempests which desolate the coasts. Iceland itself is remarkable for being the scene of the most copious discharge of lava of which we have any record.

The Mediterranean Sea is growing deeper and narrower. The detritus of its inlets is causing its bed to sink, and its volcanic shores and islands to rise, while a bar is gathering at its Gibraltar mouth — a premonitory symptom of its final fate, which is, to be, like the Caspian, excluded from all communication with the great oceans, and left to evaporate down to a deep salt lake.

The Western Islands, in the Atlantic, seem to bear the same relation to the Straits of Gibraltar that the Aleutians do to Behring's Strait. It appears to be a general law that volcanic islands have a tendency to rise in the ocean opposite the mouths of inland seas that were once a part of the ocean. It may be that the checking of the current that flows from the ocean inland, causes the gathering of detritus in the ocean's bed, nearly opposite the strait of the sea from which it is now excluded. Does not this explanation apply to the volcanoes of the Iceland Sea the Kurile chain, and the Isthmuses of Panama, Suez, and the submarine isthmus of which Java is a part?

It is plain, upon reading Lieutenant Maury's book, that he clearly perceived the laws of the ocean currents, so far as they relate to the North Atlantic; and if he does not apply the same rules to the other oceans, neither does he advance any thing in opposition to the views which I am presenting. He says, "We may assume it as a law, that the natural tendency of all currents in the sea, like the tendency of all projectiles through the air, is to describe their curves of flight in the planes of great circles."

"It appears that the course of the Gulf Stream is fixed and prescribed by exactly the same laws that require the planets to revolve in orbits, the planes of which shall pass through the centre of the sun, and that were the Nantucket Shoals not in existence, it could not pursue a more direct route."

Precisely so; and the courses of all ocean streams are subject to the same fixed laws that the Gulf Stream is; and were the land all on a level with the bottom of the ocean, the normal ocean currents would move in ellipses as they do now, but there would be only three ellipses in each hemisphere.

Mr. Keith Johnson, of Edinburgh, in his beautiful work on Physical Geography, has a map on which he represents the area disturbed by the great earthquake which destroyed Lisbon; and it is remarkable that the lines which he has drawn almost exactly coincide with those which I have made to represent the North Atlantic ellipse. In other words, the earthquake was produced by a depression of the whole area included in the North Atlantic ellipse, or Gulf Stream. Another earthquake is represented on the same map as having also disturbed an area of an elliptical form, but it did not extend more than half as far north. It appears to me that this map, in connection with the geonomic theory, amounts almost to a demonstration that those earthquakes were produced by the special depression of this particular ellipse. I have no doubt that if a careful system of soundings had been made before the earthquake, and another afterwards, the places could have been ascertained with precision where the greatest depressions and elevations or eruptions had taken place; and though the idea may excite a smile, a method like this may yet be contrived of gauging the loss of lava from the internal and the gain upon the external parts of the earth.

Mathematics alone can never originate a new science; but neither can any natural science be much advanced until brought within the jurisdiction of weights and measures. Mathematics presides in the supreme court of the sciences, and holds the scales of equity with an impartial hand. It does not condescend to collect and arrange facts nor to frame hypotheses; but when they are produced, it sits in judgment and decides upon their merits in accordance with eternal laws and with inexorable justice.

Geonomy is of such a nature as to be especially liable to be brought to this severe test; it cannot escape from the scrutiny of a tribunal from which there can be no appeal. Geonomy is a question of quantity. It relates to the rising and falling of the external parts of the earth and of the other planets, by an unvarying rule; and it is absolutely true, or its falsity can be demonstrated by circles and ellipses, angles and numerical figures, whose very essence is truth.

# SECTION IV.

## SUCCESSION OF GEOLOGICAL FORMATIONS AND THEIR RELATION TO MOUNTAIN RANGES.

THERE are few geologists, if any, who do not now admit that granite forms the foundation of the earth's crust, and that below it is a fluid mass of lava, the movements of which occasionally elevate the crust; though no one has given a satisfactory explanation of the causes that produce and direct the elevating movements.

Granite,* or consolidated lava, is not only at the foundation of all the rocky formations, so as to constitute the true crust of the earth, but it is frequently poured forth by volcanoes, so as to occupy situations above some of the stratified rocks, in such a way as to leave us in doubt whether the granite rocks, in a particular place, are a part of the original crust, or the product of comparatively modern volcanoes.

All the rocks above granite were deposited from water in strata, and are therefore called *stratified.* The rock which is generally found immediately above granite is called *gneiss*, and is composed of fragments of granite, broken and worn by attrition against each

* "That there is a basis of crystallized granite rocks beneath all the strata, in all countries, cutting off and limiting our observations, and hiding whatever wonders are concealed below, is now universally admitted." — PHILIPS.

other and against the surface of the earth, by the movements of the primitive ocean.

Gneiss is peculiar in several respects. 1. It contains no large blocks of granite, and but few other volcanic products; thus indicating that volcanoes had not commenced their labors at that early age of the world. 2. It contains in its composition less of the heavier metallic substances than the higher formations do; though it is frequently pierced by veins of metal which have passed through it on their way upward. 3. It contains no evidence of the existence of organic beings. In this last respect it agrees with several formations immediately above it. The reasonable conclusion from these facts is, that neither volcanoes, mountains, nor organized beings of any kind had been instituted at the time that this lowest stratified rock was formed. Gneiss, originally, was laid upon a granite floor at the bottom of an ocean which had no bounds, and above whose surface not a single island had yet reared its crest.

The waters were probably nowhere less than half a mile in depth, and were of nearly a uniform temperature from the equator to the poles.

The next higher formation was that which is principally composed of *mica schist* — a species of coarse, contorted slate-like rock, in which mica predominates. It appears to be constituted of some of the same elements as gneiss, but formed under different circumstances. It is probably the result of the attrition of granite and gneiss, which took place while the waters of the ocean were hot, and perhaps boiling; for it is composed of laminæ or thin layers of mica, mingled with pebbles and sediment, and bent into short, irregular curves, in a way that indicates a violent agitation of the waters in which it was deposited. In the lower portions of this formation there is evidence of some slight volcanic action; for small masses are frequent which contain iron and other metals, so heavy that they must have come from below the crust. In the higher parts of the formation heavy metals become more and more abundant, and there are also found other evidences of vigorous convulsions.

Above the mica schist are more regularly formed slates and sandstones, which seem to be produced by a greater degree of attrition and subdivision of particles, worn or dissolved from the lower rocks, and after being deposited, were subjected to the pressure of the superincumbent ocean. Most of these slates and sandstones are blue, or brown, but a very few of them are red, indicating the presence of a small quantity of iron.

After the land had been raised to a sufficient height, and the agitation of the ocean and the atmosphere had produced the requisite combinations, vegetable and animal life appeared in their lowest and simplest possible forms. This was the commencement of what is called the protozoic or first animal formations. Geologists, at the present day, admit that the best, if not the only guide which they possess to the relative ages of the stratified rocks, is the character of the organic remains which they severally contain. It is found that the organisms, both vegetable and animal, are progressively superior and more complicated, from the lower to the higher stratified formations.

The next higher formation is the *old red sandstone* system of rocks, which is very extensive, and demonstrates that, between the deposition of the gneiss and the commencement of the old red, there must have been a large quantity of iron ejected from beneath the granite.

Next above the old red sandstone is the *carboniferous* formation; so called on account of the immense quantity of carbonic rocks which it contains, especially the carbonates of lime, which were deposited from water in a way which is yet undetermined.

In the midst of these rocks are the *coal measures*, consisting of the immense beds of coal which now furnish fuel to mankind. The limestone formations differ in several important respects from any which had preceded them. Instead of being constituted of the detritus worn from other previously formed rocks, they are composed of lime which had probably been dissolved in water that contained carbonic acid. It is well known that hot water is capable of holding a much smaller quantity of lime in solution than cold water can. When, therefore, during the upward progress of the land, the waters became warmer in some places than others, the lime was precipitated to the bottom in some localities, and formed the carboniferous limestone. It is found in the largest quantities around the bases of the older mountains; owing perhaps to the fact that those elevated places were generally warmer than those in deeper situations, and their higher temperature caused the escape of a part of the carbonic acid, and a precipitation of lime to take place against their sides. It is believed that the most extensive connected formations on the present dry land are those of the mountain limestones. The coal measures were produced by the combinations and condensations from the atmosphere and water of hydrogen and carbonic acid in the form of vegetable productions. This vegetable coal formation took place soon after groups of islands had risen above the surface of the sea.* At that time carbonic acid was much more abundant, both in the atmosphere and the ocean, than it is now. The process which produced the carboniferous rocks purified the water of an immense quantity of lime, magnesia, sulphur, chlorine, and silex, which it previously held in solution. It also purified the air of a vast amount of carbonic acid. It was not until after this period commenced that any *land* animals existed to breathe the air; nor was it until after this period closed that animals were created that were above the race of low, crawling reptiles.

The next higher mass of rocks is called the *permian* system, or lower division of what is sometimes called the *new red sandstone* formation.† The carboniferous period was followed and closed by important elevations of

* A wide expanse of ocean, interspersed with islands, seems to have pervaded the northern hemisphere at the periods when the transition and carboniferous rocks were formed, and the temperature was then hottest and most uniform. Subsequent modifications of climate accompanied the deposition of the secondary formations, when repeated changes were effected in the physical geography of our northern latitudes. Lastly, the refrigeration became most decided, and the climate most nearly assimilated to that now enjoyed, when the lands in Europe and Northern Asia had attained their full extension, and the mountain chains their actual height. — LYELL.

† The prevalent red color of the saliferous system is of itself a circumstance of great interest, but of unknown origin. — PHILIPS.

the land, and the formation of a series of rocks which indicated once more the intimate connection between the red oxide of iron, the volcanic eruptions, the mountain elevations, and the progress of organisms. As the dry land increased, the geological formations partook more and more of a fresh water character, and abounded more in remains of land plants.

The permian system is mostly constituted of red sandstones, which are composed of materials torn from the bed of the ocean, alternating with magnesian limestones precipitated from solution in water in a way which has not been clearly explained by geological chemists, but probably the temperature had much to do with it.

Next higher is the saliferous triasic, or higher new red sandstone formation, which is mostly distinguished by its containing a large quantity of common salt, and also plaster Paris and magnesia. This indicates that extensive lakes had been elevated above the level of the sea, something as the salt lake of Utah is now, and that the waters had been forced by evaporation to give up their solutions to the earth again from whence they had been previously derived.

Above the saliferous is the *oölitic* formation, so called on account of the egg-shaped stones which it contains. It is a more variously compounded rock than any of the preceding; its elements combining in a greater degree the characters of land and sea, and showing that it was formed near the shores of the ancient island continents. Being derived mostly from the dry land, it has much less of the oxide of iron diffused through it than the formations immediately below it have. There are several subdivisions of the oölitic rocks, the lowest of which is called the *lias* formation. Next higher is the *cretaceous*, or chalk formation, which is still more decidedly marked by circumstances that indicate an intimate relation to the dry land in the vicinity.

Following the chalk comes the *tertiary* formation, which Mr. Lyell divides into the eocene, miocene, and pliocene, and then subdivides each of these. It is remarkable for containing the remains of a great number of land animals analogous to those now existing. The investigations and subdivisions that have been made of this system by the labors of Lyell and others all confirm the fact that the animal remains, from the lowest part of the formation to the highest, indicate a gradually improving condition of the earth, fitting it for the habitation of animals that generate warmth within their own bodies by respiration, so as to be less dependent upon the warmth imparted by the external atmosphere. The general *forms* of the great continents existed then as now, with this difference, that more than one half of the present dry land, including nearly all the present lowlands, was then beneath the sea.*

Mr. Lyell makes the following remarks concerning the relation of the tertiary to physical geography: —

"About two thirds of the present European lands have emerged since the earliest of these tertiary groups originated."

"Brocci inferred that the Apennines were elevated several thousand feet above the level of the Mediterra-

* "Various parts of the British Islands were dry land, while most of the continent of Europe was yet below the ancient ocean." — SOMERVILLE.

nean before the deposition of the recent sub-Apennine beds which flank them on either side."

The central and higher ridges of the Alps are, according to Mr. Lyell, "encircled by a great zone of tertiary rocks of different ages, both on their southern flank towards the plains of the Po, and on the side of Switzerland and Austria, and at their eastern terminations towards Styria and Hungary. This tertiary zone marks the position of former seas or gulfs, like the Adriatic, which were many thousand feet deep. These marine tertiary strata have been raised to the height of from two thousand to four thousand feet. The older tertiary groups generally rise to the greatest heights, and form interior zones nearest to the central ridges of the Alps."

"The Pyrenees, also, have acquired their present altitude, which in Mount Perdu exceeds eleven thousand feet, since the deposition of some of the newer members of our secondary series."

"The Jura owes a great part of its present elevation to subterranean convulsions which happened after the deposition of certain tertiary groups."

"The former connection of the White Sea and the Gulf of Finland is proved by the fact that a broad band of tertiary strata extends throughout part of the intervening space."

"I believe that since the commencement of the tertiary period, the dry land in the northern hemisphere has been continually on the increase. The Alps have acquired an altitude of from two thousand to four thousand feet, and even in some places still more; and the

Apennines owe considerable part of their height (from one thousand to two thousand feet) to subterranean convulsions which have happened within the tertiary epoch."

"The great lowland of Siberia, lying chiefly between the latitudes fifty-five and seventy-five degrees north, (an area nearly equal to all Europe,) is covered for the most part by marine strata, which, from the account given by Pallas and other writers, may be considered as of tertiary formation."

Between the present period and the tertiary was deposited the *drift formation*. No geological period has been the subject of so much learned discussion as that which is known as the glacial or drift period. The fact seems to be, that near the close of the tertiary period, and just before the commencement of the modern alluvial formations, some cause hitherto unexplained began to operate to convey large quantities of gravel, and also large rocks, called *bowlders*, from the north and north-west to the south and south-east, and scatter them over the surface of so much of the earth, in most of the temperate regions, as was covered by the sea. These gravelly and rocky deposits from water differ from all others in not being stratified, and in not generally containing organic remains which belong in the climate where the drift is found. They were not deposited in sediment quietly, as most of the stratified rocks were, but were evidently borne violently along in mass by some powerful force.

It is now generally believed that water and ice were both agents in producing the drift; but no satisfactory explanation has yet been made concerning the causes which set the water and ice in motion. Perhaps the most plausible suggestion is that when the polar regions became cold enough to produce icebergs, the Arctic Ocean was an extensive archipelago, and the northern temperate regions were mostly covered by the sea ; this being the case, each season would send a large crop of icebergs loaded with bowlders southward, drifted by the ocean currents. This process doubtless continued until the continents were so far elevated that the drift could not pass over them ; but even now a similar process is taking place in the Atlantic, and bowlders and drift are being scattered over the banks of Newfoundland which will ultimately be raised and exhibit appearances similar to those presented by the fields of New England and of Northern Europe.

The subdivisions and classifications made by the systematic geologists are at present very unsatisfactory, and indicate the want of more knowledge concerning the causes which produced geological phenomena. I cannot help expressing the hope that the principles here announced will be instrumental in giving a new impulse to this noble science, by furnishing new means of investigation, and indicating a rational mode of explaining many things which have appeared mysterious.

## Organic Progress.

It has been a prevailing opinion that the progress of organized beings in structure and intelligence has been accompanied by a simultaneous progress of the whole earth to a cooler and more modern condition — that, in fact, the organic progress is evidence of terrestrial progress. But when we reflect that three hundred feet of elevation has an effect upon climate equal to a removal one degree towards the pole, — when, in addition to this, we ascertain that the geological formations, which have been examined, were, in most cases, subjected to the elevating process from the time of the lowest depositions to the highest, — we shall perceive that the advance in the organic character of the remains found in the formations is not of itself a proof of the progress of the whole earth towards a more perfect state, but only of a local advance to a cooler region and a higher and rarer atmosphere.

That the whole earth has gradually progressed from a liquid state, and become gradually condensed and cooled to its present condition, there are good reasons for believing; but had it not been for the inequalities which have been produced by the depression of some parts and the elevation of others, it is certain that the ocean would now cover the whole earth: none but aquatic animals and plants would exist, and only the lower species even of these. The ocean, being of an equal depth, would be of nearly an equal temperature in all its parts. The heat of the tropics and the cold of the poles would so modify each other that it is questionable whether any ice would be found out of the polar circles.

Assuming that the surface of the earth was at one time too warm to admit of organic existence, as geology appears to demonstrate that it was, it must be obvious that the elevation of some parts of the ocean's bed would enable those parts to sooner become the nurseries of organic forms, while the lower parts would still remain uninhabited. If, afterwards, the same parts were raised again to a still higher level, they would be rendered capable of sustaining a higher class of beings. If, many ages after thus being repeatedly elevated and peopled with a succession of adapted organisms, this spot should be examined by some geologist, he might infer that the whole earth must have gradually cooled and advanced in its organic conditions in the order and to the degree indicated by these remains, when, in fact, the earth, as a whole, during the same time, had not advanced in a perceptible degree.

Suppose that, after the formation just described had been made and finished, another spot, at a distance from it, had been repeatedly elevated and inhabited in the same manner, and in subsequent ages examined by the same geologist; if similarity of organic remains is to be considered sufficient proof of contemporaneous existence, the geologist, in this case, would be entirely misled. To obviate this source of error, it will be well to consider whether there is any method of learning the relative ages of the various mountains which are distant from each other. If it should be rendered probable by further investigation, as I think it will, that the elevations commenced at the north-east,* in the polar regions, and then proceeded in a south-western direction, we

* "The division of the animal and vegetable creation into geographical districts has been contemporaneous with the rise of land." — SOMERVILLE.

shall be able to combine a knowledge of the relative ages of the elevations with those of the formations, and thus improve our geological calendar.

After carefully reviewing all the geological formations and their order of deposition in connection with the theory of the elevation of the land by the pressure and sinking of strata, we shall find that the whole subject will be greatly simplified by regarding the thinnest portions of the lowest formations as having been the first raised above the sea, and the next formation as being deposited near the shores or borders of the first elevation, so as to tend, by its subsidence, to elevate it still more. As land rose higher, it carried up with it a portion (generally the thinnest) of the next lower formation ; at a third elevatory impulse a third formation was raised, and so on until the continents assumed their present outlines, and the geological formations their present arrangements.

This view of the matter shows why it is that each formation appears to have been closed by convulsions ; for they raised some part of the formations above the reach of further deposits of a similar character, and, at the same time, qualified the locality for the reception or generation of new and higher organic forms.

I was first led to the novel conclusions, published in these pages, by observing that the directions of the principal mountain chains, and also their curves, correspond with the directions which the ocean currents must naturally have pursued when the land was submerged beneath the sea. Reasoning from the known to the unknown, I inferred that the Gulf Stream, which certainly runs in an irregular ellipse, is not governed by different laws from those which regulate the other ocean currents, and therefore they must all tend to run in similar elliptical directions ; and, as the laws of nature are the same in all ages of the world, the present dry lands were once acted upon by the ocean currents, just as the bed of the ocean is now. When to this I added the fact that the geological strata are laid in ranges which are parallel to the mountains, it only remained for me to conclude that the subsidence of the heaviest strata caused the elevation of the highest mountains, and the geonomic theory was complete.

Geology affords no evidence that there were mountains in existence before the deposition of the stratified rocks. Surely all the commonly supposed causes of volcanic excitement existed then, as now, in full vigor. This fact, when admitted, is alone presumptive evidence, that the subsidence of the strata in one place caused their elevation in another.

It explains why we have no mountains of mere granite, with horizontal stratified rocks at their bases, and why we have no mountains of the highest class, which are encased in gneiss and primary slate only.

The first stratified deposits from the waters of the primitive ocean produced a low class of elevations ; subsequent deposits, in many instances, raised those same mountains still higher by causing a greater degree of subsidence, while other mountains remained in their original lowliness. Is it to be believed that the causes of volcanic eruptions slumbered quietly in the deep bosom of the young earth, while the granite crust formed more than a mile thick over the liquid lava, and the ocean of hot waters rolled tumultuously above this new crust? What prevented the subterranean ocean of lava from sending up some permanent volcanic signs of its existence for our present instruction?

If, as some suppose, steam is the cause of volcanoes, did it not exist then in the greatest quantities? Did not internal heat exist then? Did not the attraction of the moon and the heat of the sun — in a word, did not all the supposed causes of volcanic disturbance exist, except the weight of the stratified deposits? Professor Philips says that the principal convulsions of the earth happened, 1. Immediately after the deposition of the silurian, or lowest stratified formation; 2. Immediately after the accumulation of the coal system; 3. After the deposition of the oölitic rocks; 4. After the deposition of the chalk; 5. After the formation of the tertiary system.

In this brief statement, the veteran English geologist gives a history of the principal geological formations, in the very language required by the geonomic theory. He makes five grand periods of stratified formation, each of which is *followed* by a convulsion and an additional upheaval of the land. His extensive and life-long experience has impressed upon his mind, as it has upon all practical geologists, that each convulsion and upheaval, which has left a monument of its power, took place immediately *after* the deposition of a great formation.

The following is the almost prophetic language used by Professor Philips: —

"*Principal Epochs of Convulsion.* — By pursuing this investigation in different situations, we find that these internal movements, or convulsions, happened at intervals during the whole period of time occupied in the deposition of the strata. Some of the most prevalent and remarkable cases of dislocation and unconformity are, however, observable: 1. Immediately after the deposition of the silurian series; 2. After the accumulation of the coal system; 3. After the deposition of the oölitic rocks; 4. After the deposition of the chalk; and, 5. One of the most recent, probably, of all, after the completion of almost all the formations above the chalk. It is not to be supposed that all, even of these principal cases of dislocation, can be recognized in every country; on the contrary, the subterranean forces appear frequently to have shifted their points of action. We shall have occasion to show, while speaking of the organic remains, that there is sometimes observed a singular harmony between these periods of extraordinary internal disturbance and the several epochs when the different races of animals and plants came into existence; and it is not unreasonable to suppose that in this manner it may be hereafter found possible to establish such a relation between the internal and external conditions of the earth, as to afford the greatest assistance towards defining the agencies which have produced changes so extensive and repeated in both." — Philips's *Manual of Geology*, page 36, (1855.)

We have mountains with only cambrian and silurian rocks tilted around their bases, but none of these are very high; they were raised by the subsidence of the earliest formations. We have other mountains with silurian and carboniferous rocks dipping around them; they are higher, but not equal in elevation to those that in addition have the chalk and tertiary formations inclining upon their sides. The highest mountains are those that have been more or less elevated in modern times. All high mountains bear evidence of being raised at several different epochs; as if one formation subsided and forced them up to a certain point, and then another and another superadded formation caused a further subsidence in the same locality, which raised the same mountains to their present height. I know of no other theory by which these successive upheavals of the same places have been or can be accounted for, even by conjecture, though it seems to me that nothing can be more simple or reasonable than the explanation which is afforded by the geonomic theory here given.

The elliptical circulation of the ocean waters being admitted, it follows that each distinct ellipse must be a separate geological basin, and that the phenomena which are presented in one basin must be repeated in another with but little variation. In this respect geological formations must be, like peninsulas and mountain ranges, liable to be repeated again and again, wherever the elliptical circulation of the waters is repeated. Hereafter, it will be a question when a geological examination of any district is made, To what ellipse does it belong? Assuming that mountains were caused in the first place by the sinking of the primitive strata, the secondary strata would of course be laid upon the top of the primitive. and the mountains would be parallel with both; not because the mountains or shores fenced in the currents, and forced them to assume their characteristic curves, but it is because the strata, the shores, and the mountains, received their curves from the currents to which they all owed their birth.

The geological strata are piled up as if one formation was riding upon the other behind; each new addition tending to tip the hindmost part of the load farther down. We actually find the last deposited strata, when undisturbed, in the lowest situations, and the first the highest. The lowest deposits are near the shore, and frequently extend beneath the sea; and there, over all, another formation, of unknown depth, is taking place, which, if it subsides by its weight, must press the lava up to the highest part of the slope in the manner of a wave, forcing it out at the top of a volcano, or a series of volcanoes, along a line of fractures parallel with the line of the deposits whose pressure produced the movement.

Sometimes it has probably happened that one formation, as it is called, did not weigh enough to turn the scale, and produce a movement, until another, and perhaps a third, was added; but when the mass moved, though but a few feet, it would cause a tremendous volcano at the point where it was vented.

It will be admitted that depositions of sediment have always been made horizontally; of course, the first depositions were so. If any submarine mountains had existed at that time, the strata must have been formed horizontally on the tops of those mountains; or if the mountains had been previously elevated above the sea, the strata must have formed around their bases in a horizontal manner. If, afterwards, the whole mountain had been elevated still higher, the granitic top would yet have towered high above all the strata, and borne the most decisive evidence of its priority of birth. But no such mountains exist. All granitic crags are sheathed in gneiss, slate, sandstone, or limestone, which has fallen from water, and been pierced by, and been elevated along with, the granite.

There are no granitic mountains with only horizontal strata around them. The primary stratified rocks, therefore, were not deposited at the bases of mountain ranges of granite, for none such existed when the first aqueous deposits were made ; and I conclude they never would have existed but for the pressure of the accumulated sediment in one place, forcing the lava to seek relief and an outlet above.

The igneous crust of the earth was equalized in thickness by the internal heat below it and the water which flowed above it. Bearing with equal weight upon all points of the earth's surface, it could of course produce no mountains nor valleys. But the water, alternately heated at the tropics and cooled at the poles, was made to carry detritus, and make deposits in the course of its circuit, until it formed for itself an elliptical path, bounded by strata, the weight of which has produced parallel mountain ranges and shores, whose length and height have continually increased to the present time, to give outlines to our continents and variety to our climes.

## SECTION V.

### PARALLELISM OF CURRENTS, STRATA, AND MOUNTAINS.

No class of facts relating to this subject will be as convincing to a geologist as those which show that the mountains are parallel to the strike or range of the stratified rocks, and to the ocean currents also.

Professor Philips, in his excellent Manual of Geology, (London, 1855, p. 67,) says, —

"It was long since remarked by Mitchell, (one of the best and earliest of English geologists,) that the direction of the strata, in any region, was generally parallel to the ranges of mountains — a truth of great importance in the modern system of geology.

"The most prevalent range of the strata in any country must, however, depend on another circumstance, viz., the original line of the ocean's boundary. In many parts of the globe, the most prevalent direction of the strata is observed to be north-east and south-west. Humboldt was so struck with these loxodromic [oblique] lines in Europe, that he says one of his principal inducements to visit equatorial America was to examine the directions of the strata there. He has furnished evidence that *parallelism of the strata to the great lines of mountains is a general law of nature.*"

It would certainly be difficult to defend the geonomic theory, if the general parallelism of the strata, announced by Mitchell, and confirmed by the venerable Humboldt, did not exist. But this being thus settled by the very highest authorities in science, and it being self-evident that the deposits from the water must be made in the paths of the currents, and that the currents must move in conformity with the astronomic laws which produce the changes of the seasons and the rotation of the earth, there is little else to prove.

There is nothing inconsistent with these principles in the fact that in some instances the strike of the strata run, as, according to Lyell and Von Dechen, they do in the Hartz Mountains, frequently north-east and south-west, while the geographical direction of the mountains is transverse. This may always be expected in cases where opposite currents have alternately prevailed in the same region, and passed over parts of the same area, each current depositing its burden of sediment in the line of its own path. The result would naturally be, that the *heaviest* ridge of stratified sediment would prevail, and raise a mountain parallel to its own course or strike; in doing this it would make a transverse section of the strata which run in the opposite direction. This is one of those cases where the exception clearly proves the rule.

There are some such striking parallelisms of the mountains to each other, to the sea shores, to lines of volcanoes, and to the range of stratified deposits of ancient detritus, that it was almost impossible for geologists to avoid noticing them. Elie de Beaumont inferred that those mountains that are parallel to each other were elevated simultaneously, and at a different period from the others. The reader will, however, perceive that geonomy lends no support to this theory, but rather it indicates that the mountains of Asia were created first, and that the progress of detritus was south-westward to Patagonia. Beaumont attributes the elevations, as most authors do, to the expansion of vapors and gases. Humboldt, in his "Cosmos," suggests that volcanoes rise in lines along shores, because they meet with less resistance there than at other places; but on the whole he admits his inability to understand the phenomena, and contents himself with adding essentially to our knowledge of facts. This distinguished philosopher performed a service to science by sanctioning with his authority the suggestion of Mitchell, that ranges of strata are laid parallel to ranges of mountains; though it appears to be more in accordance with the facts to say that mountains are raised in lines parallel to the ranges of strata; and I would remark, in reference to Baron Humboldt's suggestion concerning shores, that ranges of mountains rose in lines before shores existed; indeed, it was such lines that originally constituted shores.

It has often been observed that the appearance of a mountainous country resembled the waves of the sea. Professor H. D. Rogers was particularly struck with the parallelism of groups of mountains to each other, when he was engaged in the survey of the Appalachian chain in Pennsylvania, in company with his brother, Professor Wm. B. Rogers. He attempts to account for the wave-like appearances, by assuming that a sudden explosion of gaseous elements had in each instance caused an undulation of the liquid ocean below the earth's crust; that the undulation took the same form as that which is generally assumed by the ocean's waves, but more regular. These subterraneous waves, acting upwards, elevated the crust, and impressed upon it their own wave-like or undulatory forms. Although I cannot subscribe to the theory adopted by Professor Rogers, I must do him the justice to acknowledge that he has shown, by an array of important and original observations, that, in many instances, the separate groups of mountains do appear to assume the characteristic forms of waves, their crests all inclining in one direction. In some instances the mountain top is folded over so that it points downward.

If one mountain crest only presented the appearance of inclination in a particular direction, it might be attributed to accident; but it is a universal fact, that, in each distinct group of parallel mountains, the crests incline in one direction, just as do those of the waves of the sea, when urged by a strong wind. The irresistible inference is, that a common or a similar cause operated upon them all, bending them in one common direction, in such a way as to produce the wave form which is now apparent.

Professor Rogers concluded that there must have been a large body of liquid lava below the crust, the undulatory movements of which produced the appearances that he has so well described. He was confirmed in his views by noticing that the tops of these rocky waves are progressively more distant from each other, and also less elevated and less inclined, the farther they are situated from the highest petrified mountain wave, or what he denominates "the chief igneous axis of disturbance."

It had been previously remarked that the long, gentle slopes of the land are most frequently to the north and east, and that the abrupt slopes are to the south and west; but the details of the wave-like arrangement had not before been distinctly described. It must be observed, however, that while the observations of Professor Rogers indicate that the difference in the steepness of the opposite slopes of the same mountain is owing to the direction of the force which produces the elevations, it gives no clew to the cause of their assuming one direction rather than another, nor of their operating in such long extended lines as those which the Appalachians present. But the geonomic theory shows plainly and consistently how the appearance of waves originated; why they were produced in lines in one direction; why they differ in height; why they operated with most intensity at the close of the geological formations; why they are parallel to those formations, to the ocean channels, to the shores, and to each other; and also why the mountains have progressively increased in height as the stratified deposits have increased in depth. The geonomic theory also gives a perfect explanation of the fact that the abrupt slopes of the mountains are towards the east in the eastern part of Asia, Australia, and Africa, towards the south in the southern part of Asia and Europe, towards the west in the north-western part of Europe and almost every part of the two Americas. In fact the greater abruptness is towards the larger ocean, where the most detritus has accumulated, and the greater subsidences have been produced.

Although nearly all the mountains of the eastern continent slope abruptly to the east or south, the Scandinavian and British mountains are exceptions, and are most elevated towards the Atlantic Ocean.*

Subsidences unquestionably *may* produce waves in the lava beneath the crust, but it does not follow that mountains are petrified waves, nor that the lava moved in waves in the direction indicated by the foldings of the mountain crests. The probability is, that it moved in a contrary direction, and that the crests are produced by the reaction of one wave against another; the side on which there was the least subsidence overriding the other, and allowing it to spend its force against the base of the abrupt side of the mountain.

Professor Traill in his article on Physical Geography, in the Encyclopædia Britannica, remarks,—

"If we endeavor to generalize the observations on the direction of mountain chains, one very remarkable peculiarity seems deducible, namely, that they very generally present their steepest acclivities towards the great basins to which they are contiguous, while they slope more gradually in the opposite direction; and on examining their intimate structure, we find their strati-

* The gradual elevation on the west and depression on the east of the south-eastern parts of England, parallel to the line of the oölites, and prolonged in duration through the whole period of the saliferous, oölite, cretaceous, and tertiary rocks, would fully agree with the general physical features of the surface of the district." — PHILIPS'S *Manual of Geology.*

fied beds dipping generally *from* the basins to which their escarpments are presented. Thus the ridges of the Scandinavian peninsula present their boldest escarpments to the basin of the Northern Atlantic; while the opposite ranges of Greenland and Iceland also show their steepest acclivities towards that basin. Round the shores of the Mediterranean the same arrangements are especially observable. The lofty ridge of the Atlas is very bold on the northern side, and declines more gradually towards the Sahara. The chain of Spanish mountains which skirt the Mediterranean, from Gibraltar to the Pyrenees, present their escarpments towards that sea; and the Maritime Alps of France, the mountains of Switzerland and the Tyrol, of Istria, Dalmatia, and Thrace, all present their most precipitous sides to the basin of the Mediterranean. We believe that the considerable chain which in Asia Minor extends from Mount Ida to the country around Scanderoon has the escarpment directed towards the Levant seas; while the mountains of Armenia present their boldest declivities to the basin of the Euxine, and the Caucasus and mountains of Mazanderan towards that of the Caspian. The escarpment of the great chain of Africa, termed that of Lupata, which seems to be prolonged from the lofty mountains of Abyssinia to the south of the Mozambique Channel, would appear, from the little we have learned of its structure, to face the basin of the Indian Ocean; and we know that the steepest declivities of the Western Ghauts of India are directed towards the same basin. The mighty spine of the

American continent, from the shores of the Arctic Frozen Ocean to the extremity of South America, through a course of more than eight thousand six hundred British miles, presents a series of rugged precipices to the vast basin of the Pacific; and, if we might indulge in one sweeping generalization, it would seem that the chains stretching from the Persian Gulf eastward through Thibet, and thence bending to the north-east through Mongolia and Northern China to Tscheoutskoi-nos on the Frozen Ocean, present their fronts also to the Pacific Ocean.

"As such coincidences can scarcely be considered as accidental, they afford a wide field for speculation. Can we suppose that appearances, on such an immense scale, have any relation to the operation of the force which caused the elevation of the land, acting towards a central point, and producing the dip of the elevated strata all around, from a common axis of movement? Such speculations, aided by the position of volcanoes, and other mountains of igneous formation, might lead us to infer the direction of the great lines of subterranean disturbances which have modified the appearance of the crust of the earth."

The preceding observations of Professor Traill are very interesting and instructive; but the learned author did not mention that there are some remarkable exceptions to the rule that mountains present "their steepest acclivities to the great basins to which they are *contiguous*." The Appalachians, for instance, are contiguous to the Atlantic, but they present their steepest acclivities to the Pacific; and this, in my opinion, proves that at the time that the Appalachians were elevated, which was immediately after the coal period, the Pacific extended to the western side of the Appalachians, and the Rocky Mountains were not then in existence. (See Professor Guyot's *Earth and Man.*)

The rule seems to be, that if an elevation is contiguous to two oceans, it presents its steepest acclivities to the larger one, and in all cases it presents them to the basin the subsidence of which *caused* the elevation.

Perhaps one of the best authenticated cases that I can produce at present, in which earthquakes have been detected in the very act of producing elevations in lines parallel to the lines of subsidence and to the shore lines, is the following, related by Mr. Lyell: —

"A violent earthquake occurred at Cutch, in the delta of the Indus, June 16, 1819. The sea flowed in by the eastern mouth of the Indus, and in a few hours converted a tract of land two thousand square miles in area into an inland sea, or lagoon.

"Immediately after the shock, the inhabitants of Sindree saw, at the distance of five miles and a half from their sunken village, a long, elevated mound, where previously there had been a perfectly level plain. To this uplifted tract they gave the name of 'Ulla Bund,' or the 'Mound of God.'

"It has been ascertained that this newly-raised country is upwards of fifty miles in length, from east to west, running parallel to that line of subsidence before mentioned, which caused the grounds around Sindree to be flooded ; its breadth from north to south is conjectured to be in some parts sixteen miles, and its greatest ascertained height above the original level of the delta is ten feet, — an elevation which appears to the eye to be very uniform throughout."

STEAM AND EXPLOSIVE THEORY.

Whatever may be thought of my views, the steam and explosive theory is utterly inadequate to account for the origin of earthquakes and volcanoes; for even if we assume that water, in sufficient quantities, when brought into contact with melted lava, would generate steam enough to elevate mountains and continents, we must previously contrive some way for the water to penetrate through the crust of the earth.. Here our theorists rely upon "accidents" to produce eruptions, and upon "dislocations caused by previous eruptions." It appears to me that there is no known way in which the crust of the earth could be originally broken, except by external pressure. It must also be evident that it requires as great a force to break the crust downward and admit the water to the liquid lava as it does to raise the lava to the surface. When the deposits press the crust, and cause it to move downward, they must crowd away the lava which is underneath, and break the crust besides. If we have a force sufficient to do this, we require no other; for the downward movement in one line will, of itself, cause an upward, wave-like movement of the lava in a parallel line.

When the granite was first formed on the surface of the lava, and the waters and atmosphere arranged themselves concentrically above, what was there to cause the water to come into contact with the subterranean lava, except the unequal downward pressure of detritus and strata? The suggestion that crevices made during one earthquake are the passages by which the water enters to produce a subsequent explosion an indefinite time afterwards, is too palpably illogical to require a serious refutation, since the very question is, what caused the first eruptions?

Sir Charles Lyell and some others imagine that the lava which is emitted through volcanoes cause vacant places beneath the crust, so that it is liable at any time to collapse and fall beneath its own weight, and thus extend the depth of the ocean. On the other hand, when the crust is elevated by volcanic action, they suppose that it sustains itself on the principle of an arch after the lava and gases which temporarily upheld it have subsided. These are the speculations to which even superior minds are driven to support an erroneous opinion.

Let us suppose, for the sake of argument, that the water, by some accident, should actually pass through a chasm in the crust; what would be the natural effect? Would it produce an explosion which would operate in regular lines for hundreds of miles, and cause long, beautiful, petrified waves in the lava, several thousand feet high, by its reaction, and yet merely break the earth's crust at the top? Would it not, like the explosion of a mine, scatter the external crust in all directions, leaving nothing to mark the spot but a deep, irregular pit, bordered by chaotic ruins?

If any philosopher who believes in this theory possesses a practical turn of mind, he can easily verify his opinions by an experiment. Let him take a vessel which is filled with molten metal or lava, cover the surface of the liquid with a red-hot iron plate, strewn with sand and clay, to represent the earth's crust, fasten it securely in its place; now, through a pre-arranged crevice, admit a little water into the vessel, and observe the effect. Let the experimenter vary the operation in any way he may please, provided he brings liquid lava and water together, he will have nothing but an irregular and ruinous explosion. If any waves are produced in the lava, they will move in all directions, and subside again to their original place.

Reason upon this subject as we may, we must commence with a lineal cause. Whatever produces the first movement of an earthquake evidently moves in a line. If we suppose that the earthquake merely breaks through a previously prepared line, we must yet inquire what force caused the original line to extend so far in one direction, instead of radiating in many lines from one point. If we assume that the force was constrained by some limiting cause, then we must inquire what was that cause; for that also must have acted in a line. The problem appears to be solved when we ascertain that the lines of mountains are parallel with the lines of stratified deposits, and that both are in the line of the ancient ocean currents.

Some of those who advocate the steam and explosive theory combine with it the idea that the cooling and contraction of the internal nucleus of the earth leaves a space between the nucleus and the crust, so that when the crust collapses it lets the water down upon the lava beneath. According to this theory the earth may be compared to a dried fig, the outer enveloping skin of which is too large for the internal parts that have lost their juices by evaporation.

Notwithstanding that mathematical calculations appear to demonstrate that the loss of heat by radiation through the crust could not possibly be sufficient to produce the contraction which this hypothesis demands, it is still adhered to by some geologists, apparently for the want of a more plausible explanation of the facts.

According to Mrs. Somerville, "M. Fourier has computed that the central heat is decreasing from radiation by only about the one three thousandth part of a second in a century. If so, there can be no doubt that ultimately it will all be dissipated; but as far as regards organic life it is of very little consequence whether the centre of our planet be liquid fire, or ice, since its condition in either case would have no sensible effect on the climate of the surface."

Mr. Lyell remarks, that "astronomers having proved that there has been no perceptible change in the diameter of the earth during the last two thousand years, we may assume it as probable that the dimensions of the planet remain uniform. If, then, we inquire in what manner the force of earthquakes must be regulated in order to restore perpetually the inequalities of the surface, which the levelling power of the water tends to efface, it will be found that the amount of depression must exceed that of elevation. It would be otherwise if the action of volcanoes and mineral springs were suspended; for then the forcing out of the earth's envelope ought to be no more than equal to its sinking in.

"To understand this proposition more clearly, it must be borne in mind that the deposits of rivers and currents probably add as much to lands which are rising as they take from those which have risen."

Geologists have been much puzzled to find a normal force which is powerful enough to cause the upheaval of continents, and yet capable of remaining quiet when not wanted to produce terrestrial convulsions. Such a force is found. Nature is engaged during a whole geological age in accumulating at one end of a scale-beam a weight sufficient to raise the other end; and when the time has nearly arrived, the balance trembles with warning, and then moves — sometimes suddenly — just far enough to restore the lost equilibrium, but no farther. In all cases the movement upwards must be exactly equalled by the movement downwards.

We have the high authority of Lyell to sustain the assumption that the subsidences of the earth's crust are on the whole fully equal to the elevations; and the logical reader will perceive that the admission is of considerable importance to the new theory.

Sir John Herschel, being struck, as Humboldt was, by the fact that most volcanoes are situated near the sea shores, proposed a theory in which he assumed that two corresponding openings are made through the crust of the earth before the eruption commences; one at the bottom of the ocean, — not by the weight of the detritus there, but by its non-conducting qualities, like additional clothing to our bodies, preventing the escape of the internal heat, so that it melts a portion of the crust. The other opening is made near the sea shore, where the abrasion of the waves has already worn the crust very thin, and thus exposed it to cool unequally, and consequently to crack open. These two openings being thus previously made, by directly opposite causes, the superincumbent water and detritus are supposed by their weight to crowd a portion of the melted matter down through the orifice at the bottom, and to force an equal quantity of lava to vent itself through the higher opening near the shore.

This hypothesis, besides being subject to the serious objection of being founded upon two very doubtful assumptions concerning ruptures of the earth's crust, entirely fails to account for the established fact of the gradual elevation of whole countries and continents without any volcanic eruptions whatever. According to the geonomic theory advocated in these pages, earthquakes and eruptions of lava are only occasional incidents which attend the elevation of lands. Scandinavia affords an illustration in point; the depression of the southern shore and of the ocean's bed has caused the northern portion of Sweden and Finland to rise, slowly and gradually, for ages, without being visited by any volcanoes; but let the upward progress of the land be resisted and prevented, or let the crust be weakened at a particular point, and a quaking or a local eruption would be the immediate consequence. I doubt not that the volcanoes of Iceland and the Faroe Islands are caused by the same general depression which is elevating Sweden.

It has been observed (see Silliman's Journal, vol. xix. p. 55) that earthquakes happen most frequently during the time of certain tides. Is this because the weight and pressure of the ocean at that time is greater than usual in some places, and less in others? If the observation is correct, — and I have no doubt of it, — does it not harmonize with the views advocated in these pages?

### THICKNESS OF THE CRUST.

In regard to the thickness of the earth's crust, nothing certain is known. All the prominent authors who have referred to it treat the stratified rocks as if they were a part of the crust; and when they claim that they have been able to measure from ten to sixty-eight miles perpendicularly by adding together the thicknesses of a succession of overlapping strata, they appear to assume that the real crust of the earth is known to that depth. But the true original crust is granite only, upon which the strata are superimposed. Dr. Hitchcock says, —

"If we get the perpendicular thickness of a series of strata, we ascertain the character of the crust of the globe to that depth. If we measure the breadth of a series of upturned strata, on a line at right angles to their strike, and ascertain their dip, we have given the hypothenuse and angles of a right-angled triangle to find the perpendicular, which is the thickness of the strata. If the strata are perpendicular, a horizontal line across their edges gives their thickness. By measurements and calculations of this sort, it has been ascertained that the total thickness of the fossiliferous strata in Europe is not less than twenty-seven miles. In Pennsylvania, the fossiliferous rocks beneath the top of the coal measures are forty thousand feet, or more than seven and a half miles in thickness. (Rogers's *Report*.) In the peninsula of Tauris, Pallas describes a continued series of primary strata, inclined forty-five degrees over a distance of eighty-six miles; which would give a perpendicular thickness of more than sixty-eight miles. (Lyell's *Geology*.) In New England, as, for instance, on the railroad between Westfield and Pittsfield, we have strata of primary rocks, for the most part nearly perpendicular, not less than twenty miles in thickness."

I cannot help suspecting that the thicknesses of the strata are greatly overrated; but assuming the very lowest estimates to be correct, the weight of the strata gives us a force quite sufficient to account for all the phenomena of earthquakes and volcanoes.

There is nothing, with which we are acquainted, to thicken the granite crust of the earth, except the radiation of the internal heat into celestial space. It must, therefore, be of nearly a uniform thickness; and since granite is exceedingly non-conductive, I see no reason for supposing the crust to be more than one mile thick in any place.

# SECTION VI.

## RELATION OF LOWLANDS, PLATEAUS, AND MOUNTAINS TO EACH OTHER AND TO EARTHQUAKES.

The term *plateau* is applied to a series of valleys between mountains of comparatively moderate height. In the progress of continental elevation, plateaus must have once been islands, with groups of mountains running across them, after the manner of Great Britain and Ireland. The same upheaving cause which raises a succession of narrow mountains forms them into a group, and rends their axes to give vent to igneous rocks, operates in a more steady and quiet, though perhaps really more powerful manner, to produce those elevations of the land which we call plateaus. We may regard a plateau as a wider species of mountain, or a succession of nearly parallel ridges of mountains, which anciently was an island; and in being afterwards elevated to its present height, it drew the lower lands after it from the sea, and forced up the mountain ridges as much higher as it rose itself. Anatomically speaking, a plateau may be regarded as the skeleton of a continent, while the main ridge of mountains is the backbone, and the lowlands the most external and active portions.

"Viewing things on a broad scale, it appears that there is a very striking connection between the physical geography, or external aspect of different countries and their geological structure. By a minute comparison of the different parts of the land, M. Boué has shown that similarity of outward forms, while indicating similarity in the producing causes, must also, to a large extent, indicate identity of structure, and therefore from the external appearance of an unexplored country its geological structure may be inferred, at least to a certain extent.

"The form of the great continent has been determined by an immense zone of mountains and table lands, lying between the thirtieth and fortieth or forty-fifth parallels of north latitude, which stretches across it from west-south-west to east-north-east, from the coasts of Barbary and Portugal, on the Atlantic Ocean, to the farthest extremity of Asia, at Behring's Straits in the North Pacific. North of this lies a vast plain, extending almost from the Pyrenees to the extremity of Asia, the greater portion of which is a dead level, or low undulations uninterrupted except by the Scandinavian and British system on the north, and the Ural chain, which is of but small elevation.

"The table-lands which constitute the tops of mountains, or of mountain chains, are of a different character from those terraces by which the high lands slope to the low. The former are on a small scale in Europe, and of a forbidding aspect, with the exception of the Jura, which is pastoral. The mass of high land in South-eastern Europe shelves on the north to the great plain of Bavaria, three thousand feet high; Bohemia, which slopes from fifteen hundred to nine hundred feet; and Hungary, from four thousand above the sea to three hundred. The descent on the south side of the Alps is six or seven times more rapid.

"As the table lands extend from south-west to north-east, so also do the principal mountain chains, as well those which bound the high lands as those that traverse them.

"Remarkable exceptions to this equatorial direction of the Asiatic mass, however, occur in a series of meridional chains, whose axes extend from south-south-east to north-north-west, between Cape Cormorin, opposite to Ceylon, and the Arctic Ocean, under the names of the Western Ghauts, the Soliman, East Persia range, the Bola, West Tibet, and the Oural; to this may be added the Khinghan, in China.

"Tibet is a mountain valley enclosed between the chains of the Himalaya on the south, and the Kuen-lun on the north.

"The table land of Tibet is only four thousand feet above the sea towards the north; but it rises in Little Tibet to between eleven thousand and twelve thousand feet.

"The great northern plain is broken by two masses of high land, in every respect inferior to the Oural and the Scandinavian. The Scandinavian mountain has been compared to a great billow, or wave, rising gradually from the east, which, after having formed a crest, falls perpendicularly into the sea at the west." — *Mrs. Somerville.*

The lowlands and the highest mountain peaks appear to have been raised after the intermediate plateaus, for there is perfect geological evidence that the lowest Siberian lands which lie at the north-eastern terminus of the Asiatic slope have but recently emerged from the sea; at the same time the higher parts of the Himalayas contain evidence of modern volcanic elevations, which have certainly taken place since the deposition of the first tertiary formations.

In regard to the *modus operandi* of the convulsions which raised plateaus, it should be remarked that a slight depression of a vast submarine plain might quietly raise a whole country, or it might cause a tremendous earthquake in a limited region, and a remarkable outburst through a long line of parallel volcanoes. Suppose, for instance, that a subsidence of one inch should take place in a portion of the bed of the Atlantic consisting of one thousand square miles; the consequence would be, that a sheet of lava would be forced upward, which would be one inch thick and a thousand square miles in superficial extent. If, in rising, the crust of the continent did not give way in any particular locality, the result might be a quiet and imperceptible elevation of one thousand square miles of the American or European lands to the height of one inch. This movement might or might not be accompanied by a slight shock or tremulous motion of the earth in some places, and a slight commotion of the water. On the other hand, if a portion of the oppressed lava should find vent through a parallel line of volcanoes, it would elevate the whole mass of land less by so much.

The place where the pressure and subsidence is greatest may be, and doubtless it frequently is, at a great distance from that of the eruption of lava, though it may also be very near.

Jorullo, in Mexico, is one hundred and seventy-five miles from the nearest sea; but the lava which it poured forth doubtless pursued the line of the least resistance to vent itself there. The subsidence may have happened in the Gulf of Mexico, or in the Pacific, or we may never be able to determine its locality with perfect certainty. I doubt not, however, that the time will soon arrive when we shall be able, not only to trace each eruption to its source, but to predict its recurrence with approximate accuracy from a scientific knowledge of its remote causes, its direction, and the angles and slopes that it produces.

I do not wish to be understood as pretending that we can now, by looking at a common map, at once proceed to explain precisely where the subsidences took place, which caused each particular elevation ; nor can we, in all cases, point out the direction taken by the lava from its deep fountain to its place of eruption ; neither can we explain, in every instance, the relation between the forms assumed by the continents, peninsulas, and islands, without a thorough knowledge of the geological and topographical circumstances. I do, however, insist, that when a good scientific survey of a region has been made, so that its actual structure is known, all will be found consistent with the essential principles advanced in this treatise. We find but few maps of large countries which are reliable, and in regard to many regions the authorities differ so essentially that we are in considerable doubt concerning them. Nothing, however, is wanting to determine geonomic questions but a correct survey of the premises. I have no hesitation in expressing the confident belief that, with the aid of the simple principles of geonomy, an ordinary geological examiner, with ample opportunities, would now be able to give a good account of any country on the earth, and explain the origin of all its elevations and geological formations. Not only so, he would be able to predict with considerable accuracy its future changes of level. What geonomer will hereafter express surprise on hearing that the land at the north end of the Gulf of Bothnia is rising, while that at the south is sinking? Who will, after this, be puzzled to explain why there are volcanic eruptions in the Sicilian islands, the Mexican plateau, the Pacific Ocean, or along the Aleutian chain.

If I appear to avoid details in this general treatise, I frankly confess that it is in part owing to a desire not to weaken my readers' confidence in the novel principles which I am advancing, by any rash applications of them to cases where the essential topographical circumstances are not understood, and where I should consequently be liable to commit serious errors. I, therefore, shall reserve for a future time, and perhaps for other, and I hope abler hands, the task of applying these principles more particularly to special and limited regions. Experienced philosophers will appreciate my motives and approve of my cautiousness. My only object in this treatise is to announce certain laws hitherto unknown, that afford a key by means of which the physical geography of any region of the land or sea can readily be understood after it has been carefully surveyed.

The following extracts from Lyell's Principles of Geology are full of interest and instruction. The facts recorded concerning earthquakes and volcanoes are highly illustrative of the principles of geonomy, and in turn receive from them their only rational explanation. I leave the readers to make their own application of the principles to the facts as related.

"*Lisbon Earthquake.* — In no part of the volcanic region of Southern Europe has so tremendous an earthquake occurred in modern times as that which began on the 1st of November, 1755, at Lisbon. A sound of thunder was heard under ground, and immediately afterwards a violent shock threw down the greater part of the city. In the course of six minutes, sixty thousand persons perished. The sea first retired, and laid the bar dry; it then rolled in, rising fifty feet or more above its ordinary level.

"The most extraordinary circumstance which occurred at Lisbon during the catastrophe was the subsidence of a new quay, built entirely of marble, at an immense expense. The water in the place where the quay had stood is stated, in many accounts, to be unfathomable; but Whitehurst says he ascertained it to be one hundred fathoms.

"The great area over which this Lisbon earthquake extended is remarkable. The movement was most violent in Spain, Portugal, and the north of Africa; but nearly the whole of Europe, and even the West Indies, felt the shock on the same day.

"The shock was felt at sea on the deck of a ship to the west of Lisbon. Another ship, forty leagues west of St. Vincent, experienced so violent a concussion that the men were thrown a foot and a half perpendicularly up from the deck. In Antigua and Barbadoes, as also in Norway, Sweden, Germany, and Italy, tremors were felt.

"A great wave swept over the coast of Spain, and it is said to have been sixty feet high at Cadiz. At Tangier, in Africa, it rose and fell eighteen times on the coast. In Madeira it rose full fifteen feet perpendicular above the high-water mark, although the tide, which ebbs and flows there seven feet, was then at half ebb. At Kinsale, in Ireland, a body of water rushed into the harbor, whirled round several vessels, and poured into the market place.

"The sea first retired at Lisbon; and this retreat of the ocean from the shore at the commencement of an earthquake, and its subsequent return in a violent wave, *is a common occurrence.* In order to account for the phenomenon, Mitchell imagined a subsidence at the bottom of the sea, from the giving way of the roof of some cavity, in consequence of a vacuum produced by the condensation of steam."

In 1751, at St. Domingo, twenty leagues of the coast sunk down, and has since been a bay.

Mr. Lyell says that "in the earthquake at Chili, in 1822, the earth was elevated over an area of one hundred thousand square miles. Mrs. Graham observed, after the earthquake of 1822, that, besides the beach newly raised above the high-water mark, there were several older elevated lines of beach one above the other, consisting of shingle mixed with shells, extending *in a parallel direction* to the shore, to the height of fifty feet above the sea.

"Assuming the great pyramid of Egypt, if solid, to weigh, in accordance with an estimate before given, six million tons, we may state the rock added to the continent by the Chilian earthquake to have more than equalled one hundred thousand pyramids.

"The discharge of mud in one year by the Ganges equalled the weight of sixty pyramids. In that case it would require seventeen centuries and a half before the river could bear down from the continent into the sea a mass equal to that gained by the Chilian earthquake.

"Violent earthquakes, in 1812, convulsed the valley of the Mississippi, at New Madrid, for the space of three hundred miles in length. As this happened exactly at the same time as the great earthquake of Caraccas, it is probable that these two points are parts of one continuous volcanic region; for the whole circumference of the intervening Caribbean Sea must be considered as a theatre of earthquakes and volcanoes. On the north lies the Island of Jamaica, which, with a tract of the contiguous sea, has often experienced tremendous shocks; and these are frequent along a line extending from Jamaica to St. Domingo and Porto Rico. On the south of the same basin the shores and mountains of Colombia are perpetually convulsed. On the west is the volcanic chain of Guatimala and Mexico, and on the east the West India Islands—St. Vincent and Guadaloupe." The same region has been shaken again during the last year, (1857,) and a few weeks afterwards shocks were felt in the vicinity of Lake Erie.

The probability is, that the slight shocks which are felt in the interior of basins, like the Mississippi valley, and in the vicinity of the Caspian Sea, are owing to depressions produced by the gradual accumulation of sediment by the rivers in the deeper and more central portions of the great basin or valley, the weight of which occasionally is sufficient to cause a movement of the crust. If any one thinks that such small quantities of detritus are insufficient to break the crust of the earth, let him reflect that we know not how long the load has been accumulating, and that the state of the balance may be such that it only requires a small additional weight to turn the scale. The old proverb is that "it is the *last* feather that breaks the camel's back."

"In 1815 one of the most frightful eruptions recorded in history occurred in the mountain Tomboro, in the Island of Sumbawa. It began on the 5th of April, and was most violent on the 11th and 12th, and did not entirely cease till July. The sound of the explosions was heard in Sumatra, at the distance of nine hundred and seventy geographical miles in a direct line, and at Ternate, in an opposite direction, at the distance of seven hundred and twenty miles.

"The area over which tremulous noises and other volcanic effects extended, was one thousand English miles in circumference, including the whole of the Molucca Islands, Java, a considerable portion of Celebes, Sumatra, and Borneo.

"In October, 1746, Peru was visited by an earthquake which is declared to have been more tremendous and extensive than even that of Lisbon in 1755. In the first twenty-four hours, two hundred shocks were experienced. The ocean twice retired, and returned impetuously upon the land; Lima was destroyed, and part of the coast near Callao was converted into a bay; four other harbors, among which were Cavalla and Guanape, shared the same fate.

"The volcanoes of Iceland have been in activity ever since the island was discovered, in the ninth century. Hecla, though not the most considerable of these, from its position and its former activity, is the best known. It has had many formidable eruptions, twenty-two of which have been noted in about eight hundred years; and in the same period we have notices of twenty eruptions from five other Icelandic volcanoes. A succession of eruptions of Hecla lasted for six years; but the most severe convulsions of that country happened in 1783, when the dreadful eruption of the Skaptàr Yökul burst forth, and did not cease till the following year. About a month before this terrible catastrophe, a submarine volcano elevated the crater of Nyoë, seventy miles southwest of Cape Reikianes, and threw out such an immense quantity of scoriæ as to cover the sea, to the distance of one hundred and fifty miles, with a stream which impeded the progress of ships making the island; and portions of this eruption floated as far as the Shetland and Orkney Islands. Nyoë emitted smoke and scoria from several apertures; but within a year the island disappeared, and a shoal marks its former site. On the 8th of June the Skaptàr Yökul threw out smoke; on the 10th an enormous current of molten lava flowed from numerous cones on the Yökul, which, dividing into two main streams, pursued its course to the sea, filling up the beds of two large rivers, and covering an immense extent of once productive country. The horrors of the scene were aggravated by the enormous torrents of boiling water produced by the liquefaction of the glaciers that covered the Yökul, and by incessant showers of ashes, which darkened the sun; stream of lava succeeded stream from the 10th of June to the end of August, at short intervals; and noxious emanations destroyed numbers of those whom fire and water had spared. From this calamity Iceland has never recovered; for within the space of two years the island, in consequence of this eruption, lost nine thousand three hundred and thirty-six persons, eleven thousand four hundred and sixty head of cattle, twenty-eight thousand horses, and one hundred and ninety thousand four hundred and eighty sheep. The extent of the principal stream of lava is fifty miles in length; its greatest breadth is from twelve to fifteen miles; in the plains its general depth is one hundred feet, but in the channel of the Skaptà River, which it dried up, it is six hundred feet in perpendicular depth. The south-western side of Iceland appears to be one vast focus of subterranean fire; for the several eruptions of the Oræfa, the Skeiderà, Sida, and Skaptàr Yökuls, seem but as occasional *outbreakings* from one immense volcanic fissure, which really belongs to the same chain of icy mountains." — *Dr. Traill.*

## SECTION VII.

### RELATION OF THE ANCIENT AND MODERN OCEAN CURRENTS TO GEOGRAPHY.

THE fact being admitted that earthquakes, volcanoes, and mountains are caused by the downward tendency of the ocean's bed, we shall be led to inquire into the detailed effects upon the forms of the land and the sea. We shall be curious to ascertain the situation of the sea or lake that produced each particular mountain, to trace, in the curves and slopes of the mountain ranges, the direction of the ocean currents that produced their upheaval.

In this general outline it cannot be expected that I shall do more than indicate the course of study and observation which must be pursued in future; but a key to physical geography is given when it is ascertained that all elevations are but the reactions of corresponding depressions; that Asia, Europe, and North America are three elevated and extinct ellipses; and that Africa, South America, Australia, and Greenland are portions or fragments of ellipses, or else they are interspaces situated between several great ellipses, most of which are still continuing their circuits, bearing in the bosom of their waters the detrital elements that give energy to earthquakes, supply the fires of slumbering volcanoes, elevate the surfaces of continents, and contract the boundaries of oceans.

A few elements of a planet and its orbit being known, astronomers are enabled to determine its whole path, and its relations to other orbits with great precision. The same appears to be now true of the elements of oceanic ellipses, which the forms of the land present to us as indications of the entire paths pursued by the currents that gave birth to those forms. The sea is poetically characterized as the emblem of inconstancy; but the laws which govern the movements of the sea are as unchanging as gravitation, though they have not heretofore been understood. It is the land, rather than the sea, that, geologically considered, is subject to change; for the ocean currents mould the surface of the earth into correspondence and subordination to themselves, and pursue a course determined by astronomic forces, over which the earth has no essential influence.

It must be evident that if the principles which I am advocating are to be relied upon, the inequalities of surface at the bottom of the sea are mere continuations and repetitions of those seen upon the dry land; and if the whole ocean could be drained, and then carefully surveyed, what we call the dry land would be found to be but the segments or highest portions of a regular system of reliefs produced by elliptical currents.

I earnestly hope that by the liberality of our government the ocean depths throughout the world will soon be known, so far, at least, as may be necessary for scientific and practical purposes. When that knowledge is obtained, I expect that the islands of the great Pacific will be proved to be the tops of mountain ranges, which are the borders of definite marine ellipses, analogous in outline to the mountains of the dry land. It is not unreasonable to suppose that then we shall be able to predict the elevation of lands and the breaking out of volcanoes in regions where nothing of the kind is now anticipated. Mankind will then learn to regard such movements as but a part of the progressive system of nature, dependent, like tempests and thunder storms, upon a disturbance of elements which are known, and which science can subject to the ordeal of mathematical calculation.

If we look at a curious map of the bed of the Atlantic, published by Lieutenant Maury in his "Physical Geography of the Sea," we may observe that a submarine continent is forming in the middle of that vast lower region, which, in form, bears a striking resemblance to Italy, and, like that beautiful peninsula, it resembles a human leg and foot in its outlines, with its sole and heel towards the equator, and its toe pointing towards the west. The depressions around it are also analogous to the marine basins around Italy. The Gulf of Venice, the Bay of Sicily and Naples, and the Gulf of Taranto have their analogues here. We may also notice its resemblance to New Zealand, and that it is literally its antipode, the forms being exactly the reverse of each other.

Are these beautiful analogies meaningless, or do they rather speak with the irresistible logic of nature, to teach us that similar causes operated to produce similar forms? It is worthy of remark, that the part of the Atlantic's bed which must receive the greatest quantity of detritus and sediment, instead of being the most elevated, is actually the most depressed. Now, since it is well known that it is not worn by the currents, it must be sunken by its own weight.

Lieutenant Maury manifests a singular power of observation, combined with an admirable sagacity, in the following remarks, which I take the liberty to quote from his useful and elegant treatise on the Physical Geography of the Sea, p. 252.

"To measure the elevation of the mountain tops above the sea, and to lay down upon our maps the mountain ranges of the earth, is regarded in geography as an important thing, and rightly so. Equally important is it in bringing the physical geography of the sea regularly within the domain of science, to present its orography, by mapping out the bottom of the ocean so as to show the depressions of the solid parts of the earth's crust there below the sea level.

"What is to be the use of these deep sea soundings? is a question that often occurs; and it is as difficult to be answered, in categorical terms, as Franklin's question, What is the use of a new-born babe? Every physical fact, every expression of nature, every feature of the earth, the work of any and all of those agents which make the face of the world what it is, and as we see it, is interesting and instructive. Until we get hold of a group of physical facts, we do not know what practical bearings they may have, though right-minded men know that they contain many precious jewels, which science or the expert hand of philosophy will not fail to bring out, polished, and bright, and beautifully adapted to man's purposes. Already we are obtaining practical answers to this question as to the use of deep sea soundings; for as soon as they were announced to the public, they forthwith assumed a practical bearing in the minds of men with regard to the question of a submarine telegraph across the Atlantic.

"There is at the bottom of the sea, between Cape Race in Newfoundland and Cape Clear in Ireland, a remarkable steppe, which is already known as the telegraphic plateau.

"There appears to be, corresponding to this elevation of the bottom of the sea, a ridge on the land, which runs nearly, if not entirely, around the earth. Leaving this continent between the parallels of forty-five degrees and fifty degrees north, the British Islands are within its range. Passing thence to the continent, we recognize it in the great 'divide,' which separates the drainage of the Arctic Ocean from the drainage of the south. In Asia it rises up into a chain of steppes and mountains, extending across that continent from west to east, and disappearing on the shores of the Pacific. We do not know how it is at the bottom of the 'Grand Ocean;' but the chain of Aleutian Islands, rising out of the water midway between Asia and America, seem to suggest that it is there also. However, if we run the eye along to America, we shall perceive again, as soon as we come to this continent, indications of this ridge, which divides the waters that flow from the north from those that seek the ocean in more southern latitudes."

The explanation that geonomic principles give to the "remarkable steppe" in the sea and "ridge on the land," which Lieutenant Maury describes so well, is, that the northern and southern oceans have antagonized each other in the northern hemisphere, and produced the elevation of the bottom of the sea, and this ridge on the land betweeen them, which "runs nearly, if not entirely, around the earth," parallel with the Polar Sea, and also with the ancient sea that formerly washed the southern side of the annular ridge. Geonomy requires that there should be a predominance of east and west elevations and ridges near the equator and near the poles; but between these two annular ridges there should be a succession of north and south elevations. Geography demonstrates that the elevations actually exist in accordance with the requirements of this law.

In looking at the map of the world we find that all the large level plains are in the middle of ellipses, or they are between ellipses; in other words, they are in situations where the circulation of the currents could not produce subsidences and elevations: thus, Asia constitutes a great circular basin, the southern and eastern edges of which are elevated into a series of enormous, nearly parallel ridges, which correspond in direction with the course which the ocean currents must have pursued when the land was the ocean's bed, and was gradually rising. It is evident that these mountain ranges were produced by a series of subsidences, which commenced at the Altai, and proceeded southward to the Himalaya, continually increasing in height as they proceeded.

"The most ancient chains are the least elevated; while the colossal grandeur of the Andes and the Himalaya bear the traces of an upheaval comparatively very recent. In America, from the coasts of Brazil to the high table lands of Bolivia, and from the Atlantic shores to the Rocky Mountains; in Europe, from the mountains of Scandinavia to the summit of the Alps, we meet with upheavings successively less ancient." — Professor Guyot's *Earth and Man.*

On the north side of the basin there is a series of low elevations which have an east and west direction; but they are so low, so barren and cold, that they have scarcely been noticed by geographers. They are low because they have been produced by seas that are of limited dimensions, when compared with the vast areas of the Pacific and the Indian Oceans.

On the western side is a range of mountains which extend from the Caspian Sea to Nova Zembla, a distance of seventeen hundred miles, in a north and south direction generally, but curving to the west at the southern extremity of the chain, and to the east at the northern extremity. This is the Oural chain, which divides the Asiatic basin from the European. Between four systems of elevation, namely, the Aldan Mountains on the east, the Altai on the south, the Oural on the west, and the Arctic shore on the north, is a vast level plain — the largest in the world. Why should it not be level? No currents have ever crossed it to deposit layers and strata of sediment, the weight of which could break the earth's crust. The currents circulated *around* it, and left its surface unbroken.

Look now at the European basin, and observe how analogous it is to that of Asia; yet in some details how different and diminutive! Instead of the Aldan Mountains on its eastern border, it has the Oural; instead of the Himalaya and Hindoo Kosh on the south, it has the Caucasus and the Carpathians; instead of the Chinese, Bengal, and Arabian Seas, and the peninsulas of Siam, India, and Arabia, it has the deep basins of the Caspian, the Euxine, and the Eastern Mediterranean, with the peninsulas of Asia Minor, Greece, and Italy. Instead of having the Ourals on the western border, Europe has the Scandinavians. Spain, France, and Great Britain belong to the North Atlantic basin, and not to the European. This is evident from the directions of their mountains, and their correspondence with the eastern segments of the North Atlantic ellipse. But let us return to view the European basin, which, like Asia, has a succession of nearly parallel ridges on its southern border, but is bounded east and west by simple north and south ranges. Like Asia, its greatest elevation is at the south, and declines gradually to the Frozen Ocean. The North Sea and the Baltic are the depressed portions of the European basin. So the Aral Sea and the Caspian are the most depressed parts of Asia. The great plain of Asia is between the ranges of the Oural, the Altai, and the Aldan. So the great plain of Europe is between the Scandinavian, the Carpathian, and the Oural; except the trifling elevation of the Valdai, there is nothing to indicate a rupture of the earth's crust in this vast interior of the European ellipse. All around it the crust is broken up like the ground in a circus ring.

The Mediterranean and Caspian Seas were formerly the channel of the European ellipse, and though the influence of the large oceans has elevated the land all around them, they still continue to accumulate detritus and sediment, and to sink deeper, while the countries in the vicinity are kept in constant dread of the earthquakes and volcanoes which the reaction of their subsidences produce. In the same manner the Mexican and Caribbean Seas, though gradually narrowing and closing, do not abandon the ground without a struggle, which is attested by the numerous volcanoes that encircle its basins, and the dreadful earthquakes that devastate its shores. In the East Indies the same principles are illustrated in a still more powerful manner by the circle of volcanic fire that is drawn around the elliptical channels near the East Indian islands. The law seems to be, that the channels shall continue to sink as long as they can obtain sediment enough to break the crust; and it will be broken the more easily for being frequently ruptured; but between the channels the land may rise to maintain the equilibrium.

There is a peculiarity in the region of the Caspian and Aral Seas that is finely illustrative of the geonomic theory, which is, that the surface of the land is below the surface level of the surrounding seas. It seems that the oceans have caused the elevation of the land around the basin, and cut it off from all communication with the open sea. Being in a temperate climate, the water which was thus left enclosed by elevations has been evaporated away, except that which is now found in the Aral and Caspian Seas, and a number of small lakes. It is said that earthquakes frequently disturb this region. Why, then, do they not elevate it at least to a level with the ocean? The answer is, that subsidence is the only means of elevation, and of course that cannot elevate the *lowest* place. To accomplish the elevation of the Caspian or the Mediterranean, a "lower deep" must be made, to crowd the lava beneath the crust on which the Caspian rests. Instead of the Caspian rising, it is probably sinking, and thus raising the land around it, producing slight earthquakes as it does so.

The Adriatic and the Euxine have, like the Mediterranean, been for a long time sinking in the same manner, and occasionally causing elevations and eruptions which have given birth to the Apennines, the Alps, the Taurus, the Balkan, and Caucasian Mountains. We know but little of Africa; but what we do know tends to show that its creation and elevation is comparatively modern. The probability is, that at the time that the mountains around the Mediterranean were elevated above the surface of the ocean, most of Africa was at the bottom of the sea. If Africa had not risen and limited the area of the Mediterranean, the mountains of Southern Europe would have been higher than the Himalaya. Arabia appears to be an inter-land, which is nearly level from the want of a large ocean on any of its borders. When any land is surrounded by seas which are nearly of equal size, it must necessarily be almost a level country; though, if the seas are large, it may be elevated into a level table land.

The North American basin is formed on the same principles as Asia and Europe. It has three oceans, and three corresponding systems of elevations on its borders — the Appalachians and Ozark on the east, the Rocky on the west, and the low Lawrentine range on the north. Between these three, in the interior, is the vast level plain called the great valley of the Mississippi.

North America differs from Asia in the fact that the abrupt declivities are on the western side in America, and on the eastern in Asia; but otherwise it greatly resembles it.

Greenland, South America, Africa, and Australia are four continental areas of land, which are not, and never were ellipses, but are situated between them. Greenland is between three seas, the Arctic, the North Atlantic, and Baffin's Bay, which is really a sea. South America is between the North Atlantic, the South Atlantic, and the South Pacific; Africa between the North Atlantic and Mediterranean, the South Atlantic, the Indian Ocean, and the Red Sea.

Australia is situated between the Indian Ocean and the Java Sea on the west and north, the North Pacific on the north-east, the New Zealand Sea and South Pacific on the south-east, and a small oceanic ellipse which I will call the Tasmanian, on the south. The most important fact to be noticed in relation to these interlands is, that they are, without exception, the most elevated on the side which borders upon the largest ocean. Thus Australia, Africa, and Greenland are most elevated on their eastern sides, and South America on the western. Australia is the least elevated on the south; Africa and South America on the north.

What are called the trade winds blow from near the thirtieth degree of latitude to the equator, in a western direction, and carry with them the moisture which produces fertility. Those lands, therefore, which have their largest ocean, and consequently their highest lands, on the eastern border, as Australia, Africa, and Asia have, will have large barren deserts in their western parts; but those lands which, like South America, have the largest ocean on the western borders, will have their larger mountains on their western border also; so that the moist winds from the south-east will pass over the larger part of the land before they reach the mountains, and are arrested and robbed of their fertilizing moisture. This is the reason of the smallness of the deserts in South America, compared with those of other countries.

In the extreme southern part of the southern ellipses there is so little known of the submarine forms, that we are left almost entirely to conjecture from analogy. I presume that the Lagullas bank, which is a submarine plateau south-east of Good Hope, is an inter-elliptic elevation analogous to the banks of Newfoundland. I also regard the islands at the south-east of Patagonia as of the same character, and as indicating the eastern course of the current there.

It is remarked by many physical geographers that the principal mountains of the eastern continent run east and west, and of the American continent north and south. This is true if we confine our observations to the higher class of elevations, and to the dry land; but if we view the matter philosophically, and consider the submarine ridges and elevations as continuations of those above the surface of the sea, we must conclude that the prevalence of ranges of mountains in any one particular direction is only apparent.

The extraordinary elevation of the lands of the old continent is owing to the fact that the great Indian Ocean bathes the southern shores of Asia, and by its subsidences causes the elevation of the mountains in an east and west direction ; whereas, in America, the great Pacific Ocean, both north and south, bathes the western shores for eight thousand miles, and produces abrupt slopes and high mountains continuously the whole distance.

It must also be remarked that Asia and Europe are united at the Oural Mountains, so as to bring two drained ellipses together, and make the continent continuous from Kamschatka west to Iceland, a distance which extends nearly half round the earth, at the arctic circle. This union of Asia and Europe gives an appearance of great extension in an eastern and western direction. The fact, also, that the Indian Ocean and the Mediterranean combine to elevate the land on the south produces the appearances that are peculiar to the eastern continent, and which have hitherto remained without an explanation.

The rule appears to be, that the *directions* of the currents determine, in all cases, the directions of the mountains ; and the size of the contiguous ocean, all else equal, determines the size of the mountains. The condition of "all else equal" must be continually borne in mind, for it is not in reality the ocean itself directly that produces the elevation of the mountains, but the detritus which the ocean gathers from its shores and its bed, and deposits in different quantities in different places, according to circumstances. In some places, as in the Mediterranean, for instance, the subsidence has been very great, in consequence not so much of the present size of the sea, as the concentration of deposits in one great sink.

If we adopt the idea of Professor Guyot, that Italy and Cape Bon together may be considered as equivalent or analogous to the Central American isthmus, then we may regard the great circle of the Alps as the former shores of a basin analogous in form and position to the Gulf of Mexico. The peculiar forms and curves of the Alps are thus accounted for. We must not allow ourselves to be misled by the great elevation of the Alps compared with the shores of the Mexican Gulf, for the degree of elevation has nothing to do with the form of a country.

I have no doubt that Fremont's Basin was once as low as the Gulf of Mexico, and performed a similar function. The same may be said of the Himalayas and the plateau of Tibet. They both were once basins, and constituted the turning points of ancient elliptical currents, and were gradually filled, abandoned, and elevated by the action of the powerful oceans around them. The Gulf of Mexico is going through the same process ; the time will come when Florida will have mountains like those of Greece, and Texas will have Alps more exalted than those of Switzerland. Then will the valley of the Mississippi be a desert, and the plains of Kansas and Nebraska rival the frozen steppes of Siberia.

We observe, in looking at a map of the world, that there are three analogous southern continents, namely, Africa, South America, and Australia. It is near the northern borders of these that the greatest number of volcanoes are found, in the vicinity of three isthmuses, — one of which is submarine, — that unite them with the three northern continents, from which they are partially separated by three archipelagoes. In other words, there are three pairs of continents, and in each pair the region which is most volcanic is that which is intermediate, and is occupied by an archipelago.

Let us notice, that next to the three tropical intercontinental archipelagoes, in volcanic and geonomical importance, are the two arctic archipelagoes, which are also inter-continental: one, the Iceland and Faroe, is between Europe and America, and the other, the Aleutian, between Asia and America. They occupy the only situations of importance where the inter-continental currents turn from the arctic to go southward. It must be remarked that they have their analogues in the antarctic region, where Mount Terror and Mount Erebus illuminate the regions of eternal winter, and where the southern ellipses turn to carry cooling streams to the tropics.

The rocky ridges, which are found to run parallel to most large rivers and lakes, were doubtless caused by the sinking of their beds while they were ocean channels. The fact pointed out by Professor H. D. Rogers, that the Appalachian chain is divisible into eleven groups, each of which is composed of a succession of mountains, of various dimensions, but all more nearly parallel to each other than to those of other groups in the chain, is perfectly consistent with the theory of their origin which I am advancing, and I think that it will be found that each group or section of the great Appalachian chain, however much it may differ from the other groups in direction, is generally parallel, or nearly so, with the nearest ocean shore and channel. In other words, the whole chain of mountains is generally nearly parallel with the whole coast line, and each group of the chain is nearly parallel with the part of the coast line nearest to it.

The Gulf of Mexico and the mountains of Central America afford a good illustration of the production of elevations in conformity with currents. The form of the gulf is precisely such as the action of currents of water would naturally create, and yet we find it surrounded by mountains which water could not produce, except by the weight of detritus and the reaction of gravitation. If we look at such a place as Cape Cod, and its bay, which is formed entirely of sand, scooped out, as it were, by water power, and then compare the Gulf of Mexico with it, we shall perceive that they both appear to be formed on the same plan, and by the same aqueous causes, with this difference, that after the Mexican Gulf was laid out, and its shores as far advanced towards completion as Cape Cod is now, the subsidence of its bed raised a number of ridges of rocky heights along its shores and around its basin. No other conceivable force would be likely to raise mountain chains in such curves as to correspond with a water-made bay.

We shall find, upon a correct application of geonomic principles, that the form of the gulf and the direction of the mountains around it in Yucatan, the isthmus, Cuba, and Mexico, are the results of depressions produced by the detritus that has been so long pouring into that great focus of the Atlantic currents. The modern volcanoes that have arisen in this region will probably be hereafter proved to be but a continuation of a system of geonomic reactions, which commenced in the beginning of terrestrial time. It will be found that all the short curved or elliptical ranges of mountains, in the interior of the continents, are now, or once were, the borders of bays, lakes, or inland seas; while the long, nearly straight ranges, like the Andes, were produced by the main channel, which constitutes the long side of some great ellipse.

Nearly all peninsulas are formed upon one principle, by the opposition of two currents, one of which is forced to turn out of its course and in some degree turn back and double on itself.* Accordingly, we find peninsulas most developed where currents turn and encounter other currents; thus Alaska seems to be formed by the current through Behring's Strait into the Pacific, being turned or reflected south-west towards the eastern shore of Asia. Lower California appears to be formed by the current from the south, being driven in shore by

* The tendency of the land to assume a peninsular form is very remarkable, and it is still more so that almost all the peninsulas tend to the south — circumstances that depend upon some unknown cause, which seems to have acted very extensively. — MRS. SOMERVILLE.

the current from the north, which moves along the western shore of the peninsula.

The peninsula of Kamschatka was formerly an island, between which and the main land the waters once flowed; but now, the channel being obstructed, the water enters and makes a circuit, and proceeds on towards Alaska. The Japan Isles are going through the same process, and are doubtless destined to become a peninsula with a large gulf, through which a sub-ellipse will circulate. The Corea is formed on the same principle as Florida, and the Yellow Sea is like the Gulf of Mexico. The Gulf of Tonquin is still more like that of Mexico, with its islands and its peninsula to represent Cuba and Florida. The Gulf of Siam depends upon the same causes, and when the peninsula of Malacca was an island, the resemblance to the Gulf of Mexico was perfect.

Leopold von Buch has given a chart, which has been copied and approved by Sir Charles Lyell, showing the tract or band visited by earthquakes and illuminated by volcanoes among the Molucca and Sunda Islands, between Australia and Asia. And I would call especial attention to its remarkable agreement with my views of the causes of earthquakes. The band, according to the chart, is parallel to the tract of the ocean currents, as indicated by Lieutenant Maury. From Barren Island, in the Bay of Bengal, it passes to Sumatra, Java, New Guinea, and thence to the Philippine Islands, exactly parallel with the current which proceeds from the Bay of Bengal to Behring's Strait. (See Lyell's *Geology*.)

A similar volcanic band, or half ellipse, may be described as running parallel with the current which circulates in the Mexican and Caribbean Archipelago, including within its borders Guadaloupe, Caraccas, Nicaragua, and Mexico.

It is evident that a similar half ellipse once existed in the Mediterranean region; and one certainly does now in the Aleutian group, including Alaska and Mount St. Elias. Another exists in the Iceland and Faroe Islands. If we draw a line from the south of Greenland, which is said to be slowly sinking, to Iceland, and the Faroes, and the north of Scandinavia, which is gradually rising, and thence to the south of Scandinavia, which is also said to be sinking, we shall trace another arc of an ellipse which is probably analogous to the others already described.

The volcanic band copied by Mr. Lyell is exactly in the place of the southern apsis, or first segment of the North-western Pacific ellipse. The Aleutian volcanic band occupies the place of the other or northern apsis. So, also, the two volcanic bands of Mexico and Iceland are in the places of the apsides of the North Atlantic ellipse.

That the continents are in some places gradually rising, is now generally admitted; and the only theoretical explanation of the fact that has been suggested, within my knowledge, is, that it is owing to the contraction of certain parts of the earth, in consequence of the gradual radiation of heat. I will not discuss this theory, but content myself with proposing another, which seems to me much more reasonable, which is, that the oceanic basins are in many places quietly and imperceptibly, but progressively, sinking, on account of the accumulation of sediment in their beds : in consequence of this depression, the lava is pushed up under the neighboring continents with a force equal to the weight of the sinking mass; this causes a part or the whole of a continent to rise with a rapidity equal to that of the accumulation of sediment. In some parts of the ocean's bed, and particularly in the courses of the principal currents, the sediment is deposited so much more copiously than in other places, that the crust of the earth becomes locally fractured by the unequal weights that press upon it. This causes sudden local subsidences, which usually take place in lines parallel with the currents. Isolated volcanoes are probably caused by extraordinary and special accumulations in limited spaces, which produce great local depressions and corresponding elevations.*

The attention of mankind was first attracted by single volcanoes; next it was observed that they generally occur in lines, and that they seem to alternate in action, as if they are so connected below that they are capable of mutually relieving each other. It was also observed that all mountains appear to be of volcanic origin. Finally, it was ascertained that extensive countries, and even continents, have risen, while oceans have grown deeper, without any perceptible cause.

The Baron Humboldt, with very great labor, deter-

* However natural it may be that the force of running water in numerous valleys should be *spent*, it is by no means so easy to explain why the violence of the earthquake and the fire of the volcano should also have become locally extinct at successive periods. — LYELL.

mined as near as practicable the height of the several continents. The following are his results : —

| | Mean Elevation. |
|---|---|
| Europe, . . . . . . . . | 671 feet. |
| Asia, . . . . . . . . | 1151 " |
| North America, . . . . | 748 " |
| South America, . . . . | 1132 " |

In order to determine how much the lands altogether have risen, we must first calculate how deep the ocean was when it was universal and uniform. This cannot be estimated with any thing like accuracy, until the present depths of the ocean are measured in a great many places. We may doubtless be safe in assuming that the ocean has varied as far from a uniform depth as the land has from a uniform height above the level of the bottom of the primitive ocean.

If the water was once uniformly a mile in depth over the whole earth, the ocean's bed may have risen a mile in one place and sunk a mile in another place, without raising any land above the ocean's level. Now, as the lands are on an average one thousand and eight feet above the level of the ocean, they must have risen that much, besides rising from their ancient beds to the surface.

From this it does not follow that the depths of the ocean in any one place must be greater than the elevation of the land in any place, for the lava which is displaced from beneath a very large *superficial* area beneath the ocean may have been forced up into ridges and peninsulas, which are very high and narrow ; but it does follow that the same quantity of lava by *cubic* measure is elevated, which is displaced by depression.

If we view the great hemispherical circle of continents that extend from Behring's Strait south-west through the tropics, and then north-west to Behring's Strait again, we shall perceive that it is divided into an eastern and a western portion by the North Atlantic, which runs through it like a vast river whose banks are nearly parallel. We shall see that the southern points of Africa and South America are two great capes constituting the mouth of the Atlantic River, Africa being the eastern, and South America the western cape.

The inland seas of the two continents are subordinate streams to the Atlantic; thus, in the eastern continent we have the White Sea, the Baltic, and the Mediterranean, with its dependencies. In the western we have the Gulfs of Mexico and St. Lawrence, Baffin's and Hudson's Bays. All these communicate with the Atlantic. It is through the medium of the Atlantic that the north and south polar seas communicate with each other. In this view it may be regarded as a sound or strait, running north and south from the arctic to the antarctic.

If we make a map of the world on Mercator's projection, extending from Behring's Strait, west to Behring's again, and a little beyond, so as to include the eastern coast of Asia, and present a view of the Pacific as a connected whole at the west end of the map, we shall be able to represent all the ellipses, and illustrate many of the general principles of geonomy by its means. It will be observed that on this map all the principal lands *in the northern hemisphere* are included in a semicircle which extends from Behring's Strait to the tropic of Cancer, and then west to Mexico, and thence to Behring's Strait again. If we then continue the line east through the north polar sea to Behring's Strait once more, we shall have completed a vast ellipse, which includes all the lands of the northern hemisphere. This grand hemispherical ellipse appears to be divided into five smaller ellipses, which, being named in their order from Behring's Strait west, are, 1. The Asiatic; 2. The European; 3. The North Atlantic; 4. The North American; 5. The North-west American.

If we study the lands in the southern hemisphere, we shall find them to be mere points projecting from the southern border of the grand northern hemispherical ellipse, like points or projections on the border of a lady's cape which is scalloped or notched. Each of these southern points, or peninsulas, is situated between southern and northern ellipses, and in no instance does one of them constitute an ellipse of itself; indeed, there are no drained ellipses in the southern hemisphere, but only parts of the borders of such ellipses.

It may be noticed that the inland waters or lakes of the northern continents are arranged in a semicircle, or, rather, a curve, which corresponds in a remarkable manner with the polar circle, and with the outline of the lands of the northern hemisphere; so much so that they may be said to be nearly parallel with them. Thus, commencing at Lake Baikal, in Asia, and proceeding through the smaller lakes to the Aral and Caspian, the Black and the Mediterranean Seas, then across the Atlantic to the Ontario, Erie, Michigan, Superior, Winipeg, and Slave Lakes, we shall find that we have described a curve which corresponds with, and is nearly parallel with, the northern and with the southern shores or borders of the lands of the northern hemisphere. These inland waters generally have their greatest extension north and south, and their shores are generally curved just as the mountains are, to conform to the normal directions of the currents that run between the polar and tropical regions.

We shall probably be justified if we view the continental semicircle from Behring to Behring as marking the former bounds of the ancient northern sea, of which the Frozen Ocean and the North Atlantic are the remnants. We may believe that a time existed when the Asiatic, European, and North American basins were occupied by water and bounded by chains of islands which have since been elevated to constitute the two great chains of mountains that distinguish the eastern and western continents. During the progress of the lands to their present elevations, there must have been a period when there were numerous outlets from the Arctic Ocean to the tropics. Perhaps the southern peninsulas of Asia may be regarded as marking the places of some of those outlets, just as the African and South American points now mark the southern extremity of the Atlantic. Perhaps we may look upon the peninsulas of Alaska, Kamschatka, Chin India, Hindostan, and Arabia, as points, or headlands, from whence the ancient Asiatic sea found outlets, before the chain of mountains was elevated in the eastern and southern parts of Asia; and we may regard the circle of inland seas and lakes as remnants of the ancient channels which the ocean made in communicating with the tropics.

## THE THERMAL EQUATOR.

The extreme eastern points of South America, of Africa, and of Australia, are not only analogous in form, but in function. Each is a dividing point, where the westward equatorial currents of the two hemispheres, after having run a certain distance together parallel with the equator, separate, one to flow north and the other south. Perhaps it would be more correct to say that the three points were *formed* originally by the separation of the currents at these places.

The question then arises, Why are not the eastern points of these three southern inter-lands all arranged precisely at the equator, or in one line parallel with the equator? Why is the eastern point of Australia about thirty degrees south of the equator, that of Africa about ten north, and of South America about six degrees south?

The answer to this question involves an explanation of the isothermal lines, and is a rather complicated matter. I shall therefore only touch upon it generally. It is commonly assumed that the difference in the lines of equal temperature depends upon the relative positions and heights of land and sea; but if the lands were put into their present places by the action of the water, how has it happened that they are placed so differently with reference to the equator? In other words, why did not the creative currents operate in the same line, instead of producing two of the eastern points, Africa and Australia, thirty-five degrees apart, and the third, South America, intermediate? Does not the answer to this question involve another still more curious, namely, which of the three southern continents were elevated first? which second, and third?

Let us assume that a portion of Asia and Africa were the first lands to rise above the surface of the sea. What effect would their elevation have upon the thermal equilibrium of the earth? There is no doubt that it would be to increase the warmth of the northern hemisphere at the expense of the southern; and the consequence would be, that an effort (so to speak) would be made by the air and water to restore the thermal balance. To accomplish this, the winds and currents would swerve over the mid-line into the colder southern hemisphere, and meet the currents from the antarctic about six degrees south of the equator. At the location of Cape St. Roque, the two currents would again part, and return, each to its own proper hemisphere, one along the eastern coast of South America, and the other to the Gulf of Mexico, and then along the eastern coast of North America.

Having thus briefly accounted for the position of the eastern point of South America south of the equator, we must further inquire how the eastern point of Australia came to be still farther south.

Let us assume — what will probably not be questioned by any geologist — that all the other continents were elevated before Australia was: the thermal equilibrium was then farther from a balance than ever, and the winds and waters were necessarily driven still farther to the south, to disburse the excess of heat which northern lands radiated from their extensive surfaces. Under these circumstances, the currents of wind and water from the north would be likely to run, and doubtless did run, over into the southern hemisphere, as far as the thirtieth degree of latitude, before they were antagonized and arrested by the cold antarctic waters, so as to be brought into a state of equilibrium. At the point where these waters again parted, the most eastern mountains of Australia were formed.

The current which flows to the south from the eastern point of Australia probably enters the Antarctic Sea near Victoria Land, and returns to the equator through the South Pacific. The current that flows to the north of the eastern point of Australia is better known, for it has made a deep impression upon the ocean's bed, and raised a series of mural monuments to indicate its path — the north-eastern shore of Australia, the islands of Java and Sumatra, Borneo, Celebes, and New Guinea, the peninsulas of India, Siam, and Malacca, — these are the offspring of this mighty current, and their mountains are parallel to its course.

This hypothesis has the merit of accounting for the gradually increasing advance to the south of the eastern and southern points of land, successively, from India to Africa, South America, and Australia.

## THERMAL TROPICS.

If there are three eastern points where the equatorial currents originally divided and separated into two branches, one of which moved towards the north-west, and the other towards the south-west, the question is, Are there two corresponding points in the two hemispheres where the two currents turned from the north and south-west, and moved towards the north and south-east? Looking at the eastern coast of the Americas, the forms of the land give a ready answer; for Cape Horn and Yucatan are evidently the two turning points, nearly equidistant from the Cape St. Roque. The eastern coast of North America shows plainly the direction to the north-east taken by the current from the Gulf of Mexico; and we are safe in assuming that an analogous current flows south-east from Cape Horn, the effects of which will yet be learned by deep sea soundings, which I hope Lieutenant Maury will be authorized to make.

From the most eastern point of Africa we see plainly marked the track of the two currents, one to the south-west, through the Mozambique Channel, between Madagascar and Africa, and the other through the Red Sea to the north-west. An interesting question now is, Where are the corresponding points where *these* two currents turn to move eastwardly? There is a noted submarine plateau south of Madagascar, called the Lagullas bank, which rises suddenly above the bed of the ocean several thousand feet, and I have no doubt that this will prove to be the turning point which marks the path to the south-east taken by this southern branch of the African current. The northern branch moves along the Red Sea to the Isthmus of Suez: no one doubts that it once flowed through the Mediterranean; but where was its turning point to the north-*east?*

The answer is found, in the Black Sea, the Caspian, and the Oural Mountains. On the Asiatic coast the Bay of Bengal is the turning point, but the Tasmanian region is unexplored.

### OF THE MAGNETIC NEEDLE.

The magnetic needle, instead of always pointing north and south, varies to the east or to the west. It does so much more in some places than in others, and in different degrees in the same place at different times. The causes or law of this variation are unknown. Captain Sabine noticed that the compass needle varies in a manner which indicates a tendency to conform to the directions of the mountain ranges.

I have lately been struck with the correspondence between the curves of magnetic variation as indicated on the map of the world, and the elliptical curves of the ocean currents when marked on the same map. The correspondence is so remarkable, that there must be some connection between the phenomena. Is it because the submarine mountains agree in their direction with the currents, and also because the needle is influenced by the largest and nearest masses of land? or is it owing to the thermal influences of both mountains and currents upon the magnetic forces? The latter seems to me the more probable.

I have now before me "A Chart of the Magnetic Curves of equal Variation," by Peter Barlow, Esq., London, in which the curves on the west of Africa and Europe are identical with the curves of the ocean currents in the same places; one set of lines proceeding from the arctic and another from the antarctic, and the two meeting at the Canary Islands, and crossing the Atlantic together to the American coast. In the South Pacific the magnetic curves are represented as forming an ellipse, which embraces the whole ocean in a manner identical with that in which I have, in the diagram map, represented the ocean currents as running.

So, also, in the region between Australia and Asia, the magnetic curves are identical with the curves of the currents as marked on the diagram map. The same is true concerning the curves parallel with the eastern coasts of Asia and of Australia.

Again, two magnetic ellipses impinge upon each other near the Sandwich Islands; the principal part of one ellipse being in the South, and of the other in the North Pacific; just as are the two elliptic currents of water in the same places, as represented in the diagram map. The hypothesis which I would propose to account for the variations of the magnetic needle is the following: —

The rotation of the earth causes a current of thermo-electricity to move with the sun around the earth continually. Any magnet, like the compass needle, always assumes a position at right angles to a current of electricity. This theory is generally adopted, and it explains the pointing of the needle north and south. To this I would add that the inequalities of the ocean and the land cause variations of the thermo-electric current, and of course produce corresponding variations of the compass. On the land the variations correspond with the mountains and large masses of cold lands. On the water they correspond with the great currents, and they are parallel with the submarine mountains.

According to this theory, if the crust of the earth was uniform and level in all its parts, there would be no variation of the magnetic needle, and if the inequalities of the earth were all well understood, — the submarine mountains and valleys, the currents of all the oceans, and the elevations of all the lands, — the variations of the needle would be found to correspond with them, and could therefore be reduced to known laws and practical rules.

If I am not greatly mistaken, important practical results may be obtained by following up this observation of the relation which unquestionably exists between the currents, the mountains, and the needle. It is possible that not only the causes of the magnetic variations may be demonstrated, but the compass needle may be used as an indicator of the directions or forces of the currents in places where they flow unseen. It may also, perhaps, become an index of the degree of variation of the crust of the earth from uniformity of thickness or of temperature.

NOTE. *Dip of the Needle.* — Some experiments with coils of wire, which I have tried within a few days in illustration of theoretical views, have induced me to regard the dip of the magnetic needle as but a modified manifestation of the same principle as that which causes it to point north and south, namely, a tendency to balance itself at right angles to the predominant current of magnetic force. Magnetic poles appear to be centres or axes of thermo-electric circles. The thermal inequalities near the surface of the earth seem to give a tendency to increase the number of magnetic circles, axes, and poles.

## SECTION VIII.

### RELATION OF THE EARTH'S CRUST TO THE LIQUID OCEAN OF METAL BELOW, AND THE WATERY OCEAN AND THE ATMOSPHERE ABOVE.

THE earth is surrounded by an atmosphere which modifies and refracts the rays of light. It also possesses oceans of water that refract the rays still more in their passage to its depths. But astronomers have concluded, that the moon is nearly or quite destitute of an atmosphere, from the fact that light seems to be refracted but little, if any, when reflected from its surface. The telescope demonstrates that the moon has no large bodies of water; yet the existence of mountains in the moon is placed beyond all question, and their forms, sizes, and relative positions are determined with approximate accuracy. Observations made upon Venus and Mars prove that they have atmospheres, mountains, and snow-clad polar regions, and of course oceans of water, as the earth has. The moon, therefore, appears at first sight to be an exception and an anomaly.*

* "Not a drop of water, or of any fluid akin to it, is now in the moon. Besides, there are no clouds; and as the moon has a small atmosphere, this alone is decisive; for otherwise vapors would float there, and the purity of the disk appear variable. The question whether water has been there, — whether in the history of that globe, in the course of its growth and revolutions, the epoch of water, or of fluidity in general, has not come or is passed, — is of more difficult solution." — PROF. NICHOLS, *On the Solar System.*

It is utterly improbable, *a priori*, that the moon is governed by different laws from those which regulate the constitutions of other planets; we are therefore led to inquire whether there is not a process going on in this earth which is gradually tending to the final destruction of its ocean and atmosphere, though it may leave its mountains higher and its valleys deeper than they are now, thus reducing it to the same condition as the moon.

The elementary or ultimate substances which compose the earth are divisible into metallic, non-metallic earths, and gases, numbering all together about sixty; of these nearly fifty are considered metallic, eight are conjectured to be non-metallic earths, and four gaseous. Before the time of Sir Humphry Davy, many of the substances which are now known to be metals were considered as non-metallic earths; but he proved experimentally that they are metals combined with oxygen. It has been demonstrated that a large proportion of the solid crust of the earth is oxygen combined with substances most of which have a metallic basis. This oxygen must have been originally derived from the atmosphere, for in the beginning there could have been none any where else. There is no avoiding the conclusion that the atmosphere has been continually yielding its contents to the solid earth.

The original crust of the earth must have been composed of those metals and earths which have the least specific gravity, combined with oxygen. The principal of these are calcium, potassium, silicium, or silicon, sodium, aluminum, and magnesium. These substances must at one time have floated upon the liquid surface of the earth, and were thus exposed to form combinations with oxygen, sulphur, phosphorus, carbon, iodine, and other volatile substances. Upon the crust thus formed the primitive ocean fell from the atmosphere. Then commenced that series of geological operations which produced the present condition of the earth, the sea, and the air — operations which are still progressing in the same direction, under the influence of the same laws, though the combinations and circumstances are continually becoming more and more complicated. The metallic earth and the liquid ocean and atmosphere have been unceasingly acting and reacting upon each other; but in this contest the atmosphere has been continually losing substance. The earth had originally nothing to give to the atmosphere but metals, and these the atmosphere could not retain; but the atmosphere possessed an immense quantity of vaporous and gaseous substance, which the gradually increasing coldness forced it to impart to the earth.

The oxides of metals, which formed upon the surface of the new earth, being non-conductors of heat, confined most of it within the sphere of the earth itself, and thus enabled the vapors of water to condense and fall upon the oxidated surface, and form an unbounded and shoreless ocean. The heavier metals of course sunk below the first formed crust, though some of them were thrown up by eruptions afterwards. On the other hand, the lighter metals united with the oxygen to form the top of the crust, and were, therefore, first exposed to the attrition of the waters. This being the case, it would naturally follow, that the first stratified deposits would be composed of ingredients worn from the primitive crust, and constituted of the oxides of the lightest metals.

In accordance with this reasoning, we actually find potassium, sodium, aluminum, calcium, and silicium, the lightest known metals and metalloids, performing the principal part in forming the first stratified rocks that were deposited from the primitive ocean. Sodium, the lightest known metal, united with oxygen and chlorine to form common salt, which was dissolved in the ocean waters. Potassium, the next lightest of the metals, united with oxygen to form potash, which is an essential constituent of granite — and granite is the material of which the original crust was mostly formed. Silicium, or silicon, a metalloid which belongs to the lightest class, is the principal constituent of mica and quartz. Aluminum, one of the same class of light metals, is the main ingredient of clay. Calcium, another very light metal, constitutes the essential part of lime.

It has been a question how the rocks originated which are composed of the carbonate of lime. I have suggested already, in another place, that cold water will hold more lime in solution than warm will. I believe, however, that water will not hold the carbonate of lime in solution, — except, perhaps, in small quantities, when the water contains an excess of carbonic acid. Another explanation of the phenomenon has occurred to me, which is, that, when the ancient waters held a large quantity of lime in solution, and the atmosphere was also heavily charged with carbonic acid, the carbonic acid of the atmosphere would be absorbed by the water and unite with the lime, forming the insoluble carbonate of lime, which would of course be precipitated and constitute the limestones.

From this brief statement it appears that *granite* was formed by the cooling of melted lava; *gneiss*, sandstones, and clay, by the wearing away and rearranging of granite by water; and limestones and some others were deposited from solution in water.

Iron unites with oxygen to form an oxide which gives its peculiar color to all the rocks through which it is diffused; but we do not find this red color characterizing the *earliest* deposits from the ocean. Iron was, undoubtedly, thrown up as a consequence of the pressure produced by the primary stratified rocks. The formation called the old red sandstone was produced by the attrition of the sediment and the water upon the iron which had been thrown up from below the crust after the deposition of the primary strata of gneiss and the lower slates.

If the volcanic forces merely threw up the primitive crust of the earth and exposed it again and again to the action of the atmosphere and the water, there would be a limit to the absorbing power of the crust, and we might be allowed to indulge a hope that a mathematical calculation would demonstrate the impossibility of the whole ocean and atmosphere being ultimately absorbed; but when we know that the vast stores of metal below the crust are thirsting to drink up our ocean and atmosphere, digest all the gases, and assimilate them to earth, we must abandon such a hope, and look at the actual facts. "One half at least of the ponderable matter near the earth's surface is oxygen," which was once in the atmosphere; the granite and slate rocks are saturated with oxygen, and so is the iron which succeeded the earlier slates; the limestones, also, are composed principally of calcium, magnesium, carbon, and oxygen. When vegetation commenced on the earth, and the coal was formed, it drank millions of millions of tons of vapor, carbon, and oxygen from the atmosphere, and deposited it in the form of coal beds. Above this again rose new red sandstone, and chalk, and a great variety of minor rocks; but all robbed the atmosphere and the water to obtain ingredients with which to constitute themselves.

At the present time, the atmosphere weighs nearly fifteen pounds to the square inch; but it must once have been many times heavier, and it must now be continually growing lighter; for volcanoes are incessantly pouring forth lavas, and forcing up metals, which have a strong affinity for oxygen; vegetables are continually absorbing vast quantities of carbon, nitrogen, and oxygen; and animals, without conceivable number, are appropriating oxygen to produce their motions and sustain life. The gradually decreasing size of the products of vegetation in the known parts of the earth, since the carboniferous period, is evidence that its capabilities are not what they once were, and philosophy shows us no limit to this decrease until the present condition of the moon shall be reached by the earth, and ocean, air, and organic life shall all be compounded with the metals. The length of time that must transpire before these extreme results are produced will be vast, no doubt; but, logically or geologically, that makes no final difference. If it appears that the earth is continually absorbing more of the atmosphere than it restores, the time will come when there will be none left, and the analogy of the earth to the moon will be complete. If by any means all the metallic contents of the interior of the earth could be brought, in a subdivided state, into contact with the atmosphere and the ocean for only a single moment, the latter would both be entirely absorbed and amalgamated with the earth.

It is worthy of especial remark that the absence of red oxides from the very earliest deposits, and their abundance afterwards, not only proves that iron and the heavier metals had not yet been thrown to the surface in any great quantities, and that the lighter metals preceded them in composing the earth's crust, but it proves also that there could not have been any powerful volcanoes before the primary strata were deposited from the ocean; for, if there had been, iron would have been thrown up by them, and would have tinged the granite and gneiss, as it afterwards did the sandstone formations, below and above the coal measures. Before there were any mountains there could not have been much iron on the earth's surface, and the composition of the earliest rocks shows, in fact, that there was but little; but after the first convulsions and eruptions, we find iron and other metals increasing in quantity continually.

If circumstances were now to put the earth into a place where its whole surface would be melted, gravitation would at once restore all the substances on its surface to their original positions, as they were before the first strata were formed. The surface of the melted earth would be covered with the elements of the early rocks ; granite, gneiss, and sandstone would be formed upon the surface again, but iron, tin, lead, copper, and other heavy metals would be below the surface, and would remain there until pressure from above produced an eruption, which would force them up in veins. If, before such an eruption, the new granite were worn and broken up by the water, it would cause a deposit of strata composed only of the same chemical elements as those which constituted the granite, combined, perhaps, with some other substances, absorbed from the water ; but there would be no iron. Now, let an eruption ensue, and on the top of that primitive stratum there would be poured a mass of iron, the most abundant of the heavy metals, and one of the lightest of those which are beneath the granite crust, being, at the same time, remarkable for the deep color of its oxides. During the formation of the strata that followed the eruption of the iron, the oxide would be mingling its red and yellow dyes with the sand and marl which constituted the layers of strata. The iron below the crust is like the blood beneath the skin ; it never appears in large quantities, except in consequence of a wound of considerable depth.

It follows, from the foregoing, that metals should be most abundantly emitted in those places where dislocations of the earth's crust have been produced the most suddenly and the most deeply, and I believe that the appearances presented by mining regions agree with this idea. It must necessarily happen that, in some cases an immense load of detritus will collect upon a portion of the crust of the earth before it yields in any degree to its weight; but when it does give way, it produces a sudden downward movement on one side of the fissure, which is instantly followed by a corresponding reaction upward of the metallic fluid from below to the other side. This being so, it must be easy to determine on which side of the fissure the subsidence took place, and in what direction the metals may be found. A gradual pressure would be likely to crowd up only the melted lava which floats upon the surface; but a sudden, deep, and powerful fall of the ocean's bed might, by its reaction, throw up the heavier metals, which are below the lava.

In mines it is a general fact that the metallic veins run at right angles to the mountain range, or main axis of elevation; the reason of this has always been a mystery. Is not the explanation to be found in the fact that the lava and its metallic accompaniments are forced and powerfully pressed between the opposite sides of the mountain, and thus driven, in a melted state, into the crevices that run at right angles to the mountain? *

* As, after the deposit of the slates, violent dislocations happened and were succeeded by the *old red* conglomerate, so, after the deposit of the coal, similar and equally extensive interruptions of the planes and courses of strata were followed by the analogous deposit of lower red (*new red*) sandstone. — PHILIPS.

## SECTION IX.

### COMPARATIVE GEONOMY. ANALOGY OF THE EARTH TO MARS, VENUS, AND THE MOON.

In order more perfectly to conceive of the operation of geonomic principles, let us suppose that one of the planets, otherwise like this, had no equinoctial precession, nor change of seasons, the terrestrial equator, the thermal equator, and the ecliptic being identical. In such a planet, the northern and southern currents, and consequently the continents, would be nearly symmetrical. The forms of the continents and the directions of the ocean currents, the mountains, and the rivers, could all be predicted before the creation of such a world. Its condition at any given time being known, its future changes and its progress could be calculated with certainty. The positions of its latest volcanoes and the direction of its earthquakes being ascertained, it could be determined when and where the outbreak of a new volcano might be expected. Even in regard to our own planet, singular and presumptuous as it may seem, I am fully convinced that we now have the clew to the chain of facts and reasonings by which we shall be able to point with philosophical confidence to the course of future earthquakes and volcanoes, though with much less certainty than we could in the case we are supposing. In our hypothetical planet, the currents would tend to produce a series of continents which would be of an oval or elliptical form, with their long diameters to the north-east and south-west on the north side of the planet, and to the north-west and south-east on the south side. The mountains, rivers, slopes, the volcanoes, earthquakes, and even the clouds and the weather, would be nearly alike in each one of these continents; and all terrestrial phenomena would present one continuous round of tedious repetitions.

Let us now imagine another planet, so situated, if possible, that its ecliptic is constantly in the plane of the tropic of Cancer, or several degrees north of it. Of course we should have continual summer in the north and winter in the south; the currents would alternately flow from the north pole to about the thirtieth degree of south latitude and back again; the continents would all be formed in the northern hemisphere; for there would be no currents to form any in the south; nor would there be a mountain, a volcano, nor an earthquake in that forsaken hemisphere south of Capricorn. If any did exist, they would be placed, like Hecla and Erebus, as if to mark the proper bounds of the ocean currents in that direction.

Again, let us suppose, what is probably truê of Venus, that the axis of the earth, at its creation, was inclined seventy-five degrees, so that the tropical lines would be much farther apart, and very near the poles; of course, in that case, the currents from the north would extend farther over into the southern hemisphere than they do now; and the southern currents would reciprocate, by alternately extending almost to the north pole, and then, in the southern winter, being confined to the polar regions of the southern hemisphere. The consequence would be, that the mountains would be much higher in the tropics than they are now. The poles would each, alternately, at one season, be deeply covered with ice and snow, and broken up by frost, and then, at another season, overwhelmed with a flood of warm water and solar heat. The regions of the equator would be loaded with detritus from each pole in turn, and mountain ranges would consequently assume forms and directions, and rise to heights, now unknown on this earth.

Illustrations like these lead us to regard our oceans, mountains, and shore lines with new interest, as memorials of changes produced by regular and universal laws. The inequalities which form such an important feature in the face of mother earth may hereafter be considered, without fancy, as so many wrinkles which Time is continually deepening and extending to mark his inexorable progress towards the ultimate decay of terrestrial nature.*

If the mountains and valleys of the earth are formed by the movements of the liquids upon its surface, the same must be true of the moon and those planets the mountains of which can be seen by the telescope. As far as I have been able to examine the subject, the tel-

* "Amid these singular varieties one fact or feature seems so uniform, or, at least, so general, that the idea of its being a catholic or cosmical feature can hardly be evaded; I mean the presence of an UPHEAVING CAUSE, that grand energy which has elevated our ranges of mountains. In the moon, especially in Mercury, Mars, and Venus, elevations of imposing magnitude unquestionably exist.

"Assuredly enough is already known to demand the extension of our views regarding this wide-spread energy." — NICHOLS, *On the Solar System.*

escope appears to confirm the doctrines here advocated. One view of Mars, as depicted by Sir John Herschel, exhibits the outline of a continent which bears a striking resemblance to the western outline of Africa and Europe; that is to say, the land is pointed westward in the tropics, and recedes eastwardly towards both poles. This is the more strikingly analogous, from the fact that the inclination of the axis of Mars is nearly the same as that of the earth, being about twenty-eight degrees, that of the earth being twenty-three and a half degrees.

The mountains and valleys of the moon appear to be formed on an entirely different plan from those of the earth. They are numerous, short, circular, rugged, and precipitous. If I am correct in the reasoning by which I have concluded that the waters and atmosphere of the moon have been gradually absorbed by its metallic substances, and that the earth is undergoing the same process, the hypothesis agrees with the telescopic appearances of the moon's surface. Suppose that the earth had not possessed more than one eighth as much water and atmosphere as originally it did. Instead of having a few extensive oceans, bounded by long ranges of mountains, as we now have, we should have had a large number of separated lakes, like the Caspian, the Aral, and the Superior. These would have received all the detritus; and, while the crust of the earth was young and yielding, the bottoms of the lakes would have subsided, and carried down with them the remnants of the water and the atmosphere; and when they finally all dried up, they would have presented an appearance not very different from that now exhibited by the valleys and mountains of the moon. Even the islands in the lakes would be left standing in their midst, as they appear now to stand in the deep circular valleys of the moon. From this it appears that the absence of a perfect atmosphere and ocean from the moon, while, at the same time, it possesses mountains, instead of being an evidence of the insufficiency of the geonomic theory, is but an additional argument in its favor.

It should be considered as another reason for the peculiarities of the moon's surface, especially the shortness of her mountain ranges, that the inclination of her axis is but about five degrees, and that she is a whole month revolving upon her axis ; the consequence is, that her poles must be intensely cold at all times ; and her tropics alternately hot one month and cold the next. Besides, the face of the moon, which is towards us, never turns away, since she is just as long in revolving upon her axis as she is in going around the earth. The tidal influence of the earth upon the moon is computed to be more than twenty times greater than that of the moon upon the earth ; and this must have a peculiar effect upon that surface which is turned towards the earth. It is a complicated question what must have been the effect of the earth's attraction upon the waters of the moon when they did exist and were engaged in producing the mountains which remain to attest the former existence and power of those lunar oceans which have now ceased to circulate.

On the whole, the appearances of the moon's valleys and mountains are not more peculiar, abnormal, and at variance with those of the earth, than are the circumstances and conditions in which she is known to be placed. Besides these known conditions, it is reasonable to imagine that there are others which we cannot know, and may only conjecture. It is possible, for instance, that the surface of the moon may be covered, in part, by one or more fluids, entirely different from water, and more analogous to mercury, which could produce all the effects of an ocean, so far as the elevation of volcanic mountains is concerned, without necessarily being accompanied by any atmosphere like ours; but, while such conjectures may be indulged in as mere philosophical amusements, we have no *proper* mode of reasoning upon the subject except that afforded by terrestrial analogies.

If I am not mistaken, the outlines of the forms seen on the moon's surface are such as to indicate that the forces which produced them must have moved more nearly north and south than otherwise; for few of them have their long diameters east and west. This appears to be in accordance with the fact that the motion of the moon upon its axis, from west to east, is exceedingly slow, and but little calculated to communicate motions in that direction to the fluids on its surface; but the great difference in temperature between the poles and the equator is such as to promote a circulation in a northern and southern direction.

# CONCLUSION.

That the general reader may not suppose that this treatise is a mere theoretical speculation or hypothesis, originating in the fancy of the author, instead of consisting of deductions drawn from newly-discovered facts, I subjoin a statement of some of the *facts* which are independent of all theory, and which are now for the first time announced to the public.

1. It is a fact that all ocean currents, as far as we know, run in irregular ellipses, and that a natural law has always required them to do so.

2. That all large ocean currents run on the western coasts when proceeding towards the equator, and on the eastern coasts when returning towards either of the poles.

3. That the ocean currents run *alternately* towards the equator on the western sides of continents, and then from it on the eastern sides, as follows: towards the equator on the west of Europe and Africa, then from it on the east of the two Americas, then towards it on the west of the two Americas, and from it on the east of Asia and Australia, next towards it on the west of Australia, and from it on the east of Africa.

4. That all the mountain ranges which run east and west, are found in parts of the earth where ocean currents always run east and west, that is, near the tropics or near the arctic seas.

5. That all the mountain ranges in any part of the

earth, that run north and south, are in situations — that is, generally in places between the tropics and the arctic — where the ocean currents, if they run (or ever did run) there, must pursue nearly a north and south direction.

6. That the sizes, and directions, and forms of mountain curves and ranges in all parts of the world, are precisely what they would be if they were caused by the ocean currents that did once, or do now, run in the vicinity.

7. That the western sides of mountains generally bear evidence that the ocean currents once ran from the pole against them, and the eastern sides show that they have been washed by currents from the tropics.

8. That the abrupt slopes of mountains are towards the larger ocean.

9. That the principal ranges of mountains are nearly parallel with the paths of the ocean currents.

10. That instead of the ocean being shallower in those places where the most sediment is deposited, it is frequently deepest in those very places; yet the bottom of the ocean is not in the least abraded by the currents.

Besides the above newly-discovered facts, which go to sustain the geonomic theory, I believe that all other known facts accord with it.