ART. XXV.—*On the Plan of Development in the Geological History of North America*, with a map; by JAMES D. DANA.

ON other occasions, I have discussed at some length, the outline and surface features of the continents, the parallel courses of island groups, and the relations between the structure of the continental borders and the extent of the adjoining oceans; and I have endeavored in connection to elucidate the great principle of geological dynamics, which is at the basis of these characteristics of our globe.* I propose at this time to point out the relations between the operations of this principle or agency and the special geological history of the North American continent.

To render this application of the subject intelligible, it is necessary to review briefly the fundamental facts just alluded to. For this purpose, I would direct attention to a Mercator's Chart of the World, (see plate) on which the whole is open to examination—such a chart being a minature representation of the facts themselves, and the order observed among its parts, the syllables which spell out the principles.

In the first place, note the two great oceans, the Alantic and the Pacific—both widening south, and coalescing in a vast ring of ocean around the south pole, while narrowing north and uniting in a small arctic sea. The Indian Ocean is a third north and south ocean: but it reaches north only a little ways beyond the equator.

As the Atlantic is less than half the breadth of the Pacific, so the American continent is less than half the breadth of the great Orient, including Europe, Asia and Africa. It is seen also that while the North Atlantic treads off to the northeast, and the whole Atlantic is a zigzag channel with a main *northeast* course, the Pacific is a *northwest* channel, its longest diameter (represented by the line M M), being at right angles nearly with the trend of the Atlantic (N N). This longest diameter, moreover, corresponds with the general trend of the Pacific islands; for these islands have a nearly parallel course all through the ocean, the New Hebrides, Kingsmills, Samoan, Tahitian, Marquesas and Sandwich islands, lying in approximately parallel lines.†

* Am. Jour. Sci., [2], ii, 335, 352, iii, 94, 176, 381, iv, 88; Report, Geol. Expl. Exped., 756 pp. 4to., 1849, pp. 11, 414, 429; Proceedings Amer. Assoc. vol. ix, Providence Meeting, 1855, and page 305 of this volume.

† I may here add, what I have elsewhere explained at length, that the trends of the Pacific, while having a general correspondence of direction, pertain to two systems, one the Central Pacific, the other the Australasian. The Central Pacific begins in the Paumotu Archipelago, or rather still farther east, in Easter Island and Gomez; is thence continued on a west-northwest course, by the Society Islands, and the Hervey Islands more south; thence by the Samoan and Fakaafo groups; thence more northwesterly by the Vaitupu and Kingsmills, to the Radack and Ralick groups,

In the body of New Zealand, however, and some other parts, the transverse trend of Eastern America is represented.

Now what is the relation between the borders of the continents as to features and structure, and the extent of the oceans?

1. Look first to North America. Observe the general direction of the coast conforming to the prevalent trends of the globe, the northeast and northwest, and thus giving it its triangular form. See the low Appalachians facing the *small* Atlantic, the lofty Rocky Mountains, mostly a double line of heights, facing the *broad* Pacific, besides a second towering range, the Cascade and Sierra Nevada, nearer the sea. May we not say, *As the height of the Appalachians to the size of the Atlantic, so is the height or extent of the Rocky range to the size of the Pacific*?

In South America, there is the same relation—the low Brazilian mountains on the Atlantic side, the lofty Andes on the Pacific, and the latter exceeding the Rocky Mountains as much as the South Pacific exceeds the North Pacific; so that we may make another proportion, *As the height of the Rocky Mountains to the North Pacific, so is the height and boldness of the Andes to the South Pacific.*

In the Orient, the mountains towards the Atlantic, or those of Europe, are low and limited, compared with the long and lofty ranges of the Pacific side; and these last are inferior to the Himalayas, the sublimest heights of the world, which face the Indian ocean—a large and open ocean, while the Pacific towards Asia is much encumbered by islands.

In Africa, the loftiest and longest mountains are those of Abyssinia, on the east, facing the Indian Ocean, some of whose ridges are eleven to fourteen thousand feet in height, and one

which run nearly north-northwest; making thus a great sweeping curve, of several strands, over 6000 miles long. The Sandwich or Hawaian islands on the north side of the equator (2000 miles in whole length) is the opposite or northern side of the same system, slightly curving with the convexity to the north: while the Marquesas and the Fanning or Washington group lie along the axis of this great Central Pacific area. The other system is concentric around Australia, (New Holland). The line of new Hebrides, near northwest in course, is continued in the Salomon Islands, and New Ireland, becoming gradually east and west in the Admiralty Islands, north of New Guinea. The line of New Caledonia, another curving strand in the system, is continued in the Louisiade group and New Guinea, and becomes east and west in western New Guinea. The foot of the New Zealand boot, and the Coral Archipelago between New Caledonia and Australia accord with the system. The position of these lines concentric around Australia correspond with the idea that the position and extent of this continent, has had some influence in determining the directions.

These two systems, the Central Pacific and Australasian, though so distinct, are yet bound together in one. For while the great central range has its main course along the Kingsmills and Radack groups, it sends off at the Kingsmills, a western branch, the Carolines, which is actually parallel with the lines of the Australasian system.

The transverse trend of New Zealand, which is continued in the Friendly Islands north, is the correlate of the northwestern, the two having a mutual dependence, and together distinguishable in many groups of islands as well as in the features of the Continents.

peak near the equator is 20,000 feet. In Australia, the Australian Alps, as they are called, are on the east fronting the Pacific, here the wider of the bordering oceans.

Thus all over the world, the highest mountains stand fronting the largest and deepest oceans; and the "rule of three" statement of the fact scarcely conveys a wrong impression.

2. We observe further that the coasts are in general so turned as to face the widest range of ocean. The Appalachians with the neighboring coast do not face northeast towards the European continent, but southeast, towards the great opening of the Atlantic between America and Africa. So on the west side of North America the Pacific coast faces, not towards Asia, but southwest, where the broadest range of ocean is before it.

3. Consider now a little more closely the structure of these ocean borders. How is it as to the effects of heat or volcanic action?

In North America, on the side of the *small* ocean, the Atlantic, we find metamorphic rocks, some trap dykes, and a few tepid springs. On the side of the *great* ocean, the Pacific, all these phenomena occur, and besides, some of the grandest volcanoes of the globe, while basaltic floods have buried out of sight almost all other rocks over a considerable part of the country. Mount St. Helens, Mount Hood, Mount Shasta, and a dozen others, twelve to eighteen thousand feet high, make a majestic file of fire mountains not yet wholly extinct. May we not then say, *As the size of the Atlantic to the action of heat on the Atlantic border, so is the size of the Pacific to the action of heat on the Pacific border*?

In South America, there is a direct repetition of the same facts on a still grander scale: the Brazilian side, with metamorphic rocks and no volcanoes; the Pacific side, with volcanic heights of 20,000 feet and upward.

In the Orient, there are some small volcanic operations on the Atlantic side; but an unnumbered host down through Kamtschatka, Japan, and the islands south on the Pacific side.

In Africa, there are great volcanoes in the Red Sea and the lofty Abyssinian mountains, and only a few on the east, in the Gulf of Guinea, where, in fact, the continent opens on the Southern Ocean and not simply on the narrow Atlantic; the volcanoes are at the junction of the two lines, in or near the Bight of Biafra.

4. Again, these effects of heat are confined mostly to the region between the crest of the border mountains and the ocean, and are most intense towards the coast line. Thus the crystallization or metamorphism of Eastern North America, from Labrador to Georgia, is strongly marked towards the ocean, and diminishes going westward. So on the Pacific side: the great

volcanoes are not on the east or landward side of the crest, for there is not a volcano on that side, but on the seaward side, and not very far from the ocean. Thus we may almost say, *The nearer the water, the hotter the fire.*

5. Again, the mountains that make the borders, consist as is now well known since the surveys of the Professors Rogers, of rocks that have been pressed up out of place into a series of immense folds, like the folds we may make in paper by pressing laterally; only the rocky folds are many miles in range and of mountain height; and these folds or plications and displacements are most numerous towards the ocean, and are parallel nearly to the ocean. Hence again, *The nearer the water, the vaster the plications of the rocks.*

6. Over the interior of North America, there are not only no volcanoes, but there never have been any since the earlier Silurian, as shown by the absence of their remains among the strata; and this is so, notwithstanding the abundance of salt water over the regions in those ancient times. Over the interior of Asia there are no volcanoes, as is well known, except the three or four in the Thian-Chan Mountains. The great volcanic belt of the Orient stands out a short distance from the water-line of Asia, in the Japan range of islands, thus directly edging the oceanic basin; for the intervening region of shallow waters is properly a submerged part of the continent.

7. In contrast with this non-volcanic character of the interior of the continents, the islands of the oceans, it should be remembered, are all volcanic where not coral, and those of coral probably rest on a volcanic basis. Dhwalagiri, in the Himalayas, 28,000 feet high, is granitic; and surely we might have looked for some granitic peaks among the central islands of the oceans: but there are none.

At the same time, as others have remarked, the transverse seas which divide the Northern and Southern continents, the East Indies, the Mediteranean and West Indies, are characterized by volcanoes.

If then, the typical form of a continent is a trough or basin, the oceanic borders being raised into mountains; if these borders are so turned as to face the widest range of ocean; if the height of these border mountains and the extent of igneous action along them is directly proportioned to the size of the oceans,—the Pacific, accordingly, being girt with great volcanoes and lofty mountains, while the narrow Atlantic is bounded by smaller heights and but few volcanoes; if, moreover, volcanoes characterize the islands of mid-ocean and not the interior of the continents: What is the legitimate inference?

Most plainly, that the extent and positions of the oceanic depressions have some way determined, in a great degree, the fea-

tures of the land; that the same cause which originated the one, impressed peculiarities on the other; that the two had a parallel history through past time—the oceanic depressions tending downward, the continents upward; in other words, that they have both been in progress with mutual reaction from the beginning of the earth's refrigeration. The continents have always been the more elevated land of the crust, and the oceanic basins always basins, or the more depressed land.

We thence learn that the profounder features of the earth were marked out in the earliest beginnings of geological history, and that the whole subsequent progress has been a working on this basis. Other and more direct evidence of this fact I alluded to in my address before this Association last year—evidence derived from the extent and nature of the Potsdam sandstone, the earliest of the Silurian strata, showing that this primal rock was laid down over a large part of North America by a sea which just bathed its surface—thus proving that the continent was already made, and indicating in part its water level.

The relation between the extent of the oceans and the border features of the continents, which has been pointed out, is not simply a relation of fact, but of effect and dynamics, pointing to a unity of cause. The one cause is assuredly not in the waters of the oceans, for these are inert: they cannot bake rocks, light up volcanoes, fold the heavy strata, and make mountains. The cause is no paroxysmal force, exhausted in a temporary freak of nature. It is some profound, systematic, untiring force, which in its slow movement, has counted centuries as if seconds. The Appalachian range is one mark of its power; but not the result of a fitful heave: on the contrary, a work of time, and time so long, that the resisting strata could bend in many plications without being reduced to chaos; so long, that New England and regions south, which entered the period of catastrophe as a territory of sedimentary beds, came forth at last a region of granite, gneiss and crystalline schists. Most of the mountains of the globe, for the reasons stated, we must regard as other effects of this fundamental cause; and it is therefore no matter of surprise that they should have in general a common system of structure.

A unity of cause there must be for the great phenomena of geology. Such is nature in all her departments. Details are the means by which we penetrate to the deep-seated cause; and when that cause is once reached and fully apprehended, the details have new interest from the harmonious relations thus developed,—as the leaves and twigs of a tree derive their grandeur and the most of their beauty from the rising trunk and spreading branches to which they are subordinate, and with which they are in perfect harmony.

What then is the principle of development through which these grand results in the earth's structure and features have been

brought about? We detect a plan of progress in the developing germ; we trace out the spot which is first defined, and thence follow the evolution in different lines to the completed result: may we similarly search out the philosophy of the earth's progress?

The organizing agencies in the sphere are—

1. Chemical combination and crystallization.

2. Heat, in vaporization, fusion, and expansion, with the correlate force of contraction which has been in increasing action from the time the globe began to be a cooling globe.

3. The external physical agencies, preëminently water and the atmosphere, chiseling and moulding the surface.

4. The superadded agency of life.

Of these causes, the first is the molecular power by which the material of the crust has been prepared. The third and fourth have only worked over the exposed surface. But the second, while molecular in origin, is mechanical in action, and in the way of contraction, especially, it has engaged the universal sphere, causing a shrinkage of its vast sides, a heaving and sinking in world-wide movements. Its action therefore, has been coextensive with the earth's surface throughout the earth's history. If a power at all, it has been a dominant power in the great changes, and in connection with the profound structure of the crust received through consolidation, it has wrought out the earth's lineaments, varying them with her years from the first featureless sphere to the bold expressiveness and wrinkles of age. This is the cause that most concerns us at this time.

There must be system in the intimate structure of the crust. For if it was once fluid, and is now one or two scores of miles thick, all this thickness beyond that of the first film has been produced through gradual, exceedingly gradual and prolonged cooling, adding, by downward increase, to the solid surface arch: and if ice over a pond when thickening in this same way by additions downward to the surface film takes a crystalline texture perpendicular to this film, as has been proved, we may safely infer that the crystallization of the earth's crust as it slowly thickened would have taken a regular structure, and the more surely since we know that the mineral feldspar, which gives a cleavage structure to granite, is the prevailing mineral in all igneous rocks. Thus we approach some explanation of the prevalence of two great systems of trends in the features of the globe. But this subject we pass by, to the one which more immediately concerns us—the surface features of the continents.

The contraction to which I have alluded, going on after a crust was formed over the earth, would necessarily fracture, displace, or wrinkle the crust, as the same cause, contraction, wrinkles a drying apple. The large rind is more than sufficient for the contracted sphere; and the drawing downward of some parts

must cause the bulging of others. If any large areas of the crust were sinking more than the rest, this very subsidence would necessarily push up the borders of these areas into angular elevations or folds; and it follows necessarily,—the larger these areas the higher the border elevations.

These are the simple principles. The oceanic basins are these areas of greatest subsidence; and hence would necessarily flow the law, already established as a matter of fact—the larger the ocean, the higher the mountains on its borders, the deeper the fractures and displacements there, and the vaster the outflow of internal heat and lavas. The size, therefore, of the oceans, that is, their extent and depth, is relatively a measure of the force exerted on their sides.

The wrinkles or elevations on the globe seem large when man measures them by comparison with his own stature. But a section of the land, true to nature, corrects this misapprehension. In a section of the North American continent, drawn to a scale twelve feet long, one-ninth of an inch will stand for an altitude of 10,000 feet; one-sixteenth of an inch for the White Mountains, and about three-tenths for the Himalayas.

After this review of principles, let us now turn our attention to North America and seek out its plan of development.

I. The triangular form of the continent has been noted and its simple ocean boundary: and it should be observed that the continent is set quite to the west of South America, so as to possess this simplicity of boundary and therefore of moulding forces in its highest perfection.* The small Atlantic on one side, and the great Pacific on the other, indicate approximately the relative amounts of force from the two directions, the southeast and southwest, during the progressive ages of the history;—that to the eastward the power was comparatively moderate, gently folding up the Appalachians, and to the westward it was strong and mighty, even to the raising of the Rocky range and opening the great volcanoes of Oregon. We thus learn, with a degree of precision not to have been anticipated, the direction and efficiency of the great organizing forces.

Glance now at American geological history from this point of view, and consider where was the first germinant spot of the growing continent, and what was thence onward the course of development under the influence of this agency.

The earliest spot or primal area will be that of the Azoic rocks, the first in the geological series. Such an area (see Chart, A A A) extends from Northern New York and Canada, north-west to the Arctic Ocean, lying between the line of small lakes (Slave, Winnipeg, &c.) and Hudson Bay. East and west, it dips under

* The contrast with Europe in this respect is striking, and accounts, as I have said, (Address, &c., p. 311,) for the greater simplicity of North American Geology.

Silurian strata (S S;) but it is itself free from superincumbent beds, and therefore, even in the Silurian age, it must have been above the ocean. And ever since, although subject, like the rest of the world, to great oscillations, it has apparently held its place with wonderful stability, for it is now, as probably then, not far above the ocean's level.

This area is central to the continent; and, what is of prominent interest, it lies parallel to the Rocky Mountains and the Pacific border, thus proving that the greater force came from that direction in Azoic times, as well as when the Rocky Mountains were raised. Thus this first land, the germ or nucleus of the future continent, bears in itself evidence with respect to the direction and strength of the forces at work. The force coming from the Atlantic direction has left comparatively small traces of its action at that time. Yet it has made its mark in the Azoic stretching through Canada to Labrador, in the dip and strike of the New York Azoic rocks, in the direction of the channel of the St. Lawrence and the northwest coast of Lake Superior, and probably also in the triangular form of Hudson's Bay. Against this primal area, as a stand-point, the uplifting agency operated, acting from the two directions, the Atlantic and the Pacific; and the evolution of the continent took place through the consequent vibrations of the crust, and the additions to this area thereby resulting; the ocean in the meantime pursuing its appointed functions in the plan of development, by wearing exposed rocks and strewing the shores and submerged surface with sand, gravel or clay, or else growing shells, corals and crinoids, and thus storing up the material of strata and burying the life of successive epochs.

These long secular vibrations, movements by the age rather than day, dipping the surface and raising it again in many and varying successions, were absolutely essential to the progress. Had the continent been stable, there could have been no history, no recorded events of changing life and alternating deposits: all would have been only a blank past. These forces, therefore, working mainly from the southeast and southwest, were actually organizing forces, essential to the completion of the continent,—to the production of its alternations of limestones, shales, sandstones and conglomerates, and its sweeping catastrophes burying the old preparatory for higher forms of life:—the continent in the course of these movements, being at one time, it may be, just beneath the ocean's surface, and having beds of sand and gravel accumulating under the action of the waves; then in somewhat deeper and clearer waters, with limestones forming from coral or crinoidal plantations or the growth of shells; then, perhaps, rising from the waves, bringing death upon its sea tribes in one universal desolation; then, sinking slowly in the waters

again, and varying in its accumulations from sandstones to shales, pebble beds or limestones, with the depth and the currents; and then again above the tides, although destruction to all the life of the ocean was in the movement; and, perchance, lying in the open air for an era, to receive the mists and rains and sunshine, and become luxuriant through new creations with broader prairies than now cover the West. Alternations like these were again and again repeated, as geology has shown.

Through these means, the continent, which was begun at the far North, a region then tropical but afterwards to become inhospitable, gradually expanded southward, area after area as time moved on being added to the dry land.

First, as the facts show, the Silurian deposits of Canada and the North, adjoining the Azoic, were left above the sea, for these rocks there are not overlaid by later beds; and, therefore, were not the sea-bottom of later seas. Next, the adjacent Devonian were added to the main land as far south as Southern New York and around by the west; for, as the New York geologists have shown, the carboniferous beds which come next do not reach into that State. By the time of the Jurassic period, the continent had expanded much farther to the southward, for the carboniferous rocks over the land were out of water, their beds having already been folded up and elevated in the Appalachians. The red sandstone of the Connecticut Valley and of the Atlantic States from New York to Alabama leave little doubt as to the water line of that era. In the Cretaceous period the continent had farther expanded along the Atlantic; but in the Mississippi Valley the Mexican Gulf still extended north even to the head waters of the Missouri. Next, as the Tertiary opened, the continent had yet more widely enlarged its bounds, south and southeast; and if the waters of the Mexican Gulf for a while claimed a place over some part of the Nebraska plains, as late observations suggest, by the close of the period the continent in this direction had nearly reached its full maturity. These steps of progress are indelibly marked in the position, and obvious seacoast, off-shore or estuary origin of the Jurassic, Cretaceous and Tertiary beds of the country.

Passing towards the Pacific, we find evidence in the carboniferous limestone that the Rocky Mountains were mostly under shallow water as the Carboniferous age opened, the mountains themselves unborn. Later in the Cretaceous and Tertiary periods, as the rocks towards the coast testify, the continent had extended far to the southwest, and was nearly complete in that direction, as well as to the south and southeast.

Thus the enlargement went on to the southward, each period making some addition to the main land, as each year gives a layer of wood to the tree. Not that this addition was free from

oscillations, causing submergences, for these continued long to occur; but the gain, on the whole, was a gain—a progress; and the moving ages made the accession a sure and permanent gain as the continent became more stable.

II. But in the statement that the growth of the continent was to the south, southeast, and southwest, we assert only the most general truth respecting it. The continent has its special features as much as any being of organic growth, and the elimination of these features is to be traced to the same system of forces. The Appalachian range on the east, the Rocky Mountains and the subordinate chains on the west, the lower lands and lakes of the interior, all in systematic relation, are the more marked of these features; and the vast river systems, with the broad alluvial flats and terraced plains, the wide spread drift, the denuded heights and channeled slopes and lowlands, are subordinate peculiarities of the face of the continent.

The Appalachian range of heights, as I explained a year since, was commenced in the Silurian age, and even earlier long before a trace of the mountains had appeared.* The force from the southeast, in the dawn of the Palæozoic era, had made the Appalachian region generally shallower than the Mississippi valley beyond. The vast sandstone and shale deposits of the region bear marks in many parts of sea-shore action, while the limestones which were forming cotemporaneously farther west, indicate clearer and somewhat deeper seas; and the patch of Azoic in northern New York, lying at the northern extremity of part of the range, points to an anterior stage in the same course of history; so that, in early time, long before there were mountains, the future of the continent, its low centre and high borders, was foreshadowed. We can hardly doubt that the region of the Rocky Mountains was in the same condition, in the main, with that of the Appalachians. Moreover, these borders, or at least the eastern, for ages anterior to the making of the mountains, were subject to vastly greater oscillations than the interior; for the Silurian and Devonian sandstones that occur along from New York to Alabama are of great thickness, being five times as thick as the limestones and associated deposits of the same age to the west. A limestone bed, moreover, is of itself evidence of comparatively little oscillation of level during its progress.

We hence learn that in the evolution of the continental germ, after the appearance of the Azoic nucleus, there were two prominent lines of development; one along the Appalachian region, the other along the Rocky Mountain region—one, therefore, parallel with either ocean. Landward, beyond each of these developing areas, there was a great trough or channel of deeper ocean waters, separating either from the Azoic area.

* Address &c.—See this volume, page 319.

The Azoic, as has been indicated, has something of a V shape, (or \/), with Hudson Bay between its arms. This succeeding step of progress is the partial development of a larger V outside of and parallel to the Azoic nucleus. The channels alluded to lie between the two V's. The bar of the outer V on the left is of great breadth and made up of several broad parallel bands or ranges of elevations; that on the right is quite narrow comparatively, yet also etched in several parallel lines.

The Mexican Gulf is all that remains of the larger of these channels. Its waters once stretched to the Arctic Sea, and were in early time but the deeper part of the continental ocean. Later, as the ages moved on, there was land to the north, and a line of freshwater lakes along its former course; and the Gulf reached no higher than the headwaters of the Missouri. Later still, and its limits became more contracted, till now the full-grown continent has but her foot in the salt water.

The Gulf of St. Lawrence marks the outlet of the other channel, and the River St. Lawrence its course. The great lakes, as well as the smaller lakes north, lie near the limits of the Azoic nucleus within these ancient troughs or depressions; and the largest lake, Lake Superior, is at the junction of the two lines.

Such was the law of growth. The molecular forces *beneath* the continent, from the progressive cooling there going on, were not idle, and must have modified the results. But the main action causing the lifting and sinking of the crust and the final gain to the land, proceeded from the directions of the oceans. The inequality in the forces from the two directions, as well as in the form and depth of each oceanic or subsiding area whence the forces mainly came, would necessarily have produced many irregularities in the results, as I have remarked in another place,* and will not now dwell upon.

The Pacific region has always been true to its own grandeur. The force from that direction not only made the Rocky Mountains to rise and a file of lofty volcanoes to light up its waters, (while the most the gentler Atlantic could accomplish was a bending up of the strata into Appalachians, and a baking of some of the beds,) but it also added tenfold the most dry land to the continent; and even after the tertiary rocks were deposited, it elevated the continental border at least two or three thousand feet—ten times beyond what happened on the Atlantic side.†

* Amer. Jour. Sci. [2], vol. iii.

† Whatever doubts may exist as to the cause, there can be none as to the actuality of the force on the two sides, the Atlantic and the Pacific. The elevation of the mountains on each border is proof beyond question; and their relative extent and height is evidence indubitable as to the relative amounts of force exerted. The parallel *folds* on the Atlantic side show that there it *was actually lateral* force from the southeast; and the several parallel ranges on the Pacific side, parallel to the

But look further, and consider that the great lines of elevation on the Pacific side are parallel nearly to the islands of the ocean; that these islands are like a long train stretching off from Asia to the east-southeast; that New Hebrides, New Caledonia in the southwest, with the foot of the New Zealand boot and northwestern Australia, conform to the general parallelism; and it will then be comprehended that we have been considering not simply a continental system of progress, but one involving the whole globe. It appears also from the history of the coral islands of the Pacific, that while the Tertiary and Post-tertiary elevations were going forward on the Pacific border of North America, a slow and gradual subsidence was in progress over a parallel region across the middle of the ocean. The axis line of the Pacific is not only the main trend of its lands, but is also nearly the course of the great subsidence which is indicated by the history of the coral islands.*

III. I have said that these two systems of forces—the southeast and southwest—continued to act through the Tertiary period, working out the continent, and bringing it nearly to its adult extent. At the meeting of this Association at Providence I pointed out the fact that at the close of the Tertiary there was a change in the movement; that during the following period, the Post-tertiary, there were high-latitude oscillations; and I endeavored to show, that there was first an elevation of the continent over the north for the first or glacial epoch; then a subsidence (as shown by the seashore deposits on Lake Champlain, and the highest terrace of the lakes and rivers) during a second or Laurentian epoch; and finally, an elevation to its present height, for the third or Terrace epoch. Whether the elevation for the Drift epoch be admitted or not, all agree that the oscillation attending it was a northern phenomenon. These several changes thus affected mainly the latitudes north of the middle of the temperate zone, or were but slightly felt to the south of this. It is a remarkable fact that the coasts of the Arctic regions, which have now been rather widely explored, have not presented any Jurassic, Cretaceous or Tertiary deposits, and there is, therefore, no evidence of their

ocean, are proofs of similar lateral action there, but from the southwest. Then the dominance of these two trends in the uplifts over the whole continent in its oldest and newest regions and rocks, are like the warp and woof of a fabric, determined by the organizing forces themselves of the structure.

* Amer. Jour. Sci. vol. xlv, (1843) 131, and [2], iii, 396, (1847).

One consequence of these facts and principles may be here alluded to.—If the position of the Atlantic and Pacific has determined the main directions of the organizing forces through all time, and if, owing to the direction, as the facts show, elevations having the *same* strike or trend have been formed in successive geological ages, it is evident that the elevation theory of mountains, sustained by Elie de Beaumont, must be received with much hesitation. One dial-plate for the world, such as he has deduced mainly from European geology, is a splendid hypothesis; but it may not mark time for America or the other continents.

having been in those eras under water. Such beds may hereafter be detected; but the great fact will still remain, that they are there of limited extent, if not wholly absent. As far as known, there is no Tertiary on the coasts north of Cape Cod. All development or growth there seems to have ceased, or nearly so, with the Palæozoic era or the close of the Carboniferous age. But there are Post-tertiary deposits in the Arctic regions in many places, situated hundreds of feet above the sea, containing shells of existing Arctic species. This alone, independent of other evidence, would prove a change in the conditions of geological progress after the Tertiary period. The necessary inference is, then, that as long as the southwest and southeast forces were in active play, and the extremities of the continent were thereby in process of growth, there was little change going on in the far north. But when the continent was nearly finished, its extremities grown, and the stability consequent upon adult age acquired, then, through a series of oscillations, a course of development was carried on in the more northern regions, giving a final completion to the continent—an action, which, as I have elsewhere explained, involved the higher latitudes about the whole sphere, north and south of the equator.*

We shall understand more definitely the relations of the later to the older oscillations, if we consider that all were due to one grand cause, influencing the whole extent of the continent even to the Arctic ocean; that the force from the north, the southeast, and the southwest, according to the principle explained, was proportioned approximately to the sizes of the oceans, the Arctic, the Atlantic and the Pacific; that the greater forces from the southeast and southwest acted against that from the north, and through their superior strength or the concurrent greater flexibility of the crust, kept up those vibrations in the progress of which the border mountains were made; but at last, the southeast and southwest action almost ceasing through the stiffening and uplifting of the crust, then the northern force, having a stable fulcrum, made itself felt in the long and slow oscillations of the Post-tertiary. Under this mode of view it will be seen that all was part of one system of development.

If we rightly apprehend the results of the Post-tertiary period, we shall perceive that there was vast importance in these finishing operations over the sphere:—that during its progressing centuries, the great phenomena of the drift took place, covering hills and plains with earth; that the valleys for our rivers were then either made or vastly enlarged; that immense alluvial plains were spread out in terraces over the interior and in flats along the shores; that thus a large part of the brighter fea-

* Address, etc., this volume, p. 327.

tures of the globe were educed. The mountains of the earth at last stood at their full altitude, having gained some thousands of feet since the Tertiary; and rivers, true offspring of the mountains, taking their size from the size of the mountain ranges, were sent on renovating missions over the breadth of the continents. Indeed, the upper terraces of the rivers show that during the Post-tertiary, these interior waters had an extent and power vastly beyond what the streams now exhibit;—an extent which is yet unexplained, unless attributable, as I have suggested, to the declining snows of a glacier epoch. In their strength, they deeply channeled the hills, and wrought out much of the existing sublimity of mountain architecture. There was the elimination of beauty and of immediate utility in every stroke of those later waters, in striking contrast with the earlier operations of rock-making and mountain-lifting; for those very conditions, those special surface details, were developed, that were most essential to the pastoral and agricultural pursuits with which man was to commence his own development, while that grandeur was impressed on the earth that should tend to raise his soul above its surface.

This transfer of the process of development from the extremities to the more northern regions, thence evolving these new and more refined qualities of inorganic nature and humanizing the earth, has a parallel in organic growth; for the extremities are finished and adult size attained before the head and inner being are fully perfected. The analogy is fanciful; yet it is too obvious a parallelism to be left unsaid on that account.*

* I have alluded on a former page to an analogy between the progress of the earth and that of a germ. In this, there is nothing fanciful; for there is a general law, as is now known, at the basis of all development, which is strikingly exhibited even in the earth's physical progress. The law, as it has been recognized, is simply this :—Unity evolving multiplicity of parts through successive individualizations proceeding from the more fundamental onward.

The earth in igneous fusion, had no more distinction of parts than a germ. Afterwards, the continents, while still beneath the waters, began to take shape. Then, as the seas deepened, the first dry land appeared, low, barren, and lifeless. Under slow intestine movements and the concurrent action of the enveloping waters, the dry land expanded, strata formed, and as these processes went on, mountains by degrees rose, each in its appointed place. Finally in the last stage of the development, the Alps and Pyrenees and other heights received their majestic dimensions and the continents were finished out to their very borders.

Again, as to the history of fresh waters.—The first waters were all salt, and the oceans one, the waters sweeping around the sphere in an almost unbroken tide. Fresh waters left their mark only in a rain-drop impression. Then the rising lands commenced to mark out the great seas, and the incipient continents were at times spread with fresh-water marshes into which rills were flowing from the slopes around. As the mountains enlarged, the rills changed to rivers, till at last the rivers also were of majestic extent, and the continents were throughout active with the busy streams, at work channeling mountains, spreading out plains, opening lines of communication, and distributing good every where.

Again, the first climates were all tropical. But when mountains and streams were attaining their growth, a diversity of climate, (essential to the full strength of

Thus, then, the continent was completed. Contraction was the power, under Divine direction, which led to the oscillations of the crust, the varied successions in the strata, and the exuviations of the earth's life, era after era. Acting from the Atlantic and Pacific directions, it caused the southern prolongation of the growing land from the icy North to the tropics, while it raised mountains on the borders, and helped to spread the interior with plains, varied slopes, and lakes. And, finally, through its action over the north, the surface received its last touches, fitting it for a new age—the Age of Mind.

ART. XXVI.—*Re-determination of the Atomic Weight of Lithium;* by J. W. MALLET, Ph.D.; Professor of Chemistry, Univ. of Alabama.

LITHIUM is one of the elements whose atomic weight has been several times made the subject of investigation by different chemists, and yet on examining the results of their labors we find that but one or two experiments free from serious objection are recorded, from which the received equivalent number of the metal has been calculated; and even in these experiments the method pursued has not, I believe, been such as to ensure the closest approximation to the truth. Yet the formulæ of the salts of lithia, and of minerals containing this alkali, would be seriously affected by any considerable error as regards the equivalent number assumed, since this is one of the very lowest to be found in the whole list of elements—the lowest among the metals, with the single exception of glucinum. The fact that Lithium does possess so small an atomic weight—a fact which is said to have led to the discovery of the metal by Arfwedson—is in itself very remarkable when we remember the much higher numbers by which the other alkaline metals, potassium and sodium, are represented; and it gives additional interest to accurate experiments made for the purpose of fixing the number with precision.

The following historical notice of what has been already done in this direction I have taken from a valuable little work by

the latter,) was gradually evolved, until winter had settled about the poles as well as the earth's loftier summits, leaving only a limited zone,—and that with many variations,—to perpetual summer.

The organic history of the earth, from its primal simplicity to the final diversity, is well known to exemplify in many ways the same great principle.

Thus the Earth's features and functions were successively individualized:—first, the more fundamental qualities being evolved, and finally those myriad details in which its special characteristics, its magnificent perfection, and its great purpose of existence and fitness for duty, largely consist.