CHAPTER XII.

Effects produced by the powers of vitality on the state of the earth's surface—Modifications in physical geography caused by organic beings on dry land inferior to those caused in the subaqueous regions—Why the vegetable soil does not augment in thickness—Organic matter drifted annually to the sea, and buried in subaqueous strata—Loss of nourishment from this source, how supplied—The theory, that vegetation is an antagonist power counterbalancing the degradation caused by running water, untenable—That the igneous causes are the true antagonist powers, and not the action of animal and vegetable life—Conservative influence of vegetation—Its bearing on the theory of the formation of valleys, and on the age of the cones of certain extinct volcanos—Rain diminished by the felling of forests—Distribution of the American forests dependent on the direction of the predominant winds—Influence of man in modifying the physical geography of the globe.

THE second branch of our inquiry, respecting the changes of the organic world, relates to the effects produced by the powers of vitality on the state of the earth's surface, and on the material constituents of its crust.

By the effects produced on the surface, we mean those modifications in physical geography of which the existence of organic beings is the direct cause,—as when the growth of certain plants covers the slope of a mountain with peat, or converts a swamp into dry land; or when vegetation prevents the soil, in certain localities, from being washed away by running water.

By the agency of the powers of vitality on the material constituents of the earth's crust, we mean those permanent modifications in the composition and structure of new strata, which result from the imbedding therein of animal and vegetable remains. In this case, organic beings may not give rise immediately to any new features in the physical geography of certain tracts, which would not equally have resulted from the mere operation of inorganic causes; as, for example, if a lake be filling up with sediment, held in suspension by the waters

of some river, and with mineral matter precipitated from the waters of springs, the character of the deposits may be modified by aquatic animals and plants, which may convert the earthy particles into shell, peat, and other substances: but the lake may, nevertheless, be filled up in the same time, and the new strata may be deposited in nearly the same order as would have prevailed if its waters had never been peopled by living beings.

In treating of the first division of our subject we may remark, that when we talk of alterations in physical geography, we are apt to think too exclusively of that part of the earth's surface which has emerged from beneath the waters, and with which alone, as terrestrial beings, we are familiar. Here the direct power of animals and plants to cause any important variations is, of necessity, very limited, except in checking the progress of that decay of which the land is the chief theatre. But if we extend our views, and instead of contemplating the dry land we consider that larger portion which is assigned to the aquatic tribes, we discover the immediate influence of the living creation, in imparting varieties of conformation to the solid exterior which the sole agency of inanimate causes would not produce, to be very great.

Thus, when timber is floated into the sea, it is often drifted to vast distances and subsides in spots where there might have been no deposit, at that time and place, if the earth had not been tenanted by living beings. If, therefore, in the course of ages, a hill of wood, or lignite, be thus formed in the subaqueous regions, a change in the submarine geography may be said to have resulted from the action of organic powers. So in regard to the growth of coral reefs: it is probable that almost all the matter of which they are composed is supplied by mineral springs, which we know often rise up at the bottom of the sea, and which, on land, abound throughout volcanic regions thousands of miles in extent. The matter thus constantly given out could not go on accumulating for ever in the waters, but would be precipitated in the abysses of the sea, even if there were no polyps and testacea; but these animals arrest

and secrete the carbonate of lime on the summits of submarine mountains, and form reefs many hundred feet in thickness, and hundreds of leagues in length, where, but for them, none might ever have existed.

If no such voluminous masses are formed on the land, it is not from the want of solid matter in the structure of terrestrial animals and plants, but merely because, as we have so often stated, the continents are those parts of the globe where accessions of matter can scarcely ever take place,—where, on the contrary, the most solid parts already formed are, each in their turn, exposed to gradual degradation. The quantity of timber and vegetable matter which grows in a tropical forest in the course of a century is enormous, and multitudes of animal skeletons are scattered there in the same period, besides innumerable land-shells and other organic substances. The aggregate of these materials might constitute, perhaps, a mass greater in volume than that which is produced in any coral-reef during the same lapse of years; but, although this process should continue on the land for ever, no mountains of wood or bone would be seen stretching far and wide over the country, or pushing out bold promontories into the sea.

The whole solid mass is either devoured by animals, or decomposes, as does a portion of the rock and soil on which the animals and plants are supported. For the decomposition of the strata themselves, especially of their alkaline ingredients and of the organic remains which they so frequently include, is one source from whence running water and the atmosphere may derive the materials which are absorbed by the roots and leaves of plants. Another source is the passage into a gaseous form of even the hardest parts of animals and plants which die and are exposed to putrefy in the air, where they are soon resolved into the elements of which they are composed; and while a portion of these parts is volatilized, the rest is taken up by rain-water and sinks into the earth or flows towards the sea, so that they enter again and again into the composition of different organic beings.

The principal elements found in plants are hydrogen, carbon, and oxygen, so that water and the atmosphere contain all of them, either in their own composition or in solution *. The constant supply of these elements is maintained not only by the putrefaction of animal and vegetable substances, and the decay of rocks before mentioned, but also by the copious evolution of carbonic acid and other gases from volcanos and mineral springs, and by the effects of ordinary evaporation, whereby aqueous vapours are made to rise from the ocean and to circulate round the globe.

It is well known that when two gases of different specific gravity are brought into contact, even though the heavier be the lowermost, they become uniformly diffused by mutual absorption through the whole space which they occupy. By virtue of this law, the heavy carbonic acid finds its way upwards through the lighter air, and conveys nourishment to the lichen which covers the mountain top.

The fact, therefore, that the vegetable mould which covers the earth's surface does not decrease in thickness, will not altogether bear out the argument which was founded upon it by Playfair. This vegetable soil, he observes, consists partly of loose earthy materials easily removed, in the form of sand and gravel, partly of finer particles suspended in the waters, which tinge those of some rivers continually, and those of all occasionally, when they are flooded. The soil, although continually diminished from this cause, "remains the same in quantity, or at least nearly the same, and must have done so ever since the earth was the receptacle of animal or vegetable life. The soil, therefore, is augmented from other causes, just as much, at an average, as it is diminished by that now mentioned; and this augmentation evidently can proceed from nothing but the constant and slow disintegration of the rocks †."

* See some good remarks on the Formation of Soils, Bakewell's Geology, chap. xviii.

† Illust. of Hutt. Theory, § 103.

That the repair of the *earthy* portion of the soil can only proceed, as Playfair suggests, from the decomposition of rocks, may be admitted; but the *vegetable* matter may be supplied, and is actually furnished in a great degree, by absorption from the atmosphere, as we before mentioned, so that in level situations, such as in platforms that intervene between valleys where the action of running water is very trifling, the fine vegetable particles carried off by the rain may be perpetually restored, not by the waste of the rock below, but from the air above.

If we supposed the quantity of food consumed by terrestrial animals, together with the matter absorbed by them in breathing, and the elements imbibed by the roots and leaves of plants, to be derived entirely from that supply of hydrogen, carbon, oxygen, azote, and other elements, given out into the atmosphere and the waters by the putrescence of organic substances, then we might imagine that the vegetable mould would, after a series of years, neither gain nor lose a single particle by the action of organic beings. This conclusion is not far from the truth; but the operation which renovates the vegetable and animal mould is by no means so simple as that here supposed. Thousands of carcasses of terrestrial animals are floated down every century into the sea, and, together with forests of drift-timber, are imbedded in subaqueous deposits, where their elements are imprisoned in solid strata, and may there remain throughout whole geological epochs before they again become subservient to the purposes of life.

On the other hand, fresh supplies are derived by the atmosphere, and by running water, as we before stated, from the disintegration of rocks and their organic contents, and from the interior of the earth, from whence all the elements beforementioned, which enter principally into the composition of animals and vegetables, are continually evolved. Even nitrogen has been recently found to be contained very generally in the waters of mineral springs *.

* Dr. Daubeny has ascertained this interesting fact in his late tour on the continent.

If we suppose that the copious discharge from the nether regions, by springs and volcanic vents, of carbonic acid and other gases, together with the decomposition of rocks, may be just sufficient to counterbalance that loss of matter which, having already served for the nourishment of animals and plants, is annually carried down in organized forms, and buried in subaqueous strata, we believe that we concede the utmost that is consistent with probability. When more is required by a theorist—when we are told that a counterpoise is derived from the same source to that enormous disintegration of solid rock and its transportation to lower levels, which is the annual result of the action of rivers and marine currents, we must entirely withhold our assent. Such an opinion has been recently advanced by an eminent geologist, or we should have deemed it unnecessary to dwell on propositions which appear to us so clear and obvious.

The descriptions which we gave of the degradation yearly going on through the eastern shores of England, and of the enormous weight of solid matter hourly rolled down by the Ganges or the Mississippi, have been represented as extreme cases, calculated to give a partial view of the changes now in progress, especially as we omitted, it is said, to point out the silent but universal action of a great antagonist power, whereby the destructive operations before alluded to are neutralized, and even, in a great degree, counterbalanced.

"Are there," says Professor Sedgwick, "no *antagonist* powers in nature to oppose these mighty ravages—no conservative principle to meet this vast destructive agency? The forces of degradation very often of themselves produce their own limitation. The mountain-torrent may tear up the solid rock and bear its fragments to the plain below; but there its power is at an end, and the rolled fragments are left behind to a new action of material elements. And what is true of a single rock, is true of a mountain-chain; and vast regions on the surface of the earth, now only the monuments of spoliation and waste, may hereafter rest secure under the defence of a

thick vegetable covering, and become a new scene of life and animation.

"It well deserves remark that the destructive powers of nature act only upon lines, while some of the grand principles of conservation act upon the whole surface of the land. By the processes of vegetable life an incalculable mass of solid matter is absorbed, year after year, from the elastic and non-elastic fluids circulating round the earth, and is then thrown down upon its surface. In this *single* operation there is a *vast counterpoise to all* the agents of destruction. And the deltas of the Ganges and the Mississippi are not solely formed at the expense of the solid materials of our globe, but in part, and I believe also in a considerable part, by one of the great conservative operations by which the elements are made to return into themselves *."

This is splendid eloquence, full of the energy and spirit that breathes through the whole address :—

> Monte decurrens velut amnis, imbres
> Quem super notas aluere ripas,
> Fervet, immensusque ruit—

but we must pause for a moment, lest we be hurried away by its tide. Let us endeavour calmly to consider whither it would carry us.

If by the elements returning *into themselves* be meant their return to higher levels, it is certainly possible that a fraction of the organic matter which is intermixed with the mud and sand deposited in alternate strata in the delta of the Ganges, may have been derived by the leaves and roots of plants from such aqueous vapour, carbonic acid, and other gases, as had ascended into the atmosphere from *lower* regions, and which were not, therefore, derived from the waste of rocks and their organic contents, or from the putrescence of vegetables previously nourished from these sources. This fraction, and this alone, may then be deducted from the mass of solid matter annually transported into the Bay of Bengal, and what re-

* Address to the Geological Society on the Anniversary, Feb. 1831, p. 24.

mains, whether organic or inorganic, will be the measure of the degradation which thousands of torrents in the Himalaya mountains, and many rivers of other parts of India, bring down in a single year. Even in this case it will be found that the sum of the force of vegetation can merely be considered as having been in a slight degree *conservative*, retarding the waste of land, and not acting as an antagonist power.

But the untenable nature of the doctrine which we are now controverting may be set in a clearer light by examining the present state of the earth's surface, on which it is declared that "an incalculable mass of solid matter is thrown down year after year," in such a manner as to form a counterpoise to the agents of decay. Is it not a fact that the vegetable mould is seldom more than a few feet in thickness, and that it often does not exceed a few inches? Do we find that its volume is more considerable on those parts of our continents which we can prove, by geological data, to have been elevated at more ancient periods, and where there has been the greatest time for the accumulation of vegetable matter, produced throughout successive zoological epochs? On the contrary, are not these higher and older regions more frequently denuded, so as to expose the bare rock to the action of the sun and air?

Do we find in the torrid zone, where the growth of plants is most rank and luxurious, that accessions of matter due to their agency are most conspicuous on the surface of the land? On the contrary, is it not there where the vegetation is most active that, for reasons to be explained in the next chapter, even those superficial peat mosses are unknown which cover a large area in some parts of our temperate zone? If the operation of animal and vegetable life could restore to the general surface of the continents a portion of the elements of those disintegrated rocks, of which such enormous masses are swept down annually into the sea, along particular river-courses and lines of coast, the effects would have become ere now most striking; and would have constituted one of the most leading features in the structure and composition of our continents.

All the great steppes and table-lands of the world, where the action of running water is feeble, would have become the grand repositories of organic matter, accumulated without that intermixture of sediment which so generally characterizes the subaqueous strata.

Even the formation of peat in certain districts where the climate is cold and moist, the only case, perhaps, which affords the shadow of a support to the theory under consideration, has not in every instance a conservative tendency. A peat-moss often acts like a vast sponge, absorbing water in large quantities, and swelling to the height of many yards above the surrounding country. The turfy covering of the bog serves, like the skin of a bladder, to retain for a while the fluid within, and a violent inundation sometimes ensues when that skin bursts, as has often happened in Ireland, and many parts of the continent. Examples will be mentioned by us in a subsequent chapter, where the Stygian torrent has hollowed out ravines and borne along rocks and sand, in countries where such ravages could not have happened but for the existence of peat. Here, therefore, the force of vegetation accelerates the rate of decay of land, and the solid matter swept down to lower levels during such floods, counterbalances, to a certain degree, the accessions of vegetable mould which may accrue to the land by the growth of peat.

We may explain more clearly the kind of force which we imagine vegetation to exert, by comparing it to the action of frost, which augments the height of some few Alpine summits by causing a mass of perpetual snow to lodge thereon, or fills up some valleys with glaciers; but although by this process of congelation the rain-water that has risen by evaporation from the sea, is retained for awhile in a solid form upon the land, and although some elevated spots may be protected from waste by a constant covering of ice, yet by the sudden melting of snow and ice, the degradation of rocks is often accelerated. Although every year fresh snow and ice are formed, as also more vegetable and animal matter, yet there is no increase;

the one melts, the other putrifies, or is drifted down to the sea by rivers. If this were not the case, frost might be considered as an antagonist power, as well as the action of animal and vegetable life, and these by their combined energy might restore to continents a portion of that solid matter which is swept down into the sea from mountains and wasting cliffs. By the aid of such machinery might a theorist repair the losses of the solid land, sand and rocky fragments being carried down annually to the subaqueous regions from hills of granite, limestone, and shale, while vegetation and frost might raise new mountains, which, like the cliffs in Eschscholtz's Bay, might consist of icebergs, intermixed with vegetable mould.

We have stated in a former volume that, in the known operation of the *igneous* causes, a real antagonist power is found which may counterbalance the levelling action of running water; and there seems no good reason for presuming that the upheaving and depressing force of earthquakes, together with the heaping up of ejected matter by volcanos, may not be fully adequate to restore the superficial inequalities which rivers and oceanic currents annually tend to lessen. If a counterpoise be derived from this source, the quantity and elevation of land above the sea may for ever remain the same, in spite of the action of the aqueous causes, which, if thus counteracted, may never be able to reduce the surface of the earth more nearly to a state of equilibrium than that which it has now attained; and, on the other hand, the force of the aqueous agents themselves might thus continue for ever unimpaired. This permanence of the intensity of the powers now in operation would account for any amount of disturbance or degradation of the earth's crust, so far as the *mere quantity* of movement or decay is concerned; provided only that indefinite periods of time are contemplated.

As to the *intensity* of the disturbing causes at particular epochs, their effects have as yet been studied for too short a time to enable us fully to compare the signs of ancient con-

vulsions with the permanent monuments left in the earth's crust by the events of the last few thousand years. But notwithstanding the small number of changes which have been witnessed and carefully recorded, observation has at least shown that our knowledge of the extent of the subterranean agency, as now developed from time to time, is in its infancy; and there can be no doubt that great partial mutations in the structure of the earth's crust are brought about in volcanic regions, without any interruption to the general tranquillity of the habitable surface.

Some geologists point to particular cases of enormous dislocation of ancient date, and confessedly not of frequent occurrence, where shifts in the strata of two thousand feet and upwards appear to have been produced suddenly and at one effort. But they have been at no pains to prove that similar consequences could not result from earthquakes such as have happened within the last three thousand years. They have usually proceeded on *à priori* reasoning to assume that such convulsions were paroxysmal, and attended by catastrophes such as have never occurred in modern times. It would be irrelevant to the subject immediately under consideration to enter into a long digression on these topics, but we may remind the reader, that the subsidence of the quay at Lisbon to the depth of six hundred feet only gave rise to a slight whirlpool; and we may thence infer the possibility of a sinking down or elevation four or five times as great, especially in deeper seas, without any superficial disturbance unparalleled in the events of the last century.

If a certain sect of geologists were as anxious to reconcile the actual and former course of nature as they are eager to contrast them, they would perceive that the effects witnessed by us of subterranean action on supramarine land, may not be a type of those which the submerged rocks undergo, and they would proceed with more caution when reasoning from a comparison between the accumulated results of disturbing causes in the immensity of past time, and those which

are recorded in the meagre annals of a brief portion of the human era.

The same rash generalizations which are now made respecting eras of paroxysmal violence and chaotic derangement, led formerly to the doctrines of universal formations, the improbability of which might have been foreseen by a slight reference to the causes now in operation.

To the same modes of philosophising we may ascribe the unwillingness of some naturalists to admit, that all the fossil species are not the same as those now living on the globe; whereas, if the facts and reasoning set forth in a former part of this volume, respecting the present instability of the organic creation be just, it might always *à priori* have been seen that the species inhabiting the planet at two periods very remote could hardly be identical.

In our view of the Huttonian theory, we pointed out as one of its principal defects, the assumed want of synchronism in the action of the great antagonist powers—the introduction, first, of periods when continents gradually wasted away, and then of others when new lands were elevated by violent convulsions. In order to have a clear conception of the working of such a system, let the reader suppose the earthquakes and volcanic eruptions of the Andes to be suspended for a million of years, and sedimentary deposits to accumulate throughout the whole of that period, as they now accumulate at the mouths of the Orinoco and Amazon, and along the intervening coast. Then let a period arrive when the subterranean power, which had obtained no vent during those ten thousand centuries, should escape suddenly in one tremendous explosion.

It is natural that geologists who reject such portions of the Huttonian theory as we embrace, should cling fondly to those parts which we deem unsound and unphilosophical. They have accordingly selected the distinctness of the periods when the antagonist forces are developed, as a principle peculiarly worthy of implicit faith. For this reason they have declined

making any strenuous effort to account for those violations of continuity in the series of geological phenomena which are exhibited in large but limited regions; and which we have hinted may admit of explanation by the shifting of the volcanic foci, without the necessity of calling in to our aid any hypothetical eras of convulsion.

In the Oriental cosmogonies, as we have seen, both the physical and moral worlds were represented to be subject to gradual deterioration, until a crisis arrived when they were annihilated, or reverted to a state of chaos;—there had been alternating periods of tranquillity and disorder—an endless vicissitude of destructions and renovations of the globe.

In the spirit of this antique philosophy, some modern geologists conceive that nature, after long periods of repose, is agitated by fits of "feverish spasmodic energy, during which her very frame-work is torn asunder*;"—these paroxysms of internal energy are accompanied by the sudden elevation of mountain chains, "followed by mighty waves desolating whole regions of the earth†"; and, according to some authors, whole races of organic beings are thus suddenly annihilated.

It was to be expected that when, in opposition to these favourite dogmas, we enumerated the subterranean catastrophes of the last one hundred and forty years, pointing out how defective were our annals, and called on geologists to multiply the amount of disturbances arising from this source by myriads of ages during the existence of successive races of organic beings, that we should provoke some vehement expostulation. We could not hope that the self-appointed guardians of Nature's slumber would allow us with impunity thus suddenly to intrude upon her rest, or that they would fail to resent so rude an attempt to rouse her from the torpor into which she had been lulled by their hypothesis. We were prepared to see our proofs and authorities severely sifted, our

* Prof. Sedgwick, Anniv. Address, &c. 1831, p. 35. † Ibid.

inferences rigorously scrutinized; but we never supposed it possible that our adversaries would set up "as a vast counterpoise to all the agents of destruction," a cause so nugatory as "the single operation of vegetable life *."

As it will appear from what we before said, that vegetation cannot act as an antagonist power amid the mighty agents of change which are always modifying the surface of the globe, let us next inquire how far its influence is conservative,—how far it may retard the levelling power of running water, which it cannot oppose, much less counterbalance.

It is well known that a covering of herbage and shrubs may protect a loose soil from being carried away by rain, or even by the ordinary action of a river, and may prevent hills of loose sand from being blown away by the wind. For the roots bind together the separate particles into a firm mass, and the leaves intercept the rain-water, so that it dries up gradually instead of flowing off in a mass and with great velocity. The old Italian hydrographers make frequent mention of the increased degradation which has followed the clearing away of natural woods in several parts of Italy. A remarkable example was afforded in the Upper Val d'Arno, in Tuscany, on the removal of the woods clothing the steep declivities of the hills by which that valley is bounded. When the ancient forest laws were abolished by the Grand Duke Joseph, during the last century, a considerable tract of surface in the Cassentina (the Clausentinium of the Romans) was denuded, and, immediately, the quantity of sand and soil washed down into the Arno increased enormously. Frisi, alluding to such occurrences, observes, that as soon as the bushes and plants were removed, the waters flowed off more rapidly, and, in the manner of floods, swept away the vegetable soil †.

This effect of vegetation is of high interest to the geologist, when he is considering the formation of those valleys which have been principally due to the action of rivers. The spaces

* Prof. Sedgwick's Anniv. Address, Feb. 1831, p. 24.

† Treatise on Rivers and Torrents, p. 5, Garston's translation.

intervening between valleys, whether they be flat or ridgy, when covered with vegetation, may scarcely undergo the slightest waste, as the surface may be protected by the green sward of grass; and this may be renewed, in the manner before described, from elements derived from rain-water and the atmosphere. Hence, while the river is continually bearing down matter in the alluvial plain, and undermining the cliffs on each side of every valley, the height of the intervening rising grounds may remain stationary.

In this manner a cone of loose scoriæ, sand and ashes, such as Monte Nuovo, may, when it has once become densely clothed with herbage and shrubs, suffer scarcely any farther dilapidation; and the perfect state of the cones of hundreds of extinct volcanos in France, Campania, Sicily, and elsewhere, may prove nothing whatever, either as to their relative or absolute antiquity. We may be enabled to infer from the integrity of such conical hills of incoherent materials, that no flood can have passed over the countries where they are situated since their formation; but the atmospheric action alone in spots where there happen to be no torrents, and where the surface was clothed with vegetation, could scarcely in any lapse of ages have destroyed them.

During a late tour in Spain I was surprized to see a district of gently undulating ground in Catalonia, consisting of red and grey sandstone, and in some parts of red marl, almost entirely denuded of herbage, while the roots of the pines, holm oaks, and some other trees were half exposed, as if the soil had been washed away by a flood. Such is the state of the forests, for example, between Orista and Vich, and near San Lorenzo. Being at length overtaken by a violent thunderstorm, in the month of August, I saw the whole surface, even the highest levels of some flat-topped hills, streaming with mud, while on every declivity the devastation of torrents was terrific. The peculiarities in the physiognomy of the district were at once explained, and I was taught that in speculating on the greater effects which the direct action of rain may once

have produced on the surface of certain parts of England, we need not revert to periods when the heat of the climate was *tropical*.

In the torrid zone the degradation of land is generally more rapid, but the waste is by no means proportioned to the superior quantity of rain or the suddenness of its fall, the transporting power of water being counteracted by a greater luxuriance of vegetation. A geologist who is no stranger to tropical countries observes, that the softer rocks would speedily be washed away in such regions, if the numerous roots of plants were not matted together in such a manner as to produce considerable resistance to the destructive power of the rains. The parasitical and creeping plants also entwine in every possible direction so as to render the forests nearly impervious, and the trees possess forms and leaves best calculated to shoot off the heavy rains, which when they have thus been broken in their fall are quickly absorbed by the ground beneath, or when thrown into the drainage depressions give rise to furious torrents *.

The felling of forests has been attended, in many countries, by a diminution of rain, as in Barbadoes and Jamaica †. For in tropical countries, where the quantity of aqueous vapour in the atmosphere is very great, but where, on the other hand, the direct rays of the sun have immense power, any impediment to the free circulation of air, or any screen which shades the earth from the solar rays, becomes a powerful cause of humidity, and wherever dampness and cold have begun to be generated by such causes, the condensation of vapour continues. The leaves moreover of all plants are alembics, and some of those in the torrid zone have a remarkable power of distilling water, thus contributing to prevent the earth from becoming parched up.

There can be no doubt that the state of the climate, especially the humidity of the atmosphere, influences vegetation, and that, in its turn, vegetation reacts upon the climate;

* De la Beche, Geol. Man. p. 184. † Phil. Trans., vol. ii., p. 294.

but some writers seem to have attributed too much importance to the influence of forests, particularly those of America, as if they were the primary cause of the moisture of the climate.

The theory of a modern author on this subject, "that forests exist in those parts of America only where the predominant winds carry with them a considerable quantity of moisture from the ocean," seems far more rational. In all countries, he says, "having a summer heat exceeding 70°, the presence or absence of natural woods, and their greater or less luxuriance, may be taken as a measure of the amount of humidity, and of the fertility of the soil. Short and heavy rains, in a warm country, will produce grass, which, having its roots near the surface, springs up in a few days, and withers when the moisture is exhausted; but transitory rains, however heavy, will not nourish trees, because, after the surface is saturated with water, the rest runs off, and the moisture lodged in the soil neither sinks deep enough, nor is in sufficient quantity, to furnish the giants of the forest with the necessary sustenance. It may be assumed, that twenty inches of rain falling moderately, or at intervals, will leave a greater permanent supply in the soil than forty inches falling, as it sometimes does in the torrid zone, in as many hours *."

"In all regions," he continues, "where ranges of mountains intercept the course of the constant or predominant winds, the country on the windward side of the mountains will be moist, and that on the leeward dry, and hence parched deserts will generally be found on the west side of countries within the tropics, and on the east side of those beyond them, the prevailing winds in these cases being generally in opposite directions. On this principle, the position of forests in North and South America may be explained. Thus, for example, in the region within the thirtieth parallel, the moisture swept up by the trade-wind from the Atlantic is pre-

* Maclaren, Art. America, Encyc. Britannica.

cipitated in part upon the mountains of Brazil, which are but low and so distributed as to extend far into the interior. The portion which remains is borne westward, and, losing a little as it proceeds, it is at length arrested by the Andes, where it falls down in showers on their summits. The aërial current, now deprived of all the humidity with which it can part, arrives in a state of complete exsiccation at Peru, where, consequently, no rain falls. In the same manner the Ghauts in India, a chain only three or four thousand feet high, intercept the whole moisture of the atmosphere, having copious rains on their windward side, while on the other the weather remains clear and dry. The rains in this case change regularly from the west side to the east, and vice versâ, *with the monsoons.* But in the region of America, beyond the thirtieth parallel, the Andes serve as a screen to intercept the moisture brought by the prevailing winds from the Pacific Ocean; rains are copious on their summits, and in Chili on their *western* declivities; but none falls on the plains to the *eastward,* except occasionally when the wind blows from the Atlantic*."

We have been more particular in explaining these views, because they appear to us to place in a true light the dependence of vegetation on climate, notwithstanding the reciprocal action which each exerts on the other, the humidity being increased, and more uniformly diffused throughout the year, by the gradual spreading of wood.

Before concluding this chapter, we must offer a few observations on the influence of man in modifying the physical geography of the globe, for we must class his agency among the powers of organic nature.

The modifications of the surface, resulting from human agency, are only on a considerable scale when we have obtained so much knowledge of the working of the laws of nature as to be able to use them as instruments to effect our purposes. We

* Maclaren, ibid., where the position of the American forests, in accordance with this theory, is laid down in a map.

must command nature by obeying her laws, according to the saying of the philosopher, and for this reason we can never materially interfere with any of the great changes which either the aqueous or igneous causes are bringing about on the earth. In vain would the inhabitants of Italy strive to prevent the tributaries of the Po and Adige from bearing down, annually, an immense volume of sand and mud from the Alps and Apennines; in vain would they toil to re-convey to the mountains the mass torn from them year by year, and deposited in the form of sediment in the Adriatic. But they have, nevertheless, been able to vary the distribution of this sediment over a considerable area, by embanking the rivers, and preventing the sand and mud from being spread, by annual inundations, over the plains.

We have explained how the form of the delta of the Po has been altered by this system of embankment, and how much more rapid, in consequence of these banks, have been the accessions of land at the mouths of the Po and Adige within the last twenty centuries. There is a limit, however, to these modifications, since the danger of floods augments with the increasing height of the river-beds, while the expense of maintaining the barrier is continually enhanced, as well as the difficulty of draining the low surrounding country.

In the Ganges, says Major R. H. Colebrooke, no sooner is a slight covering of soil observed on a new sand-bank, than the island is cultivated; water-melons, cucumbers, and mustard, become the produce of the first year, and rice is often seen growing near the water's edge, where the mud is in large quantity. Such islands may be swept away before they have acquired a sufficient degree of stability to resist permanently the force of the stream; but if, by repeated additions of soil, they acquire height and firmness, the natives take possession, and bring over their families, cattle and effects. They choose the highest spots for the sites of villages, where they erect their dwellings with as much confidence as they would do on the main land; for although the foundation is sandy, the

uppermost soil being interwoven with the roots of grass and other plants, and hardened by the sun, is capable of withstanding all attacks of the river. These islands often grow to a considerable size, and endure for the lives of the new possessors, being only at last destroyed by the same gradual process of undermining and encroachment to which the banks of the Ganges are subject *.

If Bengal were inhabited by a nation more advanced in opulence and agricultural skill, they might, perhaps, succeed in defending these possessions against the ravages of the stream for much longer periods; but no human power could ever prevent the Ganges, or the Mississippi, from making and unmaking islands. By fortifying one spot against the set of the current, its force is only diverted against some other point; and, after a vast expense of time and labour, the property of individuals may be saved, but no addition would thus be made to the sum of productive land. It may be doubted, whether any system could be devised so conducive to *national* wealth, as the simple plan pursued by the peasants of Hindostan, who, wasting no strength in attempts to thwart one of the great operations of nature, permit the alluvial surface to be perpetually renovated, and find their losses in one place compensated in some other, so that they continue to reap an undiminished harvest from a virgin soil.

To the geologist, the Gangetic islands, and their migratory colonies, may present an epitome of the globe as tenanted by man. For during every century we cede some territory which the earthquake has sunk, or the volcano has covered by its fiery products, or which the ocean has devoured by its waves. On the other hand, we gain possession of new lands, which rivers, tides, or volcanic ejections have formed, or which subterranean causes have upheaved from the deep. Whether the human species will outlast the whole, or a great part of the continents and islands now seen above the waters, is a subject far beyond the reach of our conjectures; but thus much may be inferred

* Asiatic Trans., vol. vii.

from geological data,—that if such should be its lot, it will be no more than has already fallen to pre-existing species, some of which have, ere now, outlived the form and distribution of land and sea which prevailed at the era of their birth.

We have before shown, when treating of the excavation of new estuaries in Holland by inroads of the ocean, as also of the changes on our own coasts, that although the conversion of sea into land by artificial labours may be great, yet it must always be in subordination to the great movements of the tides and currents. If, in addition to the assistance obtained by parliamentary grants for defending Dunwich from the waves, all the resources of Europe had been directed to the same end, the existence of that port might possibly have been prolonged for many centuries. But, in the meantime, the current would have continued to sweep away portions from the adjoining cliffs on each side, rounding off the whole line of coast into its present form, until at length the town must have projected as a narrow promontory, becoming exposed to the irresistible fury of the waves.

It is scarcely necessary to observe, that the control which man can exert over the igneous agents is less even than that which he may obtain over the aqueous. He cannot modify the upheaving or depressing force of earthquakes, or the periods or degree of violence of volcanic eruptions; and on these causes the inequalities of the earth's surface, and, consequently, the shape of the sea and land, appear mainly to depend. The utmost that man can hope to effect in this respect, is occasionally to divert the course of a lava-stream, and to prevent the burning matter, for a season at least, from overwhelming a city, or other fruit of human industry.

No application, perhaps, of human skill and labour tends so greatly to vary the state of the habitable surface, as that employed in the drainage of lakes and marshes, since not only the *stations* of many animals and plants, but the general climate of a district, may thus be modified. It is also a kind of alteration to which it is difficult, if not impossible, to find anything

analogous in the agency of inferior beings. For we ought always, before we decide that any part of the influence of man is novel and anomalous, carefully to consider all the powers of other animate agents which may be limited or superseded by him. Many who have reasoned on these subjects seem to have forgotten that the human race often succeeds to the discharge of functions previously fulfilled by other species; a topic on which we have already offered some hints, when explaining how the distribution and numbers of each species are dependent on the state of contemporary beings.

Suppose the growth of some of the larger terrestrial plants, or, in other words, the extent of forests, to be diminished by man, and the climate to be thereby modified, it does not follow that this kind of innovation is unprecedented. It is a change in the state of the vegetation, and such may often have been the result of the entrance of new species into the earth. The multiplication, for example, of certain insects in parts of Germany, during the last century, destroyed more trees than man, perhaps, could have felled during an equal period.

It is a curious fact, to which we shall again advert, that the sites of many European forests, cut down since the time of the Romans, have become peat-mosses; and thus a permanent change has been effected in these regions. But other woods, blown down by winds, in the same countries, have also become peat-bogs; so that, although man may have accelerated somewhat the change, yet it may be doubted whether other animate and inanimate causes might not, without his interference, have produced similar results. The atmosphere of our latitudes may have been slowly and insensibly cooling down since the ancient forests began to grow, and the time may have arrived when slight accidents were sufficient to cause the decrease of trees, and the usurpation of their site by other plants.

We do not pretend to decide how far the power of man, to modify the surface, may differ in kind or degree from that of other living beings, but we suspect that the problem is more complex than has been imagined by many who have speculated

on such topics. If new land be raised from the sea, the greatest alteration in its physical condition, which could ever arise from the influence of organic beings, would probably be produced by the first immigration of terrestrial plants, whereby the tract would become covered with vegetation. The change next in importance would seem to be when animals enter, and modify the proportionate numbers of certain species of plants. If there be any anomaly in the intervention of man, in farther varying the relative numbers in the vegetable kingdom, it may not so much consist in the kind or absolute quantity of alteration, as in the circumstance that *a single species*, in this case, would exert, by its superior power and universal distribution, an influence equal to that of hundreds of other terrestrial animals.

If we inquire whether man, by his direct removing power, or by the changes which he may give rise to indirectly, tends, upon the whole, to lessen or increase the inequalities of the earth's surface, we shall incline, perhaps, to the opinion that he is a levelling agent. He conveys upwards a certain quantity of materials from the bowels of the earth in mining operations; but, on the other hand, much rock is taken annually from the land, in the shape of ballast, and afterwards thrown into the sea, whereby, in spite of prohibitory laws, many harbours, in various parts of the world, have been blocked up. We rarely transport heavy materials to higher levels, and our pyramids and cities are chiefly constructed of stone brought down from more elevated situations. By ploughing up thousands of square miles, and exposing a surface for part of the year to the action of the elements, we assist the abrading force of rain, and destroy the conservative effects of vegetation.

But the aggregate force exerted by man is truly insignificant, when we consider the operations of the great physical causes, whether aqueous or igneous, in the inanimate world. If all the nations of the earth should attempt to quarry away the lava which flowed during one eruption from the Icelandic volcanoes

in 1783 and the two following years, and should attempt to consign it to the deepest abysses of the ocean, wherein it might approach most nearly to the profundities from which it rose in the volcanic vent, they might toil for thousands of years before their task was accomplished. Yet the matter borne down by the Ganges and Burrampooter, in a single year, probably exceeds, in weight and volume, the mass of Icelandic lava produced by that great eruption.