

## **PHYSICAL HISTORY OF THE VALLEY OF THE AMAZONS.**

A YEAR or two ago I published in the "Atlantic Monthly," as part of a series of geological sketches, a number of articles on the glacial phenomena of the Northern hemisphere. Today I am led to add a new chapter to that strange history, taken from the Southern hemisphere, and even from the tropics themselves. I am prepared to find that the statement of this new phase of the glacial period will awaken among my scientific colleagues an opposition even more violent than that by which the first announcement of my views on this subject was met. I am, however, willing to bide my time; feeling sure that, as the theory of the ancient extension of glaciers in Europe has gradually come to be accepted by geologists, so will the existence of like phenomena, both in North and South America, during the same epoch, be recognized sooner or later as part of a great series of physical events extending over the whole globe. Indeed, when the ice-period is fully understood, it will be seen that the absurdity lies in supposing that climatic conditions so intense could be limited to a small portion of the world's surface. If the geological winter existed at all, it must have been cosmic; and it is quite as rational to look for its traces in the Western as in the Eastern hemisphere, to the south of the equator as to the north of it. Impressed by this wider view of the subject, confirmed by a number of unpublished investigations which I have made during the last three or four years in the United States, I came to South America, expecting to find in the tropical regions new evidences of a bygone glacial period, though, of course, under different aspects. Such a result seemed to me the logical sequence of what I had already observed in Europe and in North America. On my arrival in Rio de Janeiro, -the port at which I first landed in Brazil, -my attention was immediately attracted by a very peculiar formation, consisting of an ochraceous, highly ferruginous sandy clay. During a stay of three months in Rio, whence I made many excursions into the neighboring country, I had opportunities of studying this deposit, both in the province of Rio de Janeiro and in the adjoining province of Minas Geraes. I found that it rested everywhere upon the undulating surfaces of the solid rocks in place, was almost entirely destitute of stratification, and contained a variety of pebbles and boulders. The pebbles were chiefly quartz, sometimes scattered indiscriminately throughout the deposit, sometimes lying in a seam between it and the

rock below; while the boulders were either sunk in its mass or resting loose on the surface. At Tijuca, a few miles out of the city of Rio, among the picturesque hills lying to the southwest of it, these phenomena may be seen in great perfection. Near Bennett's Hotel- a favorite resort, not only with the citizens of Rio but with all sojourners there who care to leave the town occasionally for its beautiful environs -may be seen a great number of erratic boulders, having no connection whatever with the rock in place, and also a bluff of this superficial deposit studded with boulders, resting above the partially stratified metamorphic rock. Other excellent opportunities for observing this formation, also within easy reach from the city, are afforded along the whole line of the railroad of Dom Pedro Segundo, where the cuts expose admirable sections, showing the red, unstratified, homogeneous mass of sandy clay resting above the solid rock, and often divided from it by a thin bed of pebbles. There can be no doubt, in the mind of anyone familiar with similar facts observed in other parts of the world, that this is one of the many forms of drift connected with glacial action. I was, however, far from anticipating, when I first met it in the neighborhood of Rio, that I should afterwards find it spreading over the surface of the country, from north to south and from east to west, with a continuity which gives legible connection to the whole geological history of the continent. It is true that the extensive decomposition of the underlying rock, penetrating sometimes to a considerable depth, makes it often difficult to distinguish between it and the drift; and the problem is made still more puzzling by the fact that the surface of the drift, when baked by exposure to the hot sun, often assumes the appearance of decomposed rock, so that great care is required for a correct interpretation of the facts. A little practice, however, trains the eye to read these appearances aright, and I may say that I have learned to recognize everywhere the limit between the two formations. There is, indeed, one safe guide, namely, the undulating line, reminding one of roches moutonnees, and marking the irregular surface of the rock on which the drift was accumulated; whatever modifications the one or the other may have undergone, this line seems never to disappear. Another deceptive feature, arising from the frequent disintegration of the rocks and from the brittle character of some of them, is the presence of loose fragments, which simulate erratic boulders, but are in fact only detached masses of

the rock in place. A careful examination of their structure, however, will at once show the geologist whether they belong where they are found, or have been brought from a distance to their present resting-place. While the features to which I have alluded are unquestionably drift phenomena, they present in their wider extension, and especially in the northern part of Brazil, as will hereafter be seen, some phases of glacial action hitherto unobserved. Just as the investigation of the ice-period in the United States has shown us that ice-fields may move over open level plains, as well as along the slopes of mountain valleys, so does a study of the same class of facts in South America reveal new and unlooked-for features in the history of the ice-period. Some will say, that the fact of the advance of ice-fields over an open country is by no means established, inasmuch as many geologists believe all the so-called glacial traces, namely, striae, furrows, polish, etc., found in the United States, to have been made by floating icebergs at a time when the continent was submerged. To this I can only answer, that in the State of Maine I have followed, compass in hand, the same set of furrows, running from north to south in one unvarying line, over a surface of one hundred and thirty miles from the Katahdin Iron Range to the sea-shore. These furrows follow all the inequalities of the country, ascending ranges of hills varying from twelve to fifteen hundred feet in height, and descending into the intervening valleys only two or three hundred feet above the sea, or sometimes even on a level with it. I take it to be impossible that a floating mass of ice should travel onward in one rectilinear direction, turning neither to the right nor to the left, for such a distance. Equally impossible would it be for a detached mass of ice, swimming on the surface of the water, or even with its base sunk considerably below it, to furrow in a straight line the summits and sides of the hills, and the beds of the valleys. It would be carried over the depressions without touching bottom. Instead of ascending the mountains, it would remain stranded against any elevation which rose greatly above its own basis, and, if caught between two parallel ridges, would float up and down between them. Moreover, the action of solid, unbroken ice, moving over the ground in immediate contact with it, is so different from that of floating ice-rafts or icebergs, that, though the latter have unquestionably dropped erratic boulders, and made furrows and striae on the surface where they happened to be grounded,

these phenomena will easily be distinguished from the more connected traces of glaciers, or extensive sheets of ice, resting directly upon the face of the country and advancing over it. There seems to be an inextricable confusion, in the ideas of many geologists, as to the respective action of currents, icebergs, and glaciers. The facts connected with these phenomena are in truth very different from each other, and easily recognized after the discrimination has once been made. As to the southward movement of an immense field of ice extending over the whole north, it seems inevitable, the moment we admit that snow may accumulate around the pole in such quantities as to initiate a pressure radiating in every direction. Snow alternately thawing and freezing must, like water, find its level at last. A sheet of snow ten or fifteen thousand feet in thickness, extending all over the northern and southern portions of the globe, must necessarily lead, in the end, to the formation of a northern and southern cap of ice, moving toward the equator. I have spoken of Tijuca and the Dom Pedro Railroad as favorable localities for studying the peculiar southern drift; but one meets it in every direction. A sheet of drift, consisting of the same homogeneous, unstratified paste, and containing loose materials of all sorts and sizes, covers the country. It is of very uneven thickness, -sometimes thrown into relief, as it were, by the surrounding denudations, and rising into hills, -sometimes reduced to a thin layer, -sometimes, as, for instance, on steep slopes, washed entirely away, leaving the bare face of the rock exposed. It has, however, remained comparatively undisturbed on some very abrupt ascents; as, for instance, on the Corcovado, along the path leading up the mountain, where there are very fine banks of drift, -the more striking from the contrast of their deep red color with the surrounding vegetation. I have myself followed this sheet of drift from Rio de Janeiro It to the top of the Serra do Mar, where, just outside the pretty town of Petropolis, the river Piabanha may be seen flowing between banks of drift, in which it has excavated its bed; thence I have traced it along the beautiful macadamized road leading to Juiz de Fora in the province of Minas Geraes, and beyond this to the farther side of the Serra da Babylonia. Throughout this whole tract of country, in the greater part of which travelling is easy and delightful, -an admirable line of diligences, over one of the finest roads in the world, being established as far as Juiz de Fora, -the drift may be seen along the

roadside, in immediate contact with the native crystalline rock. The fertility of the land, also, is a guide to the presence of drift. Wherever it lies thickest over the surface, there are the most flourishing coffee-plantations; and I believe that a more systematic regard to this fact would have a most beneficial influence upon the agricultural interests of the country. No doubt the fertility arises from the great variety of chemical elements contained in the drift, and the kneading process it has undergone beneath the gigantic ice-plough, -a process which makes glacial drift everywhere the most fertile soil. Since my return from the Amazons, my impression as to the general distribution of these phenomena has been confirmed by the reports of some of my assistants, who have been travelling in other parts of the country. Mr. Frederick C. Hartt, accompanied by Mr. Copeland, one of the volunteer aids of the expedition, has been making collections and geological observations in the province of Spiritu Santo, in the valley of the Rio Doce, and afterwards in the valley of the Mucury. He informs me that he has found everywhere the same sheet of red, unstratified clay, with pebbles and occasional boulders, overlying the rock in place. Mr. Orestes St. John, who, taking the road through the interior, has visited, with the same objects in view, the valleys of the Rio San Francisco and the Rio das Velhas, and also the valley of Piahy, gives the same account, with the exception that he found no erratic boulders in these more northern regions. The rarity of erratic boulders, not only in the deposits of the Amazons proper, but in those of the whole region which may be considered as the Amazonian basin, is accounted for, as we shall see hereafter, by the mode of their formation. The observations of Mr. Hartt and Mr. St. John are the more valuable, because I had employed them both, on our first arrival in Rio, in making geological surveys of different sections on the Dom Pedro Railroad, so that they had a great familiarity with those formations before starting on their separate journeys. Recently, Mr. St. John and myself having met at Para on returning from our respective journeys, I have had an opportunity of comparing on the spot his geological sections from the valley of the Piahy with the Amazonian deposits. There can be no doubt of the absolute identity of the formations in these valleys. Having arranged the work of my assistants, and sent several of them to collect and make geological examinations in other directions, I myself, with the rest of my companions, proceeded up the coast to Para. I

was surprised to find at every step of my progress the same geological phenomena which had met me at Rio. As the steamer stops for a number of hours, or sometimes for a day or two, at Bahia, Maceio, Pernambuco, Parahiba, Natal, Ceara, and Maranham, I had many opportunities for observation. My friend Major Coutinho, already an experienced Amazonian traveller, first told me that this formation continued through the whole valley of the Amazons, and was also to be found on all of its effluents visited by him, although he had never thought of referring it to so recent a period. And here let me interrupt the course of my remarks to say, that the facts recorded in this article are by no means exclusively the result of my own investigations. They are in great part due to this able and intelligent young Brazilian, a member of the government corps of engineers, who, by the kindness of the Emperor, was associated with me in my Amazonian expedition. I can truly say that he has been my good genius throughout the whole journey, saving me, by his previous knowledge of the ground, from the futile and misdirected expenditure of means and time often inevitable in a new country, where one is imperfectly acquainted both with the people and their language. We have worked together in this investigation; my only advantage over him being my greater familiarity with like phenomena in Europe and North America, and consequent readiness in the practical handling of the facts, and in perceiving their connection. Major Coutinho's assertion, that on the banks of the Amazons I should find the same red, unstratified clay as in Rio and along the southern coast, seemed to me at first almost incredible, impressed as I was with the generally received notions as to the ancient character of the Amazonian deposits, referred by Humboldt to the Devonian, and by Martius to the Triassic period, and considered by all travellers to be at least as old as the Tertiaries. The result, however, confirmed his report, at least so far as the component materials of the formation are concerned; but, as will be seen hereafter, the mode of their deposition, and the time at which it took place, have not been the same at the north and south; and this difference of circumstances has modified the aspect of a formation essentially the same throughout. At first sight, it would indeed appear that information, as it exists in the valley of the Amazons, is identical with that of Rio; but it differs from it in the rarity of its boulders, and in showing occasional signs of stratification. It is also everywhere under-laid by

coarse, well-stratified deposits, resembling somewhat the recife of Bahia and Pernambuco; whereas the unstratified drift of the south rests immediately upon the undulating surface of whatever rock happens to make the foundation of the country, whether stratified or crystalline. The peculiar sandstone on which the Amazonian clay rests exists nowhere else. Before proceeding, however, to describe the Amazonian deposits in detail, I ought to say something of the nature and origin of the valley itself. The Valley of the Amazons was first sketched out by the elevation of two tracts of land; namely, the plateau of Guiana on the north, and the central plateau of Brazil on the south. It is probable that, at the time these two table-lands were lifted above the sea-level, the Andes did not exist, and the ocean flowing between them through an open strait. It would seem (and this is a curious result of modern geological investigations) that the portions of the earth's surface earliest raised above the ocean have trended from east to west. The first tract of land lifted above the waters in North America was also a long continental island, running from Newfoundland almost to the present base of the Rocky Mountains. This tendency may be attributed to various causes, to the rotation of the earth, the consequent depression of its poles, and the breaking of its crust along the lines of greatest tension thus produced. At a later period, the upheaval of the Andes took place, closing the western side of this strait, and thus transforming it into a gulf, open only toward the east. Little or nothing is known of the earlier stratified deposits resting against the crystalline masses first uplifted in the Amazonian valley. There is here no sequence, as in North America, of Azoic, Silurian, Devonian, and Carboniferous formations, shored up against each other by the gradual upheaval of the continent, although unquestionably older palaeozoic and secondary beds underlie, here and there, the later formations. Indeed, Major Coutinho has found palaeozoic deposits, with characteristic shells, in the valley of the Rio Tapajos, at the first cascade, and carboniferous deposits have been noticed along the Rio Guapore and the Rio Mamore. But the first chapter in the valley's geological history about which we have connected -and trustworthy data is that of the cretaceous period. It seems certain, that, at the close of the secondary age, the whole Amazonian basin became lined with a cretaceous deposit, the margins of which crop out at various localities on its borders. They have been observed along

its southern limits, on its western outskirts along the Andes, in Venezuela along the shore-line of mountains, and also in certain localities near its eastern edge. I well remember that one of the first things which awakened my interest in the geology of the Amazonian Valley was the sight of some cretaceous fossil fishes from the province of Ceara. These fossil fishes were collected by Mr. George Gardner, to whom science is indebted for the most extensive information yet obtained respecting the geology of that part of Brazil. In this connection, let me say that here and elsewhere I shall speak of the provinces of Ceara, Piauhy, and Maranham as belonging geologically to the Valley of the Amazons, though their shore is bathed by the ocean, and their rivers empty directly into the Atlantic. But I entertain no doubt, and I hope I may hereafter be able to show, that, at an earlier period, the northeastern coast of Brazil stretched much farther sea-ward than in our day; so far, indeed, that in those times the rivers of all these provinces must have been tributaries of the Amazons in its eastward course. The evidence for this conclusion is substantially derived from the identity of the deposits in the valleys belonging to these provinces with those of the valleys through which the actual tributaries of the Amazons flow; as, for instance, the Tocantins, the Xingu, the Tapajos, the Madeira, etc. Besides the fossils above alluded to from the eastern borders of this ancient basin, I have had recently another evidence of its cretaceous character from its southern region. Mr. William Chandless, on his return from a late journey on the Rio Purus, presented me with a series of fossil remains of the highest interest, and undoubtedly belonging to the cretaceous period. They were collected by himself on the Rio Aquiry, an affluent of the Rio Purus. Most of them were found in place between the tenth and eleventh degrees of south latitude, and the sixty-seventh and sixty-ninth degrees of west longitude from Greenwich, in localities varying from 430 to 650 feet above the sea-level. There are among them remains of Mososaurus, and of fishes closely allied to those already represented by Faujas in his description of Maestricht, and characteristic, as is well known to geological students, of the most recent cretaceous period. Thus in its main features the Valley of the Amazons, like that of the Mississippi, is a cretaceous basin. This resemblance suggests a further comparison between the twin continents of North and South America. Not only is their general form the same, but their frame-work, as

we may call it, that is, the lay of their great mountain-chains and of their table-lands, with the extensive intervening depressions, presents a striking similarity. Indeed, a zoologist, accustomed to trace a like structure under variously modified animal forms, cannot but have his homological studies recalled to his mind by the coincidence between certain physical features in the northern and southern parts of the Western hemisphere. Yet here, as throughout all nature, these correspondences are combined with a distinctness of individualization, which leaves its respective character not only to each continent as a whole, but also to the different regions circumscribed within its borders. In both, however, the highest mountain-chains, the Rocky Mountains and Coast Range with their wide intervening table-land in North America, and the chain of the Andes with its lesser plateaus in South America, run along the western coast; both have a great eastern promontory, - New-foundland in the northern continent, and Cape St. Roque in the southern; -and though the resemblance between the inland elevations is perhaps less striking, yet the Canadian range, the White Mountains, and the Alleghanies may very fairly be compared to the table-lands of Guiana and Brazil, and the Serra do Mar. Similar correspondences may be traced among the river systems. The Amazons and the St. Lawrence, though so different in dimensions, remind us of each other by their trend and geographical position; and while the one is fed by the largest river system in the world, the other drains the most extensive lake surfaces known to exist in immediate contiguity. The Orinoco, with its bay, recalls Hudson's Bay and its many tributaries, and the Rio Magdalena may be said to be the South American Mackenzie; while the Rio de la Plata represents geographically our Mississippi, and the Paraguay recalls the Missouri. The Parana may be compared to the Ohio; the Picomayo, Vermejo, and Salado rivers, to the River Platte; the Arkansas, and the Red River in the United States; while the rivers farther south, emptying into the Gulf of Mexico, represent the rivers of Patagonia and the southern parts of the Argentine Republic. Not only is there this general correspondence between the mountain elevations and the river systems, but as the larger river basins of North America -those of the St. Lawrence, the Mississippi, and the Mackenzie meet in the low tracts extending along the foot of the Rocky Mountains, so do the basins of the Amazons, the Rio de la Plata, and the Orinoco join each other along the eastern slope of the

Andes. But while in geographical homology the Amazons compares with the St. Lawrence, and the Mississippi with the Rio de la Plata, the Mississippi and the Amazons, as has been said, resemble each other in their local geological character. They have both received a substratum of cretaceous beds, above which are accumulated their more recent deposits, so that, in their most prominent geological features, both may be considered as cretaceous basins, containing extensive deposits of a very recent age. Of the history of the Amazonian Valley during the periods immediately following the cretaceous, we know little or nothing. Whether the tertiary deposits are hidden under the more modern ones, or whether they are wholly wanting, the basin having, perhaps, been raised above the sea-level before that time, or whether they have been swept away by the tremendous inundations in the valley, which have certainly destroyed a great part of the cretaceous deposit, they have never been observed in any part of the Amazonian basin. Whatever tertiary deposits are represented in geological maps of this region are so marked in consequence of an incorrect identification of strata belonging, in fact, to a much more recent period. A minute and extensive survey of the Valley of the Amazons is by no means an easy task, and its difficulty is greatly increased by the fact that the lower formations are only accessible on the river margins during the *vas ante*, as it is called, or dry season, when the waters shrink in their beds, leaving a great part of their banks exposed. It happened that the first three or four months of my journey, August, September, October, and November, were those when the waters are lowest, reaching their minimum in September and October, and beginning to rise again in November, so that I had an excellent opportunity in ascending the river to observe its geological structure. Throughout its whole length, three distinct geological formations may be traced, the two lower of which have followed in immediate succession, and are conformable with one another, while the third rests unconformably upon them, following all the inequalities of the greatly denudated surface presented by the second formation. Notwithstanding this seeming interruption in the sequence of these deposits, the third, as we shall presently see, belongs to the same series, and was accumulated in the same basin. The lowest set of beds of the whole series is rarely visible, but it seems everywhere to consist of sandstone, or even of loose sands well stratified, the coarser materials lying

invariably below, and the finer above. Upon this lower set of beds rests everywhere an extensive deposit of fine laminated clays, varying in thickness, but frequently dividing into layers as thin as a sheet of paper. In some localities they exhibit in patches an extraordinary variety of beautiful colors, -pink, orange, crimson, yellow, gray, blue, and also black and white. The Indians are very skilful in preparing paints from these colored clays, with which they ornament their pottery, and the bowls of various shapes and sizes made from the fruit of the Cuieira-tree. These clay deposits assume occasionally a peculiar appearance, and one which might mislead the observer to their true nature. When their surface has been long exposed to the action of the atmosphere and to the heat of the burning sun, they look so much like clay slates of the oldest geological epochs, that, at first sight, I took them for primary slates, my attention being attracted to them by a regular cleavage as distinct as that of the most ancient clay slates. And yet at Tonantins, on the banks of the Solimoens, in a locality where their exposed surfaces had this primordial appearance, I found in these very beds a considerable amount of well-preserved leaves, the character of which proves their recent origin. These leaves do not even indicate as ancient a period as the Tertiaries, but resemble so closely the vegetation of to-day, that I have no doubt, when examined by competent authority, they will be identified with living plants. The presence of such an extensive clay formation, stretching over a surface of more than three thousand miles in length and about seven hundred in breadth, is not easily explained under any ordinary circumstances. The fact that it is so thoroughly laminated shows that, in the basin in which it was formed, the waters must have been unusually quiet, containing identical materials throughout, and that these materials must have been deposited over the whole bottom in the same way. It is usually separated from the superincumbent beds by a glazed crust of hard, compact sandstone, almost resembling a ferruginous quartzite. Upon this follow beds of sand and sandstone, varying in the regularity of their strata, reddish in color, often highly ferruginous, and more or less nodulous or porous. They present frequent traces of cross-stratification, alternating with regularly stratified horizontal beds, with here and there an intervening layer of clay. It would seem as if the character of the water basin had now changed, and as if the waters under which this second formation was deposited had vibrated between

storm and calm, -had sometimes flowed more gently, and again had been tossed to and fro, giving to some of the beds the aspect of true; torrential deposits, Indeed, these sandstone formations present a great variety of aspects, Sometimes they are very regularly laminated, or assume even the appearance of the hardest quartzite, This is usually the case with the uppermost beds. In other localities, and more especially in the lowermost beds, the whole mass is honeycombed, as if drilled by worms or boring shells, the hard parts enclosing softer sands or clays, Occasionally the ferruginous materials prevail to such an extent, that some of these beds might be mistaken for bog ore, while others contain a large amount of clay, more regularly stratified, and alternating with strata of sandstone, thus recalling the most characteristic forms of the Old Red or Triassic formations, This resemblance has, no doubt, led to the identification of the Amazonian deposits with the more ancient formations of Europe, At Monte Alegre, of which I shall presently speak more in detail, such a clay bed divides the lower from the upper sandstone. The thickness of these sandstones is extremely variable. In the basin of the Amazons proper, they hardly rise anywhere above the level of high water during the rainy season, while at low water, in the summer months, they may be seen everywhere along the river-banks. It will be seen, however, that the limit between high and low water gives no true measure of the original thickness of the whole series. In the neighborhood of Almeirim, at a short distance from the northern bank of the river, and nearly parallel with its course, there rises a line of low hills, interrupted here and there, extending in evident connection from Almeirim through the region of Monte Alegre to the heights of Obydos. These hills have attracted the attention of travellers, not only from their height, which, because they rise abruptly from an extensive plain, appears greater than it is, but also on account of their curious form, many of them being perfectly level on top, like smooth tables, and very abruptly divided from each other by low, intervening spaces. 1. Nothing has hitherto been known of the geological structure of these hills, but they have been usually represented as the southern-most spurs of the table-land of Guiana. On ascending the river, I felt the greatest curiosity to examine them; but at the time I was deeply engrossed in studying the distribution of fishes in the Amazonian waters, and in making large ichthyological collections, for which it was very

important not to miss the season of low water, when the fishes are most easily obtained. I was, therefore, obliged to leave this most interesting geological problem, and content myself with examining the structure of the valley so far as it could be seen on the river-banks and in the neighborhood of my different collecting stations. On my return, however, when my collections were completed, I was free to pursue this investigation, in which Major Coutinho was as much interested as myself. We determined to select Monte Alegre as the centre of our exploration, the serra in that region being higher than elsewhere. As I was detained by indisposition at Manaus, for some days, at the time we had appointed for the excursion, Major Coutinho preceded me, and had already made one trip to the serra, with some very interesting results, when I joined him, and we made a second journey together. Monte Alegre lies on a side arm of the Amazons, a little off from its main course. This side arm, called the Rio Gurupatuba, is simply a channel running parallel with the Amazons, and cutting through from a higher to a lower point. Its dimensions are, however, greatly exaggerated in all the maps thus far published, where it is usually made to appear as a considerable northern tributary of the Amazons. The town stands on an elevated terrace, separated from the main stream by the Rio Gurupatuba, and by an extensive flat, consisting of numerous lakes divided from each other by low alluvial land, and mostly connected by narrow channels. To the west of the town, this terrace sinks abruptly to a wide sandy plain called the Campos, covered with a low forest growth, and bordered on its farther limit by the picturesque serra of Etrere. The form of this mountain is so abrupt, its rise from the plain so bold and sudden, that it seems more than twice its real height. Judging by the eye, and comparing it with the mountains I had last seen the Corcovado, the Gavia and Tijuca range in the neighborhood of Rio, I had supposed it to be three or four thousand feet high, and was greatly astonished when our barometric observations showed it to be somewhat less than nine hundred feet in its most elevated point. This, however, agrees with Martius's measurement of the Almeirim hills, which he says are eight hundred feet in height. Major Coutinho and I reached the serra by different roads; he crossing the Campos on horseback with Captain Faria, the commander of our steamer and one or two other friends from Monte Alegre who joined our party, while I went by canoe. The canoe journey is somewhat longer.

A two-hours ride across the Campos brings you to the foot of the mountain, whereas the trip by boat takes more than twice that time. But I preferred going by water, as it gave me an opportunity of seeing the vast variety of animals haunting the river-banks and lakes. As this was most the only occasion in my journey when I passed a day in the pure enjoyment of nature, without the labor of collecting, which in this hot climate, where specimens require such immediate and constant attention, is very great, I am tempted to interrupt our geology for a moment, to give an account of it. I learned how rich a single day may be in this wonderful tropical world, if one's eyes are only open to the wealth of animal and vegetable life. Indeed, a few hours so spent in the field, in simply watching animals and plants, teaches more of the distribution of life than a month of closet study; for under such circumstances all things are seen in their true relations. Unhappily, it is not easy to present the picture as a whole, for all our written descriptions are more or less dependent on nomenclature, and the local names are hardly known out of the districts where they belong, while systematic names are familiar to few. I started before daylight; but, as the dawn began to redden the sky, large flocks of ducks, and of the small Amazonian geese, might be seen flying towards the lakes. Here and there a cormorant sat alone on the branch of a dead tree, or a kingfisher poised himself over the water, watching for his prey. Numerous gulls were gathered in large companies on the trees along the river-shore; alligators lay on its surface, diving with a sudden splash at the approach of our canoe; and occasionally a porpoise emerged from the water, showing himself for a moment and then disappearing again. Sometimes we startled a herd of capivara, resting on the water's edge; and once we saw a sloth, sitting upon the branch of an *Almabauba* (*Cecropia*) tree, rolled up in its peculiar attitude, the very picture of indolence, with its head sunk between its arms. Much of the river-shore consisted of low alluvial land, and was covered with that peculiar and beautiful grass known as *Capim*; this grass makes an excellent pasturage for cattle, and the abundance of it in this region renders the district of Monte Alegre very favorable for agricultural purposes. Here and there, where the red clay rose above the level of the water, a palm-thatched cabin stood on the low bluff, with a few trees about it. Such a house was usually the centre of a cattle-farm, and large herds might be seen grazing in the adjoining fields. Along the

river-banks, where the country is chiefly open, with extensive low marshy grounds, the only palm to be seen is the Maraja. After keeping along the Rio Gurupatuba for some distance, we turned to the right into a narrow stream, which has the character of an Igarape <sup>2</sup>. in its lower course, though higher up it drains the country between the serra of Errere and that of Tajury, and assumes the appearance of a small river. It is named after the serra, and is known as the Rio Errere. This stream, narrow and picturesque, and often so overgrown with capiro that the canoe pursued its course with difficulty, passed through a magnificent forest of the beautiful fan-palm, called here the Miriti (*Mauritia flexuosa*). This forest stretched for miles, over-shadowing a kind of underbrush, formed of many smaller trees and innumerable shrubs, some of which bore bright, conspicuous flowers. It seemed to me a strange spectacle,-a forest of monocotyledonous trees with a dicotyledonous undergrowth; the inferior plants thus towering above and sheltering the superior ones. Among the lower trees were many Leguminosae,-one of the most striking, called Fava, having a colossal pod. The whole mass of vegetation was woven together by innumerable lianas and creeping vines, in the midst of which the flowers of the Bignonia, with its open, trumpet shaped corolla, were conspicuous. The capim was bright with the blossoms of the mallow growing in its midst, and was often edged with the broad-leaved Aninga, a large aquatic Arum. Through such a forest, where the animal life was no less rich and varied than the vegetation, our boat glided slowly for hours. The number and variety of birds struck me with astonishment. The coarse sedgy grasses on either side were full of water birds, one of the most common of which was a small chestnut brown wading bird, the Jacana (*Parra*), whose toes are immensely long in proportion to its size, enabling it to run upon the surface of the aquatic vegetation as if it were solid ground. It was in the month of January, their breeding season, and at every turn of the boat we started them up in pairs. Their flat, open nests generally contained five flesh-colored eggs, streaked in zigzag with dark brown lines. The other waders were a snow-white heron, another ash-colored, smaller species, and a large white stork. The ash-colored herons were always in pairs, the white one always single, standing quiet and alone on the edge of the water, or half hidden in the green capim. The trees and bushes were full of small warbler-like birds, which it would be difficult to characterize separately. To

the ordinary observer they might seem like the small birds of our woods; but there was one species among them which attracted my attention by its numbers, and also because it builds the most extraordinary nest, considering the size of the bird itself, that I have ever seen. It is known among the country people by two names, as the Pedreiro or the Forneiro, - both names referring, as will be seen, to the nature of its habitation. This singular nest is built of clay, and is as hard as stone (*pedra*), while it has the form of the round mandioca oven (*forno*) in which the country people prepare their farinha, or flour, made from the mandioca root. It is about a foot in diameter, and stands edgewise upon a branch, or in the crotch of a tree. Among the smaller birds, I noticed bright Tanagers, and also a species resembling the canary. Besides these, there were the wagtails, the black and white widow finches, the hang-nests, or Jape, as they are called here, with their pendent bag-like dwellings, and the familiar "*Bem ti vi*." Humming-birds, which we are always apt to associate with tropical vegetation, were very scarce. I saw but a few specimens. Thrushes and doves were more frequent, and I noticed also three or four kinds of wood-peckers. Of the latter there were countless numbers along our canoe path, flying overhead in dense crowds, and, at times, drowning every other sound in their high, noisy chatter. These made a deep impression upon me. Indeed, in all regions, however far away from his own home, in the midst of a fauna and flora entirely new to him, the traveller is startled occasionally by the song of a bird or the sight of a flower so familiar that it transports him at once to woods where every tree is like a friend to him. It seems as if something akin to what in our own mental experience we call reminiscence or association existed in the workings of nature; for though the organic combinations are so distinct in different climates and countries, they never wholly exclude each other. Every zoological and botanical province retains some link which binds it to all the rest, and makes it part of the general harmony. The Arctic lichen is found growing under the shadow of the palm on the rocks of the tropical serra, and the song of the thrush and the tap of the woodpecker mingle with the sharp discordant cries of the parrot and paroquet. Birds of prey, also, were not wanting. Among them was one called the Red Hawk, about the size of our kite, so tame that, even when our canoe passed immediately under the low branch on which he was sitting, he did not flyaway. But of all the

groups of birds, the most striking as compared with corresponding groups in the temperate zone, and the one which reminded me the most distinctly of the fact that every region has its peculiar animal world, was that of the gallinaceous birds. The most frequent is the Cigana, to be seen in groups of fifteen or twenty, perched upon trees over-hanging the water, and feeding upon berries. At night they roost in pairs, but in the day-time are always in larger companies. In their appearance they have something of the character of both the pheasant and peacock, and yet do not closely resemble either. It is a curious fact, that, with the exception of some small partridge-like gallinaceous birds, all the representatives of this family in Brazil, and especially in the Valley of the Amazons, belong to types which do not exist in other parts of the world. Here we find neither pheasants, nor cocks of the woods, nor grouse; but in their place abound the Mutun, the Jacu, the Jacami, and the Unicorn (Crax, Penelope, Psophia, and Palamedea), all of which are so remote from the gallinaceous types found farther north, that they remind one quite as much of the bustard, and other ostrich-like birds, as of the hen and pheasant. They differ also from Northern gallinaceous birds in the greater uniformity of the sexes, none of them exhibiting those striking differences between the males and females which we see in the pheasants, the cocks of the woods, and in our barn-yard fowls. While birds abounded in such numbers, insects were rather scarce. I saw but few and small butterflies, and beetles were still more rare. The most numerous insects were the dragon-flies, -some with crimson bodies, black heads, and burnished wings; others with large green bodies, crossed by blue bands. Of land shells I saw but one creeping 'along the reeds; and of water shells I gathered only a few small Ampullarire. Having ascended the river to a point nearly on a line with the serra, I landed, and struck across the Campos on foot. Here I entered upon an entirely different region, - a dry, open plain, with scanty vegetation. The most prominent plants were clusters of cactus and curua palms, a kind of stemless, low palm, with broad elegant leaves springing vase-like from the ground. In these dry, sandy fields, rising gradually toward the serra, I observed in the deeper gullies formed by the heavy rains the laminated clays which are every- where the foundation of the Amazonian strata. They here presented again so much the character of ordinary clay slates, that I thought I had at last come upon some old geological formation.

Instead of this I only obtained fresh evidence that, by baking them, the burning sun of the tropics may produce upon laminated clays of recent origin the same effect as plutonic agents have produced upon the ancient clays, that is, it may change them into metamorphic slates. After an hour's walk under the scorching sun, I was glad to find myself at the hamlet of Errere, near the foot of the serra, where I rejoined my companions. It was already noon, and they had arrived some time before. They had, however, waited breakfast for me, to which we all brought a good appetite. Break-fast over, we slung our hammocks under the trees, and during the heat of the day enjoyed I the rest which we had so richly earned. I Major Coutinho and myself passed three days in the investigation of the serra of Errere. We found it to consist wholly of the sandstone deposits described above, and to have exactly the same geological constitution. In short, the serra of Monte Alegre, and of course all those connected with it on the northern side of the river, lie in the prolongation of the lower beds forming the banks of the river, their greater height being due simply to the fact that they have not been worn to the same low level. The opposite range of Santarem, which has the same general outline and character, shares, no doubt, the same geological structure. In one word, all these hills were formerly part of a continuous formation, and owe their present outline and their isolated position to a colossal denudation. The surface of the once unbroken strata, which in their original condition must have formed an immense plain covered by water, has been cut into ravines or carried away over large tracts, to a greater or less depth, leaving only such portions standing as from their hardness could resist the floods which swept over it. The longitudinal trend of these hills is to be ascribed to the direction of the current which caused the denudation, while their level summits are due to the regularity of the stratification. They are not all table-topped, however; among them are many of smaller size, in which the sides have been gradually worn down, producing a gently rounded surface. Of course, under the heavy tropical rains this denudation is still going on, though in a greatly modified form. I cannot leave this serra without alluding to the great beauty and extraordinary extent of the view to be obtained from it. Indeed, it was here that for the first time the geography of the country presented itself to my mind as a living reality, in all its completeness. Insignificant as is its actual height, the serra of Errere commands a wider prospect

than is to be had from many a more imposing mountain; for the surrounding plain, covered with forests, and ploughed by countless rivers, stretches away for hundreds of leagues in every direction, without any object to obstruct the view. Standing on the brow of the serra the numerous lakes intersecting the low lands at its base, you look across the Valley of the Amazons, as far as the eye can reach, and through its midst you follow for miles on either side the broad flood of the great river, carrying its yellow waters to the sea. As I stood there, panoramas from the Swiss mountains came up to my memory, and I fancied myself standing on the Alps, looking across the plain of Switzerland, instead of the bed of the Amazons, the distant line of the Santarem hills on the southern bank of the river and lower than the northern chain representing the Jura range. As if to complete the comparison, I found Alpine lichens growing among cactus and palms, and a crust of Arctic cryptogamous growth covered rocks between which sprang tropical flowers. On the northern flank of this serra I found the only genuine erratic boulders I have seen in the whole length of the Amazonian Valley, from Para to the frontier of Peru, though there are many detached masses of rock, as, for instance, at Pedreira, near the junction of the Rio Negro and Rio Branco, which might be mistaken for them, but are due to the decomposition of the rocks in place. The boulders of Errere are entirely distinct from the rock of the serra, and consist of masses of compact hornblende. It would seem that these two ranges skirting a part of the northern and southern banks of the Lower Amazons are not the only remnants of this arenaceous formation in its primitive altitude. On the banks of the Japura, in the serra of Cupati, Major Coutinho has found the same beds rising to the same height. It thus appears, by positive evidence, that over an extent of a thousand miles these deposits had a very considerable thickness in the present direction of the valley. How far they extended in width has not been ascertained by direct observation, for we have not seen how they sink away to the northward, and towards the south the denudation has been so complete that, except in the very low range of hills in the neighborhood of Santarem, they do not rise above the plain. But the fact that this formation once had a thickness of more than eight hundred feet within the limits where we have had an opportunity of observing it, leaves no doubt that it must have extended to the edge of the basin, filling it to the same height throughout its whole extent. The

thickness of the deposits gives a measure for the colossal scale of the denudations by which this immense accumulation was reduced to its present level. Here, then, is a system of high hills, having the prominence of mountains in the landscape, produced by causes to whose agency inequalities on the earth's surface of this magnitude have never yet been ascribed. We may fairly call them denudation mountains. At this stage of the inquiry we have to account for two remarkable phenomena. First, the filling of the Amazonian bottom with coarse arenaceous materials and finely laminated clays, immediately followed by sandstones rising to a height of more than eight hundred feet above the sea; the basin meanwhile having no rocky barrier towards the ocean on its eastern side. Second, the wearing away and reduction of these formations to their present level, by a denudation, more extensive than any thus far recorded in the annals of geology, which has given rise to all the most prominent hills and mountain chains along the northern bank of the river. Before seeking an explanation of these facts, let us look at the third and uppermost deposit. This deposit, essentially the same as the Rio drift, has been minutely described above; but in the north it presents itself under a somewhat different aspect. As in Rio, it is a clayey deposit, containing more or less sand and reddish in color, though varying from deep ochre to a brownish tint. It is not so absolutely destitute of stratification here as in its more southern range, though the traces of stratification are rare, and, when they do occur, are faint and indistinct. The materials are also more completely comminuted, and, as I have said above, contain hardly any large masses, though quartz pebbles are some-times scattered throughout the deposit, and occasionally a thin seam of pebbles, exactly as in the Rio drift, is seen resting between it and the underlying sandstone. In some places this bed of pebbles even intersects the mass of the clay, giving it in such instances an unquestionably stratified character. There can be no question that this more recent formation rests unconformably upon the sandstone beds beneath it; for it fills all the inequalities of their denudated surfaces, whether they be more or less limited furrows, or wide, undulating depressions. It may be seen everywhere along the banks of the river, above the stratified sandstone, sometimes with the river mud accumulated against it; at the season of the enchente, or high water, it is the only formation left exposed above the water level. Its thickness is not great; it varies from twenty or thirty to

fifty feet, and may occasionally rise nearly to a hundred feet in height, though this is rarely the case. It is evident that this formation also was once continuous, stretching over the whole basin at one level. Though it is now worn down in many places, and has wholly disappeared in others, its connection may be readily traced; since it is everywhere visible, not only on opposite banks of the Amazons, but also on those of all its tributaries, as far as their shores have been examined. I have said that it rests always above the sandstone beds. This is true, with one exception. Wherever the sandstone deposits retain their original thickness, as in the hills of Monte Alegre and Almeirim, the red clay is not found on their summits, but occurs only in their ravines and hollows, or resting against their sides. This shows that it is not only posterior to the sandstone, but was accumulated in a shallower basin, and consequently never reached so high a level. The boulders of Errere do not rest on the stratified sandstone of the serra, but are sunk in the unstratified mass of the clay. This should be remembered, as it will presently be seen that their position associates them with a later period than that of the mountain itself. The unconformability of the ochraceous clay and the underlying sandstones might lead to the idea that the two formations belong to distinct geological periods, and are not due to the same agency, acting at successive times. One feature, however, shows their close connection. The ochraceous clay exhibits a remarkable identity of configuration with the underlying sandstones. An extensive survey of the two in their mutual relations, shows clearly that they were both deposited by the same water-system within the same basin, but at different levels. Here and there the clay formation has so pale and grayish a tint, that it may be confounded with the mud deposits of the river. These latter, however, never rise so high as the ochraceous clay, but are everywhere confined within the limits of high and low water. The islands also in the main course of the Amazons consist invariably of river-mud, while those arising from the intersection and cutting off of portions of the land by diverging branches of the main stream always consist of the well-known sandstones, capped by the ochre-colored clay. It may truly be said that there does not exist on the surface of the earth a formation known to geologists resembling that of the Amazons. Its extent is stupendous; it stretches from the Atlantic shore, through the whole width of Brazil, into Peru, to the very foot of the Andes. Humboldt speaks of

it "in the vast plains of the Amazons, in the eastern boundary of Jaen de Bracamoros," and says, "This prodigious extension of red sandstone in the low grounds stretching along the east of the Andes is one of the most striking phenomena - I observed during my examination of rocks in the equinoctial regions." 3. When the great natural philosopher wrote these lines, he had no idea how much these deposits extended beyond the field of his observations. Indeed, they are not limited to the main bed of the Amazons; they have been followed along the banks of its tributaries to the south and north as far as these have been ascended. They occur on the margins of the Huallaga and the Uayale, on those of the Ica, the Jutahy, the Jurua, the Japura, and the Purus. On the banks of the Japura, where Major Coutinho has traced them, they are found as far as the Cataract of Cupati. I have followed them along the Rio Negro to its junction with the Rio Branco; and Humboldt not only describes them from a higher point on this same river, but also from the valley of the Orinoco. Finally, they may be tracked along the banks of the Madeira, the Tapajos, the Xingu, and the Tocantins, as well as on the shores of the Guatuma, the Trombetas, and other northern effluents of the Amazons. The observations of Martius, those of Gardner, and the recent survey above alluded to, made by my assistant, Mr. St. John, of the valley of the Rio Guruguea and that of the Rio Paranyhyba, show that the great basin of Piauhy is also identical in its geological structure with the lateral valleys of the Amazons. The same is true of the large island of Marajo, lying at the mouth of the Amazons. And yet I believe that even this does not cover the whole ground, and that some future writer may say of my estimate, as I have said of Humboldt's, that it falls short of the truth; for, if my generalizations are correct, the same formation will be found extending over the whole basin of the Paraguay and the Rio de la Plata, and along their tributaries, to the very heart of the Andes. Such are the facts. The question now arises; how were these vast deposits formed? The easiest answer, and the one which most readily suggests itself, is that of a submersion of the continent at successive periods to allow the accumulation of these materials, and its subsequent elevation. I reject this explanation for the simple reason that the deposits show no sign whatever of a marine origin. No sea-shells nor remains of any marine animal have as yet been found throughout their whole extent, over a region several thousand miles in length, and from five to seven hundred miles in width. It is

contrary to all our knowledge of geological deposits to suppose that an ocean basin of this size, which must have been submerged during an immensely long period in order to accumulate formations of such a thickness, should not contain numerous remains of the animals formerly inhabiting it. 4. The only fossil remains of any kind truly belonging to it, which I have found in the formation, are the leaves mentioned above, taken from the lower clays on the banks of the Solimoens at Tonantins; and these show a vegetation similar in general character to that which prevails there to-day. Evidently, then, this basin was a fresh-water basin; these deposits are fresh-water deposits. But as the Valley of the Amazons exists to-day, it is widely open to the ocean on the east, with a gentle slope from the Andes to the Atlantic, determining a powerful seaward current. When these vast accumulations took place, the basin must have been closed; otherwise the loose materials would constantly have been carried down to the ocean. It is my belief that all these deposits belong to the ice-period in its earlier or later phases; and to this cosmic winter, which, judging from all the phenomena connected with it, may have lasted for thousands of centuries, we must look for the key to the geological history of the Amazonian Valley. I am aware that this suggestion will appear extravagant. But is it, after all, so improbable that, when Central Europe was covered with ice thousands of feet thick; when the glaciers of Great Britain ploughed into the sea, and when those of the Swiss mountains had ten times their present altitude; when every lake in Northern Italy was filled with ice, and these frozen masses extended even into Northern Africa; when a sheet of ice, reaching nearly to the summit of Mount Washington in the White Mountains (that is, having a thickness of nearly six thousand feet), moved over the continent of North America, -is it so improbable that, in this epoch of universal cold, the Valley of the Amazons also had its glacier poured down into it from the accumulations of snow in the Cordilleras, and swollen laterally by the tributary glaciers descending from the table-lands of Guiana and Brazil? The movement of this immense glacier would be eastward, and determined as well by the vast reservoirs of snow in the Andes as by the direction of the valley itself. It must have ploughed the valley bottom over and over again, grinding all the materials beneath it into a fine powder or reducing them to small pebbles, and it must have accumulated at its lower end a

moraine of proportions as gigantic as its own; thus building a colossal sea-wall across the mouth of the valley. I shall be asked at once whether I have found here also the glacial inscriptions, -the furrows, striae, and polished surfaces so characteristic of the ground over which glaciers have travelled. I answer, not a trace of them; for the simple reason that there is not a natural rock surface to be found throughout the whole Amazonian Valley. The rocks themselves are of so friable a nature and the decomposition caused by the warm torrential rains and by exposure to the burning sun of the tropics so great and unceasing, that it is hopeless to look for marks which in colder climates and on harder substances are preserved through ages unchanged. With the exception of the rounded surfaces so well known in Switzerland as the roches moutonnees, heretofore alluded to, which may be seen in many localities, and the boulders of Errere, the direct traces of glaciers as seen in other countries are wanting here. I am, indeed, quite willing to admit that, from the nature of the circumstances, I have not here the positive evidence which has guided me in my previous glacial investigations. My conviction in this instance is founded, first, on the materials in the Amazonian Valley, which correspond exactly in their character to materials accumulated in glacier bottoms; secondly, on the resemblance of the upper or third Amazonian formation to the Rio drift, 5. of the glacial origin of which there cannot, in my opinion, be any doubt; thirdly, on the fact that this fresh-water basin must have been closed against the sea by some powerful barrier, the removal of which would naturally give an outlet to the waters, and cause the extraordinary denudations, the evidences of which meet us everywhere throughout the valley. On a smaller scale, phenomena of this kind have long been familiar to us. In the present lakes of Northern Italy, in those of Switzerland, Norway, and Sweden, as well as in those of New England, especially in the State of Maine, the waters are held back in their basins by moraines. In the ice-period these depressions were filled with glaciers, which, in the course of time, accumulated at their lower end a wall of loose materials. These walls still remain, and serve as dams to prevent the escape of the waters. But for their moraines, all these lakes would be open valleys. In the roads of Glen Roy, in Scotland, we have an instance of a fresh-water lake, which has now wholly disappeared, formed in the same manner, and reduced successively to lower and lower levels by the breaking down or wearing

away of the moraines which originally prevented its waters from flowing out. Assuming then, that, under the low temperature of the ice-period, the climatic conditions necessary for the formation of land-ice existed in the Valley of the Amazons, and that it was actually filled with an immense glacier, it follows that, when these fields of ice yielded to a gradual change of climate, and slowly melted away, the whole basin, then closed against the sea by a huge wall of debris, was transformed into a vast fresh-water lake. The first effect of the thawing process must have been to separate the glacier from its foundation raising it from immediate contact with the valley bottom, and thus giving room for the accumulation of a certain amount of water beneath it; while the valley as a whole would still be occupied by the glacier. In this shallow sheet of water under the ice, and protected by it from any violent disturbance, those finer triturated materials always found at a glacier bottom, and ground sometimes to powder by its action, would be deposited, and gradually transformed from an unstratified paste containing the finest sand and mud, together with coarse pebbles and gravel, into a regularly stratified formation. In this formation the coarse materials would of course fall to the bottom, while the most minute would settle above them. It is at this time and under such circumstances that I believe the first formation of the Amazonian Valley, with the coarse, pebbly sand beneath, and the finely laminated clays above, to have been accumulated I shall perhaps be reminded here of my fossil leaves, and asked how any vegetation would be possible under such circumstances. But it must be remembered, that, in considering all these periods, we must allow for immense lapses of time and for very gradual changes; that the close of this first period would be very different from its beginning; and that a rich vegetation springs on the very borders of the snow and ice fields in Switzerland. The fact that these were accumulated in a glacial basin would, indeed, at once account for the traces of vegetable life, and for the absence, or at least the great scarcity, of animal remains in these deposits. For while fruits may ripen and flowers bloom on the very edge of the glaciers, it is also well known that the fresh-water lakes formed by the melting of the ice are singularly deficient in life. There are, indeed, hardly any animals to be found in glacial lakes. The second formation belongs to a later period, when, the whole body of ice being more or less disintegrated, the basin contained a larger quantity of water. Besides that arising from the

melting of the ice, this immense valley bottom must have received, then as now, all which was condensed from the atmosphere above, and poured into it in the form of rain or dew. Thus an amount of water equal to that now flowing in from all the tributaries of the main stream must have been rushing towards the axis of the valley, seeking its natural level, but spreading over a more extensive surface than now, until, finally gathered up as separate rivers, it flowed in distinct beds. In its general movement toward the central and lower part of the valley, the broad stream would carry along all the materials small enough to be so transported, as well as those so minute as to remain suspended in the waters. It would gradually deposit them in the valley bottom in horizontal beds, more or less regular, or here and there, wherever eddies gave rise to more rapid and irregular currents, characterized by torrential stratification. Thus has been consolidated ill the course of ages that continuous sand formation spreading over the whole Amazonian basin, and attaining a thickness of eight hundred feet. While these accumulations were taking place within this basin, it must not be forgotten that the sea was beating against its outer walls, against that gigantic moraine which I suppose to have closed it at its eastern end. It would seem that, either from this cause, or perhaps in consequence of some turbulent action from within, a break was made in this defense, and, the waters rushed violently out. It is very possible that the waters, gradually swollen at the close of this period by the further melting of the ice, by the additions poured in from lateral tributaries, by the rains, and also by the filling of the basin with loose materials, would overflow, and thus contribute to destroy the moraine. However this may be, it follows from my premises that, in the end, these waters obtained a sudden release, and poured seaward with a violence which cut and denuded the deposits already formed, wearing them down to a much lower level, and leaving only a few remnants standing out in their original thickness, where the strata were solid enough to resist the action of the currents. Such are the hills of Monte Alegre, of Obydos, Almeirim, and Cupati, as well as the lower ridges of Santarem. This escape of the waters did not, however, entirely empty the whole basin; for the period of denudation was again followed by one of quiet accumulation, during which was deposited the ochraceous sandy clay resting upon the denudated surfaces of the underlying sandstone. To this period I refer the boulders of Errere, sunk

as they are in the clay of this final deposit. I suppose them to have been brought to their present position by floating ice at the close of the glacial period, when nothing remained of the ice-fields except such isolated masses, ice-rafts, as it were; or perhaps by icebergs dropped into the basin from glaciers still remaining in the Andes on the edges of the plateaus of Guiana and Brazil. From the general absence of stratification in this clay formation, it would seem that the comparatively shallow sheet of water in which it was deposited was very tranquil. Indeed, after the waters had sunk much below the level which they held during the deposition of the sandstone, and the currents which gave rise to the denudation of the latter had ceased, the whole sheet of water would naturally become much more placid. But the time came when the water broke through its boundaries again, perhaps owing to the further encroachment of the sea and consequent destruction of the moraine. In this second drainage, however, the waters, carrying away a considerable part of the new deposit, furrowing it to its very foundation, and even cutting through it into the underlying sandstone, were, in the end, reduced to something like their present level, I, and confined within their present beds. This is shown by the fact that in this ochre-colored clay, and penetrating to a greater or less depth the sandstone below, are dug, not only the great longitudinal channel of the Amazons itself, but also the lateral furrows through which its tributaries reach the main stream, and the network of anastomosing branches flowing between them; the whole forming the most extraordinary river system in the world. My assumption that the sea has produced very extensive changes in the coast of Brazil -changes more than sufficient to account for, the disappearance of the glacial wall which I suppose to have closed the Amazonian Valley in the ice-period -is by no means hypothetical. This action is still going on to a remarkable degree, and is even now rapidly modifying the outline of the shore. When I first arrived at Para I was struck with the fact that the Amazons, the largest river in the world, has no delta. All the other rivers which we call great, though some of them are insignificant as compared with the Amazons, -the Mississippi, the Nile, the Ganges, and the Danube, -deposit extensive deltas; and the smaller rivers also, with few exceptions, are constantly building up the land at their mouths by the materials they bring along with them. Even the little river Kander, emptying into the

Lake of Thun, is not without its delta. Since my return from the Upper Amazons to Para I have made an examination of some of the harbor islands and also of parts of the coast, and have satisfied myself that, with the exception of a few small, low islands, never rising above the sea-level, and composed of alluvial deposit, they are portions of the mainland. detached from it, partly by the action of the river itself, and partly by the encroachment of the ocean. In fact, the sea is eating away the land much faster than the river can build it up. The great island of Marajo was originally a continuation of the Valley of the Amazons, and is identical with it in every detail of its geological structure. My investigation of the island itself, in connection with the coast and the river, leads me to suppose that, having been at one time an integral part of the deposits described above, at a later period it became an island in the bed of the Amazons, which, dividing in two arms, encircled it completely, and then, joining again to -form a single stream, flowed onward to the sea-shore, which in those days lay much farther to the eastward than it now does. I suppose the position of the island of Marajo at that time to have corresponded very nearly to the present position of the island of Tupinambaranas, just at the junction of the Madeira with the Amazons. It is a question among geographers whether the Tocantins is a branch of the Amazons, or should be considered as forming an independent river system. It will be seen that, if my view is correct, it must formerly have borne the same relation to the Amazons that the Madeira River now does, joining it just where Marajo divided the main stream, as the Madeira now joins it at the head of the island of Tupinambaranas. If in countless centuries to come the ocean should continue to eat its way into the Valley of the Amazons, once more transforming the lower part of the basin into a gulf, as it was during the cretaceous period, the time might arrive when geographers, finding the Madeira emptying almost immediately into the sea, would ask themselves whether it had ever been indeed a branch of the Amazons, just as they now question whether the Tocantins is a tributary of the main stream or an independent river. But to return to Marajo, and to the facts actually in our possession. The island is intersected, in its southeastern end, by a considerable river called the Igarape Grande. The cut made "through the land by this stream seems intended to, serve as a geological section, so perfectly does it display the three characteristic Amazonian formations above described. At its

mouth, near the town of Soure and at Salvaterra, on the opposite bank, may be seen, lowest, the well-stratified sandstone with the finely laminated clays resting upon it, overtopped by a crust; then the cross-stratified, highly ferruginous sandstone, with quartz pebbles here and there; and, above all, the well-known ochraceous, unstratified sandy clay, spreading over the undulating surface of the denudated sand-stone, following all its inequalities, and filling all its depressions and furrows. But while the Igarape Grande has dug its channel down to the sea, cutting these formations, as I ascertained, to a depth of twenty-five fathoms, it has thus opened the way for the encroachments of the tides, and the ocean is now, in its turn, gaining upon the land. Were there no other evidence of the action of the tides in this locality, the steep cut of the Igarape Grande, contrasting with the gentle slope of the banks near its mouth, wherever they have been modified by the invasion of the sea, would enable us to distinguish the work of the river from that of the ocean, and to prove that the denudation now going on is due in part to both. But besides this, I was so fortunate as to discover here unmistakable and perfectly convincing evidence of the onward movement of the sea. At the mouth of the Igarape Grande, both at Soure and at Salvaterra, on the southern side of the Igarape, is a sub-merged forest. Evidently this forest grew in one of those marshy lands constantly inundated, for between the stumps is accumulated the loose, felt-like peat characteristic of such grounds, and containing about as much mud as vegetable matter. Such a marshy forest, with the stumps of the trees still standing erect in the peat, has been laid bare on both sides of the Igarape Grande by the encroachments of the ocean. That this is the work of the sea is undeniable, for all the little depressions and indentations of the peat are filled with sea-sand, and a ridge of tidal sand divides it from the forest still standing behind. Nor is this all. At Vigia, immediately opposite to Soure, on the continental side of the Para River, just where it meets the sea, we have the counterpart of this submerged forest. Another peat-bog, with the stumps of innumerable trees standing in it, and encroached upon in the same way by tidal sand, is exposed here also. No doubt these forests were once all continuous, and stretched across the whole basin of what is now called the Para River. Since I have been pursuing this inquiry, I have gathered much information to the same effect from persons living on the coast. It is well remembered that, twenty years ago, there

existed an island, more than a mile in width, to the northeast of the entrance of the Bay of Vigia, which has now entirely disappeared. Farther eastward, the Bay of Braganza has doubled its width in the last twenty years, and on the shore, within the bay, the sea has gained upon the land for a distance of two hundred yards during a period of only ten years. The latter fact is ascertained by the position of some houses, which were two hundred yards farther from the sea ten years ago than they now are. From these and the like reports, from my own observations on this part of the Brazilian coast, from some investigations made by Major Coutinho at the mouth of the Amazons, on its northern continental shore, near Macapa, and from the reports of Mr. St. John respecting the formations in the valley of the Parahyba, it is my belief that the changes I have been describing are but a small part of the destruction wrought by the sea on the northeastern shore of this continent. I think it will be found, when the coast has been fully surveyed, that a strip of land not less than a hundred leagues in width, stretching from Cape St. Roque to the northern extremity of South America, has been eaten away by the ocean. If this be so, the Parahyba and the rivers to the northwest of it, in the province of Maranhão, were formerly tributaries of the Amazons; and all that we know thus far of their geological character goes to prove that this was actually the case. Such an extensive oceanic denudation must have carried away not only the gigantic glacial moraine here assumed to have closed the mouth of the Amazonian basin, but the very ground on which it stood. During the last four or five years, I have been engaged in a series of investigations, in the United States, upon the subject of the denudations connected with the close of the glacial period there, and the encroachments of the ocean upon the drift deposits along the Atlantic coast. Had these investigations been published in detail, with the necessary maps, it would have been far easier for me to explain the facts I have lately observed in the Amazonian Valley, to connect them with facts of a like character on the continent of North America, and to show how remarkably they correspond with facts accomplished during the same period in other parts of the world. While the glacial epoch itself has been very extensively studied in the last half-century, little attention has been paid to the results connected with the breaking up of the geological winter and the final disappearance of the ice. I believe that the true explanation of the presence of a large part of the superficial

deposits lately ascribed to the agency of the sea during temporary subsidences of the land, will be found in the melting of the ice-fields. To this cause I would refer all those deposits which I have designated in former publications as remodelled drift. When the sheet of ice, extending from the Arctic regions over a great part of North America and coming down to the sea, slowly melted away, the waters were not distributed over the face of the country as they now are. They rested upon the bottom deposits of the ice-fields, upon the glacial paste, consisting of clay, sand, pebbles, boulders, etc., underlying the ice. This bottom deposit did not, of course, present an even surface, but must have had extensive undulations and depressions. After the waters had been drained off from the more elevated ridges, these depressions would still remain full. In the lakes and pools thus formed, stratified deposits would be accumulated, consisting of the most minutely comminuted clay, deposited in thin laminated layers, or sometimes in considerable masses, without any sign of stratification; such differences in the formation being determined by the state of the water, whether perfectly stagnant or more or less agitated. Of such pool deposits overlying the drift there are many instances in the Northern United States. By the overflowing of some of these lakes, and by the emptying of the higher ones into those on a lower level, channels would gradually be formed between the depressions. So began to be marked out our independent river systems, -the waters always seeking their natural level, gradually widening and deepening the channels in which they flowed, as they worked their way down to the sea. When they reached the shore, there followed that antagonism between the rush of the rivers and the action of the tides, -between continental outflows and oceanic encroachments, -which still goes on, and has led to the formation of our eastern rivers, with their wide, open estuaries, such as the James, the Potomac, and the Delaware. All these estuaries are embanked by drift, as are also, in their lower course, the rivers connected with them. Where the country was low and flat, and the drift extended far into the ocean, the encroachment of the sea gave rise, not only to our large estuaries, but also to the sounds and deep bays forming the most prominent indentations of the continental coast, such as the Bay of Fundy, Massachusetts Bay, Long Island Sound, and others. The unmistakable traces of glacial action upon all the islands along the coast of New England, sometimes lying at a very

considerable distance from the mainland, give an approximate, though a minimum, measure of the former extent of the glacial drift seaward, and the subsequent advance of the ocean upon the land. Like those of the harbor of Para, all these islands have the same geological structure as the continent, and were evidently continuous with it at some former period. All the rocky islands along the coast of Maine and Massachusetts exhibit the glacial traces wherever their surfaces are exposed by the washing away of the drift; and where the drift remains, its character shows that it was once continuous from one island to another, and from all the islands to the mainland. It is difficult to determine with precision the ancient limit of the glacial drift, but I think it can be shown that it connected the shoals of Newfoundland with the continent; that Nantucket, Martha's Vineyard, and Long Island made part of the mainland; that, in like manner, Nova Scotia, including Sable Island, was united to the southern shore of New Brunswick and Maine, and that the same sheet of drift extended thence to Cape Cod, and stretched southward as far as Cape Hatteras;-in short, that the line of shallow soundings along the whole coast of the United States marks the former extent of glacial drift. The ocean has gradually eaten its way into this deposit, and given its present outlines to the continent. These denudations of the sea no doubt began, as soon as the breaking up of the ice exposed the drift to its invasion; in other words, at a time when colossal glaciers still poured forth their load of ice into the Atlantic, and fleets of icebergs, far larger and more numerous than those now floated off from the Arctic seas, were launched from the northeastern shore of the United States. Many such masses must have stranded along the shore, and have left various signs of their presence. In fact, the glacial phenomena of the United States and elsewhere are due to two distinct periods: the first of these was the glacial epoch proper, when the ice was a solid sheet; while to the second belongs the breaking up of this epoch, with the gradual disintegration and dispersion of the ice. We talk of the theory of glaciers and the theory of icebergs in reference to these phenomena, as if they were exclusively due to one or the other, and whoever accepted the former must reject the latter, and vice versa. When geologists have combined these now discordant elements, and consider these two periods as consecutive, -part of the phenomena being due to the glaciers, part to the icebergs and to freshets consequent on their breaking up, -they will find they have

covered the whole ground, and that the two theories are perfectly consistent with each other. I think the present disputes upon this subject will end somewhat like those which divided the Neptunic and Plutonic schools of geologists in the early part of this century; the former of whom would have it that all the rocks were due to the action of water, the latter that they were wholly due to the action of fire. The problem was solved, and harmony restored, when it was found that both elements had been equally at work in forming the solid crust of the globe. To the stranded icebergs alluded to above, I have no doubt, is to be referred the origin of the many lakes without outlet existing all over the sandy tract along our coast of which Cape Cod forms a part. Not only the formation of these lakes, but also that of our salt-marshes and cranberry-fields, I believe to be connected with the waning of the ice-period. I hope at some future time to publish in detail, with the appropriate maps and illustrations, my observations on our coast changes, -and upon other phenomena connected with the close of the glacial epoch in the United States. It is reversing the natural order of things to give results without the investigations which have led to them; and I should not have introduced the subject here, except to show that the fresh-water denudations and the oceanic encroachments which have formed the Amazonian Valley, with its river system, are not isolated facts, but that the process has been the same in both continents. The extraordinary continuity and uniformity of the Amazonian deposits are due to the immense size of the basin enclosed, and the identity of the materials contained in it. A glance at any geological map of the world will show the reader that the Valley of the Amazons, so far as any attempt is made to explain its structure, is represented as containing isolated tracts of Devonian, Triassic, Jurassic, cretaceous, tertiary, and alluvial deposits. As is shown by the above sketch, this is wholly inaccurate; and whatever may be thought of my interpretation of the actual phenomena, I trust that, in presenting for the first time the formations of the Amazonian basin in their natural connection and sequence, as consisting of three uniform sets of comparatively recent deposits, extending throughout the whole valley, the investigations here recorded have contributed something to the results of modern geology.

~ THE END ~

1. The atlas in Martius's Journey to Brazil, or the sketch accompanying Bates's description of these hills in his Naturalist on the Amazons, will give an idea of their aspect.

2. Water-path in the forest.

3. Bohn's edition of Humboldt's Personal Narrative, p.134. Humboldt alludes to these formations repeatedly: it is true that he refers them to the ancient conglomerates of the Devonian age, but his description agrees so perfectly with what I have observed along the banks of the Amazons, that there can be no doubt he speaks of the same thing. He wrote at a time when many of the results of modern geology were unknown, and his explanation of the phenomena was then perfectly natural. The passage from which the few lines in the text are taken shows that these deposits extend even to the Llanos.

4. I am aware that Bates mentions having heard, that at Obydos, calcareous layers, thickly studded with marine shells, had been found interstratified with the clay, but he did not himself examine the strata. The Obydos shells are not marine, but are fresh-water Unios, greatly resembling Aviculas, Solens, and Arcas. Such would-be-marine fossils have been brought to me from the shore opposite to Obydos, near Santarem, and I have readily recognized them for what they truly are, fresh-water shells of the family of Naiades. I have myself collected specimens of these shells in the clay beds along the banks of the Solimoens, near Teffe, and might have mistaken them for fossils of that formation had I not known how Naiades burrow in the mud. Their resemblance to the marine genera mentioned above is very remarkable, and the mistake as to their true zoological character is as natural as that by which earlier ichthyologists, and even travellers of very recent date, have confounded some fresh. water fishes from the Upper Amazons of the genus Pterophyllum (Heckel) with the marine genus Platax.

5. As I have stated in the beginning, I am satisfied that the unstratified clay deposit of Rio and its vicinity is genuine glacial drift, resulting from the grinding of the loose materials interposed between the glacier and the solid rock in place, and retaining to this day the position in which it was left by the ice. Like all such

accumulations, it is totally free from stratification. If this be so, it is evident, on comparing the two formations, that, the ochraceous sandy clay of the Valley of the Amazons has been deposited under different circumstances; that, while it owes its resemblance to the Rio drift to the fact that, its materials were originally ground by glaciers in the upper part of the valley, these materials have subsequently been spread throughout the whole basin and actually deposited under the agency of water.