Art. LXX.—*Denudation as a Factor of Geological Time.*

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The many discussions among geologists and physicists which have taken place from time to time as to the age of the earth have brought under review wide diversities of opinion. The mind is lost in wonder as we go back and back from age to epoch, from epoch to period, and from period to era in the order of geological time as illustrated by stratigraphy, or the sequence of the rocks; but these chronological terms only represent one aspect of activity in the full history of the earth. Time was when the conditions of the earth were such that life, as we know it to-day, could not exist; when the waters which now cover its surface could not have remained as a liquid; and when from pole to pole the rocks were heated beyond the possibility of sustaining life. The geologist is unable to say how long the earth remained in the condition of inability to sustain organic life, for, reasoning from the known, his aim is to estimate time by the changes such as he knows must have taken place since life first became possible on the earth, and when differentiations were the fewest consonant with what is understood as the maintenance of the simplest organisms. The physicist, on the other hand, deals with the history of the earth from an altogether different standpoint. He views it as something to be interpreted only by the application of certain laws to physical or assumed physical conditions, his conclusions being based—first, upon the assumed original temperature of the earth, and its annual rate of cooling; second, upon the loss of energy of the earth's rotation in virtue of the moon's attraction, as evidenced by the tides; and third, upon the origin and age of the sun as a dispenser of heat. On the supposed original temperature of the earth and its annual loss of heat by radiation, estimates have been made that the globe could not have become consolidated less than twenty millions of years ago, nor more than four hundred millions ago; for, had the latter been the case, there would have been no alteration of temperature when descending into the earth, such as is everywhere experienced by miners when sinking or boring through the earth's crust. As to the loss of energy of the earth's rotation owing to the friction of the tide-wave, Sir William Thompson contends that, had the earth become solid some ten thousand million years ago, or, indeed, any period beyond one hundred million years, the polar flattening would have been greater than now,

owing to the more rapid motion which would have taken place; whilst Professor Tait, agreeing generally with the views put forward by Helmholtz and Newman, says that "the amount of heat produced by the impact of masses from space which are assumed to have given origin to our sun could not have supplied the earth even with its present quantity of heat for a much longer period than twenty millions of years. *Nature*, 3rd January, 1895, contains a criticism by Mr. John Perry of Sir William Thompson's (now Lord Kelvin) estimate, in which it is stated that "if at the beginning of time there was an increase of 1° Centigrade in 45ft. (towards the earth's interior), and now there is an increase of 1° Centigrade in 90ft., the lapse of time is 28,930,000,000 years, or 290 times Lord Kelvin's estimate, and the core has cooled from 8,000 to 4,000 degrees."

It will thus be seen how diverse are the views of the physicists who deal with the age of the earth from a mathematical standpoint, and it seems very doubtful whether such estimates as those given above have any scientific value whatever. Were it to be announced that a bank-note for a large amount had been lost either between Napier and Dunedin, or between those places and the Cape of Good Hope, the announcement would be just as general and unsatisfactory as that made by Sir William Thompson and others as to the age of the earth. It is true that such estimates often form the basis of what are termed "working theories"; but as standards of scientific value they are of small importance, and it is well to keep this in mind when considering the question of earth-changes such as we now see in daily progress. But it is curious how geologists, having received a "time-period theory" from the mathematicians, have endeavoured to bring that theory into the full light of day by striving to show that the organic and surface changes on the earth must have required an allowance of time equal to what the mathematicians say must have gone by since the earth became a solid mass and assumed its present form. The late Dr. Croll, for example, suggested a period of not less than sixty millions of years as being needed to bring about the changes or the conditions such as we now have; whilst Dr. Houghton, in the second of his able lectures on "Physical Geography," pp. 94–95, estimates "the whole duration of geological time down to the Miocene-Tertiary epoch at 152,675,000 years, and for the whole duration of geological time a minimum of two hundred millions of years." Now, Croll and Houghton have based their estimates upon the maximum thickness of the known stratified rocks, and with this they have taken the rates of denudation of certain rivers as determined by the amount of sediment which such rivers annually carry to the sea. Thus, Dr. Houghton says that the total

thickness of all the "Azoic, Palæozoic, and Neozoic rocks amounts to 177,200ft., and, allowing 861·6 years as the time required for the denudation of 1ft. of surface in the several river-basins, at least a hundred and fifty-two million years must have passed of geological time down to the close of the Miocene-Tertiary epoch."

I have purposely prefaced my subject on "Denudation as a Factor of Geological Time" with the views which are held, or have been held, by the leaders of geological thought, as it enables us to see what vast steps have been taken backward, as it were, into the past since the days when men thought that the earth's history dated back some four or five thousand years before the Christian era. But, great as is the factor of denudation in estimating the history of change on the earth's surface, the traces of past life as unfolded in the stratified rocks raise questions for consideration which, as far as our present knowledge goes, can only be settled by assuming long intervals of time, as by no other means—unless special centres of creation are recognised—can it be supposed that animals and plants representing a past highly-differentiated fauna and flora could have dwelt on the earth and have become adapted to conditions such as do not now and could not now exist. And here I would emphasize a fact too often overlooked by naturalists and geologists—viz., that, whilst change has gone on ever since time was, at no two moments are the conditions of existence the same. This is why life is ever-changing and various. We cannot have two plants or two animals alike, for, try how we may, we cannot place them as to origin and treatment under absolutely the same conditions. This is nature's mode of dealing with matter. To change is to live, and could we learn the art of changing our physical nature—that is, of constantly adapting ourselves to environment—the "elixir of life" would be ours, and man's mastery over nature would be complete. But, fortunately for us, nature will still be our master, for no modification, no change, will ever differentiate the flesh into spirit or the spirit into flesh; for, as Marcus Aurelius puts it,—

> What springs from earth dissolves to earth again,
> And heaven-born things fly to their native seat.

When this earth of ours first became solidified, as it must have become in the process of cooling, many years passed by before its temperature was sufficiently cool to enable the watery vapour of the atmosphere to be condensed. Water does not and cannot remain as water, except under special conditions, above a temperature of 100° C. or 212° Fahr. It is possible that the vapour enveloped the whole earth to the point of saturation at a temperature much above what is now experienced. My reason for thinking so is that the dimen-

sions of the earth were much greater than now, and the pressure of the atmosphere on the surface was therefore less. We know as a physical fact that there is a relationship between the pressure of the air and the change of water into vapour, and if the pressure of the air, as suggested, was less in the earlier history of the earth and long after the surface-temperature was below 100° C. the conditions then existing were quite unlike what we are acquainted with in these times. Then the water would have been heated by convection from below rather than by conduction, as now, from above. There would certainly have been more evaporation, and the slightest temperature-changes in the atmosphere such as there would necessarily be must have brought about heavy mists and a moist heated climate over the entire surface of the earth. Conditions such as these would produce abundance of life without great differentiations, for differentiations in the organic world are the direct outcome of temperature contrasts. When the earth was in process of solidifying it was with its atmosphere in direct contact with its external surroundings. The temperature of outer space—that is, of the space outside the limits of the atmosphere—is said to be 250° or more below the zero of Centigrade. An incandescent earth with a temperature outside its enclosing envelope approaching the zero of cold is placing two opposites in direct contrast to one another. At such a time there were no contrasts within the earth itself, and it was only when the earth began to part with its heat into outer space at an unequal rate, as it does now, that earth-contrasts became possible, and that differentiation in the animal and vegetable world began. But these differentiations for a long time were necessarily small, seeing that they varied in proportion to the conductivities and radiating capacities of the surface-rocks at that time. As pointed out above, the waters were heated by convection rather than by conduction, and it was by this means that the climatic conditions of the earth were similar, or nearly so, throughout each zone.

It will appear from these considerations that when life first made its appearance on the earth the types were the simplest possible; for high types, both in the animal and vegetable kingdom, imply great differentiations and wide contrasts. Thus the types have continued to increase in number and complexity in direct proportion to the changes which have been brought about on the earth's surface by the operation of those laws which depend upon the inequality of temperatures for their effective action. From this it follows that life is dependent on environment. To suppose that animals or plants could flourish under conditions not adapted or suited to them is to assume an impossibility. Plants and animals in a state of nature are best adapted to their environment, because were

it otherwise they would die. It is therefore a manifest impossibility for the climates and environment of the past to have been similar to what they now are. We know what the organic results are of our present environment, such as have been brought about by differentiations and adaptations operating through all past time; but, because these are known, can it be asserted or even suggested that similar causes operated to bring about the organic results such as are found among the ruins and rearrangements of the past? Were the physical conditions of New Zealand to-day similar to what they were when the Dinornis and Harpagornis were found living, we might wonder what has caused their disappearance at a comparatively recent period; but the operation of the law which brought about the extinction of Palæotherium in the Lower Tertiary, of Deinotherium in the Pliocene, and of the Mastodon in the American drift, no doubt brought about the disappearance of the noble avifauna of New Zealand. The physical conditions in the earth are widely unlike what they once were, and every remove, every change, is necessarily accompanied by modifications and adaptations in the organic world. Nor could anything else be expected if we suppose that organic life always exists under conditions best adapted to it. Every remove onward in time is like the effect produced upon a people by great social or political changes. To many, a social or political change means succour, to others disaster; but the impulse is nevertheless forward, as evolution always is. Viewed from this standpoint, it is evident that life in each age, epoch, period, and era was the best of its kind suited thereto; but can it be imagined that an estimate of earth-change such as is now in operation can be taken as a basis in estimating changes in the ages gone by—a complex differentiation by which to interpret a simple one in the order of nature? All palæontological evidence implies simpler physical conditions in times gone by, and a growing complexity as we approach Post-Tertiary times; and it is therefore impossible, without running serious risk of error, to base the physical changes of the past upon what we now see in progress. As a geological factor denudation is of high importance in estimating change, and it must have been of yet higher importance in the earlier periods of the earth. The work done by moving water can only be imagined in part by bringing into prominence the fact that not less than thirty miles of sedimentary rocks are said to have been deposited from the beginning of the Azoic era to the close of the Tertiary. But from whence came so much material?

The average height of the land-surface of the earth at the present time is not more than 2,500ft., or less than half a mile, so that the thickness of the sedimentary rocks, as estimated

by leading geologists, exceeds the average height of the land-surface by not less than sixty times. These sedimentary deposits have been removed, principally by the agency of water, from some place where they were *in situ*, just as rocks are now removed by means of denudation from a higher to a lower level. Denudation is a necessary condition of inequality of surface when acted on by physical agents. The greater the instability of rock-masses the more certain is the prospect of denudation, for every physical agent acts in breaking down rocks and bringing them to one common level. But, recognising all this, is it possible to formulate a standard for the measurement of past time by an assumed standard of denudation which, the world over, must vary according to the character of the deposits composing every river-basin, in conjunction with its specialised-climatic conditions?

As a test of actual change now in progress a knowledge of the amount of material borne by rivers to the sea is of high scientific value, and the results obtained by actual experiment give some idea as to the prospects to come. But even here the knowledge is of relative value only, for rivers, like everything else in nature, differentiate; they have a beginning, they undergo change, attain their maximum of development, and in course of time they disappear. Every river in Hawke's Bay affords evidence of the truth of this statement, and every tributary is an illustration of the surface-changes in progress, and of the differentiations which rivers undergo during the course of their history. The index of denudation of those rivers where experiments have been made shows wide variations, as is seen in the case of the Danube and the Po in Europe. The basin of the Danube is said to be lowered at the rate of one foot in 6,846 years, and that of the Po one foot in 729 years; but these rates have varied, and must have varied, ever since the rivers first began to flow. The elevation of the Po and Danube in their upper course, where denudation is always most powerful, would largely increase their effective power for transport of denuded material; and a similar remark applies to every river on the earth's surface. The increase in the denuding-power of moving water varies, according to Hopkins, as the sixth power of the velocity of the current; so that by simply doubling the rate of flow in a river its effective carrying-power is increased to no less than sixty-four times, and if trebled its power is increased 729 times. And every geologist must recognise the importance of this varying power in estimating surface-changes as brought about by the action of moving water. For years my attention has been directed to this aspect of geological inquiry, and it has always appeared to me that the plan of estimating the amount of material

carried by a few rivers to the sea and taking this as the index-standard by which to provide a time-measure for estimating the age of the earth is by no means satisfactory. No account appears to have been taken of the power of ice as a denuding factor within the arctic regions, and, as far as I am aware, no one has ever attempted to glean information as to breakaways and land-slips which take place within specified areas. Both of these are aspects of denudation which cannot be overlooked in formulating an index of past time as estimated in terms of denudation. The lowering of a river-basin necessarily modifies the rate of flow, and the carrying capacity varies in proportion to the lowering of the basin by means of land-movements of all kinds. The east-coast district of this island extending from Cape Turnagain to East Cape, a distance of about three hundred miles, will illustrate what I mean.

This district is bounded towards the west by the Ruahine and Raukumaru Mountain-ranges, and embraces an area of 8,970 square miles, or 5,740,800 acres. The counties included within this area are Patangata, Waipawa, Hawke's Bay, Wairoa, Cook, and Waiapu. The land is mostly hilly, and the rocks abutting on the sea-coast belong mainly to the Later Secondary and the Older Tertiary formations, and are made of stiff blue clays, marls, sandstones, with here and there indurated limestones. In the interior the rocks belong to the Younger Tertiary group—shingle, grits, clays, and limestones predominating. The average rainfall for the whole district is about 40in., being less along the coast than towards the uplands in the west. The rainfall, however, is a varying quantity, and appears to increase and decrease in regularly-recurring cycles of from six to nine years. Thus, in 1866 there was a deficiency of rainfall in the district of 7·2in.; in 1872, or six years later, the deficiency was 13·32in.; in 1878, or six years later, the deficiency rose to 16·16in.; and in 1886–87, or eight years later, the deficiency was actually 20·26in. The years of diminished rainfall were followed by years in excess of the average, some years showing a large increase, whilst others approached the normal standard. In 1892 the average rainfall was more than reached, but in the two succeeding years the rainfall exceeded all previous records, more particularly in 1893, when more than 60in. of rain fell over the entire district. Now, 40in. of rainfall spread over the district under notice represents 5·6 cubic miles of water. This water disappears from the land by river-drainage, by percolation, by evaporation, and by the demands of vegetation. During years of shortage the rainfall was diminished by one-third the normal quantity, which means that about 3·7 cubic miles of water fell instead of 5·6 miles. In years of excess the quantity was

increased by one-third; or, in other words, the rainfall was increased to 7·5 cubic miles. The difference between 3·7 cubic miles and 7·5 cubic miles is very great, and wide differences must be expected in the denuding effects which each quantity of water is likely to produce when spread over the same area.

But even an excessive rainfall may be so distributed as to time that its effects as a denuding power are but slightly greater than under what may be termed normal conditions. As pointed out above, it is the intensity of flow, or of movement, that produces unusual denuding effects, and this is well shown by the effects of the floods which took place in this district in December and January, 1893–94. When going over the district shortly after the floods had taken place, I was surprised to find how much the appearance of the country had changed. Thousands of breakaways or slips were to be seen, some of them of large extent; and I was impressed with the absolute necessity of keeping a record of surface-changes such as had been produced not so much by an excessive rainfall as by a heavy continuous downpour at a time when the surface of the country was saturated. I had traversed the district for sixteen years, but, although occasional large slips had been met with, there had been nothing to approach the marvellous changes in 1893–94, which showed in the completest manner how largely a district may have its surface-features modified by a rainfall which represents only a slight deviation from the normal conditions of that district. As I did not see how to obtain the necessary information concerning the changes brought about in so extensive a district without a heavy expenditure of time such as I was unable to afford, I communicated with Sir James Hector, the head of our New Zealand Geological Department, and he very kindly offered to obtain from the settlers such information as I might deem necessary for the purpose of my inquiry. Subsequently a circular letter was issued by Sir James, as follows: "For the purpose of keeping a record of the destructive landslips which took place along the east coast of the North Island during the years 1893–94, holders of land will oblige by filling in the queries given below, and returning the paper at the earliest opportunity: 1. County and locality. 2. Owner. 3. Area and situation of land. 4. What area do you estimate slipped away at the period named? 5. Do you remember any similar period when slips were as numerous? 6. Give rock-materials—*i.e.*, whether clays, sands, or hard rock." It was manifestly impossible to send a letter to every settler throughout the district irrespective of the area of land occupied, and only large holders were communicated with. In the majority of cases the queries have been answered; and I wish here to express my thanks and obligations to Sir James Hector for the

valuable help he has rendered me in this matter. The summarised results will be found at the end of this paper, and I am satisfied that in years to come they will be found of great public and scientific value. As far as I am aware, they constitute the only reliable data dealing with surface-denudation as the result of excessive rainfall, and they provide likewise unmistakable evidence that denudation as estimated by the material held in suspension and carried by certain rivers is by no means a true index of the time which has gone by since rock-materials began to differentiate as sedimentary deposits.

For the purpose of easy reference the results are classed under three heads: 1st, occupiers in the Counties of Patangata and Waipawa; 2nd, occupiers in Hawke's Bay; 3rd, occupiers in Wairoa and Cook *cum* Waiapu.

As already pointed out, the total area of the district is about five and three-quarter millions of acres, but this includes mountain-tops, forest-lands, and large areas still in the possession of the natives and from which no returns are available. Answers have been received from owners representing 1,158,237 acres, and from these sufficient information is available to show the extent of the denudation in a number of important river-basins. In some cases the owners omit to give an estimate of the area of slips on their lands, although they point out their frequency and the alterations they have caused by filling up creeks and modifying waterways. Thus, the Hon. J. D. Ormond writes, "Slips everywhere; the banks of creeks especially have slipped badly, but it is hard to estimate the acreage." Mr. Rechab Harding, of Mount Vernon, says, "Some of the hills appear to have been filled with water like sponge, whilst their bases have been enlarged and their heights lowered." Sir George Whitmore says of his property at Tuparoa, County Waiapu, "Cannot furnish a reliable estimate. At one spot the coast for quite half a mile has moved towards the sea." Mr. Arthur Harding, of the Kereru, writes that he has resided in his present district for sixteen years, and has never known anything approaching the extent of destruction. "It is impossible," he continues, "to estimate the damage done, but I have never seen one-quarter of the slips during the whole time I have resided in the district." Mr. Moore, of Waimarama, south of Cape Kidnappers, says in a note, "It is impossible to say the extent of the slips in this district, as the whole coast for fifteen miles on this run appears to be on the move. In some instances hundreds of thousands of tons have come down, blocking the beach up, but the sea washes the clay away very quickly. These large slips came down in December, 1893, when the creeks were higher than has ever been known by the oldest Maoris."

In answer to question No. 5, "Do you remember any

similar period when slips were as numerous?" the replies are emphatic and decisive. Several of the settlers refer to the heavy rainfall that took place on certain days. Thus, Mr. Gray, of Waiohika, Poverty Bay, says, "The rainfall at Waiohika measured over 15·36in. from 6 a.m. on 17th June to 6 a.m. on 19th June, sometimes falling at the rate of 0·7in. per hour." Mr. W. H. Smith, of Petane, noticed a similar downpour in December, when 3in. of rain fell in five hours, 5·49in. in ten hours, and 6·30in. in nineteen consecutive hours. It is when rains like these take place over a district that denudation becomes so marked and often disastrous, as in the case of the Hawke's Bay floods in December, 1893; and most of the slips along the East Coast appear to have taken place at this period of unusual rainfall.

The total estimate of slips for an area of 1,158,237 acres is 7,693 acres: this is exclusive of the "slips everywhere" which are said to have taken place on certain lands where estimates are not given. The estimates given here amount to 0·66 per cent. of all the land from which returns have been received. In some districts the slips or breakaways appear to have been unusually large. Thus, Mr. George Ormond, on Te Mahia, facing Hawke's Bay, estimates that 500 acres in a block of 5,000 acres have slipped away. Mr. Woodbine Johnson, of Maraetaha, Poverty Bay, estimates his slips at 1,500 acres out of a total area of 11,500 acres, or more than 13 per cent. of the whole. But even this estimate is exceeded in the case of Mr. Gray, of Waiohika, who estimates that 15 per cent. of his land slipped away in one property of his containing 2,200 acres, and which was improved grass-land. Open and improved country appears to have suffered most and bush country least. I have seen some of the extraordinary results of the slips on Mr. Gray's land at Waiohika. In one case a whole hill-side, some hundreds of feet in height, broke away, crossed a creek at its foot, filled an adjoining valley, and passed over a public road on the opposite side. The impetus was such that huge boulder-like rocks were lodged on the adjacent hill-side. In a few years all traces of this immense breakaway will have disappeared, and some geologist may even suggest that the perched blocks were lodged on the hill-side by means of glaciers. But glacial action is not needed to account for the transference of such blocks, for the degradation of the land is constant, and is much more influenced by water than ice; and this was truer in the earlier periods of sedimentation than now.

The large area which is shown to have broken away within a specified district will enable us to understand some of the effects produced on the earth's surface by a rainfall somewhat in excess of the annual average. But let it be assumed that the abnormal rainfall became the average rainfall over the district,

and then observe the rapidity with which denudation would proceed. The average annual rainfall for the district aggregates 5·6 cubic miles of water for distribution. This quantity would be increased to 7·5 cubic miles, as it was in 1893–94, when disastrous floods and breakaways occurred. If we assume that one-third of the total rainfall is carried back to the ocean by streams and rivers, then the carrying capacity of the rivers is represented by 1·9 cubic miles. This quantity was increased to 2·5 cubic miles in 1893. The amount of sedimentary matter held in suspension by the rivers varies very much according to the time of the year. In winter it is greatest, in summer least, in what may be termed normal conditions of flood; but in times of heavy flood the quantity of material suspended in the water is much increased. In some cases I have observed along the coast quite one-twentieth of the whole stream made up of earthy matter, but the instances are local and rare; and from numerous experiments carried on by me in the case of the river-waters of the Tutaekuri and Ngaururoro I conclude that, taking the three periods, winter, summer, and flood, into account, not less than 1 in 450 parts by volume of all the river-waters in this district consists of organic and inorganic matter held either in suspension or solution. On this estimate there is annually carried to the sea by our rivers 0·004 of a cubic mile of denuded earth; or, in other words, one cubic mile of the surface is carried away by the rivers and deposited in the sea in 250 years. The average height of the land throughout the district is certainly not more than 900ft., so that the 8,970 square miles which it embraces contain 1,530 cubic miles of land above sea-level, and which is available for denudation. Assuming the same rate of river-denudation as is now in progress, it will take on this estimate 382,500 years to plane down the land to sea-level and bring about conditions when the circulation of water in the land would be impossible by means of rivers. I have purposely worked out this case to show how useless as a geological index of time it would be to apply the known rate of denudation by means of our rivers to the age of the earth, in the face of the changes—the surface-changes—which are shown to have taken place over this district, and which are altogether independent of river-denudation. The 7,693 acres of breakaways, in a total area of 1,158,237 acres, represents 0·66 of an acre per cent., and if the average movement of each slip is only 50ft. the lowering of the entire district amounts to over 4in. As the entire area of the district under notice contains 5,740,800 acres, I do not think the estimate is overdrawn by naming 20,000 acres as having slipped away during the period of 1893–94, or an area which represents the lowering of the land by not less than 12in. To this must be added the enormous denudation which is constantly proceeding along the coast,

there being a glacier-like movement of the rocks seaward for not less than a hundred miles between the East Cape and Turnagain.

These modifying results of denudation are to be met with everywhere, and operating more or less under all conditions and climes. River-basins become lowered, the rate of flow and the power of carriage are diminished, new basins are formed, and these in combination with the varying character of climate make it impossible to accept results depending upon so many complex and modifying causes in estimating the past age of the earth and as a standard measure of denudation in past time. We are certain that long periods of time must have gone by to bring about changes of the earth's surface and the differentiations in the flora and fauna such as are recorded in the rocks themselves; but whether the years are to be reckoned by tens of thousands, hundreds of thousands, or by millions there is no means of knowing. No matter how we strive to arrive at a correct index of geological time the difficulties are the same. The animal equally with the vegetable kingdom has reached a complex—indeed, a highly complex—period of differentiation; but this differentiation has not been brought about by corresponding differentiations of the earth's surface, acted on as it has been from the beginning by forces all of which primarily depend on the sun for their activity and effectiveness. The world has grown from the simple to the complex by ever-changing and ever-modifying conditions. Every to-day differs essentially from its yesterday; and, although we know that animals and plants have come down through the ages by a constant advance in adaptation and specialisation, it cannot be asserted what conditions prevailed in times past to produce all those earth-changes without which changes in the flora and fauna were impossible. One thing, however, is certain: that time cannot be measured by river-denudation, and the estimates given by Houghton and others as to the time necessary for the deposition of the sedimentary rocks are just as uncertain and unsatisfactory as the estimates which the physicists and mathematicians have given us. The facts relating to surface-denudation which appear below supply evidence of rapid changes of surface irrespective of river-denudation, and the time will no doubt come when similar facts will be collated for other areas and countries. Such facts, however, whilst they supply valuable information to the geologists as to surface-changes now in progress, and to the possibility of great changes when physical conditions deviate but slightly from what may be termed the normal standard, cannot supply a reliable factor in the determination of geological time, any more than the inferences to be drawn from denudation by rivers, whether European, Asiatic, or other.

WAIPAWA *cum* PATANGATA COUNTIES.—Square miles, 1,091; acreage, 1,216,640.

Owner.	Area.	Position.	Estimated Slips.	Similar Period.	Rock-materials.
	Acres.				
J. Rhodes	7,000	Ruataniwha ..	1 acre	No	Yellow clay with shingle.
A. Carlyon	10,000	Ruataniwha ..	2 "	No	Yellow clay with shingle.
John Harding ..	15,000	Ruataniwha ..	15 "	In 1867 (June) almost similar	Limestone and chalk marls.
J. Cowper and Knight..	16,000	Left bank Manawatu	10 "	No	Limestone, papa, and clay.
J. and F. Holden ..	12,000	Ruataniwha and Waimate	20 "	No	Shingle and clays.
F. J. Tiffen	7,000	Oero, Patangata ..	Minor slips	Yes	Clay on papa.
Archdeacon S. Williams	38,000	Patangata ..	280 acres	In 1878 (Mangakuri)	Limestone, clay, and papa.
Bank of New Zealand..	31,000	Mangakuri, Danevirke	30 "	No	Clay on papa, and shingle.
Trustees C. J. Nairn ..	26,000	Pourere ..	30 "	Never	Clays on papa and limestone.
J. Speedy	4,000	Wainui	5 "	No	Clay and papa.
J. D. Ormond ..	30,000	Wallingford ..	Cannot estimate	(See *ante*.) In 1878–79, bad	Clay and marls.
R. S. Curling.. ..	15,000	Oero, Patangata ..	60 acres	No	Limestone, sandstone, and papa.
G. and P. Hunter ..	30,000	Porangahau	300 "	No	Clay and limestone.
Beetham Brothers ..	14,300	Patangata, 10 miles coast	1,000 "	No	Blue clay (papa) and limestone.
St. Hill Brothers ..	29,000	Near Cape Turnagain, sea-coast	400 "	No	A papa clay.
Totals	284,300		2,153 acres		

HAWKE'S BAY COUNTY.—Square miles, 3,232; acreage, 2,068,480.

Owner.	Area.	Position.	Estimated Slips.	Similar Period.	Rock-materials.
	Acres.				
N. E. Beamish ..	19,000	25 miles west of Napier ..	50 acres	Never	Chiefly limestone and papa clays.
John Chambers ..	7,000	Havelock Riding ..	75 "	No	Clays and papa.
Meinertzhagen and Moore	35,000	South of Cape Kidnappers	(See *ante*)	No	Blue-marl or papa.
J. B. Chambers ..	5,500	Havelock Riding ..	6 acres	Not for many years	Hard clays and limestone.
W. Heslop's trustees ..	5,000	Puketapu	Numerous	No	Black soil (?), clays, and limestone.
H. S. Tiffen	2,400	Taradale	None	No	Limestone.
Thomas Tanner ..	16,700	Havelock–Petane ..	18 acres	No	Tertiary limestone.
Arthur Harding ..	32,000	Kereru.. . ..	160 "	No	Clay and slate.
A. and W. Birch ..	115,000	Eweburn	..	..	Limestone and slate.
Russell Brothers ..	30,000	..	..	..	Limestone and shingle.
Hugh Campbell ..	13,000	Te Aute district ..	20 acres	Approached in 1883-84	Limestone and papa.
Thomas Hallett ..	33,500	Puketitiri	4 "	No	Limestone, clays, and conglomerates.
T. H. Lowry	14,700	20 miles west of Napier ..	25 "	No	Clays.
A. Sheild	16,000	Waikonini	40 "	22 years. No ..	Papa; little limestone.
W. Shrimpton.. ..	14,123	Matapiro	3 "	No	Mostly limestone.
John Bennett	7,000	Puketapu	None	No	Mostly limestone.
Maurice Mason ..	2,000	Heretaunga Riding ..	10 acres	20 years. No ..	Limestone and hard sandstone.
John Studholme ..	200,000	Rangitikei–Owhaoko ..	Unable to say	In November, 1872	Papa, limestone, and blue rock.
Gordon and Moore ..	28,000	Mangaharuru	100 acres	No	Clays and sands.
Thomas E. Gordon ..	13,314	Kidnappers	Extensive	No	Conglomerate and loess.
Totals	639,237		511 acres		

WAIROA, COOK, *cum* WAIAPU COUNTIES.—Square miles, 3,837; acreage, 2,455,680.

Owner.	Area.	Position.	Estimated Slips.	Similar Period.	Rock-materials.
	Acres.				
J. McKinnon	15,000	Moaeangiangi	Numerous	Always slips; wet ground	Limestone.
H. Twigg	4,600	Moaeangiangi	20 acres	No; for 30 years	Limestone and papa.
John Cowper	8,500	Frasertown	200 " (less than neighbour's)	No; for 20 years	Sands, clays, and limestone.
Niel Walker	16,000	Wairoa	100 acres	No	Clay and papa, with sand.
George Ormond	13,000	Te Mahia	500 "	Slips in 1880, or thereabouts	Clay and papa.
W. Elliott	12,300	Frasertown	300 "	April, 1892 ..	Clay marls.
J. Hunter Brown	18,000	Whakaki, Wairoa ..	200 "	No	Clay, limestone, and papa.
James Macandrew ..	25,000	Waikare-Wairoa ..	70 "	No	Clay and papa.
Guthrie-Smith and Stuart ..	20,000	Tutira Lake	1,000 "	10 years ago many slips	Clays and limestone.
James Woodbine Johnson ..	11,500	Nick's Head	1,500 "	No; bad in 1880	Papa rock.
Walter Withered	4,400	Waikohu Bay	30 "	Never ..	Papa.
P. Baker	4,000	Near Gisborne	200 "	No; for 16 years	Clay and papa.
G. S. Whitmore	20,000	Tuparoa, East Coast ..	(See *ante*)	Some previous large slips—1883–88	Clays.
H. H. Wall	5,000	Patutahi	3 acres	No	Clay and sands.
Charles Seymour	21,500	Whangara	150 "	No; for 14 years	Papa and sands.
Charles Gray	6,600	Waimate-Waikohu ..	550 "	(See *ante*) ..	Clays and coarse limestone.
Ewen Jameson	1,000	Upper Patutahi ..	200 "	No; for 25 years	Clay and papa.
M. Hutchison	17,000	Waikohu	None	..	Papa and sandstone.
W. Morice	10,300	23 miles west of Gisborne	No estimate	Yes; in 1876 ..	Papa and sandstone.
G. Scott	1,500	15 miles west of Gisborne	6 acres	No; for 29 years	Soft papa.
Totals	234,700		5,029 acres		

SUMMARY.—1. Waipawa *cum* Patangata: Acres returned, 284,300; slips, 2,153 acres. 2. Hawke's Bay: Acres returned, 639,237; slips, 511 acres. 3. Wairoa and Cook: Acres returned, 234,700; slips, 5,029 acres. Total acres returned, 1,158,237; slips, 7,693 acres = 1 acre slipped in each 150 acres, or 0·66 of an acre per 100 acres.