ART. XXXV.—*The Pre-Glacial Decay of Rocks in Eastern Canada*,* by ROBERT CHALMERS, of the Geological Survey of Canada.

THE pre-glacial decay of rocks in glaciated countries is a subject which has not hitherto received much attention from geologists. In North America the chief investigations regarding subaerial rock decay have been made in regions to the south of the glaciated zone, and but little has been attempted in those portions once occupied by Pleistocene glaciers. The prominence given to the action of these glaciers may have been one of the causes of this neglect or inattention to the products of rock-decomposition. The boulder-clay and certain gravels and sands overlying it being of considerable thickness, and their origin having apparently been found readily explicable from the action of these glaciers, the sedentary beds beneath, which occur usually in thin and detached sheets in glaciated regions, have thus, to a large extent, been overlooked. That they form a very important member of the superficial deposits, nevertheless, in the glaciated areas of Eastern Canada at least, and one from which the boulder-clay and all the other overlying stratified deposits have been mainly derived, no geologist will now attempt to deny.

In the regions of North America to the south of the glaciated belt the beds formed from rock decomposition have been studied, together with the stratified deposits resulting from their modification, by a number of leading geologists. Chamberlin and Salisbury, McGee, Hilgard and others have investigated their character and relation to the later superficial deposits; while near the limits of the glaciated area, T. Sterry Hunt† and Pumpelly‡ have shown the depths to which this process of decay penetrated and the manner in which the different kinds of rocks have been attacked by it. Russell has treated the question in its wider bearings and given detailed notes and descriptions regarding the chemical and mechanical agencies by which these changes in the rocks are effected; but his work also appertains to non-glaciated portions only of the United States.§ Prof. Kerr has shown how frost affects the decayed rock materials on slopes and declivities, an action which must be of more potent effect in Canada than in the Southern Appalachians.||

* Paper read in Section C (Geology) British Association for the Advancement of Science, Toronto, August, 1897.

† This Journal, vol. xxvi. 1883, pp. 190–213, etc.

‡ Ibid., 3d series, vol. xvii, 1879, pp. 133–144.

§ Bulletin U. S. Geological Survey, vol. viii, 1888–89.

|| This Journal, 3d series, vol. xxi, 1881, pp. 345–358.

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An ample field for the study of rock-decay and of the different agencies by which it is effected exists in Canada, in which few workers have yet been found. In the eastern portion, previous to 1882, when the writer began investigations in the surface geology of the Maritime provinces, only two geologists were known to have observed phenomena of this kind. Sir J. W. Dawson had noted decomposed slates at Les Eboulements on the north side of the St. Lawrence below Quebec;* and Dr. T. Sterry Hunt observed the products of rock-decay on the south side of Mount Royal, at Montreal, and also at Rigaud Mountain in Vaudreuil.† In these and other places, e. g., Ste. Anne de Beaupre, Charlesbourg near Quebec, Portneuf, Lachute, etc., the materials in question lie at the southern base of ridges or hills and have escaped the eroding action of the Pleistocene ice. Since the date above mentioned the writer has collected a considerable body of facts relating to this subject in the eastern portion of Canada to which reference has been made in reports on the surface geology of New Brunswick, Nova Scotia and Prince Edward Island in the volumes since published by the Geological Survey of Canada. In the present paper an attempt is made to collect together the results of the scattered observations of these years and draw the attention of geologists to these ancient and very interesting products of rock-decay which seem to be the only remnants now in existence here representing the long ages which elapsed between the Carboniferous, or rather the Triassic, and the Pleistocene.

The question of rock-decay in the geological ages which preceded the Tertiary, however, is not here considered. No remnants of such, as distinct from those of later ages, have been recognized in the region under discussion. But it is possible they do exist, though indistinguishable from those of Tertiary age. Fossil evidence is, so far, entirely wanting in the pre-glacial decayed rock materials of Eastern Canada.

Definition of Terms.

Preliminary to a discussion of the pre-glacial decayed rock materials, it is, perhaps, desirable to explain and define certain terms employed in this paper regarding them. The materials in question have been found to be principally of two classes—*sedentary* and *modified*. The term *sedentary* is used to designate all those portions of the rock surface of the region which have decomposed *in situ* whether to greater or less depths, and which, although now in the form of loose gravel, sand, etc.

* Notes on the Post-Pliocene Geology of Canada, Can. Naturalist, 1872.

† This Journal, vol. xxvi, 1883, pp. 208-209.

have not been removed from their original situation. These have sometimes been called residuary or indigenous, or simply rotten rock *in situ*.

The *modified* pre-glacial beds consist really of the sedentary material removed from their original position, and worn and changed by the agency of rivers, streams, and, perhaps, to some extent by that of the atmosphere before they were deposited in stratified beds. They are best developed in protected valleys, although oftentimes greatly eroded and in places almost wholly swept away by glacial denudation and river action. In some valleys, owing to the heavy filling of bowlder-clay thrown down upon them during the glacial period, or to the dislocation of portions of the valleys from local differential movements, they have been partially preserved and form thick stratified deposits.

Physiographic Features of the Region.

Topographically the region embraced in these observations exhibits highly diversified features and its geological formations include a great variety of rocks of different ages and character. It has also been the theater of a remarkable system of mountain-building action, and has undergone great and repeated oscillations of level. The subærial erosion and base-levelling to which it has, from time to time, been subjected, have doubtless largely obliterated the original features, except within a few limited areas,—the only plane surfaces of any extent now existing, properly attributable to these causes, being the St. Lawrence valley and the Carboniferous area of New Brunswick. The northeast Appalachian Mountain system constitutes the principal topographical feature, extending throughout the entire length of the region and terminating at Gaspé. This system has subsidiary and parallel ranges or spurs with intervening valleys. As a rule these valleys are floored with the latest rocks, and thick deposits of Pleistocene age usually occupy them. Although the existing mountain ranges and valleys were originally due to orogenic movements, the minor topographical features are largely the result of the processes of disintegration referred to slowly and unceasingly in progress. The slates and sandstones seem to have been more deeply decomposed than the crystalline rocks. In the valleys and especially beneath the bowlder-clay, the decomposed products under consideration are found in the thickest beds, although usually occurring also upon the slopes and ridges. Thus while glacial erosion and other forms of denudation have been active and long-continued, these sedentary and other pre-glacial stratified beds have been preserved in sheets of greater or less extent and thickness in every part of the country.

Distribution of the Decayed Rock Materials.

Pre-glacial beds of decomposed rock, sedimentary and stratified, have been observed by the writer in Quebec, New Brunswick, Nova Scotia, Prince Edward Island and the Magdalen Islands. In some localities the sedimentary or indigenous materials occur apparently in extensive sheets; in others they are detached and local. For the most part they were met with in fragmentary masses, however, having evidently been much denuded before the boulder-clay was laid down upon them. In a few places in Quebec and in Prince Edward Island, also in the Magdalen Islands, these decomposition products have been partially assorted, and now form thick stratified deposits in river valleys. It is in the bottom of these that gold is found in the Chaudière valley, and other places in the "Eastern Townships" of Quebec. Similar assorted and re-assorted fluvatile deposits, though of greatly reduced thickness, occur in certain parts of Nova Scotia, having been observed along the northern slope and base of the Cobequid Mountains, also in several parts of Prince Edward Island. The Magdalen Islands are non-glaciated, and hence the decayed rock materials there are nearly in the same condition yet as they were in other parts of Eastern Canada previous to the glacial period, forming thick beds which have been slightly assorted by marine action during the Pleistocene submergence. It is in the river valleys of southeastern Quebec as referred to above, that the decomposed materials underwent the greatest transportation and assortment, as will appear by the sections of these beds given on the following pages.

Wherever these decomposition products occur in sedimentary beds, though mantled by boulder-clay, the rock surface beneath is without striation from ice. And from the occurrence of these in so many localities it is evident that a considerable extent of rock surface in Eastern Canada has not been scored nor abraded during the glacial period, the ice apparently having slid over the beds which covered it with a sluggish motion, impinging only against the more prominent parts of the solid rock beneath and striating these.

In the province of Quebec these beds appear, as stated above, to have been least denuded in the hilly broken country lying between the St. Lawrence River and the International boundary, the ridges serving as barriers to protect them in many places from denudation by the Pleistocene ice. The comparatively light erosion of the first glaciation of the Appalachian system, and the mantling of these beds by the boulder-clay produced by it, preserved them also, to some extent, from the more powerful erosion of the Laurentide ice which followed.

Hence the occurrence of these sedentary beds, locally, in greater thickness here than in most other parts of the region under review. It is, however, chiefly in the form of deposits which have been assorted and re-assorted from the original sedentary material that they are found in the ancient river bottoms. Sections of these have been exposed in the banks of the Chaudière, Du Loup, Ditton and other rivers from which a knowledge of their character and relation to the other deposits, as well as to the solid rocks beneath, has been obtained.

At St. George, on the east bank of the Chaudière River, a tunnel was run in 800 or 900 feet in search of the pre-glacial channel of Slate Creek—a small tributary—passing through boulder-clay and other beds beneath to the rock surface. The beds inferior to the boulder-clay, which is here about 60 feet in thickness, were found to be in descending order,—(1) stratified sand and clay (locally called by the miners quicksands and pipe-clay); (2) coarse stratified gravel with pebbles and a few boulders; (3) a local deposit of coarse slaty materials, apparently decomposed quartzose slate, thrown down probably as talus at the foot of a slope or bank, though at present forming a compact bed; (4) fine-grained, yellow sand with ochreous streaks. The stratification of this is obscure, but it is evidently parallel to that of the next bed beneath wherever it is seen. (5) The last graduates into rotten rock *in situ*, the stratification of which is quite distinct, dipping southeastward at a high angle; (6) slates and sandstones, decaying, fissile, and non-glaciated.

This section it will be seen, exhibits in descending order three different kinds of deposits beneath the boulder-clay, viz: (1) transported and water-worn material, (2) talus, and (3) sedentary beds passing into the solid rocks below.

Another section of the pre-glacial deposits is shown in an old hydraulic pit in the valley of Rivière du Loup, about a quarter of a mile from its junction with the Chaudière. The succession here is as follows, in descending order: (1) boulder-clay, with an intercalated, stratified band,—thickness of the whole 75 feet; (2) tough, dark gray, stratified clay, 1 to 3 feet; (3) gray, ochreous sand, stratified, (quicksands of the gold miners,) 12 to 14 feet; (4) compact unstratified clay, (pipe-clay of the miners,) 6 feet; (5) gray unstratified gravel, with numerous pebbles and a few water-worn boulders, 5 feet; (6) hard, yellow, oxidized gravel, stratified, with an abundance of worn boulders from two feet in diameter downwards, containing alluvial gold in the bottom, 28 to 30 feet. None of the materials are glaciated and all are of local origin. The foot of the bank was covered with tailings, but near by the

sedentary materials and non-glaciated rock surfaces were observed.

Beneath the boulder-clay in this section we have, therefore, a thickness of about 45 feet of assorted, water-worn, stratified deposits, apparently all derived from sedentary, decayed rock material. The lower portions are coarse and oxidized throughout, the upper mostly finer and showing less oxidation, having evidently been laid down in deeper and quieter waters. These appear to rest upon denuded beds of rotten rock and non-glaciated rock surfaces. No fossil remains have yet been detected in them; but they are probably of Tertiary age. It is not unlikely that they are the equivalents of certain beds discovered many years ago at the western base of the Green Mountains at Brandon, Vermont. These were said to form a deposit lying beneath the boulder-clay and resting upon the solid rocks, which showed gravel and sand with kaolin or porcelain clay, and lignite or fossil wood, as well as several other oxidized materials. Fossil fruits were also discovered there, from which Mr. Lesquereux was led to refer the beds to the Miocene.*

In the valley of the Little Ditton River, oxidized pre-glacial materials, carrying gold, were also noted. Like those of Rivière Du Loup, they are chiefly of alluvial origin, but the portions resting immediately upon the rough, broken, jagged surfaces of the non-glaciated slates were sedentary.

Beyond the limits of the "Eastern Townships" so called, these materials were observed in a great number of places in southeastern Quebec not only in valleys, but on the hillsides and at the base of declivities, where they have been, in some way, protected from denudation. They were noted on Orleans Island, in Montmagny county, also near Rivière du Loup, Inter-colonial railway, and at Little Metis. Indeed, many parts of the Notre Dame Range, on the St. Lawrence slope, exhibit more or less pre-glacial rock debris *in situ* with talus at the base, the glaciation here having been produced chiefly by northward moving ice which failed to remove it.

In the Gaspé peninsula similar decomposition products occur in some localities, and certain non-glaciated marginal areas were seen along the coast. The most remarkable example of this kind met with is on the point of land terminating in Cape Gaspé. This point has never been glaciated, and is covered with decayed rock material and devoid of boulder-clay. We have here a remnant of the land surface in the same condition as it was in the Tertiary period.

Local sheets of these decayed rock materials were first noted

* Geology of Canada, 1863, p. 929.

in the maritime provinces of New Brunswick, Nova Scotia and Prince Edward Island upon areas occupied by Carboniferous rocks, and have subsequently been observed in almost every part both of the higher and lower grounds. In the numerous localities where they were seen the superposition of the boulder-clay was a constant feature, except in the Magdalen Islands, where the products of glacier action seemed to be absent. In the great Carboniferous plain the general character and condition of these beds are closely similar throughout and are such as to indicate that, in pre-Pleistocene time, a thick continuous sheet existed. They are much thicker and of greater bulk in Prince Edward Island, however, than on the mainland, in many places exceeding the boulder-clay beds in volume. In the central part of the island along the railway line, where they seem to have suffered less denudation than on the coast, beds of sedentary material, five, ten and even twenty feet in thickness were observed. In many places they are capped only by stratified or partially stratified gravel, sand, and clay of variable thickness, due to fluvial, marine, or perhaps ordinary atmospheric action, though usually boulder-clay overlies them throughout the island. On the mainland of New Brunswick and Nova Scotia, especially near the coast, the decomposed materials were seldom seen *in situ* of greater thickness than about five feet, and often not exceeding a foot or two. A section at one of the numerous localities in which these products occur in the Carboniferous area of New Brunswick, seen along the highway between Chatham and Richibucto near the Black River bridge, is as follows: (1) Gravel and sand, unstratified, containing flat, angular fragments of rock apparently *in situ* imbedded therein, thickness, eighteen inches; (2) rotten rock, with loose pieces of the underlying sandstones also in place, but with a little gravel and sand in the interstices, four to five feet; (3) gray sandstone showing still less decomposition, and evidently passing into the solid rocks (millstone grit) beneath, which here lie nearly horizontal.

Wherever the unabraded or non-glaciated rock surface beneath the decayed rock is exposed, it usually presents a mammillated appearance, showing that the corroding action has penetrated more deeply in some spots than in others. No foreign boulders or other drift materials occur in these beds, though they are not uncommon in the overlying boulder-clay and upon the surface.

In southern New Brunswick and in some parts of northwestern Nova Scotia the character of the decomposed beds is different from that of those met with upon the Carboniferous areas, being dependent upon, and of course closely related to, the underlying rocks there. On the pre-Cambrian the materials

are coarser and often contain pebbles and boulders of considerable size, the finer matter having evidently been carried away by post-glacial denudation. In the hilly districts bordering the Bay of Fundy, talus was observed at the base of the slopes in a few places. On the Cambrian and Cambro-Silurian this debris is finer and where slates prevail the materials are in loose, fissile beds, i. e. they occur in the form of thin laminæ or scaly fragments of all sizes lying in the same position as the original strata. Materials of this kind were observed in the southern counties of New Brunswick, also on the south side of the St. Lawrence near Quebec. The decayed rock upon these and the older formations is less gravelly and sandy than upon the Carboniferous sandstone areas, as might naturally be supposed.

In many parts of the Maritime provinces these decomposition products were observed to have been only partially or slightly acted upon by the Pleistocene ice. In this condition they seemed to contain the same angular pebbles or gravel as the rotten rock *in situ* beneath, but were shifted greater or less distances from their original position by glacier-ice, and the interstices filled with a bluish or gray clay, or sandy clay, as the case might be, which baked hard on exposure. Beds of this kind usually graduate upwards into true boulder-clay.

The occurrence of such extensive sheets of decomposed sedimentary rock in the region under consideration, much denuded as they seem to be, points to the former existence of a universal mantle of this material overspreading the country everywhere in Tertiary and preceding ages, probably from the first appearance of dry land. It was, however, partly modified by the same agencies as are in operation around us at the present day, namely by rivers, lakes, rain, snow, etc., and in the valleys, especially, was changed into deposits of stratified clay, sand and gravel. During the glacial period this decayed rock furnished the principal portion of the material constituting the boulder-clay, and also that of the overlying, modified, post-glacial beds.

Agencies which produced Decomposition of the Rocks.

The indigenous materials under discussion appear to be the result mainly of two different agencies—mechanical and chemical. Although it is not the purpose of the writer to enter into details regarding these in the present paper, it may be stated, that under the climatic conditions of this country, the most important seem to be (1) the precipitation, and (2) the carbonic acid of the atmosphere and of decaying vegetable matter, the latter usually resulting in what is called oxidation. The changes of temperature which have such a wide range in these latitudes must also have exerted a direct influence in pro-

ducing expansion and contraction of the rocks, thus causing numerous superficial cracks, crevices and joints which open them to the disintegrating agents referred to. Exfoliation, which is often seen in granite districts, and sometimes on diorite bosses, is chiefly due to this expansion and contraction. Although at first glance decomposition would seem not to have been as deep in this country as to the south of the glaciated zone, yet such an inference may not be correct, owing principally to the fact that denudation has been so much greater; and the existing remnants of these pre-glacial beds do not by any means show the amount of rock-decay which took place. The removal of so much of the decayed materials by atmospheric and glacial action must have exposed some portions of the rock surfaces at least to a renewed attack of the disintegrating processes time after time—a condition of things which would not occur so generally in regions upon which ice never gathered. It is true that the mantle of snow which envelopes the earth's surface here for five or six months every year and the freezing of the superficial beds during the same period have a conservative effect, and tend to check and practically arrest decomposition for a certain time; but rock-decay, nevertheless, may have been more effective and rapid at other seasons than in those parts of the earth where the decayed materials lie and accumulate as residuary beds to a great thickness. Thus while the process referred to does not exhibit the accumulated beds here that are found in southern latitudes, it does not necessarily follow that the depth of such action may not have been as great. The fact just stated has to be borne in mind, namely, that the decayed materials have undergone great denudation, thus giving the disintegrating forces renewed power at intervals to act directly upon the rocks.

The principal oxidation and decay of the rocks would seem to be from chemical agencies, whether on the surface as the rotten rock was denuded, or deep-seated beneath a load of sedentary material, or along joints, cracks, etc. These processes have been in incessant operation since the region became dry land. At present the great mantle of boulder-clay acts as a preserver of the rocks from the decaying processes in many districts, though even under this impervious capping the agents of decomposition, doubtless, to some extent, carry on their work.

It thus appears that if the climate and the seasons of Eastern Canada in past ages were at all similar to those prevailing at the present day, the conditions of rock-decay would necessarily be somewhat unlike those of tropical and non-glaciated regions, though probably the results may not have been very far different. The general character of the beds might possibly be nearly

the same in both regions, but for the reasons stated they may never have been as deep in the glaciated zone. The facts would seem to point to the conclusion, however, that rock-decay has been in progress in this country for long ages, probably as long as in southern climates, although somewhat irregular and intermittent in its operations.

From the extent and depth of the sedentary and assorted beds found beneath the boulder-clay it may be inferred that the Pleistocene glaciers were not as heavy, or of such erosive power, as many geologists have supposed. This has been the case especially in the flat districts of the Maritime provinces occupied with Carboniferous rocks. In these districts the ice has been of a less vigorous and sweeping character than in the more elevated parts of the country, and was apparently sluggish in movement, passing over the loose deposits and rock surfaces without eroding them deeply. Only from certain low ridges, or from the brows of hills exposed to the full force of the grinding ice masses, have the decomposition products been wholly removed and the surfaces of the solid rocks beneath scored and laid bare.

The general aspect of the dry land in Eastern Canada before the advent of the glacial period must have been closely similar to that of the country to the south of the glaciated area. The greater denudation it has suffered since from subærial and glacial agencies and the filling up of the valleys, partially or wholly with the boulder-clay, thus levelling and reducing the inequalities of the surface, have largely modified, in some places entirely changed, the appearance. But amid all the vicissitudes of climate and oscillations of level which the region underwent, and the denudation to which the surface has been subjected, these products of rock-decay, representing the subærial action of long ages, have thus been preserved in remnants and detached sheets, the recognition of which unfolds another episode in the geological history of Eastern Canada hitherto overlooked, and adds new interest to the study of its superficial deposits.

Geological Survey Office, Ottawa, May, 1897.