ART. VIII.—*The Geological History of Eastern Marlborough.*

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[*Read before the Otago Institute, 9th November, 1920; received by Editor, 31st December, 1920; issued separately, 27th June, 1921.*]

CONTENTS.

INTRODUCTION.

IN two papers, published in 1917 and 1919, Dr. J. Allan Thomson champions the views of Dr. C. A. Cotton (1913, 1914A, and 1914B) as to the genesis of the physiographic features of eastern Marlborough and origin of the so-called post-Miocene conglomerate. In the last of these papers he restates at great length the observations of McKay made in 1886, 1890, and 1892, and the opinions of Cotton, and disagrees with my view that the post-Miocene conglomerate is morainic. With the zeal of an advocate he contends that my "hypothesis involves the formation of the great Clarence and other faults in the late Notopleistocene, and is quite untenable." Why untenable? Geophysicists recognize that the crust of the earth will be subject to tensional stresses, fracturing, and faulting so long as the denudation of mountain-chains and the piling-up of sediments on the sea-floor continue.

The view I have always maintained is that the Clarence fault is of considerable antiquity, and that the involvement of the glacial and older strata was caused by a revival of movement along the old fault-plane. Great faults are of slow growth.

As if doubtful of warranty for his extreme pronouncement, Thomson adds, "In any case, the evidence for the fluviatile origin of the lower beds of the series is overwhelming." But even if partly fluviatile, this would not invalidate my view that the great conglomerate is morainic. There are moraines and moraines. The morainic matter carried on the back of a glacier invariably consists of a tumbled pile of angular blocks of rock. In such a deposit fluviatile material is usually absent. Curiously enough, this appears to be the only type of moraine that Thomson recognizes as undeniably glacial. But terminal moraines, of which we have in New Zealand many fine examples, both ancient and modern, are invariably composed of fluviatile drifts mingled to a greater or less extent with tumbled ice-carried blocks.

During the past two years I have attempted to determine the relative proportions of fluviatile drift and tumbled blocks in some well-known terminal moraines in Otago and Southland, and I may say that the task proved more difficult than I anticipated. The results obtained I can only claim to be rude approximations, but they are sufficiently near the truth to demonstrate the conspicuous part played by fluviatile drifts in the structure of such deposits. In all cases the observations were made at points free from re-sorting.

The great Clyde moraine contains about 60 per cent. of silts, sands, and gravels of fluviatile origin; the Queenstown Domain moraine, 55 per cent.; the Kingston moraine, 55 per cent.; the Manapouri moraine, 65 per cent. The Clyde, Kingston, and Manapouri moraines appear to rest on beds of fluviatile drift. I have not yet made a quantitative estimate of the material composing the Tasman terminal moraine, but if my recollection is not at fault I should say that fluviatile drift is conspicuously represented. According to many independent writers, the Pleistocene glacial deposits of Canada and the United States contain a large, or even dominant, proportion of fluviatile material.

A Question of Nomenclature.

Before going further I wish to express my views as to some new names that have been lately suggested by Thomson. In my paper (1905, pp. 497–501) "On the Marine Tertiaries of Otago and Southland" I recognized (*a*) that the main orographical features of New Zealand were determined by an early Cretaceous diastrophic movement that folded and elevated the Juro-Triassic and older formations, and (*b*) that the Upper Cretaceous and Tertiary strata were laid down as "marginal" deposits on a platform that contoured around the early Cretaceous strand. These views I reiterated in 1910 (p. 85). Thomson (1917 p. 407), in a discussion of the younger covering strata, thought it "desirable for many purposes in New Zealand geology to have a name which will embrace them all, a name which will replace the earlier name of 'marginal rocks' used by Park and myself, and the physiographic and structural term of 'covering strata,' when an age significance is intended."

I was the first to describe (1905) the late Cretaceous and Tertiary strata as "marginal," and have no recollection that this term was used by Thomson till many years afterwards. Apart from this, I am in agreement with him that the substitution of a name for my "marginal" strata is desirable. But the term "Notocene," which he has suggested, is inappropriate; and I agree with Marshall (1919, p. 240) that it is unscientific. The suffix "cene" (from *kainos* = recent) is used as the termination of the four epochs into which the Cainozoic era has been divided, and to use it in the structure of a word intended to cover the Upper Cretaceous and the whole of the Cainozoic would be certain to lead to misunderstanding. Moreover, there is nothing *recent* about the Albian and later groups of the Upper Cretaceous, in the sense that "cene" is used in the words Eocene and Miocene. If it had not been previously used in a much narrower sense—that is, as meaning Cretaceo-Eocene—Hector's term "Cretaceo-Tertiary" would be quite satisfactory, but it must also be ruled out on the score of possible confusion.

Following the precedent set by the Geological Survey of India, a native group-name may be appropriately used for the marginal Cretaceo-Pliocene strata of New Zealand. The name I now suggest is "Awatean."*

For the post-Jurassic and pre-Albian N.E.–S.W. orogenic movements that folded and elevated the Juro-Triassic of the main chains I propose to use the term "Rangitatan movement."

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* Awatea was the name of the great Polynesian deity who heralded the emergence of the land from the void.

In 1916 Cotton gave the name "Kaikoura movements" to the Pliocene uplift that affected eastern Marlborough. I was the first (1905, pp. 501–2, and 1910, p. 110) to recognize and describe the differential character of this uplift, and should prefer the name "Ruahine movement." In the Ruahine Range the effects of differential axial elevation are better displayed than elsewhere. Moreover, Professor Suess (1909) included the Ruahine Range of New Zealand in his Third Australian Arc of folding, elevation, and vulcanicity, and used the name "Ruahine" as representative of the uplift and vulcanicity of that region. I think the term "Ruahine movement" ought to stand.

SYNOPSIS.

My view is that the folding and elevation of the Juro-Triassic and older rocks took place in the pre-Albian period of the Lower Cretaceous. This orogenic movement, which I have called the "Rangitatan movement," gave birth to the existing N.E.–S.W. axial chains of New Zealand. The folding was accompanied by fracturing, faulting, and subsidence along lines of structural weakness. The climatic conditions were pluvial, and the denudation of the newly uplifted chains was relatively rapid.

During the Albian, while the peneplaining of the mainland was in progress, the sea began to invade the Clarence depression, where it laid down Albian sediments. At the close of the Albian the Cenomanian transgression became general, and soon the sea encroached on the newly formed peneplain, Tahora,* that everywhere fringed the remnants of the main chains. On the surface of this peneplain, and on the Albian beds already deposited in the Clarence depression, sediments were laid down throughout the remainder of the Upper Cretaceous period.

Then followed the Eocene uplift, during which the weak post-Albian beds were removed from the greater part of the uplifted Tahoran peneplain and from the Clarence depression. At the close of the Eocene began the Oamaruian subsidence, during which the great Miocene formation was deposited, in some areas on the slightly eroded surface of the surviving Cretaceous strata, but mainly on the surface of the recently uncovered peneplain.

At the close of the Miocene there began a differential uplift in Otago and Auckland, pivoting on the Napier–Wanganui zone, where the movement still continued downward, this arising from the thrust accompanying the tilting of the ends of the main chains.

Before the advent of the newer Pliocene the Marlborough and north Hawke's Bay areas were raised above sea-level. In the Napier–Wanganui zone the deposition of marine sediments continued till the close of the newer Pliocene, when this region also rose above sea-level.

During the succeeding Pleistocene the alpine chains and the Kaikouras were covered with ice-fields that fed the Clarence glacier, which, in my opinion, formed the great post-Miocene conglomerate.

GEOLOGICAL HISTORY.

In Marlborough we are confronted with geological and physiographic conditions altogether unlike those prevailing along the main axial chain. The Inland Kaikoura and Seaward Kaikoura Mountains are well-defined ranges composed of folded argillites and greywackes of Juro-Triassic age, in

* In Maori, *tahora* = great plains and low-lying maritime lands.

many places intruded by a network of basic, semi-basic, and acidic dykes. The post-Jurassic (or Rangitatan) diastrophic movement that folded the ranges of the main axial divide was also responsible for the folding and elevation of the Kaikoura chains, and the subsequent intrusion of the igneous magmas.

McKay (1886, p. 65) has shown that the rocks composing these chains are arranged in two simple synclinal folds, separated by an anticlinal fold, the crest of which runs parallel with the present course of the Clarence Valley.*

The folding and elevation of the Jurassic and older rocks took place in the pre-Albian stage of the Lower Cretaceous. The denudation of the newly elevated folds of the main divide began immediately, and continued throughout the whole of the Albian, resulting in the base-levelling of the great peneplain elsewhere called Tahora. At this time the Seaward Kaikoura chain existed as an island, or as a long narrow peninsula.

During the progress of the Albian base-levelling of the mainland, Albian sediments were being deposited in the deep, clear waters of the fiord-like Clarence Sound, that separated the Kaikoura chains. After the post-Jurassic folding, and before the Albian, the crown of the Clarence anticline was deformed by powerful faults, the most important of which followed the base of the Inland Kaikoura chain.

The floor of the Clarence Valley is occupied by a sheet of strata many thousand feet in thickness, ranging in age from Lower Utatur (Albian) to newer Pliocene or even Pleistocene. Two unconformities have been recognized in this pile of material. The Lower Utatur strata are followed by the Amuri limestone, which, according to Henry Woods (1917, p. 4), favours the view that the latter is of Tertiary age, since the Upper Utatur (Lower Chalk) beds that normally follow the Lower Utatur in India, Japan, Madagascar, and Zululand are not known to be represented in New Zealand. The second unconformity comes between the Awaterean marine clays and a remarkable deposit which McKay (1886) called the "post-Miocene conglomerate."

The Post-Miocene Conglomerate.

This deposit attains in places a thickness of 600 ft. It is mainly composed of water-worn drift, derived from the Juro-Triassic argillites, greywackes, and associated dyke-rocks that compose the Kaikoura chains, mingled with a confused pell-mell of angular slabs and irregular masses of Amuri limestone, "gray marls," and fossiliferous Awatere (older Pliocene) clay-rock, some of the former of enormous size. Patches of this deposit occur near the Marlborough coast, resting on an eroded surface of the Amuri limestone. But its greatest development is in the Clarence Valley, where it lies on the "grey marls," a clayey formation that conformably follows the Amuri limestone.

McKay in his report on the Cape Campbell district (1876, p. 190) gives a good description of this breccia-conglomerate. He says, "These conglomerates are composed in chief part of well-rounded boulders, but have a large percentage of angular blocks of great size, so that they often present the appearance of old morainic accumulations. A great variety of rocks

* Thomson (1919, p. 305) expresses the opinion that the strikes observed by him would tend to show that a strike west of north is prevalent in at least some parts of the Kaikoura area; and Cotton (1913, p. 244), arguing from the variability of strikes and dip, considers it probable that the older axes of folding make an angle with the general N.E.–S.W. trend of the chains. In my opinion the meagre evidence produced by these writers is not sufficient to invalidate the considered generalizations of McKay.

is represented in these conglomerates, including old slates and sandstones and crystalline rocks from the inland ranges, volcanic rocks belonging to the Amuri group, green sandstone from the 'saurian beds,' and great masses of Amuri limestone, and large blocks of fossiliferous conglomerate containing abundance of Awatere fossils; also blocks of sandy limestone and fine-grained standstones with abundance of Awatere fossils. These beds cannot be less than 200 ft. in thickness, and in places they rise to a height of 850 ft. above the sea. Like the Awatere beds, the conglomerates never pass to the eastward of the Amuri limestone, nor do they reach to the lower grounds on the west side of the range; but, as they are but the remnant of a formation that must once have covered a considerable extent of country, other outliers of them will probably yet be found to the south and west."

Referring to the conglomerates at Heaver's Creek, he says (1886, p. 115), "They are rudely stratified, at places showing that the beds are standing nearly vertical; in the lower part are enormous blocks of Amuri limestone and masses of soft marly strata, which it seems impossible to convey any distance and deposit in the position in which they are found. . . . It is impossible to give any description which will convey a correct idea of the pell-mell manner in which the various materials of this conglomerate-breccia are mixed together." Further on he says some of the masses of Amuri limestone in this deposit at Shades Creek "are of such an extent that at first sight they might be taken for an outcrop of this rock *in situ*."

RELATIONSHIP OF POST-MIOCENE CONGLOMERATE TO UNDERLYING TERTIARY FORMATIONS.

The stratigraphical succession of the formations represented in eastern Marlborough is:—

(1.) Post-Miocene conglomerate.
(2.) Awatere clay and marly beds.
(3.) "Grey marls."
(4.) Amuri limestone.
(5.) Cretaceous strata.
(6.) Juro-Triassic basement rocks.

Near the coast the conglomerate-breccia rests on the Amuri limestone, and in the Clarence Valley on the "grey marls." It contains angular masses derived from the underlying Cretaceous strata, Amuri limestone, "grey marls," and Awatere beds. McKay (1886 and 1890) and Hector (1886) considered it unconformable to the Awatere beds, a conclusion which I had no difficulty in endorsing in 1910.

Cotton (1910), in a general account of the geology and physiography of eastern Marlborough, expressed the view that the conglomerate-breccia was conformable to the "grey marls," and this opinion appears to be supported by Thomson (1919). If this tumbled and confused deposit is conformable to the "grey marls," the question arises, what has become of the Awatere beds? And in like manner, where it rests on the Amuri limestone, we may ask, what has become of both the "grey marls" and Awatere beds? It may be suggested that the conglomerate-breccia is the equivalent of the Awatere beds; but clearly this is impossible, as large masses of the latter are contained in the conglomerate.

Referring to the difficulty presented by the view of conformity, Thomson (1919) says, "Cotton accounts for the peculiar features of the conglomerate —viz., that it lies conformably on the 'grey marls' but contains materials of all the underlying Notocene [Cretaceous and Tertiary] beds—by assuming that a neighbouring area was differentially elevated to the extent of perhaps as much as 12,000 ft. without seriously disturbing the horizontal attitude of that portion of the Notocene series which, a little later, had the conglomerate deposited upon it." This hypothetic assumption does not make the position easier. By all the criteria of stratigraphical geology, whatever its origin, there must be a time-break between the conglomerate-breccia and the "grey marls."

Involvement of Post-Miocene Conglomerate.

Along the base of the Inland Kaikoura Range the Cretaceous and Tertiary deposits, including the post-Miocene conglomerate, are down-faulted towards the north-west, and appear to plunge below the Juro-Triassic rocks composing that chain.

There is no evidence that the Kaikoura chains were ever reduced to a sea-level peneplain, and all surmises to the contrary are purely hypothetical. At the time the Tahoran peneplain was being base-levelled the Kaikouras existed as ridges, separated by the Clarence Valley, into which the sea during the Albian stage gradually encroached. The advancing sea first formed a basal bed of conglomerate, which is entirely composed of material derived from the neighbouring mountain-walls. As the sea continued its invasion of the Clarence Valley the bed of conglomerate spread slowly landward, forming a deltaic deposit, on the emergent surface of which vegetation grew till destroyed and buried by sediments deposited by the advancing sea.

If the sea advanced from the north-east, as seems to be indicated by the distribution of the Cretaceous strata and Amuri limestone, the conglomerates laid down at the head of the sound should be coeval with the fine marine sediments deposited in the deeper water near the entrance of the sound. As the transgression progressed the conglomerates became everywhere covered with the finer muds and sands of the Upper Utatur.

At the beginning of the Cenomanian the advancing sea overspread the base-levelled Tahoran peneplain and covered it with a sheet of Upper Cretaceous sediments. During the Eocene uplift the newly formed Upper Cretaceous sediments in the Clarence fiord, in north and west Nelson, and throughout Westland, Southland, and south Otago, were completely removed by denudation. Only in north Otago and Canterbury did some remnants escape the general destruction of this period.

The Eocene uplift was followed by slow persistent submergence, during which the Oamaruian and Awatere sediments were deposited. At the close of the Miocene, differential uplift began along the axial chains, accompanied at the north and south by a tilting movement that pivoted about a zone extending from Napier to Wanganui, along which submergence continued till the close of the Pliocene, as witnessed by the newer Pliocene beds on the coasts of Hawke's Bay and Wanganui Bight. The movement was faster along the axial divide than at the east and west coasts, and this generated crustal stresses which found relief by fracturing and faulting, followed by the uplift and tilting of mountain blocks.

There was also, as already indicated, a general tilting of both ends of New Zealand coeval with the axial uplift. This tilt was greatest in Auckland and Otago, and least in the Napier–Wanganui zone. As a consequence of this unequal uplift the youngest marine strata known in Otago and south Canterbury are late Miocene; in Marlborough, older Pliocene; and in the Wanganui and Hawke's Bay areas, newer Pliocene.

NEWER PLIOCENE.

As a further consequence of the pivotal (or differential) elevation, the refrigeration which afterwards culminated in the glaciation of a large part of the South Island and a small part of the North Island began in Otago and Southland as far back as the early Pliocene, and in Marlborough in the late Pliocene. The general advance of the alpine glaciers began in the late Pliocene, and throughout the South Island this was a period of intense fluviatile activity. In the early Pleistocene the high Kaikoura chains were covered with permanent ice-fields that fed the Clarence glacier, the terminal face of which reached the sea at the time of maximum refrigeration.

It was during the early Pleistocene that the Marlborough fluvio-glacial conglomerate was deposited. The piling-up of from 4,000 ft. to 12,000 ft. of sediments and other rocky detritus on the floor of the Clarence Valley disturbed the isostatic condition of the crustal strip lying along the Clarence fault, and as a result of this disturbance there was a revival of movement along the old fault-plane. McKay reported in 1886 that a distinct depression marked the line of the great fault, and this depression was said by the settlers to have been formed by the historic earthquake of 1855, which is also known to have opened gigantic earth-rents in other parts of Marlborough, as well as in Wellington.

I would suggest that it was the overloading of the Clarence segment which caused the Inland Kaikoura chain to creep towards the south-west. This and crustal weakness originated the overthrust which eventually entangled the Cretaceous and Tertiary strata and post-Miocene conglomerate along the course of the Clarence fault. But this suggestion is purely hypothetical and incapable of proof.

CONCLUSION.

Herbert Spencer has laid it down in his *First Principles* that no hypothesis is capable of more than partial proof, and that of two rival hypotheses the one that approaches nearest the truth is that which does least violence to fundamental principles. I venture to think that Cotton's titanic faulting and stupendous walls of weak, unconsolidated sediments (*vide* fig. 2, Cotton, 1913) postulate conditions that appear almost impossible. Moreover, his and Thomson's contention that the post-Miocene conglomerate is conformable to the "grey marls," notwithstanding that it is composed of material derived from all the underlying formations, is opposed to all the canons of stratigraphical geology. The view of conformity did not even suggest itself to Hector, McKay, or myself.

According to Cotton's hypothesis, the faulting was a single catastrophic movement of such magnitude as to expose the Tertiary and Cretaceous strata in a stupendous fault-scarp from the steep face of which blocks and vast slabs of the different beds, under the influence of gravity, fell or slid into the valley below, forming the "pell-mell" so well described by McKay. But the blocks are contained in a matrix of fluviatile drift composed mainly of the basement Juro-Triassic rocks. Evidently the Clarence Valley was already drained by a well-established river-system. It seems incredible that the titanic dislocation required by Cotton's view could have taken place without causing serious disarrangement of the pre-existing drainage-system.

If it be conceivable that the faulting proceeded by a series of catastrophic displacements that exposed in a steep escarpment first the Tertiary and afterwards the Cretaceous strata in the order to their superposition, we should expect to find the Awatere rocks, as the first exposed to shattering and crumbling, predominating in a stratum towards the base of the great conglomerate. Above this stratum there should appear a succession of layers dominated by blocks of "grey marl," Amuri limestone, and Cretaceous rocks, and in the inverse order of their superposition. But the blocks of the different formations do not occur in this orderly succession: they are mingled in a confused jumble. Clearly this conception also fails.

It is generally recognized that all great faults are of slow growth. If the growth of the Clarence fault were slow, the denudation of the newly uplifted covering strata would result in the formation of the slopes normal to weak strata, and there would be no dislocation of the established drainage-system.

The Tertiary strata were laid down on the floor of the sea, and elevated before the process of shattering and denudation began. Surely this uplift and the geographical changes which it brought about must represent a time-break between the post-Miocene conglomerate and the underlying Tertiary strata which figure so conspicuously in its composition.

I do not know of any natural agency other than ice that could transport and leave stranded among fluviatile drifts slab-like masses of soft friable rock ranging from a few feet up to 70 ft. in length; and I can see nothing unreasonable in my suggestion that high chains like the Kaikouras could support ice-fields during the period of Pleistocene maximum refrigeration. I do not suggest that my view is the obvious truth. My contention is that it is a reasonable interpretation of the known facts. The obvious truth may often resemble a truism, which Carlyle has defined as an invention for concealing the real truth. The uplifted hand may obscure a landscape; and a simple truth may be presented in such a manner as to hide a whole gospel.

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