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The Chronicle of the Rocks

Rock strata in a cliff on the Taranaki coast. J. W. Chapman-Taylor

Historians tell us that Polynesian voyagers reached the shores of New Zealand many centuries ago. Precisely when is a matter of dispute; some authorities say they first arrived in the eighth century, others several hundred years later. Yet it is certain that they had been in possession of the land for many generations before the first Europeans touched here in 1642, sailing on again to leave the country undisturbed for a further 127 years. Then followed that troubled period of European contact which ended one hundred years ago with the establishment of British rule and the beginning of organised colonisation.

Thus the historian of peoples, looking back over centuries, generations, and decades, divides the history of New Zealand roughly into periods— first the Maori period; then the period of navigators and other casual visitors and settlers; finally the period of settled European occupation.

But the history of New Zealand—of the mountains and rocks and rivers of this interesting land —goes back infinitely beyond the date when the first voyagers from Hawaiki could have arrived here. Man, indeed, has been in occupation for only a small fraction of time. Through long ages before his coming the land was moulded by rain, running water, and wind; it sank beneath the sea and rose again; it was carved by giant glaciers; it was convulsed by land movements and eruptions; it was clothed by forests long since gone and occupied by strange creatures which have been extinct for millions of years.

This fascinating story is revealed to us by the earth-historian—the geologist—and he, like the historian of men, divides his story into periods which cover, not centuries and decades, but hundreds of thousands and even millions of years.

The materials of the historian are the traditions, the legends, the writings, the implements, and so on which men leave behind them during their

A fossil shell of Tertiary age. J. Marwick

brief existence. The geologist builds his story from the rocks which he finds exposed on the outer part of the earth's surface.

The origin of these rocks is extremely varied; some were once in a liquid or molten state; others such as sandstones are derived from the worn-down materials of pre-existing rocks; others again like limestones, have been built up from the skeletons of marine creatures. Every rock, if correctly interpreted, tells us something about its history through long geological ages.

But the geologist does not read the book of Nature merely by examining samples of rock. He studies the layers, or strata, of rock exposed in a cliff or in a surface outcrop and from their arrangement constructs a longer and more complicated story. The oldest rocks are at the bottom of the cliff, the youngest at the top; in between are the rocks of intermediate age. In this simple way a time sequence is determined, and the geological column is built up.

Even more fascinating is the way in which the geologist reconstructs the past from the traces or actual remains of plants and animals long since extinct. Some 550 million years ago certain primitive sea-animals, defeated by the intense competition near the surface, were forced towards the shallow sea floor and became bottom dwellers. The relatively inactive life in these new surroundings caused bodily changes, one of which was the inability to get rid of all the mineral salts taken in with food. One way out was to deposit this excess material in the form of a skeleton which kept its shape and solidity after the animal had died. Obviously these hard parts had some degree of permanence and, if buried by sediment, might survive indefinitely to yield their mite of evidence millions of years later.

In the rocks of all ages since the beginning of the Cambrian Period, when this interesting and

Maui fishing New Zealand out of the ocean. It is interesting to contrast the Maori legends of the origin of New Zealand with the less poetical explanations given by scientists. This fine sketch was drawn by W. Dittmer.

important change occurred, fossils have been preserved, sometimes in great abundance and sometimes in such exquisite detail that the student of ancient life—the palaeontologist, as he is called— can reconstruct the past with great accuracy.

Life began in the sea. The sketch shows an artist's reconstruction of plant and animal life in the Cambrian Period.

Building up a Time-scale

HIS ability to re-clothe the past at successive intervals of time has enabled the geologist to extend the realm of history for hundreds of millions of years and to picture, still incompletely and with many a tantalising gap, the story of life as it developed on land and in the sea.

As he studies the succession of fossils, he sees the grand outlines of organic evolution emerge. And combining this with what he learns from the study of rocks in their relative order, he builds a time-scale such as the one on the opposite page.

The time-scale can be followed easily if it is remembered that the earliest intervals of time are at the bottom, exactly as the oldest layers of rock are at the base of a cliff. Working up gradually we come to recent times, which correspond to the sprinkling of earth at the very top of the cliff. The geological terms used in the scale are long and slightly alarming, but when explained they make geology as simple as history.

To begin with the geologist divides the earth's story into great intervals of time called *eras.* There is first of all an immensely long era, not represented by rocks in New Zealand, which can be called *Pre-Cambrian* because it comes in the time-scale before the Cambrian Period. Then follow two eras named from a Greek word *zo-on,* meaning *animal*—the *Palaeozoic,* or Era of Ancient Life, and the *Mesozoic,* that is Era of Middle or Intermediate Life. Next come the third and fourth eras since Pre-Cambrian times—the *Tertiary* and *Quaternary* Eras.

But these vast eras, extending as they may for hundreds of millions of years, have to be split up into smaller intervals, or *periods,* which are usually named after the places where the rocks were first examined. Hence we find such terms as *Devonian,* after the County of Devonshire in England, and *Jurassic,* after the Jura Mountains of Europe. Other terms are descriptive, like *Carboniferous,* used to describe the age when the greatest beds of coal were formed.

The periods which concern us in this story are:

Equipped with this chart, we can now start on a journey of exploration, covering millions of years, through the course of New Zealand's ancient history.

A spirally coiled ammonite, characteristic of the Mesozoic Era. P. Marshall

This time-scale shows the main intervals of geological time and gives the sequence of the more important physical and organic events. The chart will help the reader to follow the story told in this survey.

The Oldest Fossils in New Zealand

A slab of fossils of attractive form found in the Wairoa Gorge, Nelson. These shells are widespread in rocks of the Triassic Period mentioned on page 9. Wm. C Davies. Cawthron Institute

How old is New Zealand? The land as we know it is of comparatively recent origin, but in remote places at both ends of the South Island geologists have discovered traces of life which existed in the Ordovician Period, some 450 million years ago. At Preservation Inlet and Cape Providence in Fiordland and in the Mount Arthur and West Haven districts in the north are found the oldest fossils in New Zealand, the most numerous of which are the graptolites.

The graptolites were surface-dwellers in the oceans of that ancient period. After death their skeletons rained down into the bottom sediments or were swept by winds and currents into bays, to be preserved in black muds, where no scavengers could live to destroy them. Hence their fossil remains are usually found in dark-coloured mud-stones or slates, forming a white, flattened impression on a dark ground. The graptolites were quite unlike any marine animals of to-day and they left no descendants. But the fossil remains of these creatures are of great value to the geologist as signs of that remote period so many million years ago.

There followed a long interval of time during which the history of New Zealand is unknown. Then another episode in the story is revealed by rocks exposed at Reefton and farther north in the Baton and Wangapeka Valleys of Nelson. In these places there are mudstones and sandstones rich in marine fossils, the most abundant being ancestors of the modern lamp-shells. These creatures are comparatively rare and unimportant in modern seas, but in ancient oceans they were dominant. The local fossils are closely related to those which are found in Devonian rocks in parts of Europe. For this reason it has been suggested that they migrated here by means of an ancient sea-way, called Tethys, separating Eurasia from Africa and now reduced to a small remnant in the Mediterranean Sea.

The rocks at Reefton provide yet another link in the story. Here the lower beds with lamp-shells are followed by dark-coloured limestones containing corals of varied size and character. These belong to the middle part of the Devonian Period, and the seas in which the corals lived also flooded Eastern Australia where similar forms are known.

The seas of the Devonian Period finally retreated, and there followed another lengthy period not represented by rocks in New Zealand. In the

This title refers to the era and period shown by the time-scale on page 5. It will assist the

reader to note the relation of this and the eleven succeeding titles to the time-scale.

Palaeozoic Era Ordovician Period Devonian Period Northern Hemisphere at this time flourished the great forests of the Carboniferous Period which were to form widespread coal-measures, but these are completely absent in New Zealand. Our local coal-fields are much younger.

Before the Palaeozoic Era finally closed, seas again invaded this area, as we know from a few poorly preserved fossils of Permian age found in Nelson and at Clinton in Otago. These are the last remnants of that ancient era, so scantily developed in New Zealand.

Graptolites, the oldest fossils found in New Zealand. W. N. Benson

A lamp-shell from rocks at Reefton, drawn by E. T. Talbot.

Cross-section of a Devonian coral from Reefton. R. S. Allan

The West Haven district, Nelson, where the oldest fossils In New Zealand are found. Thelma R. Kent

A Great southern continent

Terraces cut by glaciers in the Rangitata Valley, Canterbury. V. C. Browne

The earliest European navigators who visited New Zealand came here in search of a Great Southern Continent. Tasman thought he had discovered it; Cook disproved its existence. But millions of years earlier, during a great part of the Mesozoic Era, New Zealand did actually form the shore-line of a great continent, named Gondwana-land, which extended far to the west. The Tasman Sea did not then exist, and New Zealand was joined to Tasmania and Australia.

During this time spoil from the eastern part of Gondwanaland was washed down and deposited on the present site of New Zealand. But, owing to the fluctuations of the continental margin, sometimes it lay beneath the sea, sometimes it formed a low-lying coastal-land with widespread lakes or lagoons. As a result, there were built up coarse

A fossil plant of the Mesozoic Era—a fern-like form abundant enough to be called a Mesozoic weed. A. E. Newell Arber

marine sandstones and pebble-beds of great thickness which alternated with fresh-water plant-bearing strata.

The marine fossils of the Mesozoic Era reached New Zealand by the ancient sea-way which stretched northwards to New Caledonia, thence via the Malay Archipelago to the Himalayas (still unborn) and so to the Mediterranean. The characteristic fossils of this era are the spirally coiled ammonites, relatives of the octopus. With them are found extensive banks of mussel-like shells and the last representatives of some Palaeozoic types. Marine Mesozoic rocks are best developed in the Hokonui Ranges of Southland, but they are also found, often without fossils, in other mountainous parts of both islands.

The Mesozoic Era is known not only by fossil animals, but by fossil plants. At intervals during the Upper Triassic and Jurassic Periods the New Zealand area was above sea-level long enough for forests to flourish. The oldest are found in Canterbury—at Mount Potts in the Rangitata Valley and in the Clent Hills. Slightly younger are those in the Malvern Hills, at Mokoia, near Gore, and, most famous of all, at Curio Bay, near Waikawa, Southland. The Curio Bay beds, indeed, are a remarkable example of a petrified forest dating back to Jurassic times. Here the plant-beds are exposed by sea erosion, and the shore-line is thickly strewn with fallen trunks and limbs of petrified trees, many of them over fifty feet in length and two feet across. Even well-preserved impressions of leaves may be found in abundance. Flowering plants had not yet made their appearance and most of these fossils are remains of fern-like plants, cycads (a kind of palm), and conifers.

Mesozoic Era Upper Triassic and Jurassic Periods

The floor of the South-west Pacific, showing that New Zealand still retains submarine connections with northern lands. The sketch shows the depths in fathoms. T. G. Taylor

Cycads and fern-like plants, typical of the Jurassic Period. An artist's reconstruction of plant life on land.

During his first voyage Captain Cook proved that New Zealand was not part of a Great Southern Continent. This 'Dauphin' map of the world, made by Pierre Desceliers in 1546 to the order of Francis I. of France, for the education of his son, the Dauphin, shows the mythical

'Terra Australis' or Great Southern Continent. Note that the geographers of the period reversed all objects on one side of the Equator.

The First Period of Mountain-building

So great was the volume of spoil deposited on the shores of Gondwanaland that it caused the earth's crust to sag. Lateral pressure on this zone of weakness then led to folding on a large scale and the uplift of an extensive mountain system. The layers of rock laid down in Mesozoic times were partly altered by this pressure, the sandstones being changed into greywackes and the mudstones into argillites—the two types of rocks which make up most of the Southern Alps. The intense folding and crumpling of rock strata at this time can be seen very clearly near Mount Cook.

Agents of erosion at once attacked the new mountains and slowly reduced them to a more or less featureless plain over which seas advanced in later Cretaceous times. From the sediments then deposited many fossils have been collected in North Canterbury, Marlborough, and Kaipara Harbour, Auckland.

During this period the ammonites, those curious relatives of the modern octopus, still dominated the seas, but their relatives, the now extinct belemnites, were also numerous. Snails and shellfish, too, were abundant, and ancestors of the modern oyster throve exceedingly, for in parts of Canterbury their skeletons remain as massive shell-beds.

The fossil remains of these creatures suggest another interesting link between New Zealand and other parts of the world. They are very similar to those found in rocks of the same age in Grahamsland, in Patagonia, and in Chile. Since they lived in shallow water, it has been suggested that New Zealand was at this time connected to Antarctica by a land-bridge, forming a coastline along which marine life could pass to and fro between New Zealand and South America.

Kaipara Harbour, Auckland Province, where fossil seekers have found interesting specimens. The Weekly News

Upper Cretaceous Period

Mount Cook, from the Hooker Glacier. Government Tourist

A cross-section of Mount Cook. The section shows the folded strata of New Zealand's highest peak. J. Park

Giant Reptiles of the Sea

A Mosasaurus, an elongated reptile of the Mesozoic Era, the appearance of which is as fearsome as its name. This scraper-board drawing was based on data in S. W. Williston's 'Water Reptiles of the Past.'

IN Upper Cretaceous times the New Zealand seas were peopled by great marine reptiles, or saurians. The fantastic land reptiles of this period in the Northern Hemisphere did not exist here. But the long-necked sea lizards, or Plesiosaurs, which took the place of the whales and other sea mammals of modern times, lived in our seas in great numbers. Their fossil remains have been discovered in the Weka Pass—Waipara district of Canterbury and at Amuri Bluff, south of Kaikoura.

As long ago as 1874 the geologist, Sir James Hector, had assembled portions of forty-three reptiles, mostly of gigantic size and belonging to

An aerial view of the Canterbury Plains and Pegasus Bay. This infrared photograph has eliminated all haze, but has turned the sea to an unnaturally dark colour. The Kaikouras can be clearly seen in the distance. V. C. Browne

at least twelve distinct species. Besides six different species of Plesiosaurus, Hector recognised an extremely elongated reptile, a Mosasaur, and some new groups, one of which he named Taniwhasaurus after the fabled monster of the Maoris.

These ancient reptiles were most fearsome in appearance. The head of the Plesiosaur was snakelike in shape, while its neck was longer in proportion than that of any other animal. The body was thick-set, and the tail short and stout. Two pairs of large paddles provided adequate locomotion. The teeth were long, slender, pointed, and back-wardly curved—efficient weapons for a flesh-eating monster which sometimes reached a length of fifty feet, though the New Zealand species were only ten feet long.

The Mosasaurs were equally remarkable flesh-eating sea-reptiles which attained a length of thirty feet. The body was greatly elongated and the limbs converted into swimming paddles. The skull, up to five feet in length, was large in proportion to the rest of the animal, and the jaws were armed with numerous sharp, strong, conical teeth, showing the fiercely carnivorous habits of these fish-eaters.

Neither of these ferocious monsters survived the Cretaceous Period.

Less spectacular, but highly important products of the Cretaceous Period are New Zealand's oldest coal-fields at Greymouth and at Kaitangata in Otago. After the retreat of the Mesozoic seas the land surface was low and forests flourished. Great quantities of peat and of the remains of plants— stems, trunks, pollen-grains, and so on—accumulated in depressions of the land, or drifted into lagoons or wide tidal estuaries. As the seas advanced once more, these piles of vegetable material were covered by sands and clays, and the pressure of this load of sediment changed the partly decomposed plants into the valuable rock known as coal.

Mesozoic Era Cretaceous Period

Extensive banks of mussel-like shells are found in Mesozolc strata. Wm. C. Davies,

Cawthron Institute

Long-necked sea lizards, or Plesiosaurs, which inhabited New Zealand seas in the Mesozoic Era.

The Era of Modern Life

Limestone formation in Castle Hill Basin, Canterbury. Thelma R. Kent

The next era, the Tertiary, though it began some sixty million years ago, is described as 'modern' by the geologist, since, during its course, many forms of life known to us began to appear. In New Zealand it commenced with a gradual advance of the sea over the old land-surface of Mesozoic times. The spoil then carried down from the uplands formed coarse-grained grits, conglomerates, and sandstones. These were succeeded by coal-measures similar in origin to those of Upper Cretaceous times. As the sea advanced farther, shallow-water greensands were laid down,

Shark's tooth of Tertiary age. F. Chapman

Microscopic fossils—primitive plants and animals from the Oamaru district. J. Park

and finally accumulations of the hard parts of sea animals were built up in water too far removed from the land to contain sand or mud. These are termed limestones, and they are so widespread in Middle Tertiary formations that very little land could have remained above the sea.

That some land did survive, however, is proved by fresh-water deposits containing impressions of plants. These are quite modern in type, showing that flowering plants had now replaced the fern-like and conifer plants of the Mesozoic Era.

After Middle Tertiary times the downward movement of the New Zealand area was reversed, and the land began to rise. Limestone continued to be formed, particularly in parts of the North Island, but as the waters became shallower, there gradually appeared different deposits. These were fine-grained muds and sands washed into the sea from the emerging land.

The uplift of most of the South Island ended marine sedimentation, but in Marlborough and Tertiary Era

'Papa,' of blue mudstone, deeply carved by water, is a familiar formation in the North Island. This photograph shows the RangItikei River, near Mangaweka. New Zealand Railways

Tertiary foraminifera, marine fossils which help geologists in their search for petroleum. The pictures of these fossils are greatly enlarged. H. J. Finlay

Lamp-shells in limestone, Kakanui, Otago. J. Boehm

over much of the North Island it continued to a later date. The spoil worn down from the granite mountains of Nelson and northern Westland was carried north by ocean currents and spread over Taranaki, Wellington, and Hawke's Bay to form the widespread blue mudstones, or 'papa,' which are the youngest Tertiary strata in those areas.

Throughout the Tertiary Era there was a gradual change in climate, a change that was to culminate in a severe ice age in the next era. In Early and Middle Tertiary times, however, the climate in New Zealand was much warmer than at present, and in the shallow seas which flooded the land there flourished a rich and varied animal life, including some forms now found only in warm-temperate and tropical climates. From sands, limestones, and mudstones formed in these times, therefore, many well-preserved fossils can be collected. The specimens from the earliest strata belong to extinct kinds, but as we pass to higher strata, there is a gradual increase in the number of species which are identical with the life in New Zealand seas to-day.

The fossils of the marine beds belong to many groups. The lowly, single-celled Foraminifera, found in great numbers, are of great value to geologists when seeking for petroleum in commercial quantities. The spicules, which form the framework of sponges, are numerous in the famous chalk-like deposits of the Oamaru district. These also contain exquisitely constructed primitive plants called diatoms and lowly animals known as radiolaria. Among the larger fossils the most important are shells of many varieties, while corals, barnacles, and crabs are found in smaller numbers. Vertebrates (animals with a spinal column) are rare, but occasionally fragments of fossil reptiles and whales have been discovered. Fossil bones of a gigantic penguin are known, and sharks' teeth are comparatively common. Altogether, these Tertiary deposits provide a wonderful hunting-ground for the geologist, amateur or professional.

The Kaikoura Period of Mountain-building

Towards the end of the Tertiary Era the New Zealand area was subjected to intense pressure which was relieved by the breaking of the earth's crust along more or less vertical fractures, or 'faults.' The present relief of New Zealand is almost entirely due to movements which occurred in this period of mountain-building, or 'orogeny' as it is termed by the geologist; and, as its most notable result was the Kaikoura Mountains, it is called the ' Kaikoura Orogenic Period.'

Professor Cotton has aptly described New Zealand ' as a concourse of earth-blocks of varying size and shape.' These earth-blocks were raised during this period of mountain-building. The edges of each block were defined by great faults— or lines of fracture in the earth's crust—along which movement took place, some blocks rising to great heights, while others were pressed down or failed to rise. The highest blocks form the -mountainous back-bone, so typical of New Zealand, and, generally speaking, the present coastal areas and foothills are the marginal low-lying

The results of glacial action are evident in this photograph of the head of the Perth Valley, Westland. Note that the glaciers have

retreated, leaving a short level valley Uttered with rock debris (moraine), and that the cliffs on the right have been carved by the force of the ice. J. D. Pascoe

An aerial view of the Kaikoura Mountains. V. C. Browne

Late Tertiary Era

Diagrams showing how land features were formed in the Kaikoura period of mountain-building. A. The covering strata shield the 'undermass' but are worn down by erosion. B. The wearing-away of the covering strata has produced the typical land-surface of to-day. W. N. Benson

The Kaikoura Mountains from Island Bay, Wellington. On the left are the Seaward Kaikouras, in the centre is Mount Tapuaenuku (9,465 feet), the highest peak of the Inland Kaikouras. Government Tourist

blocks. Perhaps the most spectacular movements of this period were those which brought the Kai-koura Mountains into existence, for in their formation upward movements of 10,000 feet occurred. The structure of the blocks is two-fold. First there is an 'undermass' of rocks formed by the sediments of Mesozoic times, but now folded and altered. Above this lie horizontal beds of Upper Cretaceous and Tertiary age, these forming the 'covering strata.' The subsequent geological history of New Zealand is the story of the wearing down of this concourse of earth blocks by agents of erosion. Rain, running water, and wind have played their part. Changes in temperature and the freezing of water have also assisted in wearing down the rocks. But perhaps the most remarkable changes were brought about by the action of moving ice during New Zealand's great Ice Age.

Unstable conditions naturally resulted from these movements of mountain-building. The force of gravity acting downwards tended—and still tends—to cause readjustment, and this action is increased by erosion which removes material from the higher blocks and deposits it on lower country. Stresses are set up between adjacent blocks, and these, if sufficiently great, are relieved from time to time by renewed movement along the old faults. This movement sets up a vibration which travels outwards in all directions as an earth wave or earthquake. New Zealand's liability to earthquakes is, therefore, an aftermath of the Kaikoura period of mountain-building.

The Great Ice Age in New Zealand

Mounts Tasman and Cook, the highest peaks of the Southern Alps. This photograph is taken from Lake Matheson and shows part of the Fox Glacier, Westland. M. C. Lysons

The period of mountain-building which gave final form to New Zealand was not confined to this country. It coincided with a time of world-wide mountain-building which created the present mountain chains of the earth. The great changes of relief thus brought about were accompanied by equally great changes in climate. In both hemispheres polar ice-caps spread into the temperate zones. In the Northern Hemisphere, where the pole is surrounded by large areas of land, the polar ice sheet advanced far into North America and Europe; but in the South, where the Antarctic Continent is surrounded by ocean, conditions were somewhat different. Here, as a result of the intense cold, immense glaciers were formed in the newly raised mountains of the South Island and in Patagonia.

From the great snowfields on the high mountains of the South Island glaciers descended to the lower country. Their former extent, far beyond the limits of the present-day glaciers, may be de-tected by the tell-tale land-forms which the moving ice sculptured, and by the terminal moraines dropped at their farthest points of advance.

Probably one-third of the South Island was covered by ice during the Pleistocene Period. From north-west Nelson to Hokitika glaciers spilled down the valleys, sometimes uniting to form extensive ice-sheets on the lower country. Behind them they left great piles of ice-borne rubble, some of which still exist to dam back lakes such as Brunner and Kanieri. Farther south the moving ice reached the sea, there to break off as icebergs.

On the Canterbury side of the Alps the ancient glaciers made their way down all the main valleys, actually reaching, in the Rakaia and the Rangitata,' as far as the Canterbury Plains. South of Mount Quaternary Era Pleistocene Period

Lake Pukaki, one of the great glacier lakes of Canterbury. The ancient moraine in the foreground has dammed back the Tasman River. V. C. Browne

'Loess,' a glacial silt deposited by the wind. This example is found near Oamaru. J. Park

Cook a great glacier system extended far into the Mackenzie Plain. Lakes Ohau, Pukaki, and Tekapo are each bounded by huge moraines left by glaciers of this period. Western Otago was heavily glaciated, but the east coast was probably free from ice.

The retreat of the glaciers was followed by interesting climatic changes, and as the land was freed from ice, plants advanced from the non-glaciated regions. Recent study suggests that the first plants to re-people the newly exposed land were grasses and sedges. These were followed by an invasion of beech-forest, and finally by a mixed, warm rain-forest in which such trees as the kahi-katea, the miro, and the totara were dominant.

As the glaciers melted away, they left behind them a deposit of the finest sediment produced by the grinding of the ice over its bed. This 'rock-flour' was spread by streams over the wide valleys, picked up later by the prevailing north-west winds, and so carried over much of Canterbury and parts of Otago. This is the 'loess,' a wind-borne silt of glacial origin, which forms an excellent cover to much of the shingle of the Canterbury Plains.

The Franz Josef Glacier, Westland, which descends from icefields at 8,000 feet under the Main Divide, to rain forest 700 feet above sea level. The sharp peak on the skyline is Mount Spencer (9,167 feet). M. C. Lysons

Moas and Other Extinct Birds

The Pleistocene Period was the time when the remarkable flightless moas roamed over a great part of New Zealand in large numbers. Fossil remains are found in the loess, in sand-dunes, in caves, and in greater abundance, in swamps, particularly along the foot-hills of Canterbury. They varied greatly in size, and since they had no mammalian enemies, they flourished exceedingly. They survived until the Recent Period, but authorities differ as to the reasons for their extinction. Some claim, on the evidence of recent excavations, that they were finally killed out by Maori hunters only a few centuries ago.

The moas were the dominant land-dwellers of this period, but they shared the country with several other species now extinct. Of these the most notable are the Notornis, or takahe, and a gigantic eagle, Harpagornis, of which fossil remains are also found in swamp-deposits.

A moa. This illustration of 'Dinornis ingens' was taken from Walter Rothschild's 'Extinct Birds' (1907).

A cartoon of the discoveries of moa bones by W. B. D. Mantell, a well-known geologist. The original by James Brown is in the Hocken Library, Dunedin.

Quaternary Era Pleistocene to Recent Periods

Tuis, which are still found in bush areas in both islands. The songs of these birds have a wonderful musical quality. Tuis probably came

to New Zealand from the north a long time ago. The lithograph was taken from Sir W. L. Buller's history of New Zealand birds.

A lithograph of 'Notornis Mantelli,' of 'takahe,' from Professor R. Owen's 'Memoirs of the Extinct Wingless Birds of New Zealand' (1879).

Volcanic Activity in the South Island

An aerial view of Otago Harbour and Peninsula. V. C. Browne

The few active volcanoes of modern New Zealand represent the dying phase of an earlier period when volcanic activity was more widespread and vastly greater in scope than at present. As early as Middle Tertiary times there were outbreaks of explosive violence, for in several places, notably in the Oamaru district and in the Trelissick basin in Canterbury, great piles of volcanic ash lie between layers of limestone of that period. Lava-flows, including the remarkable pillow-lavas of Oamaru, are also found.

The great period of volcanic activity was, however, the Upper Tertiary. At this time great forces were setting in motion the Kaikoura movements of mountain-building. In all probability the same forces, working beneath the earth's crust, forced to the surface great quantities of molten material, or 'magma.' The same thing occurred throughout the world, and New Zealand is but a part of the so-called 'girdle of fire' that encircles the Pacific Ocean.

In late Tertiary time the Dunedin district was the site of vigorous volcanic activity. Vast outpourings of lava flowed from several sources, while huge masses of material were ejected and fell as ash-showers. Flagstaff, Mount Cargill, Signal Hill, and many other parts of the district from Saddle Hill to Karitane, are mainly or entirely of volcanic origin.

Farther north Banks Peninsula is formed of two volcanoes, the centres of eruption being at Quail Island in Lyttelton Harbour and at Onawe Peninsula in Akaroa Harbour. Both are surrounded by well preserved crater rims, and in each case part of the rim has been broken down, thus allowing the sea to flow in over the old crater floor.

A scraper-board drawing of columnar basalt near Mount Cargill, Dunedin.

Lyttelton Harbour, from the air. This harbour is the drowned crater of an old volcano. V. C. Browne

North Island Volcanoes

The cone of the extinct volcano, Mount Egmont, from the air. V. C. Browne

Boiling mud in the thermal region, North Island. Government Tourist

During the same period in the North Island activity was even more intense and widespread. Thick lava-flows cover a great part of the centre of the island, and rising above this central plateau are the more recent cones of the Tongariro group. Mount Egmont, the almost perfect cone which dominates Taranaki, was formed at about the same time.

One of the most interesting volcanic areas is the Auckland Isthmus, where there are a large number of small cones so recent in origin that they retain their form perfectly. Of these Rangitoto is the largest and most famous. Still farther north Whangarei and the Bay of Islands were the scene of great volcanic activity.

Within historic times activity has been confined to the area comprising Ruapehu, Ngauruhoe, Tongariro, Tarawera, and White Island. Ruapehu (9,175 feet) must have been very active in Upper Tertiary times, but it is now more or less extinct. Nevertheless, at different times, notably in 1890 and 1906, the crater-lake has displayed violent geyser-like action. Its long history is perhaps not completed. Ruapehu's neighbour, Ngauruhoe, is New Zealand's most continuously active volcano, and mild eruptions occur every few years.

The most spectacular and disastrous eruption within recent times took place in 1886, when Mount Tarawera was split in two. A fissure some eight miles in length opened, and from a series of about twenty new craters an immense mass of fragmentary material was erupted. Ash-showers covered an area of 4,000 square miles and the eruption destroyed the famous Pink and White Terraces on Lake Rotomahana.

The volcanic districts of the centre of the North Island, from Ruapehu to Rotorua, have entered the dying stage of the volcanic cycle. The main activity has largely ceased, but hot springs, geysers, steam-jets, mud volcanoes, 'porridge-pots,' and so forth still remain as signs of dying vulcanicity.

An aerial photograph of Mounts Tongariro, Ngauruhoe and Ruapehu. Note the signs of past and present volcanic activity. V. C. Browne

Tertiary Era to Presernt Day

The White Terraces, which were destroyed in the Tarawera eruption of 1886. The original oil painting by C. Blomfield hangs in the rooms of the Speaker of the Legislative Council.

Waimangu Geyser, Rotorua. Government Tourist

The Present Relief of New Zealand

Wilkie's Pools, Egmont, The photograph shows a youthful stage in stream erosion, with the formation of pot-holes. Government Tourist

We have seen that New Zealand took form as a result of the Kaikoura movements of mountain-building. This left the land a mosaic of earth blocks, each composed of two units—first an ancient 'undermass,' then above that horizontal younger rocks. Our geological history since that time has been the story of the wearing-down of those earth blocks by all the agents of erosion. Of these the most powerful, under normal circumstances, are rain, running water, and physical processes like changes in temperature and the freezing of water. Waves play their part on the coasts; glaciers are immensely powerful agents in certain limited areas; and under dry conditions wind can also be effective in wearing down the rocks.

These eroding agents quickly attacked the surface of the higher blocks, and in the course of time the less resistant upper layers were stripped

The Wanganui River, North Island. Here rapids and falls have disappeared and the river fills a steep-sided trench. Government Tourist

off to re-expose the more ancient rocks beneath. At the present time the mountains of the Southern Alps are carved in the older greywackes of the undermass, while the once continuous cover has, with rare exceptions, been completely removed. On the lower blocks which form the coastal lands on either side of the mountain ranges, however, the upper layers are only partly stripped.

The covering-beds have still survived in a few places on the surfaces of inland blocks which failed to rise with their neighbours. The edges of such blocks are faults, forming the boundaries of the higher surrounding blocks whose cover has been removed by erosion. Such 'intermontane basins,' as they are termed, are well developed in Central Otago and in Canterbury.

The Otago Central Railway follows a chain of lowlands which are the depressions in a broken plateau of block mountains. Here part of the cover of younger rocks is still preserved in the basins, but the uplands are of schist or greywacke, the re-exposed ancient rocks of the undermass. Even more striking are the inland basins of Canterbury. The Trelissick or Castle Hill Basin, with its weathered limestones of Tertiary age, is an enclosed space some five miles long by three broad, almost surrounded by greywacke mountains 6,000 to 7,000 feet in height. Of similar formation are the Waiau-Hurunui and the Hanmer Basins.

Quaternary Era

The Buller River, Westland, meandering over gravel and sand deposits. Government Tourist

An aerial view of Mount Grey, Canterbury, with ridges of Tertiary limestone. V. C. Browne

After the Ice Age

A glaciated 'U'-shaped valley in Fiordland, from the air. Glacial valleys are broad-floored and steep-sided; they have few curves and ape not interrupted by overlapping spurs. Former spurs have been cut back or truncated by the ice. The floor of the valley is often uneven, with sudden steps and lake-filled irregularities. Tributary streams, which flow in hanging-valleys often high above the main valley, cascade in as waterfalls, whereas tributaries of a normal stream meet it at stream level. M. C. Lysons

This scraper-board diagram shows the origin of a mountain such as Mount Cook. Cirques (armchair-like hollows) have been, enlarged until they met in converging ridges, which are worn away until a sharp peak is left. Geologists foretell that some day Mount Cook will be reduced to the fragment shown at the bottom of the diagram.

THE improvement of climate which gradually succeeded the intense cold of the Ice Age in New Zealand, was accompanied by the gradual retreat, still in progress, of the valley glaciers in the mountains of the South Island.

In Westland, in Fiordland, in Canterbury, and in the Lake District of Otago, it is now possible to examine country that was formerly glaciated, and so gain some appreciation of the powerful erosive action of moving ice. It is found that glacial erosion, slow but relentless in its action, produces characteristic land-forms very different from those which result from the operation of rain and running water. Such land-forms are developed on a magnificent scale in New Zealand.

The valley head in glaciated country is usually as wide as the rest of the valley, or may even expand into an armchair-like hollow, or 'cirque.' The more or less perpendicular walls of adjacent cirques, each eating backwards into a mountain peak, may meet in a steep-sided, jagged ridge, of which Mitre Peak in Milford Sound is a superb example. A number of ridges, each separated from its neighbour by a cirque, may converge to form an isolated, pyramidal mountain. Many of the finest peaks in the glorious pile which dominates South Westland—Elie de Beaumont, Cook, Tasman, La Perouse, and Sefton—owe their origin and their beauty to this process; and on them all it is still in progress.

Valley-head cirques sometimes intersect to produce a gap or 'col' which may serve man as a mountain-pass. Such is the origin of the Lake Harris Saddle between the Routeburn Valley and the Hollyford; and of McKinnon's Pass, between Te Anau and Milford Sound, which separates the Clinton Canyon, a magnificent glacial trough, from the Arthur Valley.

Of the same type and origin as the Clinton Canyon, but differing in that they are drowned or invaded by the sea, are the fiords of southwestern New Zealand. These scenic masterpieces have all the characteristics of heavily glaciated country—vertical walls, great depths, broad floors, cirques at their heads or in side valleys, and Recent Period

Pancake rocks at Punakaiki, Westland, showing the result of the erosion of limestone by rain-water. Government Tourist

An aerial view of the course of the Franz Josef Glacier. Note the extent of the crevassed area of snowfields. These high snow basins feed the glacier below. M. C Lysons

hanging-valleys from which plunge spectacular water-falls such as Stirling Falls or Bowen Falls.

Land-forms of yet another type are frequently found in the lower parts of glacial valleys where moraines, which consist of debris transported by the glacier, have dammed back a stream to form a lake. Such is the origin of Lakes Wakatipu, Wanaka, and others in Otago; of Tekapo, Pukaki, and Ohau, the triple gems of Canterbury; of lovely Lake Matheson at Weheka; of Mapourika and Ianthe near Waiho; of Brunner, Kanieri, Rotoiti, and Rotoroa.

The bulk of the waste derived from the land by the agents of erosion is deposited finally on the sea-floor. Part of it, however, may build land-forms of some permanence. In the glacially-formed valleys of Canterbury, for example, waste descends to valley level as screes or 'shingle-slips.' Where a tributary enters the main valley, this type of deposit may develop into an alluvial fan or cone. Land-forms of this origin are developed to perfection in the Rakaia and Waimakariri Valleys.

When a number of streams emerge from a mountain tract on to a lowland they deposit much of their load to form broad, gently sloping fans. As these grow forward and enlarge they merge and ultimately form a continuous apron of waste. The Canterbury Plains are a fine example of such a land-form. If the waste carried to the river mouth is greater than can be removed by off-shore currents, deltas will form, and these may grow into delta-plains. The Southland Plains and the Heretaunga Plain of Hawke's Bay are of this origin.

Shingle slopes on the Whitcombe Pass—the 'No Man's Land' between Canterbury and

Westland.

This photograph from Mount Oakden, near Lake Coleridge, shows the Rakaia, Mathias, and Wilberforce Valleys. The floors of the main valleys form valley-plains of shingle and sand, over which the streams wander in the 'braided' channels so characteristic of many South Island rivers. J. D. Pascoe

What the Maoris Found

Celmisias, or mountain-daisies, in a remote Westland valley. A. F. Pearson

The tuatara lizard, a 'living fossil' found to-day on a few outlying islands, but formerly common on the mainland. Government Tourist

The long history so briefly outlined in this story of *The Beginning* ends with the formation of a land surface which its first European discoverers were to call New Zealand. But it was more than a land surface; it was the home of an interesting fauna and a rich and varied flora. These inhabitants, long undisturbed by man, also have a history which in part is explained by the geological events that have already been outlined.

Three groups with rather different histories may be distinguished. First come the plants and animals which are such distinctive local products —forms of primitive type and ancient lineage, which, whatever their origin, underwent developments in the New Zealand area. These are the ancient inhabitants of the Dominion. Included here are the tuatara, a reptile of a type which became extinct in the Mesozoic Era in other parts of the world, and the New Zealand frogs. Of perhaps a later date but still of the same type are the wingless birds so characteristic of New Zealand—the extinct moas, the kiwis, and the rails. Plants of comparable antiquity include the native flax, the Veronicas, or koromiko, the Coprosmas, to which belongs the karamu, the Olearias, of which the daisy-tree is a common example, and the Celmisias, or mountain-daisies.

A second group, and a most important one, has affinities with northern lands—New Caledonia, New Guinea, and Malaya. The plants of this group originated in a tropical climate, and many are not entirely happy in New Zealand, for they can tolerate very little frost. Here botanists include the kauri, the cabbage-tree, the nikau, the fern-trees, most New Zealand orchids, the rata, and the manuka. Among the animals are the large land-snails, the parrakeets, the huias, wrens and pigeons, and many insects. This invasion of forms of northern origin is assumed to have taken place in Cretaceous times during the first mountain-building period, when New Zealand was of continental dimensions and extended northwards as a continuous land area to New Caledonia and New Guinea. It could not have been later for the mammals which migrated southwards from Asia in Upper

Cretaceous and Early Tertiary times are, with the exception of the native bats, absent from New Zealand. The ancient northern land-bridge had disappeared before they could use it.

The third element in the New Zealand flora and fauna is of southern origin and probably reached this area from Antarctica, perhaps during the same time of continental expansion. The plants of this group are chiefly the southern beeches, the bidi-bidi, the fuchsia, and other forms with relatives in South America. The penguins and shags are birds of similar origin.

In certain respects there has been intense competition between the elements of southern and of northern origin—a silent battle of trees—with sometimes the beech-forests advancing northwards, sometimes the warm rain-forest pushing south as minor climatic changes occurred. With the forests went the insects, spiders, and birds which depended on them for shelter or food.

At long last Polynesian voyagers discovered this southern land, found in it an equable climate and an abundant food supply. The Maoris arrived with the implements and ideas of a primitive people, lacking the means or the desire to alter the face of the land to any marked degree. It was not until Europeans came some centuries later that changes of significance took place. Since that date, as Guthrie-Smith has written, '...successive tides of biological change have swept New Zealand, each of them bringing its special perils to the ancient inhabitants of land and water, its special modifications to the very surface indeed and contour of the land.'

A group of five brilliant pioneer geologists, whose work laid the foundation of present-day knowledge. Sir Julius von Haast (1822-87).

F. W. Hutton (1836-1905).

Sir James Hector (1834-1907). Dominion Museum

Alexander Mackay (1833-1909). Dominion Museum

F. R. von Hochstetter (1829-84).

A kauri forest in the Auckland Province. Government Tourist

Later numbers of *Making New Zealand* will tell the story of these changes—some good, some bad—which have transformed primeval New Zealand into the busy modern state we know to-day.

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The following books will help those who wish to study the subject further

Making new zealand

Already issued

- The beginning
- the maori

In preparation

- Navigators and explorers
- Whalers and sealers
- Missionaries and settlers
- The voyage out
- The squatters
- Gold
- The forest
- The mountains
- Pasture land
- Refrigeration
- Power
- Bread
- Manufacturing
- Tracks and roads
- The railways
- Sea and air
- Communications
- Houses
- Furniture
- Public buildings
- Dress
- Defence
- Recreation
- Racing
- Summer sports
- Winter sports
- Polynesians
- The changing land

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