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Outline of the geology of New Zealand.

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OUTLINE OF THE GEOLOGY OF NEW ZEALAND.

THE geological reports, maps, and sections which are issued by the Geological Department of New Zealand (see appended list) indicate in detail our present knowledge of the structure of the Islands and the distribution of the chief groups of rock formations; and the leading features have been drawn on the index-map which accompanies this pamphlet.

The terms used in classifying the stratified rocks are the following :—

AGE.
 SYSTEM.
 Formation.
Series.
 Beds.

The term "group," which by some is used to signify two or more formations, is reserved for the classification of igneous and metamorphic rocks, in dealing with which a collective term is frequently necessary.

EXPLANATION OF TERMS OF PROPOSED CLASSIFICATION.

AGE.—This is a collective term of general adoption, and is applied to the larger divisions of the stratified rocks that are accepted as indicating great periods in the history of life on the globe, distinguished in all countries by palæontological evidence, such as Palæozoic, Mesozoic, and Cainozoic ages, which are chiefly of use in dealing with the larger questions of physical geology and geography, there being no really well-pronounced natural divisions or periods in the history of the earth as a whole which correspond with them.

SYSTEM.—This term is applied to the subdivisions which are subordinate to the "ages," each representing a lengthened period of time, the strata deposited during which had in all parts of the earth a number of mineral and fossil characters in common, and may be therefore regarded as each representing one great physical epoch in the evolution of the stratified portions of the earth's crust.

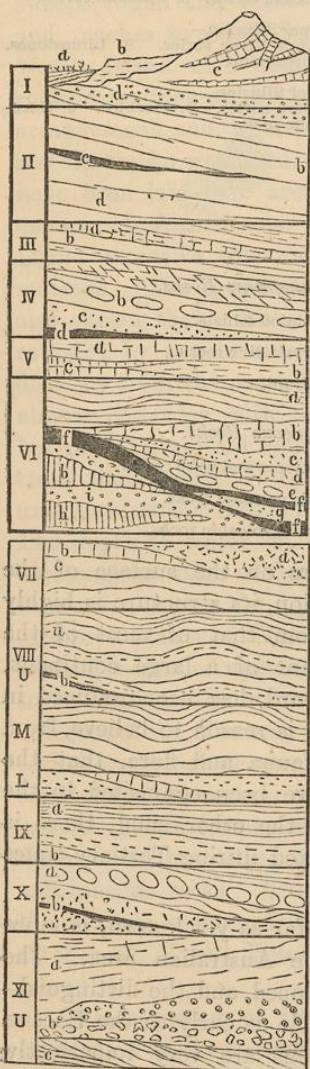
Each system is distinguished in all maps and sections by the definite colour or tint allotted to it in the schedule.

Formations.—These are the large systematic divisions actually in use in describing the geology of New Zealand, being a natural classification of the stratified rocks, founded on observation. Each formation is distinguished in the map, plan, or section, and when referred to in reports, by Roman numerals or capital letters, and by a distinctive marking impressed on the colour of the system to which it belongs. As far as possible the names usually applied to the equivalents of these formations in other countries have been employed, for the convenience of those to whom local names are unfamiliar; but in several instances the natural subdivisions of the strata which admit of being mapped overlap the conventional subdivisions. In such cases, local or composite terms have been used, as, for instance, "Waipara" or "Cretaceo-tertiary formation," which includes the Lower Eocene and Upper Cretaceous of ordinary classifications, for the reason that no division-line that can be used for the purpose of practical geology can be interposed. The term "formation" is therefore to be read as the local development in the New Zealand area of any system or part of a system the boundaries of which can be distinctly traced in mapping the country.

Series.—The terms "series" and "beds" are of use chiefly in descriptive geology, and can rarely be employed as distinguishing features in general maps; but in local geological plans, and in illustrative sections, they are frequently introduced. Each series is part of and subordinate to a formation, and bears the name of the locality where the most typical, or, in some cases, the first-discovered, section of the particular series of beds was found. Each series is indicated by an Arabic numeral following the number, letter, or name of the formation in which it occurs. The division of any formation into series is dictated entirely by practical utility. As far as possible, the different series adopted in the classification are arranged so as to be consecutive in superposition and age, but in some cases the term has necessarily been used in a descriptive sense.

The "beds" (layers or strata), in the particular application of the word, are the things to be classified under the foregoing phrases, and this term is therefore of very varied application. As a rule the term is employed to indicate an imperfect and local development of a series, or a portion of a series, that has well-marked distinctive characters, founded on its mineral composition or fossil contents.

The following classification has been adopted in the construction of the index-map, which is a reduction of the geological map on the scale of 12in. to the mile prepared for the Exhibition; but it must be borne in mind that, notwithstanding the large amount of data that has been collected, the extent and rugged nature of the country and the very limited staff have precluded minute surveys being effected, so that the attempt now made to express the results obtained in a systematic form must be considered as merely provisional.



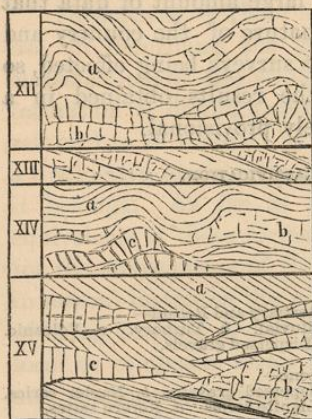
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Index-Map.

CLASSIFICATION.

- Yellow. {
- I. Post-tertiary and Recent—
a. Alluvial. b. Turbary. c. Volcanic.
d. Dispersed gravels.
 - II. Pliocene—
a. Dispersed gravels. b. Napier series.
c. Lignite series. d. Kereru series.
- Orange. {
- III. Upper Miocene—
a. Te Aute series. b. Tauern series.
 - IV. Lower Miocene—
a. Awatere series. b. Pareora series.
c. Awamoia series.
 - V. Upper Eocene—
a. Mount Brown series. b. Oamaru series.
c. Waitaki series.
- Green. {
- VI. Cretaceo-tertiary—
a. Waitemata series. b. Ototara series. *
c. Mawhera series. d. Chalk series.
e. Waireka series. f. Coal series. g. Black
grit series. h. Propylite breccia series. Acc
i. Great conglomerate series.
 - VII. Lower Greensand—
a. Buller series. b. Porphyry breccia
series. c. Amuri series.
- Blue. {
- VIII. Jurassic—
a. Mataura series. b. Putataka series.
c. Flag Hill series.
 - IX. Liassic—
a. Catlin's River. b. Bastion.
 - X. Triassic—
a. Otapiri (Rhaetic) series. b. Wairoa
series.
 - XI. Permian—
a. Oreti series. b. Kaihiku series.

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Index-Map.

*Tr. Permian-Carb. ?
Australia ?*



- Sepia. {
- XII. Carboniferous—
a. Maitai series. b. Limestones.
 - XIII. Devonian—
a. Te Anau series. b. Kakanui series.
 - XIV. Upper Silurian—
a. Baton River series. b. Limestones.
c. Serpentine.
 - XV. Lower Silurian—
a. Aorere series. b. Marbles. c. Horn-
blende rock.

Metamorphic Rocks.

- Purple. XVI. Foliated schists.
- Crimson
Lake. {
- XVII. Crystalline rocks.
 - XVIII. Granite.

Igneous Rocks.

- Carmine. {
- XIX. Plutonic and dyke rocks.
 - XX. Basic volcanic rocks.
- Pink. XXI. Acidic volcanic rocks.

New Zealand presents a peculiar feature on the surface of the globe, as, notwithstanding its isolated position, its structure is highly complicated, in which respect it differs from that of most of the oceanic islands. It is, in fact, the remnant of a large continent, which, formerly extending far to the eastward, has been reduced in area by the erosive action of the sea. There is reason to believe, from consideration of the existing and extinct fauna and flora, that the continent of which it formed part may have been connected in the temperate zone with South America. On the other hand, there is no clear evidence of its having been connected during Tertiary times with Australia, lying to the westward.

On the whole, the geological record, so far as yet known, is more complete in the New Zealand than in the Australian area. The Tertiary strata are perhaps equally well developed, and the distinguishing facies of each existing fauna is discernible as early as the Eocene formations. The upper Mesozoic formations are very imperfectly

represented in Australia, but have enormous development in New Zealand, in which country, as in America, the Tertiary facies of the fauna and flora springs from a shore-line and land-surface of pre-Cretaceous age. This is the period of the chief coal deposits in New Zealand.

The surface configuration of New Zealand is that of a mountainous country having a leading range chiefly composed of upper Palæozoic rocks. This mountain-range commences on the south-east of Otago, sweeps round the West Coast, where it culminates in Mount Cook, and reaches to Cook Strait. Thence it is continued through the North Island in a north-easterly direction to the East Cape. The rock-formations of this backbone range have, on the whole, a synclinal arrangement, and, where highest, have an easterly dip, thus presenting a scarp to the westward, along the base of which, in the South Island, have been laid bare areas of metamorphic rock supporting synclinal masses of fossiliferous Lower Palæozoic strata, and in the North Island extensive volcanic outbursts, associated with vast Tertiary formations. The investigations of the "Challenger" expedition have also shown that, unlike other oceanic islands, New Zealand is surrounded by a submarine plateau or shelf, which extends a varying distance from the coast. On the south-west the edge of this plateau almost coincides with the coast-line, which here presents a massive buttress of granitoid rocks to the prevailing erosive action of the ocean from that quarter. To the eastward the extent of the plateau is unknown, except that it probably reaches as far as the Chatham Islands. The depth of water on the plateau is about 300 to 600 fathoms, the surrounding water of the ocean having a depth of from 2,000 to 2,600 fathoms. Along the base of the mountains in the South Island are extensive plains of Tertiary fluvial formation, with occasional protruding ridges of upper Mesozoic rocks, forming low mountain-ranges subordinate to the main axis. In the North Island there are similar outcrops of the Mesozoic rocks through the marine Tertiary and volcanic formations which occupy the greater portion of the surface. In many cases the evidence is very marked that in New Zealand the newer and unconsolidated formations have only survived and escaped denudation through the protecting influence of the harder masses of metamorphic and igneous rocks. This is illustrated by reference to the relation of the volcanic system of Banks Peninsula to the Canterbury Plains, and of that of Mount Egmont to the great Tertiary plain of the North Island.

The inspection of the large geological model facilitates the comprehension of the structure of the Islands. The best point of view to

commence the examination is at the East Cape. The great leading range of Upper Palæozoic rocks (dark sepia) is seen to stretch through both Islands as a narrow range, dislocated at Cook Strait, and spreading out into two branches in the far south to enclose the extensive schistose area of the interior of Otago. Schistose and other metamorphic rocks (purple and vermilion) are seen to crop out along the western base of the mountains of the South Island, and are found nowhere else, with the exception of small areas on the south side of Cook Strait, where they appear to have been faulted up. On the eastern side of the mountains we have evidence of a succession of a synclinal or trough-like arrangement of all the formations up to the close of the Waipara or Cretaceo-tertiary formation (green); while the Tertiary formations (Upper, chiefly of fluviatile and lacustrine origin—yellow; and Lower, chiefly of marine origin—pale pink) occupy the bays and indentations of the higher lands, and, although ascending to a considerable altitude, have their distribution always in obvious relation to the existing orographical features.

In the North Island the Tertiary formations occupy a much greater extent of surface, and have a more continuous distribution. Those of a marine origin form a semicircle, extending from Mokau on the west to the East Cape on the east, and rise from the sea-level on the coast to 3,700ft. altitude on the south slope of the Kaimanawa Mountains (Palæozoic slates), the centre of the dome being formed by the great volcanic mountains of Ruapehu and Tongariro, the latter of which is still active. On the other hand, in the north-west part of the North Island the Tertiary rocks are, with a few insignificant exceptions, of fluviatile or lacustrine origin, resting unconformably on formations of greater age than the marine Tertiaries, and smothered by extensive igneous accumulations, the products of long-continued volcanic eruptions. The formation of the west coast of both Islands is worthy of attention, taking the scarp of palæozoic rocks that forms the main range as the division between east and west. This commences on the east coast, at Shag Point, in Otago, and sweeps north-west through Mount Cook, across the narrowest part of Cook Strait, and through the North Island, along its eastern border, to the East Cape. Lying to the west of the longitudinal division thus defined are three large areas which require special attention, as they are occupied by exposures of those deep-seated formations which yield metallic ores. The first of these is the Otago area, which is the crown of a flat anticlinal dome, the denudation of which has exposed metamorphic schists over an area of 8,000 square miles, the rocks within this area having been changed from the original sediments into

foliated mica schists. Schistose rock of this kind is quite unable to resist even the feeblest denuding agency, as it is easily broken up into fine micaceous matter that almost floats away, leaving a residue of quartz-fragments that rapidly wear into rounded gravel, in which form it is also easily moved by water. This is proved by the manner in which the surface of the schistose area has been worn into ridges and furrows by the action of the smallest streams, while the larger rivers act like gigantic sluice-boxes, through which an enormous amount of detrital matter is carried, leaving behind in a concentrated "wash" the gold and other metallic particles which are disseminated through the mineralized rock.

On the weather side, or the south-west, of the foliated schists lies a great area of crystalline schists, in which the original sediments have been thoroughly crystallized into the toughest and most obdurate forms of rock. This area (light vermilion) has acted as a protecting buttress, without which the soft schistose area would have been long since removed; and its hard, resisting surface is seamed by the scars of denuding agencies, the action of which has been continued throughout many geological ages. It is in this manner that the grand scenery characterizing the fiords and sounds of south-west Otago has been produced.

From Jackson's Bay northwards the west side of the main range presents an abrupt scarp, but having on each Island a triangular projection stretching to the north-west, remnants, as it were, of extensions of land in that direction which have resisted and survived the denuding influence that has elsewhere eaten back into the very core of the mountain-range. The projecting area from the South Island terminates at Cape Farewell, and has its base from Greymouth to Nelson. The corresponding area from the North Island is much more extensive, and terminates in the North Cape, having its base along the western side of the main range, from the Manawatu to Opotiki. Both of these areas present one remarkable feature in common, in which they differ from the prevailing character of the rest of New Zealand—and that is, in the extensive and complicated development of igneous rocks which they exhibit, the only difference being that in the South Island these igneous rocks are irruptive or plutonic, while in the North Island they are eruptive or volcanic.

In the north-west area of Nelson, where we have the most ancient fossiliferous formations associated and interbedded with plutonic rocks, intense local mineralization has occurred, attended by the formation of veins that contain a great variety of valuable metallic ores. The remnant of the great western land extension in the North Island

has been so heavily enveloped in the volcanic products of recent geological periods that the underlying mineralized and metalliferous formations are only rarely accessible, although there is conclusive evidence of their existence. The hydro-thermal agencies that mark the expiring activity of volcanic outbursts has led to the infiltration of siliceous veins, carrying gold, silver, and other metals, into rocks of comparatively modern date. Where the deep-seated portions of such infiltrated areas have been exposed by erosive denudation, as, for instance, in the exposed peninsula of Cape Colville, the metalliferous veins are brought within the reach of the miner as the result of marine denudation; and there are probably infiltrated areas in the interior where the hot springs have become dormant, and in which the cores have been laid bare by the intense atmospheric denudation that affects elevated alpine areas, in the same manner as the mineral veins have been laid bare in the Sierra Nevada and other alpine mining districts in America.

DETAILED DESCRIPTION OF FORMATIONS.

I. RECENT AND POST-TERTIARY.

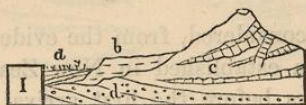


Fig. 1.

a. Alluvial. *b.* Turbary. *c.* Volcanic. *d.* Dispersed gravels.

DEPOSITS of this description have accumulated with great rapidity in New Zealand, as the mountainous character of the country gives to the rivers, even when of large size, the character of torrents, which are liable to occasional floods of extreme violence. To some extent, also, the remarkable indications of change which are everywhere manifest must be attributed to alterations of relative level which have affected the surface, some of which have occurred during the present century. Such changes are more easily detected on the sea-coast, where they effect sudden alterations of the shore-line; but there is no doubt that they have been equally potent in inland districts, and have caused, for instance, marked alterations in the courses of some of the rivers. The rapidity with which the coastal drifts accumulate and are again dispersed by such changes is well exemplified on the west coast of the South Island by the following section, exposed by the gold-miners in their search for the gold-dust brought down by the rivers and again cast back on the ocean-beach by the action of the waves:—

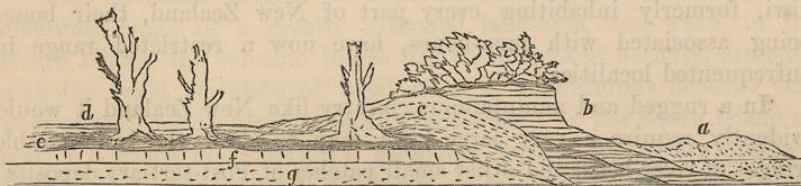


Fig. 2.

North of Buller River, Coastal Drifts. *a.* Modern shingle-beach. *b.* Ancient river-silt. *c.* Ancient shingle-beach. *d.* Modern lagoon-silt. *e.* Soil and forest. *f.* Blue clay. *g.* Black sand (auriferous).

The earthquake-rents, which are observed in many parts of the country, afford further evidence of recent change; but they seem to

have opened along lines which have been affected in the same manner from very remote periods. The cumulative tendency in one direction of such disturbances has produced the most astonishing results, considering the limited geological period from which they date. Recent surveys have shown that some of these earthquake-rents are vertical to and coincide in direction with great displacements of strata by faulting, amounting, in the case of the Great Clarence Fault, to several thousand feet, the earlier movements being probably of Pliocene date.

The Maori race is considered, from the evidence afforded by their traditions, to have been established in New Zealand for little more than five hundred years before the first arrival of Europeans; but during that period, while the islands were being explored in all parts by this intelligent and adventurous native race, the spread of fires, causing the destruction of the primeval forests and rank vegetation, was the means of setting free vast accumulations of loose soil and disintegrated rock that were formerly retained on the mountain-slopes. The material thus displaced has accumulated in the river-courses, causing them to raise their beds above the adjacent lands, so that they have broken away from their channels in many places.

The race of gigantic moa birds (*Dinornis*) had its maximum development in the New Zealand area, and only became extinct during the recent period; but their extermination must have commenced at an earlier date than the first human occupation, as their bones are found in vast numbers deeply imbedded in the gravels and swamps, while the evidences of human occupation are confined to the surface-soil, shelter-caves, and sand-dunes.

Other genera of flightless birds besides *Dinornis* have disappeared from the New Zealand area within recent times—namely, *Harpagornis*, *Cnemioornis*, and *Aptornis*—whilst the *Notornis*, the kakapo, and the kiwi, formerly inhabiting every part of New Zealand, their bones being associated with moa-bones, have now a restricted range in unfrequented localities.

In a rugged and mountainous country like New Zealand it would evidently require a very large-scale map to show the innumerable fringes of river-beds, and other small patches of Post-tertiary deposits; and accordingly these have been neglected in the geological map, and indications of the recent deposits have been limited to those places where the structural rock of the country is not exposed. These deposits, however, cover a considerable area of country in the Canterbury Plains, the Mackenzie country, around the mouth of the Waitaki River, and in the Maitaura, Waimea, and Five Rivers plains,

in the South Island; and in the Manawatu, Waikato, Thames, and Kaipara districts, and the isthmus between Awanui and North Cape, in the North Island.

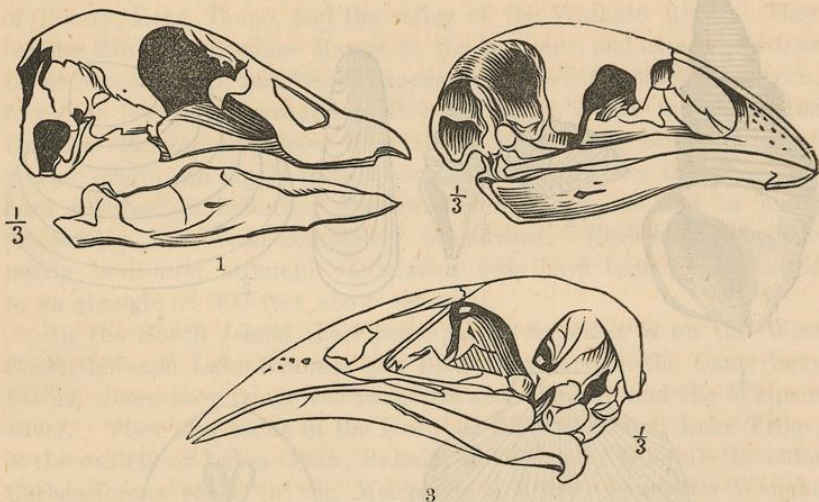


Fig. 3.
1. Cnemiornis. 2. Dinornis. 3. Aptornis.

II. PLIOCENE.

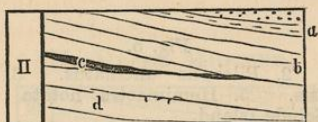


Fig. 4.
a. Dispersed gravels. *b.* Napier series. *c.* Lignite series. *d.* Kereru series.

This formation belongs to a period when New Zealand was the mountain-range of a greatly extended land-area, and when, in the North Island, the volcanic forces had their greatest activity, attended with the rapid elevation of local areas of fossiliferous deposits that were at this period forming in adjacent seas. In the South Island no marine deposits of importance belonging to this period are present; but the great area of land above the shore-line intensified the erosive action of the glaciers radiating from the mountain centres, and gave rise to enormous deposits of gravel, such, for instance, as compose the greater part of the Canterbury Plains, and the Moutere Hills in Nelson.

The marine beds of Pliocene age are characterized by the great abundance of the existing shell, *Rotella zealandica*, and among extinct

species, *Struthiolaria fraseri*, *Pleurotoma tuberculata*, *Pileopsis uncinatus*, and *Lutraria solida*.

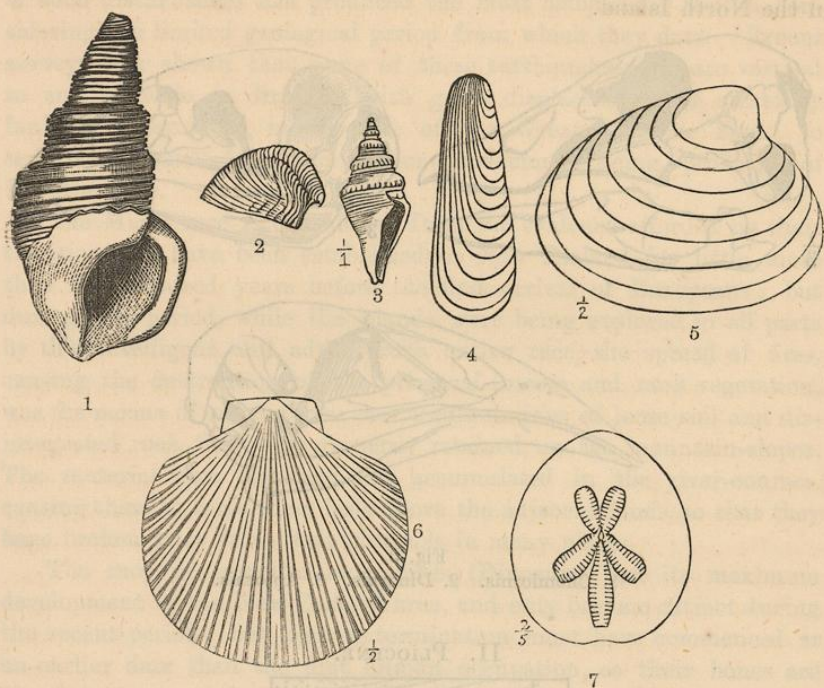


Fig. 5.

1. *Struthiolaria fraseri*. 2. *Pileopsis uncinatus*. 3. *Pleurotoma tuberculata*.
4. *Lithodomus striatus*. 5. *Hemimactra notata*. 6. *Pecten accrementa*.
7. *Amphidotus* (sp.), Scinde Island.

The economic importance of some formations of this age is very considerable, from their containing the richest deposits of alluvial gold that support the mining population. In the elevated schistose area of Otago the ancient drainage-channels of this period, with the earliest-formed auriferous gravels, have been intersected by the modern watercourses, and now occupy elevated positions, where their presence is often unsuspected until revealed by accident.

In the north they are represented by marine beds on various parts of the coast and around Manukau Harbour, and, as fluvial beds, cover a considerable area of country in the districts between Alexandra and the Upper Thames, and stretch from Lake Taupo towards Opotiki, fringing the coast between that point and Katikati.

They also occur as a marine deposit at Wanganui, where they are highly fossiliferous; and, as superficial drifts, stretch back from there

towards the Rangitikei and Pohangina Rivers. As pumice-sands they cover the elevated country round the base of Tongariro and Ruapehu, and thence form the sloping plain that stretches to the Bay of Plenty, Lake Taupo, and the valley of the Waikato River. They further flank the Ruahine Range on the east side, and extend north as far as Moeangiangi, and, besides appearing as isolated patches between, form the low hills surrounding Poverty Bay. Where they flank the Ruahine Ranges they have a great thickness, and, being there of marine origin, are highly fossiliferous. In that district they have also been involved in extensive structural movements, so that in many places they have been completely overturned. Elsewhere they are nearly horizontal, although the marine beds have been locally raised to an altitude of 300 feet above sea-level.

In the South Island their principal development is on the West Coast, between Lake Brunner and Bruce Bay, and in the Canterbury Plains, where they fringe the range between Timaru and the Waipara River. They also occur in the Hurunui Plains; around Lake Tripp; at the outlets of Lakes Ohau, Pukaki, and Tekapo; fringing the older Carboniferous rocks in the Mackenzie country; from the Wanaka and Hawea Lakes as far south as Wakefield; the upper lacustrine gravels of the Manuherikia and Maniototo Plains; also between Lake Te Anau and the Mararoa River; and in the Southland Plains, a part of which is composed of these beds.

III. UPPER MIOCENE.

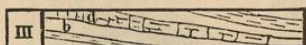


Fig. 6.

a. Te Aute series. b. Taueru series.

The marine beds of this age are limited in their extent to the southern and eastern districts of the North Island, where, on the south slope of the Kaimanawa Range, they have a full development up to 3,700 feet above the sea-level from the coast-line at Wanganui.

In the South Island they occur as patches, inland from Timaru, between Peel Forest and the Waitaki River; at the mouth of the Waipara; at Ross; to the south of Greymouth; and in Nelson, from Lake Rotoiti to the sea; but here, as at many other places, these beds are often represented by gravel conglomerates that, from the absence of fossils, have not been distinguished from the preceding formation.

Their mineral character is a series of sandy, calcareous, and

argillaceous strata, the distribution of which, and, as a rule, also the mineral character, indicate that they were related to a closely-adjacent shore-line, as they often pass almost suddenly from coarse conglomerates into narrow strips of fine mud and clay, such as are deposited in the centres of deep channels and inlets.

The New Zealand seas have yielded about 450 species of existing shells, of which 120 have been found in this formation, together with 25 forms which are now extinct.

They are specially characterized by the occurrence of *Ostrea ingens*, *Murex octagonus*, *Fusus triton*, *Struthiolaria cingulata*, *Chione assimilis*, *Chama huttoni*, and *Pecten gemmulatus*.

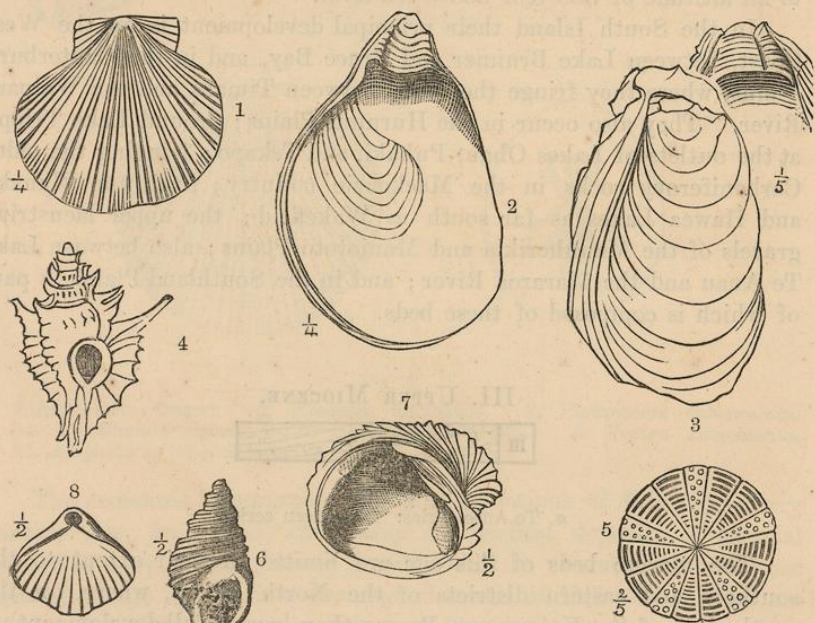


Fig. 7.

1. *Pecten vellicatus*. 2, 3. *Ostrea ingens* (Te Ante). 4. *Murex zealandica*. 5. *Arachnoides zelandiæ*. 6. *Struthiolaria sulcata*. 7. *Chama huttoni*. 8. *Terebratella cruenta*.

In Otago the beds are partly marine, partly lacustrine, with lignite deposits at their base. The marine beds are exemplified at Mataura Falls and in the vicinity of Landslip Hill, Pomahaka Valley; the lacustrine beds by deposits containing fossil fish at Bannockburn and St. Bathans, Central Otago.

IV. LOWER MIOCENE.



Fig. 8.

a. Awatere series. b. Pareora series. c. Awamoa series. d. Lignite.

This formation, which is distinguished from the foregoing chiefly

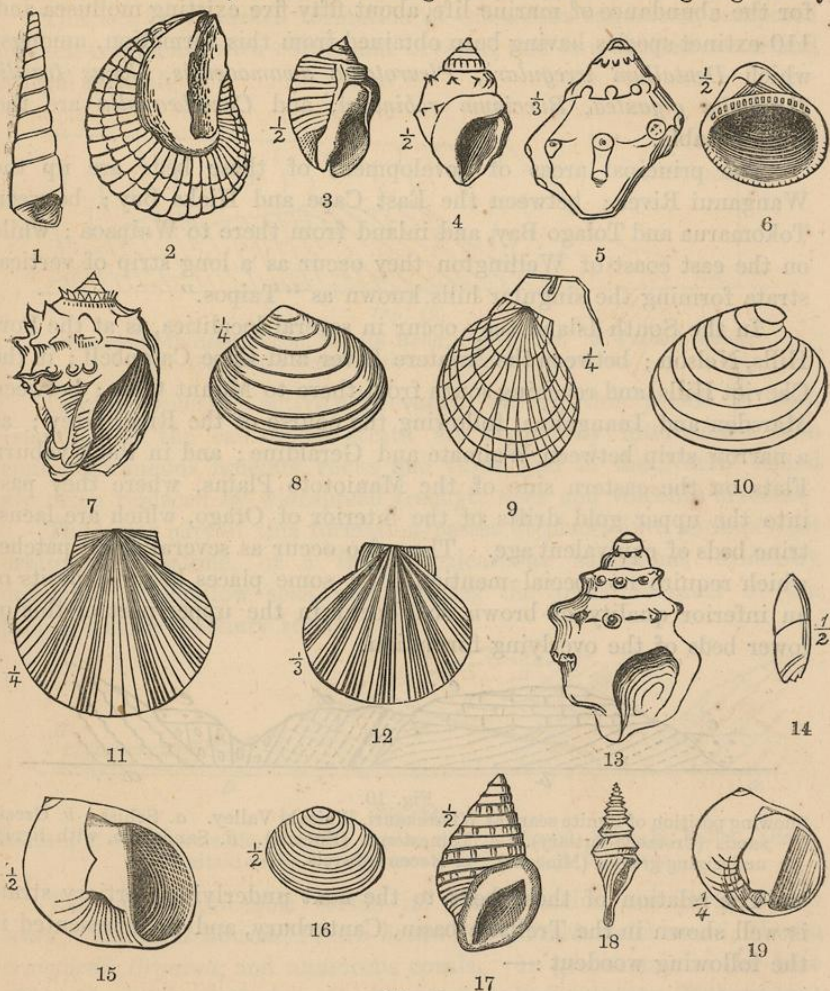


Fig. 9.

1. *Turritella gigantea*. 2. *Ostrea corrugata*. 3. *Buccinum carinatum*. 4. *Struthiolaria tuberculata*. 5. *Fusus crawfordi*. 6. *Pectunculus cordatus*. 7. *Cassis muricata*. 8. *Crassatella ampla*. 9. *Hinnites trailli*. 10. *Cytherea enysi*. 11. *Pecten crawfordi*. 12. *Pecten secta*. 13. *Struthiolaria spinosa*. 14. *Ancillaria hebera*. 15. *Natica ovata*. 16. *Callista elegans*. 17. *Struthiolaria cingulata*. 18. *Pleurotoma pagoda*. 19. *Natica solida*.

by its fossils, is a calcareous and argillaceous formation, widely spread over the east and central part of the North Island and both sides of the South Island, and, when not removed by denudation, can be traced to an altitude of 2,500 feet above the sea. It represents a period of great depression, and the deposits are remarkable for the absence of evidence of volcanic activity in any part of the region and for the abundance of marine life, about fifty-five existing mollusca and 110 extinct species having been obtained from this formation, amongst which *Dentalium irregulare*, *Pleurotoma awamoensis*, *Conus trailli*, *Turritella gigantea*, *Buccinum robinsoni*, and *Cucullea alta* are the most notable.

The principal areas of development of these beds are up the Wanganui River; between the East Cape and Hicks Bay; between Tokomarua and Tolago Bay, and inland from there to Waipaoa; while on the east coast of Wellington they occur as a long strip of vertical strata forming the singular hills known as "Taipos."

In the South Island they occur in several localities, as at the Port Hills, Nelson; between the Awatere River and Cape Campbell; in the Cheviot Hills, and reaching south from there to Mount Grey; between Marsden and Inangahua, following the course of the River Grey; as a narrow strip between Waimate and Geraldine; and in the Kyeburn Flats on the eastern side of the Maniototo Plains, where they pass into the upper gold drifts of the interior of Otago, which are lacustrine beds of equivalent age. They also occur as several small patches which require no special mention. In some places heavy deposits of an inferior quality of brown coal occur in the upper part of this or lower beds of the overlying formation.

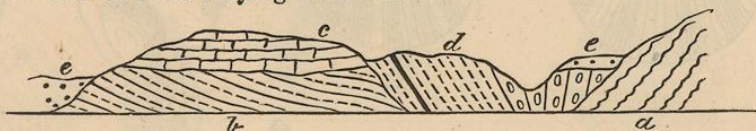


Fig. 10.

Showing position of lignite seam at Wharekauri, Waitaki Valley. *a*. Schist. *b*. Greensands (Cretaceo-tertiary). *c*. Limestones (Eocene). *d*. Sandstone, with lignite underlying gravels (Miocene). *e*. Recent gravels.

The relation of these beds to the next underlying Tertiary strata is well shown in the Trelissic basin, Canterbury, and is represented in the following woodcut:—



Fig. 11.

Section from Hog Back (Trelissic basin) along north bank of Broken River. 6. Weka Pass stone. 8. Mount Brown limestone. 9. Pareora beds. 10. Recent.

V. UPPER EOCENE.

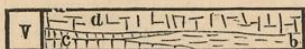


Fig. 12.

a. Mount Brown series. b. Oamaru series. c. Waitaki series.

This is a very marked formation of calcareous sandstone, composed of shell-fragments with corals and bryozoa, and is a shallow-water and littoral deposit.

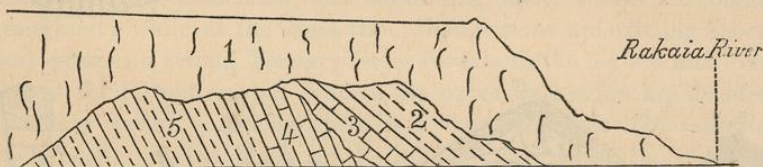


Fig. 13.

Section at Curiosity Shop, Rakaia River, Canterbury. 2. Pareora series. 3. Mount Brown series. 4, 5. Ototara series.

Intense volcanic activity prevailed during this period in both Islands, and the calcareous strata are frequently interbedded with contemporaneous igneous rocks and tufas, and in the North Island are often replaced by widespread trachyte floes and volcanic breccias.

The lower part of this formation passes at places into an imperfect orbitolite limestone, or a friable calcareous sandstone, evidently deposited in shallow seas, and forming the lowest member of the proper marine Tertiary series.

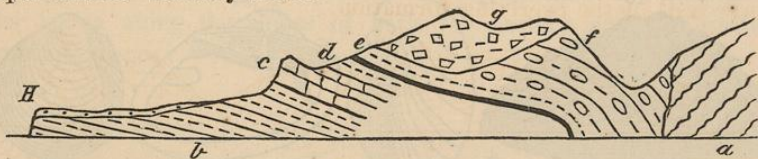


Fig. 14.

Section, E.-W., across the Tertiary basin at Wharekauri, Waitaki Valley, Otago. b. Waitaki series. c. Oamaru series. d, e, f. Miocene.

The more noticeable fossils in this formation are *Struthiolaria senex*, *Pecten hutchinsoni*, *Pecten hochstetteri*, *Terebratella suessi*, *Meoma crawfordi*, *Bryozoa*, and numerous corals. In greensands at the base of this formation, remains of a huge zeuglodont cetacean (*Kekenodon*) have been discovered by Mr. A. McKay, allied to those found in strata of equivalent age in Europe and America.

The distribution of these beds is limited in area, the principal

development being about the Waiau River, in Southland, and on the eastern side of Te Anau Lake, with a few patches up the east coast of

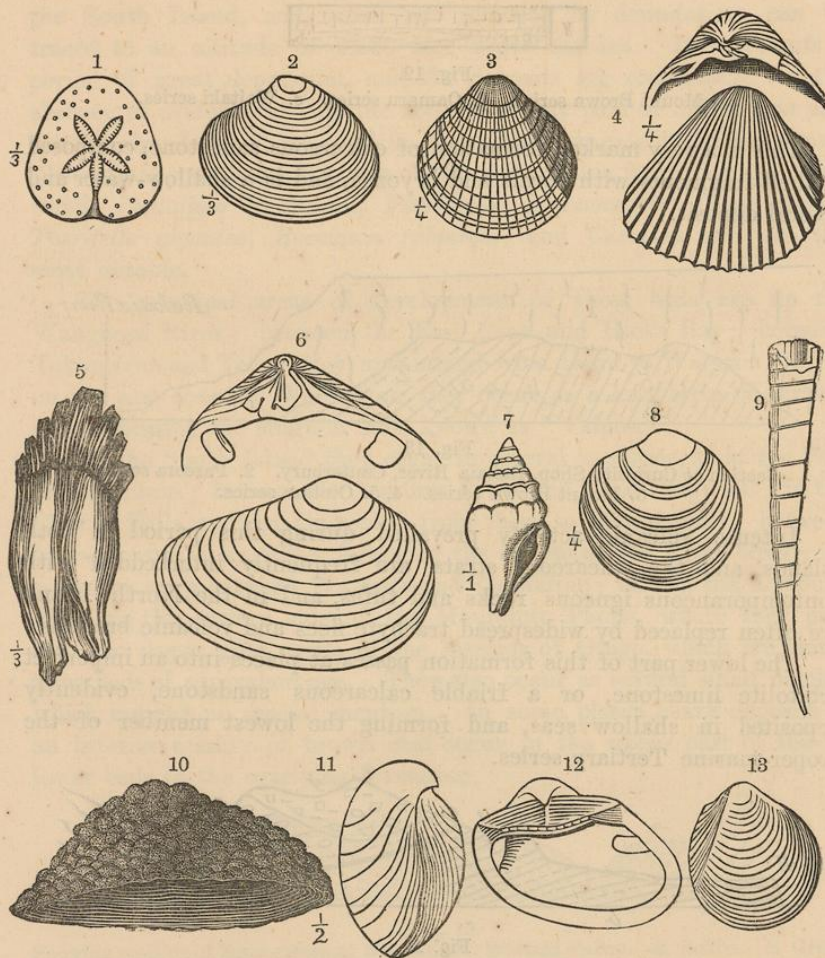


Fig. 15.

1. *Hemiaster posita*. 2. *Tapis curta*. 3. *Cardium patulum*. 4. *Cardium spatiosum*.
5. *Kekenodon onomata* (tooth). 6. *Crassatella attenuata*. 7. *Pleurotoma latescens*.
8. *Dosinia magna*. 9. *Dentalium giganteum*. 10. *Celeporina papalosa*. 11. *Terebratula angulare*. 12. *Cucullæa attenuata*. 13. *Protocardium serum*.

the South Island at Oamaru, Geraldine, Mount Somers, and Mount Grey; while in the North Island they are principally developed from Cape Kidnappers south and inland up the Tukituki River. A small patch of the same beds also occurs at Mokau and Kaipara.

VI. CRETACEO-TERTIARY FORMATION.

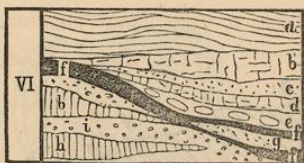


Fig. 16.

a. Grey marls. b. Ototara series. c. Mawhera series. d. Chalk series. e. Waireka series. f. Coal series. g. Black grit series. h. Propylite breccia series. i. Great conglomerate series.

These strata constitute the Cretaceo-tertiary formation, being stratigraphically associated, and containing many fossils in common throughout; while, at the same time, though none are existing species, many present a strong Tertiary facies from both the highest and lowest parts of the formation, but even in the upper part a few are decidedly Secondary forms. Among these is a true belemnite (*B. superstes*), which occurs in the black marls, immediately under the chalk and flints, in the Coverham or Middle Clarence Valley section.

The distribution of this formation shows that it was not, like the foregoing formations of latter date, deposited in relation to a form of the land like that at present obtaining in the New Zealand area, except in the vicinity of some of the oldest and most lofty land-masses in the south, which appear to have remained above the water-line since the Lower Cretaceous period.

In the northern part of the South Island the thickness of the strata thus included under the term Cretaceo-tertiary is very considerable, and the beds reach an elevation exceeding 5,000 feet above sea-level, and are deeply involved in complicated movements of older strata along the slopes of both the eastern and the western mountain-ranges.

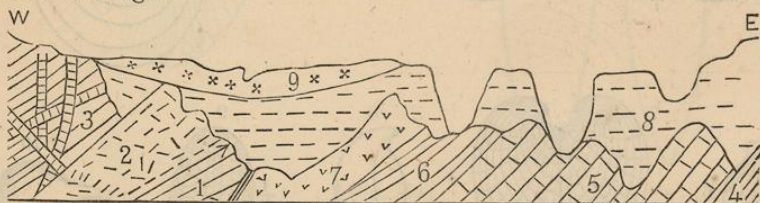


Fig. 17.

Section along north-east bank of Dart River, Clarence Valley, 2,500 feet above sea-level, showing the higher Cretaceo-tertiary beds (5 and 6), together with (7) Post-miocene conglomerates, passing under beds 1, 2, and 3, of old Secondary or Palæozoic age. Valley gravels (Post-pliocene), 8 and 9.

The upper part of this formation is a deep-sea deposit, but the lower subdivisions indicate the close vicinity of land, and are replaced in some areas by true estuarine and fluvial beds containing coal.

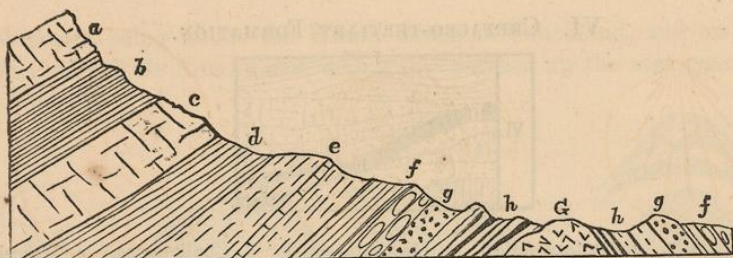


Fig. 18.

Section at source of Karamea River. *a.* Grey concretionary limestone. *b.* Grey marls, with *Pecten pleuronectes*. *c.* White, splintery limestone. *d.* Fucoidal greensand. *e.* Chalk-marls, with bands of chert. *f.* Dark greensand and concretionary sandstone. *g.* Brown grit and sandstone, with *Cardium brunneri*. *h.* Brown sandstone, with fossil plants and coal-seams. G. Granite.

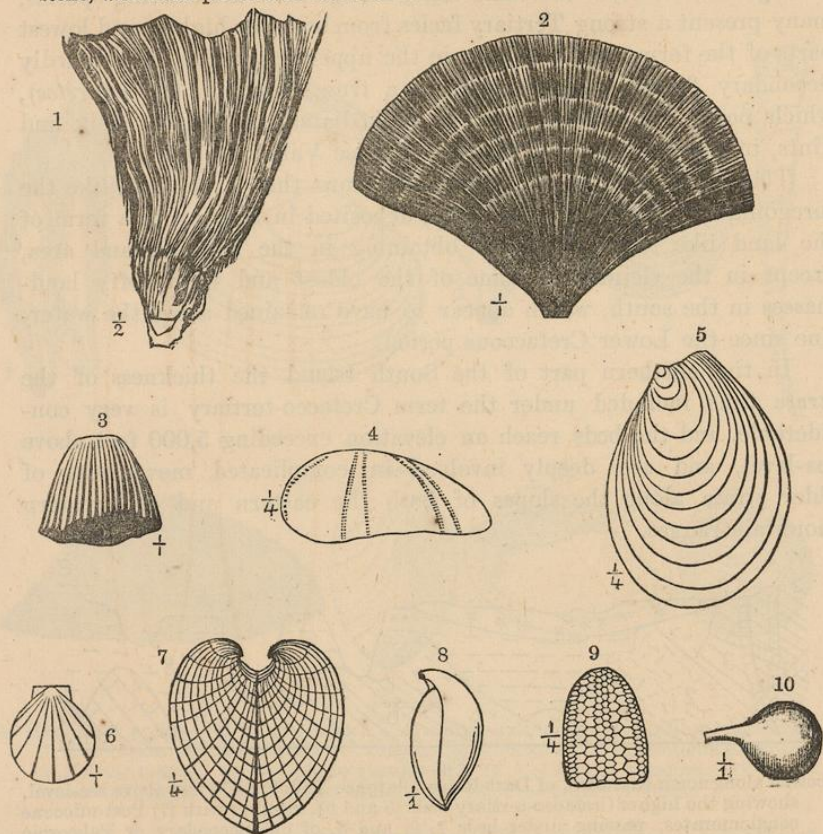


Fig. 19.

1. *Flabellum irregulare*, Motunau. 2. *Flabellum radians* (Kakanui North). 3. *Flabellum huttonianum*. 4. *Macropneustes* (Cobden). 5. *Lima laevigata*. 6. *Pecten zittelli* (Jenkins' Hill, Nelson). 7. *Hemicardium cordatum* (Mahemo, Oamaru). 8. *Waldheimia* (Cobden). 9. *Galerites cobdenensis*. 10. *Neera kirki* (Whangape Lake).

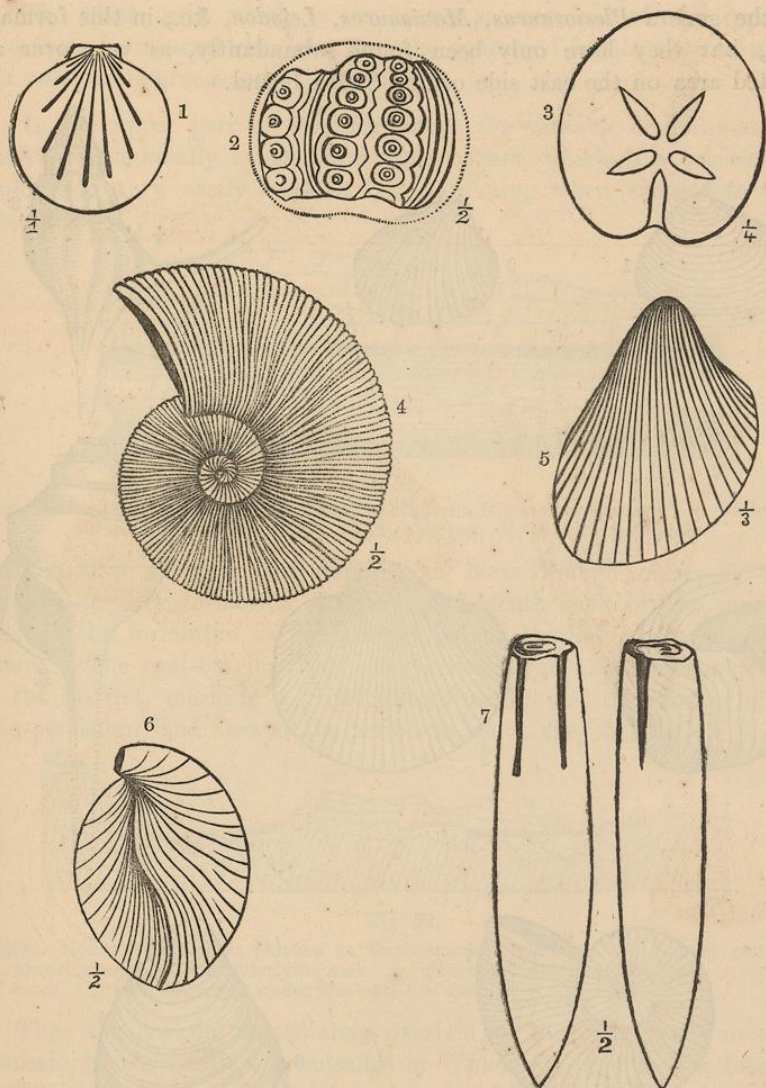


Fig. 19A.

1. *Pecten zittelli* (Whangape Lake).
2. *Cidaris* (Waihoa, South Canterbury).
3. *Meoma crawfordii*.
4. *Ammonites McKayi* (Waipawa Gorge, Hawke's Bay).
5. *Cardium coxii* (Castles, Collingwood).
6. *Terebratula* (Kakanui Mouth).
7. *Belemnites superstes* (Upper Marls, Coverham).

The marine fossils include, besides well-marked Greensand forms, such as *Ancyloceras*, *Belemnites*, and *Rostellaria*, a number that have still a marked affinity to the Tertiary fauna. Saurian bones occur,

of the genera *Plesiosaurus*, *Mauisaurus*, *Leiodon*, &c., in this formation, but they have only been found abundantly, as yet, over a limited area on the east side of the South Island.

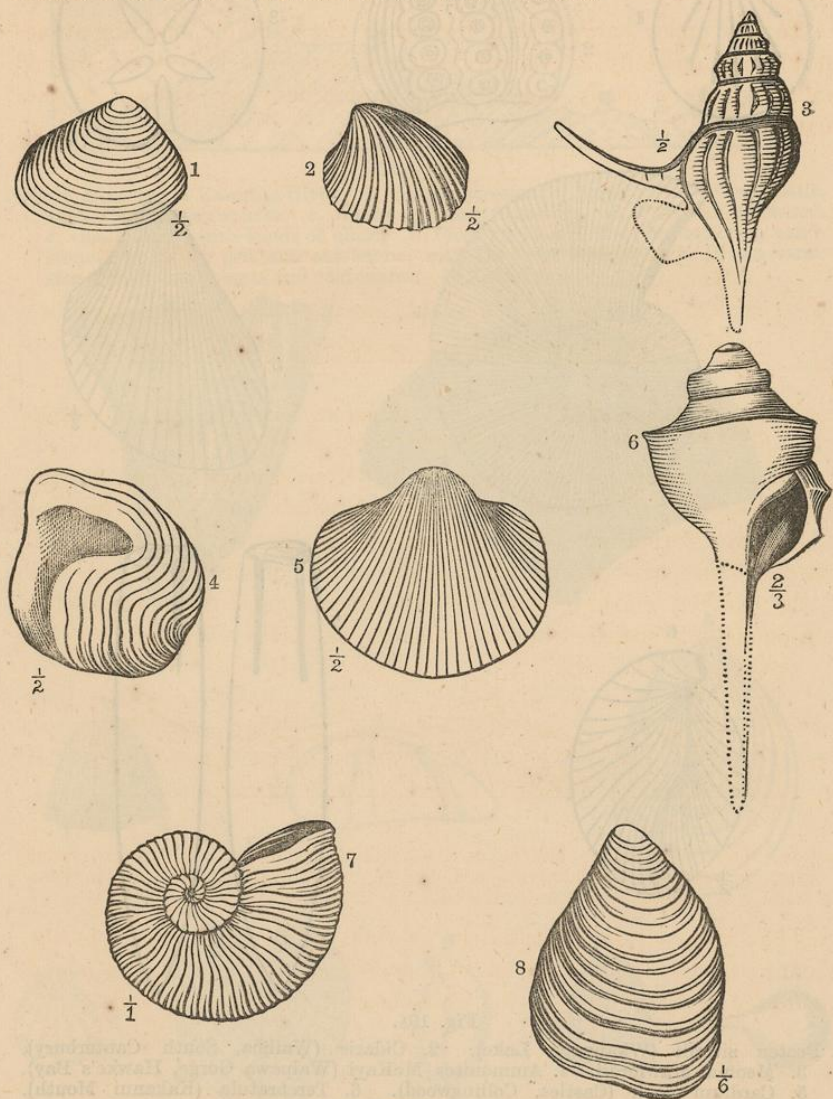


Fig. 20.

1. *Astarte australis* (Kakahu). 2. *Hemicardium* (Blackpoint, Waitaki). 3. *Rostellaria waiparensis* (Saurian beds, Waipara and Amuri Bluff). 4. *Conchothyra parsisitica* (McCoy). 5. *Cardium brunneri* (Brunnerton). 6. *Tudicla biangulata*. 7. *Ammonites haumuriensis* (Coverham and Amuri group, Amuri Bluff). 8. *Inoceramus* (Coverham and Wellington).

The black grit, which is the lowest marine bed of this group, resembles, in mineral character and the contained fossils, the carstone and calcareous greensand of England.

In the upper part of this formation the valuable building-stone known commercially as Oamaru stone occurs, which is a calcareous sandstone, very easily worked, but hardening when exposed to the weather.

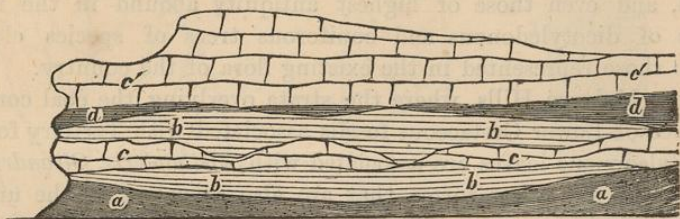


Fig. 21.

Section showing Oamaru stone, east bank of Kakanui River, near Oamaru. *a*. Waireka tufas. *b*. Chalk-marls. *c*. Ototara series. *c'*. Weka Pass stone.

The most valuable coal deposits of New Zealand occur in the Cretaceo-tertiary formation, but always beneath such of the marine beds of the formation as are present in the locality where the coal occurs. The coal-bearing beds always rest upon the basement rock of the district, marking a great unconformity and the closing of a long-persistent land area at the period to which they belong.

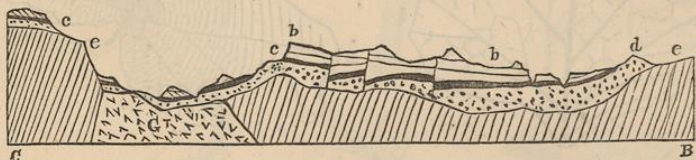


Fig. 22.

Section, Mount William to plateau at Coalbrookdale, showing coal series resting unconformably on the underlying rock. *b*. Quartz-grit overlying the coal. *c*. Coal-seam. *d*. Conglomerates under the coal. *e*. Slates. *g*. Granite.

Thus the coal is immediately overlaid by the grey marls in the Waikato, by the fucoidal greensands at Whangarei, and by the Island Sandstone in Otago and on the west coast of the South Island.



Fig. 23.

Section, Greymouth to Brunner, showing Island Sandstone immediately overlying coal-seam. *a-d*. Higher beds of the Cretaceo-tertiary group. *f*. Upper coal. *g*. Lower coal. *h*. Great conglomerate. *sl*. Slate.

The coals immediately beneath the marine beds are everywhere hydrous brown coals; but on the West Coast these rest upon an immense formation of micaceous sandstones, grits, and conglomerates, in which are seams of valuable bituminous coal, and this lower part of the formation is possibly the equivalent in time of the Lower Greensand group.

The same fossil plants are found associated with all these coal-deposits, and even those of highest antiquity abound in the fossil remains of dicotyledonous and coniferous trees of species closely allied to those represented in the existing flora of the country.

In the Malvern Hills, where the strata overlying the coal contain abundance of Lower Cretaceous fossils associated with Tertiary forms, the dicotyledonous leaves are associated with *Alethopteris*, *Oleandridum* (*Teniopteris*), and other forms that are also prevalent in the underlying Jurassic beds.

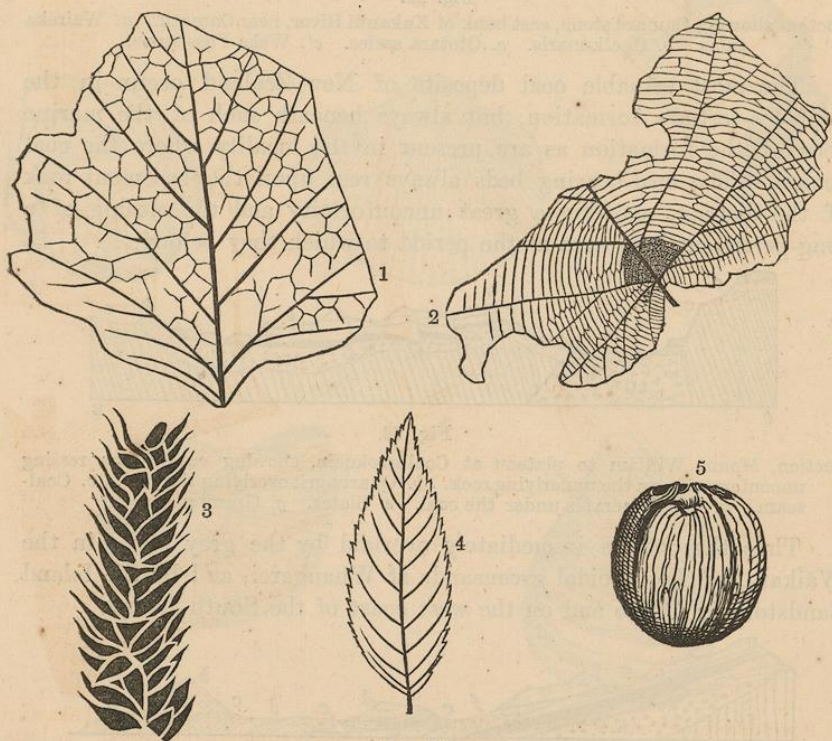


Fig. 24.

Fossil plants of New Zealand coal formation (see p. 61). 1. *Phylites whaurangi* (Shag Point). 2. *Protophyllum* (Pakawau). 3. *Auricaurites buchanani* (Shag Point). 4. *Phylites rubiformis*. 5. Palm-nut (Cooper Beach, Mongonui; also Livingstone Tunnel, Oamaru).

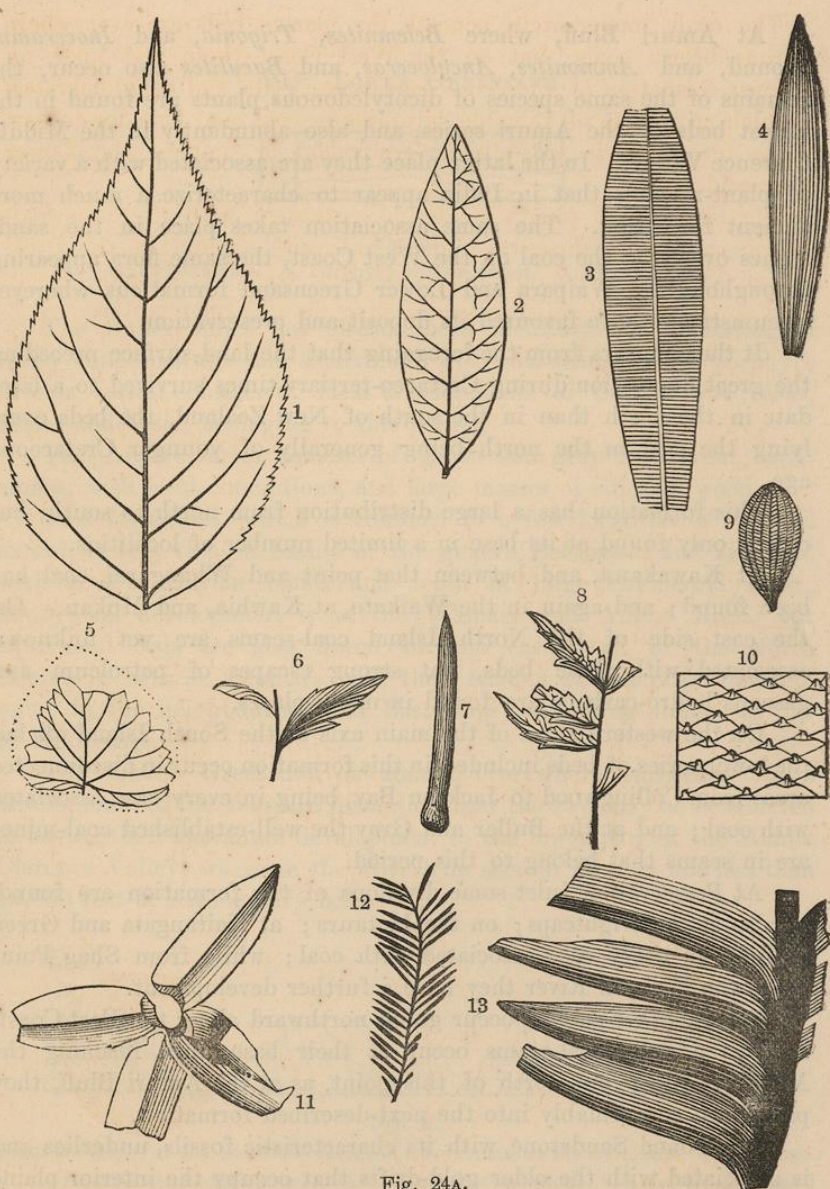


Fig. 24A.

Fossil plants of New Zealand coal formation (see p. 60). 1. *Patete scheffleri* (Pakawau). 2. *Phylites karamu* (Wangapeka). 3. *Taeniopteris stipulata* (Pakawau). 4. *Damarites lanceolata*. 5. *Phylites geumoides* (Pakawau). 6. *Taxites tanekaha* (Wangapeka). 7. *Aciphylla pungens* (Wangapeka). 8. *Taxites toa-toa* (Wangapeka). 9. *Potomageton ovatum* (Trelissic basin, coal-shales). 10. *Cycaditus* (Malvern Hills). 11. *Auricaurites buchanani* (Waipara). 12. *Taxites maitai* (Shag Point). 13. *Auricaurites carinaria* (Shag Point).

At Amuri Bluff, where *Belemnites*, *Trigonia*, and *Inoceramus* abound, and *Ammonites*, *Ancyloceras*, and *Baculites* also occur, the remains of the same species of dicotyledonous plants are found in the lowest beds of the Amuri series, and also abundantly in the Middle Clarence Valley. In the latter place they are associated with a variety of plant-remains that in India appear to characterize a much more ancient formation. The same association takes place in the sandstones overlying the coal on the West Coast, the same flora appearing throughout the Waipara and Lower Greensand formations wherever circumstances have favoured its deposit and preservation.

It thus appears from the foregoing that the land-surface preceding the great depression during Cretaceo-tertiary times survived to a later date in the north than in the south of New Zealand, the beds overlying the coal in the north being generally of younger Cretaceous age.

This formation has a large distribution from north to south; but coal is only found at its base in a limited number of localities.

At Kawakawa, and between that point and Whangarei, coal has been found; and again in the Waikato, at Kawhia, and Mokau. On the east side of the North Island coal-seams are yet unknown associated with these beds, but strong escapes of petroleum and gaseous hydro-carbons are found in many places.

On the western slope of the main axis of the South Island all but the lower series of beds included in this formation occur in disconnected areas from Collingwood to Jackson Bay, being in every case associated with coal; and at the Buller and Grey the well-established coal-mines are in seams that belong to this period.

At Preservation Inlet some divisions of the formation are found, as also at the Nightcaps; on the Matura; at Kaitangata and Green Island—in every case associated with coal; while from Shag Point up to the Waitaki River they have a further development.

Several other patches occur going northward along the East Coast, and, as a rule, coal-seams occur at their base until reaching the Malvern Hills; but north of this point, as at the Amuri Bluff, they pass down conformably into the next-described formation.

The Island Sandstone, with its characteristic fossils, underlies and is associated with the older gold-drifts that occupy the interior plains of Otago, proving that these great valleys were excavated prior to the Cainozoic period.

VII. LOWER GREENSAND.



Fig. 25.

a. Buller series. b. Porphyry breccia series. c. Amuri series.

The Buller series has already been mentioned as consisting of heavy conglomerates and sandstones, with coal-seams. The porphyry breccia series consists of local developments of the igneous rocks, acidic and basic, belonging to this period.

The Amuri series consists of green and grey incoherent sandstones, with hard concretions, and large masses of silicified wood.

This formation, which is confined to a few localities of limited extent, is very rich in fossils of the genera *Belemnites* and *Trigonia*, with a few saurian bones and teeth of large chimaeroid fishes. Its typical development is at the Waipara and Amuri Bluff, but equivalent beds are also found on the east coast of the North Island in several localities, and they have a considerable development in the neighbourhood of East Cape, extending inland as far as Hikurangi.

The Lower Greensand is almost everywhere succeeded by a development of the Waipara formation, and the two may be considered as having their maximum development in the lower part of the Middle Clarence Valley, where in the Coverham section there is not less than 12,000 feet of sedimentary beds.

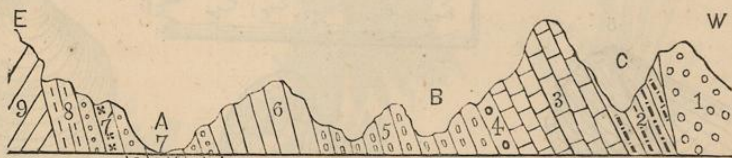


Fig. 26.

From the slopes of the Sawtooth Range north-west across the Coverham Chalk Range.

1. Post-miocene conglomerate. 2-5. Waipara formation. 6-8. Lower Greensand formation.

Higher up the Clarence Valley thick beds of tufa and solid floes of volcanic rocks interbed with the coal-bearing strata and partly with the marine rocks belonging to the Amuri group.

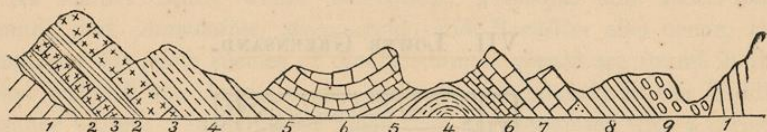


Fig. 27.

Section of left bank of Seymour River (Heron Creek), Middle Clarence Valley. 4-8. Waipara formation. 2. Coal beds, Lower Greensand. 3. Volcanic, Lower Greensand.

From this formation fossils have been most abundantly collected at the Amuri Bluff; but the same beds are fossiliferous on the coast-line farther north, and yield abundance of characteristic fossils where they are found in the Clarence Valley.

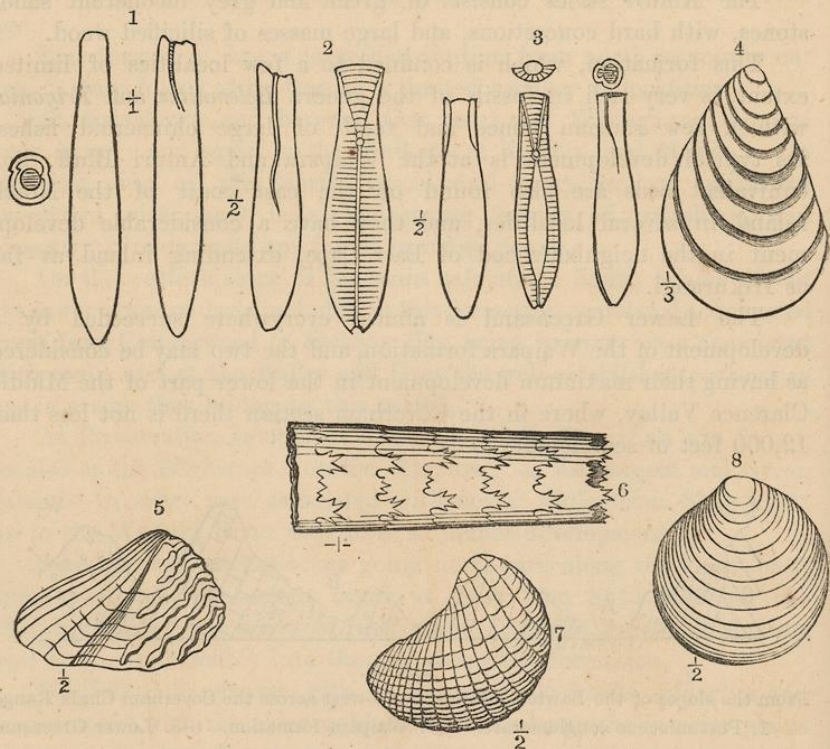


Fig. 28.

1. *Belemnites australis*, var. *a.* 2. *Belemnites australis*, var. *b.* 3. *Belemnites australis*, var. *d.* 4. *Inoceramus haastii*. 5. *Trigonia sulcata*. 6. *Baculites anceps*. 7. *Trigonia pseudo-cundata*. 8. *Lucina americana*.

VIII. JURASSIC.

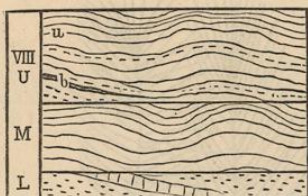


Fig. 29.

a. Mataura series. b. Putataka series. c. Flag Hill series.

These beds, which are the youngest of the Lower Secondary formation in New Zealand, require mention under their several subdivisions, although on the general map no distinction has been made between them.

The Mataura series consists largely of estuarine beds, marine fossils being absent or rare. It consists of dark-coloured marls and fine-grained sandstones, and contains the fossil remains of a number of plants, of which eight species have been recognized. Amongst these are *Camptopteris*, *Cycadites*, and *Echinostrobus*, which connect these with the plant-beds of the next lower formation. Those found at Waikawa and Mataura falls are especially interesting from at least one species, *Macrotaniopteris lata*, being identical with a plant found in the Rajmahal beds of India, which are considered to be of Liassic age.

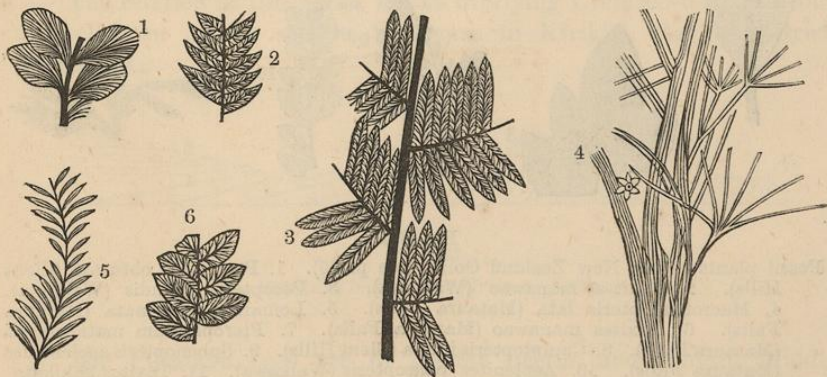


Fig. 30.

Fossil plants of the New Zealand Oolite (see p. 66). 1. *Asplenites rhomboides* (Clent Hills). 2. *Pecopteris acuta* (Clent Hills). 3. *Pecopteris linearis* (Clent Hills). 4. *Vetebraria novæ-zealandiæ* (Clent Hills). 5. *Taxites maitai* (Clent Hills). 6. *Pecopteris ovata* (Clent Hills).

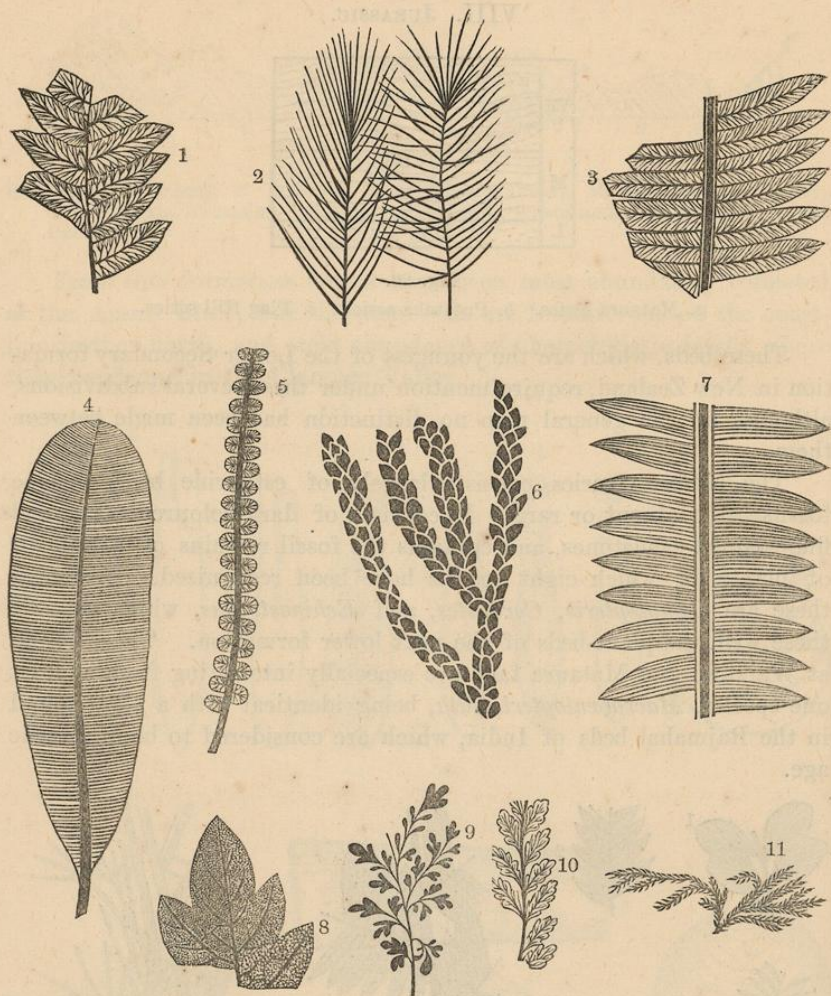


Fig. 30A.

Fossil plants of the New Zealand Oolite (see p. 65). 1. *Pecopteris obtusata* (Clent Hills). 2. *Taxites manawao* (Waikawa). 3. *Pecopteris pectenata* (Waikawa). 4. *Macrotæniopteris lata* (Mataura Falls). 5. *Lomarites pectenata* (Mataura Falls). 6. *Taxites manawao* (Mataura Falls). 7. *Pterophyllum matauriensis* (Mataura Falls). 8. *Camptopteris incisa* (Clent Hills). 9. *Sphenopteris asplenoides* (Mataura Falls). 10. *Asplenites palæopteris* (Waikawa). 11. *Taxites kahikate* (Mataura Falls).

The Mataura series shows its relationship to the other formations of the Lower Secondary sequence very clearly in the typical section.

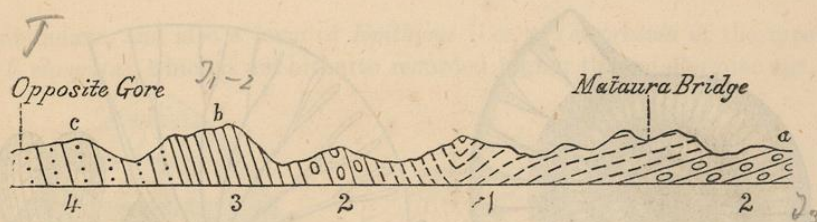


Fig. 31.

Section, Gore to Mātāura Falls, east bank of Mātāura River. 1. Mātāura series. 2. Flag Hill series. 3. Bastion series, Otapiri series. 4. Wairoa series.

The Mātāura series, overlying the Putataka series, closes the old secondary sequence at Kawhia, in the Auckland District, and the same plants are found in the Clent Hills plant-beds, and from the natural sections, and also from the very characteristic fossils immediately below them, there can be no doubt that they should be referred to the Upper Oolite period.

The Putataka series, which has its typical development at Waikato Heads as marlstones, is represented in southern districts by coarse-grained sandstones, which pass near the base of the formation into conglomerates with bands of indurated shale, enclosing plant-remains and irregular coal-seams, which have been included in the next group as its upper member.

The relation of this series to the overlying Cretaceo-tertiary group is well seen in the section Waingara to Kirikiri, Raglan district, Auckland.

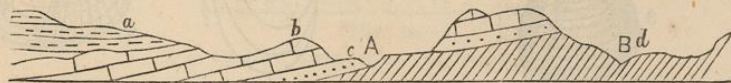


Fig. 32.

d. Putataka beds. a-c. Cretaceo-tertiary.

The Putataka beds are of marine origin, and contain Middle Oolite fossils, of which eleven species have been identified. The fossils figured are mainly from the Putataka beds exposed along the shores of Kawhia Harbour.

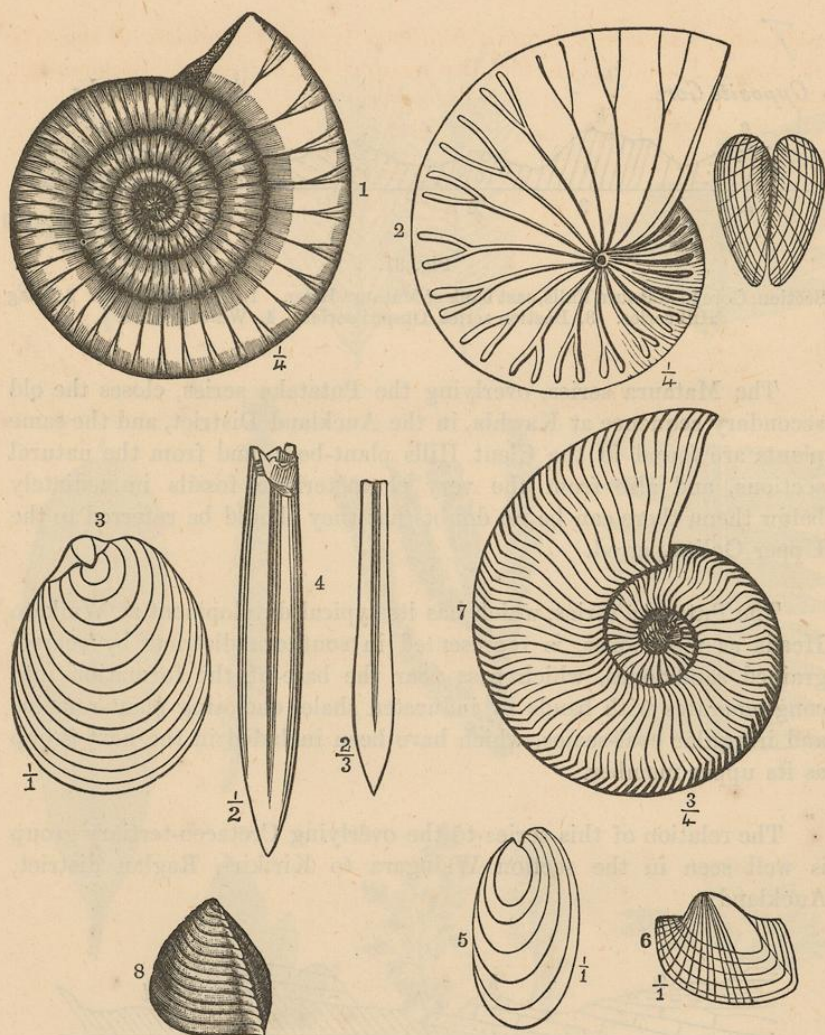


Fig. 33.

1. *Ammonites sisyphi*. 2. *Ammonites* (Kawhia). 3. *Aucella* (Kawhia). 4. *Belemnites aucklandica* (Kawhia). 5. *Aucella plicata* (Waikato Heads). 6. *Cucullæa*. 7. *Ammonites aucklandicus*. 8. *Trigonia costata*, var.

The Flag Hill series, which is principally developed in the Hokanui Range, Southland, is marine, and is characterized by eighteen forms of fossil shells which have been identified, besides many others which have yet to be examined.

The Brachiopoda are interesting, as, besides seven forms of *Rhynchonella* and three of *Terebratula*, *Spiriferina rostrata*, of the Lias, is

abundant, and also a form of *Epithyris* (i.e., a *Terebratula* of the type *T. elongata*), which is not hitherto recorded higher than of Permian age.

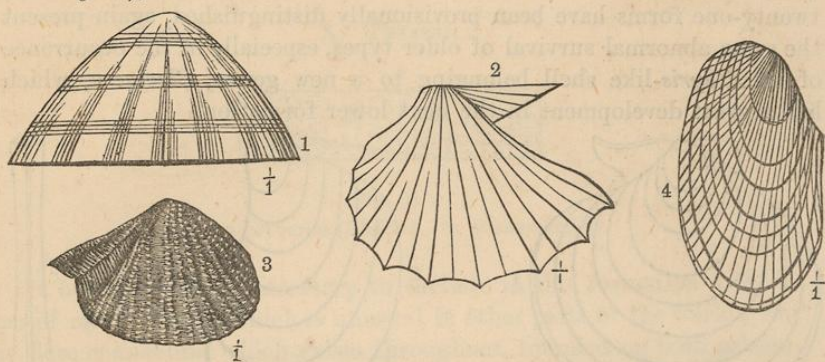


Fig. 34.

1. *Patella* (cast). 2. *Avicula cynipes*, var. 3. *Trigonia navis*, var. 4. *Pholadomya*, sp.

The distribution of these beds, as at present known, is confined to the Hokanui Ranges, and a block of country on both sides of the Waikawa River, and extending inland to the Mataura Falls, as well as a narrow strip on Catlin's River, in Southland; a small patch at Amuri Bluff; another at Kawhia and the Waikato Heads; and a strip of country running from Raukokore, in the Bay of Plenty, in the direction of Waikaremoana Lake.

The minor subdivisions of these beds have as yet only been made in the Hokanui Ranges.

IX. LIASSIC.



Fig. 35.

a. Catlin's River series. b. Bastion series.

This formation consists in its upper part of conglomerates and sandy grits, with plant-remains too indistinct for identification; and in the lower of marly sandstones in banded layers of different colours, at the base having a concretionary structure, which has led to their being termed the "cannon-ball sandstone." Similar sandstones also occur in the Otapiri formation.

Fossils are plentiful, and divide the strata into distinct horizons, ammonites being specially common. Fifteen species of fossils have been determined, but a large number of others are present which have not yet been identified.

The general facies of the fauna is on the whole Liassic, although many Lower Oolite forms occur; but the Brachiopoda, of which twenty-one forms have been provisionally distinguished, again present the same abnormal survival of older types, especially in the occurrence of an *Athyris*-like shell belonging to a new genus, *Clavigera*, which has a great development in the next lower formation.

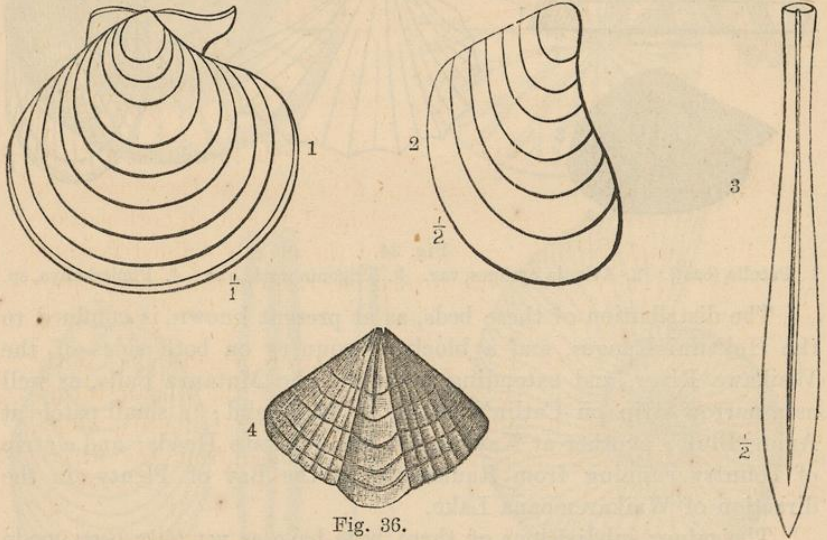


Fig. 36.

1. *Plagiostoma grandis*. 2. *Pholodomya tumida*. 3. *Belemnites catlinensis*. 4. *Spiriferina radiata*.

Our knowledge of this as a fossiliferous formation has until lately been confined to the Hokanui Range and the country between Gore and the sea-coast at the mouth of Catlin's River; but within the past two years it has been proved present at Kawhia and in the Raglan district, Auckland. When the Lower Mesozoic formations are examined in detail elsewhere, the Liassic strata will be found to have a much greater development than is at present ascribed to them. Though not yielding marine fossils, it has been shown that they are present in the Amuri district of the north-east part of the South Island, as shown in the woodcut below.

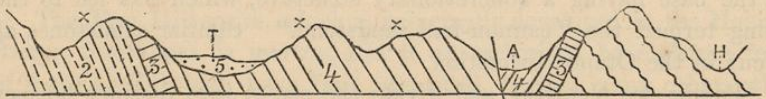


Fig. 37.

Section from mountains west of Tairāhake east across Alma Valley to Acheron River.
3. Trias (*Monotis* beds). 4. Upper Trias, Lias, &c.

X. TRIASSIC.



Fig. 38.

a. Otapiri series (Rhætic). b. Wairoa series.

It has been found necessary to include in this formation a thickness of marine strata which is unusual in other parts of the world; but the close connection which exists throughout, founded on both palæontological and stratigraphical grounds, and the clearly-defined Permian character of the next underlying formation, renders this classification absolutely necessary.

The Otapiri series consists of a group of strata which I place in the Upper Trias, or more properly as an equivalent of the Rhætic formation, and is remarkable for the mixed character of its fossils, which, however, contain many forms identical with those from the Rhætic formation of the European Alps.

This series constitutes an important group of strata in the northern part of the Canterbury Provincial District, the relation to the Middle Trias of the beds referred to it being as shown in the section below.

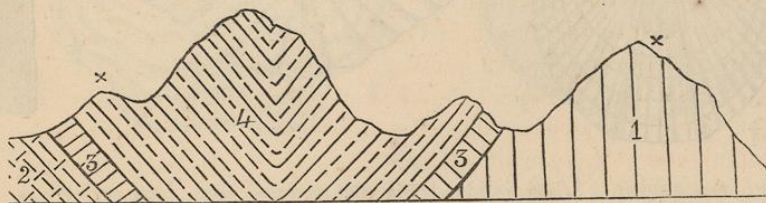


Fig. 39.

Section from Glentui Gorge across Mount Thomas Range, Ashley District, Canterbury.
 2. Lower Trias. 3. Middle Trias (diabase, ash, &c., calcareous, with *Monotis*, &c.).
 4. Upper Trias, Otapiri series (with *Trigonia*, fossil plants, &c.).

The mixed character of the fossils is shown by the presence of *Belemnites otapiriensis*, which is near to *B. elongatus* of the English Lias, along with *Pleurotomaria ornata* and *Tancredia truncata*, which are Oolite forms, associated with a preponderance of Triassic and even

Permian forms, fourteen species of which have been determined, amongst which are *Nautilus mesodiscus* and *Nautilus goniatites*, Cephalopoda found in the Hallstadt or Rhætic beds of Europe.

The remarkable feature of the Otapiri series is the abundance of Brachiopoda, which are elsewhere so rare in formations of this period; but, as might be expected, they are chiefly peculiar forms—*Clavigera*, which has seven species, representing the genus *Athyris*, and a sub-genus of *Spiriferina*, which I name *Rastelligera*, with five species, being almost entirely confined to this formation. Plant-remains also occur.

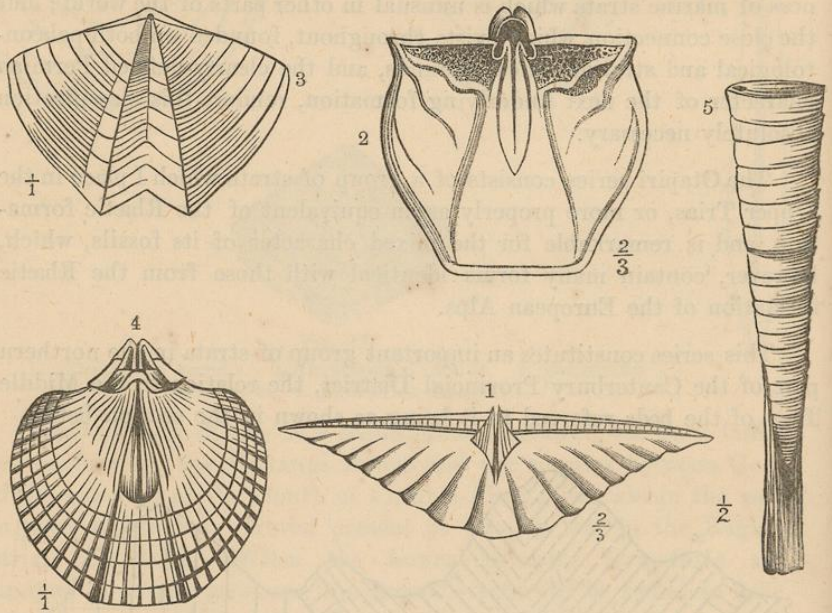


Fig. 40.

1. *Rastelligera*. 2. *Clavigera* (internal cast). 3. *Clavigera*. 4. *Spiriferina*.
5. *Belemnites otapiriensis*.

The Wairoa series has been generally admitted to be Trias since it was first described by Dr. von Hochstetter as characterized by *Monotis salinaria*, *Halobia lomelli*, &c. Eleven species have now been determined, and Brachiopoda are represented by the earliest appearance of *Clavigera*, *Rastelligera*, and a form allied to *Spiriferina*, but having the dental plates conjoined with the rostral septum (*Psioidea*).

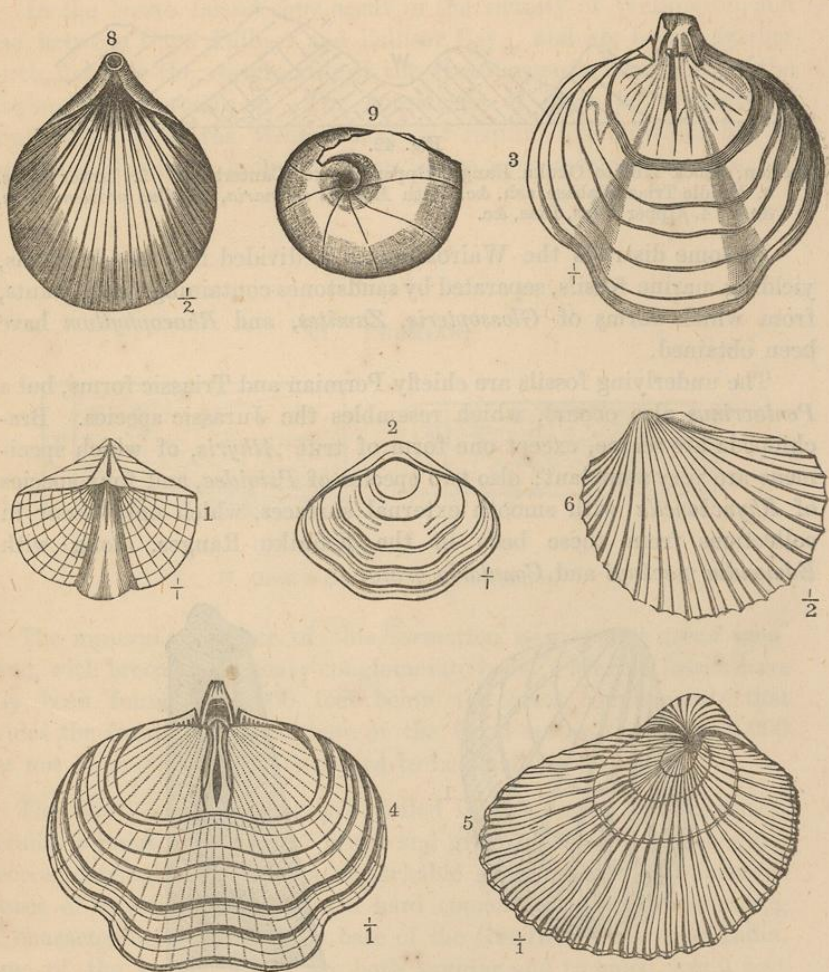


Fig. 41.

1. *Psioidea* (sp.). 2, 3. *Spirigera wreyii* and interior cast. 4. *Spirigera* (sp.) (interior cast). 5. *Monotis salinaria* (ventral valve). 6. *Monotis* (dorsal valve). 7. *Mytilus problematicus* (dorsal valve). 8. *Retzia* (sp.). 9. *Nautilus frieslibendi*.

In the typical district near Nelson, and in the Hokanui Hills, Southland, the presence and relationship of the Wairoa series is well understood; but there is not the same unanimity of opinion respecting the occurrence and stratigraphical importance of the beds in Northern Canterbury and Eastern Nelson. The section below is taken as showing the mode of occurrence and relation of the different divisions of the Trias within the Canterbury District.

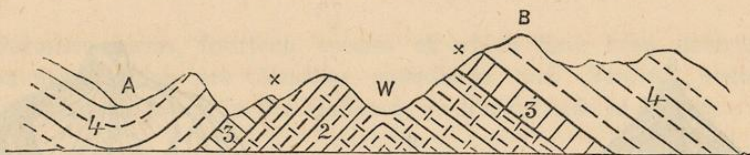


Fig. 42.

Section, Block Hill to Okuku Range, Upper Okuku, Canterbury. 2. Lower Trias. 3. Middle Trias (diabase, ash, &c., with *Monotis salinaria*, *Mytilus problematicus*, &c.). 4. Upper Trias, Lias, &c.

In some districts the Wairoa series is divided into two horizons, yielding marine fossils, separated by sandstones containing fossil plants, from which forms of *Glossopteris*, *Zamites*, and *Rhacophyllum* have been obtained.

The underlying fossils are chiefly Permian and Triassic forms, but a *Pentacrinus* also occurs, which resembles the Jurassic species. Brachiopoda are scarce, except one form of true *Athyris*, of which specimens are very abundant; also two species of *Psioidea*, and four species of *Rhynchonella* with smooth external surfaces, which only occur in collections from these beds in the Kaihiku Ranges, along with *Edmondia mackayi* and *Conularia grata*.

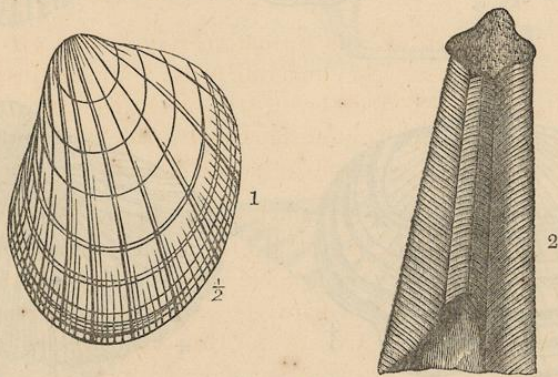


Fig. 43.

1. *Edmondia Mackayi*. 2. *Conularia grata*.

These Triassic beds are best known in the Moonlight and Hokanui Ranges in Southland, and extending as a narrow strip to the sea-coast at Nugget Point. They also occur at the Wairoa Gorge, in Nelson, where they were first discovered by Dr. von Hochstetter; but they are also found in the Jollie Range, at the head-waters of the Rakaia and Rangitata Rivers; bounding the Hanmer Plains and forming the Lowry Peaks; and also at the mouth of the Dillon River, and at the gorge of the Ashley, where the limestones are highly fossiliferous.

In the North Island they occur in the vicinity of Wellington, and also between Cape Palliser and Palliser Bay; and are found, farther north, flanking the western side of the Hakatarimata Range, where the Raglan track crosses it. The boundaries of these beds, except in Southland and at the Wairoa, may yet require modification, but in the above places the beds have been traced with considerable care.

XI. PERMIAN.

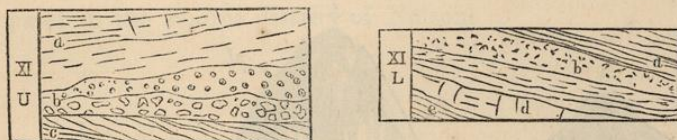


Fig. 44.

U. Oreti series. L. Kaihiku series.

The mineral character of this formation is grey and green sandstone, with breccia and heavy conglomerate beds. Marine fossils have only been found at 1,000 feet below the great conglomerate that divides the formation at the base of the Oreti series, the lower 5,000 feet not having yet been discovered to be fossiliferous.

The Oreti series (formerly included in the Lower Wairoa series) includes a great formation of green and grey tufaceous sandstones and breccias, having at its base a remarkable conglomerate of enormous masses of crystalline rocks, in a hard cementing matrix, resembling the character described for the base of the Gondwinda series in India. Some of the blocks, which are both angular and rounded, are 5 feet in diameter. This conglomerate has a thickness varying from 50 feet to 400 feet, and is never absent from its proper sectional position in any part of the Hokanui district. These strata have been sometimes termed "ash-beds" on account of their tufaceous and brecciated character.

The leading fossils are Permian species, of which a large number have been recognized; and the greater number which have been found in Southland also occur at Mount Potts in Canterbury, and also in Nelson, where beds of the same age are present. *Trigonotreta undulata* is a common and characteristic form.

Saurian remains are associated with these beds at Mount Potts, which in 1871 I referred to *Ichthyosaurus*.

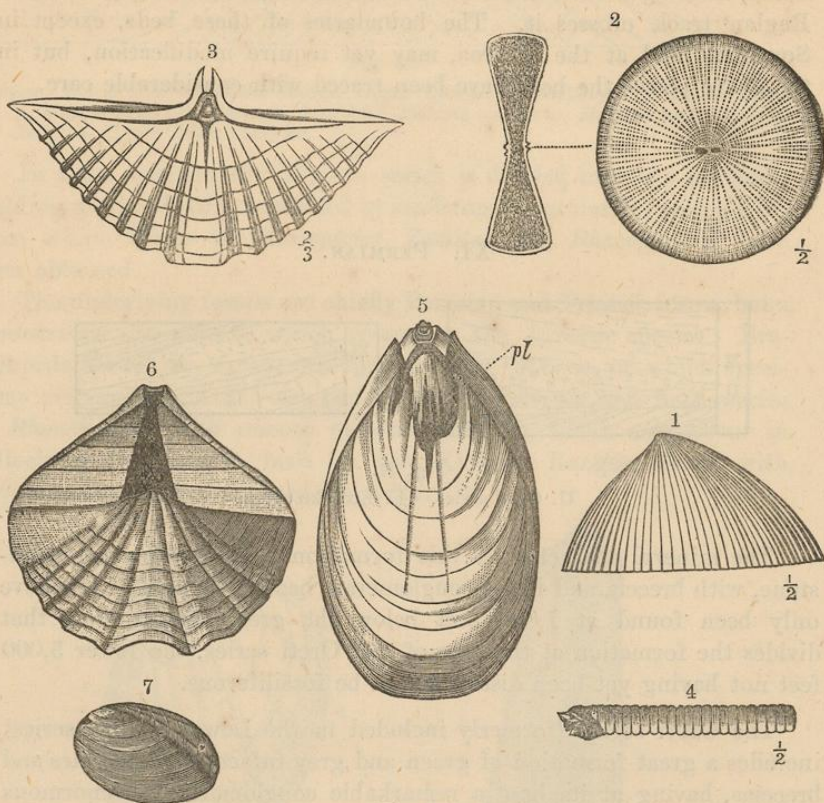


Fig. 45.

1. Patella. 2. Ichthyosaurus (vertebra). 3. Trigonotreta undulata. 4. Epithyris elongata. 5. Spiriferina (cristata?). 6. Spiriferina (cristata?). 7. Pleurophorus costatus.

It is worthy of note that from a formation of the same age, near Nugget Point, Otago, and also in the Otapiri series in the Wairoa district, Nelson, teeth having *Labyrinthodont* characters have been obtained.

The occurrence of these saurian remains, together with the survival of many Permian forms into the Wairoa and even the Otapiri series, and the absence of true *Spirifera*, *Productus*, and other usual Palæozoic elements of a Permian fauna, would seem to connect the Kaihiku series rather with the Mesozoic than the Palæozoic formations of New Zealand.

At the base of the Kaihiku series are the *Glossopteris* beds of Mount Potts; but these were not found in the Hokanui section, although from the thickness of the strata the relative beds must be included in it; while in the Kaihiku district *Glossopteris* occurs in the lower beds as developed in Popotunoa Gorge.

The distribution of these beds, so far as at present proved by fossils, is confined to the South Island, where they have been recognized in the Hokanui Ranges; extending from there to the coast at Nugget Point; in Mount Hamilton; and in the Mount Potts district, where they cover a considerable area, included between two belts of Carboniferous rocks in that district; and they are found again as a small patch in the Wairoa district of Nelson.

XII. CARBONIFEROUS.

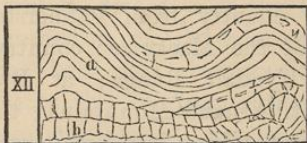


Fig. 46.

a. Maitai series. b. Limestone series.

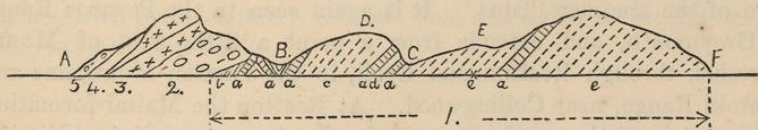


Fig. 47.

4. Taylor's Stream. B. North Ashburton. C. Pudding Hill Stream. D. Pudding Hill. E. Annelid tubes. F. Rakaiia Terrace. a. Sandstone, with veins of quartz. b. Black, graphitic, earthy slates. c. Dark-coloured slates. d. Red and green slates. e. Dark-coloured slates. 2. Secondary strata. 3. Liparites. 4. Coal measures. 5. Liparite tufas and breccias.

This formation is of considerable importance from the large share it takes in the structure of the great mountain-ranges, and from the occasionally great development in it of contemporaneous igneous

rocks, with which are associated metalliferous deposits. In its upper part this formation consists of fine-grained argillaceous slates (Maitai slates of Hochstetter), becoming calcareous and passing into true limestones at their base. These limestones, which close the Maitai series, contain the following Lower Carboniferous fossils: *Spirifera bisulcata*, *S. glaber*, *Productus brachythærus*, *Cyathophyllum*, and *Cyathocrinus*.

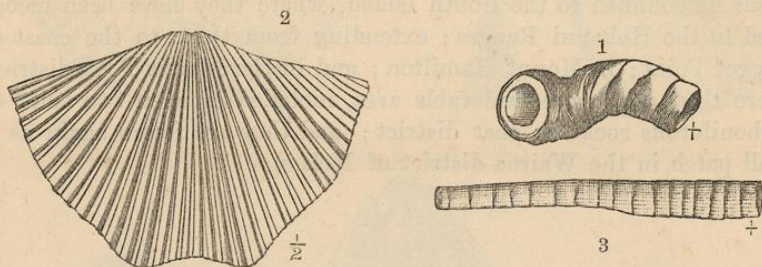


Fig. 48.

1. Tubicolar annelide. 2. *Spirifera bisulcata*. 3. Encrinite.

In Northern Otago and Canterbury the Maitai formation makes a continuous belt of country from Palmerston to Mount Cook, embracing the whole of the Mackenzie country; from there north it is found in the Tyndall Range; at Browning's Pass; the Spencer Mountains; St. Arnaud Mountains; thence through Nelson to D'Urville Island; and, taking in a large area of the Marlborough District, it reappears from below the rocks in the Kaikoura Mountains. It is also found on the eastern side of the Permian rocks at Geraldine; Mount Peel; the Palmer Range; Big Ben Range; Okuku Range; crossing the Hurunui River, and appearing on the edge of the Hanmer Plains. It is again seen in the Paparoa Range at Greymouth, and extends from a point a little west of Mount Herschel, through Reefton and Lyell, to the Tasman Mountains and Anatoki Range, near Collingwood. At Reefton the Maitai formation is the matrix of the auriferous reefs in that important mining district, and is distinctly seen to rest unconformably upon richly-fossiliferous limestones and quartzites of Lower Devonian age. The auriferous cements which are worked at Reefton belong to the coal-bearing formation of the West Coast, which is of Cretaceous age.

In the North Island the principal development of this formation is through the Rimutaka, Tararua, Ruahine, and Kaimanawa Ranges, and thus on to the Whakatane country, where it reaches the sea-coast between Opotiki and Kotiki Point. It also occurs as several isolated patches

more to the westward, between Tuhua and Rangitoto; in the Haka-rimata, Pataroa, and Wairoa Ranges; in the gorge of the Waikato above Cambridge; again at the Thames and Cape Colville Peninsula; and, appearing once more at Whangarei, extends from there along the coast-line to the Bay of Islands, also appearing in the same district as several isolated patches.

XIII. DEVONIAN.



Fig. 49.

a. Te Anau and Reefton series.

Immediately underlying the Lower Carboniferous limestones of the Maitai series in the typical locality are the rocks of the Dun Mountain mineral belt, with respect to which there may be a doubt as to whether they should be placed with the Maitai or the Te Anau series, and so be regarded as of Devonian age. As, however, the rocks of the mineral belt pass downwards into rocks that are undoubtedly referable to the Te Anau series, and with which they are closely related stratigraphically, and much more in their mineralogical characters, it is not doubted that they find their proper position as here placed.

The Te Anau series in its typical locality comprises an enormous thickness of greenstone breccias, aphanite slates, and diorite sandstones, with great contemporaneous floes and dykes of diorite, serpentine, syenite, and felsite.



Fig. 50.

Across Wakatipu Lake. 1-3. Schists. 5. Te Anau series. 6. Maitai series.
8. Cretaceo-tertiary (in fault-line).

The beds occur in the Longwood Range, the Takitino Mountains, and between the mouth of the Molyneux River and Martin's Bay, occupying the area between Te Anau and Lake Wakatipu.



Fig. 51.

Longwood Range. *a.* Pliocene clays, with marine fossils. *b.* Vesicular basalts of Mount Pleasant. *c.* Sandstone. *d.* Coal and oil-shale beds at Orepuke, overlaid. Te Anau series.—(*e.*) Greenstone slates and breccia, auriferous quartz-veins; (*f.*) Syenites; (*g.*) Siliceous slates.

At Reefton beds of Lower Devonian age occur; but these are of a different character from the Te Anau series, and consist of alternating beds of quartz, chert, and limestone, the latter yielding many fossils, of which *Spirifera vespertilio* and *Homalonotus expansus* are the most characteristic forms; also *Avicula*, *Orthis*, and *Strophomena*.

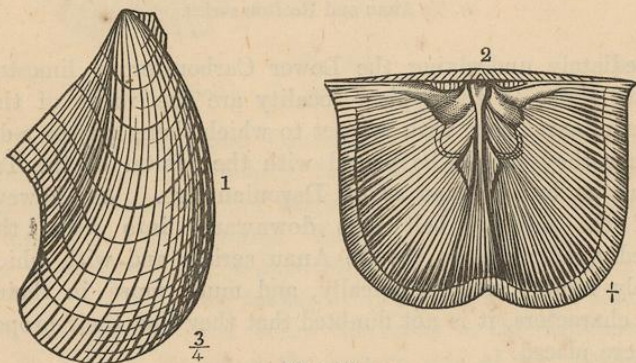


Fig. 52.

1. *Avicula*. 2. *Strophomena*.

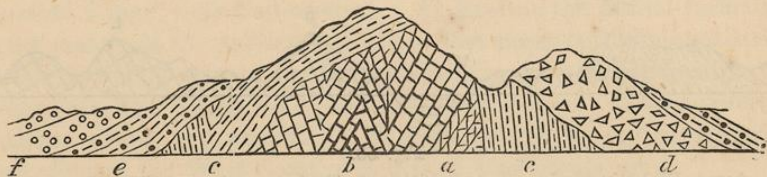


Fig. 53.

North beach of Inangahua. *a.* *b.* Reefton series, Lower Devonian. *c.* Maitai (auriferous slates), Lower Carboniferous. *d.* *e.* *f.* Cretaceous-tertiary.

XIV. UPPER SILURIAN.



Fig. 54.

a. Baton River series. b. Limestones. c. Serpentes.

A great part of the area coloured on the map as metamorphic schists should probably be included in this formation, but it has only been distinguished by its fossil contents in the north-west district of Nelson, where both Upper and Lower Silurian rocks are present.

The Upper Silurian rocks consist of grey cherts, sandstones, and calcareous slates, with occasional beds of blue limestone.

In the Baton River they contain a great variety of fossils in the calcareous strata, and not infrequently in the sandstones and cherts, of which thirteen species have been determined, besides which a great variety of corals and corallines occur; crinoids also are very abundant.

Some few of the species are identical with those found in the Lower Devonian beds of Reefton, whilst others occur in the Lower Silurian rocks of America; but the prominent facies of the collections is undoubtedly Upper Silurian. The characteristic fossils are *Spirifera radiata*, *Stricklandia lyrata*, *Pterinea spinosa*, *Murchisonia terebralis*, and *Calymene blumenbachii*.

XV. LOWER SILURIAN.



Fig. 55.

a. Aorere series. b. Marbles. c. Hornblende rock.

These rocks form the mass of Mount Arthur and the range to the north-east as far as Separation Point, and they consist chiefly of a dark bituminous slate, associated with a blue or grey sub-metamorphic limestone, which is in places developed to a very large extent. White crystalline limestones are also associated with these beds throughout the whole length of the district from Mount Owen to Motueka.

The whole series is disturbed by eruptive hornblendic and syenitic rocks, which are probably of Devonian age.

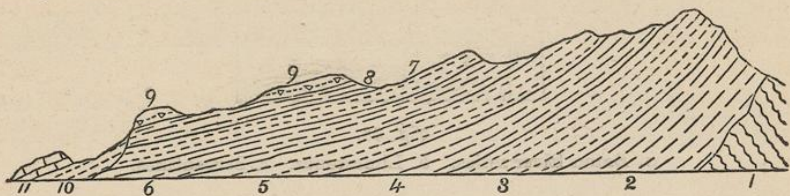


Fig. 56.

Aorere River, Collingwood to West Coast. Lower Silurian.—1. Metamorphic schists. 2. Blue slates. 3. Cherty sandstone. 4. Blue slates. 5. Cherty sandstone. 6. Dark-coloured slates. 7. Cherty sandstone. 8. Carbon slates (graptolites). 9. Cherty sandstone breccia (Cretaceo-tertiary). 10. Calcareous sandstones. 11. Limestone.

As proving the presence of Lower Silurian rocks, fossils have been found in two localities only, and these consist entirely of encrinuritic remains, one species of coral not yet determined, and a few graptolites, which occur in the slates.

The central axis of these beds consists of true mica schists, to the east and west of which the limestone and bituminous slates overlie.

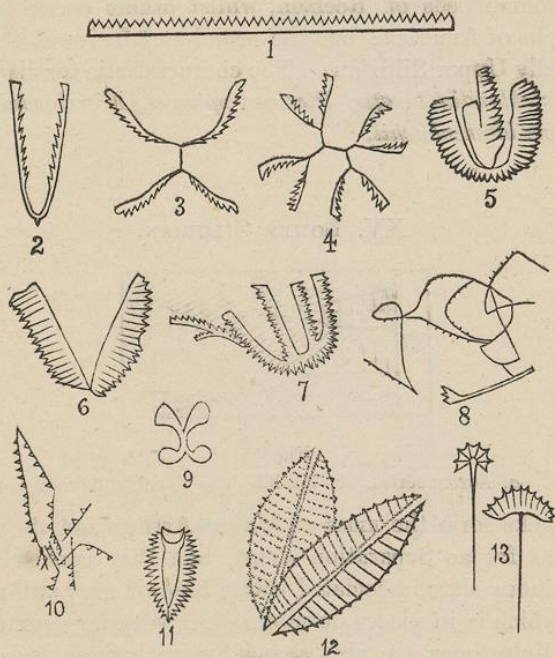


Fig. 57.

New Zealand graptolites, from the carbon slates, North-west Nelson District.

XVI. FOLIATED SCHISTS.

The metamorphic rocks under this division have as yet been only subdivided according to their mineral character; but they probably consist chiefly of altered Silurian rocks, and even those of formations as young as the Maitai or Lower Carboniferous beds. The less metamorphosed areas of Lower Palæozoic rocks in the south of New Zealand have yielded no fossils. They were formerly classed as the Kaihiku series, but this name has latterly been transferred to the Permian formation, of which the Kaihiku Range is more largely composed.

The schists occupy the central portion of the Otago District, where they have an area of nearly 8,000 square miles, and thence they crop out along the western flank of the central range through Westland and Nelson, a detached area also appearing in the Marlborough District, between Queen Charlotte Sound and the Pelorus. They are unknown in the North Island.

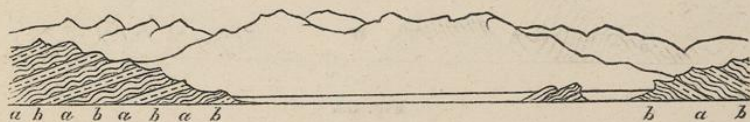


Fig. 58.

Moa Flat to Tapanni Mountains. *a*. Highly-contorted mica-schists, with interfoliated quartz, interbedded with *b*, Flaggy schists, without contortions, and with only small veins of quartz.

They have been subdivided as follows:—

Upper.—A grey arenaceous and slaty rock, containing a little quartz in the form of veins and laminae, with fine-grained quartz breccias and roofing slates, and having massive beds of crystalline limestone locally developed.

Middle.—Soft blue slates, often highly micaceous, and intersected with quartz-veins of small size, the quartz being often rotten and decomposed. The thickness of this formation is not more than from 500 to 1,000 feet, and it is probably from this formation that most of the gold in the western or lake goldfields has been derived, by the direct erosion of glaciers and mountain-torrents. This blue-slate formation has been removed by denudation from the greater part of the central anticline of Otago, only remaining in a few localities, that are difficult of detection on account of its soft and perishable nature.

Lower Contorted Schist.—This is a clay-schist, foliated, not with mica nor felspar, but with quartz. It is often chloritic, when veins of magnetite occur in it, and also crystals of that mineral disseminated through the mass; and in the upper part the quartz is nearly wanting.

The schists, apparently, lie very flat, and cover a great extent of country. The foliated quartz does not commence at a distinct horizon, but beds thus altered occur in the regular sequence of the strata, separated by quartzless rock. In the lower part of the series, however, as exposed in the deep valleys that cut right through the central district of Otago, the whole mass of schist is intersected by concretionary laminae of quartz (generally of a bluish tinge and horny appearance) that conform to the planes of foliation as in mica-schist. Gold occurs segregated in the interspaces of this contorted schist; but it is rarely found *in situ*. Quartz-reefs are confined to the upper schists; but there are but few instances of any other than true fissure-reefs having been discovered—that is, reefs that cut the strata nearly vertically, and have a true “back” or wall independent of the foliation-planes, and filled with brecciated material.

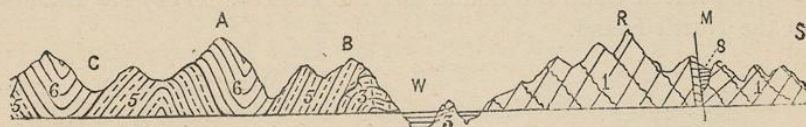


Fig. 59.

From west side of Livingstone Mountains across Lake Wakatipu to Shotover River.
 1. Foliated schists. 3. Lake Harris schists. 5. Serpentinæ. 6. Te Anau series.
 7. Maitai series. 8. Tertiary and Cretaceous rocks. A. Ailsa Mountains.
 B. Greenstone Spur. C. Greenstone Valley. M. Moonlight Gorge. R. Richardson Mountains. S. Shotover River. W. Lake Wakatipu.

XVII. CRYSTALLINE SCHISTS.

The south-western portion of the District of Otago is composed of crystalline rocks, forming lofty and rugged mountains, of which the chief characteristic is their cubical form, due to their being intersected in all directions by profound but narrow valleys, with abrupt precipitous sides to three-fourths of the extreme height of the adjacent mountains. The valleys are occupied on the west by arms of the sea, and on the east by those of inland lakes, that resemble the Norwegian fiords, and present most wonderful mountain scenery.



Fig. 60.

Coast north of Breaksea Sound. a. Basic rocks. b. Gneiss.

The base-rock of this formation is foliated and contorted gneiss, corresponding to Humboldt's gneiss-granite of South America, and associated with it are granite, syenite, and diorite, which belong to the next group.



Fig. 61.

a. Eurite vein (metalliferous) invading basic rocks, Milford Sound.

Wrapping round these crystalline strata, and sometimes rising to an altitude of 5,000 feet on its surface, is a series of hornblende schists, soft micaceous and amphibolic gneiss, clay-slate, and quartzites, associated with felsestone dykes, serpentine, and granular limestone. I believe these latter to be metamorphic rocks of not very ancient date—probably of Devonian age.

XVIII. GRANITE.

Areas within the crystalline schists where true granite occurs, either metamorphosed or in the form of perfect dykes, have been distinguished under this group.

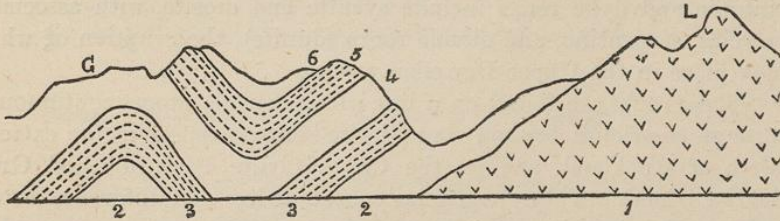


Fig. 62.

Lead Hill to Goulund Downs. 1. Granite. 2. Blue slates, with graptolites. 3. Cherty sandstone. 4. Blue siliceous slates. 5. Cherty sandstone. 6. Blue slates. L. Lead Hill. G. Goulund Downs.

Granites of pre-Silurian age, of a light-grey colour and very fine grain, are found in the Nelson and Westland districts, forming isolated hills along the boundary of the foliated schists on the east and Lower Devonian beds on the west. In the south-western extremity of New Zealand, at Preservation Inlet, coarsely-crystalline granites, of white and flesh-colour, appear to break through and overlie the younger members of the crystalline schists.

Igneous Rocks.

XIX. PLUTONIC AND DYKE ROCKS.

XX. BASIC VOLCANIC ROCKS.

XXI. ACIDIC VOLCANIC ROCKS.

Or, if grouped according to age, as in the geological sections,—

- A. Volcanic group. Recent and Post-tertiary.
 - a. Basaltic.
 - b. Rhyolitic.
- B. Trachytic group. Eocene.
 - a. Trachyte-porphyrries.
 - b. Trachyte-breccias.
- C. Dolerite group. Upper Cretaceous.
 - a. Trachy-dolerites.
 - b. Anamesites.
- D. Propylite group. Lower Cretaceous.
- E. Diabase group. Triassic.
- F. Diorite group. Lower Carboniferous.

The igneous rocks have played an important part in almost every formation in New Zealand, marking great movements of the earth's crust at the different geological periods, while the superficial and later-formed volcanic rocks occupy nearly one-third of the area of the North Island.

They are divided on the map into the above groups, of which the plutonic and dyke rocks include syenite and diorite, with associated breccias, serpentine, and olivine rocks (dunite), the eruption of which took place in the Upper Devonian period.

These rocks are found on a line which extends almost continuously through the South Island; but diorite rocks reappear in the extreme north of Auckland, and on the Cape Colville Peninsula and Great Barrier Island. They are generally more or less metalliferous, chrome and copper being the ores of most frequent occurrence.

Basic Volcanic Rocks.—These belong to three distinct periods, when there were active eruptions, attended by the formation of flöes of both compact igneous rocks and tufaceous breccias.

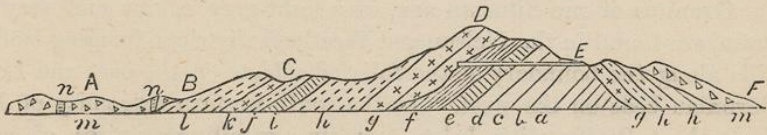


Fig. 63.

Beeson's Island, Kennedy's Bay. a-f. Palæozoic. g-k. Basic porphyry and tufas (propylite). m, n. Dolerites and breccias.

The earliest of these occurred during the Triassic period, and consists chiefly of diabase and serpentinous breccias. The next eruptions took place about the close of the Jurassic period, along the eastern base of the Canterbury Alps, where the rocks occur in dome-shaped mountains as melaphyres associated with felsite (quartz) porphyries, which belong to the next group.

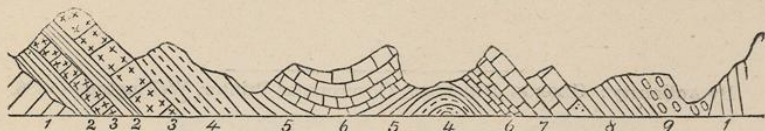


Fig. 64.

Left bank of Seymour River. 1. Palæozoic. 2-8. Waipara formation. 9. Interbedded basalts.

In the Cretaceo-tertiary period are massive trappan eruptions of trachy-dolerite and dolerite, which are clearly interbedded with the coal-beds at the base of the Waipara series; while in the same period must be placed the propylite group, consisting of greenstone trachytes and fine- and coarse-grained breccia rocks, which form the matrix of the auriferous reefs of the Thames Goldfields.

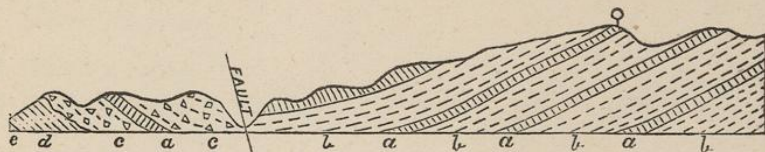


Fig. 65.

Section of Te Aroha Mountain. *a.* Bands of diorite, porphyry, or propylite. *b.* Decomposed tufas and sandstones. *c.* Breccia. *d.* Palæozoic.

In Eocene times dolerite flöes were contemporaneous with the limestones of the period of the Hutchinson's Quarry beds; while lastly in this group have been placed the basaltic lavas of Pliocene age in the northern parts of the colony, and also certain dykes of vesicular lava that cut through and alter the Upper Pliocene gold-drifts in the Maniototo Plain, in the interior of Otago.

Acidic Volcanic Rocks.—The rocks belonging to this group have a similar distribution in time to the foregoing, the earliest being the felsite (quartz) porphyries, while trachyte porphyries and breccias played an important part during Cretaceo-tertiary and older Tertiary periods, scoriaceous lavas and rhyolites being the characteristics of the later outbursts, which have continued down almost to the present time.

The geysers and boiling springs in the North Island give rise to the formation of siliceous sinter, which must be included as the most purely acidic products of volcanic action, and as due to the decomposition of the older rocks by the action upon them of fresh water; but in the case of White Island, and other localities where the decomposition is brought about by the agency of sea-water, the sinter deposits are formed chiefly of sulphate of lime, and not silica.

By Authority: GEORGE DIDSBURY, Government Printer, Wellington.—1886.