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New Zealand Fossils

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NEW ZEALAND GEOLOGICAL SURVEY
DEPARTMENT OF SCIENTIFIC AND
INDUSTRIAL RESEARCH

COVER: *Monotis richmondiana* Zittel, Awakino Gorge.

Photo: S. N. Beatus, N.Z. Geological Survey.

an "opposition" group whose views were more in accord with Wynyard's, he was called upon to select three colleagues to join the Executive Council. On 31 August 1854 Forsaith, and E. J. Wakefield, W. T. L. Travers, and James Macandrew (*qq.v.*), took their seats in the Executive Council, but without portfolio. The "Ministry's" views were set forth in the Governor's Address to the second session of Parliament, and included such items as an elective Legislative Council, revision of electoral districts, and clarification of the relative spheres of the General and Provincial Governments. The drafting of this speech was the "Ministry's" sole official act and, when their prepared Address in Reply was rejected by the House on 3 September 1854, Forsaith and his colleagues resigned. Constitutionally, Forsaith, like his predecessor FitzGerald, has no claim to be regarded as a Premier of New Zealand.

Shortly before his elevation to office, Forsaith had tabled a motion to secure religious toleration and, on 28 August 1855, he defeated Carlton's (*q.v.*) attempt to have Bishop Selwyn's salary made a charge on the Colonial Government. This had the effect of disestablishing the Anglican Church in New Zealand. Defeated at the polls in 1855, Forsaith returned to business, becoming a Justice of the Peace in 1857. He was re-elected to Parliament in April 1858, but his sincere, if ill-timed defence of Wiremu Kingi (*q.v.*) after the Waitara affair, effectively terminated his political career, and he retired in 1860.

In 1862 Forsaith gave up his business to enter the church. The Presbyterian authorities (he had joined that church in 1850) offered him a post as missioner at Tuapeka goldfields but he declined this, preferring to continue theological studies preparatory to ordination as a minister. In July 1865, however, he was ordained to the new Congregational pastorate at Port Chalmers. In 1867 he accepted a call to a similar pastorate at Woollahra, New South Wales. From there he removed (1868) to Parramatta and, in 1872, became chairman of the Congregational Union of New South Wales. In 1878 he was appointed resident chaplain at Camden Theological College, and, while there, founded a branch mission at Haslam's Creek (now Hampden), New South Wales. He returned to Parramatta in 1882, and later toured Canada, America, and Europe. In Britain he gave a series of public lectures which attracted many new immigrants to New Zealand, and for a short time he officiated at the Presbyterian Church in Venice. In 1884 he left Europe and for some years relieved at churches in Australia and New Zealand (notably in Dunedin and Invercargill). Early in 1898 Forsaith began his memoirs but had not proceeded far when he died, at Parramatta, on 29 November 1898.

As one of the earliest settlers in the Kaipara district, Forsaith acquired the unique reputation of dealing fairly with the Maoris in land transactions. His understanding of Maori language and customs and his tactfulness in dealing with their problems made his services invaluable to New Zealand's first three Governors. As a parliamentarian, he impressed his contemporaries as a serious thinker and an able debater, and it was unfortunate that his political career ended at such an early stage. Forsaith was a deeply religious man. Although he was a Presbyterian for many years, his best services were given to the sect of his youth, the Congregationalists. He entered their ministry relatively late in life but proved, in a quiet unassuming way, both in Australia and in New Zealand, that he was a truly great pioneer of the church. B.J.F.

I.A. 1/80 (MSS), National Archives; *O.L.C. 626, 628* (MSS), National Archives; *N.Z.P.D.* 1854–55, 1855–60; *New Zealand Spectator*, 10 May 1845.

FOSSILS

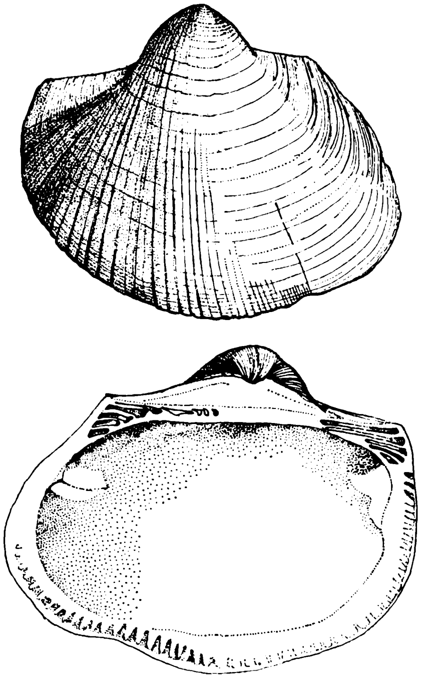
Marine fossils are known in New Zealand from 13 of the 15 major divisions of geologic time (*see* Geology – Time Scale, p. 771). Fossils belonging to the Silurian and Carboniferous periods have not been definitely recognised in the New Zealand succession.

The New Zealand fossil record is predominantly marine and most phyla of marine animals are represented; the record of terrestrial or freshwater life is extremely poor. As Phyla vary widely in their structure for preservation as fossils (hard-shelled creatures are more likely to be preserved than those with soft bodies), the fossil record at best only provides glimpses of the history of life in the past.

Of the marine Protozoa, Foraminifera are particularly well represented in the Upper Cretaceous and

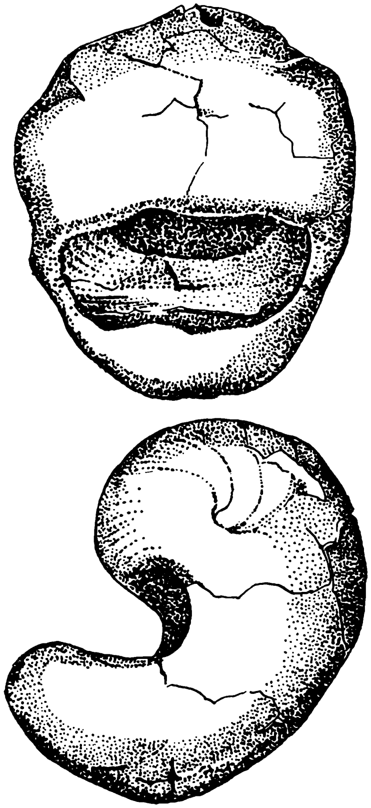
Foraminifera. Cibicides karreriformis *Hornibrook. Lower Oligocene. Magnified 30 times*

Tertiary of New Zealand, but older records are rare, owing to the hardness of the enclosing rocks. Scattered Lower Cretaceous faunas are known, and rare Jurassic and Permian faunas. The study of fossil Coccolithophorida and Radiolaria from New Zealand is yet in its infancy, but Coccoliths occur in the Upper Cretaceous and Tertiary, and Radiolaria in the Tertiary and Triassic (radiolarian cherts). Sponge remains (Porifera), mainly isolated spicules, are preserved in the Cambrian, Ordovician, Upper Cretaceous, Lower Tertiary, and Pleistocene, but they have been little studied. *Receptaculites*, a spongelike fossil, but of uncertain systematic position, is recorded from the Devonian of New Zealand. The fossil record of the Coelenterata in New Zealand starts in the Devonian, when Rugose and Tabulate corals flourished. Two types of coral assemblage characterise the New Zealand Permian: solitary, cool-water types in the Lower Permian, and reef-building, warm-water types in the Upper Permian. Apart from a conularid found in the Upper Triassic, the post-Permian records of coelenterates are from the Cretaceous and Tertiary rocks – a few Hydrozoa and Anthozoa and abundant Zoantharia (Scleractinia). Marine tube-forming Annelida are represented by tubes and shells. Not much work has been done on New Zealand fossil annelids, but two species have been described from the undifferentiated Triassic-Jurassic rocks of the main ranges of the North and South Island, and these may be of Triassic age. Other worm tubes are known from the Jurassic, Cretaceous, and Tertiary. Marine Arthropoda are well represented in New Zealand by Ostracoda and Cirripedia and by rarer Decapoda and Trilobita, but other Arthropoda have extremely poor fossil records and terrestrial groups are hardly represented at all apart from insects in late Quaternary deposits. The oldest New Zealand Ostracods are from the Cretaceous, and the group ranges



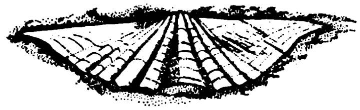
Pelecypoda. Cucullaea *aff.* worthingtoni *Hutton. Oligocene. Half natural size*

throughout the Tertiary. Fossil Cirripedes occur in the Tertiary, and fossil Decapoda in the Lower and Upper Jurassic, Upper Cretaceous, and Tertiary. Phyllocarids (Leptostraca) are preserved in the Ordovician, and Trilobites in the Cambrian, Ordovician, and Devonian. Shelled Mollusca have the most complete record of all larger invertebrates, but land shells are not recorded as fossils in New Zealand before the Pleistocene, and freshwater groups are little known. Gastropoda range back to the Cambrian, but it is not until the Devonian that the first Pelecypoda appear.



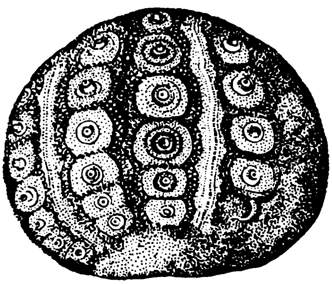
Gastropoda. Conchothyra parasitica *Hutton. Upper Cretaceous. Natural size*

From the Permian to the present day, each of the geologic periods in New Zealand is characterised by important pelecypod and gastropod faunas. About 240 genera of pelecypods and 570 gastropod genera have been described from the New Zealand Tertiary and Quaternary. The Scaphopoda, appearing first in the Triassic of New Zealand, are a minor element in the fossil invertebrate fauna, but become locally abundant in the Middle Tertiary. Because of their usefulness for dating and correlation, Cephalopoda are important Mesozoic fossils, but they are, on the whole, sparsely distributed in New Zealand. Rare Dibranchiata are known from the Upper Triassic, but none from the Lower Jurassic. The record improves in the Middle and Upper Jurassic, when belemnites are abundant and useful fossils. The Lower Cretaceous lacks belemnites, but distinctive belemnites characterise the Upper Cretaceous. Ammonoids occur in the Triassic and ammonites in most of the Jurassic stages and from some of those of the Cretaceous. Nautiloids are a minor element in the New Zealand fossil fauna and occur in the Mesozoic and Tertiary. Polyzoa are known from Devonian, Triassic, and Tertiary rocks. Brachiopoda are found in all of the geologic periods



Brachiopoda. Spiriferina (Rastelligera) gypaetus *Trechmann. Upper Triassic. Half natural size*

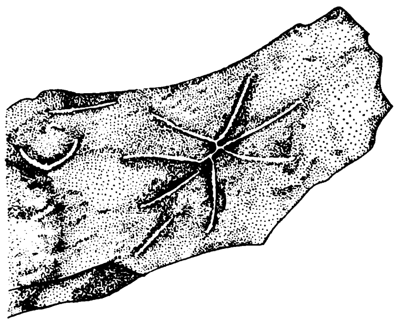
present in New Zealand. Primitive types (Atremata) are recorded from the Cambrian and Ordovician and more advanced forms from the Devonian. The Middle and Upper Jurassic and Cretaceous brachiopods are little known. Tertiary brachiopod faunas are of importance and rich faunas characterise the Oligocene. Echinodermata are rare in the Palaeozoic and Mesozoic of New Zealand. A carpoid is known from the Devonian, a cidarid (Echinoidea) from the Upper Triassic, an ophiuroid from the Upper Cretaceous, and asteroids from the Upper



Echinodermata. Histocidaris mackayi *Fell. Lower Oligocene. Two-thirds natural size*

Jurassic and Upper Cretaceous. Good echinoid faunas are known from the Tertiary. New Zealand crinoids are not well known, but fragments occur in the Permian, Triassic, Upper Jurassic, and Tertiary. Primitive Chordata are represented in New Zealand by the graptolites (Stomochorda), found in the Ordovician.

Vertebrata have a sparse record in New Zealand and those that are preserved are mainly marine forms. Sharks and saw-sharks are represented by teeth, found in the Upper Cretaceous and Tertiary. Elephant Fish and Chimaerids have left some bone fragments in an Upper Cretaceous deposit. Rays have left rare grinding teeth and spines. Bones and scales of Teleost fish are occasionally preserved, but their commonest remains are otoliths. There is a single Pliocene record of a freshwater fish (*Galaxias*). Reptilia are known from Middle Triassic, Jurassic, and Cretaceous. In the late Cretaceous, large marine Mosasaurs and Elasmosaurs were not uncommon. No terrestrial dinosaurs (known in Australia and Patagonia) have been reported from New Zealand and the Tuatara (*q.v.*) (*Sphenodon*) of the present day has no fossil record before the Holocene. Birds have a poor fossil record, except for the penguins. The oldest moa (*q.v.*) bones (Dinornithiformes) are Upper Miocene, and footprints, perhaps *Apteryx*, are about the same age. Extinct subfamilies of penguins (Sphenisciformes) are well represented from Lower Eocene to Oligocene, and there is a single Pliocene skeleton, but the living Spheniscinae are unknown before the late Pleistocene. A possible albatross bone is known from the Oligocene, but other flying birds have no record in New Zealand before the Pleistocene. Two groups of marine mammals are represented by scanty fossils: Cretacea in the Oligocene, Pliocene, and Pleistocene; Pinnipedia by a few bones from the Pliocene and Pleistocene.

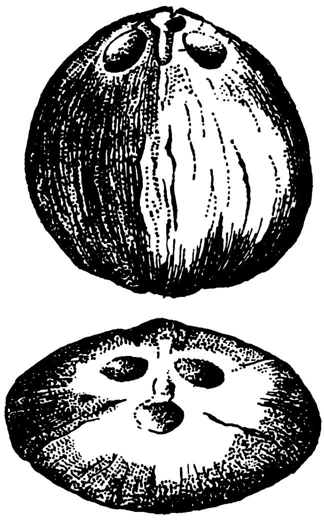


Chordata. Dichograptus octobrachiatus *(Hall). Lower Ordovician. Half natural size*

Abundant coals, lignites, and peats, ranging in age from Jurassic to Recent, yield pollen grains and spores of land plants and provide a good basis for study of past plant life. Leaf, seed, and wood fossils, still not adequately studied, are a valuable supplement to the pollen record. The oldest recognisable plants in the New Zealand succession are fernlike fossils from the Permian of Southland. Middle Jurassic vegetation is represented by the well-known Curio Bay (*q.v.*) fossil forest of Waikawa, Southland; and Upper Jurassic vegetation by the Port Waikato plant fossils. Angiosperms arose and spread throughout the world at the end of the Lower Cretaceous, and angiosperm pollen grains of this age are known in New Zealand. Many good Tertiary floras are known, and in the Miocene they include fossil coconuts in Northland. Late Pliocene and Pleistocene floras reflect the gradual world-wide cooling in the Late Pliocene, followed by the oscillating climate of the Pleistocene. Marine and freshwater Algae have left no record, except for some marine calcareous forms and marine and freshwater diatoms.

Overseas Affinities

The study of plant and animal fossils has thrown light on the overseas relationships of the past life of New Zealand and has also given some idea of past climates. Cambrian and Ordovician faunas are virtually cosmopolitan in their affinities, but those of the Cambrian are close to those of Queensland, Manchuria, and the Baltic, and those of the Ordovician, to Victoria. Close relationship to Eastern Australia is also shown by the Devonian faunas, but again with cosmopolitan (Europe, North America) elements. Two definite faunas characterise the Permian – a Lower Permian fauna of brachiopods, pelecypods, and solitary corals closely related to South-East Australia and, to a lesser extent, South Africa, South America, and India; and an Upper Permian warm-water fauna of fusulinid Foraminifera and reef corals with Indo-Pacific affinities. In the Triassic and Lower Jurassic, many brachiopods and pelecypods are confined to New Zealand or occur elsewhere only in New Caledonia; at this time the two countries were evidently isolated from the remainder of the Indo-Pacific. On the other hand, during the same time the ammonites, which probably lived in the surface waters, and pterioid pelecypods, such as *Daonella*, *Halobia*, *Monotis* and *Rhaetavicula*, which probably had pelagic larvae, were able to migrate freely, and cosmopolitan forms in these groups are found in New Zealand.



Monocotyledonae. Cocos zeylandica *Berry. Miocene. Natural size*

The Middle Jurassic is characterised by the arrival of another pterioid pelecypod (*Meleagrinella*) and other pelecypods and gastropods from Indo-Pacific countries. Indo-Pacific affinities also persist into the Upper Jurassic. Climatically, in the Triassic and Jurassic New Zealand probably lay in the warm temperate zone. The Lower Cretaceous is represented by ammonites and some pelecypods of European affinities, other pelecypods of Southern Hemisphere affinities, and belemnites of Australasian affinities. The Upper Cretaceous faunas, in contrast, show strong southern (for example, South American) affinities. Cretaceous climate was probably temperate or warm temperate. Distinct South American affinities are continued into the lowermost Tertiary molluscan faunas, but accompanied by Indo-Pacific, Australasian, and endemic elements. These latter three elements are also found in the faunas of the remainder of the Tertiary and in the Quaternary. Throughout the Tertiary, temperatures in the New Zealand region were temperate or marginal tropical at best (Lower Miocene of Northland). The Pleistocene history of New Zealand is dominated by successive periods of cooling, which caused the extinction of warm-water forms and allowed the incoming of southern cool-water forms, although Indo-Pacific and Australian elements have continued to colonise. G.R.S.

For illustrations, *see* plate 42A (full page), and 44A.

MICROFOSSILS

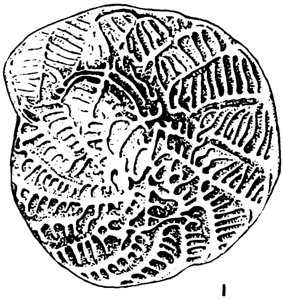
Rivers and ocean waves constantly erode the land, and carry large quantities of sand and mud far out to sea to be deposited on the bottom in layers. Myriads of minute organisms, some living a benthic existence on the sea bottom, others floating in the upper layers of the sea as plankton, leave behind hard skeletons and shells which accumulate on the sea bed and become entombed in the sediment along with minute skeletal parts of larger organisms. Over a long period of time the layers of sediment become compacted and hardened to form rock strata, and may be exposed as dry land in a later geological period by withdrawal of the sea or uplift.

Rock strata, like the leaves of a book, are the pages of geological history which can be read by the micropaleontologist who studies assemblages of microfossils preserved in successive beds. As an archaeologist can assign artefacts to certain periods of human culture or a historian identify the characteristics of a period of history, so can a micropaleontologist tell in which geological age an assemblage of microfossils from a particular stratum was buried in the sea bed. Microfossils therefore help the field geologist to work out correctly the sequence of rocks and their geological structure in areas where the earth's crust is strongly contorted and dislocated or obscured by vegetation or young deposits.

New Zealand sedimentary rocks of upper Cretaceous and Tertiary age are rich in microfossils and there are numerous publications dealing with them.

Planktonic microfossils (freely floating in life) are widely distributed throughout the oceans by currents and similar assemblages of species are found in rocks of the same age in different parts of the world. Planktonic forms are therefore particularly useful for correlating rocks of the same age throughout the world and they help geologists to piece together more accurately the story of geological events in the earth's history.

Microfossils are used by oil exploration geologists in their surveys of possible oil fields. Their abundance and small size makes them especially easy to collect



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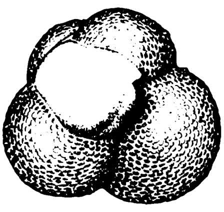

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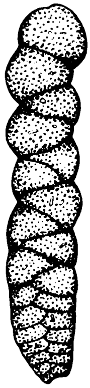

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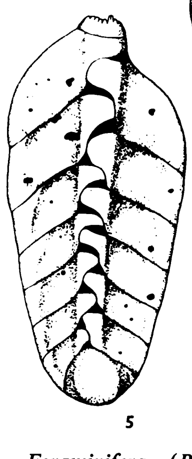

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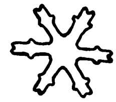
Figs. 1–5. Foraminifera (Protozoa, primitive one-celled animals with hard shells of lime or agglutinated sandgrains and growing by adding chambers in a variety of ways, fairly constant for each species). Size range: 0·01 mm.–3 c.m. Fig. 1, Notorotalia targetensis (*Miocene, Oamaru*). Notorotalia *is very characteristic of New Zealand microfaunas, appearing earliest in the Eocene and remaining an endemic genus throughout most of the Tertiary. The deeper water species,* N. clathrata *has reached the east coast of South America. Fig. 2,* Globigerina turgida (*Eocene, Northland*). *An example of a planktonic foraminifer confined to the Eocene in New Zealand. Fig. 3,* Victoriella conoidea (*Miocene Greensand, Kakanui*). *A shallow water, probably subtropical species common also in the Tertiary of Australia. Fig. 4,* Haeuslerella pukeuriensis (*Miocene, Oamaru*). *An arenaceous agglutinating foraminifer with regular alternating initial chambers becoming irregular with growth. It has evolved through a series of intermediate forms from a species which has entirely regular chambers, present in underlying strata. Fig. 5,* Polymorphina marshalli (*Oligocene, Wharekuri*). *A large species (4½ mm.) common in the greensands and limestones in North Otago*



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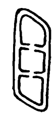

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Figs. 6–7. Nannoplankton (extremely minute organisms or parts of organisms that were once part of the plankton. Size: about one hundredth of a millimetre. Coccoliths, which resemble discoasters, are discrete geometrical plates of calcium carbonate forming a coccosphere in the living animal which is a flagellated protozoan. Other forms of the nannoplankton are parts of unknown organisms now extinct). Fig. 6, Discoaster tani (*Upper Eocene, Oamaru*). *A discoaster (an extinct group of uncertain affinities) originally described from the Oamaru diatomite deposits and since found all over the world in Upper Eocene rocks. Fig. 7,* Isthmolithus recurvus (*Upper Eocene, Oamaru*). *A distinctive form of unknown affinities described from the Oamaru diatomite and now recognised as a world-wide index fossil for Upper Eocene*

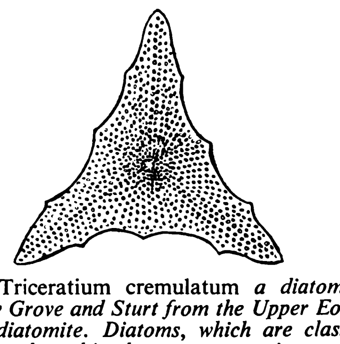
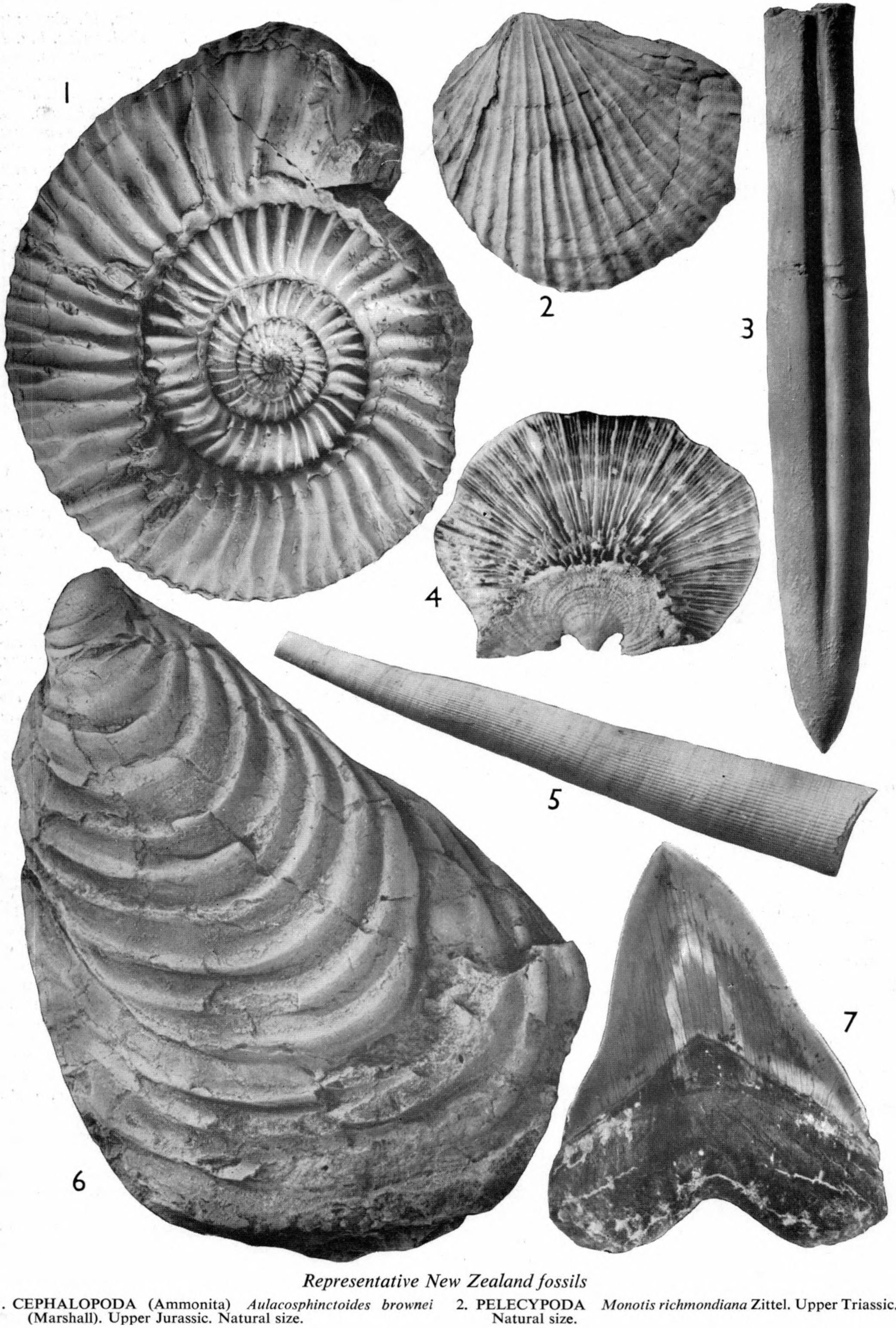


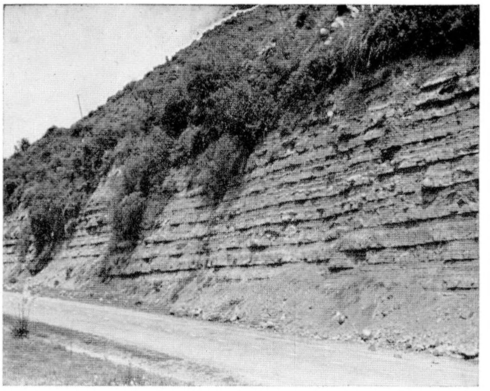
Fig. 8. Triceratium cremulatum *a diatom described by Grove and Sturt from the Upper Eocene, Oamaru diatomite. Diatoms, which are classified under the plant kingdom, secrete minute, hard, geometrically perfect tests of opaline silica, consisting of two halves which fit together perfectly. The Oamaru diatomite, which consists almost entirely of diatoms radiolaria and sponge spicules, formed in the sea during a period of intense volcanic activity some 40 to 50 million years ago. It is famous for its variety and wealth of species*



Representative New Zealand fossils

1. CEPHALOPODA (Ammonita) *Aulacosphinctoides brownei* (Marshall). Upper Jurassic. Natural size.
2. PELECYPODA *Monotis richmondiana* Zittel. Upper Triassic. Natural size.

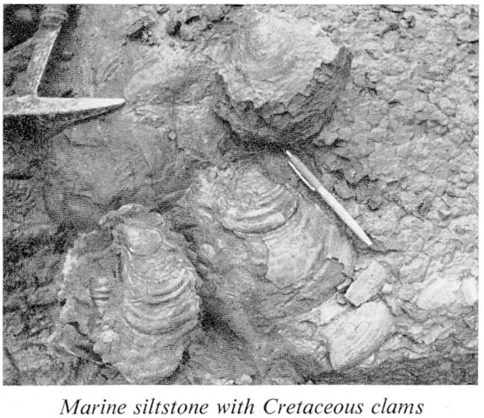
Lower Pleistocene tilted marine sandstones, conglomerates and pumiceous tuffs, near Cape Kidnappers



Upper Oligocene tilted marine sandstones and siltstones, north of Taumarunui

Marine benches, Baring Head, Wellington

River terraces, Rangitikei Valley



Marine siltstone with Cretaceous clams (Inoceramus)

Stewart Island. Rounded granite outcrops

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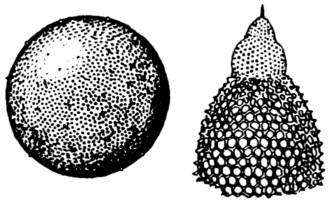
3. CEPHALOPODA (Dibranchiata) *Belemnopsis aucklandica* (Hochstetter). Upper Jurassic. Natural size.
4. COELENTERATA *Flabellum pavoninum circulare* Tenison-Woods. Eocene and Oligocene. Natural size.
5. SCAPHOPODA *Dentalium solidum* Hutton. Oligocene and Miocene. Natural size.
6. PELECYPODA *Inoceramus galoi* Boehm. Upper Jurassic. Natural size.
7. VERTEBRATA *Carcharodon megalodon* Agassiz. Lower Tertiary. Half natural size.



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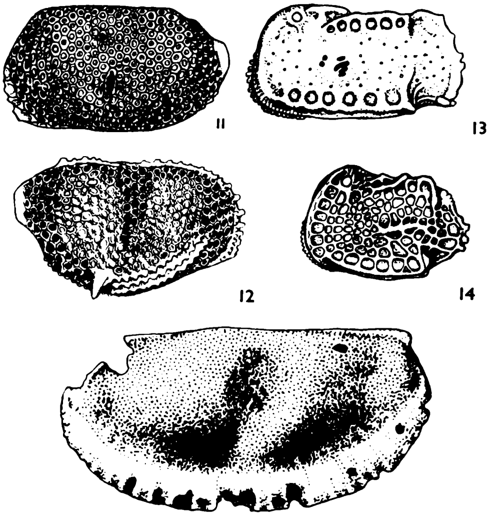
Figs. 9–10. Radiolaria (*minute Protozoa containing an outer skeleton of silica in the form of a lattice of great variety and geometrical perfection). Fig. 9, spherical radiolarian abundant in Eocene rocks in New Zealand. Fig. 10, radiolarian from the basal part of the Totara Limestone (Upper Eocene, Oamaru)*



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Figs. 11–15. Five genera of Ostracoda particularly distinctive of the New Zealand fauna (minute primitive crustacea protected by a paired, hinged limey shell, the two halves of which are termed valves. Some families develop interlocking teeth and sockets in the hinges which are used for classification and all exhibit distinctive scars where the closing muscles are attached. Only the valves are preserved as fossils. Size: one-tenth of a millimetre up to 1 mm.). Fig. 11, Cytheralison. *Fig. 12,* Bythoceratina. *Fig. 13,* Bradleya. *Fig. 14,* Quadracythere. *Fig. 15,* Puncia goodwoodensis (*Goodwood Limestone, N.E. Otago, Miocene). The only fossil species found so far of the genus* Puncia *which was found living off North Cape.* Puncia *does not resemble any other known living Ostracoda but appears related to Ostracoda of the Order Beyrichiida which were thought to have become extinct during the Paleozoic Period, some 300 million years ago.* P.novozealandica, *from off North Cape, could be described as one of New Zealand's "living fossils"*

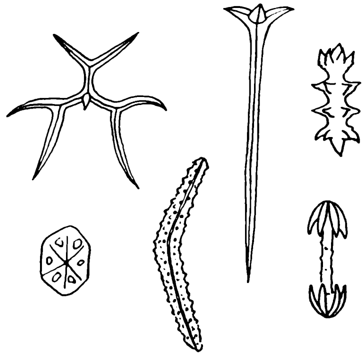


Fig. 16. Sponge spicules from the Oamaru diatomite. Some types of sponges contain a supporting skeleton of glassy spicules, common as fossils

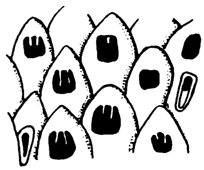


Fig. 17. Patsyella dentata (*Mt. Brown Limestone, Miocene). An example of a polyzoa or bryozoan (minute animals which form colonies, usually encrusting on rocks or shells of other animals but sometimes filamentous and branching. The peculiar, barnacle-like animals inhabit protective limey cases common as fossils)*

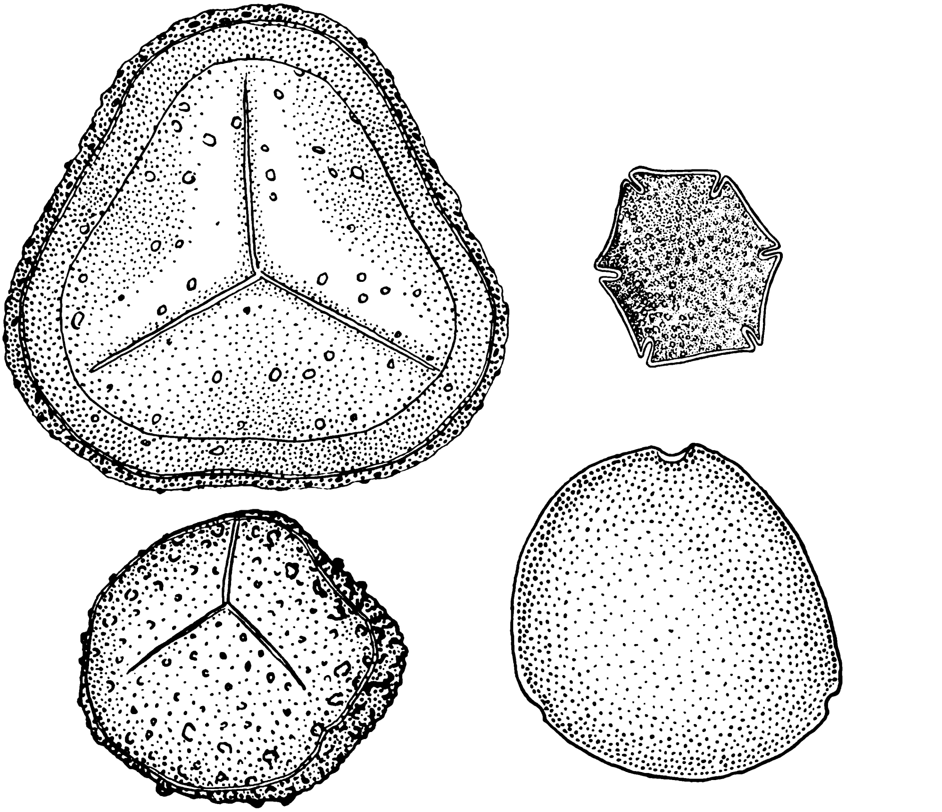
and store. A pea-sized piece of soft limestone or limey mudstone may contain many thousands of microfossils. Most soft limestones, mudstones or sandstones in New Zealand will yield Foraminifera, Ostracoda or Bryozoa if they are first well soaked and then washed over a fine sieve with holes of a millimetre or less in diameter. N. de B.H.

See also Geology, Marine Microbiology, etc.

The Tertiary Cheilostomatous Polyzoa of New Zealand, Brown, D. A. (1952); *New Zealand Geological Survey Paleontological Bulletin 18,* Tertiary and Recent Marine Ostracoda of New Zealand, Hornibrook, N. de B. (1952); *New Zealand Geological Survey Paleontological Bulletin 34,* Tertiary Foraminifera from Oamaru District (N.Z.), Hornibrook, N. de B. (1961); *Introduction to Microfossils,* Jones Daniel, J. (1956).

PLANT FOSSILS – PALEOBOTANY

Plant fossils are classified into two groups: (1) macrofossils, which are the larger plant members, such as stems and leaves, usually detached and often fragmented; and (2) microfossils, which are the shells or resistant outer walls of minute plants, such as



Types of fossil spores and pollen. Left, top, spore of the large black tree-fern, Cyathea medullaris *(Forst. f. Swartz, found from the Upper Pliocene to the present day; bottom, spore (type specimen) of* Osmundacidite wellmanii *Couper, a fern, Jurassic to Cretaceous. Right, top, pollen of* Nothofagus cranwellae *Couper, beech now extinct, mid Oligocene to early Pleistocene; bottom* Triorites harrisii *Couper, a common fossil from the Upper Cretaceous to early Pleistocene, indistinguishable from pollen of the Australian She-oak* Casuarina. SCALE 1,000x

diatoms (*q.v.*), or of pollen grains and spores. Fruits and seeds vary considerably in size and overlap each group.

For several reasons pollen and spores have a particular importance in present-day geological research in New Zealand. (1) Being produced in large numbers, readily dispersed, and highly resistant, they are more often preserved than macrofossils. (2) They occur in sediments of terrestrial origin where no marine fossils are available, often in sufficient numbers for a comparison to be made of the relative abundance of different types. (3) Since they are also deposited in coastal waters and may be found associated with marine organisms they help to "date" sedimentary rocks in relation to marine fossil sequences.

Evidence of Climatic Change

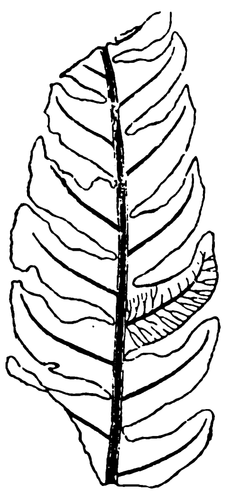
Much of the evidence of climatic change depends on the former occurrence of lowland trees north or south of their present limits, the number of degrees in latitude giving some indication of the magnitude of the climatic difference. Wood and resin, indistinguishable from that of the living kauri (*q.v.*), occur in Tertiary lignites in Otago. These show that kauri forests once grew much further south than their present range, and indicate a warmer climate in the Tertiary. Kauri pollen occurs in South Island Upper Miocene to Pliocene deposits, and well-preserved leaves of Oligocene age have been found at Landslip Hill (see map, p. 741), so that the southern extension of the group to which the kauri belongs is shown by these different fossils – wood, resin, leaves, and pollen. Cone scales from Shag Point (Upper Cretaceous) and Mokoia and Waikawa (Jurassic) show also that the kauri family has had a long history in New Zealand.

Seasonal variation in climate may be shown by differences in growth rings. These are clearly shown in Upper Jurassic fossil woods from Waikawa, Curio Bay (*q.v.*), and Waikato Heads. Coniferous wood, which seems to have predominated in the formation of the Tertiary lignites of the South Island, also shows growth rings. (The Tertiary fossil woods, as well as spores and leaf cuticles, are described by W. P. Evans in the *N.Z. Journal of Science and Technology*, Vol. 9–19, 1928–37.)

Apart from numerous, but small and mostly unclassifiable fragments of Mid-Devonian to Carboniferous age, Paleozoic plant life is represented in New Zealand by plant fossils from the Gore district. The fossils identified are of Permian age and link New Zealand with the supposed ancient southern continent, Gondwanaland, and in particular with Queensland through the occurrence there and in New Zealand of *Cladophlebis roylei* Arb. (a fern-like plant), *Sphenopteris lobifolia* Morris (seed-fern), and *Neoggerathiopsis hislopii* (Bunbury) (a cone-bearing plant).

Links With Modern Ferns

One of the oldest plant microfossils so far named from New Zealand deposits is *Osmundacidites wellmani* Couper. This Jurassic spore is considered to be related to the living family Osmundaceae, which is represented in New Zealand by three species of *Todea*. The apparent link between this ancient spore and the modern ferns (*q.v.*) is supported by other evidence. Fossil stems known as *Osmunda dunlopi* Kidston and Gwynne-Vaughan, from Waikawa and Kawhia (Jurassic) are evidently closely related.



Cladophlebis australis (*Morr.*) *presumed to be the foliage of an osmundaceous fern, Cretaceous*

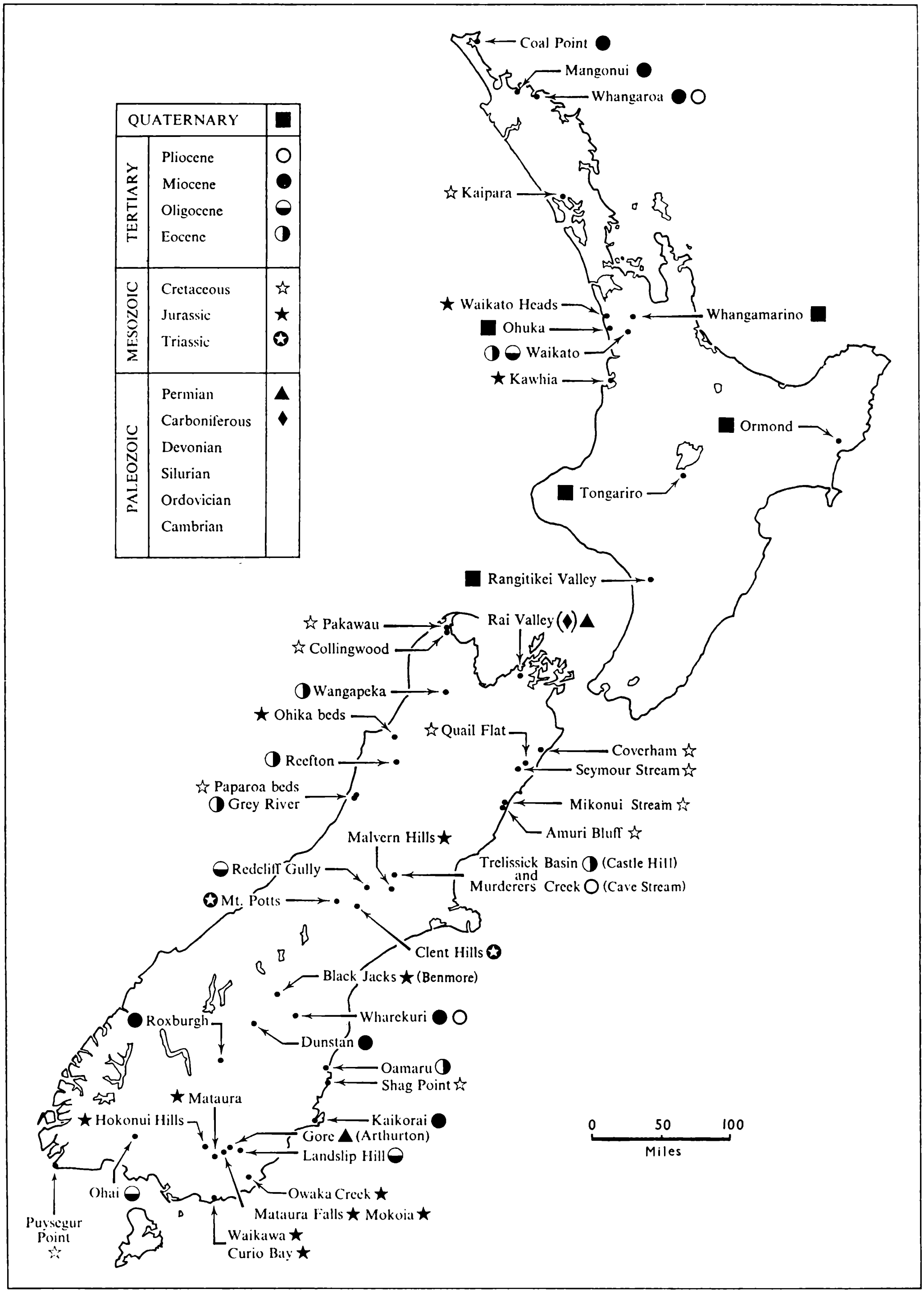
These are of interest on account of their anatomical similarity to modern forms, and they show the extreme slowness with which the family structure has been modified. According to Sinnott (*Annals of Botany*, 1914) "there is perhaps no other case among vascular plants where there has been so little change from Mesozoic time to the present". This stability over a period of more than 135 million years is well exemplified by our living *Todea barbara* (L.) Moore, not only in stem anatomy but also in frond and spore type.

Cladophlebis australis (Morris) is presumed also to be the foliage of an osmundaceous fern. Hence there is a plausible linkage between micro- and macrofossils which has a bearing on the ancestry of certain present-day ferns. The history of the Osmundaceae in New Zealand is extended by the presence of *Cladophlebis roylei* among the Permian plant fossils mentioned above. Of similar antiquity is *Cyathidites*, a fern spore which may be ancestral to the modern tree-fern (*q.v.*) genus *Cyathea*, the spores of which are common in Quaternary deposits. The black tree fern *Cyathea medullaris* (Forst. f.) Swartz, the finest of our present-day tree-ferns, appears to be a comparative newcomer in this ancient lineage, since the spores have not been found in deposits older than Upper Miocene, though common in younger deposits.

Character of Earlier Forests

Branchlets from Cretaceous and Eocene beds in the South Island were identified as belonging to the genus *Casuarina*, which contains the modern sheoaks of Australia and Polynesia. Also believed to represent this genus, and first appearing in the Upper Cretaceous, is *Triorites harrisii* Couper, a pollen type which is common in most Tertiary assemblages, but became extinct with the onset of the Pleistocene glaciations. The presence of *Casuarina* suggests that a forest of more open type than today's dense rain forest was prevalent in the warmer epochs of the Tertiary. Important groups in New Zealand Tertiary vegetation were beeches, conifers, and casuarinas.

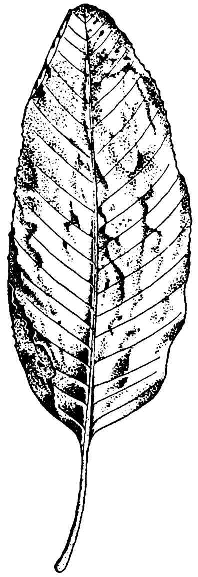
The oldest dated deposits with the remains of angiosperms (flowering plants with enclosed seeds) are the Mid-Cretaceous beds in the Clarence valley, near Coverham. The pollen grains are of an unspecialised type, but with the three furrows which distinguish them as dicotyledonous. Of the three more specialised pollen types of the southern beeches, two appear during the Cretaceous and the third in the early Tertiary. The first to appear, and the one which became dominant during the Tertiary, represents a section of the genus *Nothofagus* with living species in New Guinea and New Caledonia, but now extinct in New Zealand. Fossil *Fagus* (European beech) pollen has not been identified in New Zealand as yet and, as it is of an unspecialised type, confident identification is hardly to be expected. Thus the linkage of the southern beeches, genus *Nothofagus*, with the Northern Hemisphere beeches, genus *Fagus*, remains obscure. As a possible "missing link" may be mentioned the much discussed leaf fossils known as *Artocarpidium arberi* Laurent of Upper Cretaceous age from Pakawau. Oliver, in an unpublished manuscript, points out the resemblance of the venation to that of *Fagus sylvatica* and proposes a new genus for them, *Protofagus*. Oliver also suggests an affinity of the New Zealand leaf fossil *Nothofagus ulmifolia* Ett. (Cretaceous) with the South American beeches, in particular *N. procera*. Most of the fossil southern



Map showing localities for plant fossils, and the geological age of the plant beds. The locality names are those found in the literature, some of them now obsolete

CORRECTION: The Trelissick Basin and Murderers Creek localities should be shown as Cretaceous or Eocene.

beeches had larger leaves than the living New Zealand species. The leaf fossil *Nothofagus ninnisiana* Unger from the Upper Cretaceous (Shag Point) and Lower Tertiary (Waikato and Ohai) is a broad-leaf type and fossil wood, believed to be that of large-leaved beeches, was described by Evans in the articles



Leaf fossil Nothofagus ninnisiana *Unger, range Upper Cretaceous to lower Tertiary*

mentioned above. In the fossil record, as compared with the four or five species now living, 23 species have been named from macrofossils and 12 or 13 from microfossils, indicating the variety and importance of the southern beeches in the former vegetation of New Zealand and the closeness of present-day New Zealand to the centre of evolution and dispersal within this group.

Fruits and Seeds

Fossil fruits and seeds as yet yield a meagre record. At Coopers Beach, Mangonui, and at one or two other localities along the east coast, fossil coconuts of probable Miocene age have been found. These were named *Cocos zealandica* by Berry. The coconut fruits may have been brought by oceanic drift, but in favour of a more local origin are the facts that New Zealand may have consisted at the time of an archipelago of small islands, and that large palm fronds have been found at the same and other localities. Berry also referred to another fruit resembling that of a species of the Australian *Hakea*. *Hakea*-like pollen is known from the Eocene of New Zealand. Seeds are more commonly preserved in Quaternary sediments and may make a valuable contribution to our knowledge of the Quaternary history of the flora. In 1953 D. R. McQueen described an assemblage of fossil seeds from the Rangitikei Valley Quaternary), of which 24 belonged to living species.

A concise summary of the history of the flora of New Zealand was published by W. R. B. Oliver in a Swedish journal (*Svensk Botanisk Tidskrift*, 1955), and Oliver also contributed a similar article to *Tuatara* (1950). A useful work on the conditions under which the New Zealand flora evolved is *New Zealand Biogeography*, by C. A. Fleming, in *Tuatara* (1962). In the *Transactions of the Royal Society of New Zealand*, Vol. 83, there are papers by Shona Bell, H. J. Harrington and I. C. McKellar, and D. R. McQueen, and these give further useful references to the literature on New Zealand plant fossils. For plant microfossils the reader is referred to *N.Z. Geological Survey Paleontological Bulletin 32* (1960), by R. A. Couper.

W.F.H.

See also Geology, Forests (Native), Indigenous Vegetation of New Zealand, Tree Ferns, etc.

FOVEAUX STRAIT

Foveaux Strait is a seaway, 16 miles wide, separating Stewart Island (*q.v.*) from the South Island. The strait is mainly flat-floored, between 10 and 15 fathoms deep, but with scoured channels and hollows down to 25 fathoms. Near the centre the floor of the strait consists of sandy pebbles and, to each side, fine sand. To the east and west the sea bottom slopes gently away and is covered mainly with fine sand. A persistent tidal drift passes to the east through the strait at 3 knots, but greater velocities probably scour some of the more constricted parts of the bottom and give rise to the coarse composition of the bottom sediments. Several islands lie within or near the strait; the largest is Ruapuke Island (*q.v.*). Dog Island, just off Bluff, has a lighthouse, as does Centre Island, near Riverton. The strait lies within the area of the continental shelf surrounding New Zealand and was probably dry land during the lowest sea-level stand of the Pleistocene ice ages.

Early in March 1770, in the course of circumnavigating the South Island, Captain Cook (*q.v.*) sighted the entrance to the strait. He was inclined to think, however, that Stewart Island was part of the mainland.

Foveaux Strait was discovered by an American, O. F. Smith, while searching for seals in 1804. In March 1806 he passed on the information to the Governor of New South Wales. Named after Major Joseph Foveaux, an aide of the Governor of New South Wales, it was renamed Tees Strait in 1824 by a Captain Kent. The old name, however, survived. Several whaling stations, belonging to Johnny Jones (*q.v.*) of Waikouaiti, existed along the shores of Foveaux Strait prior to 1834. In that year Captain John Howell established headquarters at the mouth of Jacobs River or Aparima (*q.v.*), which later became the site of the town of Riverton. The main stations were at Preservation Inlet, Jacobs River, One (Sandy Point), Bluff (Awarua), Toitois (Mataura), and Waikawa.

The prevailing winds are westerly and the strait is often rough to stormy. The submarine conditions

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