Fossil Leaves from the Waikato District.

With a Description of the Coal Measure Series.

By W. H. A. Penseler, M.Sc., B.E., A.O.S.M.

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Introduction.

As a result of mining operations in the Pukemiro Colleries leaf remains were discovered by the writer in the claystone underlying the coal seam, and on subsequent search were found to be fairly commonly distributed in the shaly claystone which in many places forms the roof of the coal. Similar leaves were found in the other mines of the Waikato district. These leaf remains can rarely be observed at outcrops on account of weathering, and they can be obtained in a fresh condition only when, through the necessities of mining, "bottoms have to be lifted," or the roof "taken down," or in "stone drives," etc. Even then the rocks so disturbed do not invariably contain these fossils. Probably, during the years in which mining operations have been carried on in this district many fossil leaves have been encountered and specimens have been irrecoverably lost through lack of scientific interest on the part of the technical staff of the different colleries.

Assistance in the identifications of the fossil leaves collected was rendered by Mr. W. R. B. Oliver, M.Sc., Director of the Dominion Museum, Wellington, to whom the writer extends his thanks. Palaeobotany in New Zealand has been much neglected and therefore comparisons with other fossil leaves were difficult. In assigning a generic name to a leaf its resemblance to recent leaves was the deciding factor, especially because the leaves were all dicotyledonous.

The writer acknowledges his indebtedness to the Dominion Laboratory, Wellington, for the analyses on p. 460.

The leaves collected by the writer have been lodged with the palaeontological collections of the N.Z. Geological Survey, Wellington.

Historical Account.

Hochstetter (1859), when describing the outcrop of coal at Kupakupa on the west bank of the Waikato River near Huntly, referred to the occurrence of fossil plants, principally dicotyledonous leaves, in the shale overlying the coal. He found no ferns accompanying the leaves. In 1864 and 1867 he stated that, of some fossil dicotyledonous leaves found in the coal measures near Drury, the following species had been determined by Unger:—

	Analogies.
Fagus ninnisiana Ung.	*F. procera* Pöppig from South Chile.
Loranthophyllum griselinia Ung.	*Loranthus forsterianus* Schult., and *Griselinia lucida* Forst., of the family Cornae, diffused throughout New Zealand.
Loranthophyllum dubium Ung.	*Loranthus longifolius* Deso.
Myrtifolium lingua Ung.	No analogy with other fossil leaves of plants of that day.
Phyllites purchasi Ung.	Imperfectly preserved: genus indeterminate.
Phyllites ficoides Ung.	
Phyllites novae-zelandiae Ung.	
Phyllites laurinium Ung.	

Unger (1864) described and illustrated these leaves, of which, however, *L. griselinia* is from the Bay of Islands and not from Drury. Unger's descriptions and illustrations will be considered later.

Hutton (1867) described the geological section at Kupakupa and found, overlying the coal, four feet of "dark blue shale containing leaves of dicotyledonous plants similar to those of Drury and Nelson." Later, Hutton (1870) mentioned that there were four or five varieties of these dicotyledonous leaves from Drury and Waikato.

Cox (1877) noted the dicotyledonous leaves in the sandstone roof on the coal seam at Kupakupa.

Park (1886) obtained a small collection of fossil plants from the fireclays at the Taupiri Coal Mine, but gave no description. This collection now forms part of the palaeontological collections of the New Zealand Geological Survey and consists of 18 specimens. On examination by the writer the leaf remains appeared to be similar to those collected and described later in this paper, but the carbonised leaf remains have peeled off the stone and have broken into small pieces so that they cannot now be identified with certainty. All that can be said about the collection is that the leaf remains are mixed with a great amount of fragmentary vegetal matter.

Later, Park (1899) when discussing the coals of New Zealand stated that "the Tertiary coals of New Zealand are the result of forest vegetation of long continued growth, among which dicotyledonous plants are well represented, including oak, myrtle, laurel, cypress, cycads and conifers. Remains of ferns are also abundant."

Possibly, part of this statement was based on the fossil plants found near Huntly.

Henderson and Grange (1926, p. 49) noted the occurrence of unidentifiable carbonised and fragmentary plant remains in the coal measures.

Excepting Unger's description, therefore, no detailed account of these fossil leaves has been published and their occurrence seems to have been neglected. It was Hector's intention, apparently, to publish an account of the fossil leaves of New Zealand, including those collected by Park, but this intention was never realised, although drawings of them had been made. There are no descriptions of these drawings and it is therefore, in the absence of the specimens, impossible to determine their origin.

OUTLINE OF STRATIGRAPHY.

On a gently undulating, planed surface of folded Mesozoic greywackes, argillites, and indurated sandstones, a coal measure series of early Tertiary age was laid down. This series consists of brown and grey claystones, sometimes sandy, and from 80 to 300 feet thick. One to three thick seams of coal, and in places some thin seams, occur near the base of these rocks which are locally known as "fireclays."

Overlying the Coal Measure Series is the Whaingaroa Series of pale coloured claystone followed by bluish-green calcareous glauconitic sandstone and dark grey calcareous claystone containing a marine fauna. Following this is the Te Kuiti limestone of which only the basal members are present in this district.

The ages of these series are as follow:—

Shingle, sand, clays, etc., and swamp deposits		Pleistocene to Recent.
Limestone	Te Kuiti Series	Ototaran Stage, Oligocene
Grey claystone Greensand *Lingula claystone	Whaingaroa Series	
Claystones and Coal,	Coal Measure Series	
Greywackes, Argillites, etc.		Mesozoic

Note: The grouping and naming of the individual beds is a result of the writer's investigations, the series and their ages being quoted from Henderson (1929).

COAL MEASURE SERIES.

The rocks forming this series are dominantly argillaceous, and, though commonly referred to as fireclays, are better classified as claystones. In places where leaching by organic acids has taken place the claystones approach a true fireclay and are then used for brickmaking and pottery work, and for fire brick in gasworks. Analyses of some of these rocks (Henderson and Grange, 1926, pp. 87-90) are given in Table 1.

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*See Penseler, 1930B.

TABLE 1.
ANALYSES OF CLAYSTONES.

	1	2	3	4	5	6	7	8
Silica, SiO_2	41.40	47.71	53.80	59.00	56.67	61.96	60.91	62.88
Alumina. Al_2O_3	39.40	29.95	31 80	26.20	24.28	23.87	23.33	22.22
Ferric oxide, Fe_2O_3 ...	1.60	0.98	1.76	2.20	1.60	1.07	2.44	2.20
Lime, CaO	0.20	0.11	nil	nil	0.10	0.09	0.34	0.43
Magnesia, MgO	0.10	0.12	0.10	0.10	Trace	—	—	nil
Titanium dioxide TiO_2 ...	—	0.83	—	—	0.92	1.33	0.92	0.92
Potash, K_2O	0.50	0.22	0.40	0.10	0.48	0.43	0.39	0.36
Soda, Na_2O		0.10			0.39	0.28	0.21	0.23
Combined water and organic matter	16.80	11.99	12.14	12.40	7.76	9.37	9.17	8.29
Water at 100°C.	—	8.11	—	—	8.10	*2.08	*2.69	*2.48
	100.00	100.12	100.00	100.00	100.30	100.48	100.40	100.01

No. 1.—Fireclay, Waikato (probably Huntly, but precise locality not given). Twenty-seventh Ann. Rep. Col. Lab., 1904, p. 11.

No. 2.—Clay from weathered Mesozoic rock, Te Pake Road.

No. 3.—Fireclay, at least 4 ft. thick, below coal, main haulage-way, Taupiri Extended Mine. Fifty-second Ann. Rep. Dom. Lab., 1919, p. 22.

No. 4.—Fireclay, 10 ft. thick, below coal, Rotowaro Mine. Idem.

No. 5.—Fireclay, Waikato Extended Mine. Fifty-fifth Ann. Rep. Dom. Lab., 1922, p. 21.

No. 6.—Fireclay, Pukemiro Junction Mine. Fifty-ninth Ann. Rep. Dom. Lab., 1925, p. 29.

No. 7.—Fireclay, 15 ft. thick, works of Huntly Brick and Tile Company. Fifty-sixth Ann. Rep. Dom. Lab., 1923, p. 17.

No. 8.—Fireclay, below coal, Rotowaro Mine. Fifty-sixth Ann. Rep. Dom. Lab., 1923, p. 18.

The theoretical mineral compositions of the "dry" clays, Nos. 5, 6, 7 and 8 have been calculated as follow:—

	5	6	7	8
Felspar	7.19	5.41	5.96	6.32
Quartz	27.78	32,14	32.38	35.82
Limonite	1 94	1.28	2.92	2 64
Clay substance and combined water	63.09	58.67	58.74	55.22
Minor constituents	—	2.50	—	—
	100.00	100.00	100.00	100.00

The claystones of the Coal Measure Series are often indistinguishable from the weathered argillites on the surface of the underlying unconformable Mesozoic rocks. As shown by some borehole logs the one grades insensibly into the other and it is only when

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*Water at 105°C.

the basement rock is hard and unweathered (e.g. greywacke).) that the driller can tell with certainty that the "fireclays" have given place to the "understone."

The Coal Measure Claystones vary in thickness from 80 to 300 feet and contain near their base one to three thick seams of coal and often some minor seams of less extent. The Coal Measure Series is naturally thickest in the deepest portion of the original basin.

The origin of this series as a freshwater estuarine deposit may be stated now instead of as a conclusion. The logical sequence is thus to some extent inverted, but by keeping this conclusion in mind the significance of the features to be described will be realised better.

The main characteristic of the series is its variability both lithologically and in colour. Though in the main argillaceous, sandy patches are encountered grading into normal claystone vertically and laterally. The base of the series is usually sandy, and in some districts, e.g., Glen Afton, contains rounded pebbles of hardened clay, quartz, sandstone, etc., up to 1" in diameter embedded in fine claystone (Figs. 1 and 2). Coarse conglomerates or gravels are not found. Small, shaly, i.e., laminated, beds are common, but bedding on a large scale is shown only by the succession of beds of different colour, by dark coloured carbonaceous beds grading for a few inches into dirty coal, and by the occurrence of nodular bands of spathic iron ore. In hand specimens the typical claystone shows no bedding or lamination and appears homogeneous. The records of boreholes in the Waikato district show very well the change from place to place of the series, more especially of the beds overlying the coal seam or seams. This change is due to the lenticularity of the different beds in the series.

The colour of the claystones varies from dark grey for the carbonaceous shaly bands through dark brown, brownish-yellow, and light brownish grey to grey. The last named colour predominates and indicates reduction by decaying organic matter of most of the iron compounds, which have been removed in solution. This reduction of iron is due also to moist conditions in a warm temperate or subtropical region with plentiful rainfall where sediments are deposited under water or on damp, ill drained flats (Twenhofel, 1926, p. 547). The layers of fine, brownish-yellow claystone are a result of floods in the estuary when an increased quantity of water carrying yellowish mud in suspension overspread the river flats, scouring out previous deposits in the main channels and depositing the fine yellow muds in the quieter areas.

The claystones weather to a soft, sticky, yellow clay which obscures most outcrops and obliterates differences between successive beds. Underground, contact with mine air causes fretting and spalling off. The joints become loosened and the rock breaks up, and this necessitates timbering in those sections of the mines which have a claystone roof or sides.

During consolidation the sediments settled and shrank and, as the original site of deposition was undulating, differential settling would modify the positions of successive strata, and differential loading would cause an adjustment of the sediments to the pressure

FIG. 1.—Conglomerate from near base of Coal Measure Series, Glen Afton.

FIG. 2.—Intraformational conglomerate from Coal Measure Series, Glen Afton.

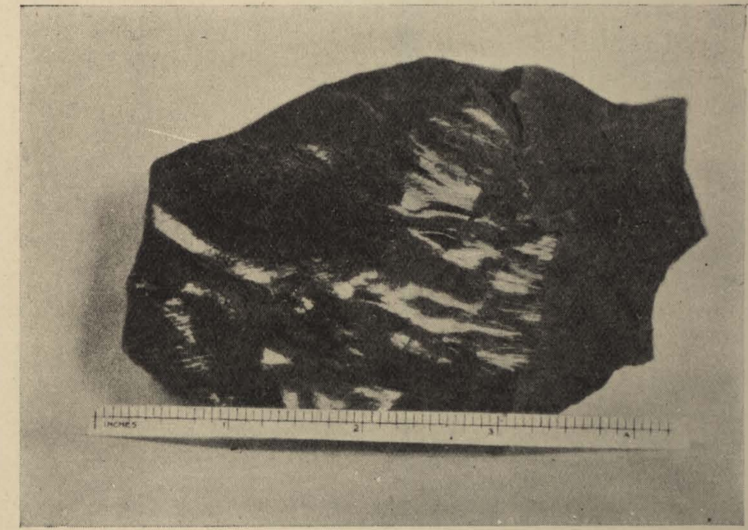


FIG. 3.—Polished surface from joint face of a claystone block.

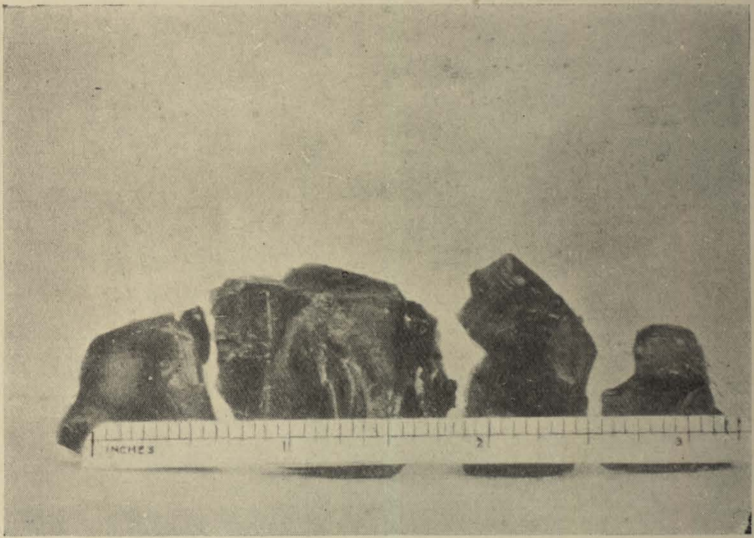
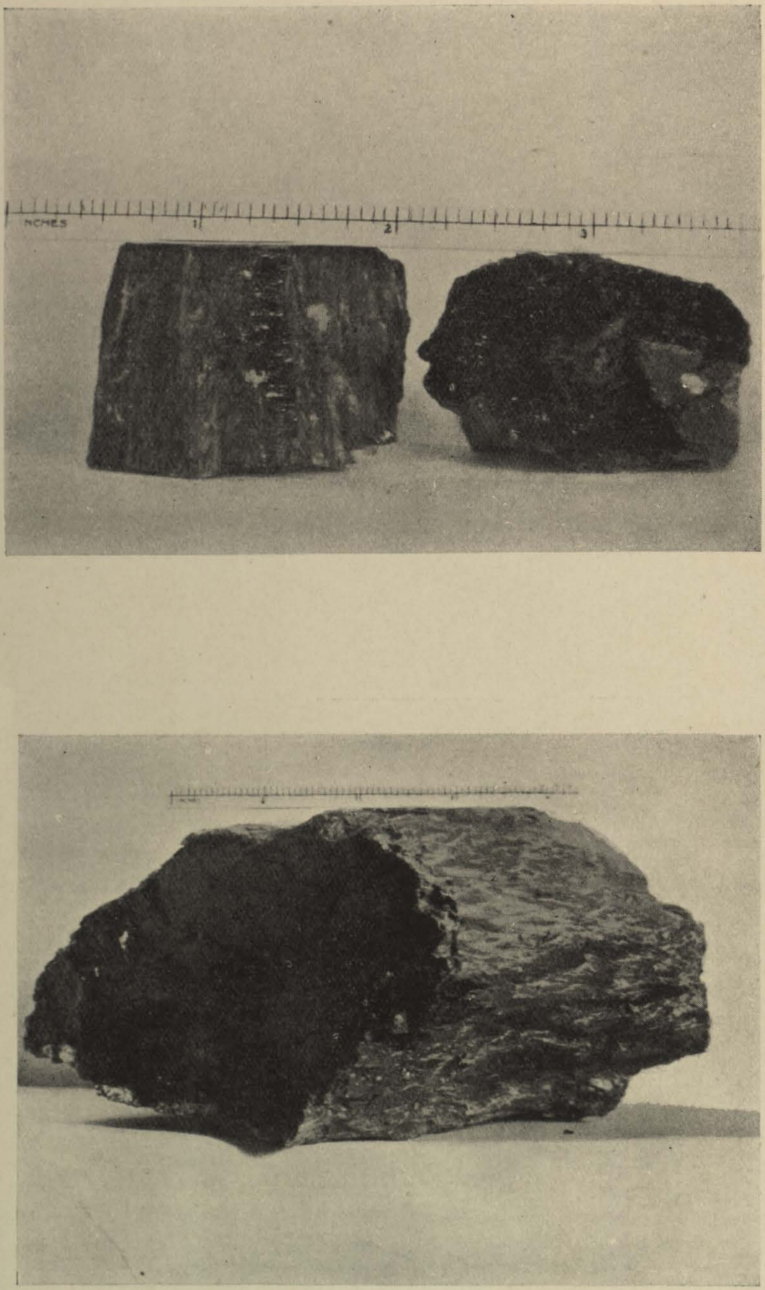


FIG. 4.—Lumps of fossil resin from Coal Measure Series.



FIGS. 5 & 6.—Coalified plant remains occurring in claystones.

FIG. 7.—Coalified Fungus.

FIG. 8.—Coalified wood from claystones showing "bark."

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FIG. 41.—*Cinnamomum waikatoensis* n. sp.
FIG. 42.—*Pisonia oliveri* n. sp.
FIG. 43.—*Beilschmiedia tarairoides* n. sp.
FIG. 44.—*Cassia pluvialis* n. sp.

imposed. On a large scale the effects would be variable and would in general induce lenticularity of the strata, but on a small scale the result is comparable with the cleat in the coal. Settling or shrinkage in the claystones, which may amount to 20 to 50 per cent. or more (Twenhofel, 1926, p. 526) results in a large number of small block faults each block rounded more or less vertically by polished faces (Fig. 3). The blocks may be a few inches square and up to a foot or so long—the thickness of the particular bed—or may be, as is more usual, a few feet square. In the former instance, that of a thin layer broken up by many inclined fractures, the effect may be due to compression and differential movement between the beds, and may thus be regarded as a form of fracture cleavage (Leith, 1923, pp. 148-158).

The larger and irregularly spaced joints or "faults" in a thick bed stand in various directions and attitudes. They may intersect, but commonly one joint either dies out before reaching another, or is cut off by another joint crossing it at an angle. Such joints die out vertically or merge into small monoclines. Leith (1923, p. 33), referring to joints related to the contraction of a crystallising and cooling mass of lava, said that "similarly, joints may be very abundant in flat-lying, partially consolidated beds of sediments, which plainly have not been disturbed by great exterior forces. One of the causes in this case is doubtless the change in volume incidental to the drying and settling of the beds. Mud cracks are one manifestation of this process. Joints formed in this manner are likely to be limited to particular beds and may die out above or below; there may be evidence that jointing in a given bed was complete before the next layer of sediment was deposited. They are likely to be especially abundant near the contacts of different beds or formations (a fact often noted by well-drillers in search of water)." This type of local tensional jointing he said (*op. cit.*, p. 50) "is developed by the drying out of a sediment, resulting in the formation of mud cracks and of shrinkage cracks on a large scale. The joints so formed lack regularity and persistence, vertically and horizontally."

It is evident therefore that the irregular jointing observed in the coal measure claystones is a result of the settling and shrinkage, including effects due to slumping in the original sediments.

The blocky nature of the claystones, combined with their property of flaking and loosening on exposure to the damp mine air, is a source of danger underground. A claystone roof is incapable of supporting itself and requires timbering.

The bands of iron ore are commonly in the form of nodules irregularly spaced and often up to 4 feet thick. They occur below, between and above the different seams and are the result of precipitation of iron from iron bearing solutions in the presence of decaying organic matter which, by providing excess of CO_2, causes precipitation in the form of carbonate. Twenhofel (1926, p. 331) considers that iron sediments are deposited usually in quiet waters, e.g., bogs, marshes, lakes, lagoons, and the sea, and are also precipitated where iron bearing solutions issue from the ground.

Similar views are held also by Clarke (1924, pp. 536-538). With regard to the concretionary type the iron may be brought in as ferrous bicarbonate solution from which, on escape of excess CO_2 and under conditions which do not allow of its replacement by oxygen, iron carbonate is precipitated (Twenhofel, *op. cit.*). Such conditions, according to this authority, obtain in marshes, shallow waters of the sea, lake coasts, and river flood plains where the growing vegetation extracts the CO_2 from the water and the decay of vegetation uses up the oxygen. Further, any iron precipitated as hydroxide might be altered to the carbonate by decaying organic matter. The presence of these concretionary masses of iron ore in the Coal Measure Series indicates, therefore, shallow water conditions such as would obtain in river flats in an estuary where the iron leached from the clays and sediments is precipitated on reaching the surface. There must have been excess CO_2 present from the abundant decaying vegetal matter in these sediments to prevent precipitation in the form of hydrated oxide. The iron ore bands occur at no definite horizon, but though horizontally bedded are irregularly spaced, and were therefore determined by local conditions at each place. An analysis of one sample is as follows: (from 56th Ann. Rep. Dom. Lab., N.Z., 1923, p. 24, quoted by Henderson and Grange, 1926, p. 96).

SiO_2	15.15
Al_2O_3	4.29
Fe_2O_3	0.54
FeO	41.48
MgO	1.78
CaO	2.96
K_2O	0.19
Na_2O	Nil
Water lost at 105°C.	2.12
Water lost above 105°C.	0.56
CO_2	29.10
TiO_2	0.24
P_2O_5	0.36
MnO	1.11
	99.88

As shown by this analysis the deposits are impure, as would be expected where sedimentary material is abundant.

Fossils of the Coal Measures.

A fossil fauna is absent.

Lumps of fossil resin similar to those occurring in the coal and named *Ambrite* by Hochstetter (1867) are common in the claystone (see Fig. 4). They have been observed so far only in the vicinity of the coal seam or seams, but this may possibly be owing to the lack of facilities for examining the remainder of the series. Hochstetter's (1867, p. 79) description is still applicable, and according to him the resin is transparent, brittle, and has a glossy conchoidal fracture. In colour it is bright yellow to dark brown. It is easily ignited and burns with a steady fast-sooting flame with a bituminous rather than aromatic smell. He thought that the resin originated from a coniferous tree related to the present Kauri pine, and gave the following analysis:—

Carbon	76.65
Hydrogen	10.38
Oxygen	12.78
Ash	0.19
	100.00

which is equivalent to the formula $C_8 H_{13} O$.

Its hardness was 2, and specific gravity 1.034.

Analyses of other fossil resins with which this is comparable are given by Moore (1922, pp. 102-104), and the amber mined from Tertiary rocks on the shore of the Baltic Sea in East Prussia is described by Prockat (1930).

The low specific gravity of the resin would enable it to be readily transported by even slight currents, but any argument based on its present properties is unsafe because of the alteration it has undergone by hardening, loss of volatile matter, etc., since it was deposited. When a lump of resin occurs in a shaly layer the laminae are bent round it and it seems reasonable to suppose that it was drifted into secluded backwaters where it became entombed by the covering muds. Where the current was stronger the resin would be carried out to sea.

The resin in the claystones and that in the coal differ in origin to the extent that the former was allochthonous and the latter autochthonous, although both might have been derived from the same species of tree.

On exposure to the weather the resin becomes opaque and waxy looking.

The presence of the resin may be taken as evidence of the occurrence of coniferous trees in the flora of that time.

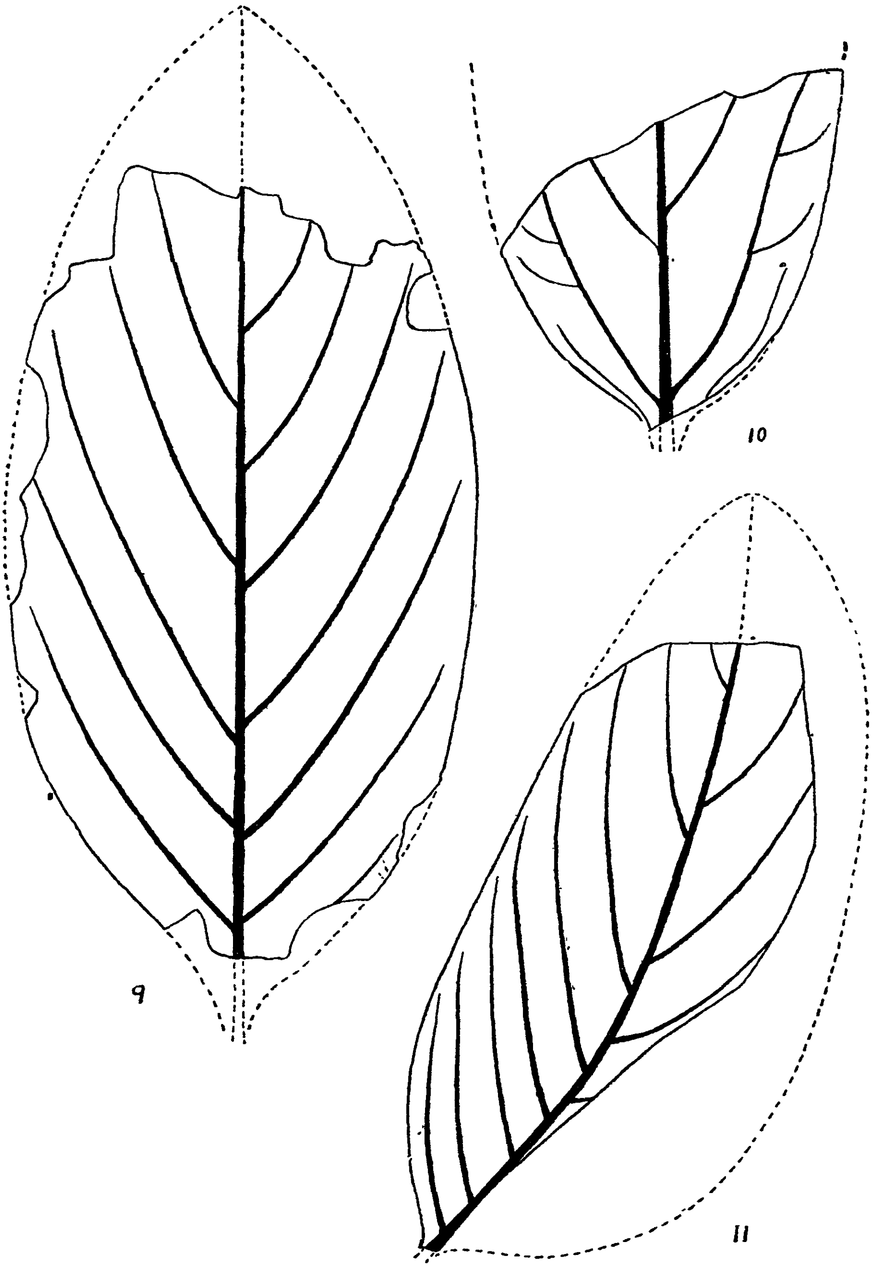
Fragmentary coalified plant remains (see Figs. 5 and 6) are of common occurrence and vary in size from small pieces, which represent twigs, up to large masses 6 feet or more long and 2 feet broad. The larger remains are usually more or less flattened and all have a black colour and a shining lustre. Smaller branching remains resembling roots also occur, and what appears to be a coalified fungus is shown in Fig. 7. One fragment had the "bark" still adhering (Fig. 8). These coalified plant remains are homogeneous, i.e., not laminated like the coal, and on account of their friability only small portions can be preserved as specimens. They occur in any part of the claystones and often are embedded partly in one variety of "fireclay' and partly in another. They represent fragments of plants that have been drifted in by the rivers which deposited the muds around them when they became stranded. Their analogy with the strips of "bright coal" in the seam (see Penseler, 1930A) is shown by the following analyses:—

	Bright Coal	Coalified fragment in fireclay above seam	Coalified fragment in fireclay below seam	Normal Coal
Water	22.94	18.49	20.14	15.34
Volatile Matter	28.22	27.79	28.68	35.88
Fixed Carbon	47.79	49.46	48.84	46.22
Ash	1.05	4.26	2 34	2 56
	100.00	100.00	100.00	100.00
Sulphur	0 26	0.53	0.48	0.30
B. Th. U.	9950	9734	9939	10802
On a dry ash-free basis:				
Volatile Matter	37.1	36.0	37.0	43.7
Fixed Carbon	62.9	64.0	63.0	56.3
	100.0	100.0	100 0	100.0
B. Th. U.	13090	12600	12820	13160

It will be seen from these analyses that the coalified remains are similar in analysis to the bright coal and are higher in water and fixed carbon and lower in volatile matter than normal coal.

The bright strips in the coal represent unmacerated fragments of wood in the original vegetable mass, and because the coalified remains found in the claystones are clearly derived from fragments of wood the above results were therefore to be expected. The point of interest, however, is that the wood in the form of logs buried in the clays has in the course of time been changed into "coal" similar to that formed from the remains of small pieces of wood in the peaty deposit now forming the coal seam proper. The latter are what was left when the general process of maceration and bacterial decay was suppressed by the smothering action of overlying material and by the probable development of toxic conditions in the peaty mass, and it may be concluded that the logs buried in the fireclays had not been subjected to any process involving maceration but had undergone bacterial decay. Heat and pressure in addition were responsible for the change from wood to coalified material.

Where the normal claystone changes to a laminated shaly clay, dark grey in colour, it often includes very thin streaks of bright coaly matter and on splitting these dark coloured laminated clays leaf remains are found. After splitting a fragment of shale containing a leaf, apparently two leaves are obtained due to separation of the leaf along the centre of the lamina. The state of preservation of the leaves depends on several factors. If the enclosing material is at all coarse grained (comparatively speaking) the leaves may be broken and fragmental, or impressions only may be left owing to opportunities for access of air and water. If the shale during the extensive shrinking which occurred in the coal and in the muds



FIGS. 9-11.—*Cinnamomum waikatoensis* n. sp. × 1.
From Coal Measure Claystones, Pukemiro Colliery.

[*W.H.A.P., del.*

was subjected to pressure resulting in lateral movement the surfaces and outlines of the leaves are blurred. It is only when the enclosing material is sufficiently fine grained and has not been distorted that favourable conditions obtain. Another important point is that leaves which have been transported by muddy water for some distance become bruised, torn, and fragmental, but those deposited in sheltered backwaters after very little transportation are more likely to be preserved whole. Fragmental leaves are often associated with much general vegetal debris such as portions of bark, broken twigs, branches, etc., as in Park's collection referred to previously.

The best preserved specimens were obtained from a dark grey shaly layer, a few inches thick, occurring in a light grey, rather sandy claystone about 6 feet below the base of the coal seam in the West Drive of the Pukemiro Colliery. The leaves, though not perfectly preserved in all detail, are much better than those collected at other places. They are all black in colour and occur horizontally bedded in this thin layer. Less well preserved and poorly preserved leaves were found in many places where a dark grey, shaly clay forms the roof of the coal seam, but in most instances prolonged contact with the mine air had caused the leaves to peel and scale off. This property of scaling has to be guarded against in specimens, which also have a marked tendency to break up into small rectangular pieces by a series of fine joints at right angles to each other.

On account of the weathering of the claystones into a sticky yellow clay, outcrops of the Coal Measure Series are disappointing to the collector. Any contained plant remains are usually broken up or obliterated, and even in sandy and shaly beds, which weather differently, plant remains quickly disintegrate.

The fossil leaves thus differ from the fragments of fossil "wood" described before in that the former are bedded and the latter irregularly distributed. No leaves have been observed joined to twigs in the form of sprays, and no leaves have been observed in conjunction with the masses of coalified wood.

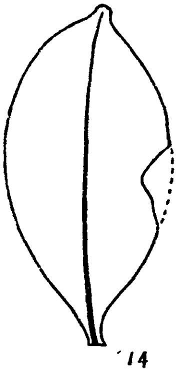
FOSSIL LEAVES.

a. *Description.*

Cinnamomum waikatoensis n. sp. Figs. 9 to 13, and 41.

Holotype: Figs. 12 and 41.

Leaf oblong-elliptic, the apex slightly more acute than the base. Margin entire. Midrib well marked; secondaries alternate or sub-opposite, 6 to 8 on either side of the midrib, arising at regular intervals at an angle of about 45° and gently curving forwards and becoming obsolete near the margin; they are prominent and almost parallel. Tertiary veins, shown on Fig. 10, branch towards the margin, arising from the secondary veins at an angle of about 60° and curving forwards. On this specimen also a pair of small veins, probably tertiary, are seen near the base of the leaf.



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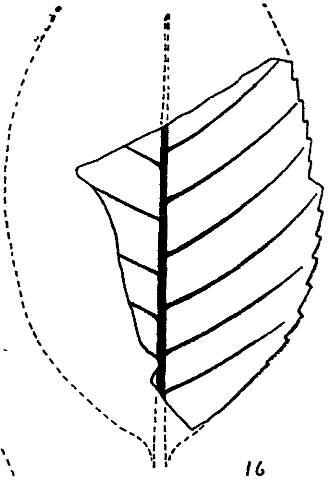

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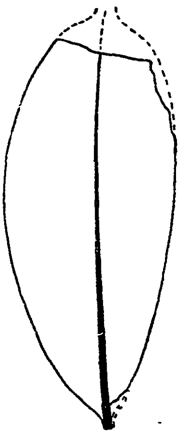

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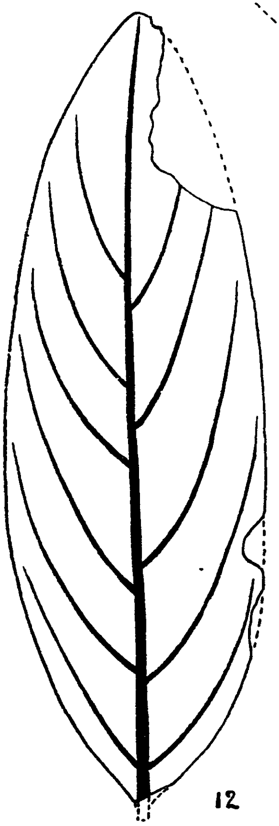

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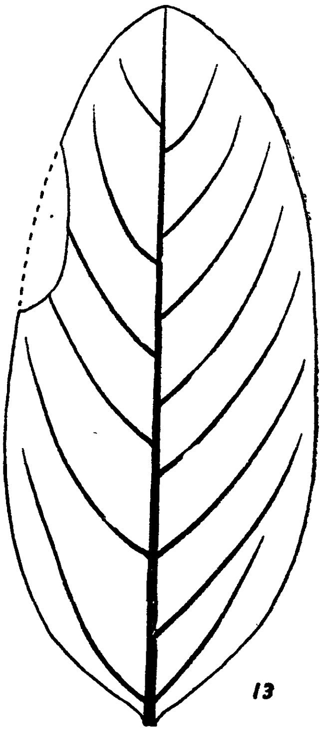

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FIGS. 12, 13.—*Cinnamomum waikatoensis* n. sp. × 1.
From Coal Measure Claystones, Pukemiro Colliery.

FIGS. 14, 15.—*Cassia pluvialis* n. sp. × 1.
From Coal Measure Claystones, Renown Colliery, Waikokowai.

FIG. 16.—*Fagus ninnisiana* Ung., × 1.
From Coal Measure Claystones, Pukemiro Colliery.

[*W.H.A.P., del.*

Dimensions of laminae: 94 × 38 mm. (Fig. 13), 105 × 32 mm. (Figs. 12 and 41), 135 × 58 mm. (Fig 9), 117 × 45 mm. (Fig. 11).

This is the most commonly occurring leaf observed by the writer. It has been placed in the genus *Cinnamomum* because of the occurrence of two well marked opposite secondary veins at the base; and in order to give some means of identification to the leaf the specific name "*waikatoensis*" has been assigned to it. No form resembling this was collected by Hochstetter or described by Unger, and it has been impossible to find definite relationships with any modern genus in New Zealand. (Cf. *C. intermedium,* Ettingshausen, 1887, Taf. 4, Fig. 20).

Cassia pluvialis, n sp. Figs. 14, 15, and 44.

Holotype: Figs. 14, 44.

Leaf elliptic, widest in the middle and tapering towards either end. Base acute, apex produced into a rounded protuberance or drip point. Margin entire; midrib prominent. Secondary venation not observable.

Dimensions: 44 × 20 mm. (Fig. 14), 55 × 21 mm. (Fig. 15).

No leaf like this has been found among the living New Zealand flora, but it bears some resemblance to *C. pseudophaseolites* (Ettingshausen, 1887, Taf. 4, Fig. 6) from Shag Point and Murderer's Creek, the apices of which are missing or turned over and buried in the rock. The apices of *C. pluvialis* were bent over into the claystone and were discovered only by carefully picking out the covering rock.

Fagus ninnisiana, Ung. Fig. 16; see also Figs. 24 to 32.

A fragment without either base or apex, and showing a portion of one side only. Leaf apparently broadly elliptical. Margin serrate. Secondary veins arise regularly from midrib at an angle of about 60°, and terminate in the indentations within the marginal teeth.

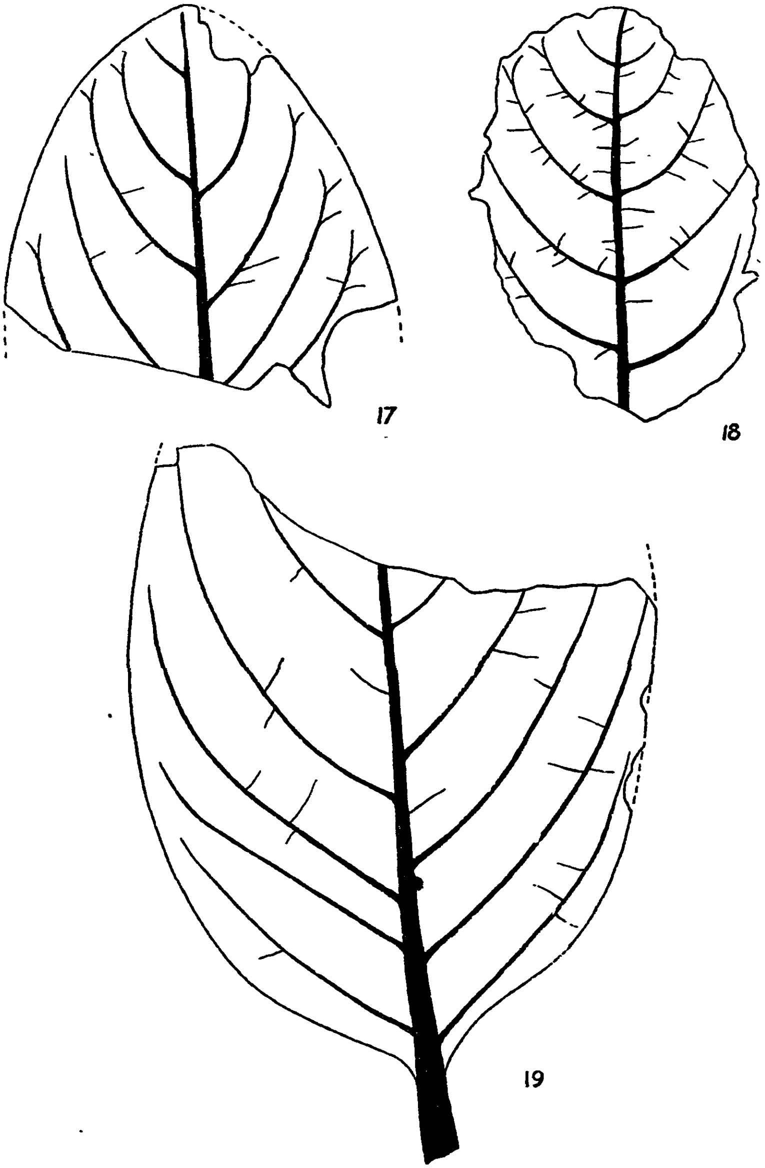
Distance from midrib to margin, 19 mm.

Estimated size of leaf, 72 × 38 mm.

This leaf is similar to those collected by Hochstetter from beds of about the same age at Drury and classed as *F. ninnisiana* by Unger (Figs. 24-32), and for the want of better specimens has been taken as belonging to the same species.

Unger compared *F. ninnisiana* with *F. obliqua* Mirb. and with *F. procera* Pöpp., recent species from Chile, which vary not only in size and shape but also in the marginal teeth exactly as do the fossil leaves. The longer petiole in the fossil leaves (Figs. 24 and 25) may be due to especially strong root force, although in other cases (Figs. 28 and 31) the size is not abnormal.

"It is remarkable that a plant form with its related kinds, which occurs in South Chile, Patagonia, Tasmania, and New Zealand, appears also in the Tertiary flora of these countries as well as in the Tertiary flora of the Northern Hemisphere. This may be an indication that the stock of *Fagus* originated in and spread readily from the Southern Hemisphere. What is particularly remarkable is that the large leaved kinds of this genus, with the folded bud position of the leaves, as also the small leaved kinds with mostly leather-like leaves, are represented in the Tertiary flora, while New Zealand at present possesses only the latter kind." *F. ninnisiana* occurs also at Shag Point, Otago, and was described by Ettingshausen (1887, p. 24, and Taf. 4, Fig. 1; 1890, p. 270, and Pl. 27, Fig. 1).



FIGS. 17-19.—*Beilschmiedia tarairoides* n. sp. × 1. From Coal Measure Claystones, Pukemiro Colliery.

[*W.H.A.P., del.*

Beilschmiedia tarairoides, n. sp. Figs. 17 to 19, and 43.

Holotype: Figs. 19 and 43.

Leaf broadly elliptic, margin entire. Midrib broad, prominent and prolonged into a thick petiole. Secondaries alternate or subopposite, arising at rather wide intervals at an angle of about 50° and arching forwards. They terminate near the margin and nearly parallel to it, and sometimes bifurcate at their extremities. Tertiary veins cross between the secondaries and nearly at right angles to them.

Breadth of largest leaf (Fig. 19) is 65 mm. The most similar leaf among the existing New Zealand flora is that of *Beilschmiedia tarairi,* and accordingly the fossil form has been given the specific name *tarairoides.*

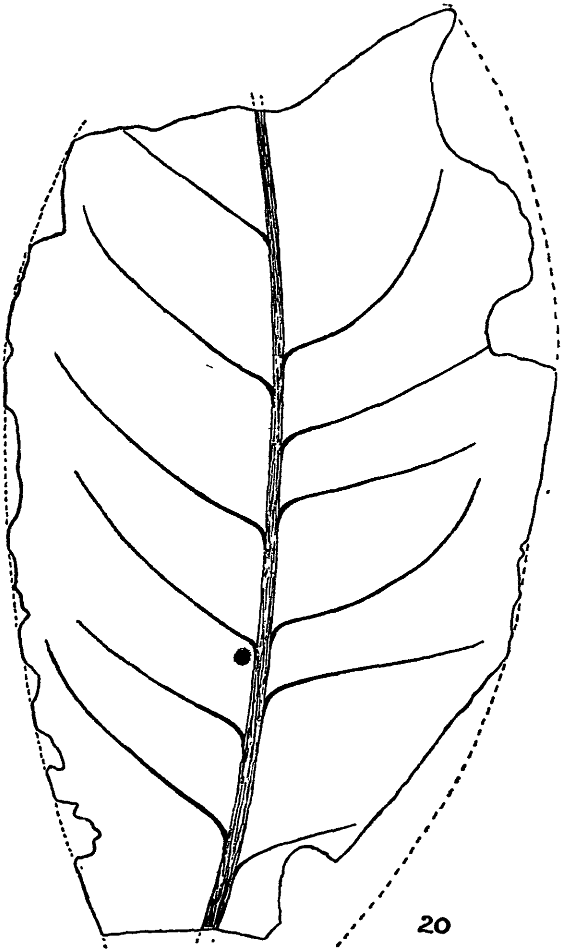


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FIG. 20.—*Pisonia purchasi* (Ung.) × 1.
From Coal Measure Claystones, Pukemiro Colliery.

[W.H.A.P., del.

Pisonia purchasi (Ung). Fig. 20 and cf. Fig. 36.

A fragment of a large leaf without either base or apex. Leaf oblong elliptic. Margin imperfectly preserved, but apparently entire. Midrib well marked, and in this specimen, which shows the under surface of the leaf, is characteristically ribbed longitudinally. Secondary veins branch from the midrib at irregular intervals and are not always parallel. They leave the midrib at an acute angle but soon bend round to an angle of 65° to 70° and near the margin curve forwards again. Tertiary venation not observable. Maximum width of leaf 68 mm.

Unger (1864, p. 11) described a small fragment (Fig. 36) of a large leaf under the name *Phyllites purchasi,* which could not be compared with leaves of living or fossil plants. Comparison of

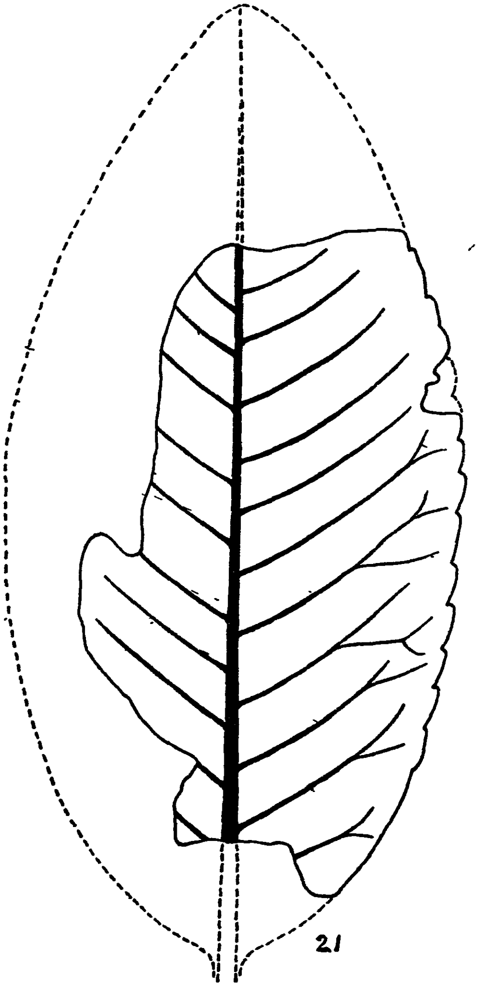
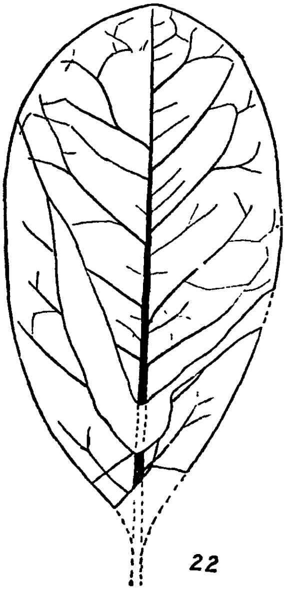


Fig. 21.—*Pisonia oliveri* n. sp. × ½.
From Coal Measure Claystones, Pukemiro Colliery.
[*W.H.A.P., del.*

Figs. 20 and 36 shows that these fragments are probably of the same kind. Moreover, the larger fragment collected by the writer is almost identical with leaves of the recent *Pisonia brwnoniana* now living in North Auckland. The fossil leaves are accordingly placed in this genus and Unger's specific name retained.

Pisonia oliveri n. sp. Figs. 21 and 42, Holotype.

A fragment of a large leaf without base and apex. Leaf oblong elliptic, the apex probably slightly more acute than the base. Margin widely crenate. Midrib well marked. Secondaries alternate, parellel, branching from midrib at an angle of about 65° and sometimes bifurcating once and occasionally twice near the margin.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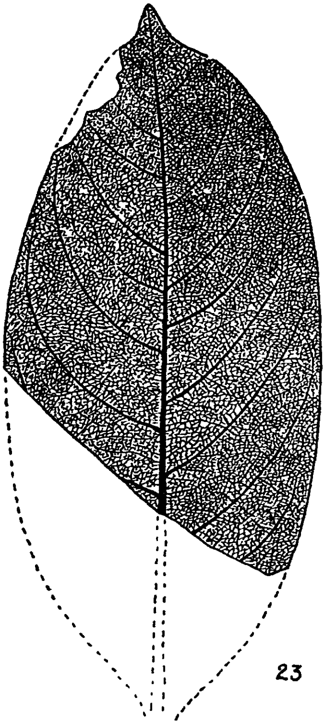
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FIG. 22.—*Coprosma pseudoretusa* n. sp. × 1.
FIG. 23.—*Geniostoma apiculata* n. sp. × 1.
From Coal Measure Claystones, Pukemiro Colliery.
[*W.H.A.P., del.*

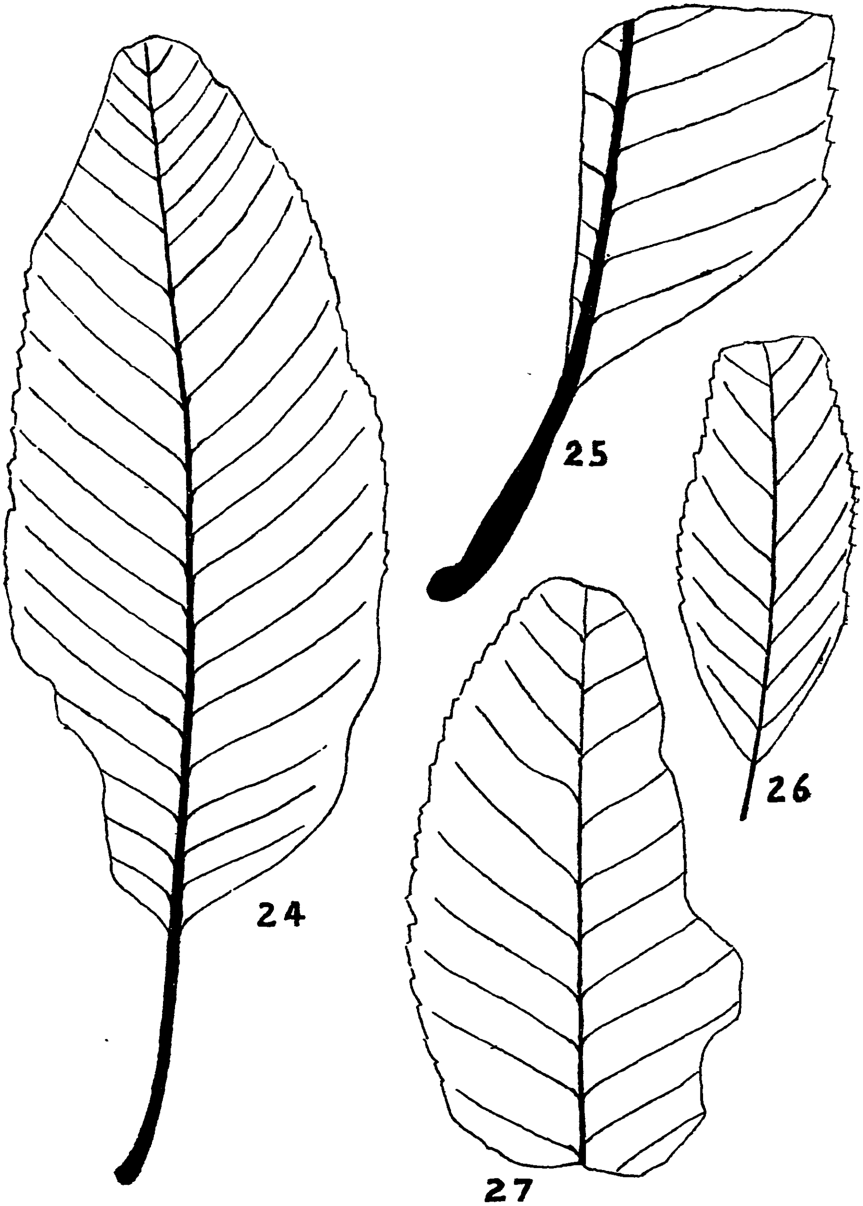
Estimated dimensions, 255 × 112 mm.

This leaf differs specifically from *P. purchasi* (Ung.) in the secondary venation and in the margin but it still has strong affinities with the genus Pisonia.

Coprosma pseudoretusa n. sp. Fig. 22, Holotype.

Leaf obovate. Margin entire. Secondary veins are alternate, straight and parallel, and branch from midrib at an angle of 45° to

50°. They anastomose near the margin and the tertiary venation, which is partly preserved, probably consists of a coarse network joining the secondaries. Dimensions, 75 × 34 mm. This leaf is very similar to the recent *C. retusa.*



FIGS. 24-27.—*Fagus ninnisiana* Ung. × 1.
From Mr. Pollock's Spring Hill Shaft near Drury, in a firm ferruginous sandstone of a fine grain and a brown colour.
[*After Unger.*

Geniostoma apiculata n. sp. Fig. 23, Holotype.

Leaf oblong elliptic; apex produced into a blunt point. Margin entire. Midrib and secondary veins well marked, the latter alternate, parallel and curving regularly forwards. The tertiary venation on this leaf is remarkably well preserved and consists of a fine network into which the ends of the secondary veins merge.

Dimensions, 95 (estimated) × 39 mm.

The following leaves collected by Hochstetter, were not found by the writer in the Coal Measure Series of the Waikato district, but their occurrence near Drury in beds of approximately the same age justifies their mention in this paper. Most of the leaves are so fragmental that comparison with existing forms would be without benefit because of the probable inaccuracy involved.

Loranthophyllum dubium Ung. Figs. 33 and 34.

This leaf was named from its similarity to *L. griselinia* Ung. (1864, pp. 8-9, Taf. 3, Fig. 13) and to *Loranthus longifolius* Deso. A remnant of a stem (Fig. 31) from the same locality shows the original opposite positions of the leaves and the protruding leaf cushions such as occur also on the stem of *L. longifolius* (Fig. 32).

Myrtifolium lingua Ung. Fig. 37.

Unger found no resemblance to this well preserved leaf among either fossil or living forms. There is no known living form similar to this in New Zealand.

Phyllites laurinium Ung. Fig. 38.

This leaf scrap bears some resemblance to *Laurum princeps,* "but that does not in the slightest degree mean its complete accord."

Phyllites ficoides Ung. Fig. 39.

This was compared doubtfully with the leaves of some kinds of *Ficus.* (A smaller fragment from the Pukemiro Mine appears to be from the same kind of leaf).

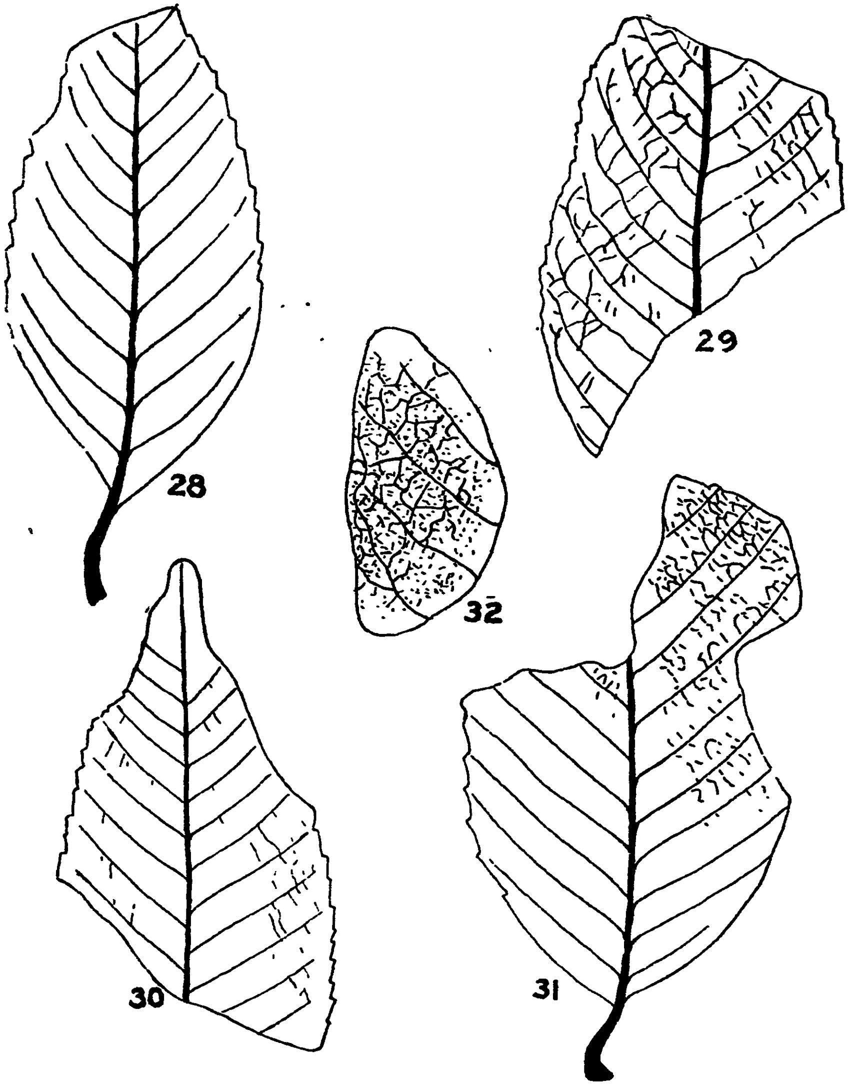
Phyllites novae-zelandiae Ung. Fig. 40.

Unger found no similarity of this leaf with leaves of New Zealand trees and obtained no true identification with other living or fossil leaves.

b. *Discussion.*

These dicotyledonous leaves belong to forest trees and shrubs the modern representatives of which are confined to warm temperate or subtropical regions. They have a general Malayan character. An attempt to determine the probable plant associations from this small collection would be unwise. If more types are in the future discovered it may then be possible to reconstruct the flora which contributed the vegetable debris now constituting the coal seams of the district, although fossil leaves are but poor material for botanical classification. At present the only safe conclusions are those concerning the climate and the predominantly angiospermous nature of the flora.

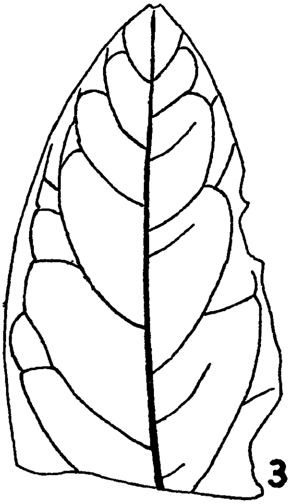
The latter characteristic is of great importance because it influences the nature of the peat formed from this type of vege-



FIGS 28-31.—*Fagus ninnisiana* Ung. × 1.
FIG. 32.—Portion of margin of *F. ninnisiana* free from teeth, showing venation, × 6.
From Mr. Fallwell's place near Drury, in a coffee-brown, soft, and fine shaly claystone.

[*After Unger.*

tation, and hence that of the resulting coal. From the leaf remains collected by the writer, and also by Hochstetter and others, it can be deduced that the swamp was of the wooded or forested type in which angiosperms were the dominant form, though conifers were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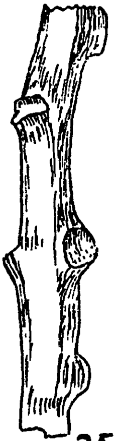
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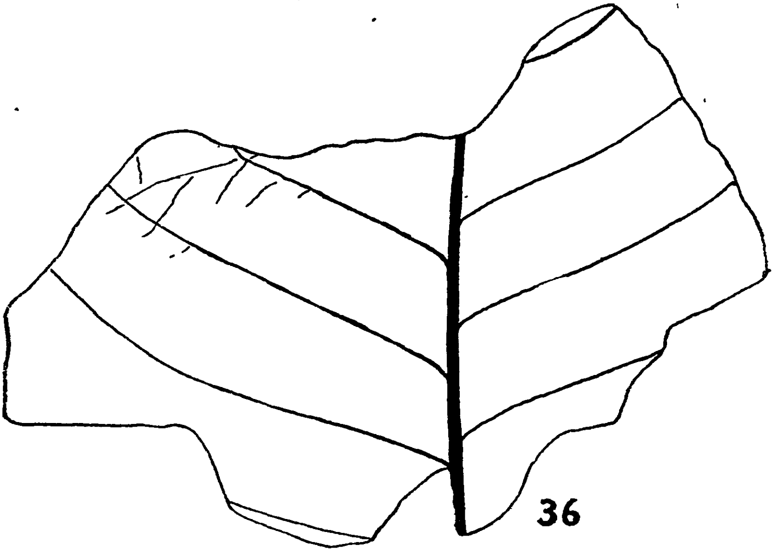
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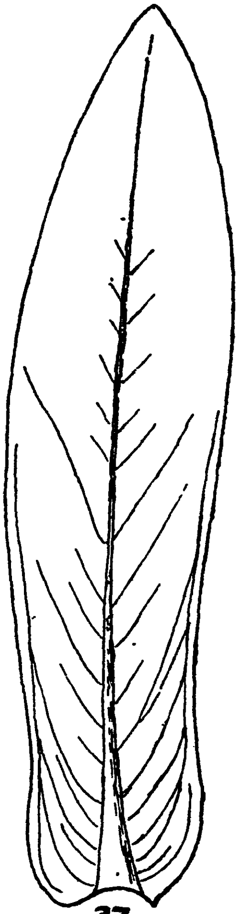
Figs 33, 34.—*Loranthophyllum dubium* Ung. × 1.
(33.) Piece of leaf.
(34.) Piece of a twig with strongly protruding leaf cushions.
From Mr. Fallwell's place near Drury, in a light grey, greasy claystone.

Fig. 35.—*Loranthus longifolius* Sprgl. × 1.
Piece of twig for comparison with Fig. 34.

Fig. 36.—*Phyllites purchasi* Ung. × 1.
From Mr. Fallwell's place near Drury, in a light grey, greasy claystone.

[*After Unger.*

present in subordinate amount as evidenced by the occurrence of resin. According to Thiessen (1928, p. 38), "Peat formed from the wooded swamp is of particular interest because it appears to be analogous to most of the bituminous coals and to many lignites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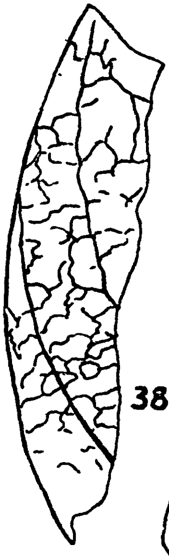
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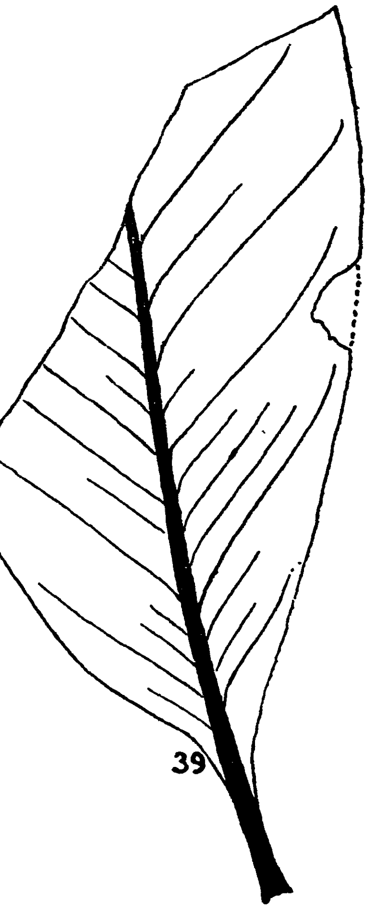
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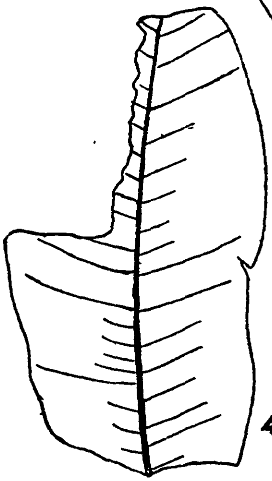
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FIG. 37.—*Myrtifolium lingua* Ung. × 1.
FIG. 38.—*Phyllites laurinium* Ung. × 1.
FIG. 39.—*Phyllites ficoides* Ung. × 1.

These are from Mr. Pollock's Spring Hill Shaft near Drury, in a firm ferruginous sandstone.

FIG. 40.—*Phyllites novae zelandiae* Ung. × 1.

From Mr. Fallwell's place near Drury, in light grey, greasy claystone.

[*After Unger.*

and sub-bituminous coals. Each peat deposit that results from the different types has a distinct character. The greatest distinction is to be found in peat derived from angiosperms (the ordinary leafy trees) and that from conifers." He states further that "the angiosperms yielded readily to decay and disintegration, leaving little more than an amorphous muck or attritus; the conifers, on the other hand, wherever present, resisted decay and maceration to a far greater extent, due to their toxic resinous contents, and left a large proportion of better-preserved woody material." Coals derived from a coniferous flora are therefore always woody, whereas those derived from an angiospermous flora are always more or less amorphous. The two types are readily distinguished.

The coal from the Waikato district has the amorphous appearance described by Thiessen. It consists mainly of a relatively dull matrix in which are embedded small strips of bright coal (the "anthraxylon" of Thiessen) though in small amount only. Rarely are large strips of bright coal seen (see Penseler, 1930A).

The reason for the present characteristics of the Waikato coal is thus clear. Its origin in a freshwater wooded swamp from a predominantly angiospermous flora is evident from the palaeobotany and the geological history of the Coal Measure Series. From this type of flora, a characteristically Tertiary one, coal of a special nature is to be expected, and this expectation is confirmed by an examination of the Waikato coal.

GEOLOGICAL HISTORY.

During and after the planation of the Mesozoic rocks a large estuary occupied the site of the present Lower Waikato Basin. Rivers flowing into this estuary carried the products of weathering of the low lying surrounding country which, owing to the moist subtropical climate, was thickly covered with vegetation. The sediments deposited on the estuarine flats consisted therefore mainly of fine decomposed, rather than disintegrated, rock material. Organic acids leached out or reduced most of the iron compounds to a soluble state, resulting in grey or brownish grey colours. The sediments were deposited irregularly owing to the swinging of the rivers from side to side, and owing to the probable braided estuarine channels; and the gradual subsidence of the land permitted the continual building up of the sediments. Differences in the strength of the currents caused by seasonal changes in rainfall and by floods of greater or less magnitude caused differences in the nature, thickness, and colour of the sediments, and further irregularities were caused by the scouring out of previously deposited material, the by-passing of fine material, and the deposition of coarser material (see Eaton, 1929). Differential settling on an originally undulatory surface caused subsequent deposits to be not parallel, and because each successive surface of deposition would be irregular and not necessarily parallel to the preceding surface general uneveness and lenticularity of the beds was developed.

Because a subsiding land surface does not subside at an even rate, "hesitations" of longer or shorter duration occurred, and during these periods the elevation of the land remained either constant in elevation or subsided much more slowly than the average rate. At such a time then the sediments in the estuary were built up to a profile of equilibrium proper to the conditions, after which no sediment was deposited until the base level of deposition or profile of equilibrium was lowered either by the scouring out of some of the accumulated sediments during a flood, or by renewed or increased subsidence of the land. Thus there occurred periods in the history of this estuary during which the land was relatively stable, when the sediments had been built up to a profile of equilibrium, and when shallow water prevailed over a large portion of the estuary. The filling in of the dips and hollows in the old land surface by the sediments formed a broad low-lying swampy district. Conditions were then favourable for the luxuriant growth of vegetation and the accumulation of a vast quantity of vegetal matter on these swampy lands, and the extent to which it accumulated depended on the duration of the period of hesitation in subsidence. It was necessary for the inception of growth of this vegetation that the district should be above water-level for a period, but it was necessary for the accumulation of vegetal matter that a slow subsidence should be taking place fast enough to allow the peaty matter to grow and be always more or less covered with water, but not so fast that accumulation could not keep pace with subsidence. If that rate was exceeded then the vegetation was killed and the peat mass covered by muds and clays deposited to be built up to a new profile of equilibrium.

The writer does not propose here to discuss the processes and reactions taking place in the vegetal matter to form this kind of coal, and the presence of coal seams in the Coal Measure Series is considered only in the light of an event in the history of this series.

A longer or shorter period of hesitation determined the nature and thickness of the vegetal matter—a long period resulted in a seam of coal and a short period in a layer of impure coal or carbonaceous matter—but these accumulations would not be found over the whole estuary. Their occurrence, more particularly for the smaller masses, is controlled by favourable local conditions, although for a thick seam of coal it is evident that widespread favourable circumstances must have existed.

The nodules of bog iron ore were formed during some of these periods of hesitation, and may be seen forming to-day under similar conditions.

During flood times logs, branches, and general debris were washed down by the rivers. The majority of these were undoubtedly carried out to sea where they were destroyed by the scavenging animals present and by general decay. Some of the logs, however, were washed over the shallow river flats inundated by the flood and here, becoming water-logged or sticking in the muds and clays, they were left when the flood subsided, partly or completely buried in sediment. Subsequently deposited sediment may be different in colour and texture, and in the Pukemiro Collieries some of these old fragments were seen lying at an angle to the bedding of the claystones embedded partly in one kind and partly in another kind of rock. The majority of this debris was carried some distance because the fragments are stripped bare of bark, twigs, leaves, etc. In one instance only was the " bark " still present (Fig. 8).

In periods of flood, leaves and twigs were broken up or carried out to sea. As previously noted, leaves are found in thin bedded layers which can be accounted for only by supposing that they were drifted into sheltered waters where, becoming waterlogged, they sank to the bottom and were thus deposited with the fine mud and fine carbonaceous debris to form a thin laminated layer. The state of perfection of the leaves at the time of burial depended on the distance to which they had been transported and the conditions to which they had been subjected. The roof of the coal seam in many places contains leaf remains, as would be expected because in the calm shallow waters which gradually extended over the buried vegetal matter conditions were favourable for the preservation of leaves in the fine sediments deposited from the overspreading muddy waters.

Taking into consideration the many factors and combinations of factors which could influence the deposition of sediments (including vegetal matter) in the estuary, the cause of the variations in the Coal Measure Series becomes apparent, and, conversely, these variations can be explained only by reason of their depositions in an estuary under the conditions outlined.

After the Coal Measure Series was deposited, continued subsidence of the land permitted a transgression of the sea (see Penseler 1930B), and during the first stage of the succeeding Whaingaroa Series shallow brackish water covered the site of the estuary and initiated the overlying series of marine sediments.

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