(d) Detailed botanical and ecological data are recorded for a certain proportion of each plot.
(e) Final results will give total volume estimates by species and by diameter classes for major forest regions. Figures will be obtainable for that proportion of the total volume which is considered merchantable by present-day standards.

FOREST ASSOCIATIONS OF THE LONGWOOD RANGE, SOUTHLAND.

By J. T. HOLLOWAY.

This preliminary note is intended mainly to outline the complex nature of the ecological problem presented by the forest within this area. It is hoped that a fuller account may be given at a later date.

The Longwood Range has its main axis from north-west to south-east, but has extensive outlying spurs radiating from the main portion of the range. In effect it is a highland area of approximately circular outline and with a diameter of approximately 17 miles, the maximum elevation being 2,500 feet. It is almost entirely forested, from sea level behind Colac Bay on Foveaux Strait to small open tops above 2,300 feet. Marginally the forest has been cleared for agriculture but such clearings are in the main confined to the easier lower slopes below 400 feet elevation. The present forest area is approximately 77,000 acres which includes extensive remaining low altitude areas mainly within the basins of the Waimeamea and Pourakino Rivers.

Geologically the range is most complex. It is built up of rocks varying from granites, norites and basalts to metamorphic rocks and to late tertiary sandstones and mudstones with extensive recent alluviums within the stream basins. Topographically the land forms are mature with rounded slopes and spurs but toward the west steep gullies and sharp ridges are characteristic of the areas of younger sedimentary rocks. These marked stratigraphical and topographical complexities have resulted in the development of a very considerable range of soil types.

Prevailing winds are from the south-west and north-west. Winds from the former direction may be experienced for weeks on end at any season of the year. They are very cold, frequently reach gale force at higher levels and bring heavy rain with snow, sleet or hail at any season. Snow lies periodically on the open tops throughout the winter but only very occasionally at sea level for one or two days at a time. The north-west winds may also bring heavy rain which may be cold after passage over the mountainous country to the west in winter or spring, or warm in summer or autumn. In the latter

seasons, however, the north-west wind is frequently of the nature of a hot dry *foehn* of high velocity which may persist for several weeks at a time.

In general the rainfall is from sixty to eighty inches per annum, decreasing from south to north and from west to east, but with considerable variations due to local topographical factors. The rainfall is well distributed throughout the year but exposed faces may suffer local drought when the dry north-west winds blow for any length of time. In winter frost may be severe with minimum night temperatures between 10 and 20° F., still lower temperatures being recorded in some localities. Mist does not seem to be a factor of significance. Normally the summit of the range is below the general cloud ceiling and drifting mist does not appear to be more frequent at any one altitude or on any given aspect than elsewhere. Autumn river fogs are common along the lower valleys but are of brief duration.

In Cockayne's terms the forest is made up variously of the two major forest associations, sub-antarctic beech forest and sub-tropical rain forest together with mixtures of these. This is a radical oversimplification of the position as it actually exists and for practical purposes is valueless. In the Longwoods *Nothofagus menziesii* (silver beech) is the only species of *Nothofagus* present and it may form pure stands at any altitude from sea-level to the timber limits. In one area there may be silver beech forest in the river valleys with podocarp-*Weinmannia* forest on the higher slopes; elsewhere there will be heavy podocarp forest on the valley floor with beech forest above. Frequently podocarps will be found on spur crests in predominantly beech areas but alternatively isolated stands of beech occur on ridges within podocarp areas. Above 1,500 feet silver beech forest alone is found. The steeper mid-slopes may carry either beech or podocarp-*Weinmannia-Metrosideros* and the beech may in one place be restricted to the cold shady slopes, in another to the warm dry north and west slopes.

The relative distributions of the two types of forest are too complex to be susceptible of explanation by any simple hypothesis involving a consideration of a single site factor or any simple group of factors. Nevertheless the distribution does appear to follow a definite pattern, and the general outline of this pattern will be indicated below. It is necessary, however, to consider first of all the validity of several commonly made assumptions.

The first assumption is made by implication in the use of Cockayne's terms Sub-antarctic Beech Forest or Sub-antarctic Rain Forest and Sub-tropical Rain Forest.

The use of the words sub-tropical and sub-antarctic is derived largely by consideration of the affinities of the flora. They belong to the field of plant geography. Used in an ecological sense they imply far more than can be accepted: a greater degree of warmth or a greater degree of cold than normal in a temperate insular climate.

The incorporation of the word "rain" is likewise misleading. Both major forest types *can* exist in areas where the annual rainfall is no more than sufficient to maintain a forest vegetation. With a decrease in rainfall the forest would be replaced by a vegetation of a completely different type but not by a drier type of forest. The most that can be said with accuracy is that we are dealing with *Nothofagus* forest or beech forest (in the Longwoods with *N. menziesii* or silver beech forest), and with mixed podocarp-*Weimannia-Metrosideros* forest or, for short, podocarp forest.

The second assumption is one which is made very generally throughout Cockayne's published work. It is to the effect that the plant species characteristic of the podocarp forest derive from the north and have migrated to the south while species characteristic of the beech forest have entered from the south, migrated north and been driven back on the advent of the northern species. Now since the beginning of the Pleistocene Period extensive kauri (*Agathis*) forests have existed in Southland and Von Post's work on pollen analysis of Southland peats has indicated at least three major climatic periods since that time. Despite the comparative slowness with which forest associations migrate, since all our present species of forest plants became established within New Zealand, there has been time for many major fluctuations as between beech forest and podocarp forest. There has been a sufficient length of time since the beginning of the Pleistocene for all species and associations to become thoroughly mixed. All we can say from a consideration of present distribution is that each species or each association is occupying a site suited to it or a site recently suited to it, but from which it has not yet disappeared solely because species better suited to the site have not had time to migrate there.

Both types of forest are temperate forests, the one, more widely developed in the north or at lower altitudes, a warm temperate forest; beech forest, more widely developed in the south or at higher altitudes, a cool temperate forest. Certain types of podocarp forest, with respect to their associated species are, or may be, true rain forest but this is not an essential feature of podocarp forests as such. Similarly certain beech forests may be rain forests but are not necessarily so.

The third assumption usually made is that beech forest or podocarp forest in one place is ecologically the equivalent of apparently similar forest existing elsewhere. At least in the case of the beech forests this is not true. Two beech forests, floristically similar, may be of entirely different ecological status. One may be climax, climatic or physiographic, the other a migratory or a successional type. These differences are not merely of academic importance since they are usually reflected in differences in average tree size, tree form, average stocking and sometimes in timber quality. They are more frequently reflected in the manner and degree of regeneration either within the virgin forest or after exploitation and/or fire. These differences,

Cockayne, as a botanist, did not take into account. For the forester they are of fundamental importance.

We are then, in effect, dealing with two temperate forest associations, or more accurately, with two association complexes. The climatic requirements of each complex can be deduced by studying its full distribution. Such an analysis broadly indicates that present forest climates throughout New Zealand are suited to the development of beech forests of one or more of the indigenous species of *Nothofagus*, that the podocarp forests have a narrower climatic range but that within this range the podocarps and their associated species will be dominant except in such places as local site factors tend to out-balance the climatic factors. Beech forests existing within the climatic range of podocarp forests will then be successional associations (associes) of varying degrees of stability. Wherever the climatic factors are not markedly favourable to the development or continued existence of podocarp forest local edaphic, physiographic or historical factors will determine the type of forest. At the same time, under such climatic conditions, there must exist considerable areas not more favourable to the one complex than to the other, and mixed beech-podocarp forests will be found. In such areas of marginal climate small climatic variations will result in disproportionate changes in the composition of the forest with continuous adjustment and readjustment of species to site. Such climatic fluctuations have occurred in geologically recent times and there is no evidence that a condition of stability has been reached. On the other hand there is evidence that such changes are in progress or that adjustment to a recent change is still in progress. (This is outside the scope of the present paper but details in support of this statement will be given in a further communication).

The present hypothesis is that in Southland, and in the Longwood Range in particular, we have such an area of marginal climate, and that the climate is at the moment unstable or that the forest as a whole has not reached a position of stability consequent on a recent climatic change. Such changes of climate and forest, as compared with human experience, proceed extremely slowly and are not immediately evident by consideration of the virgin forest. But by studying the reactions of the forest after biotic interference, particularly its redevelopment after exploitation, the sequence of events becomes clearer. With respect to the podocarp forests such inter-relationships are confused by the intricacies of the life history of the podocarp-*Weinmannia-Metrosideros* association complex itself, but the position with respect to the beech associations is simpler. On this account, in the following description of the Longwood Forest silver beech associations will be dealt with in some detail, but the podocarp associations in general terms only.

Further, since these forests have been subjected to the new biotic factor, the presence of deer, cattle and pigs for a sufficient period to have occasioned considerable changes in the forest with

respect to the composition of the subordinate vegetation, but not for a sufficient period to have brought about changes in the distribution or habit of growth of the association dominants, the description is chiefly concerned with the latter, listing secondary species only where these appear to be of special importance.

1. The Silver Beech Climax Associations.

The first areas to be considered are those silver beech forests existing above the maximum altitude reached by the podocarps or their associated species. Such beech forests are true climatic climax forests established outside the climatic range of the podocarp forest associations. This type of silver beech forest divides naturally into two distinct associations. The first occupies the highest altitudinal belt from 1,800 or 2,000 feet to 2,300 feet. The second from 1,500 feet grading upwards into the former. For simplicity of nomenclature they may be called the montane and the sub-montane silver beech associations. The montane forest is characterised by the heavy ground cover of wet moss and liverwort cushions. The trees are stunted and misshapen and normally below 18 inches D.B.H. There may be occasional stunted *Podocarpus hallii* or *Dacrydium biforme* but for the most part the lower tiers of the forest are open and largely made up of sapling and pole beech. Any or all of the secondary shrub species listed for the sub-montane type described below may be present but tree-ferns, *Blechnum discolor* and other tuft ferns are absent. Marginally, species belonging to true sub-alpine scrub may be present. This montane type silver beech is non-commercial protection forest. It regenerates freely after fire or windfall and is apparently little damaged by deer.

The sub-montane beech association has a heavier undergrowth of *Coprosma* species of the *foetidissima*, *cuneata* and *linariifolia* groups, *Nothopanax simplex* and *Pseudopanax crassifolium* are the chief araliads, *Suttonia divaricata*, *Grisellinia littoralis* and *Elaeocarpus hookerianus* (juvenile form) are frequent. The moss and liverwort cushions give place to mats of *Hymenophyllum* species with scattered *Blechnum discolor* and *Polystichum vestitum*. The canopy trees reach a diameter of 30 inches D.B.H. with a proportion of trees of good bole form, but decay following snow damage is always in evidence and for the most part the stands are unmillable from this cause. Regeneration is free, particularly where the ground cover is *Hymenophyllum*. Where group regeneration follows extensive windthrow bole form is better than average. That is to say that under management an improved stand could be developed subject to the risk of snow damage. Because of difficulty of access and the low volume per acre of the virgin stands this association must at present be classed as non-commercial.

The sub-montane beech grades downwards into beech-*Weinmannia-Metrosideros*-podocarp forest which will be described below.

The third silver beech climax association characteristically occupies stream basins or comparable land forms below 1,500 feet to 400 feet. It is frequently surrounded by podocarp forest on the upper basin slopes. The trees are from 24 to 36 inches D.B.H. and of average height (26 to 30 feet log length). The characteristic shrub species is *Coprosma foetidissima* with heavy *Blechnum discolor* ground cover. Stands are merchantable but after felling develop to a dense scrub of *Coprosma foetidissima, Fuchsia,* and *Aristotelia serrata.* After felling and light burning leaving seed trees, or wherever the ground is mechanically disturbed in logging, regeneration is profuse. Resultant pole stands are of excellent quality. The governing factor in the development of this basin type of silver beech association is the degree of winter frost. Where such forest is felled the ground cover of *Blechnum discolor* is killed or badly damaged by frost whereas it is not so damaged on adjacent areas where podocarp forest has been felled. The association occupies frost pockets. Above the rim of the frost pocket there is an abrupt change to podocarp forest.

The fourth silver beech climax association is swamp forest also on areas subject to frost. The characteristic shrub species is *Suttonia divaricata* with scattered ground cover of *Blechnum discolor* and *Polystichum vestitum.* Sedges are frequent. Commonly there is a proportion of *Podocarpus dacrydioides, P. hallii* and *Elaeocarpus hookerianus* throughout the stands with, in some localities, the development of a distinct silver beech-*Podocarpus dacrydioides* association. After exploitation there is an immediate development of swamp scrub dominated by divaricating shrubs with a very slow redevelopment of the original type of forest. After fire the area develops to sedge swamp with local invasion of *Phormium tenax.* These low altitude swamp beech areas are not suited to forest management.

The mid-slope beech associations fall into two main classes. Firstly on the colder slopes with south or east aspect they may be simply a downward proliferation of the sub-montane type described above and differ in detail only. Thus the tree ferns *Hemitelia smithii* and *Dicksonia squarrosa* are commonly found here but not in the true sub-montane type. Conversely on the drier slopes with aspect to the sun a completely different beech association is commonly developed. Here the trees are normally below 30 inches D.B.H. but with good merchantable length and high volume per acre. The characteristic shrub species is *Myrtus pedunculata.* The undergrowth is very open and the ground cover scattered mats of *Hymenophyllum* species or frequently the leaf litter is bare. Such stands yield a high proportion of best quality bending silver beech. After milling regeneration is profuse, the stands redeveloping through sapling and pole phases. Such stands occupy exposed steep slopes with shallow soil and exposure of basal rock. After fire they will redevelop in the presence of seed trees but otherwise the site is invaded by *Leptospermum* and other heath species. The governing factor here is the rapid drainage with poor water holding power of the soil coupled with

exposure to the north-west wind. Such stands are eminently suited to intensive management. They exist on the dry side of the podocarp forest climate.

2. Successional Silver Beech Associations.

Beech forest of this type is most widely developed on alluvial ground. The two main classes occupy respectively river gravel and river silt areas. Silver beech establishes itself rapidly on any area of new ground as a pioneer species. There is seldom lack of seed since it is readily water-borne from permanent beech forests existing at higher altitudes. On both types of site the initial stand is of similar form to the dry slope beech described above. But whereas on the gravels this stand form persists for some time, on the wetter silts there is a rapid change to an association of heavy boled trees (D.B.H. 40 inches and upwards) with heavy canopies. Under this canopy all shrub species of podocarp forest on similar terrain become established. The undergrowth is dense with groves of tree ferns and a heavy ground cover of tuft ferns. This type of silver beech forest gives the largest volume per acre of any virgin stand. Regeneration within the virgin forest is scanty and largely confined to groups of saplings or poles growing on decaying logs and stumps. After exploitation the stands develop to extremely dense second growth scrub of very varied composition. Regeneration of silver beech in such areas is scattered and almost invariably of log or stump origin. Ultimately the area will redevelop the original type of stand but regeneration is insufficient in amount for profitable management. Virgin forest on such sites tends to be invaded by podocarp species and *Weinmannia* and, although this process is slow, all stages up to complete replacement can be traced. But since such areas are also commonly subject to heavy frost a balance between podocarp and beech is often reached before replacement is complete with the consequent development of a quasi-permanent mixed beech-podocarp forest.

By the controlled use of fire silver beech regeneration can be established on such areas in amount and quality sufficient for management, but a seed year must follow the burn. Such operations then entail a considerable element of chance.

On the gravel areas the stages of succession are passed through very slowly and depend upon the upbuilding of a water retaining soil. Stands on these sites are comparable in timber quality to dry slope beech. Regeneration after felling varies according to the depth of soil above the gravels, profuse on stony ground and restricted by competition with secondary species on the wetter areas. Fire tends to throw the succession back to an earlier stage and so improve the amount of regeneration. Abnormal developments of this gravel area beech type are found in several places within the Longwood Range where alluvial gold mining has been carried on. The old gravel tailings and outwash fans characteristically carry dense stands of silver beech

in the early pole phases. Other comparable areas of silver beech are to be found on old landslip areas within podocarp forest. Of such origin is the next silver beech association to be described.

3. Migratory Silver Beech Associations.

A characteristic feature of the Longwood forests is the existence of a stream belt silver beech association down all major streams linking the upland and the lowland silver beech stands. This stream belt may be only a tree or two in width or it may widen out to several chains. Silver beech becomes established on bank erosion areas along the streams by water-borne seed. From such chance established trees the beech stands extend up the slopes for varying distances. Such stands are markedly uneven aged and the upper slope portion may at times be cut off from the stream by closure of podocarp forest species around it. But the beech is continually re-establishing itself wherever stream bank erosion occurs. Away from the streams the trees are usually of the heavy boled form but along the streams in the gully or valley bottoms normally are of medium diameter pole form.

4. The Podocarp Associations.

As has already been explained the term podocarp used in this sense includes not only the true podocarp species but also the commonly associated dicotyledonous species, *Weinmannia racemosa* and *Metrosideros lumbellata* (syn. *lucida*). Thus areas where either or both of these species are dominant is here called, for brevity, podocarp forest, since it is one phase in the complex life cycle of the association complex characterised by the podocarps as timber trees. The podocarp forest as a whole is, in the Longwoods, a forest association of the relatively warmer lowlands and of the mid-slopes. The association is not readily susceptible of classification. There are, however, several distinct types characterised by dominance of one or other of the podocarps. More often rimu (*Dacrydium cupressinum*) is of most frequent occurrence, but in one place it may have *Podocarpus hallii* as a co-dominant, in another miro (*Podocarpus ferrugineus*) or in another kahikatea (*Podocarpus dacrydioides*). Stands differ also in the maximum average size of the podocarps present and such changes are paralelled by changes in the composition or density of the secondary vegetation. Thus on sites marginal to dry slope silver beech, rimu, miro and Hall's totara are normally small diameter but very clean trees, and there will be much *Myrtus pedunculata* and *Coprosma foetidissima* present. Stands also differ in the relative abundance and habit of growth of the co-dominant *Metrosideros* and *Weinmannia* and these latter may form minor associations without any representation of podocarps. These minor associations may represent phases in the life cycle of the association complex. Here the sequence of events would appear to be: (1) mature podocarps with heavy irregular boled *Metrosideros* or *Weinmannia*, (2) heavy *Metrosideros*

and/or *Weinmannia* with small diameter trees of the same species with regular bole form, (3) the disappearance of the large trees and the re-establishment of podocarps within the stand, (4) the re-development of phase (1). In phase (1) there is a dense understory of small trees and shrubs with tree ferns and tuft ferns. These disappear in phases (2) and (3) and reappear in a late stage of phase (4). The variation in the habit of growth of *Weinmannia* and *Metrosideros* would seem to be linked to the presence or absence of tree ferns. The heavy boled trees have an epiphytic origin and the small ones a normal ground origin.

Weinmannia is the normal co-dominant at altitudes from sea level to approximately 600 feet, *Metrosideros* as well is present from 600 feet to 1,400 or 1,600 feet according to aspect. At these upper limits there may be areas of silver beech-*Weinmannia* forest where the beech is of good merchantable quality and the *Weinmannia* forms a second tier. This is in effect a tension belt, and here the advance of the one association at the expense of the other can be best studied.

The distribution of the particular podocarp association with matai (*Podocarpus spicatus*) as a co-dominant presents anomalous features. Matai areas, or the exploited remnants of such forest, are found in the east at 500 to 700 feet altitude, in the south at 100 to 200 feet and in the west at 200 to 600 feet. In the east the soils are derived from basalts, in the west from tertiary mudstones and in the south from recent alluvia. One feature in common is that in all areas matai is accompanied by *Pennantia corymbosa*, *Melicope simplex* and occasionally by *Paratrophis microphylla*. These species are of rare occurrence elsewhere in the Longwood forests.

An anomalous and at present inexplicable podocarp association is found at 1,000 feet on the west slopes of the Pourakino basin. Here, in an area of several hundred acres, the forest is composed of stunted rimu, stunted Hall's totara and small trees up to 11 inches D.B.H. and 40 feet height of *Phyllocladus alpinus*, normally of shrub form. Elsewhere in the Longwoods *Phyllocladus* occurs (a) at sea level in swamp beech-podocarp forest near Colac Bay, (b) associated with matai and *Paratrophis microphylla* at low altitudes in the south and (c) scattered throughout the montane and sub-montane silver beech forests.

A further abnormal association is found on the west of the range east of the mouth of the Waiau River. Here there is an extensive area of *Weinmannia-Melicytus ramiflorus* forest with dense undergrowth of *Rhipogonum scandens*. This area is near the sea but it cannot be called true coastal forest since there are extensive areas of true podocarp forest between it and the sea. It is the only area from which *Melicytus ramiflorus* has yet been recorded for the Longwoods, although *Melicytus lanceolatus* is of frequent occurrence in second growth podocarp forest. The soil in the above area is light and sandy, derived from an uncemented sandstone.

5. Mixed Podocarp-Silver Beech Associations.

It will be realised that there will be many areas where the various podocarp associations abut upon one or other of the beech associations with the resulting development of mixed forest types of very varied composition. In most cases these can be resolved by consideration of the nature of the component associations. In some cases however additional assumptions must be made. Many areas show definite evidence of the advance of one association at the expense of another. For example in one area there are large silver beech up to 600 years old straddling with immense root buttresses prostrate undecayed *Metrosideros* logs, where the latter species is now represented by a few specimens of shrub form. Conversely an area where heavy overmature silver beech with no replacement stock available has an understory of *Weinmannia* and podocarp species in a late pole stage. The adjustment to climate may proceed in one direction in one locality and in another direction a short distance away. To consider this on theoretical grounds we will suppose a climatic fluctuation brought about by a change in the prevailing wind direction from predominantly south-west to redominantly north-west. On an exposed slope with skeletal soil this wind direction change will so alter the site factors as to swing the balance to dry slope beech against mid-slope podocarp forest. On a nearby lee slope where formerly there was a cold wet slope beech stand the increasing warmth will result in the establishment of a mid-slope podocarp association. Any overall picture of the whole forest must be sufficiently flexible to allow such interpretations. The position is a dynamic not a static one.

6. Silvicultural Deductions.

Firstly with respect to the silver beech associations, without exception after exploitation the beech forest will redevelop. But it will do so in a different manner and at different rates according to the ecological status of the original association. Only a few association types will regenerate in such a manner as to permit satisfactory silvicultural control. The non-commercial associations will regenerate satisfactorily and, under management, marginal areas could be raised in status. The dry slope association is of productive value and regenerates well but such sites in the Longwoods are of limited area. The frost basin type can be so managed as to produce a satisfactory second crop but those areas which to date have produced the bulk of silver beech timber milled in Southland are, by and large, unsuited to perpetual yield management. They will produce a second crop, but this will not in general exceed in volume the timber removed from the virgin stands and will be comparable in quality. This must prove insufficient to pay the costs of management.

Considered as a whole the Longwood silver beech forests are not promising with respect to long term permanent yield management. The satisfactory areas are too limited in extent and too scattered.

The Woodlaw project on the other hand is based largely upon dry slope beech associations and upon fire-induced regeneration on cold slope, frost pocket and mixed low altitude beech-podocarp associations, a relatively favourable complex. The projected Lilburn-Alton development, based upon dry slope beech with local cold slope and frost pocket areas, over the whole of which the beech associations are actively advancing at the expense of the podocarp association remnants, is yet more promising.

Little fresh light can be shed upon the future development of exploited podocarp forest. The secondary successions following exploitation proceed in varying ways according to the exact status of the original association. But without exception there is a prolonged interval during which the forest passes through scrub and small tree phases of worthless species. In a few areas in the Longwoods a sufficient interval has elapsed since felling for these secondary phases to reach their maturity but it is still not yet certain what the final development will be. In former mixed beech-podocarp areas however it is evident that the new forest will contain a very much higher proportion of beech.

In conclusion it may be stressed that in planning the silvicultural treatment and management of silver beech forests for permanent yield, each area must be considered independently and on its own merits. No definite overall rules can be enunciated. Two apparently similar areas of forest may respond very differently to the same treatment.

7. Summary.

A short preliminary descriptive account is given of the various forest associations found in the Longwood Range, Southland. In this area the forest, which is made up of *Nothofagus menziesii*, of mixtures of this species with podocarps or of the latter with *Weinmannia racemosa* or *Metrosideros lucida* in various combinations, presents many apparently anomalous features in the distribution of the several associations. An attempt is made to analyse these variations and to account for their relative distribution in terms of site and succession. In respect to the *N. menziesii* associations the manner of natural regeneration is indicated and the importance of the recognition of the different types of association in the selection of management areas stressed.