RESIN POCKETS: THEIR OCCURRENCE AND FORMATION IN NEW ZEALAND FORESTS

D. J. COWN*

SYNOPSIS

Results of a nation-wide questionnaire survey of resin pocket incidence show that this defect occurs in many conifer species throughout New Zealand and confirm that the frequency of occurrence is exceptionally high on the Canterbury Plains. A small number of radiata pine logs from the Canterbury area was investigated for possible relationships between individual tree characteristics and resin pocket numbers, but no simple correlations were found with stem diameter, tree height, crown class or wood density. Evidence is presented which indicates that water stress, rather than gale force winds, may be the primary factor influencing pocket formation.

INTRODUCTION

Resin pockets have been noted in several countries to be a defect of conifer timber (Forsaith, 1931; Frey-Wyssling, 1942; Giordano, 1951; de Carvalho, 1957), but from the sparse literature on the subject it is inferred that they rarely occur in sufficient quantity to cause significant degrade in sawn timber. In certain areas of New Zealand, however, their frequency is such as to invoke concern.

The influence of resin pockets on the strength properties of round produce and framing grade timber is slight, depending on the dimensions and position of the defect (Forsaith, 1931), but serious degrade can occur when they appear in wood destined for finishing quality products — *e.g.*, clearwood and veneer. Attention was first drawn to their deleterious effect in New Zealand following a grade study on first rotation produce from Ashley Forest in 1961. Since then, the Forest Service has undertaken mill studies in the Canterbury area, in 1962, 1963 and 1967. The main conclusions (unpublished) were:

(1) Resin pockets are more common on the Canterbury Plains than in the foothills of the Southern Alps.

(2) Exposed trees are more affected than sheltered trees.

(3) Dominant and co-dominant stems are more affected than others.

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*Forest Research Institute, Rotorua.

(4) Resin pockets are virtually absent above the 150 mm diameter level in stems.

(5) Crops with a plentiful supply of water are less likely to develop pockets than those which experience drought.

(6) Exposure to wind appears to be the critical factor in pocket formation.

In Europe, Frey-Wyssling (1942) held that wind causes tangential splits in the cambial zone, which develop into resin pockets, and this explanation has been widely accepted there (Giordano, 1951; de Carvalho, 1957). Clifton (1969) presented data to support his contention that gale force winds *per se* are the causative factor in the Canterbury area of New Zealand. However, the evidence given was circumstantial and conflicting data have been accumulated on several occasions (Chandler, 1970). Clifton recognized two types of pocket as either "normal" or "abnormal". The "normal" pockets are those discussed in this paper (Fig. 1); "abnormal" pockets were taken to be those caused by such agencies as insect attack (Snyder, 1927), fire and mechanical damage. These latter types are often characterized by the presence of resin streak and/or deformed grain.

The distribution of resin pockets within trees was also described by Clifton on the basis of a number of sample trees which were felled and cut into discs. Pocket frequency was found to increase with tree height to a maximum at around the mid-point of the stem and thereafter to decrease towards the apex. In the horizontal direction, the number of pockets increased outwards to about the 150 mm diameter level and then decreased to the bark. No significant relationships were found between pocket numbers and cardinal direction or year of formation.

Resin pockets may, in the future, have a more widespread impact on New Zealand forestry as new areas are planted and more crops are managed with finishing quality products in mind. Significant numbers have been recorded in some areas of both Auckland and Wellington Conservancies (I. P. Armitage, pers. comm.; Chandler, 1970) in environments different from that of Canterbury.

METHODS

A nation-wide questionnaire survey of resin pocket incidence was undertaken. The following information was requested:

(1) The estimated level of incidence of resin pockets by species according to the scale — absent; sparse; frequent; abundant.

(2) A list of site factors thought to be associated with resin pockets.

(3) Details of any silvicultural treatment thought to affect resin pocket incidence.

(4) A list of any wood defects observed to be associated with resin pockets.

A limited amount of sampling was carried out in Canterbury Conservancy to investigate the possibility of establishing relationships between resin pocket incidence and individual tree characteristics. One radiata pine crop from each of the four major forests (Eyrewell, Ashley, Balmoral and Hanmer State Forests) was chosen and log samples removed from five trees in each, representing the range of diameters and crown classes present. The compartments were selected on the basis of the local forester's knowledge as being likely to contain a high incidence of resin pockets (Table 1).

TABLE 1: SAMPLE CROP DATA

Forest (and Compt)	Elevation (m)	Soil	Planting Date	Remarks
Eyrewell (18)	170	Very stony gravel	1948	Regeneration on wind-blown area
Ashley (7)	270	Stony loam over gravel	1940	Sample trees felled on exposed ridge
Balmoral (74)	220	Stony alluvium	1929	Samples taken from exposed trees left after 1955 fire
Hanmer (22)	430	Loam over gravel	1957	Natural regeneration. Thinned to 1235 stem/ha (1962-3) and to 445 stems/ha (1966-7)

At Eyrewell, Ashley and Balmoral, 2 m lengths were removed from the mid-points of the tree stems, but in the young, naturally regenerated stand at Hanmer, the 2 m sample billets were taken from the butt ends of the stems. Tree characteristics measured in the field were diameter at breast height (dbh), height and crown class. In the laboratory, resin pocket numbers were obtained by sawing the logs into discs 20 mm thick, and a wood sample from the mid-point of each was used for density determination.

Most of the resin pockets thus detected were retained for microscopic examination along with other samples collected from various forests throughout New Zealand.

RESULTS AND DISCUSSION

The Questionnaire Survey

Of the 80 questionnaires distributed, 52 were returned by the date stipulated. Negative returns amounted to 21, with 9 from areas in which no utilization had been carried out.

The zonation of New Zealand into regions of different resin pocket incidence is a difficult task owing to the lack of data from most areas and the large variation in numbers known to occur both within crops and between crops. Arbitrary groups were selected as follows:

(5) An assessment of the effect of resin pockets on silvi-
cultural policy.

Within the Forest Service, copies were sent to conservancy,
district, and forest offices so that the benefit of experience at
all levels could be obtained. Copies were also dispatched to
the managers of major private forest areas.

FIG. 1: *Resin pockets in radiata pine from Eyrewell Forest, showing the
appearance in tangential and radial section.*

1. Normal incidence — up to $5/10\ m^2$ (clearwood yield un-affected).

2. High incidence — up to $20/10\ m^2$ (clearwood yield can be significantly reduced).

3. Very high incidence — up to $50/10\ m^2$.

4. Epidemic incidence — over $50/10\ m^2$ (clearwood yield greatly reduced).

The classes refer to the average incidence in sawn timber. Forest areas have been placed in these categories on the basis of: the results of the questionnaire survey; figures quoted in previous reports; and personal observation in sawmills throughout the country.

The main feature which emerges is that resin pockets are present in nearly all (if not all) exotic forests in a wide range of species, but epidemic levels are reached only in Canterbury Conservancy.

(a) *Radiata Pine*

Figure 2 shows the estimated incidence levels over the whole country.

Resin pocket formation reaches its maximum in the forests of the Canterbury Plains, where frequencies of over 100 pockets/$10\ m^2$ can occur. In the foothills to the west of the plains, incidence decreases but less markedly than along the east coast, where none of the sand dune crops sampled shows a frequency above normal. A recent study by R. Bagnall (pers. comm.) gave figures of 4.8 and 5.3 for two compart-ments sampled in Golden Downs Forest, and for practical purposes the forests around Nelson would be rated as normal. Further east, however, in the region of the Awatere Valley, pocket numbers are considerably greater.

In the North Island, Chandler's (1970) figures show that the incidence in the Wairarapa area can be high, whereas the incidence in Gwavas and Te Wera Forests is normal. The frequency of resin pockets in the Waitemata district is not yet certain, but results so far suggest that it might be high in some areas. Data from a log grade study of a clearfelled crop in Woodhill Forest gave a figure of $3.5/10\ m^2$ (W. R. J. Sutton, pers. comm.), but I. P. Armitage (pers. comm.) recorded that 26% of the veneer outturn in a trial from the same region had been degraded solely on account of resin pockets.

Reports from many other forests, as far apart as Pebbly Hills in Southland and Aupouri in North Auckland, have acknowledged the presence of resin pockets in radiata pine in small insignificant amounts which have no effect on current utilization.

(b) *Corsican and Ponderosa Pines*

Corsican and ponderosa pines were widely planted in New Zealand between 1920 and 1940, but their performance has generally been poor compared with radiata pine. Few crops

North
Auckland

Waitemata

Bay
of
Plenty

Hawke's
Bay

Wairarapa

Awatere Valley

Canterbury

FREQUENCY

Southland

☐ – NORMAL (UP TO 5/100 bd.ft)

▨ – HIGH (UP TO 20/100 bd.ft)

▤ – VERY HIGH (UP TO 50/100 bd.ft)
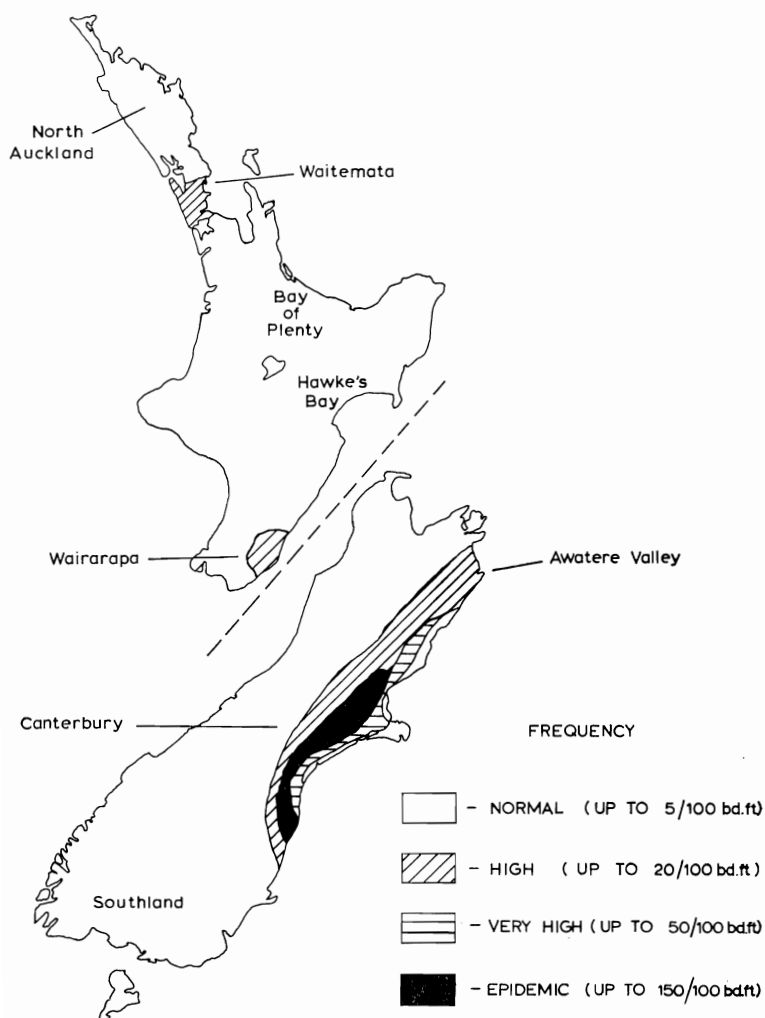
■ – EPIDEMIC (UP TO 150/100 bd.ft)

FIG. 2: *The distribution of resin pockets in radiata pine.*

have received silvicultural treatment, with the result that clearwood production will be strictly limited. In many areas local forest policy advocates the clearfelling of such stands to provide wood chips and round produce and to allow their replacement with radiata pine.

Resin pockets are known to occur in these timbers in most areas but the questionnaire results confirm that they are likely to be abundant only in Canterbury stands. Incidence levels above normal have been reported from central North

Island and Southland forests (Karioi and Pebbly Hills Forests, respectively).

The planting of both Corsican and ponderosa pines has lessened dramatically over the last two decades owing to their slow growth rates; it has virtually ceased now that their lifelong susceptibility to *Dothistroma pini* has been established. Resin pockets will have no appreciable effect on utilization of the timbers as high quality produce is not expected.

(c) *Other Species*

The survey revealed that all pine species utilized in New Zealand contain resin pockets to some extent, although often the numbers are insignificant and the size of the pockets small.

The southern pines, *P. elliottii* and *P. taeda*, in North Auckland and Bay of Plenty forests occasionally reveal examples of small resin pockets, 2 to 3 mm longitudinally. The current survey also revealed pockets in *P. pinaster* at Aupouri and Waitarere, *P. contorta* at Kaingaroa and Karioi, *P. strobus* at Whakarewarewa and Kaingaroa, *P. patula* at Rotoehu, *P. muricata* at Aupouri, Kaingaroa and Hanmer, and *P. jeffreyi* at Naseby.

In isolated cases, resin pockets have been noted in species other than the pines already discussed. Wood samples collected during other studies have revealed specimens in European larch *(Larix decidua)*, Sitka spruce *(Picea sitchensis)*, and Norway spruce *(Picea abies)* from Ashburton County.

Douglas fir *(Pseudotsuga menziesii)* is the second most widely planted conifer in New Zealand but is almost free of resin pockets. The only reported cases were of sparse occurrence in Kaingaroa and Hanmer forests, where they were also noted to be small in size.

(d) *Associated Site Factors*

In the questionnaire replies, there were no consistent observations on relationships between site factors and resin pocket frequency. Most forests reported no obvious correlations, but four areas within Canterbury mentioned exposure to winds as being an important factor. However, it is not clear whether these comments reflect local experience or merely follow the currently held belief (Clifton, 1969). Examples have been found of sheltered crops having more pockets than very exposed crops in the same area (Chandler, 1970).

On the whole, sawmillers tend to agree that large, old trees from crop edges and shelterbelts are the most likely to contain resin pockets.

The occurrence of resin pockets in sand dune forests such as Aupouri, Woodhill and Waitarere State forests suggests that their absence from stands along the Canterbury coastal sands is due to some environmental factor other than the soil type.

The questionnaire replies indicated that nothing is known about the effects of silvicultural treatment on resin pocket incidence and that the influence of resin pockets on forest policy is slight. The very high numbers of pockets in some Canterbury forests have contributed to a reduction in the amount of pruning in that area, and it is clear that, at current levels of incidence, pruning for clearwood production in crops growing on the plains could not be justified, even if growth rates were more favourable.

Some concern has been expressed recently at the downgrading of high quality produce, attributed to resin pockets, in areas other than Canterbury. B. Keating (pers. comm.) emphasized the need for further investigation at Ngaumu State Forest to determine whether expenditure on pruning was warranted. Similarly, further work is planned at Riverhead State Forest to look into the effects of site factors on pocket incidence (F. G. Day, pers. comm.).

Gross Tree Characteristics

Table 2 gives the sample tree data and the number of resin pockets found in each 2 m sample log.

The numbers of resin pockets cannot be compared directly between forests owing to the different ages of the crops and the different sampling position in the Hanmer trees.

The sample tree with the greatest number of pockets in each compartment is either dominant or co-dominant, indicating that there may be some kind of relationship between crown class and pocket incidence. Tree height by itself is not a measure of dominance or exposure, and no correlation was seen between this factor and pocket number in the samples. In the Eyrewell, Ashley and Balmoral trees, the stems of largest diameter have the greatest numbers of resin pockets, but this is not necessarily indicative of a relationship since the other trees in the group do not fit such a pattern. Wood density affects the strength properties of timber and may influence the reaction of tree stems to environmental factors such as wind. The Eyrewell and Hanmer samples show the greatest incidence of pockets in the highest density trees but no such relationship is apparent in the other groups of samples.

It is possible that complicated correlations may exist between individual tree factors or groups of factors and resin pocket incidence, but a much more intensive type of sampling would be required to elucidate them. On the basis of the sampling so far, it can be said that no simple linear relationships have been found between resin pocket incidence and any of the parameters measured.

Wood Structure and the Occurrence of Resin Pockets

The most striking feature of resin pocket incidence is the vast difference in the scale of occurrence between Canterbury and elsewhere, suggesting that strong environmental factors

The resin pocket samples obtained from the dissected logs were found to be invariably associated with false rings in the timber (Fig. 3), their initiation taking place during or immediately following false latewood production. Such narrow bands of thick-walled cells are a characteristic feature of wood
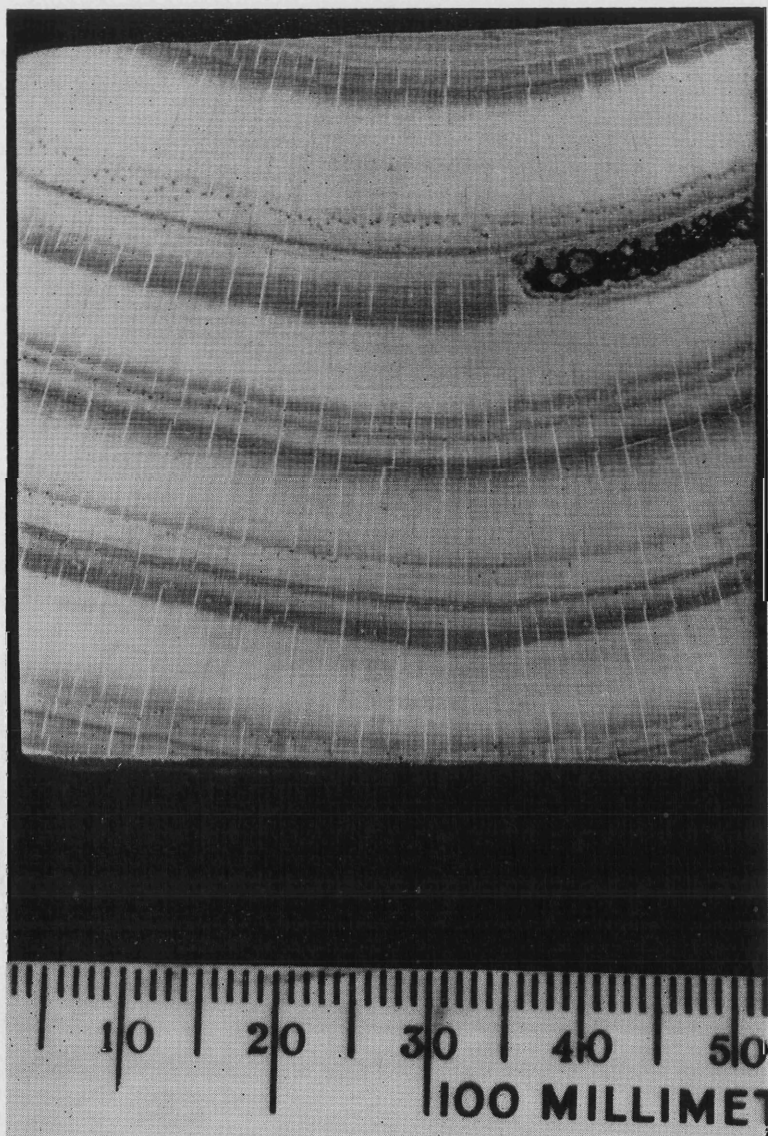

FIG. 3: *Radiata pine from Ashley Forest, showing the association of resin pockets with false rings.*

TABLE 2: SAMPLE TREE DATA

Tree No.	dbh (mm)	Height (m)	Crown Class	Density (kg/m³)	No. of Resin Pockets
Eyrewell S.F.					
1	274	15.5	CD	470	5
2	366	11.0*	D	490	50
3	254	16.8	D	460	0
4	180	13.4	SD	450	0
5	238	15.5	SD	470	1
Ashley S.F.					
1	340	21.9	SD	480	1
2	518	24.7	D	470	0
3	424	24.7	CD	520	0
4	373	24.4	SD	440	2
5	518	30.5	D	430	11
Balmoral S.F.					
1	620	23.8	D	520	5
2	404	19.2	SD	610	2
3	424	28.0	D	510	1
4	396	25.6	D	580	0
5	236	14.6	S	460	3
Hanmer S.F.					
1	183	15.2	CD	390	0
2	195	16.5	CD	430	7
3	254	17.1	CD	420	5
4	236	17.1	D	410	1
5	137	14.0	SD	400	0

Crown Classes: D — dominant. SD — subdominant. CD — co-dominant. S — depressed.

*Top broken.

are involved. The Canterbury climate can be summarized as follows:

(1) Low annual rainfall — 500 to 750 mm on the plains and 750 to 1250 mm in the foothills.

(2) Low relative humidity during spring and summer — values below 50% are very common.

(3) The characteristic fohn wind which sweeps over the mountains from the north-west during spring and summer and can often reach gale force.

The soils of the plains are mostly stony, alluvial gravels of low water-retention capacity, tending more towards loam types in the foothills of the mountains. In late spring and summer, the climatic and edaphic conditions are such that desiccation of plant crops can occur (Garnier, 1950). Severe droughts are recorded about once in every decade.
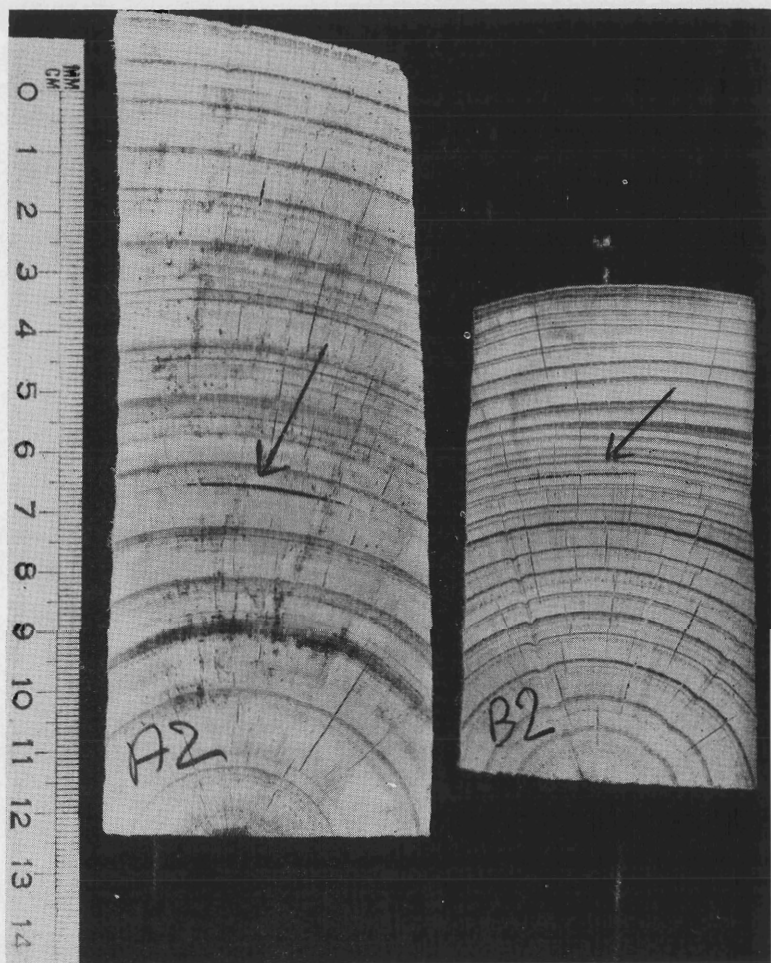
Fig. 4: *Radiata pine timber from Ashley and Balmoral Forests. Cracks have appeared along the false rings, indicating planes of weakness.*

a pocket, showing a transition from normal latewood tracheids to septate tracheids, to rectangular parenchyma to callus cells. This series of cell types is almost identical with that surrounding resin canals (Bannan, 1936), apart from the presence of callus in the pocket cavity and the apparent lack of distinct, epithelial cells. It was at first thought that such sections passed through vertical resin canals but serial sampling showed that this is not a local effect and, in fact, it occurs to some extent all around the pocket on both the inner and the outer edges. The strand tracheid and parenchymatous cells can be seen to occur in radial sequence with the normal tracheids and must,

from the forests sampled and are formed in late spring or summer. The phenomenon has been widely reported as being an indirect effect of drought on xylem formation (Zahner and Oliver, 1962; Larson, 1963; Glock and Agerter, 1966) and their presence in Canterbury is undoubtedly due to the climatic factors mentioned earlier. Visual inspection of discs cut from the sample logs revealed that the patterns of false ring formation from year to year were very similar between trees of the same crop, and the gross features — *i.e.,* the more pronounced rings, occurred in the same years between forests, confirming that their formation is dependent on widespread environmental conditions (Dobbs, 1953). It is suggested that the epidemic incidence of resin pockets is in some way connected with water stress.

Examination of pocket samples from several other forests throughout New Zealand revealed that Ngaumu State Forest is the only area outside Canterbury where an association with false rings exists. Wood from most other regions is virtually free from false latewood bands and resin pockets occur predominantly in the first-formed earlywood. It is interesting to note that timber from the coastal region of Canterbury, which is virtually free of resin pockets, does not exhibit the false rings so typical of produce from the harsh, inland sites.

(a) *False Rings as Zones of Weakness*

For the visual comparison of patterns of false latewood development within and between crops mentioned above, a radial strip 50 mm wide and 10 mm deep had been prepared from each 2 m log and sanded to accentuate the earlywood/latewood contrast. Many of these strips, on drying indoors at ambient temperature and relative humidity, split tangentially either partially or completely (Fig. 4). On close examination it was seen that the splits tended to follow the false latewood/earlywood boundary — *i.e.,* the growth horizons in which resin pockets are initiated — demonstrating the existence of zones of weakness along the outer boundaries of the false rings.

Microscopic examination of transverse wood sections containing false rings reveals that in some cases a distinct tangential row of closely spaced vertical resin canals is present within or immediately outside the region of false latewood (Fig. 5), which would contribute towards the weakening effect.

(b) *Wood Anatomy of Resin Pockets*

Canterbury resin pockets originate from tangential ruptures in the wood tissue near the outer boundaries of false rings. Macroscopically, the inner edge of the pockets usually appears as a clean break, but microscopically it can be seen to be a more irregular shear where the split follows the line of least resistance — *e.g.,* resin canals.

Radial longitudinal sections through resin pockets reveal the different types of cells involved in the structure of the defect. Figure 6 is such a section through the inner face of
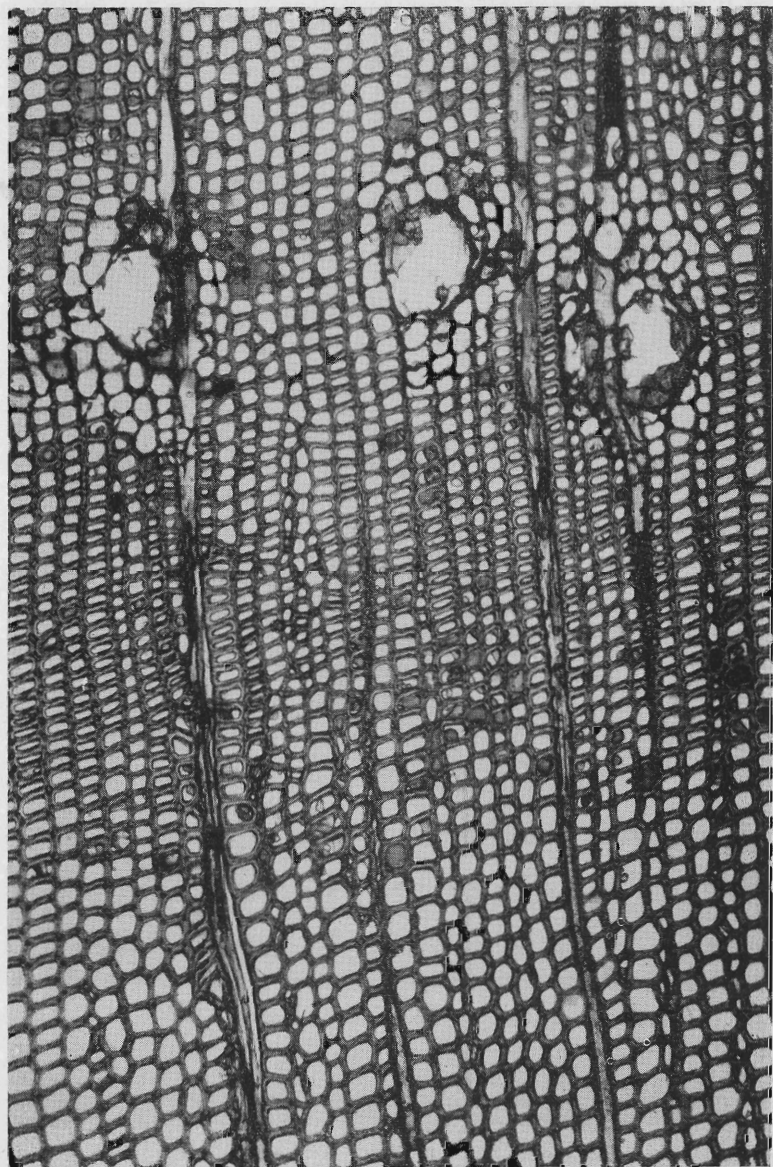
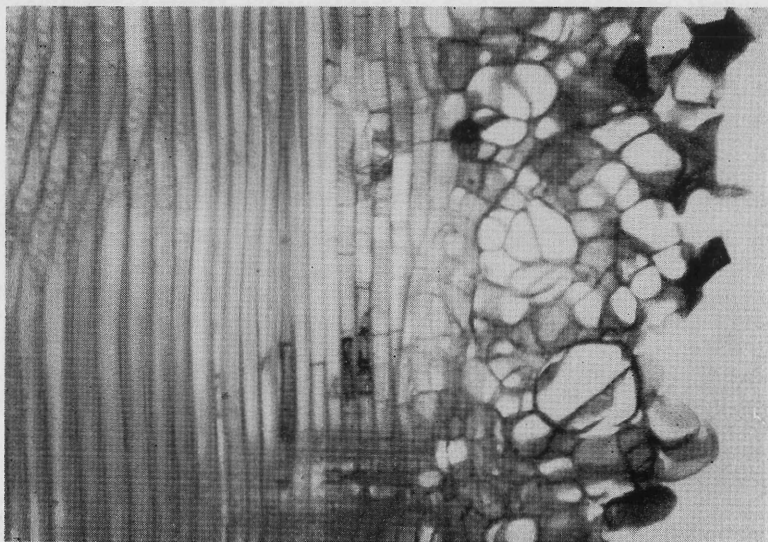Fig. 5: *Radiata pine from Ashley Forest. False ring followed by a band of vertical resin canals.* × 100

FIG. 6: *Radiata pine from Eyrewell Forest. Radial section through resin pocket border showing the transition from latewood tracheids → strand tracheids → parenchyma → callus tissue.* × 70

therefore, have been formed from fusiform elements prior to differentiation. This clearly indicates that the initial split takes place in the cambial zone.

The callus tissue results from the proliferation of ray parenchyma and resin canal parenchyma cells into the pocket cavity. The growth and development are very rapid in radiata pine with the result that none of the samples available could show the start of the process clearly. However, a section of Norway spruce which had comparatively little callus growth within the pockets demonstrated the initial stages of ray proliferation (Fig. 7). The nodules frequently found on the inner and outer faces of pockets in pine species (Clifton, 1969) arise when callus protruding from the rays develops a meristematic zone and continues to expand by cell division until the free space available has been filled by woody tissue.

(c) Resin Pocket Initiation and Enlargement

It has been suggested above that high levels of resin pockets tend to occur in areas where water stress develops periodically. creating false rings within the timber.

Winds, or extreme gusts, are normally held to be the main factor contributing towards pocket initiation (Frey-Wyssling, 1942; Clifton, 1969), but, apart from the obvious effects of high wind on trees, such as windthrow and stem breakage, little is known about the influence of wind sway on the cambial zone. Hocking (1949) observed that some radiata pine stems yielded under the compressive forces exerted by gale
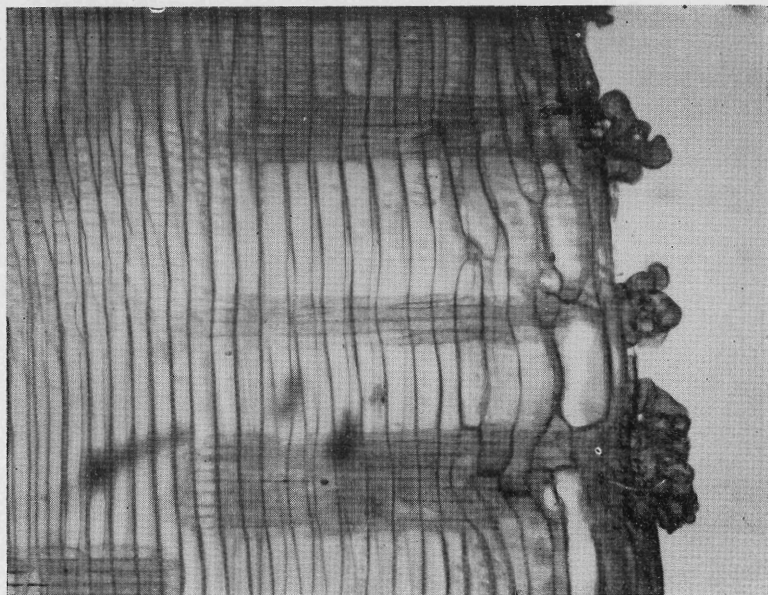
Fig. 7: *Proliferation of ray cells into resin pocket cavity in a sample of spruce timber.* × 80

force winds in the Manawatu district in 1948, and remaining trees showed horizontal fractures in the region of collapse on the leeward side. This type of failure is obviously an effect of wind. According to the currently held belief, these failures might be expected to be prevalent in crops predisposed to resin pocket formation. No reference can be found to indicate that these two defects exist side by side. Wind-induced mechanical stresses would be greatest around branch bases, particularly in the middle and upper crown, but Clifton (1969) found that branch-associated pockets were the exception rather than the rule, and that large numbers can occur in the pruned parts of stems.

An alternative hypothesis would be that pocket initiation results from the rupture of cells along the false latewood/earlywood boundary immediately after the relief of water stress. Vité (1961) established a relationship between water potential deficit and oleoresin pressure, recording a seasonal decline in pressure in ponderosa·pine as summer droughts developed. Hence, following the drought period when the sap tension is released and production of large diameter, thin-walled cells is renewed, there is an accompanying increase in resin pressure at a stage when the cambial zone would be particularly sensitive to mechanical or physiological stress conducive to cell rupture — *e.g.*, wind sway or high turgor pressure. Resin would then enter the resulting cavity from the horizontal resin canals and tend to enlarge it along the line of least resistance — *i.e.*, longitudinally and radially along
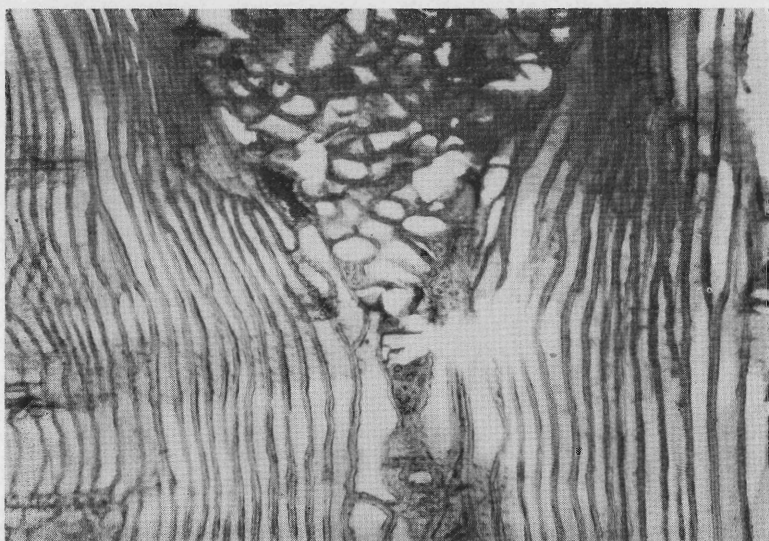
FIG. 8: *Resin pocket walls forced apart by resin pressure in radiata pine.*
× 70

the false latewood/earlywood boundary. Day (1959) cites several cases of such collapse in meristematic tissue related to water shortage.

The regular outline and shape of resin pockets, not only in New Zealand-grown timbers but also in those grown in other countries where pockets have been recorded, suggest that the factors which control the enlargement of the cavity are the same in all cases. Circumstantial evidence points to resin pressure and the volume of resin available as being these factors. The dimensions of pockets in radial section suggest that resin pressure determines the shape (Fig. 1), and some microscopic sections show a distinct forcing apart of the pocket walls, as in Fig. 8. The size of pockets is known to increase greatly from the pith outwards in the stem (Clifton, 1969) and this parallels the increase in length of the vertical resin canals in pines (Bannan, 1936). Thus, since the vertical and horizontal canals are part of an anastomosing system, a rapidly increasing volume of resin would become available to be forced under pressure into cavities in the xylem with increasing distance from the pith.

Pocket development is thus envisaged as being controlled by resin availability and pressure, so that in any one year there may be a few large or many small pockets formed within trees.

(d) *Within- and Between-tree Variation in Resin Pocket Numbers*

Since resin pocket initiation in Canterbury appears to be related to water shortage, the variation in the numbers of

pockets found between trees of a predisposed crop may be related to the degree of moisture stress developed within individual trees, as well as to other factors such as oleoresin exudation pressure and exposure to desiccating and buffeting winds. Thus it would be very difficult to predict which trees in a particular crop would be most likely to be susceptible to pocket formation — *e.g.*, dominant and co-dominant trees may have more water available to them through larger root systems, but are more exposed to warm winds and may develop greater water stress.

Within individual trees, resin pockets tend to be concentrated in the lower half of the bole, with very few in the upper portion of the crown (Clifton, 1969) and no relationship with compass direction has been established. These facts are consistent with the water stress hypothesis, since drought stresses develop first in the lower stem and progress towards the apex as the severity increases (Zahner, 1968).

IMPLICATIONS FOR FOREST MANAGEMENT

Resin pockets do not greatly affect the properties of round-wood, pulpwood or framing grades and influence the economics of forest management only when present in numbers greater than about $5/10 \text{ m}^2$. The production of clearwood in future will be almost entirely from radiata pine and concentrated mainly on sites of high productivity in the Bay of Plenty, Hawke's Bay, Nelson and Southland regions where resin pocket incidence is negligible. The region of highest pocket incidence — *i.e.*, Canterbury — is such that the low site indices and the physical limitation imposed on rotation length by wind make the large-scale production of clearwood impracticable. Pruning for board production can only be considered in the more sheltered parts of the foothill forests, where the growth increment is better and the numbers of resin pockets comparatively few.

Degrade due to resin pockets is most likely to occur in crops being managed for clearwood production or a specific high quality end use in areas where pocket incidence can be above normal — *e.g.*, the Wairarapa and possibly parts of Nelson and Auckland Conservancies. In such areas, silvicultural policy may be affected in that marginally-economic pruning may have to be discontinued. For example, the figures in Table 3,

TABLE 3: PERCENTAGE OF BOARDS DEGRADED SOLELY BECAUSE
OF RESIN POCKETS

	Heavy Thinning	Moderate Thinning
Butt log	4.6	7.9
Second log	2.7	8.6
Third and fourth logs	—	2.9
Weighted mean	3.5	7.5
No. of resin pockets per 100 bd ft	6.9	12.4

supplied by Sutton and McDonald (1971) from a log study of thinnings from Ngaumu State Forest, show the effect of resin pockets on board outturn.

Thus, even resin pocket levels which are low by Canterbury standards can cause a significant reduction in clearwood production in other areas. The problem for the forest manager is that there can be a very great variation in the numbers of pockets from tree to tree and from site to site, so that in marginal areas the economics of pruning particular stands cannot be readily evaluated. In future it should be possible to delineate pocket-prone areas on the basis of the grade returns from first rotation crops.

Although factors other than the presence of resin pockets usually dictate silvicultural policy, it is possible that thinning and pruning processes, themselves, could alleviate part of the water stress and create conditions less favourable to pocket formation — e.g., by increasing the amount of water available to each tree and reducing losses through transpiration. Future developments of strip planting systems for shelter and irrigation schemes on the Canterbury Plains may also help to reduce the current levels of resin pocket incidence.

ACKNOWLEDGEMENTS

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