260. *Diterpenes. Part VII.*[1] *Kaurene.**

By LINDSAY H. BRIGGS, B. F. CAIN, R. C. CAMBIE, B. R. DAVIS, P. S. RUTLEDGE, and J. K. WILMSHURST.

(−)-Kaurene is shown to be a stereoisomer of phyllocladene (I) and to possess the absolute configuration (XXI; R = CH_2); " cryptomerene " is found to be identical with isokaurene (XXVI) and " γ-kaurene " to be the tertiary alcohol (III; R = OH) arising from hydration of the double bond.

FROM the leaf oil of the New Zealand kauri (*Agathis australis* Salisb.) Hosking [6] isolated a crystalline hydrocarbon, $C_{20}H_{32}$, m. p. 59—60°, which he named kaurene. Later, Nishida and Uota [7] isolated a diterpene, " α-podocarprene," m. p. 50°, $[\alpha]_D$ −71·9°, and a liquid, " β-podocarprene," $[\alpha]_D$ −15·9° (probably impure " α-podocarprene ") from the leaf oil of *Podocarpus macrophyllus* Don. Kawamura [8] isolated the same crystalline hydrocarbon from the leaf oil of *Sciadopitys verticillata* S. et Z. along with an isomeric diterpene " δ-podocarprene," m. p. 65°, $[\alpha]_D$ −27·1°. Butler and Holloway,[9] from the leaf oil of the New Zealand matai (*Podocarpus spicatus* R. Br.), also isolated " α-podocarprene." The identity of kaurene with " α-podocarprene " was subsequently established [10] and Hosking's kaurene shown [11] to be optically active, contrary to the latter's report. McGimpsey and Murray [12] showed that the kaurene from *P. spicatus* was the dextrorotatory isomer, $[\alpha]_D$ +80°, which had also been obtained from the leaf oil of the New Zealand miro (*P. ferrugineus* D. Don).†

The previous work established that kaurene has the formula $C_{20}H_{32}$, forms a monohydrochloride and is tetracyclic. It was also found [8,10,13] that kaurene can be converted into the isomeric isokaurene (identical with Kawamura's " δ-podocarprene " [8]). Kaurene and isokaurene yielded the same hydrochloride and dihydro-derivative which suggested merely a difference in position of a double bond, resembling the relationship between phyllocladene (I) and isophyllocladene (II).[14] Evidence is now presented showing that kaurene and isokaurene are indeed stereoisomers of phyllocladene and isophyllocladene, respectively.

Isokaurene has now been shown to be identical with " α-cryptomerene," ‡ obtained by Uchida [15] from the leaf oil of *Cryptomeria japonica* Don. We suggest, however, that the name isokaurene be retained for this compound because of its established place in the literature.

Another compound, " γ-kaurene," m. p. 196—198°, obtained [13] by treatment of kaurene with alcoholic sulphuric acid under reflux is almost certainly identical with " γ-podo-

* Preliminary accounts of portions of this work have been published.[2-5]

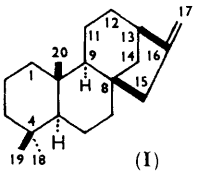
† The optical rotation, $[\alpha]_D$ +101°, previously recorded for kaurene from this source was shown subsequently to be incorrect (see Experimental).

‡ We are indebted to Dr. S. Uchida for a sample of this material.

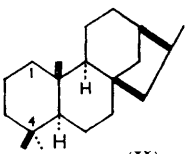
[1] Part VI, *J.*, 1962, 1850.
[2] Briggs, Cain, Davis, and Wilmshurst, *Tetrahedron Letters*, 1959, No. 8, 8.
[3] Briggs, *J. New Zealand Inst. Chem.*, 1959, **23**, 92.
[4] Briggs, Cain, Cambie, and Davis, *Tetrahedron Letters*, 1960, No. 24, 18.
[5] Djerassi, Quitt, Mosettig, Cambie, Rutledge, and Briggs, *J. Amer. Chem. Soc.*, 1961, **83**, 3720.
[6] Hosking, *Rec. Trav. chim.*, (*a*) 1928, **47**, 578; (*b*) 1930, **49**, 1036.
[7] Nishida and Uota, *J. Agric. Chem. Soc. Japan*, 1931, **7**, 157, 957.
[8] Kawamura, *Bull. Imp. Forestry Exp. Sta. Tokyo*, 1931, No. 31, 93.
[9] Butler and Holloway, *J. Soc. Chem. Ind.*, 1939, **58**, 223.
[10] Briggs and Cawley, *J.*, 1948, 1888.
[11] Briggs and Taylor, *J.*, 1950, 407.
[12] McGimpsey and Murray, *J. Appl. Chem.*, 1960, **10**, 340.
[13] Briggs, Cawley, Loe, and Taylor, *J.*, 1950, 955.
[14] Part V, Briggs, Cain, Cambie, and Davis, *J.*, 1962, 1840.
[15] Uchida, *J. Amer. Chem. Soc.*, 1916, **38**, 687.

carprene," m. p. 196—198°, produced by Nishida and Uota [7] by the action of potassium hydroxide on kaurene hydrochloride. It is also probably identical with " β-cryptomerene," m. p. 211°, isolated [15] as a by-product in the preparation of " α-cryptomerene " hydrochloride. We have now established that " γ-kaurene," whose melting point has been raised to 217°, is not a hydrocarbon but a saturated alcohol, $C_{20}H_{34}O$,* which exhibits strong hydroxyl absorption in the infrared spectrum at 3375 cm.$^{-1}$ and forms a monoacetate (III; R = OAc). Treatment of " γ-kaurene " with hydrogen chloride affords kaurene hydrochloride (III; R = Cl). It is thus formulated as kauran-16-ol (III; R = OH)† and the name " γ-kaurene " should therefore be discontinued. Chromatography of the hydrochloride on alumina or dehydration of kauran-16-ol with phosphorus oxychloride produced a mixture of kaurene and isokaurene. Despite the analytical results [15] supporting a hydrocarbon structure we still consider that " β-cryptomerene " is the alcohol, kauran-16-ol.

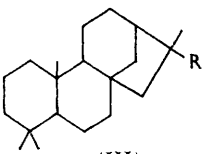
Pimanthrene was the sole product isolated by Hosking [6b] from dehydrogenations of kaurene. It would appear from their reports that the hydrocarbons obtained both by Hosking [6] and by Butler and Holloway [9] were mixtures of kaurene and isokaurene but this does not invalidate the above result.



(I)



(II)



(III)

The previous evidence supports the fact that kaurene and isokaurene are stereoisomeric with phyllocladene (I) and isophyllocladene (II), respectively. The infrared spectra are in agreement with this formulation and, in particular, the spectrum of kaurene exhibits strong bands at 876, and at 1387 and 1368 cm.$^{-1}$ attributable to $C{:}CH_2$ and CMe_2 groups,[16] respectively. Isokaurene has a band at 820 cm.$^{-1}$ indicative of a trisubstituted double bond.[16] The spectra of the two isomers are very similar but show differences comparable to those between phyllocladene and isophyllocladene.[14,17] Furthermore, the nuclear magnetic resonance spectrum of kaurene shows the presence of the group $C{:}CH_2$, an angular methyl group, and a *gem*-dimethyl group, while that of isokaurene indicates the presence of a trisubstituted double bond, a *gem*-dimethyl group, and two other methyl groups with different environments (see Experimental section).‡

On hydrogenation at high pressure with a Raney nickel catalyst kaurene gave two dihydro-derivatives, m. p.s 84—85° and 54—56°, in yields of 82 and 4%, respectively. These are presumably isomeric at C-16 and are designated kaurane [1] and epikaurane respectively, corresponding in stereochemistry about C-16 to phyllocladane and 16-epiphyllocladane.[14] Kaurane, obtained from both kaurene and isokaurene, is identical with the α-dihydro-compound previously described [6–8,10] and with a hydrocarbon derived from steviol.[18] Epikaurane is identical with the isomeric hydrocarbon derived from stevioside.[18] The infrared spectra of the two isomers are very similar but show differences comparable to those between phyllocladane and epiphyllocladane.[14]

The selenium dehydrogenation of kaurene has been reinvestigated. The isolation of

* Apparently unaware of our preliminary report,[2] McGimpsey and Murray [12] have also shown that " γ-kaurene " has the formula, $C_{20}H_{34}O$.

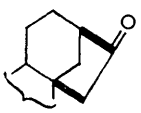
† [*Added in proof.*] The hydroxyl group has now been shown to be α-oriented. Drs. B. E. Cross, R. H. B. Gatt, and J. R. Hanson have informed us of their independent confirmation of this.

‡ We are greatly indebted to Dr. J. N. Shoolery, of Varian Associates, for these measurements.

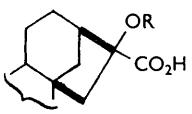
[16] Bellamy, " The Infra-red Spectra of Complex Molecules," Methuen, London, 2nd edn., p. 34.
[17] Bottomley, Cole, and White, *J.*, 1955, 2624.
[18] Dolder, Lichti, Mosettig, and Quitt, *J. Amer. Chem. Soc.*, 1960, **82**. 246.

pimanthrene has been confirmed and it was also the only product isolated from the dehydrogenation of isokaurene. In view of the formation of both pimanthrene and retene from vigorous dehydrogenation of phyllocladene [14,19] and of retene as the sole product of the dehydrogenation of iosene [20] (identical with phyllocladane [21]) kaurane was subjected to prolonged selenium dehydrogenation. Retene was not isolated directly from the mixture of products but chromatography on alumina of the oxidised aromatic hydrocarbons gave both pimanthrenequinone and, in small yield, retenequinone. Normal dehydrogenation being assumed, 18 of the 20 carbon atoms of kaurene can thus be assigned. Since kaurene is tetracyclic the fourth ring is probably a bridged one as in phyllocladene.

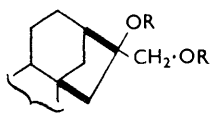
Oxidations have established the nature and size of the bridge ring. Ozonolysis of kaurene gave formaldehyde and the nor-ketone (IV). The latter's spectrum possesses a strong band at 1745 cm.$^{-1}$ indicating that the carbonyl group is present in a five-membered ring as in the corresponding phyllocladene nor-ketone.[14,17] Oxidation of kaurene with potassium permanganate gave the nor-ketone (IV) and a hydroxy-acid, $C_{20}H_{32}O_3$, whose structure (V) was confirmed by further oxidation with sodium bismuthate to the nor-ketone (IV). Kaurene was oxidised by osmium tetroxide to kaurane-16,17-diol (VI; R = H), which could be further converted into the nor-ketone (IV) by treatment with lead tetra-acetate. Reduction of the nor-ketone (IV) with sodium borohydride led to 17-norkauran-16-ol (VII).



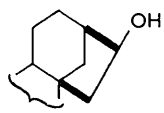
(IV)



(V)

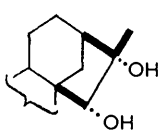


(VI)

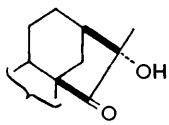


(VII)

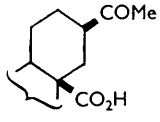
Oxidation of isokaurene has given products analogous to those obtained in the isophyllocladene series [14] and which fully support a structure isomeric with (II). Systematic fractionation of the products of oxidation with potassium permanganate in dry acetone solution afforded kaurane-15α,16-diol (VIII), 16-hydroxykauran-15-one (IX), and the keto-acid (X). When isokaurene was oxidised by osmium tetroxide alone or in the presence of t-butyl hydroperoxide, at room temperature, the diol (VIII) was formed but with the latter reagent at 50° the α-ketol (IX) was the main product.



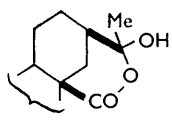
(VIII)



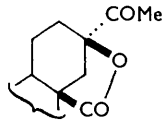
(IX)



(X)



(XI)



(XII)

On the assumption that oxidation would occur on the less hindered α-face (for the absolute configuration of kaurene, see later) the hydroxyl groups in the diol and ketol are given the α-configuration.* Their infrared spectra and derivatives are in agreement with the suggested structures. In particular, the ketol exhibited strong hydrogen-bonded hydroxyl absorption at 3279 cm.$^{-1}$ while the carbonyl peak at 1736 cm.$^{-1}$ corresponds to a five- rather than to a six-membered ring ketone [22] and has a similar frequency to that of the analogous 16-hydroxyphyllocladan-15-one.[14] Reduction of the ketol (IX) with potassium borohydride gave the diol (VIII).

* For a recent proof of the same stereochemical assignment of the corresponding hydroxyl groups in cafestol, see Finnegan, *J. Org. Chem.*, 1961, **26**, 3057.

[19] Nishida and Uota, *J. Agric. Chem. Soc. Japan*, 1935, **11**, 489; 1936, **12**, 308; Uota, *J. Dept. Agric. Kyushu Imp. Univ. Japan*, 1937, **5**, 117; Brandt, *New Zealand J. Sci. Tech.*, 1938, **20***B*, 8.

[20] Soltys, *Monatsh.*, 1929, **53—54**, 175.

[21] Briggs, *J.*, 1937, 1035.

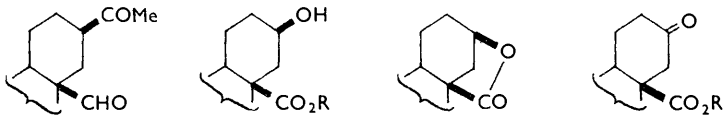
[22] Bellamy, " The Infra-red Spectra of Complex Molecules," Methuen, London, 2nd edn., p. 132.

The acetyl and the carboxyl group of the keto-acid (X) must both have the same configuration (later shown to be β) since the infrared spectrum in a potassium bromide disc (bands at 3279, 1739, and 1692 cm.$^{-1}$) shows that in the solid it occurs mainly as the lactonol (XI).[23] In carbon tetrachloride solution it exists mainly as the keto-acid (X) (bands at 1718 and 1692 cm.$^{-1}$ and absence of hydroxyl absorption). Its formulation as a methyl ketone follows from a positive iodoform test and Brady's reaction but, in keeping with the steric hindrance engendered by the axial conformation of both groups, the keto-acid failed to react with Girard's reagent P.

Oxidation of the ketol (IX) with excess of periodic acid led, unexpectedly, to the γ lactone (XII) of a hydroxy-keto-acid analogous to a similar product obtained by direct oxidation of isophyllocladene.[14] The infrared spectrum did not exhibit hydroxyl absorption but possessed carbonyl bands at 1789 and 1718 cm.$^{-1}$, assigned to γ-lactone and aliphatic carbonyl groups, respectively.[22] The lactone formed an oxime and a 2,4-dinitrophenylhydrazone, gave a positive iodoform reaction, and was unchanged by further oxidation with chromium trioxide. In its formation the acetyl group originally present must undergo epimerisation to the more stable equatorial position before hydroxylation at C-13 and final lactonisation. The lactone failed to react with sodium bismuthate in boiling acetic acid solution. After alkaline hydrolysis of the lactone and acidification with dilute acetic acid the corresponding hydroxy-keto-acid was apparently formed (infrared spectrum), but on attempted crystallisation or treatment with sodium bismuthate, as above, the lactone was recovered almost quantitatively.

The lactone (XII) was also isolated as the end product of periodic acid oxidation of kaurane-15α,16-diol, followed by oxidation and epimerisation[24] of the oily aldehyde (XIII) with 8N-chromic acid–sulphuric acid.[25] In keeping with the axial nature of the acetyl-group of (XIII), preferential attack by 2,4-dinitrophenylhydrazine led to a monoderivative, which, like the parent aldehyde, still gave a positive iodoform reaction.

In order to obtain a suitable derivative for the study of the stereochemistry of kaurene by rotatory dispersion measurements, the keto-acid (X) was subjected to Baeyer–Villiger oxidation and hydrolysis, analogous to a reaction sequence carried out[24] in the phyllocladene series. Oxidation with trifluoroperoxyacetic acid and hydrolysis of the resultant ester gave the hydroxy-acid (XIV; R = H) and its γ-lactone (XV), separated by chromatography on silica gel. Like the corresponding acid (epimeric about C-13) from isophyllocladene, the silver salt of the hydroxy-acid (XIV; R = H) gave only the lactone (XV) by



(XIII) (XIV) (XV) (XVI)

Hunsdiecker degradation. Treatment of the hydroxy-acid (XIV; R = H) with diazomethane gave the methyl ester (XIV; R = Me) which, when oxidised with 8N-chromic acid–sulphuric acid,[25] formed the keto-ester (XVI; R = Me). The hydroxy-acid (XIV; R = H), on similar oxidation, gave the keto-acid (XVI; R = H), which yielded the same keto-ester (XVI; R = Me) on esterification with diazomethane. Reduction of the keto-acid (XVI; R = H) with sodium borohydride gave the lactone (XV).

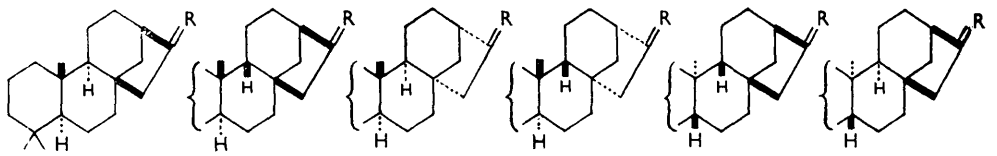
Kaurene occurs in enantiomorphic forms. All of the oxidative work presented here was carried out on the lævorotatory form obtained from *Agathis australis*. A *trans*-A/B

[23] Cf. Grove and Willis, *J.*, 1951, 877; Uskoković, Dorfman, and Gut, *J. Org. Chem.*, 1958, **23**, 1947; Atwater and Ralls, *J. Amer. Chem. Soc.*, 1960, **82**, 2011. See also Turner, *J. Amer. Chem. Soc.*, 1950, **72**, 579; Woodward and Kovach, *J. Amer. Chem. Soc.*, 1950, **72**, 1009, for related discussions.

[24] Cf. Grant and Hodges, *Tetrahedron*, 1960, **8**, 261.

[25] Bowers, Halsall, Jones, and Lemin, *J.*, 1953, 2548.

ring junction being assumed, for which there is no known exception in the naturally occurring diterpenoid series, diterpenes of the general structure (I) can theoretically exist in four isomeric forms (XVII—XX; R = CH_2) and their corresponding enantiomers.

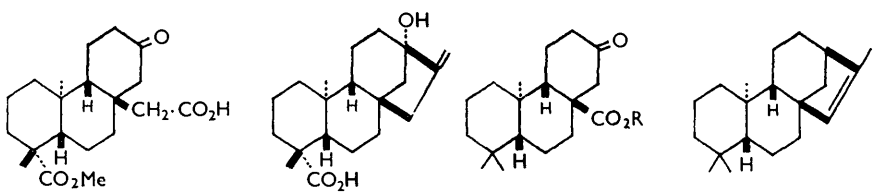


(XVII) (XVIII) (XIX) (XX) (XXI) (XXII)

Phyllocladene has been shown unequivocally by degradation [14,24] and synthesis [26] to have the absolute configuration (XVII; R = CH_2). Structure (XVIII; R = CH_2) with a *trans-syn-cis*-configuration would have considerable strain and will not be considered further. Phyllocladene and kaurene coexisting in *Podocarpus ferrugineus* are both dextrorotatory and since phyllocladene belongs to the normal steroid series, (+)-kaurene presumably belongs to the same series and hence must have the configuration (XIX; R = CH_2) or (XX; R = CH_2). (−)-Kaurene would then have the antipodal structure (XXI; R = CH_2) or (XXII; R = CH_2). In confirmation of a β-bridge ring the rotatory dispersion of (−)-17-norkauran-16-one (XXI; R = O) or (XXII; R = O), $[\alpha]_{320}$ +1500°,[4] has the expected positive Cotton effect {cf. 17-norphyllocladan-16-one (XVII; R = O), $[\alpha]_{322\cdot5}$ +2240°, and epoxynorcafestanone, $[\alpha]_{324}$ +2000°}.[27]

Models of the nor-ketones (XXI; R = O) and (XXII; R = O) show that the latter more closely resembles the whole molecules of phyllocladene nor-ketone (XVII; R = O) and epoxynorcafestanone, particularly in regard to rings B, C, and D; this accords with the rotatory dispersion.[27b] On the other hand, Grove and his co-workers have shown [28] that the configuration at 4*b* of gibberic and epigibberic acids, epimeric at a position similar to the C-9 position of (−)-kaurene, has little effect on the shape of the rotatory dispersion curves so that the above measurements cannot be used to determine the configuration of (−)-kaurene at C-9.

Mosettig *et al.* transformed steviol and stevioside into isomeric hydrocarbons, stevane-A and stevane-B, identical with (−)-kaurane and (−)-16-epikaurane, respectively.[18,29] Steviol has also been transformed into the keto-acid (XXIII) with a rotatory dispersion almost the mirror image of that of 5β-cholestan-3-one.[5]



(XXIII) (XXIV) (XXV) (XXVI)

From results for steviol and for (−)-kaurane, steviol must unequivocally be represented by (XXIV). It could then be assumed that (−)-kaurene has the same absolute configuration. During the conversion of steviol into kaurane,[18] however, one step consists of the replacement by bromine of the hydroxyl group at the C-13 bridgehead position.

[26] Turner and Gänshirt, *Tetrahedron Letters*, 1961, No. 7, 231.
[27] (*a*) Djerassi, Riniker, and Riniker, *J. Amer. Chem. Soc.*, 1956, **78**, 6362; (*b*) Djerassi, Cais, and Mitscher, *J. Amer. Chem. Soc.*, 1959, **81**, 2386.
[28] Grove, MacMillan, Mulholland, and Turner, *J.*, 1960, 3049.
[29] Mosettig, Quitt, Beglinger, Waters, Vorbrueggen, and Djerassi, *J. Amer. Chem. Soc.*, 1961, **83**, 3163.

A similar reaction occurs in the transformation of caryophyllene alcohol into the corresponding bromide.[30] If this reaction proceeds by ring opening and closing * at positions 8—14 then inversion at C-9 could occur. With this doubt, the configuration of (−)-kaurene at C-9 cannot be assigned on the above evidence alone.

The weak positive rotatory dispersion curves † of the keto-acid (XVI; R = H), $[\alpha]_{305}$ +150°, and the keto-ester (XVI; R = Me), $[\alpha]_{313}$ + 88·7°, however, are essentially mirror images of that of a 3-keto-5β-steroid [31] and are only consistent with a β-bridge system and, specifically, with a 9β-hydrogen. Their formulæ can thus be expanded to (XXV).

This conclusion resolves the remaining doubt in the absolute configuration of (−)-kaurene, which can now be represented by (XXI; R = CH_2) [and (−)-isokaurene by (XXVI)].

[*Added in proof.*] Since this paper was submitted further results have been published by other workers. ApSimon and Edwards (*Canad. J. Chem.*, 1962, **40**, 896) have proved the structure of atisine and thence those of the *Garrya* alkaloids and (−)-kaurene. With the exception of C-9, their work also proves the absolute configuration of these compounds. Cross, Gatt, Hanson, and Klyne (*Tetrahedron Letters*, 1962, 145) have independently confirmed the stereochemistry of (−)-kaurene; Vorbrueggen and Djerassi (*J. Amer. Soc.*, 1962, **84**, 2990) have published further work of the Stanford group; and Bell, Ireland, and Partyka (*J. Org. Chem.*, 1962, **27**, 3741) have recorded a total synthesis of (±)-kaurene.

Experimental

Analyses were by Dr. A. D. Campbell and Associates, University of Otago, New Zealand. Infrared spectra, unless otherwise stated, were measured for potassium bromide discs with a Beckman IR2 instrument. Light petroleum was of b. p. 50—60°.

(−)-*Kaurene*.—The fresh leaves and terminal branchlets of *Agathis australis*, collected at Titirangi, were steam-distilled for 24 hr., and the more volatile constituents removed from the resulting oil (0·23% yield) by distillation. The high-boiling oils, in light petroleum, were percolated through activated alumina to remove oxygenated compounds. The residue, after removal of solvent, crystallised from ethanol (cooling by solid carbon dioxide) to give needles of (−)-kaurene, m. p. 51°, $[\alpha]_D^{11}$ −72° (*c* 1·0 in chloroform); hydrochloride, m. p. and mixed m. p. 116—118°. Isokaurene, prepared from the hydrochloride,[10] had m. p. and mixed m. p. 61°.

Nuclear magnetic resonance: kaurene, 5·27 (C:CH_2), 8·97, 9·13, and 9·18 τ (saturated C–Me); isokaurene, 4·93 (C:C*H*), 8·29 (17-CH_3 doublet), 8·97, 9·13, and 9·18 τ (saturated C–Me).

(+)-*Kaurene*.—In the same way, (+)-kaurene was obtained from the essential oil of *Podocarpus ferrugineus*, collected from Pureora by the courtesy of members of the New Zealand State Forest Service. It had m. p. 49—50°, $[\alpha]_D^{17}$ +74° (*c* 2·8 in chloroform), with an infrared spectrum identical with that of the lævorotatory isomer.

All the reactions recorded below, unless otherwise stated, were carried out on the lævorotatory isomer.

Kauran-16-*ol* (III; R = OH).—The solids from the mother liquors of the preparation of kaurene hydrochloride on successive crystallisation from benzene, ethyl acetate, and light petroleum afforded fine needles of *kauran*-16-*ol* ("γ-kaurene"), m. p. 217° (Found: C, 82·7, 82·85; H, 11·3, 11·8. $C_{20}H_{34}O$ requires C, 82·7; H, 11·8%), $\nu_{max.}$ 3375 cm.$^{-1}$ (OH), $[\alpha]_D^{21}$ −39° (*c* 8·25 in EtOH).

The *acetate*, prepared by the use of acetic anhydride, alone (100°; 1 hr.) or with pyridine (100°; 2 hr.), formed flat needles, m. p. 141—143°, from light petroleum (Found: C, 79·4; H, 10·9; Ac, 12·6. $C_{22}H_{36}O_2$ requires C, 79·5; H, 10·9; Ac, 12·9%). Deacetylation, by heating under reflux with 2N-methanolic potassium hydroxide for 4 hr., regenerated kauran-16-ol, m. p. and mixed m. p. 212—214°.

In attempted dehydration, kauran-16-ol was unaffected by treatment with iodine and toluene

* We are grateful to Professor E. Wenkert for discussions on this point.

† We are grateful to Professor C. Djerassi for these measurements.

[30] Barton, Bruun, and Lindsey, *J.*, 1952, 2210; see also Schöllkopf, *Angew. Chem.*, 1960, **72**, 252.

[31] Djerassi, "Optical Rotatory Dispersion," McGraw-Hill Book Co., New York, 1960.

(100°; 12 hr.) or by heating it under reflux with 7% methanolic sulphuric acid. On treatment in pyridine solution with phosphorus oxychloride at 0° for 24 hr. it yielded a mixture, m. p. 57°, of kaurene and isokaurene, as determined by the infrared spectrum.

Kauran-16-ol (150 mg.), dissolved in the minimum amount of dry ether, was treated with dry hydrogen chloride for 2 hr. Crystallisation of the resulting oil from ethyl acetate gave kaurene hydrochloride (18 mg.), m. p. and mixed m. p. 113—114°. Chromatography of the hydrochloride (1·16 g.) in light petroleum on alumina (Grade I) afforded a mixture (958 mg.), m. p. 52—54°, of kaurene and isokaurene.

Kaurene—2,4-Dinitrobenzenesulphenyl Chloride Adduct.—Kaurene was heated under reflux with an equivalent amount of 2,4-dinitrobenzenesulphenyl chloride in carbon tetrachloride for 2 hr. The *adduct* crystallised from ethanol as irregular yellow plates (82% yield), m. p. 173·5—174° (Found: C, 66·3; H, 7·2; N, 5·4. $C_{26}H_{34}N_2O_4S$ requires C, 66·4; H, 7·3; N, 5·9%). The same adduct (78% yield) was prepared by similar treatment of isokaurene. If pure hydrocarbon was not used the adduct could be readily purified by percolation of a benzene solution through alumina (Grade I), unchanged reagent being firmly adsorbed on the column.

Hydrogenation of Kaurene.—(*a*) Kaurene (300 mg.), in ethanol (100 c.c.), was hydrogenated at 40 lb./sq. in. and room temperature for 21 hr. in the presence of a palladium–charcoal catalyst (100 mg.). Repeated crystallisation of the product from ethanol–ethyl acetate gave kaurane (α-dihydrokaurene) (234 mg.; 77%) as long needles, m. p. and mixed m. p. 83—84°, $[\alpha]_D^{21}$ −32°. Hydrogenation of isokaurene under identical conditions gave the same product in 83% yield. The same product, in 71% yield, was also obtained by hydrogenation of kaurene with a platinum oxide catalyst at 30 lb./sq. in. for 5 hr.

(*b*) Kaurene (452 mg.), dissolved in cyclohexane (25 c.c.), was hydrogenated at 3000 lb./sq. in. and 200° in the presence of a Raney nickel catalyst (75 mg.) for 4 hr. Crystallisation of the product afforded kaurane (357 mg.; 82%), m. p. and mixed m. p. 84—85°. Cooling of the residual oil from the mother liquors in acetone–carbon dioxide yielded 16-*epikaurane* (β-*dihydrokaurene*) (16 mg.; 4%), which slowly crystallised from ethyl acetate–ethanol as needles, m. p. 54—56°, $[\alpha]_D^{21}$ −67° (*c* 1·0 in $CHCl_3$) (Found: C, 87·6; H, 12·5. $C_{20}H_{34}$ requires C, 87·5; H, 12·5%).

The enantiomorph, prepared from (+)-kaurene in a similar experiment, had m. p. 51·5—52° $[\alpha]_D^{19}$ +49° (*c* 8·4 in chloroform) (identical infrared spectrum).

Dehydrogenation of Isokaurene.—Isokaurene (368 mg.) was heated with selenium (500 mg.) at 280—305° for 16 hr. The product, isolated in the usual manner, was converted into the trinitrobenzene complex. Purification yielded pimanthrene–trinitrobenzene complex (97 mg.), m. p. and mixed m. p. 160—161°. The same product was obtained by similar dehydrogenation of kaurene.

Dehydrogenation of Kaurane.—Kaurane failed to dehydrogenate under the conditions used for isokaurene. Kaurane (520 mg.) and selenium (1 g.) were heated at 380° for 22 hr. Attempted separation of the products by fractional crystallisation of the hydrocarbons or their trinitrobenzene complexes was unsuccessful. The hydrocarbon mixture (231 mg.), dissolved in acetic acid (5 c.c.), was treated dropwise with a solution of chromium trioxide (350 mg.) in acetic acid with cooling. The mixture was kept at room temperature for 2 hr., heated to 50°, cooled, and poured into water. After preliminary separation of nonquinonoid constituents on alumina, the product was reabsorbed on alumina and fractions (6 × 25 c.c.) were eluted with benzene–light petroleum (3 : 17). After crystallisation of the derived solids from ethanol, and on the basis of mixed m. p.s, fractions 1—4 were combined and recrystallised to yield pimanthrenequinone (108 mg.), m. p. and mixed m. p. 163—164°.

Fraction 6 (11·5 mg.), on further crystallisation, gave retenequinone (6 mg.), m. p. and mixed m. p. 192—194°.

Ozonolysis of Kaurene.—(*a*) (+)-Kaurene (119 mg.), dissolved in dry chloroform (20 c.c.), was treated with ozone in the usual manner at −20°. Solvent was removed *in vacuo* at room temp., the resulting oil heated under reflux with water (5 c.c.) for 5 min., and the mixture steam-distilled. Successive fractions (each 25 c.c.) were collected, neutralised with 0·01N-sodium hydroxide solution, and each treated with M-sodium acetate (10 c.c.), M-hydrochloric acid (5 c.c.), and a saturated aqueous solution of dimedone. Recrystallisation of the products from fractions 1—3 from aqueous ethanol gave the dimedone derivative of formaldehyde (77 mg., 61%), m. p. and mixed m. p. 189—190°.

(*b*) The oil obtained by decomposition of the ozonide produced in a similar experiment from kaurene (877 mg.) was treated with Girard's reagent P (800 mg.) in refluxing acetic acid–ethanol

(25 c.c. of 10%) for 40 min., followed by hydrolysis in N-hydrochloric acid. The oil obtained, when treated with 2,4-dinitrophenylhydrazine, yielded 17-*norkauran*-16-*one* 2,4-*dinitrophenylhydrazone*, which, after repeated crystallisation from chloroform–methanol, formed yellow needles, m. p. 243—244° (Found: C, 66·0; H, 7·5; N, 12·5. $C_{25}H_{34}N_4O_4$ requires C, 66·05; H, 7·5; N, 12·3%).

Oxidation of Kaurene.—(*a*) *With permanganate.* Potassium permanganate (718 mg.; 2 atoms of oxygen), in acetone (100 c.c.), was added to an ice-cold solution of kaurene (928 mg.) in acetone (100 c.c.) with stirring during 2 hr. On decolorisation (65 hr.), the acetone was removed under reduced pressure and the residue treated with sodium hydrogen sulphite and dilute hydrochloric acid. The solid was then triturated with light petroleum.

The insoluble fraction (134 mg.), after repeated crystallisation from aqueous ethanol, formed fine needles of 16-*hydroxykauran*-17-*oic acid* (V), m. p. 203—204·5° (Found: C, 75·6; H, 10·2. $C_{20}H_{32}O_3$ requires C, 75·0; H, 10·1%), $\nu_{max.}$ 3425 (OH), 1701 (CO_2H), 2681 cm.$^{-1}$ (carboxyl OH).

The soluble fraction was chromatographed on alumina (Grade II) and eluted with the same solvent. The first fractions yielded unchanged kaurene (480 mg.), m. p. and mixed m. p. 45—46°. Later fractions yielded 17-*norkauran*-16-*one* (IV) (103 mg.), which after repeated crystallisation from aqueous methanol gave needles, m. p. 117° (Found: C, 83·5; H, 11·1. $C_{19}H_{30}O$ requires C, 83·15; H, 11·0%); $\nu_{max.}$ 1745 cm.$^{-1}$ (C:O); rotatory dispersion (*c* 0·23) in dioxan, $[\alpha]_{700}$ −25°, $[\alpha]_{589}$ −25°, $[\alpha]_{320}$ +1500°, $[\alpha]_{295}$ −1000°. The 2,4-dinitrophenylhydrazone had m. p. and mixed m. p. 243—244°.

(*b*) *With osmium tetroxide.* Kaurene (511 mg.), in ether (40 c.c.), was treated with osmium tetraoxide (494 mg.) for 48 hr. at room temperature. The solution was saturated with hydrogen sulphide and filtered. The material recovered from the filtrate crystallised from acetone to form needles of *kaurane*-16,17-*diol* (VI; R = H) (380 mg.), m. p. 189° (Found: C, 76·4; H, 11·35. $C_{20}H_{34}O_2,\frac{1}{2}H_2O$ requires C, 76·1; H, 11·2%). The compound had the same m. p. when crystallised from ether (Found: C, 76·4; H, 11·1%), $\nu_{max.}$ 3390, 1068, 1027 cm.$^{-1}$ (OH).

The *diacetate* (VI; R = Ac), prepared by use of acetic anhydride–pyridine (4 hr.; 100°) or refluxing glacial acetic acid (8 hr.) crystallised from light petroleum as plates, m. p. 135° (Found: C, 73·55, 74·1; H, 9·4, 9·95. $C_{24}H_{38}O_4$ requires C, 73·8; H, 9·8%).

The *dibenzoate* (VI; R = Bz) prepared by use of benzoyl chloride–pyridine (4 hr.; 100°; or at the b. p.), crystallised from ethanol as needles, m. p. 169° (Found: C, 79·2; H, 7·8. $C_{34}H_{42}O_4$ requires C, 79·3; H, 8·2%).

Oxidation of Kaurane-16,17-*diol* (VI; R = H).—The diol (260 mg.), in benzene (80 c.c.), was heated under reflux with lead tetra-acetate (810 mg.) for 1 hr. The mixture was poured into water, and the product extracted with benzene (3 × 20 c.c.). Sublimation of the recovered brown oil at 110—115°/5 mm. yielded crystalline material (140 mg.), which, on recrystallisation from light petroleum, gave needles of 17-norkauran-16-one, m. p. and mixed m. p. 117°.

Oxidation of 16-*Hydroxykauran*-17-*oic Acid* (V).—The hydroxy-acid (68 mg.), in glacial acetic acid (5 c.c.), was heated at 90° with sodium bismuthate (75 mg.; assayed as 84·5% pure) for 4 hr. To the cooled solution an equivalent amount of phosphoric acid was added and the precipitated bismuth removed. Concentration of the filtrate, *in vacuo*, followed by repeated crystallisation of the residue from aqueous methanol yielded 17-norkauran-16-one (45 mg.), m. p. and mixed m. p. 113—115°. The 2,4-dinitrophenylhydrazone had m. p. and mixed m. p. 242—243°.

Reduction of 17-*Norkauran*-16-*one* (IV).—An ethanolic solution of the norketone (38 mg.), cooled in carbon dioxide, was treated with sodium borohydride (10 mg.), and the mixture kept in the cold for ½ hr., and then at room temperature for 24 hr. The product recovered from the concentrated solution, after repeated crystallisation from aqueous ethanol, yielded fine needles of 17-*norkauran*-16β-*ol* (VII) (30 mg.), m. p. 160—161° (Found: C, 82·7; H, 11·6. $C_{19}H_{32}O$ requires C, 82·5; H, 11·7%), $\nu_{max.}$ 3333 (OH), 1116 and bands between 1339 and 1263 cm.$^{-1}$ (secondary OH).

Permanganate Oxidation of Isokaurene in Anhydrous Acetone.—Isokaurene (8 g.), in dry acetone, was treated with potassium permanganate (9·3 g.; 3 atoms of oxygen), portionwise, with stirring during 1 hr. and the mixture kept at room temperature for 2 days. The oxidation products were isolated as follows:

(*a*) 13β-*Acetyl*-5β,9β,10α-*podocarpane*-8-*carboxylic acid* (X). The precipitated manganese dioxide was removed, washed with dilute sodium carbonate solution (100 c.c.), and finally with

hot water (1 l.). Acidification of the aqueous filtrate gave a flocculent precipitate (A) (2·61 g.). Treatment of a suspension of the manganese dioxide in water with sulphur dioxide until colourless gave a small amount of solid which was added to (A). Repeated crystallisation of this solid afforded 13β-*acetyl*-5β,9β,10α-*podocarpane*-8-*carboxylic acid* (2·01 g.), large needles, m. p. 140° (Found: C, 74·4; H, 10·1%; equiv. by microtitration with 0·1N-alkali, 322. $C_{20}H_{32}O_3$ requires C, 75·0; H, 10·1%; *M*, 320·5); $\nu_{max.}$ 3279 (OH), 1739 (lactonol C:O) and 1692 cm.$^{-1}$ (weak, CO_2H); (in carbon tetrachloride) 1718 (C:O) and 1692 cm.$^{-1}$ (CO_2H). The acid gave a positive test with Brady's reagent and when treated with iodine–potassium iodide solution in aqueous alkali yielded iodoform, m. p. and mixed m. p. 121—122°.

The residue (600 mg.) from the mother liquors of the above purification was treated under reflux with Girard's reagent P (1·5 g.) in ethanol (50 c.c.)–glacial acetic acid (5 c.c.) for 4 hr. Appropriate working up and crystallisation from aqueous methanol afforded a further 500 mg. of the pure acid.

(*b*) 16-*Hydroxykauran*-15-*one* (IX) and *kaurane*-15α,16-*diol* (VIII). Acetone was removed from the original oxidation solution. The residue was taken up in ether, freed from traces of acids by extraction with sodium hydroxide solution, and recovered, to yield 4·67 g. of neutral material. A solution of this in ethanol (100 c.c.) and glacial acetic acid (10 c.c.) was heated under reflux with Girard's reagent P (5 g.) for 6 hr. Water (500 c.c.) was added to the cooled solution (B) which was extracted with ether (3 × 250 c.c.). The gum obtained from the extract was triturated with light petroleum (10 c.c.) to give a soluble fraction (C) and an insoluble fraction (D) (4·49 g.).

The insoluble fraction (D), dissolved in the minimum amount of benzene, was chromatographed on activated alumina (Grade II) in light petroleum, and empirical fractions (200 c.c.) were eluted with the following successive solvents: light petroleum (fraction 1); light petroleum–benzene (1 : 1; fractions 2—3); benzene (fractions 4—15); benzene–ether (1 : 1; fractions 16—17); ether (fractions 18—20). Fraction 1 contained isokaurene (20 mg.), m. p. and mixed m. p. 57—60°, while fraction 4 contained a trace of an unidentified ketone, m. p. 147°, $\nu_{max.}$ 1718 (C:O) cm.$^{-1}$.

Repeated purification of the solids from fractions 5—14 by slow evaporation of acetone solutions gave an acetone solvate of 16-*hydroxykauran*-15-*one* (2·1 g.), which formed microcrystalline needles, m. p. 180—181° (Found, for sample dried at room temp.: C, 75·9; H, 10·5. $C_{20}H_{32}O_2,C_3H_6O$ requires C, 76·2; H, 10·6%. Found, for sample dried at 100°: C, 78·8; H, 10·7. $C_{20}H_{32}O_2$ requires C, 78·9; H, 10·6%); $\nu_{max.}$ 3279 (OH) and 1736 cm.$^{-1}$ (C:O). The 2,4-*dinitrophenylhydrazone*, after chromatography in benzene solution on alumina and crystallisation from chloroform–methanol, formed yellow needles, m. p. 166—168° with softening at 160° (Found: N, 11·7. $C_{26}H_{36}N_4O_5$ requires N, 11·6%). The *acetate*, formed by the action of acetic anhydride–pyridine, crystallised from methanol as large plates, m. p. 181—182° (Found: C, 75·9, 76·25; H, 9·75, 9·6; Ac, 12·35. $C_{22}H_{34}O_3$ requires C, 76·3; H, 9·9; Ac, 12·4%); $\nu_{max.}$ 1745 and 1250 cm.$^{-1}$ (Ac). The *benzoate*, formed by the action of benzoyl chloride–pyridine, crystallised from methanol as long needles, m. p. 154—154·5° (Found: C, 79·4; H, 8·8. $C_{27}H_{36}O_3$ requires C, 79·4; H, 8·9%); $\nu_{max.}$ 1745 (C:O) and 1724 cm.$^{-1}$ (Bz).

Repeated crystallisation of the solids from fractions 16—18 from acetone–light petroleum with slow evaporation gave *kaurane*-15α,16-*diol* (250 mg.), as needles, m. p. 184—186° (Found: C, 78·7; H, 11·3. $C_{20}H_{34}O_2$ requires C, 78·4; H, 11·2%); $\nu_{max.}$ 3333, 1106, and bands at 1304—1266 cm.$^{-1}$ (OH). The *diacetate*, formed by the action of acetic anhydride–pyridine, after successive crystallisation from ligroin–methanol and aqueous ethanol, formed needles, m. p. 116—117° (Found: C, 73·45; H, 9·5. $C_{24}H_{38}O_4$ requires C, 73·8; H, 9·8%); $\nu_{max.}$ 1736 and 1250 cm.$^{-1}$ (Ac). The diol could be recovered by hydrolysis with 2N-methanolic potassium hydroxide solution.

The *dibenzoate*, formed by the action of benzoyl chloride and pyridine, after repeated crystallisation from methanol–ligroin and then ethanol, formed needles, m. p. 169—170° (Found: C, 79·5; H, 8·7. $C_{34}H_{42}O_4$ requires C, 79·3; H, 8·2%); $\nu_{max.}$ 1715 and 1701 cm.$^{-1}$ (Bz).

(*c*) The soluble fraction (C) was concentrated and chromatographed on activated alumina (Spence, Grade H). Fractions eluted with light petroleum gave a gum which afforded isokaurene (117 mg.), m. p. and mixed m. p. 60—61°, after crystallisation from ethanol with carbon dioxide cooling.

Fractions eluted with ether afforded kaurane-15α,16-diol (20 mg.), m. p. and mixed m. p. 182—184°, after crystallisation from acetone–light petroleum with slow evaporation.

(*d*) The aqueous solution (B) on acidification gave a small yield of a mixture of two unidentified ketones, separated by chromatography of the 2,4-dinitrophenylhydrazones on alumina, but not obtained pure.

Oxidation of Isokaurene.—(*a*) *With osmium tetroxide.* Isokaurene (700 mg.), in ether (50 c.c.), was treated with osmium tetraoxide (1 g.) for 48 hr. at room temperature, and the solution then saturated with hydrogen sulphide and filtered. The material recovered from the filtrate, after crystallisation from acetone–light petroleum, formed needles of kaurane-15α,16-diol (570 mg.), m. p. and mixed m. p. 186°.

(*b*) *With osmium tetroxide and t-butyl hydroperoxide at room temperature.* A solution of isokaurene (4 g.) osmium tetroxide (6 mg.), and t-butyl hydroperoxide (1·32 g.) was kept at room temperature for 12 days. The solvent was removed *in vacuo* and the resultant needles chromatographed on alumina (Grade I—II). Elution with light petroleum gave isokaurene (3·92 g.), m. p. and mixed m. p. 63°; elution with ether afforded kaurane-15α,16-diol (72 mg.), m. p. and mixed m. p. 186°.

(*c*) *With osmium tetroxide and t-butyl hydroperoxide at* 50°. A solution of isokaurene (3·92 g.), osmium tetroxide (40 mg.), and t-butyl hydroperoxide (13·5 g.) in t-butyl alcohol (20 c.c.) was maintained at 50° for 48 hr. The solvent was removed *in vacuo* at 100° and the product chromatographed on alumina (Grade I—II) with light petroleum, benzene, and ether–methanol (10 : 1) as successive eluants. The light petroleum eluate yielded isokaurene (27 mg.), m. p. and mixed m. p. 63°. The other eluants both yielded needles of 16-hydroxykauran-15-one (1·7 g.), m. p. and mixed m. p. 180—181°, when an acetone solution was slowly evaporated.

Reduction of 16-Hydroxykauran-15-one (IX).—The ketol (1·3 g.), in ethanol (20 c.c.), was treated with potassium borohydride (500 mg.) at room temperature for 24 hr. Chromatography on alumina (Grade I—II) and elution with ether and methylene chloride afforded kaurane-15α,16-diol (796 mg.), m. p. and mixed m. p. 186°.

Oxidation of 16-Hydroxykauran-15-one (IX) *with Periodic Acid.*—Periodic acid (50%; 460 mg., 4 moles) was added to the ketol (173 mg.) in ethanol (5 c.c.), and the solution warmed on the water-bath for 2 min. and then kept at room temperature for 16 hr. After addition of water the product was crystallised repeatedly from aqueous methanol to give the *γ-lactone* (XII) of 13α-acetyl-13β-hydroxy-5β,9β,10α-podocarpane-8-carboxylic acid as rods, m. p. 166·5—167° (Found: C, 75·4; H, 9·3. $C_{20}H_{30}O_3$ requires C, 75·4; H, 9·5%); $\nu_{max.}$ 1789 (γ-lactone), 1718 cm.$^{-1}$ (C:O).

The 2,4-*dinitrophenylhydrazone* crystallised from chloroform–methanol as yellow needles, m. p. 248—250° (Found: N, 11·0. $C_{26}H_{34}N_4O_6$ requires N, 11·2%). The *oxime* crystallised from aqueous methanol as plates, m. p. 210—211° (Found: C, 72·0; H, 9·3. $C_{20}H_{31}NO_3$ requires C, 72·0; H, 9·4%); $\nu_{max.}$ 1773 cm.$^{-1}$ (γ-lactone).

Oxidation of Kaurane-15α,16-diol (VIII) *with Periodic Acid.*—Periodic acid (50%; 650 mg.) was added to a solution of kaurane-15α,16-diol (550 mg.) in ethanol (25 c.c.), and the mixture warmed on the water-bath and kept at room temperature for 2 hr. Water was added and the product (364 mg.) recovered by extraction with chloroform. Chromatography in light petroleum on alumina (Spence, grade H) and elution with benzene–light petroleum (1 : 1) gave an amber-coloured oil (290 mg.); $\nu_{max.}$ (in carbon tetrachloride) 1739 and 1715 cm.$^{-1}$ (C:O), which resisted attempts at crystallisation. The oil gave a positive iodoform test and reduced ammoniacal silver nitrate.

The *mono-2,4-dinitrophenylhydrazone* of 13β-acetyl-5β,9β,10α-podocarpan-8-aldehyde (XIII), after chromatography on alumina (Grade I—II) in benzene and four crystallisations from chloroform–methanol, formed yellow needles, m. p. 143—145° (Found: C, 64·2; H, 7·7; N, 11·8. $C_{26}H_{36}N_4O_5$ requires C, 64·4; H, 7·5; N, 11·6%); $\nu_{max.}$ 1712 cm.$^{-1}$ (C:O). This derivative also gave a positive iodoform test.

Oxidation of 13β-Acetyl-5β,9β,10α-podocarpan-8-aldehyde (XIII).—8N-Chromic acid–sulphuric acid was added, dropwise, to a solution of the keto-aldehyde (247 mg.) in acetone (5 c.c.) until the brown colour persisted. The mixture was warmed and then kept at room temperature for 30 min. Dropwise addition of water precipitated an amorphous solid (174 mg.) which, after repeated crystallisation from ethanol, yielded the lactone (XII), m. p. and mixed m. p. 166·5—167°.

Oxidation of 13β-Acetyl-5β,9β,10α-podocarpane-8-carboxylic Acid (X) *with Pertrifluoroacetic Acid.*—The keto-acid (427 mg.), in methylene chloride (3 c.c.), was added dropwise to a cooled and stirred solution of trifluoroperoxyacetic acid, prepared from trifluoroacetic anhydride

(0·435 c.c.) and hydrogen peroxide (65% solution; 0·12 c.c.). The mixture was maintained at 0° for 15 min., heated under reflux on the water-bath for 30 min., and hydrolysed by treatment with boiling 2N-methanolic potassium hydroxide for 1 hr. Most of the solvent was removed, the product obtained on pouring into water was chromatographed in benzene on silica gel, and empirical fractions (25 c.c.) were collected.

Fractions 4—7, eluted with benzene and benzene–chloroform (1 : 1), yielded material which was repeatedly crystallised from aqueous methanol to form small needles (85 mg.) of the *lactone* (XV), m. p. 125—126° (Found: C, 78·2; H, 9·9. $C_{18}H_{28}O_2$ requires C, 78·2; H, 10·2%); $\nu_{max.}$ (in carbon tetrachloride) 1778 cm.$^{-1}$ (γ-lactone).

Material obtained from fractions 8—13, eluted with chloroform, and fractions 14—24, eluted with chloroform–methanol, when recrystallised from aqueous methanol formed needles (230 mg.) of 13β-*hydroxy*-5β,9β,10α-*podocarpane*-8-*carboxylic acid* (XIV; R = H), m. p. 254—256°, with sintering at 127° (Found: C, 73·3; H, 10·4. $C_{18}H_{30}O_3$ requires C, 73·4; H, 10·3%); $\nu_{max.}$ 3472 (OH) and 1689 cm.$^{-1}$ (CO_2H).

Hunsdiecker reaction on the silver salt of the hydroxy-acid (XIV; R = H) following Grant and Hodges's method [24] for 13α-hydroxypodocarpane-8-carboxylic acid, gave the γ-lactone (XV), m. p. and mixed m. p. 123—125°.

Methylation of the hydroxy-acid (XIV; R = H) with an ethereal solution of diazomethane afforded the *methyl ester* (XIV; R = Me), which crystallised from aqueous methanol as fine needles, m. p. 109—111° (Found: C, 74·1; H, 10·2. $C_{19}H_{32}O_3$ requires C, 74·0; H, 10·5%); $\nu_{max.}$ 3333 (OH) and 1730 cm.$^{-1}$ (ester C:O).

Oxidation of 13β-*Hydroxy*-5β,9β,10α-*podocarpane*-8-*carboxylic Acid*.—A stirred solution of the hydroxy-acid (40 mg.), in dry acetone (5 c.c.), was treated, dropwise, with 8N-chromic acid–sulphuric acid. The mixture was warmed on the water-bath for 5 min., kept at room temperature for 30 min., and then poured into water. Crystallisation of the product from aqueous methanol gave 13-*oxo*-5β,9β,10α-*podocarpane*-8-*carboxylic acid* (XVI; R = H) as needles (35 mg.), m. p. 169—170° (Found: C, 73·9; H, 9·8. $C_{18}H_{28}O_3$ requires C, 73·9; H, 9·65%); $\nu_{max.}$ (in carbon tetrachloride) 1718 (C:O), 1698 cm.$^{-1}$ (CO_2H). Rotatory dispersion (*c* 0·04) in methanol, $[\alpha]_{700}$ +20°, $[\alpha]_{589}$ −20°, $[\alpha]_{305}$ +150°, $[\alpha]_{260}$ −438°, $[\alpha]_{252}$ −435°.

Reduction of the oxo-acid (22 mg.), in methanol (5 c.c.), with sodium borohydride (40 mg.) at room temperature for 12 hr. followed by acidification, gave the lactone (XV; 15 mg.), m. p. and mixed m. p. 124—126°.

Oxidation of Methyl 13β-*Hydroxy*-5β,9β,10α-*podocarpane*-8-*carboxylate* (XIV; R = Me).—Oxidation of the methyl ester (35 mg.) with 8N-chromic acid in the previous manner gave a resin which could not be crystallised before or after chromatography on alumina. Sublimation at 100—110°/5 mm., gave microneedles (4·5 mg.) of the *oxo-ester* (XVI; R = Me), m. p. 115—116° (Found: C, 74·8; H, 10·1. $C_{19}H_{30}O_3$ requires C, 74·5; H, 9·9%); rotatory dispersion (*c* 0·12) in methanol, $[\alpha]_{650}$ 0°, $[\alpha]_{589}$ +1·6°, $[\alpha]_{340}$ +40·4°, $[\alpha]_{313}$ +88·7°, $[\alpha]_{270}$ −167°, $[\alpha]_{250}$ −92°.

Methylation of the oxo-acid (XVI; R = H) with an ethereal solution of diazomethane gave a further yield of the same ester, m. p. and mixed m. p. 115—116° resin (identical infrared spectrum).

One of the authors (L. H. B.) gratefully acknowledges assistance from the Chemical Society, the Rockefeller Foundation of New York, the Australian and New Zealand Association for the Advancement of Science, and the Research Grants Committee of the University of New Zealand. Three of them (B. F. C., B. R. D., and P. S. R.) are indebted for Research Fund Fellowships.

Department of Chemistry, University of Auckland,
New Zealand. [*Received, December 8th*, 1961.]