Buffered Acetolyses of the Toluene-*p*-Sulphonates of *exo*- and *endo*-17-Norkauran- and 17-Norphyllocladan-16-ols [1]

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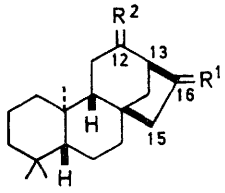
The norkauranol tosylates (IXa) and (Xa) each furnished six acetates and three olefins on solvolysis. The equivalent norphyllocladane esters (IIIa) and (Va) gave the enantiomers of these six acetates, one additional acetate (XXIIb), and only one olefin (VI). These transformations provided a route for the conversion of (−)-kaurene (VII) into (−)-phyllocladene [*enantio*-(VIII)], (−)-atiserene (XXIX), and (−)-neoatiserene (XXX) and could in principle be utilised for the formation of (+)-kaurene, (+)-atiserene, and (+)-neoatiserene from (+)-phyllocladene. Mechanistic aspects of the solvolyses are discussed; in particular, a pathway, which includes a 1,2-hydride shift from C-15 to C-16, is tentatively suggested as a rationalisation of the high yield of (VI) from (Va).

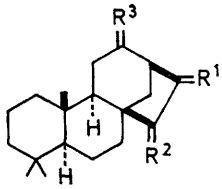
A RECENT examination [2a] of the solvolytic behaviour of *exo*- and *endo*-bicyclo[3,2,1]octan-6-yl toluene-*p*-sulphonates was undertaken as an extension of our studies [2b] of the acid-catalysed rearrangement of the bicyclic portion of several tetracyclic diterpene hydrocarbons. The present investigation represents a further extension of this work in which the composition of the solvolysis products from *exo*- and *endo*-6-substituted bicyclo-[3,2,1]octanes has been determined for cases when these systems constitute portions of certain tetracyclic diterpenoid skeletons. At present two such *exo,endo*-pairs are known. One pair is derived from 17-norkaurane (I), the other from 17-norphyllocladane (II), and in these the ethano-bridge is respectively *anti* and *syn* to the C-10 methyl group.

Two groups have studied the solvolysis of norphyllocladanol esters. The solvolysis of arenesulphonates of 17-norphyllocladan-16β-ol (III) in buffered acetic acid was reported, by Briggs and his co-workers [3] to give, surprisingly, 17-norphyllocladan-16-one (IV) as the only isolable product. Turner and his co-workers [4] found that the tosylate of the epimeric 16-ol (V) on buffered acetolysis yielded mainly olefinic material and only traces of acetates. The olefinic fraction, on the basis of i.r. analysis, appeared to be largely norphyllocladene (VI).

In the present study (−)-kaurene (VII) and (+)-phyllocladene (VIII) were converted [5] with osmium tetroxide–sodium periodate into the corresponding 17-norketones [3–6] which on reduction with lithium aluminium hydride gave *endo*-norkauranol [6] (IX) and *endo*-norphyllocladanol [3] (III), respectively. These two compounds, on equilibration with sodium n-butoxide in n-butanol, furnished the *exo*-isomers (X) and (V).[4] The four tosylates (IIIa†),[4] (Va),[4] (IXa), and (Xa) were then prepared and individually subjected to buffered acetolysis at 100° and the nature and distribution of the products were determined (see Tables 1 and 2). The compositions of the olefinic fractions were determined by a combination of chromatography over silica gel impregnated with silver nitrate and gas–liquid chromatography. The norditerpenes (VI),[7] (XI), and (XII) required for comparison were prepared from the alcohols (V), (X), and



(I) $R^1 = R^2 = H_2$
(VII) $R^1 = CH_2$, $R^2 = H_2$
(IX) $R^1 = H,\beta\text{-OH}$, $R^2 = H_2$
(X) $R^1 = H,\alpha\text{-OH}$, $R^2 = H_2$
(XIV) $R^1 = O$, $R^2 = H_2$
(XXI) $R^2 = O$, $R^1 = H_2$
(XXV) $R^2 = H,\alpha\text{-OH}$, $R^1 = H_2$



(II) $R^1 = R^2 = R^3 = H_2$
(III) $R^1 = H,\beta\text{-OH}$, $R^2 = R^3 = H_2$
(IV) $R^1 = O$, $R^2 = R^3 = H_2$
(V) $R^1 = H,\alpha\text{-OH}$, $R^2 = R^3 = H_2$
(VIII) $R^1 = CH_2$, $R^2 = R^3 = H_2$
(XIX) $R^2 = O$, $R^1 = R^3 = H_2$
(XX) $R^3 = O$, $R^1 = R^2 = H_2$
(XXII) $R^2 = H,\alpha\text{-OH}$, $R^1 = R^3 = H_2$
(XXIV) $R^3 = H,\alpha\text{-OH}$, $R^1 = R^2 = H_2$

(XIII) by elimination of toluene-*p*-sulphonic acid from the derived tosylates.

Analysis of the acetate mixtures was more laborious, since they could not be separated by either t.l.c. or g.l.c. However, reduction of each mixture with lithium aluminium hydride gave the corresponding alcohols, which were separated by preparative t.l.c. into fractions consisting of either individual components or mixtures

† The letters 'a' and 'b' following a Roman numeral refer to the derived tosylate and acetate respectively throughout this paper.

[1] For a preliminary account of part of this work see R. A. Appleton, P. A. Gunn, and R. McCrindle, *Chem. Comm.*, 1968, 1131.

[2] (*a*) R. A. Appleton, J. C. Fairlie, R. McCrindle, and W. Parker, *J. Chem. Soc.* (*C*), 1968, 1716; (*b*) R. A. Appleton, A. J. McAlees, A. McCormick, R. McCrindle, and R. D. H. Murray, *ibid.*, 1966, 2319.

[3] L. H. Briggs, B. F. Cain, R. C. Cambie, and B. R. Davis, *J. Chem. Soc.*, 1962, 1840.

[4] R. B. Turner, K. H. Ganshirt, P. E. Shaw, and J. D. Tauber, *J. Amer. Chem. Soc.*, 1966, **88**, 1776.

[5] H. Vorbrueggen and C. Djerassi, *J. Amer. Chem. Soc.*, 1962, **84**, 2990.

[6] L. H. Briggs, B. F. Cain, R. C. Cambie, B. R. Davis, P. S. Rutledge, and J. K. Wilmhurst, *J. Chem. Soc.*, 1963, 1345.

[7] R. Henderson and R. Hodges, *Tetrahedron*, 1960, **11**, 226.

TABLE 1

Approximate composition (%) of acetate fraction * from buffered acetolysis of (IIIa), (Va), (IXa), and (Xa)

	(Xa)	(IXa)		(Va)	(IIIa)
(Xb)	30	45	*enantio*-(Xb)	†	+
enantio-(Vb)	5	5	(Vb)	†	50
(XIIIb)	20	15	*enantio*-(XIIIb)	†	10
(XXIIIb)	25	15	*enantio*-(XXIIIb)	†	5
(XXb)	10	10	*enantio*-(XXVb)	†	20
enantio-(XXIVb)	10	10	(XXIVb)	†	5
enantio-(XXIIb)	0	0	(XXIIb)	†	10

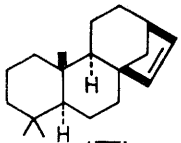
* Total yield of acetates formed from (Xa), 90%; (IXa), 85%; (Va), 20%; (IIIa), 75%. † Detected but yield not determined. Values should be accurate to ±3%.

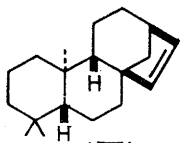
TABLE 2

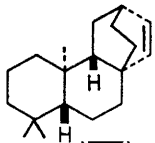
Approximate composition of olefin fraction (%)

	(Xa)	(IXa)		(Va)	(IIIa)
enantio-(VI)	20	20	(VI)	100	100
(XI)	45	55			
(XII)	35	25			

of only two components. These two-component mixtures when oxidised furnished in each case two ketones, separable by t.l.c. The single components were also separately converted into the corresponding ketones.

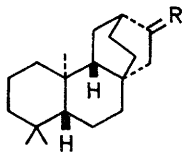

(VI)

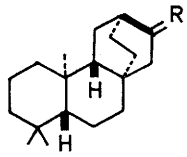

(XI)


(XII)

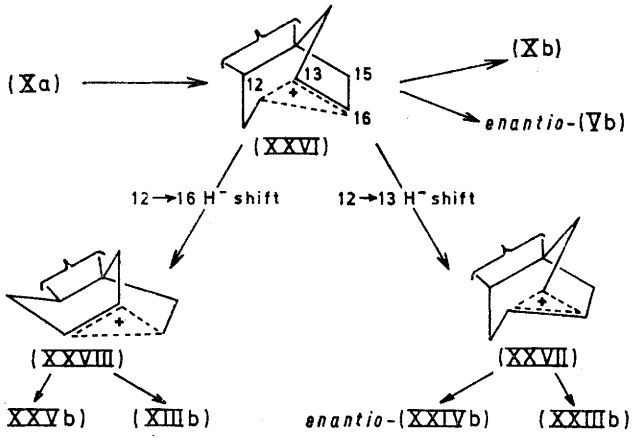
Seven ketones were obtained in all, and of these, two, 17-norkauran-16-one [6] (XIV) and 17-norphyllocladan-16-one [3-5] (IV), were already available for direct comparison. An authentic sample of 17-noratisan-16-one [8,9] [*enantio*-(XV)] was prepared from (+)-phyllocladene *via* the ketol (XVI) by base catalysed cyclisation of the derived tosylate (XVIa). 17-Noratisan-13-one [8] (XVII) was prepared by a similar route from (−)-kaurene *via* the ketol (XVIII) and the tosylate (XVIIIa). The spectral and physical characteristics of the fifth ketone coincided with those reported [4,7] for 17-norphyllocladan-15-one (XIX). The constitution of the remaining two ketones, (XX) and (XXI), was inferred from (*a*) their conversion into 17-norphyllocladane [7] and 17-norkaurane, which were also obtained, for g.l.c. comparison, by a modified [10] Wolff–Kishner reduction of the 16-ketones, and (*b*) the i.r. carbonyl stretching frequencies. Assignment of the oxygen function to C-12 rather than to C-11 is favoured on the basis of the mechanism of the solvolytic rearrangement, which presumably follows the behaviour [2a] of the parent bicyclo[3,2,1]octyl system.

The configurations of the hydroxy-groups in the alcohols derived from the acetate fraction are formulated as shown on the basis of the following considerations. The *exo*-orientation of the functional groups in norkauran-16-ol (X) and norphyllocladan-16-ol (V) was established by direct comparison with authentic specimens; the physical properties [7] of the norphyllocladan-15-ol (XXII) showed it to be the *exo*-isomer also. The noratisan-13-ol (XIII) derived from the acetolysis product was also prepared by reduction of the ketone (XVII) with lithium aluminium hydride and is therefore probably the α-isomer. Configurations are tentatively assigned to the other three alcohols (XXIII), (XXIV), and (XXV) solely on the basis of the supposed mechanism for their formation (see later).


(XIII) R = H,α-OH
(XVII) R = O
(XXX) R = CH_2


(XV) R = O
(XXIII) R = H,β-OH
(XXIX) R = CH_2

We first discuss the formation of the acetates obtained by acetolysis from the tosylates (IXa) and (Xa). The solvolysis of the tosylate of *exo*-norkauranol (Xa) gave six acetates (see Table 1). In view of the behaviour [2a] of the parent bicyclo[3,2,1]octyl system a mechanistic scheme (see Scheme) can be formulated as the major



SCHEME

pathway to these products. Ionisation of (Xa) with participation of the 12,13 σ-bond gives the non-classical ion (XXVI),* which can (*a*) suffer solvent capture at either C-13 or C-16 to give *enantio*- (Vb) and (Xb) respectively; (*b*) undergo a 12,13 hydride shift which leads to the ion (XXVII), from which (XXIIIb) and *enantio*- (XXIVb) can be derived; or (*c*) undergo a 12,16 hydride shift leading to the ion (XXVIII), which can furnish (XIIIb) and (XXVb). The intervention of these bridged ions would explain the stereospecificity of

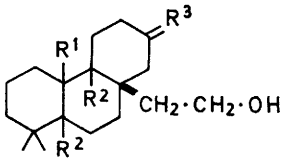
* Non-classical ion formulations are used only for convenience. We do not wish to rule out the possibility of equilibrating classical ions as intermediates.

[8] L. H. Zalkow and N. N. Girotra, *J. Org. Chem.*, 1964, **29**, 1299.

[9] R. A. Bell, R. E. Ireland, and R. A. Partyka, *J. Org. Chem.*, 1966, **31**, 2530.

[10] D. J. Cram, M. R. V. Sakyun, and G. R. Knox, *J. Amer. Chem. Soc.*, 1962, **84**, 1734.

product formation, only one epimer being isolated in each of the six cases. The *endo*-tosylate (IXa) furnished the same six acetates. The product distribution appears to indicate that in this case ionisation can lead either directly to the *exo*-acetate (Xb) or presumably *via* a classical C-16 carbonium ion to the mesomeric ion



(XVI) R^1 = β-Me, R^2 = α-H, R^3 = O
(XVIII) R^1 = α-Me, R^2 = β-H, R^3 = O
(XXXI) R^1 = β-Me, R^2 = α-H, R^3 = H,β-OH
(XXXII) R^1 = α-Me, R^2 = β-H, R^3 = H,β-OH

(XXVI) and thence to the six acetates as before (see Scheme).

Analogous considerations probably apply to the solvolysis of the *exo*- and *endo*-derivatives of norphyllocladane (IIIa) and (Va) as far as acetate products are concerned, although in the case of the *exo*-isomer the yield of acetates was so low that no estimate could be made of the relative amounts produced. However in these solvolyses an additional product, the 15-acetate (XXIIb) of norphyllocladane, was formed. In the phyllocladane skeleton there is severe steric compression between the C-10 methyl group and the *endo*-hydrogen atom at C-15. This strain is relieved when C-15 becomes sp^2-hybridised and thus products resulting from a 1,2 hydride shift from C-15 to C-16 on solvolysis of a 16-tosylate are to be expected.

We next consider the olefins obtained in these solvolysis experiments. The only olefins isolated from reaction of the norkaurane derivatives were (XI), *enantio*- (VI), and (XII). The latter pair may well be derived from the ions (XXVI) and (XXVIII), which are involved in the formation of the corresponding acetates *enantio*- (Vb) and (XIIIb). Significantly, there is considerable interaction between the C-15 methylene and the C-10 methyl group in these two acetates. In the norphyllocladane series only the Δ^{15}-olefin (VI) related to the parent system was isolated. Notable here however is the high proportion of the total product which the olefin constitutes, especially in the case of the *exo*-form (*ca.* 80%). Presumably, the reduction in the amount of steric compression between C-15 and C-20 when C-15 becomes sp^2-hybridised is again a major factor. This argument should apply to a similar extent to (IIIa) and (Va). However, the formation of a much larger proportion of olefin from the *exo*- than from the *endo*-tosylate may reflect the fact that it is the *endo*-proton attached to C-15 which is strongly compressed against the C-10 methyl group. Loss of this proton as C-15 becomes trigonal may then be especially favoured even although its orientation (*trans*) with respect to the tosylate function in the *exo*-ester is analogous to that of its geminal counterpart in the *endo*-ester. There appear to be at least two possible pathways for formation of (VI) from (Va). The first, direct *trans*-elimination of toluene-*p*-sulphonic acid, involves removal of the *endo*-proton from C-15 and the ester function from C-16. However molecular models reveal that loss of this proton by such a mechanism may not be favoured for two reasons. Elongation of the σ-bond joining the *endo*-hydrogen atom to C-15 appears to produce even more severe steric interactions with the C-10 methyl group, and also access to this proton by external base is restricted by steric crowding. A second and perhaps more attractive possibility involving a 1,2 hydride shift from C-15 to C-16 * as heterolysis proceeds would form a C-15 cation, which could then either capture solvent (see before) or lose a proton from C-16 to give (VI) in which C-15 remains trigonal. Experiments now being carried out may allow an estimate of the relative importance of these two pathways. However, some other mechanism (*e.g.* cyclic) may play a major part in the elimination.

Treatment of the ketones *enantio*- (IV), (XV), and (XVII) with methylenetriphenylphosphorane in ether gave (−)-phyllocladene [*enantio*- (VIII)], (−)-atisirene[8,9] (XXIX), and (−)-neoatisirene[13] (XXX). Thus the solvolyses of the norkauranol tosylates provides a route for the conversion of (−)-kaurene into these three diterpenes. In principle the ketones derived *via* the nor-tosylates from (+)-phyllocladene could be utilised for the formation of (+)-kaurene, (+)-atisirene, and (+)-neoatisirene.

EXPERIMENTAL

T.l.c. was carried out on Kieselgel G (Merck). Woelm alumina (neutral) was used for column chromatography. G.l.c. analyses were performed with a Perkin-Elmer F11 gas chromatograph [stainless steel column ($\frac{1}{16}$ in. × 13 ft.) containing 2½% SE-30 at 190°C; nitrogen gas pressure 17 lb./in.^{2}].

M.p.s were determined with a Kofler hot-stage apparatus. Specific rotations refer to solutions in chloroform (*c* 0·5—1, unless otherwise stated) at 20°. Light petroleum refers to the fraction of b.p. 60—80°. I.r. spectra were recorded for solutions in carbon tetrachloride with a Perkin-Elmer 257 grating spectrophotometer, and n.m.r. spectra with Perkin-Elmer R10 and Varian Associates HA-100 spectrometers for dilute solutions in deuteriochloroform or benzene with tetramethylsilane as internal standard. Microanalyses were performed by Mr. J .M. L. Cameron, Glasgow, and his staff.

17-*Norkauran*-16-*one* (XIV).—The norketone was prepared from (−)-kaurene (VII) (m.p. 51—52°, $[\alpha]_D$ −78°) by the osmium tetroxide–sodium periodate method.[5] The

* The major product, phyllocladan-15-one, obtained from treatment[7,11,12] of isophyllocladene epoxide with Lewis acids results from such a 1,2-hydride shift. In contrast, similar treatment of the equivalent derivative of isokaurene gives[11] mainly the allylic primary alcohol.

[11] L. H. Briggs, R. C. Cambie, and P. S. Rutledge, *J. Chem. Soc.*, 1963, 5374.
[12] J. G. St. C. Buchanan and B. R. Davis, *Chem. Comm.*, 1967, 1142.
[13] L. H. Zalkow and A. C. Oehlschalager, *J. Org. Chem.*, 1967, **32**, 808.

product gave needles, m.p. 116—119° (from aqueous methanol) (lit.,[6] 117°), $\nu_{max.}$ 1742 cm.$^{-1}$, τ 8·91, 9·13, and 9·17 (all 3H, s).

The Tosylate (IXa) *of* 17-*Norkauran*-16β-*ol*.—The ketone (XIV) (1 g.) was treated with excess of lithium aluminium hydride in refluxing dry ether for 1 hr. Work-up with a saturated aqueous solution of sodium sulphate furnished a mixture of the α- and β-16-ols (*ca.* 1 : 5) (952 mg.). These alcohols on preparative t.l.c. [ethyl acetate–light petroleum (3 : 17)] yielded the β-epimer (806 mg.) as fine needles, m.p. 162—163° (from aqueous ethanol) (lit.,[6] 160—161°), τ 8·95, 9·15, and 9·18 (all 3H, s), and 5·70 (1H, m, width 30 Hz). Chilled solutions of this alcohol (IX) (500 mg.) in dry pyridine (6 ml.) and toluene-*p*-sulphonyl chloride (650 mg.) in the same solvent (4 ml.) were mixed and kept at 18° for 12 hr. Work-up gave the tosylate (IXa) as an oil (754 mg.), which showed one spot on t.l.c. [(ethyl acetate–light petroleum (1 : 9)], τ 7·58, 8·97, 9·16, and 9·21 (all 3H, s), 5·21 (1H, m), and 2·40 (4H, q).

The Tosylate (Xa) *of* 17-*Norkauran*-16α-*ol*.—Sodium (2 g.) was dissolved in n-butanol (40 ml.) and the alcohol (IX) (200 mg.) was heated in the resulting solution at reflux for 1 hr. Preparative t.l.c. of the products furnished 17-*norkauran*-16α-*ol* (X) (133 mg.) and starting material (54 mg.). The former gave fine needles, m.p. 159—160° (from aqueous ethanol), τ 8·98, 9·14, and 9·18 (all 3H, s), and 5·92 (1H, m, $W_{\frac{1}{2}}$ 14 Hz) (Found: C, 82·7; H, 11·95. $C_{19}H_{32}O$ requires C, 82·55; H, 11·65%). The *tosylate* (Xa) was prepared as described for the β-isomer; m.p. 132—133° (from methanol), τ 7·56, 8·98, 9·15, and 9·18 (all 3H, s), 5·35 (1H, m), and 2·41 (4H, q) (Found: C, 72·55; H, 8·85. $C_{26}H_{38}O_3S$ requires C, 72·5; H, 8·9%).

17-*Norphyllocladan*-16-*one* (IV).—Treatment [5] of (+)-phyllocladene (VIII) (m.p. 94—97°, $[\alpha]_D$ +15°) with osmium tetroxide–sodium metaperiodate gave the norketone (IV) which yielded needles, m.p. 99—102° (from methanol) (lit.,[3] 101—102°), $\nu_{max.}$ 1742 cm.$^{-1}$, τ 9·15 (6H, s) and 9·20 (3H, s).

The Tosylate (IIIa) *of* 17-*Norphyllocladan*-16β-*ol*.—The ketone (IV) (1 g.) was reduced with excess of lithium aluminium hydride in refluxing dry ether and the resulting mixture of *exo*- and *endo*-alcohols (1 : 9) (972 mg.) was separated by preparative t.l.c. The β-isomer (III) gave plates, m.p. 150—152° (from ethanol) (lit.,[7] 150—152°), τ 9·10, 9·17, and 9·20 (all 3H, s), and 5·65 (1H, m, width 30 Hz). The corresponding tosylate had m.p. 108—110° (from light petroleum) (lit.,[3] 107—108°), τ 7·58 (3H, s), 9·19 (6H, s), 9·21 (3H, s), 5·11 (1H, m), and 2·53 (4H, q).

The Tosylate (Va) *of* 17-*Norphyllocladan*-16α-*ol*.—Equilibration of the *endo*-alcohol (III) with sodium in n-butanol as already described furnished the *exo*-isomer (V), m.p. 155—156° (from ethanol) (lit.,[7] 156—157°), τ 9·12, 9·16, and 9·20 (all 3H, s), and 5·98 (1H, m, $W_{\frac{1}{2}}$ 12 Hz). The corresponding *tosylate* (Va) had m.p. 132—133° (from methanol) (isolated previously [4] as an oil), τ 7·56 (3H, s), 9·20 (6H, s), 9·25 (3H, s), 5·28 (1H, m), and 2·42 (4H, q) (Found: C, 72·55; H, 8·85. $C_{26}H_{38}O_3S$ requires C, 72·5; H, 8·9%).

Buffered Acetolyses.—Each tosylate (1 g.) was heated at 100° for 6 hr. in dry acetic acid (50 ml.) containing sodium acetate (300 mg.). The mixture was then poured into water and extracted with ether three times. The extracts were combined, washed with saturated aqueous sodium hydrogen carbonate and then brine, and dried ($MgSO_4$). Removal of the solvent *in vacuo* left in each case a colourless oil which ran on analytical t.l.c [ethyl acetate–light petroleum (1 : 9)] as two spots, one of intermediate, the other of very low, polarity. These oily products were each separated into olefinic and acetate fractions by chromatography over alumina (Grade I) with first light petroleum and then ether as eluant (for yields see footnote to Table 1).

Olefins.—The mixtures of olefins from the norkauranol *exo*- and *endo*-tosylates (Xa) and (IXa) were separated by preparative t.l.c. on silica gel impregnated with silver nitrate (10%), with ethyl acetate–light petroleum (1 : 99) as developing solvent. Both substrates gave three olefins (for yields see Table 2) identical (g.l.c., n.m.r. spectrum, and m.p.) with authentic samples of 17-norkaur-15-ene, 17-norphylloclad-15-ene, and 17-noratisir-13-ene. The only olefin isolated from the norphyllocladanol tosylates (IIIa) and (Va) was 17-norphylloclad-15-ene (VI), again identified by direct comparison with an authentic sample. The authentic samples were prepared by heating the tosylates (Va), (Xa), and (XIIIa) in refluxing collidine for 30 min. 17-Norphylloclad-15-ene (VI) gave plates, m.p. 71—72° (from aqueous methanol) (lit.,[7] 73°), τ 9·16, 9·20, and 9·27 (all 3H, s), and 4·23br (2H, s). 17-*Norkaur*-15-*ene* (XI) crystallised on sublimation and had m.p. 33—36°, τ 8·98, 9·17, and 9·21 (all 3H, s), 4·50 (1H, d, *J* 6 Hz), and 4·17 (1H, q, *J* 6 and 3 Hz) (Found: C, 88·35; H, 11·8. $C_{19}H_{30}$ requires C, 88·3; H, 11·7%). 17-*Noratisir*-13-*ene* (XII) after purification by preparative t.l.c. (SiO_2–$AgNO_3$ as before) and then sublimation had m.p. 41—46°, τ 9·10, 9·14, and 9·21 (all 3H, s), 4·60 (1H, q, *J* 10 and 4 Hz), and 4·04 (1H, m), *m/e* 258.

Acetates.—The acetate fractions were separately converted into mixtures of alcohols by treatment with excess of lithium aluminium hydride in refluxing dry ether for 1 hr.

The alcohols from both norkauranol tosylates (IXa) and (Xa) ran in each case as five spots on t.l.c. [ethyl acetate–light petroleum (1 : 6); developed twice]. Preparative t.l.c. gave five fractions which were treated as follows (in order of increasing polarity: the yields of the alcohols quoted in Table 1 were estimated from the quantities of each recovered from t.l.c.). Fraction one contained 17-*norkauran*-12-*ol* (XXV), m.p. 127—129° (from ethyl acetate–light petroleum), τ 8·84, 9·18, and 9·21 (all 3H, s), and 6·30 (1H, m, $W_{\frac{1}{2}}$ 13 Hz) (Found: C, 82·5; H, 11·5. $C_{19}H_{32}O$ requires C, 82·55; H, 11·65%). Fraction two gave 17-*noratisiran*-13α-*ol* (XIII), m.p. 129—130° (from ethyl acetate–light petroleum), τ 9·00, 9·18, and 9·22 (all 3H, s), and 6·10 (1H, m, $W_{\frac{1}{2}}$ 20 Hz) (Found: C, 82·7; H, 11·8%). Fraction three gave 17-*norphyllocladan*-12-*ol* [*enantio*-(XXIV)], m.p. 144—146° (from ethyl acetate–light petroleum), τ 9·12, 9·17, and 9·21 (all 3H, s), and 6·22 (1H, m, $W_{\frac{1}{2}}$ 9 Hz (Found: C, 82·35; H, 11·65%). A portion of the fourth fraction after repeated preparative t.l.c. [ethyl acetate–light petroleum (3 : 17)] gave 17-norphyllocladan-16-ol [*enantio*- (V)], m.p. 153—155° (from ethyl acetate–light petroleum), and 17-*noratisiran*-16β-*ol* (XXIII), m.p. 171—172° (from the same solvent), τ 9·18 (6H, s), 9·23 (3H, s), and 6·16 (1H, m, $W_{\frac{1}{2}}$ 22 Hz) (Found: C, 82·7; H, 11·7%). The separation process was not completely effective and the ratio of the two alcohols in the mixture was estimated by oxidation of another portion of fraction four and separation of the resulting ketones by preparative t.l.c. The fifth fraction contained 17-norkauran-16α-ol (X), m.p. 159—160° (from ethyl acetate–light petroleum).

The six alcohols were converted into the corresponding ketones with Jones reagent.[14] 17-*Norkauran*-12-*one* (XXI)

[14] K. Bowden, I. M. Heilbron, E. R. H. Jones, and B. C. L. Weedon, *J. Chem. Soc.*, 1946, 39.

had, after sublimation, m.p. 120—124°, $[\alpha]_D$ −12° (*c* 0·1), $\nu_{max.}$ 1710 cm.$^{-1}$, τ 9·16 (6H, s) and 9·20 (3H, s) (Found: C, 83·0; H, 11·0. $C_{19}H_{30}O$ requires C, 83·15; H, 11·0%). 17-*Noratisiran*-13-*one* (XVII) * had m.p. 123—125° (from methanol) (reported [8] m.p. of enantiomer 126—127°), $[\alpha]_D$ −37°, $\nu_{max.}$ 1725 cm.$^{-1}$, τ 9·14 (3H, s) and 9·21 (6H, s) (Found: C, 82·95; H, 11·25%). 17-*Noratisiran*-16-*one* (XV)* had m.p. 147—148° (from methanol) (reported [8] m.p. of enantiomer 145—146°), $[\alpha]_D$ −173°, $\nu_{max.}$ 1727 cm.$^{-1}$, τ 9·00, 9·15, and 9·18 (all 3H, s) (Found: C, 83·35; H, 11·25%). 17-*Norphyllocladan*-12-*one* [*enantio*- (XX)] had, after sublimation, m.p. 122—124°, $[\alpha]_D$ −51°, $\nu_{max.}$ 1710, τ 9·14 (6H, s) and 9·20 (3H, s) (Found: C, 83·15; H, 10·95%). 17-Norphyllocladan-16-one [*enantio*- (IV)] had m.p. 100—101° (from ethyl acetate), $[\alpha]_D$ −70°, $\nu_{max.}$ 1742 cm.$^{-1}$, τ 9·15 (6H, s) and 9·20 (3H, s). 17-Norkauran-16-one (XIV) had m.p. 113—115° (from methanol), $[\alpha]_D$ −23°, $\nu_{max.}$ 1742 cm.$^{-1}$, τ 8·91, 9·13, and 9·17 (all 3H, s).

The alcohols from the norphyllocladanol tosylates were separated as already described. The alcohols from the *endo*-substrate were identical in m.p., n.m.r. spectrum, and t.l.c. behaviour with those obtained from the norkauranol tosylates. The derived ketones were also identical in all respects except $[\alpha]_D$ value (similar magnitude but opposite sign in all cases) with those obtained previously. One additional alcohol, the 17-norphyllocladan-15-ol (XXII), was obtained (see Table 1) and had m.p. 124—126° (from aqueous methanol) (lit.,[7] 125—126°). The derived ketone (XIX) had m.p. 128—130° (from light petroleum) (lit.,[7] 132—133°), $[\alpha]_D$ −31°, $\nu_{max.}$ 1738 cm.$^{-1}$, τ 9·18 (6H, s) and 9·21 (3H, s). The alcohols from the *exo*-norphyllocladanol tosylate were identified by their n.m.r. and t.l.c. behaviour and by conversion into the corresponding ketones and comparison of these with authentic samples by i.r. and t.l.c.

Preparation of 17-*Noratisiran*-16-*one* [enantio-(XV)] *from the Diol* (XXXI).—The diol (XXXI) (800 mg.), m.p. 168—171° (lit.,[4] 167—169°), was prepared by the method [4] of Turner and his co-workers and then kept in the dark for 1 hr. with *N*-bromoacetamide (1 g.) in a mixture of acetone (80 ml.), methanol (20 ml.), and water (20 ml.). Propan-2-ol (80 ml.) was then added and after a further 1 hr., the solvents were removed *in vacuo*. The *ketol* (XVI) (530 mg.) was extracted from the residue with ether and had m.p. 152—155° (from ethyl acetate), $\nu_{max.}$ 1740 cm.$^{-1}$, τ 9·11, 9·15, and 9·19 (all 3H, s), and 6·25 (2H, m) (Found: C, 77·9; H, 11·05. $C_{19}H_{32}O_2$ requires C, 78·05; H, 11·05%). The derived *tosylate* (XVIa) (431 mg.) had m.p. 156—157° (from methanol), $[\alpha]_D$ +10°, τ 7·51, 9·10, 9·13, and 9·19 (all 3H, s), 5·85 (2H, m), and 2·38 (4H, q) (Found: C, 69·95; H, 8·7. $C_{26}H_{38}O_4S$ requires C, 69·95; H, 8·6%). The tosylate (243 mg.) in anhydrous benzene (10 ml.) was stirred with potassium t-butoxide (0·26 g.) in t-butyl alcohol (10 ml.) for 2 hr. at 20°. The ketone [*enantio*- (XV)] (153 mg.) was recovered with chloroform and had m.p. 147—148° (from light petroleum) (lit.,[8] 145—146°), $[\alpha]_D$ +186°, τ9·00, 9·15, and 9·18 (all 3H, s).

Preparation of 17-*Noratisiran*-13-*one* (XVII) *from the Diol* (XXXII).—The diol (500 mg.), m.p. 154—156° (lit.,[15] 155—156°), was converted with *N*-bromoacetamide as just described into the *ketol* (XVIII) (212 mg.), m.p. 90—92° (from ethyl acetate), $\nu_{max.}$ 1710 cm.$^{-1}$, τ 8·87 (3H, s), 9·11 (6H, s), and 6·12 (2H, m) (Found: C, 77·9; H, 11·0. $C_{19}H_{32}O_2$ requires C, 78·05; H, 11·05%). The derived *tosylate* (XVIIIa) had m.p. 140—142° (from methanol), $[\alpha]_D$ +98°, τ 7·55, 8·91, 9·13, and 9·16 (all 3H, s), 5·92 (2H, t), and 2·40 (4H, q). This tosylate (198 mg.) was cyclised with base as already described and gave 17-noratisiran-13-one (XVII) (93 mg.), m.p. 124—125° (from light petroleum) (reported [8] m.p. of enantiomer 126—127°), $[\alpha]_D$ −42°, τ 9·14 (3H, s) and 9·21 (6H, s).

17-*Norkaurane*.—The ketone (XIV) was reduced under modified Wolff–Kishner conditions [10] to 17-*norkaurane* (I), m.p. 56—60° (after sublimation) (Found: C, 87·8; H, 12·65. $C_{19}H_{32}$ requires C, 87·6; H, 12·4%). Reduction of 17-norkauran-12-one (XXI) under the same conditions gave a product with a g.l.c. retention time identical with that of 17-norkaurane.

17-*Norphyllocladane*.—The hydrocarbon (II) [7] derived from the ketone (IV) had g.l.c. properties identical with those of the product derived in the same manner from the ketone (XX).

(−)-*Phyllocladene*.—The ketone [*enantio*- (IV)] (50 mg.) was treated with freshly prepared [9] methylenetriphenylphosphorane in ether. Work-up and chromatography of the product over alumina (Grade I) in light petroleum gave (−)-*phyllocladene* [*enantio*- (VIII)] (21 mg.), which after sublimation had m.p. 92—96°, $[\alpha]_D$ −12° (Found: C, 87·9; H, 11·8. $C_{20}H_{32}$ requires C, 88·15; H, 11·85%) identical in n.m.r., g.l.c., and t.l.c. (SiO_2–$AgNO_3$) behaviour with (+)-phyllocladene from *Cryptomeria japonica*.[16]

(−)-*Neoatisirene*.—17-Noratisiran-13-one (XVII) (50 mg.) was converted into (−)-neoatisirene (XXX) (17 mg.) as described before; m.p. 73—76° (from methanol), $[\alpha]_D$ −85° (reported [13] for enantiomer: m.p. 75—76°, $[\alpha]_D$ +89°), τ 9·14 (6H, s), 9·19 (3H, s), 5·47 (1H, narrow q), and 5·28br (1H, s) (Found: *M* 272·2504. $C_{20}H_{32}$ requires *M*, 272·2504).

(−)-*Atisirene*.—17-Noratisiran-16-one (XV) (50 mg.) was converted into (−)-atisirene (XXIX) (33 mg.) as described before; m.p. 56—58° (from methanol), $[\alpha]_D$ −36°, identical in all respects with (−)-atisirene from *Erythroxylon monogynum*.[2b,17]

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* In our preliminary communication [1] the m.p.s of these two compounds were confused.

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