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COMPONENTS OF THE ROOT OF *LINDERA STRYCHNIFOLIA* VILL—VII[1]

STRUCTURE OF LINDERANE

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Abstract—Linderane (I), isolated from *Lindera strychnifolia* vill., is the first example of a ten-membered monocyclic sesquiterpenic lactone having a furan ring in the molecule and represented by formula I.

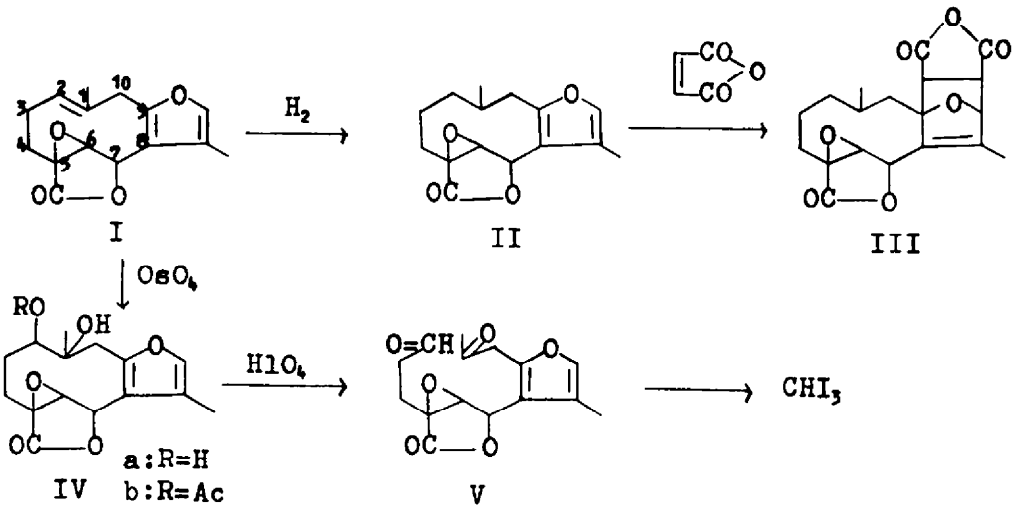
LINDERANE (I), a neutral crystalline component, was isolated as colourless needles, $C_{15}H_{16}O_4$, m.p. 190–191°, $[\alpha]_D$ +180·3°, together with 1-borneol, linderene[1,2] and other compounds from the root of *Lindera strychnifolia* Vill.[3–5] From the U.V. (λ_{max} 214 mμ, ε 6770) and I.R. spectra (ν_{max} 3130, 3060, 1616 and 1556 cm^{-1}) and from the positive Ehrlich's colour test, it is assumed that linderane has a furan ring in the molecule. Moreover, the I.R. spectrum of linderane shows a frequency at 1779 cm^{-1} (γ-lactonic carbonyl group) and no absorption bands which can be attributed to the hydroxyl group. Therefore, it may be concluded that one of the oxygen atoms is present as a furan ring, another two oxygen atoms are present in a γ-lactone function and the remaining oxygen atom constructs an ether linkage.

The following data of the N.M.R. spectrum of linderane support this assumption: a methyl signal on a furan ring at 8·00 τ (doublet J = 1·1); one furan ring proton at 2·87 τ (quartet J = 1·1). On catalytic hydrogenation of linderane with 5% palladium–calcium carbonate, dihydrolinderane (II), colourless prisms, m.p. 88–89°, $[\alpha]_D$ +60·5° was obtained.

Dihydrolinderane also shows characteristics of the furan ring in the I.R. spectrum, N.M.R. spectrum and Ehrlich's colour test, and affords a maleic anhydride adduct (III), colourless needles, m.p. 138–139°. These facts further confirm the presence of the furan ring in linderane. On oxidation with 1 mole of osmium tetroxide, linderane (I) afforded dihydroxy linderane (IVa) (amorphous), which was acetylated with acetic anhydride–pyridine to give the monoacetate (IVb), colourless needles, m.p. 176–177° $[\alpha]_D$ +62·2°.

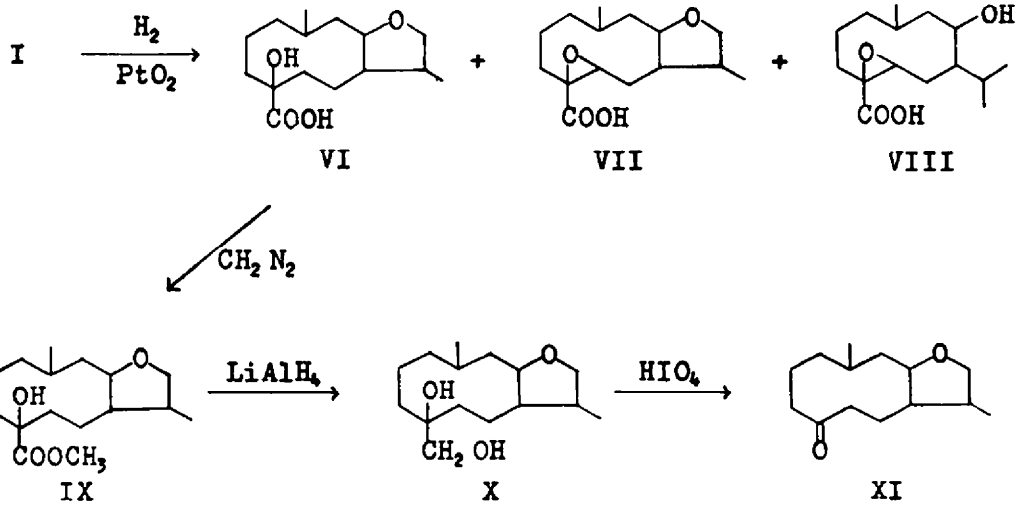
When dihydroxylinderane (IVa) was oxidized with sodium periodate, it afforded an oily keto-aldehyde derivative (V), which exhibited frequencies at 2764 and 1723 cm^{-1} corresponding to an aldehyde group. Compound V was shown to have an acetyl group, since it gave iodoform by sodium hypoiodite oxidation. These

[1] K. Takeda, *Chem. Pharm. Bull. Japan* **1**, 244 (1953).
[2] K. Takeda and T. Shimada, *Yakugaku Zasshi* **64**, 154 (1944).
[3] H. Kondo and T. Sanada, *Yakugaku Zasshi* **40**, 1047 (1925).
[4] H. Suzuki, *Yakugaku Zasshi* **50**, 714 (1930).
[5] H. Kondo and K. Takeda, *Yakugaku Zasshi* **59**, 504 (1939).



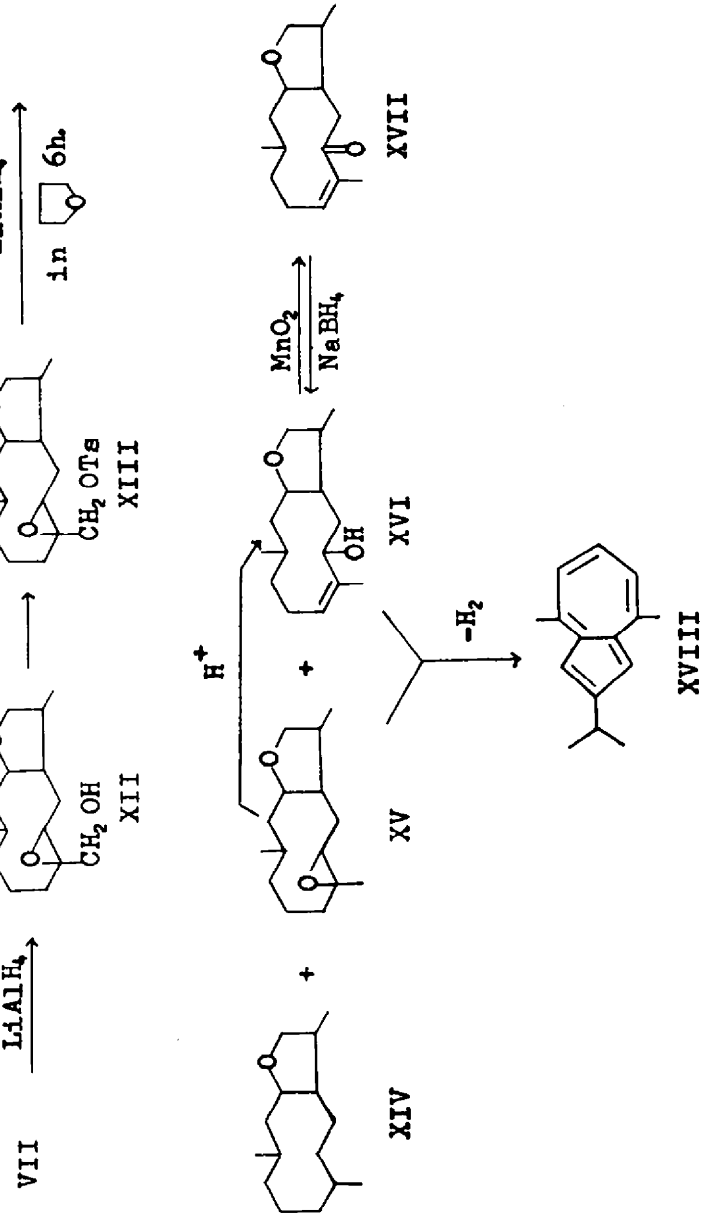
facts are also confirmed by the N.M.R. spectrum of V. Hence it is concluded that linderane (I) has a trisubstituted ethylenic double bond having a methyl group which is the one isolated from the furan ring, since linderane exhibits the U.V. maximum at 214 mμ as mentioned above. From these results, it is considered that linderane may be a ten-membered monocyclic sesquiterpenic lactone having a furan ring and an ether linkage.

When linderane was hydrogenated in acetic acid with Adams' catalyst, 4·5 moles hydrogen were taken up to give quantitatively a mixture of three carboxylic acids, VI, m.p. 178–181°, VII, m.p. 158–160°, and an oily carboxylic acid (VIII).



As this fact is elucidated by hydrogenolysis of the γ-lactone function, the lactonic oxygen must be located at the allylic position of the furan ring or the ethylenic double bond.

Although it was observed in the I.R. spectrum that the methyl ester (IX) of the acid (VI), m.p. 72–74°, possessed a hydroxyl group, the hydroxyl compound (IX)

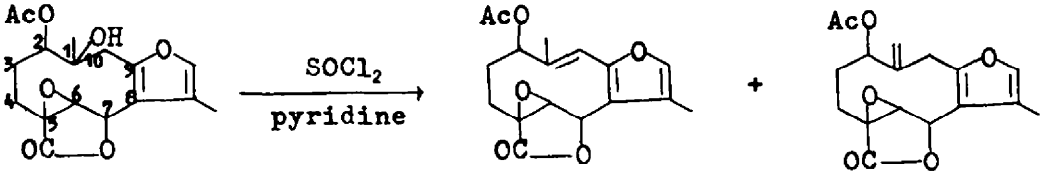

VII
LiAlH4
CH2 OH
XII
CH2 OTs
XIII
LiAlH4
in
6h
XIV
+
H+
XV
+
OH
XVI
MnO2
NaBH4
XVII
-H2
XVIII

was resistant to acetylation and chromium trioxide oxidation. Therefore, it is probable that this hydroxyl group is a tertiary one and is not formed from the furan ring but from the ether linkage on hydrogenation. A carbonyl compound (XI) having fourteen carbon atoms, m.p. 55·5–56°, ν C=O 1702 cm^{-1}, was obtained by reduction of IX with lithium aluminum hydride, followed by sodium periodate oxidation of X, m.p. 122–124°. This demonstrates that compound X is an α-glycol and that the lactonic carbonyl group and the ether linkage are attached to the same carbon atom in linderane.

Compound VII is an octahydro derivative of linderane. Reduction of VII with lithium aluminum hydride led to a hydroxy derivative (XII), m.p. 146–147°, the tosylate (XIII) of which, m.p. 130–131·5°, gave XV, m.p. 111–112°, XVI, m.p. 143·5–144°, and a small amount of an oily compound XIV, b,p. 140–150°/0·2 mm (bath temp), on lithium aluminum hydride reduction in tetrahydrofuran.

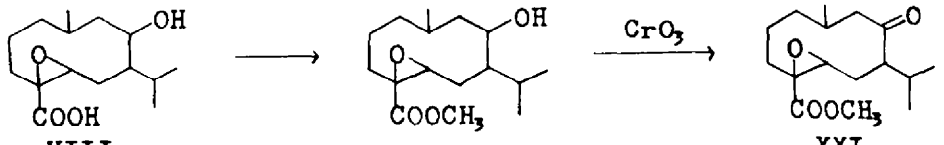
The N.M.R. data of XV are compatible with this structure (a tertiary methyl at 8·53 τ; an epoxidic proton at 7·07 τ). Compound XV gave XVI by treatment with dioxane–water containing one drop of perchloric acid at room temperature. Compound XVI shows the presence of an hydroxyl group and a trisubtituted double bond having a methyl group in its I.R. and N.M.R. spectra. Oxidation of XVI with manganese dioxide led to an α,β-unsaturated ketone (XVII), m.p. 109–110°, λ_{max} 237 mμ (ε 2940), which was reconverted to XVI by sodium borohydride reduction. The fact that the allylic alcohol (XVI) was formed under the above-mentioned conditions further confirms that XV and linderane (I) both possess an epoxide ring in their molecules.

Dehydrogenation of a mixture of XV and XVI with palladium charcoal led to vetivazulene (XVIII) together with unidentified naphthalene derivatives. Moreover, when compound IVb was dehydrated with thionyl chloride in pyridine, two dehydration products (XIX and XX) were obtained. As the U.V. spectrum of XIX shows an absorption maximum at 249·5 mμ (ε 7290), the newly formed double bond of XIX must be conjugated with the furan ring.



IVb XIX XX

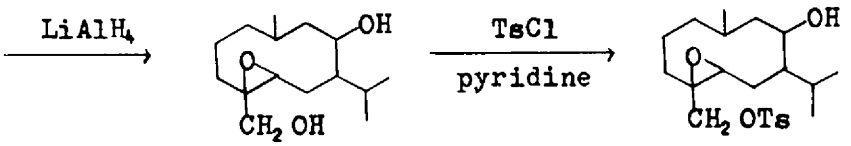
These results demonstrate that the methyl group on the ethylenic double bond of linderane (I) is not located at C-5 but at C-1, that the lactonic carbonyl group is attached to C-5 and the lactone ring is consequently closed between C-5 and 7 or C-5 and 3. A keto ester (XXI), m.p. 106–106·5°, was obtained by treatment of VIII with diazomethane, followed by chromium trioxide oxidation. Compound XXI shows a signal due to an isopropyl group in the N.M.R. spectrum and presence of the



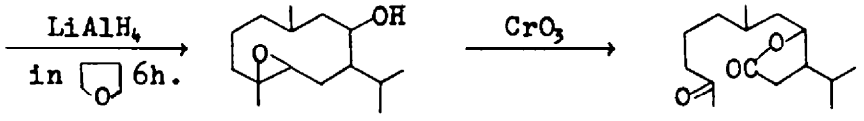
VIII XXI

ether linkage in the I.R. spectrum and elemental analysis. Therefore, it is concluded that VIII is obtained by hydrogenatic cleavage of the furan ring, and that the hydroxyl group of VIII and the carbonyl group of XXI can both be ascribed to the oxygen of the furan ring and are located at C-9.

Reduction of XXI with lithium aluminum hydride led to two dihydroxyderivatives, XXIIa, m.p. 166–172°, and XXIIb. The monotosylate (XXIII), m.p. 157–158°,



XXIIa, b XXIII



XXIV XXV

obtained from XXIIa afforded the monohydroxy derivative (XXIV), b.p. 120°/0·7 mm (bath temp), on reduction with lithium aluminum hydride in tetrahydrofuran. When XXIV was oxidized with chromium trioxide in dimethylformamide–sulfuric acid, it afforded an oily lactone (XXV), b.p. 140–145°/0·6 mm (bath temp), which exhibited absorption bands at 1776 cm^{-1} (γ-lactonic carbonyl) and at 1713 cm^{-1} (ketonic carbonyl) in the I.R., and a methyl signal due to an acetyl group at 7·88 τ in the N.M.R. This fact confirms that the epoxide ring of linderane (I) is located at C-5 and 6, since the hydroxyl group of XXIV is situated at C-9.

The formula incorporating all these observations for linderane must be I or XXVI.

I XXVI

The N.M.R. spectrum of IVb shows a triplet-like signal due to a proton attached to the carbon atom carrying the acetoxyl group at 5·02 τ. This fact indicates the existence of two protons on C-3 and formula XXVI is precluded. Moreover, ozonolysis of linderane led to acetone, acetaldehyde* and a nonvolatile residue, which afforded succinic acid on oxidation with potassium permanganate. This result confirms that linderane has a —CH_2—CH_2— grouping in the molecule and must be represented by formula I.

This is the first example of a ten-membered sesquiterpenoid having a furan ring in the molecule.

* Acetone and acetaldehyde may probably be formed by the secondary reaction.

EXPERIMENTAL

NMR spectra were taken on deuterated chloroform solutions with a Varian A 60 NMR Spectrometer. All m.p. were measured on a Kofler blok ("mono-scope" Hans Bock Co., Ltd. Frankfurt am Main, Germany) and corrected.

Isolation of linderane (I) *from the root of the plant*

The dried and sliced root (4·69 kg) were soaked in ether (7 l.) at room temp. for 7 days. The ether extract was filtered and re-extraction with ether (8 l.) was performed. The combined extracts were evaporated into about one-tenth *in vacuo*, washed with 5% NaOH, dried (Na_2SO_4) and evaporated into about 300 ml *in vacuo*. The residual extract was left overnight in an ice box to give crude linderane (I) as a crystalline substance (3·57 g). The filtrate was evaporated to dryness *in vacuo*, dissolved in pet ether (50 ml) and left in an ice box to give crude linderene[1] (9·35 g). Crude linderane (I) was recrystallized from acetone giving colourless needles (3·1 g), m.p. 190–191° (dec), $[\alpha]_D^{24}$ +180·3° (±2°) (*c*, 1·043, dioxane), λ_{max}^{alc} 214 mμ (ε 6770), $\nu_{max}^{CHCl_3}$ 3130, 3060, 1779, 1616 and 1556 cm^{-1}, NMR 2·87 (quartet, J = 1·1), 8·00 (doublet, J = 1·1) and 8·43 τ (Found: C, 69·26; H, 6·21; O, 24·04. $C_{15}H_{16}O_4$ requires: C, 69·21; H, 6·20; O, 24·59%).

Catalytic hydrogenation of linderane (I) *with 5% palladium–calcium carbonate*

A mixture of 5% Pd—$CaCO_3$ (700 mg) and linderane (I, 1·0 g) in acetone (35 ml) was reduced catalytically at room temp. giving a neutral fraction (610 mg) and an acid fraction (320 mg). A neutral fraction was recrystallized from ethanol to give dihydrolinderane (II) as colourless prisms, m.p. 88–89°, $[\alpha]_D^{21}$ +60·5° (±4°) (*c*, 0·512, $CHCl_3$), $\nu_{max}^{CHCl_3}$ 1778 cm^{-1} (Found: C, 68·52; H, 7·02. $C_{15}H_{18}O_4$ requires: C, 68·67; H, 6·92%).

Dihydrolinderane (II)*—maleic anhydride adduct*

A solution of dihydrolinderane (II, 200 mg) and maleic anhydride (90 mg) in dry ether was left at room temp for 24 hr. The separated crystalline substance was filtered and recrystallized from ethyl acetate giving maleic anhydride adduct (III) as colourless needles (220 mg). m.p. 138–139° (Found: C, 63·06; H, 5·51. $C_{19}H_{20}O_7$ requires: C, 63·31; 5·60%).

Osmium tetroxide oxidation of linderane (I)

A solution of osmium tetroxide (970 mg) in dry benzene (10 ml) was added to a solution of linderane (I, 1·0 g) in dry benzene (20 ml) and left for 3 days at room temp. Dioxane (20 ml) was added to this mixture and saturated with hydrogen sulphide. The black precipitate was filtered off and well washed with dioxane. The filtrate and washings were evaporated *in vacuo*, extracted with chloroform, dried (Na_2SO_4) and evaporated leaving colourless viscous oil (876 mg). The residue was dissolved in benzene (80 ml) and chromatographed on neutral alumina (27 g) giving dihydroxylinderane (IVa), a colourless amorphous powder (625 mg). IVa was acetylated with acetic anhydride–pyridine at room temp. giving the monoacetate (IVb), colourless needles, m.p. 176–177°, $[\alpha]_D^{23}$ +62·2° (±2°) (*c*, 1·065, dioxane) (Found: C, 61·12; H, 6·03. $C_{17}H_{20}O_7$ requires: C, 60·71; H, 5·99%).

Oxidation of dihydroxylinderane (IVa) *with sodium periodate*

A solution of sodium periodate (214 mg) in water (10 ml) was added to a solution of IVa (146 mg) in methanol (10 ml) and left at room temp. for 64 hr. This mixture was evaporated *in vacuo* and extracted with chloroform. The chloroform extract was washed with 2N Na_2CO_3 and water, dried (Na_2SO_4) and evaporated *in vacuo* leaving an yellow viscous oil (V, 107 mg), ν_{max}^{film} 2764, 1780 and 1723 cm^{-1}, NMR 0·20 τ (—CHO) and 7·80 τ (CH_3CO—), which gave iodoform, m.p. 118–119° by sodium hypoiodite oxidation.

Catalytic hydrogenation of linderane (I) *with Adams' catalyst*

(a) A mixture of Adams' catalyst (100 mg) and linderane (I, 500 mg) in ethyl acetate (30 ml) was reduced catalytically at room temp. When 3·03 moles of hydrogen had been absorbed, the reaction stopped, and the catalyst and the solvent were removed. The residue was extracted with ether and

the ether solution was extracted (saturated $NaHCO_3$ aq.). The acid fraction, a colourless oil (465 mg) was crystallized from ether giving VI (33 mg) as colourless needles, m.p. 178–181° (Found: C, 66·46; H, 9·71. $C_{15}H_{26}O_4$ requires: C, 66·63; H, 9·69%). The methyl ester (IX): colourless needles, m.p. 72–74°, ν_{max}^{Nujol} 3476 and 1725 cm^{-1}.

(b) A mixture of Adam's catalyst (1 g) and linderane (I, 10 g) in acetic acid (400 ml) was reduced catalytically at room temp. When 4·5 moles of hydrogen had been absorbed, the reaction stopped and the mixture was worked up as described above leaving an acid fraction, a colourless oil (10·5 g) and a neutral fraction, a light yellow oil (360 mg). The acid fraction was crystallized from ether giving VII (1·04 g) as colourless needles, m.p. 158–160°, $[\alpha]_D^{24}$ +76·7° (±2°) (*c*, 1·04, dioxane) (Found: C, 67·10; H, 9·00. $C_{15}H_{24}O_4$ requires: C, 67·13; H, 9·02%) and a colourless oil (9·0 g) containing VI, VII and VIII, which was afforded its methyl ester (9·2 g) by application of diazomethane. The methyl ester was chromatographed on alumina (100 g) giving a colourless viscous oil (A, 5·75 g), which had not a hydroxyl group in the IR and a light yellow viscous oil (B, 4·86 g) having a hydroxyl group in the IR. By saponification with 5% KOH–methanol, oil A (5·75 g) gave VII(1·6 g). A solution of oil B (4·86 g) in dimethylformamide (60 ml) was added dropwise to a solution of chromium trioxide (4·8 g) in dimethylformamide (50 ml) containing conc. H_2SO_4 (8 drops) in an ice bath and left over night at room temp. The reaction mixture was poured into ice-water, extracted with ether, washed (water, $NaHSO_3$ aq., 2N Na_2CO_3), dried (Na_2SO_4) and evaporated leaving a light yellow oil (4·3 g), which was chromatographed on alumina (80 g). Elution with pet ether and pet ether –benzene (1:1) afforded a colourless oil (2·5 g), which was crystallized from ether–pet ether giving XXI (1·05 g) as colourless needles, m.p. 106–106·5°, $[\alpha]_D^{24}$ +166·6° (±2°) (*c*, 0·991, dioxane), $\nu_{max}^{CHCl_3}$ 1736 and 1694 cm^{-1} (Found: C, 68·27; H 9·35. $C_{16}H_{26}O_4$ requires: C, 68·05; H, 9·28%). Further elution with benzene afforded a colourless oil (330 mg), which was saponified with 5% KQH–methanol to give VI (80 mg). Further elution with chloroform afforded an yellow oil (1·4 g), which was saponified with 5% KOH–methnol to give VI (350 mg).

Reduction of IX *with lithium aluminum hydride*

A solution of IX (78·5 mg) in dry ether (5 ml) was added to a suspension of $LiAlH_4$ (80 mg) in dry ether (3 ml) and stirred for 3 hr at room temp. The mixture was decomposed by addition of water, extracted with ether, washed with water, dried (Na_2SO_4) and evaporated leaving a crystalline substance (61·2 mg). The residue was recrystallized from ether giving X as colourless needles (44 mg), m.p. 122–124°, $[\alpha]_D^{22}$ +49·0° (±2°) (*c*, 1·059, dioxane) (Found: C, 70·07; H, 10·91. $C_{15}H_{28}O_3$ requires: C, 70·27; H, 11·01%).

Oxidation of X *with sodium periodate*

A solution of sodium periodate (72 mg) in water (4 ml) was added to a solution of X (43 mg) in methanol (2 ml) and dioxane (2 ml) and left at room temp 70 hr. The mixture was evaporated *in vacuo* and extracted with ether. The ether extract was washed with 2N Na_2CO_3, dried (Na_2SO_4) and evaporated leaving a pale yellow oil (35·3 mg). The residue was chromatographed on alumina (1·0 g) to give a crystalline substance (32 mg), which was sublimated at 70–80° under red. press. (1·5 mm Hg) and recrystallized from pet ether to give XI as colourless needles, m.p. 55·5–56°, $\nu_{max}^{CHCl_3}$ 1702 cm^{-1} (Found: C, 74·89; H, 10·78. $C_{14}H_{24}O_2$ requires: C, 74·95; H, 10·78%).

Reduction of VII *with lithium aluminum hydride*

Application of diazomethane to VII afforded its methyl ester, a colourless viscous oil, b.p. 118–120°/0·02 mm (Found: C, 68·47; H, 9·38. $C_{16}H_{26}O_4$ requires: C, 68·05; H, 9·28%). A solution of the methyl ester (6·2 g) in dry ether (50 ml) was added dropwise to a suspension of $LiAlH_4$ (880 mg) in dry ether (30 ml) with stirring at room temp and then stirred for 3 hr. The mixture was decomposed by addition of water, extracted with ether, washed with water, dried (Na_2SO_4) and evaporated leaving a crystalline substance (5·3 g). The residue was recrystallized from ether giving XII (4·7 g) as colourless needles, m.p. 146–147°, $[\alpha]_D^{24}$ +91·6° (±2°) (*c*, 1·074, dioxane) (Found: C, 70·92; H, 10·40. $C_{15}H_{26}O_3$ requires: C, 70·83; H, 10·30%).

Reduction of XIII *with lithium aluminum hydride*

On tosylation with tosylchloride–pyridine at room temp, XII afforded its tosylate (XIII), colourless plates, m.p. 130–131·5° (Found: C, 64·80; H, 7·88; S, 8·08. $C_{22}H_{32}O_5S$ requires: C, 64·67; H, 7·90; S, 7·85%).

(a) A mixture of XIII (240 mg) and $LiAlH_4$ (150 ml) in dry tetrahydrofuran (10 ml) was refluxed for 6 hr in an oil bath, decomposed by addition of water and then 2N H_2SO_4 in an ice bath, extracted with ether, washed with 2N Na_2CO_3, dried (Na_2SO_4) and evaporated leaving a colourless viscous oil (145 mg). The residue was dissolved in pet ether (15 ml) and chromatographed on alumina (3 g) giving XIV (7 mg), b.p. 140–150°/2 mm (bath temp.) (Found: C, 80·42; H. 12·34. $C_{15}H_{28}O$ requires: C, 80·29; H, 12·58%), XV (41 mg), colourless needles, m.p. 111–112° (from pet ether), $[\alpha]_D^{28}$ +87·5° (±2°) (*c* 1·129, dioxane) (Found: C, 75·92; H, 10·97. $C_{15}H_{26}O_2$ requires: C, 75·58; H, 11·00%) and XVI (70 mg), colourless needles, m.p. 143·5–144° (from pet ether), $[\alpha]_D^{28}$ +47·6° (±2°) (*c*, 0·928, dioxane) (Found: C, 75·74; H, 11·08. $C_{15}H_{26}O_2$ requires: C, 75·58; H, 11·00%).

(b) A mixture of XIII (4·27 g) and $LiAlH_4$ (450 mg) in dry tetrahydrofuran (80 ml) was refluxed for 10 hr in an oil bath, decomposed by addition of water only in an ice bath, extracted with ether, washed with water, dried (Na_2SO_4) and evaporated leaving a colourless viscous oil (2·46 g). The residue was dissolved in pet ether (200 ml) and chromatographed on alumina (60 g) giving XV (47 mg), XVI (1·44 g) and an oil (656 mg) having absorption bands related to tosyl group in the IR. This oil was reduced once more with $LiAlH_4$ under same conditions giving XV (7 mg) and XVI (490 mg).

Conversion of XV *into* XVI

A solution of XV (87 mg) in dioxane (1·5 ml) and water (0·5 ml) containing one drop of 60% perchloric acid was left overnight at room temp.; and then extracted with chloroform, washed with 2N Na_2CO_3, dried (Na_2SO_4) and evaporated leaving an oil (79 mg). The residue was dissolved in pet ether (8 ml) and chromatographed on alumina (2·5 g) giving the starting material (XV, 20 mg) and colourless needles (41 mg), m.p. 143–143·5°, identical with XVI by mixed m.p. and IR comparison.

Oxidation of XVI with manganese dioxide

A mixture of manganese dioxide (500 mg) in a solution of XVI (78 mg) in pet ether (6 ml) and benzene (2 ml) was shaken for 7·5 hr at room temp. and then filtered. The filtrate was evaporated leaving an oil (55 mg), which was dissolved in pet ether (5 ml) and chromatographed on alumina (1·5 g) giving the starting material (19 mg) and colourless needles (XVII, 26 mg), m.p. 109–110° (from pet ether), $[\alpha]_D^{28}$ +157·9° (±4°) (*c*, 0·554, dioxane), λ_{max}^{alc} 237 mμ (ε 2940), ν_{max}^{Nujol} 1677 and 1647 cm^{-1} (Found: C, 76·21; H, 10·28. $C_{15}H_{24}O_2$ requires: C, 76·22; H, 10·24%).

Reduction of XVII *with sodium borohydride*

A mixture of $NaBH_4$ (10 mg) in a solution of XVII (13·7 mg) in tetrahydrofuran (1 ml) was stirred for 3 hr at room temp. The mixture was decomposed by addition of 2N H_2SO_4, extracted with ether, washed with 2N Na_2CO_3 and water, dried (Na_2SO_4) and evaporated leaving XVI (3 mg), m.p. 138–142° and an unidentified oily alcohol (10 mg).

Dehydrogenation of a mixture of XV *and* XVI

A mixture (627 mg) of XV and XVI (about 1 : 2) and 20% Pd–C (300 mg) was heated at 300–340° (bath temp.) for 20 min, during which time 72 ml of hydrogen was generated. The residue was extracted with pet ether and the pet ether solution was extracted with conc. H_3PO_4. The pet ether layer was washed with 2N Na_2CO_3 and evaporated leaving an yellow oil (A, 220 mg). Water was added to the conc. H_3PO_4 solution to separate azulenes and extracted with pet ether. The pet ether solution was washed with 2N Na_2CO_3, dried (Na_2SO_4) and evaporated leaving a violet oil, which was chromatographed on alumina giving a violet oil (46 mg) containing azules and an yellow oil (B, 177 mg). The non-azulenic oil (A + B, 397 mg) was dehydrogenated once more with 20% Pd–C (200 mg) under same conditions and a violet oil containing azulenes (28 mg) was obtained. The violet oil containing azulenes (74 mg) was dissolved in pet ether (20 ml) and rechromatographed on alumina (30 g) giving a blue oil (12 mg) and a reddish-violet oil (12 mg). The reddish-violet oil afforded its 2,4,6-trinitrobenzene adduct (12 mg) as maroon needles (from ethanol), m.p. 152–153° (Found: C, 61·65; H, 5·20; N, 10·45. $C_{21}H_{21}O_6N_3$ requires: C, 61·31; H, 5·15; N, 10·21%), which was identical with an authentic sample of 2,4,6-trinitrobenzene adduct of vetivazulene (XVIII) by mixed m.p.

The 2,4,6-trinitrobenzene adduct (6 mg) was dissolved in pet ether and filtered through a column of alumina (2 g) giving a reddish-violet oil (3 mg), which was identical with an authentic sample of vetivazulene (XVIII) by comparisons of UV, visible and IR spectra.

Dehydration of dihydroxylinderane monoacetate (VIb) *with thionyl chloride-pyridine*

Thionyl chloride (0·2 ml) was added dropwise to a solution of IVb (217 mg) in dry pyridine (2 ml) with stirring in an ice bath and then stirred for 30 min at the same temp. After stirring at room temp. for an additional 2 hr, the mixture was poured onto ice-water (20 ml), extracted with chloroform. washed with 2N H_2SO_4, water and 2N Na_2CO_3, dried (Na_2SO_4) and evaporated leaving an yellow oil (160 mg). The residue was dissolved in pet ether (20 ml) and chromatographed on acid alumina (6 g, Merck) giving an amorphous powder (XIX, 49 mg), λ_{max}^{alc} 249·5 mμ (ε 7290), ν_{max}^{Nujol} 1781 and 1737 cm^{-1} and colourless prisms (XX, 12 mg), m.p. 136–138° (from ether), λ_{max}^{alc} 212·5 mμ (ε 7420), ν_{max}^{Nujol} 1772 and 1733 cm^{-1}.

Reduction of XXI *with lithium aluminum hydride*

A solution of XXI (400 mg) in dry ether (10 ml) was added dropwise to a suspension of $LiAlH_4$ (200 mg) in dry ether (10 ml) with stirring and stirred for 3 hr at room temp. The mixture was decomposed by addition of water in an ice bath, extracted with ether, washed with water, dried (Na_2SO_4) and evaporated leaving a colourless viscous oil (380 mg). The residue was crystallized from ether giving XXIIa, colourless small needles (124 mg), m.p. 166–172° (Found: C, 70·42; H, 11·38. $C_{15}H_{28}O_3$ requires: C, 70·27; H, 11·01%) and a colourless viscous oil (XXIIb, 250 mg). By acetylation with acetic anhydride–pyridine at room temp., XXIIa afforded the monoacetate, colourless needles (from ether–pet ether), m.p. 112–113°, $[\alpha]_D^{28}$ +95·3° (±2°) (*c*, 1·079, dioxane), $\nu_{max}^{CHCl_3}$ 3580 and 1731 cm^{-1} (Found: C, 68·41; H, 10·11. $C_{17}H_{30}O_4$ requires: C, 68·42; H, 10·13%), whereas XXIIb afforded the diacetate, colourless needles (from pet ether), m.p. 107–108°, $\nu_{max}^{CHCl_3}$ 1726 cm^{-1} (Found: C, 67·21; H, 9·46. $C_{19}H_{32}O_5$ requires: C, 67·03; H, 9·47%).

Tosylation of XXIIa

A solution of tosyl chloride (1·26 g, 2 equiv.) and XXIIa (845 mg) in dry pyridine (25 ml) was allowed to stand overnight at room temp. Then the crude monotosylate was extracted with chloroform in usual manner and recrystallized from chloroform–ether giving XXIII (1·15 g) as colourless needles, m.p. 157–158° (Found: C, 64·53; H, 8·42; S, 7·50. $C_{22}H_{34}O_5S$ requires: C, 64·36; H, 8·35; S, 7·81%).

Reduction of XXIII *with lithium aluminum hydride*

A mixture of XXIII (370 mg) and $LiAlH_4$ (150 mg) in dry tetrahydrofuran (10 ml) was refluxed for 6 hr, and then decomposed by addition of water and 2N H_2SO_4. The mixture was extracted with chloroform, washed with 2N Na_2CO_3, dried (Na_2SO_4) and evaporated leaving a colourless oil (228 mg). The residue was chromatographed on alumina (7 g) giving XXIV (188 mg) as a colourless oil, b.p. 120–125°/0·7 mm (bath temp.), ν_{max}^{film} 3486 cm^{-1} (Found: C, 74·75; H, 11·79. $C_{15}H_{28}O_2$ requires: C, 74·95; H, 11·74%). XXIV was resistant to the cleavage of the epoxy ring with perchloric acid or $LiAlH_4$–$AlCl_3$.

Oxidation of XXIV *with chromium trioxide*

A solution of XXIV (155 mg) in dimethylformamide (1·5 ml) was added to a solution of chromium trioxide (150 mg) in dimethylformamide (1 ml) containing one drop of conc. H_2SO_4 in an ice bath and left overnight at room temp. The mixture was poured onto ice water and extracted with ether. The ether extract was washed with 2N Na_2CO_3, dried (Na_2SO_4) and evaporated leaving a light yellow oil (110 mg), which was saponified with 10% K_2CO_3–methanol giving a neutral fraction, the starting material (XXIV, 71 mg) and a lactonic fraction, an yellow oil (36 mg). The 2N Na_2CO_3 extract was acidified with 4N H_2SO_4, salted out with Na_2SO_4, extracted with ether, washed with saturated $NaHCO_3$ aq., dried (Na_2SO_4) and evaporated leaving an oily lactone (42 mg). The lumped oily lactone was distilled to give XXV as a colourless oil, b.p. 140–145°/0·6 mm (bath temp.), $[\alpha]_D^{28}$ +45·9° (±2°) (*c*, 1·084, dioxane), ν_{max}^{film} 1776 and 1713 cm^{-1}, NMR 7·88 τ (CH_3CO—) (Found: C, 70·54; H, 10·43. $C_{15}H_{26}O_3$ requires: C, 70.83; H, 10·30%).

Ozonolysis of linderane (I)

Linderane (I, 650 mg) in ethyl acetate (30 ml) was ozonized at 0°, and the issuing gas was passed through two bottles containing water (A) in an ice bath. The solution of ozonide was decomposed by heating with water (30 ml) for 2 hr and distilled to give an ethyl acetate solution (B, 30 ml) and

an aqueous solution (C, 20 ml). The presence of acetone in the aqueous solution (C) was proved as its *p*-nitrophenylhydrazone (1·2 mg), m.p. 147–148°. From (B), acetoaldehyde–*p*-nitrophenylhydrazone (0·8 mg), m.p. 126–128° was obtained. From (A), the carbonyl derivative was not obtained at all. The distillation residue (ca. 10 ml) was evaporated *in vacuo* leaving a brown oil (ca. 500 mg). The residue was dissolved in acetone (10 ml) and oxidized by addition of $KMnO_4$ (1·6 g) in water (30 ml) with stirring for 2 hr at room temp. After filtration, the filtrate was evaporated *in vacuo*, acidified to pH 4–5 with 4N H_2SO_4, evaporated to dryness and extracted with acetone. The acetone extract was evaporated to give a brown oil (220 mg). The residue was crystallized from acetone giving succinic acid (73 mg), colourless prisms, m.p. 187–188°, which was identical with an authentic sample by mixed m.p.