Constituents of Erythroxylon Species. Part VII.[1] Diterpenoids from *Erythroxylon australe*

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The structures of seven new stachene- and erythroxydiol X-related diterpenoids from the root wood of *E. australe* have been assigned on the basis of chemical and spectroscopic evidence. It is of interest that all the new compounds have an oxygen substituent at C-1.

THE previous papers [1-6] in this series have been concerned with the light petroleum extract of *E. monogynum* which proved to be a prolific source of diterpenoids. In an extension of this work we have examined the ethyl acetate extract of powdered root wood of *E. australe* and have obtained seven new diterpenoids whose structures are described below. The following known compounds were also isolated: stachene (1),[2] devadarene,[7] atisirene,[7] erythroxylol A,[2] erythroxydiol X,[3] and erythroxytriol Q [4] (see Experimental section).

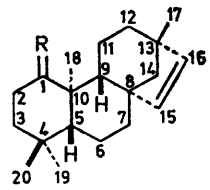
It was obvious from their n.m.r. spectra (see Experimental section) that five of the new compounds, the ketone (2), the epoxy-ketone (3), the α-ketol (4), the diosphenol (5), and the keto-alcohol (6), were related to stachene.[2] The isolation of the ketone (2), the α-ketol (4), and the diosphenol (5) is interesting since *Spirostachys africana* [8] has been reported to give stach-15-en-3-one, 2-hydroxystach-15-en-3-one, and the diosphenol, 2-hydroxystach-1,15-dien-3-one. It was soon apparent, however, that the compounds from *E. australe*, while possessing a stachene (1) skeleton, differed from the *S. africana* series in the position of the functional groups.

The ketone (2), $C_{20}H_{30}O$, m.p. 77—78°, $[\alpha]_D$ −114°, $\nu_{max.}$ (CCl_4) 1708 cm^{-1} (cyclohexanone), had in its n.m.r. spectrum resonances for four tertiary methyl groups and a *cis*-disubstituted double bond. On treatment with *m*-chloroperbenzoic acid in chloroform it was smoothly converted into the keto-epoxide (3), $C_{20}H_{30}O_2$, m.p. 131—132°, $[\alpha]_D$ −58°, identical with the keto-epoxide isolated from the extract. Since the *cis*-disubstituted double bond is very susceptible [5] to oxidation this keto-epoxide may well be an artefact. Wolff–Kishner reduction of the ketone (2) yielded a mixture of stachene (1) and stachane, identified by n.m.r. and g.l.c. comparison with authentic samples, thus confirming the stachene nucleus.

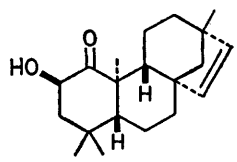
In a separate attempt to remove the ketonic carbonyl group the ketone (2) was reduced with sodium borohydride to the alcohol (7), stach-15-en-1β-ol, which was converted to the tosylate and treated with lithium aluminium hydride. The reaction proceeded entirely by way of sulphur–oxygen cleavage and only the starting alcohol was recovered. This result indicated the hindered nature of the hydroxy-group and supported the placing of the carbonyl group at C-1 in (2). Confirmation of this assignment was obtained from o.r.d. evidence and by a direct inter-relation of (2) and the

[1] Part VI, A. Martin and R. D. H. Murray, *J. Chem. Soc.* (*C*), 1970, 2023.
[2] R. McCrindle, A. Martin, and R. D. H. Murray, *J. Chem. Soc.* (*C*), 1968, 2349.
[3] J. D. Connolly, R. McCrindle, R. D. H. Murray, A. J. Renfrew, K. H. Overton, and A. Melera, *J. Chem. Soc.* (*C*), 1966, 268.
[4] J. D. Connolly, D. M. Gunn, R. McCrindle, R. D. H. Murray, and K. H. Overton, *J. Chem. Soc.* (*C*), 1967, 668.
[5] A. Martin and R. D. H. Murray, *J. Chem. Soc.* (*C*), 1968, 2529.
[6] J. C. Fairlie, R. McCrindle, and R. D. H. Murray, *J. Chem. Soc.* (*C*), 1969, 2115.
[7] A. H. Kapadi, R. R. Sobti, and Sukh Dev, *Tetrahedron Letters*, 1965, 2729.
[8] W. H. Baarschers, D. H. S. Horn, and Le Roy F. Johnston, *J. Chem. Soc.*, 1962, 4046.

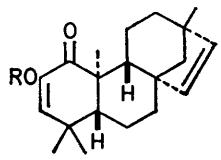
α-ketol (4) (*vide infra*). The hydroxy-group in the alcohol (7) is β (axial) [τ 6·4 (m, $W_{\frac{1}{2}}$ 7 Hz)].



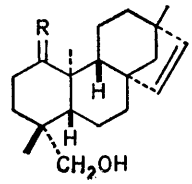
(1) R = H_2
(2) R = O
(3) R = O; 15,16 epoxide
(7) R = H, β-OH



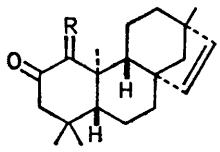
(4)



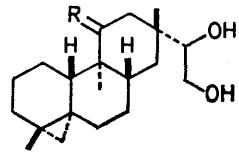
(5) R = H
(8) R = Ac



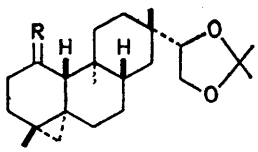
(6) R = O
(12) R = H_2



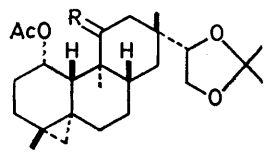
(9) R = H, α-OH
(10) R = H, β-OH
(11) R = H_2



(13) R = H_2
(14) R = H, α-OH
(20) R = H, α-OAc



(15) R = H, α-OH
(16) R = H, α-OAc
(17) R = O



(18) R = H, α-OH
(19) R = H, α-OAc
(21) R = O

The α-ketol (4), 2β-hydroxystach-15-en-1-one, $C_{20}H_{30}O_2$, m.p. 109—110°, $[\alpha]_D$ +220°, $\nu_{max.}$ (CCl_4) 3470 and 1705 cm^{-1}, had a signal at τ 5·5 [1H, q, J_{obs} 12·5, 5 Hz (after D_2O exchange)] due to a secondary alcohol adjacent to a carbonyl group and a methylene group [CH_2·C(OH)*H*·CO]. This part structure can only be accommodated in ring A of a stachene nucleus. Since the α-ketol (4) was transformed by tosylation, lithium aluminium hydride reduction, and subsequent oxidation into the ketone (2) and since it differed from the known α-ketol [8] (2-hydroxystach-15-en-3-one) from *Spirostachys africana* it follows that the carbonyl group must be at C-1. The ketone (2) is therefore stach-15-en-1-one and the α-ketol (4) 2β-hydroxystach-15-en-1-one. The equatorial (β) nature of the hydroxy-group follows from the half-band width ($W_{\frac{1}{2}}$ 17·5 Hz) of the C*H*OH proton.

The diosphenol (5) and the ketone (2) were very similar in polarity and were not easily separable by t.l.c. This problem was easily resolved by acetylation of the mixture, t.l.c. separation of the ketone and the diosphenol acetate (8), and saponification of the latter. The diosphenol, stach-2,15-dien-1-one, thus obtained, had m.p. 108—109°, $[\alpha]_D$ −11°, $\nu_{max.}$ (CCl_4) 3440, 1682, and 1660 cm^{-1}, $\lambda_{max.}$ 270 nm (ε 10,000) in neutral ethanol, changing to $\lambda_{max.}$ 315 nm (ε 6000) on addition of one drop of 0·1M-potassium hydroxide. In the n.m.r. spectrum the sharp singlet due to the C-3 olefinic proton was superimposed on the AB quartet arising from the C-15 and C-16 protons of the *cis*-disubstituted double bond. In the corresponding acetate (8) the C-3 olefinic proton moved downfield to τ 4·04.

The structure of the diosphenol as (5) was readily confirmed by preparing it from the α-ketol (4) by bismuth oxide oxidation using the conditions described by Rigby.[9] When the reaction was carried out under milder conditions a mixture of starting material, diosphenol, and a new ketol (9) was obtained. This suggested that the bismuth oxide was causing, at least in part, some equilibration of the original α-ketol. The same three compounds together with a more polar ketol (10) resulted from equilibration of (4) in refluxing 5% ethanolic potassium hydroxide for 5 h. The structures of these two new ketols followed readily from their spectroscopic properties.

Thus the less polar compound (9), m.p. 104—106°, had, in the n.m.r. spectrum, a sharp singlet (after D_2O exchange) at τ 6·11 and a singlet (2H) at τ 7·66 CH_2·CO·C(OH)H indicating that it was a 1-hydroxystach-15-en-2-one. The configuration of the hydroxy-group is α (equatorial) since it gives rise to an intramolecularly bonded hydroxy-band at 3465 cm^{-1} (CCl_4; no change on dilution).

The more polar ketol (10), m.p. 169—170°, has the same gross structure [τ 6·41 (1H, s) and 7·05 and 7·89 (AB q, J 12 Hz)] and is therefore 1β-hydroxystach-15-en-2-one. The i.r. spectrum showed that the hydroxy-group was intermolecularly bonded [$\nu_{max.}$ (CCl_4) 3620 and 3440 cm^{-1} (change in relative intensities on dilution)]. When exposed separately to the equilibrating conditions these two ketols yielded a similar mixture to that described above.

Confirmation of the placing of the carbonyl group at C-2 in the ketol (9) was obtained in the following way. The ketol (9) was treated with toluene-*p*-sulphonyl chloride in pyridine and the resulting tosylate was reduced with chromous chloride to give stach-15-en-2-one (11) identical in all respects (n.m.r., m.p., and o.r.d.) with that prepared by Hanson.[10]

From the later fractions of the extract the keto-alcohol (6), 19-hydroxystach-15-en-1-one, $C_{20}H_{30}O_2$, m.p. 105—106°, $[\alpha]_D$ −31°, $\nu_{max.}$ (CCl_4) 3630 and 1709 cm^{-1}, was isolated. In addition to the typical stachene olefinic AB quartet it had, in the n.m.r. spectrum, three tertiary methyl resonances and a second AB quartet [τ 6·16 and 6·37 (J 11 Hz)], arising from a hydroxymethyl group. The chemical shift of this suggested [2] it was axially oriented at C-4 and this was readily confirmed by

[9] J. Rigby, *J. Chem. Soc.*, 1951, 793.
[10] J. R. Hanson, *Tetrahedron*, 1967, **23**, 793.

Wolff–Kishner reduction of (6) to give erythroxylol A (12),[2] identical with an authentic specimen (n.m.r., m.p., mixed m.p., and $[\alpha]_D$). The carbonyl group was placed at C-1 on the basis of o.r.d. evidence (see Experimental section).

Examination of the more polar fractions of the extract was facilitated by the formation of isopropylidene acetals using acetone and anhydrous copper sulphate. In this way two new compounds were isolated in addition to the known erythroxydiol X (13)[3] and erythroxytriol Q (14).[4] Both of the new compounds contained a cyclopropane ring [τ 9·71 (J_{AB} 4·5 Hz, one half of AB q)] and appeared to be related to erythroxydiol X.

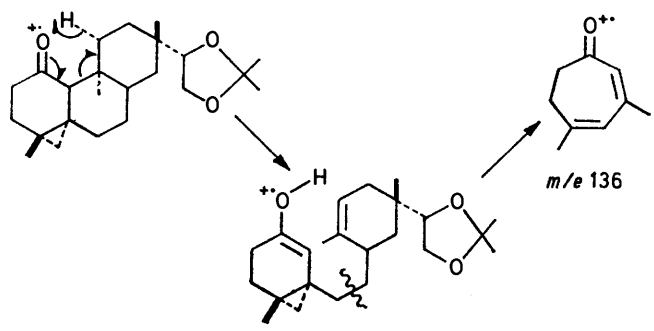
The first compound was the monohydroxylated erythroxydiol X isopropylidene acetal (15), m.p. 161—162°, $[\alpha]_D$ −4·4°. The n.m.r. spectrum showed a broad singlet ($W_{\frac{1}{2}}$ 8 Hz) at τ 5·78 (C*H*OH) which moved downfield to τ 4·78 in the corresponding acetate (16), m.p. 138—139°. The alcohol (15) failed to form a tosylate under normal conditions but was readily converted to the ketone (17), m.p. 103—104°, $\nu_{max.}$ (CCl_4) 1710 cm^{-1}, on treatment with Jones' reagent. Sodium borohydride reduction of the ketone yielded exclusively the original alcohol (15).

The ketone (17) incorporated three atoms of deuterium on exposure to sodium deuterioxide in dioxan–D_2O. Sodium borohydride reduction gave the corresponding trideuterio-alcohol in which the C*H*OH resonance appeared as a sharp singlet. These results can be accommodated by placing the original oxygen function at either C-1 or C-7. A decision in favour of the former was reached by use of the Eu(DPM)$_3$ shift reagent.[11] In the shifted spectrum of the alcohol (15) and the acetate (16) the proton attached to C-1 moves downfield as a doublet (J 3·5 Hz). It appears as a singlet in the shifted spectrum of the ketone (17) and is not present in the deuteriated alcohol and ketone. Thus the new alcohol is 1α-hydroxyerythroxydiol X.

Confirmatory evidence was obtained from the mass spectrum of the ketone (17) which has the base peak at *m/e* 101 (100%; isopropylidene acetal residue). The next most intense peak is at *m/e* 136 (22%) and can arise by a McLafferty rearrangement involving the carbonyl group at C-1 and the 11α-H followed by cleavage of the C-6–C-7 bond (see Scheme 1). In the trideuterio-ketone this peak moves to *m/e* 139.

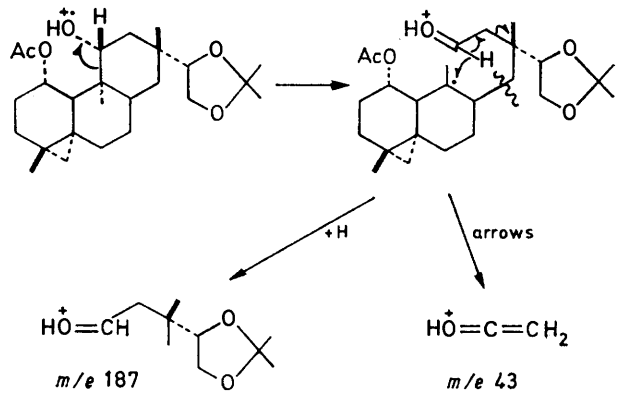
The second new isopropylidene acetal was the hydroxyacetate (18), m.p. 186—187°, $[\alpha]_D$ −26°. The C*H*OAc resonance [τ 4·65br (s, $W_{\frac{1}{2}}$ 8 Hz)] was very similar in shape and chemical shift to the corresponding signal in (16). The C*H*OH resonance was obscured by the acetal protons (τ 6·2—6·5) but appeared as a quartet [τ 5·1 (J_{obs} 10 and 6 Hz)] in the diacetate (19), m.p. 175—176° [*cf.* erythroxytriol Q acetate (20)]. The original C*H*OAc resonance suffered an upfield shift to τ 5·19 on formation of the diacetate (19), suggesting the close proximity of the two oxygen functions.

Oxidation of the hydroxyacetate (18) with Jones' reagent yielded the keto-acetate (21). Again there was a considerable change in the chemical shift of the C*H*OAc resonance which moved downfield to τ 4·15.



SCHEME 1

The relative positions of the two oxygen functions was readily settled by use of the benzene solvent shift method on the keto-acetate (21). In benzene relative to $CDCl_3$ the C*H*OAc resonance was deshielded by τ 0·3 and must therefore lie in front[12,13] of the carbonyl reference plane. This is only possible in an erythroxydiol X skeleton if the acetate and ketone are attached to C-1 and C-11. This result, in conjunction with the other n.m.r. data, confirms the structure of the hydroxyacetate as 1α-acetoxy-11α-hydroxyerythroxydiol X.



SCHEME 2

The mass spectrum of (18) is of interest since the base peak is no longer the isopropylidene acetal residue at *m/e* 101 but occurs jointly at *m/e* 43 and 187 (see Scheme 2). This is in accord with recent findings[14] for 11-oxygenated steroids where cleavage of the C-9–C-11 bond dominates the breakdown pattern.

EXPERIMENTAL

For general experimental details see Part I.[2]

Extraction.—Powdered root wood of *E. australe* was extracted with hot ethyl acetate in a Soxhlet and the crude

[11] C. C. Hinkley, *J. Amer. Chem. Soc.*, 1969, **91**, 5160.

[12] N. S. Bhacca and D. H. Williams in 'Applications of N.M.R. Spectroscopy in Organic Chemistry. Illustrations from the Steroid Field,' Holden Day, San Francisco, 1964, ch. 7; *Tetrahedron Letters*, 1964, 3127.

[13] J. D. Connolly and R. McCrindle, *Chem. and Ind.*, 1965, 379.

[14] H. Obermann, M. Spiteller-Friedmann, and G. Spiteller, *Tetrahedron*, 1971, **27**, 1093, 1101, 1737, 1747.

extract (90 g) chromatographed over silica gel using gradually increasing proportions of ethyl acetate in light petroleum. The column was finally washed with ethyl acetate and then methanol. Preparative t.l.c. of the early hydrocarbon fractions over silver nitrate-impregnated silica gave the known hydrocarbons, stachene (1) (100 mg),[2] devadarene [7] (30 mg), and atisirene [7] (150 mg) (identified by n.m.r. and g.l.c.). 2β-*Hydroxystach*-15-*en*-1-*one* (4) (6 g), was isolated by preparative t.l.c. and crystallised from light petroleum as needles, m.p. 109—110°, $[\alpha]_D$ +220° (*c* 0·99); $\nu_{max.}$ (CCl_4) 3470 (sharp bonded ⁻OH) and 1705 cm^{-1}, τ 9·06, 8·99, 8·92, and 8·86 (tertiary methyls), 5·5 (q, J_{obs} 12·5 and 5 Hz, after D_2O exchange, C*H*OH), 4·53 and 4·42 (olefinic AB q, J_{AB} 5·5 Hz) (Found: C, 79·55; H, 10·0. $C_{20}H_{30}O_2$ requires C, 79·4; H, 10·0%), o.r.d., Φ_{218} +13,770, Φ_{272} −6075, and Φ_{313} +9315.

The ketone (2) and the diosphenol (5) were initially separated by multiple preparative t.l.c. A more convenient method of separation involved acetylation of the mixture followed by t.l.c. and saponification (see later). *Stach*-15-*en*-1-*one* (2) (1·2 g) was recrystallised from methanol as prisms, m.p. 77—78°, $[\alpha]_D$ −114° (*c* 1·88), $\nu_{max.}$ (CCl_4) 1709 cm^{-1}, τ 9·06, 9·00, 8·92, and 8·87 (tertiary methyls), 4·53 and 4·42 (olefinic AB q, J_{AB} 5·5 Hz) (Found: C, 84·0; H, 10·6. $C_{20}H_{30}O$ requires C, 83·9; H, 10·6%), Φ_{217} −11,855, Φ_{250} −2020, Φ_{279} −2890, and Φ_{319} +585. *Stach*-2,15-*dien*-1-*one* (5) (1·1 g), was recrystallised from light petroleum as needles, m.p. 108—109°, $[\alpha]_D$ −11° (*c* 4·56), $\nu_{max.}$ (CCl_4) 3440, 1682, and 1660 cm^{-1}, $\lambda_{max.}$ (EtOH) 270 nm (ε 10,000) changing to $\lambda_{max.}$ 315 nm (ε 6000) on addition of 0·1M-KOH, τ 8·96 and 8·86 (9H) (tertiary methyls), 4·36 and 4·5 (olefinic AB q, *J* 5·5 Hz), and 4·35 (s, 3-H) [Found: M^+ (mass spectrometry), 300·2091. $C_{20}H_{28}O_2$ requires *M*, 300·2091].

A minor product present in these fractions and separated by preparative t.l.c., was the *epoxy-ketone* (3) (100 mg) which was crystallised from light petroleum as needles, m.p. 131—132°, $[\alpha]_D$ −36° (*c* 1·72), $\nu_{max.}$ (CCl_4) 1709 cm^{-1}, τ 9·04, 8·97, 8·91, and 8·71 (tertiary methyls), 6·62 and 6·93 (epoxide protons, *J* 4 Hz) (Found: C, 79·35; H, 9·95. $C_{20}H_{30}O_2$ requires C, 79·4; H, 10·0%).

19-*Hydroxystach*-15-*en*-1-*one* (6) (100 mg), was isolated from the intermediate fractions and recrystallised from light petroleum as needles, m.p. 105—106°, $[\alpha]_D$ −31° (*c* 1·93), $\nu_{max.}$ (CCl_4) 3630 (sharp, free OH), 3480 (bonded OH), and 1709 cm^{-1}, τ 9·00, 8·96, and 8·90 (tertiary methyls), 6·37 and 6·16 (AB q, *J* 11 Hz, CH_2OH), 4·53 and 4·38 (olefinic AB q, *J* 5·5 Hz) [Found: M^+ (mass spectrometry), 302·2243. $C_{20}H_{30}O_2$ requires *M*, 302·2246]. Two further compounds present in these fractions were identified (m.p., t.l.c., and n.m.r.) as erythroxylol A (12) (200 mg),[2] and erythroxydiol X (13) (12 g).[3]

The combined later fractions (1 g) were stirred with anhydrous copper sulphate (2 g) in acetone (50 ml) and the crude product subjected to preparative t.l.c. to yield erythroxydiol X isopropylidene acetal (780 mg) and erythroxytriol Q isopropylidene acetal (20 mg) (both identified [3,4] by n.m.r. and comparison with authentic samples). 1α-*Hydroxyerythroxydiol X isopropylidene acetal* (15) (120 mg), was recrystallised from methanol as needles, m.p. 161—162°, $[\alpha]_D$ −4·4° (*c* 0·79), $\nu_{max.}$ (CCl_4) 3620 cm^{-1}, τ 9·12, 8·99, and 8·97 (tertiary methyls), 8·66 and 8·72 (isopropylidene acetal methyls), 9·71 (d, *J* 4·5 Hz, one part of cyclopropane AB q), 5·78br (1H, s, $W_{\frac{1}{2}}$ 8 Hz, C*H*OH) (Found: C, 76·1; H, 10·4. $C_{23}H_{38}O_3$ requires C, 76·2; H, 10·55%). 1α-*Acetoxy*-11α-*hydroxyerythroxydiol X isopropylidene acetal* (18) (35 mg) was recrystallised from methanol as needles, m.p. 186—187°, $[\alpha]_D$ −26° (*c* 1·86), $\nu_{max.}$ (CCl_4) 3624 (free OH), 3500 (bonded OH), and 1735 cm^{-1}, τ 9·71 (d, *J* 4·5 Hz, one part of cyclopropane AB q), 9·10, 9·04, and 8·98 (tertiary methyls), 8·65 and 8·72 (isopropylidene methyls), 8·09 (CH_3CO_2), 6·4 (C*H*OH, obscured by acetal ABC system), and 4·65br (s, $W_{\frac{1}{2}}$ 8 Hz, C*H*OAc) (Found: C, 71·15; H, 9·65. $C_{25}H_{40}O_5$ requires C, 71·4; H, 9·6%).

Epoxidation of the Ketone (2).—Ketone (2) (20 mg) and *m*-chloroperbenzoic acid (25 mg) were dissolved in chloroform (4 ml) and left at room temperature for 1 h. The reaction mixture was filtered through a short column of basic alumina and the epoxy-ketone (3) was purified by preparative, t.l.c. and crystallised from light petroleum as needles (15 mg), m.p. 131—132°, $[\alpha]_D$ −36° (*c* 1·5) (identical in all respects with natural material).

Stachan-1-*one*.—The ketone (2) was hydrogenated over 10% Pd–C in ethyl acetate for 4 h. The product, *stachan*-1-*one*, was crystallised from light petroleum as needles, m.p. 72—73°, $\nu_{max.}$ (CCl_4) 1709 cm^{-1}, τ 9·04 (6H), 8·96, and 8·70 (tertiary methyls) (Found: C, 83·0; H, 11·0. $C_{20}H_{32}O$ requires C, 83·25; H, 11·2%).

Wolff–Kishner Reduction of Ketone (2).—Ketone (2) (20 mg), hydrazine hydrate (0·3 ml), triethylene glycol (5 ml) and sodium hydroxide (100 mg) were heated at 200° for 1·5 h under nitrogen. The hydrocarbon fraction (12 mg) of the product was a mixture of stachene (1) and stachane (n.m.r. and g.l.c. on 2% SE-30 at 170° and 15% ApL at 240°).

Stach-15-*en*-1β-*ol* (7).—Ketone (2) (78 mg) in methanol (5 ml) was reduced with excess of $NaBH_4$ over 4 h. The crude product was crystallised from light petroleum to yield *stach*-15-*en*-1β-*ol* (7) (65 mg), m.p. 82—84°, $\nu_{max.}$ (CCl_4) 3610 cm^{-1}, τ 9·21, 9·13, 9·08, and 8·98 (tertiary methyls), 6·4 (m, C*H*OH), and 4·30 and 4·54 (olefinic AB q, *J* 6 Hz) [Found: M^+ (mass spectrometry), 288·2454. $C_{20}H_{32}O$ requires *M*, 288·2453]. Tosylation of the alcohol (7) under normal conditions, followed by $LiAlH_4$ reduction resulted in recovery of the original alcohol.

Acetylation of the Diosphenol (5).—The mixture of ketone (2) and diosphenol (5) (175 mg) from the extract was acetylated under normal conditions. The product was separated by preparative t.l.c. to yield the ketone (2) (*vide supra*) and the *diosphenol acetate* (8) (57 mg) which was recrystallised from light petroleum as fine needles, m.p. 162—163°, $[\alpha]_D$ −43° (*c* 1·45), $\nu_{max.}$ (CCl_4) 1768 and 1700 cm^{-1}, τ 9·00, 8·89, 8·86, and 8·83 (tertiary methyls), 7·85 (CH_3CO_2), 4·32 and 4·47 (olefinic AB q, *J* 5·5 Hz), and 4·04 (s, 3-H) (Found: C, 76·95; H, 8·9. $C_{22}H_{30}O_3$ requires C, 77·15; H, 8·85%). Saponification of the acetate (8) (55 mg) in 1·5% ethanolic KOH (12 ml) under reflux for 1 h gave the diosphenol (5) (52 mg), m.p. 108—109° (from light petroleum), identical with natural material.

2β-*Acetoxystach*-15-*en*-1-*one*.—The α-ketol (4) was acetylated under normal conditions and the product crystallised from light petroleum to give 2β-*acetoxystach*-15-*en*-1-*one* as needles, m.p. 112—113°, $\nu_{max.}$ (CCl_4) 1750 and 1728 cm^{-1}, τ 9·02 (6H), 8·96, and 8·94 (tertiary methyls), 7·85 (CH_3CO_2), 4·2—4·6 (superimposed C*H*OAc and olefinic AB q) (Found: C, 76·60; H, 9·35. $C_{22}H_{32}O_3$ requires C, 76·70; H, 9·35%).

Interconversion of the α-Ketol (4) *and the Ketone* (2).—The α-ketol (4) (45 mg) was treated with toluene-*p*-sulphonyl chloride (0·2 g) in dry pyridine (2 ml) at 20° for 60 h. The

crude tosylate was reduced with excess of $LiAlH_4$ in refluxing ether for 4 h and the product, in acetone (3 ml), subjected to oxidation with Jones' reagent at 20° for 3 min. Preparative t.l.c. afforded stach-15-en-1-one (2) (24 mg), identical with natural material.

Interconversion of the α-Ketol (4) *and the Diosphenol* (5).—The α-ketol (95 mg) in acetic acid (2 ml) was heated with an excess of bismuth oxide on a steam bath for 45 min. The solution was filtered, diluted with water, and extracted several times with benzene. The crude product (90 mg) was purified by preparative t.l.c. and crystallisation from light petroleum gave the diosphenol (5), m.p. 108—109°, identical with natural material.

1α-*Hydroxystach*-15-*en*-2-*one* (9).—The α-ketol (4) (30 mg) in acetic acid was exposed to bismuth oxide at 100° for 15 min. The product was a mixture of three components which were separated by t.l.c. and identified as diosphenol (5) (10 mg), starting ketol (6 mg), and 1α-*hydroxystach*-15-*en*-2-*one* (9) (11 mg). The new ketol was crystallised from light petroleum as prisms, m.p. 104—105°, $\nu_{max.}$ (CCl_4) 3465 and 1712 cm^{-1}, τ 9·34, 9·09, 9·01, and 8·93 (tertiary methyls), 6·11 (s, C*H*OH), and 4·43 and 4·55 (olefinic AB q, *J* 5·5 Hz) (Found: C, 79·2; H, 9·95. $C_{20}H_{30}O_2$ requires C, 79·4; H, 10·0%), o.r.d.,[15] Φ_{221} +10,100, Φ_{241} +9830, Φ_{258} +10,430, and Φ_{304} −4250. The corresponding *acetate* crystallised from light petroleum as needles, m.p. 151—152°, τ 5·03 (s, C*H*OAc) [Found: M^+ (mass spectrometry), 344·2352. $C_{22}H_{32}O_3$ requires *M*, 344·2351].

Equilibration of the Ketol (4) *with Base*.—The ketol (4) (60 mg) was refluxed for 5 h in 5% ethanolic KOH (20 ml) under nitrogen. The product consisted of four compounds, separable by preparative t.l.c. These were the diosphenol (20 mg), starting material (16 mg), 1α-hydroxystach-15-en-2-one (9) (3 mg), and a more polar *ketol* (10) (13 mg) (1β-*hydroxystach*-15-*en*-2-*one*). The more polar ketol was recrystallised from chloroform–light petroleum as needles, m.p. 169—170°, $\nu_{max.}$ (CCl_4) 3620, 3440, and 1720 cm^{-1}, τ 9·28, 9·13, 8·99, and 8·92 (tertiary methyls), 6·41 (s, C*H*OH), and 4·30 and 4·50 (olefinic AB q, *J* 5·5 Hz) (Found: C, 79·3; H, 10·0. $C_{20}H_{30}O_2$ requires C, 79·4; H, 10·0%), o.r.d.,[11] Φ_{222} +10,550, Φ_{266} +4950, Φ_{283} +5420, Φ_{325} −5600, and Φ_{400} −1480. The derived *acetate* was crystallised from methanol as needles, m.p. 150—151°, τ 5·51 (s, C*H*OAc) [Found: M^+ (mass spectrometry), 344·2351. $C_{22}H_{32}O_2$ requires *M*, 344·2351].

Stach-15-*en*-2-*one* (11).—1α-Hydroxystach-15-en-2-one (9) (26 mg) was converted into the corresponding tosylate under the usual conditions. To the tosylate (30 mg) in acetone (8 ml) and acetic acid (2 ml) was added excess of chromous chloride solution and the mixture was stirred under nitrogen at reflux temperature for 4 h. The crude product was plated to remove unchanged tosylate. Stach-15-en-2-one (10 mg) was recrystallised from methanol and had m.p. 118—119° (lit.,[10] 119—120°), o.r.d., Φ_{216} +7440, Φ_{226} +5675, Φ_{266} +5300, and Φ_{310} −2510.

19-*Acetoxystach*-15-*en*-1-*one*.—The keto-alcohol (6) was acetylated under normal conditions to give 19-*acetoxystach*-15-*en*-1-*one*, m.p. 90—91° (from methanol), τ 5·60 and 6·05 (CH_2OAc, J_{AB} 11 Hz) [Found: M^+ (mass spectrometry), 344·2344. $C_{22}H_{32}O_3$ requires *M*, 344·2351], o.r.d., Φ_{220} −3775, Φ_{250} −950, Φ_{282} −2755, and Φ_{323} +1680.

Wolff–Kishner Reduction of the Keto-alcohol (6).—The keto-alcohol (70 mg), KOH (200 mg), hydrazine hydrate (0·6 ml), and triethylene glycol (10 ml) were heated at 200° under nitrogen for 3 h. Preparative t.l.c. of the product afforded erythroxylol A (12) (55 mg), m.p. 119—120°, $[\alpha]_D$ +40°, as needles from light petroleum (lit.,[2] 119—120°, $[\alpha]_D$ +39°).

1α-*Acetoxyerythroxydiol X Isopropylidene Acetal* (16).—1α-Hydroxyerythroxydiol X isopropylidene acetal (15) (30 mg) in dry pyridine (3 ml) and acetic anhydride (3 ml) was heated on the steam bath for 4 h. Normal work-up followed by preparative t.l.c. gave the *acetate* (16) (28 mg), m.p. 138—139° (fine needles from methanol), τ 4·7br (s, $W_{\frac{1}{2}}$ 8 Hz, C*H*OAc) (Found: C, 74·1; H, 9·95. $C_{25}H_{40}O_4$ requires C, 74·2; H, 9·95%).

1-*Ketoerythroxydiol X Isopropylidene Acetal* (17).—The alcohol (15) (20 mg) in acetone (2 ml) was treated with Jones' reagent (3 drops) at room temperature for 3 min. Preparative t.l.c. afforded the *ketone* (17) (14 mg), m.p. 103—104° (plates from methanol), $\nu_{max.}$ (CCl_4) 1710 cm^{-1} [Found: M^+ (mass spectrometry), 360·2670. $C_{23}H_{36}O_3$ requires *M*, 360·2664]. Sodium borohydride reduction of (17) gave back the original alcohol (15).

Deuterium Exchange Experiments.—The ketone (17) (40 mg) was dissolved in dry dioxan (10 ml) and deuterium oxide (3 ml) under nitrogen. Sodium (100 mg) was added in small pieces and the reaction mixture stirred at 60° for 96 h. The solvents were removed *in vacuo* and the residue was extracted with dry ether. Mass spectral analysis of the product showed 0 $^2H_0$, 0 $^2H_1$, 10 $^2H_2$, 90 $^2H_3$, and 0% $^2H_4$.

The deuteriated ketone (20 mg) was reduced with sodium borohydride to give the trideuteriated alcohol, τ 5·79 (sharp s, C*H*OH). Mass spectral analysis showed 0 $^2H_0$, 0 $^2H_1$, 12 $^2H_2$, 88 $^2H_3$, and 0% $^2H_4$.

1α,11α-*Diacetoxyerythroxydiol X Isopropylidene Acetal* (19).—The hydroxy-acetate (18) was acetylated under normal conditions to give the diacetate (19) which was crystallised from methanol as needles, m.p. 175—176°, τ 5·1 (q, J_{obs} 10 Hz, 6 Hz, 11-H, C*H*OAc) and 5·19br (s, $W_{\frac{1}{2}}$ 8 Hz, 1-H, C*H*OAc) (Found: C, 69·95; H, 9·2. $C_{27}H_{42}O_6$ requires C, 70·1; H, 9·15%).

1α-*Acetoxy*-11-*ketoerythroxydiol X Isopropylidene Acetal* (21).—Oxidation of the hydroxy-acetate (18) (10 mg) in acetone, with Jones' reagent at room temperature for 3 min afforded the acetoxy-ketone (21) as a gum, $\nu_{max.}$ (CCl_4) 1736 and 1704 cm^{-1}, τ 4·15br (s, $W_{\frac{1}{2}}$ 8 Hz, 1-H, C*H*OAc) [Found: M^+ (mass spectrometry), 418·2717. $C_{25}H_{38}O_5$ requires *M*, 418·2719].

We thank Professor W. Klyne and Dr P. M. Scopes, Westfield College, London, for running o.r.d. curves and Dr R. D. H. Murray, Department of Chemistry, University of Glasgow, for authentic stach-15-en-3-one. One of us (A. E. H.) is indebted to the S.R.C. for a studentship.

[2/387 *Received*, 21*st February*, 1972]

[15] W. Klyne, *Adv. Org. Chem.*, 1960, **1**, 291.