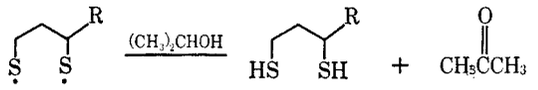
ketone. If the solvent is $CH_3OH$, $H_2S$ and a ketal may be the end products. In a solvent such as 2-propanol, where a hydrogen is easily abstracted from the hydroxylic carbon, dihydrolipoic acid and acetone are formed along with product A and the other oligomers. Since these are only preliminary experiments, it is indicated



that a thorough product study should be made of the aqueous and alcoholic solutions. In solvents such as $C_6F_6$, where the products are mainly long chain polymers, it is evident that the reaction is a simple attack of the dithiyl radicals on other LA molecules. In solvents such as $CHCl_3$, $CCl_4$, $C_6H_6$, and $C_6H_{12}$, other products are formed as well as fair amounts of polymer. This indicates the possibility of other reactions proceeding at the same time as polymerization. Such possibilities include the abstraction of a chlorine atom from $CCl_4$ and formation of a chloro-LA derivative, the formation of a $\pi$-bond complex with benzene, the abstraction of a hydrogen atom from $CHCl_3$ and a subsequent coupling of the thiyl radical with the trichlorocarbon radical, etc.

Therefore it is concluded that the photolysis of LA is solvent dependent and that the final products formed are dependent on the ease of hydrogen abstraction and upon the presence or absence of water.

**Registry No.**—$\alpha$-Lipoic acid, 62-46-4.

# The Structure of Jegosapogenol (Barringtogenol C, Aescinidin) and the Configuration at C-21 and C-22 in Barringtogenol D, Aescigenin, Protoaescigenin, and Isoaescigenin[1,2]

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The structure of jegosapogenol was established as 3$\beta$,16$\alpha$,21$\beta$,22$\alpha$,28-pentahydroxyolean-12-ene (**1a**) on the basis of chemical as well as spectroscopic data and this triterpene was shown to be identical with barringtogenol C (aescinidin). The configuration at C-21 and C-22 in barringtogenol D, aescigenin, protoaescigenin, and isoaescigenin is discussed on the basis of nmr spectra, and their structures are revised to **12b**, **24a**, **25a**, and **26**, respectively.

The fruits of *Styrax japonica* Sieb. *et* Zucc. (Japanese name "egonoki") were once used as a substitute for soaps and as a fish poison. In 1899, Keimatsu[4] isolated from the skins of this fruit a saponin named jegosaponin. Since then, the elucidation of the chemical structure of this saponin has been the subject of a number of investigations.[5] However, in spite of these intensive studies, no structure could be proposed for this fish poison.

The earlier workers[5] reported that the acid hydrolysis of jegosaponin yielded 2 equiv each of glucuronic acid and glucose[6] as well as a sapogenin which, on digestion with alkali, was hydrolyzed to tiglic acid and jegosapogenol. For the sake of brevity, we have at the outset given the correct formula **1a** for jegosapogenol and will summarize later the relevant evidence. The nmr spectra of the acetyl derivatives (**1b**, **1c**, **1d**, **1e**, and **1f**) (see Table I) indicated that jegosapogenol has one primary hydroxyl group, which was confirmed by the preparation of a monotrityl ether **1g**, and all the remaining hydroxyl groups are secondary, one of which may be more hindered than the rest. From a biogenetic point of view, one hydroxyl group is assumed to be located at C-3, and a quartet (spacings of 6 and 12 Hz) at $\tau$ 5.28 in the 100 MHz nmr spectrum (benzene) of the pentaacetate **1b** corresponds to the axially oriented proton at C-3.[7]

The mass spectrometric fragmentation patterns[8] of jegosapogenol and its tetraacetate **1c** and also the detection of seven quaternary C-methyl groups as sharp singlets in the 100-MHz nmr spectrum (benzene) of the pentaacetate **1b**[1] suggested that jegosapogenol must be a $\beta$-amyrin-type triterpene alcohol, whose one primary and three secondary hydroxyl groups are located on rings D and E.

The uv spectrum of jegosapogenol exhibited an absorption maximum at 203 m$\mu$ ($\epsilon$ 6000), which was

(1) Preliminary accounts of this work were presented in T. Nakano, M. Hasegawa, T. Fukumaru, S. Tobinaga, C. Djerassi, L. J. Durham, and H. Budzikiewicz, *Tetrahedron Lett.*, 365 (1967), and T. Nakano, M. Hasegawa, and J. B. Thomson, *ibid.*, 1675 (1967). The present paper represents part III in the series "Terpenoids" by T. Nakano and part LXIII in the series "Terpenoids" by C. Djerassi, *et al.*

(2) This work was supported by Research Grants GM-09362 and GM 06840 of the National Institutes of Health.

(3) To whom correspondence concerning this paper should be addressed.

(4) S. Keimatsu, *J. Chem. Soc. Jap.*, **20**, 1052 (1899).

(5) Y. Asahina and K. Momoya, *Arch. Pharm.*, **252**, 56 (1914); *Yakugaku Zasshi*, **34**, 105 (1914); **35**, 1 (1915); C. Sone, *Acta Phytochim.* (Tokyo), **8**, 23 (1934); **9**, 83 (1936); S. Tobinaga, *Yakugaku Zasshi*, **78**, 526, 529 (1958).

(6) Matsunami [*J. Pharm. Soc. Jap.*, **545**, 87 (1927)], however, identified glucuronic acid (1 mol), rhamnose (1 mol), and glucose (2 mol) in this hydrolysis.

(7) This proton appears as a triplet (spacing of 8 Hz) at around $\tau$ 6.5 and 5.5, respectivey, in the 60 MHz nmr spectra of the C-3-OH ($\beta$) derivatives and the acetates (see Table I). This signal constitutes the X part of an ABX pattern and its change of appearance in different solvents is consistent with a change of the relative positions of A and B. These chemical shifts are in good accordance with those of the axial proton of $\alpha$- and $\beta$-amyrin and taraxerol and their acetates [see M. Shamma, R. E. Glick, and R. C. Mumma, *J. Org. Chem.*, **27**, 4512 (1962)].

(8) H. Budzikiewicz, J. M. Wilson, and C. Djerassi, *J. Amer. Chem. Soc.*, **85**, 3688 (1963).

TABLE I
NUCLEAR MAGNETIC RESONANCE DATA[a]

| Compd | H-3 | H-21 | H-22 | $H_2$-28 | H-16 | H-12 |
|---|---|---|---|---|---|---|
| 1b[b] | 5.28 (q, 6; 12) | 4.38 (s) | 4.38 (s) | 6.12 (AB q, 13) | 4.50 (m) | 4.70 (m) |
| 1c | 5.48 (t, 8) | 4.43 (d, 10) | 4.60 (d, 10) | 6.33 (s) | 5.81 (m) | 4.63 (m) |
| 1d | 5.48 (q, 7; 9) | 5.97 (d, 10) | 4.77 (d, 10) | 6.30 (s) | 5.79 (m) | 4.60 (m) |
| 1e | 5.34 (m) | 3.77 (d, 10) | 4.02 (d, 10)[c] | 5.75; 6.00 (AB q, 11) | 5.34 (m) | 4.54 (m) |
| 1f | 5.27 (m) | 5.64 (d, 10) | 4.21 (d, 10) | 5.87 (diffused s) | 5.56 (m) | 4.62 (m) |
| 1h | 5.50 (t, 8) | 4.52 (d, 11) | 4.62 (d, 11) | 6.33 (s) | 5.77 (m) | 4.62 (m) |
| 3b | 5.48 (t, 7) | 4.42 (d, 10) | 4.79 (d, 10) | 5.54; 5.87 (AB q, 12) | ... | 4.20 (s) |
| 4a | 5.50 (t, 7) | 4.42 (d, 11) | 4.82 (d, 11) | 5.50; 5.85 (AB q, 13) | ... | 4.50 (m) |
| 5[d] | 6.53 (t, 7) | 6.48 (d, 9) | 5.81 (t, 9) | ... | ... | 4.43 (m) |
| 8b | 5.23 (t, 8) | ... | 3.34 (d, 3) | ... | ... | 4.32 (m) |
| 10 | 5.48 (t, 7) | 5.20 (d, 10) | 4.62 (d, 10) | 6.23 (s) | 4.25; 4.33[e] (2 H, AB q, 10) | 4.60 (m) |
| 12a | 5.47 (t, 7) | 6.40 (s) | 4.70 (s) | 5.86; 6.20 (AB q, 12) | 5.72 (m) | 4.70 (m) |
| 12c | 6.80 (t, 7) | 6.48 (s) | 5.62 (s) | 6.95 (s) | 5.85 (m) | 4.86 (m) |
| 13a | 6.75 (t, 7) | 6.27 (d, 10) | 5.78 (d, 10)[c] | 6.36; 6.65 (AB q, 12) | 5.23 (m) | 4.70 (m) |
| 13b | 5.47 (t, 8) | 6.26 (d, 10) | 5.77 (d, 10)[c] | 6.36; 6.66 (AB q, 12) | 5.20 (m) | 4.70 (m) |
| 14a[d] | 6.55 (t, 8) | 5.64 (d, 9) | 5.30 (d, 9)[c] | 5.89; 6.15 (AB q, 11) | 4.65 (m) | 4.31 (m) |
| 14c | 5.47 (t, 8) | 4.75 (d, 9) | 5.93 (d, 9)[c] | 5.92 (s) | 6.25 (m) | 4.62 (m) |
| 15 | 5.50 (t, 7) | 6.53 (s) | 5.84 (s) | 6.35 (s) | 5.22 (m) | 4.79 (m) |
| 16a | 6.80 (t, 7) | 5.33 (s) | 4.07 (s) | 5.50; 6.60 (AB q, 11) | 5.65 (m) | 4.63 (m) |
| 18 | ... | 4.82 (s) | ... | 5.78; 6.10 (AB q, 10) | ... | 4.40 (m) |
| 20a | ... | 6.46 (s) | 5.60 (s) | 6.91 (s) | 5.81 (m) | 4.81 (m) |
| 20b | ... | 6.51 (s) | 5.79 (s) | 6.37 (s) | 5.53 (m) | 4.75 (m) |
| 20c | ... | 6.44 (s) | 6.04 (s) | 5.68; 6.23 (AB q, 12) | 5.72 (m) | 4.69 (m) |
| 20d | ... | 6.42 (s) | 4.72 (s) | 5.89; 6.20 (AB q, 11) | 5.73 (m) | 4.72 (m) |
| 21a | ... | 6.57 (s) | ... | 6.40 (s) | 5.74 (m) | 4.68 (m) |
| 22b | 5.48 (t, 7) | 6.25 (d, 6) | 4.73 (d, 6) | 6.06 (s) | 5.97 (m) | 4.67 (m) |
| 24b[f] | 5.40 (t) | 6.35 (s) | 4.60 (m) | 6.00 (AB q) | 5.70 | 4.60 (m) |
| 25b[g] | 5.5 (t) | 4.7 | 4.7 | 6.3 (s) | | 4.7 |
| 25c[g] | 5.47 (t) | 4.7 (m) | 4.7 (m) | 6.27 (s) | 4.7 (m) | 4.7 (m) |
| 27[g] | 5.50 (t) | 4.78 (d, 9) | 5.95 (d, 9) | 5.93 (s) | 6.24 (t) | 4.65 (m) |
| 28[g] | 5.41 (t) | 4.64 (d, 11) | 6.18 (d, 11) | 6.46 (AB q) | 4.15 (m) | 4.7 (m) |

[a] Unless otherwise specified, the nmr spectra were taken on a Varian A-60 in $CDCl_3$ using TMS as an internal standard. Chemical shifts are given in ppm on the $\tau$ scale. Abbreviations in brackets denote singlet (s), doublet (d), triplet (t), quartet (q), and multiplet (m). [b] Recorded on a Varian HR-100 in benzene. [c] In this case, the assignment of H-21 and H-22 cannot be made unequivocally and could be reversible. [d] Determined in pyridine. [e] The protons at C-15 and C-16. [f] Data from ref 23 [R. Tschesche and G. Wulff, *Tetrahedron Lett.*, 1569 (1965)]. [g] Data from ref 24 [R. Kuhn and I. Löw, *Tetrahedron*, **22**, 1899 (1966)].

shifted to 242 m$\mu$[9] ($\epsilon$ 9900) in the oxidation product **3a**. The normal oleanene skeleton is attributed to jegosapogenol, since the selenium-dioxide oxidation of the tetraacetate **1c** led to a heteroannular diene showing triple ultraviolet absorption maxima (242, 250, and 260 m$\mu$) characteristic of $\Delta^{11-12,13-18}$-dienes of the $\beta$-amyrin series.[10] (See Chart I).

On treatment with alkali in methanol–dioxane at 0° overnight, the keto tetraacetate **4a** underwent a retro aldol reaction[11] to furnish the nor ketone **5**,[12] which showed the absence of a primary hydroxyl group in the nmr spectrum. On titration it consumed 0.67 mol of periodic acid, indicating the presence of one $\alpha$-glycol moiety. One of the two protons in the $\alpha$-glycol system, $H_\alpha$, exhibits a triplet signal ($J$ = 9 Hz) at $\tau$ 5.81 due to the coupling with an adjacent newly generated proton (see A → B). Dehydration of **1c** with thionyl chloride–pyridine furnished an olefin, **10** (Chart II). In its nmr spectrum, the newly generated ethylenic protons (H-15 and H-16) appear as an AB quartet signal ($J$ = 10 Hz) at $\tau$ 4.25 and 4.33, respectively (see C → D). The axial nature of the hydroxyl group at C-16 and the diequatorial configuration of the $\alpha$-glycol system were established from nmr spectral as well as chemical evidence.[1]

On alkali treatment in methanol–dioxane at room temperature, the nor ketone **5** gave rise to a product which exhibited two absorption maxima at 247[13] and 300 m$\mu$ in the uv spectrum. This product is assumed to be a mixture of **6a** and **7a**. On refluxing with methanolic alkali, **6a** changed completely into its more stable isomer **7a**, which absorbs at 300 m$\mu$ in the uv spectrum. The mixture of compound **6a** and **7a** obtained above was oxidized with chromium trioxide–acetic acid and the resulting product was chromatographed on silica gel to afford **8a**, showing a uv absorption maximum at 250 m$\mu$. On addition of 1 drop of alkali, this maximum was shifted to 300 m$\mu$ (**8a** → **9a**). Similar results were obtained in a retro aldol reaction of the keto tetrabenzoate **4b**. Treatment of **4b** with alkali in methanol–dioxane gave **6b**,[14] which was then oxidized with manga-

(9) This value of maximum is abnormally low compared with the value (*ca.* 250 m$\mu$) usually observed for 11-keto-$\Delta^{12}$-triterpenes [for leading references, see C. R. Noller, *J. Amer. Chem. Soc.*, **66**, 1269 (1944)]. This suggested the influence of some additional structural features upon this chromophore [see C. Djerassi, C. H. Robinson, and D. B. Thomas, *ibid.*, **78**, 5685 (1956)].

(10) L. Ruzicka, G. Muller, and H. Schellenberg, *Helv. Chim. Acta*, **22**, 767 (1939); D. H. R. Barton and C. J. W. Brooks, *J. Chem. Soc.*, 257 (1951).

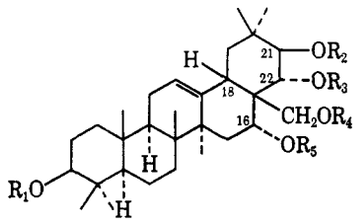
(11) D. H. R. Barton and P. de Mayo, *J. Chem. Soc.*, 887 (1954).

(12) In this retro aldol reaction, no epimerization at C-17 appears to have occurred, since the ORD curve of the nor ketone **5** gave a negative Cotton effect [ORD (methanol) $[\alpha]_{350}$ −89°, $[\alpha]_{315}$ −2460° tr, $[\alpha]_{295}$ 2140° pk; see C. Djerassi, J. Osiecki, and W. Closson, *J. Amer. Chem. Soc.*, **81**, 4587 (1959)].

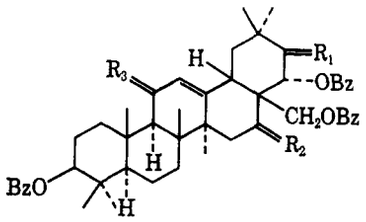
(13) The absorption maximum at 247 m$\mu$ is due to the $\alpha,\beta$-unsaturated carbonyl chromophore in **6a**.

(14) In its uv spectrum, the benzenoid absorption at 231 m$\mu$ ($\epsilon$ 20,800), 249 (sh), 273 (sh), and 283 (sh) masks absorption due to the $\alpha,\beta$-unsaturated carbonyl chromophore at 247 m$\mu$.

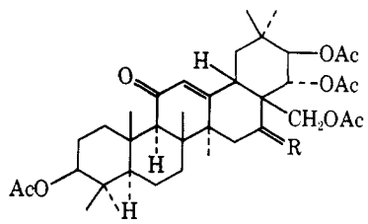
CHART I



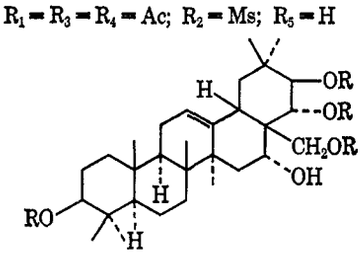
**1a**, $R_1 = R_2 = R_3 = R_4 = R_5 = H$
**b**, $R_1 = R_2 = R_3 = R_4 = R_5 = Ac$
**c**, $R_1 = R_2 = R_3 = R_4 = Ac$; $R_5 = H$
**d**, $R_1 = R_3 = R_4 = Ac$; $R_2 = R_5 = H$
**e**, $R_1 = R_2 = R_3 = R_4 = Bz$; $R_5 = H$
**f**, $R_1 = R_3 = R_4 = Bz$; $R_2 = R_5 = H$
**g**, $R_1 = R_2 = R_3 = R_5 = H$; $R_4 = C(C_6H_5)_3$
**h**, $R_1 = R_3 = R_4 = Ac$; $R_2 = Ms$; $R_5 = H$



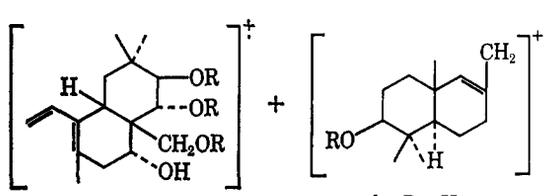
**2a**, $R_1 = \alpha$-OH, $\beta$-H; $R_2 = O$; $R_3 = H_2$
**b**, $R_1 = R_2 = O$; $R_3 = H_2$
**c**, $R_1 = R_2 = R_3 = O$



**3a**, $R = \alpha$-H, $\beta$-OAc
**b**, $R = O$

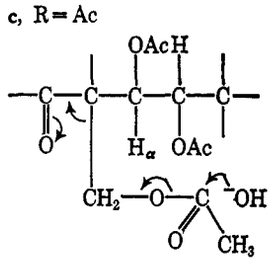


**1a**, R = H
**c**, R = Ac

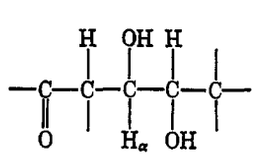


**a**, R = H
**c**, R = Ac

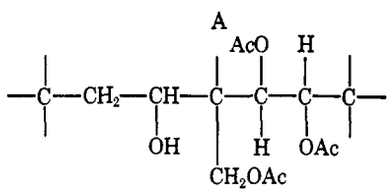
**b**, R = H
**d**, R = Ac



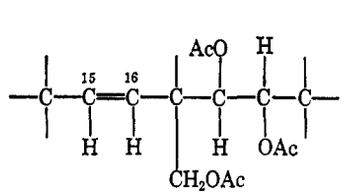
A



B



C



D

nese dioxide in chloroform to **8b**. The uv spectrum of the latter showed a maximum at 232 mμ with shoulders at 236, 247, and 278 mμ,[15] whereas addition of alkali generated a new maximum at 300 mμ (**8b** → **9b**). The nmr spectra of **6**–**8** support the conclusions derived from the above uv spectral evidence. The ethylenic proton at C-12 found at τ 4.48 in **6b** and at τ 4.32 in **8a** and **8b** undergoes a downfield shift to τ 3.75 in **7b**.[16] Compounds **8a** and **8b** exhibited a sharp doublet signal ($J$ = 3 Hz) at τ 3.37 and 3.34, respectively. These peaks are assignable to the proton at C-22 in coupling with the allylic proton at C-18. This large allylic coupling constant suggests that the overlap of the σ bond of $C_{18}$–H and the π bond of $C_{17}$ — $C_{22}$ is maximal.[17] This is reflected in the ready double-bond migration of **6** and **8** to the corresponding isomers **7** and **9**.

On treatment with methanesulfonyl chloride–pyridine at room temperature, the triacetate **1d** was converted into a monomesylate, **1h**. Refluxing of **1h** with pyridine led to an epoxide, **12a**. The same epoxide was also obtained either by refluxing of **1d** with methanesulfonyl chloride–pyridine or reduction of **1h** with lithium aluminum hydride. In the nmr spectrum of the epoxide **12a**, the doublet signal at τ 4.77 (CHOAc at C-22) observed in the triacetate **1d** now changed to a singlet (τ 4.70),[18] and a new singlet signal (1 H) (CHO at C-21) occurred at τ 6.40 in **12a**, while the doublet at τ 5.97 (CHOH at C-21) found in **1d** disappeared. This

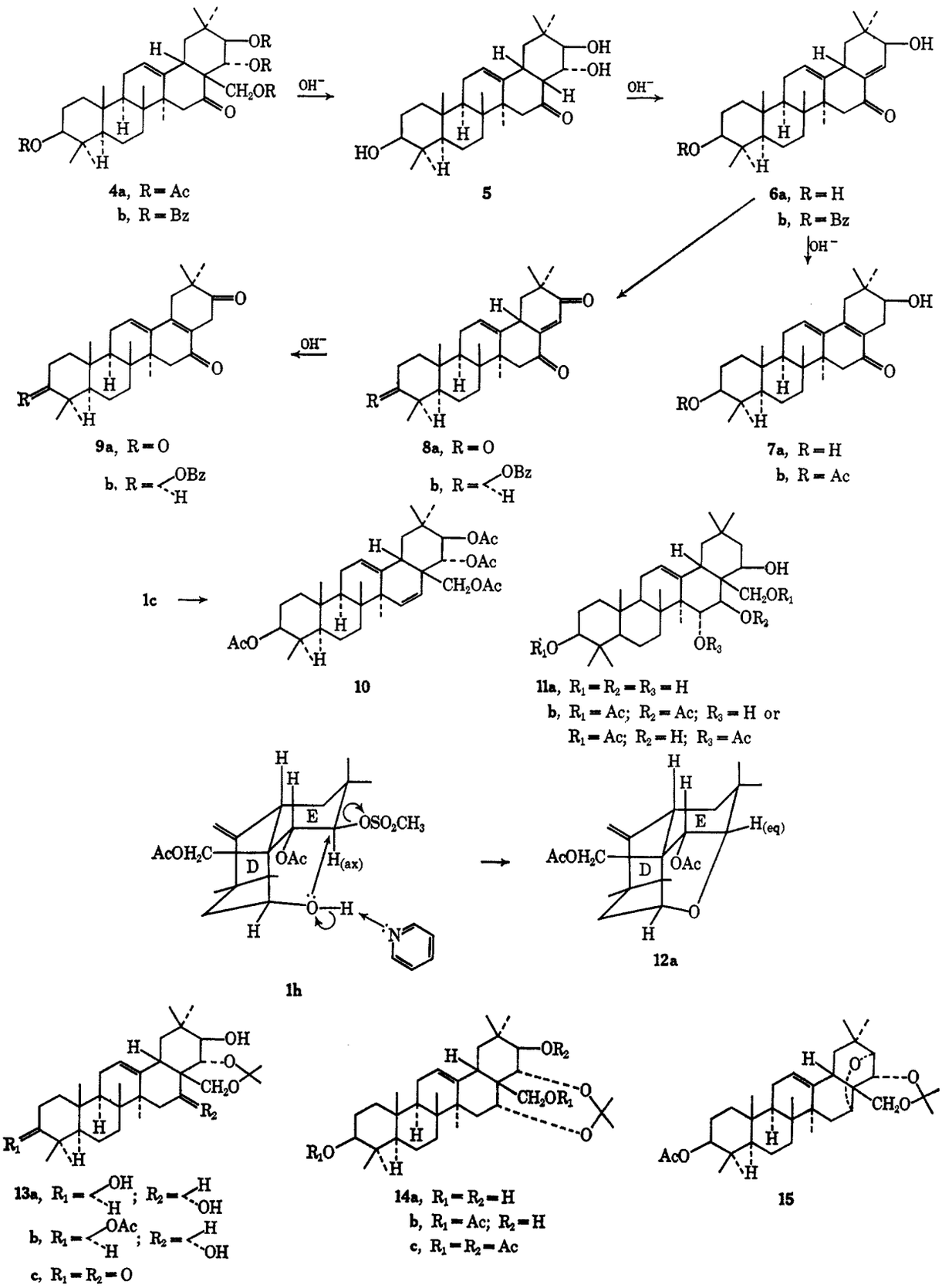
(15) Also in this case, absorption due to the α,β-unsaturated carbonyl chromophore at 250 mμ is masked by overlapping with the benzenoid absorption.

(16) For similar examples in which the introduction of the double bond conjugated to the carbonyl group causes a large downfield shift of the β proton, see N. S. Bhacca and D. H. Williams, "Application of Nmr Spectroscopy in Organic Chemistry," Holden-Day Inc., San Francisco, Calif., 1964, p 89.

(17) Inspection of Dreiding models showed that the angle (θ) between the plane of the double bond of $C_{17}$ — $C_{22}$ and the adjacent $C_{18}$ H bond is approximately 90°. $J_{a_1}$ is very small (<0.5 Hz) when θ < 20° or θ > 170°, whereas $J_{a_1}$ lies in the range 1.3–3.1 Hz for θ = 60–110° (see p 108 of ref 16).

(18) Dreiding models of the epoxide **12a** showed that the dihedral angle of 21β-H and 22β-H is near 90°, so that $J_{21\beta\text{-H}-22\beta\text{-H}}$ must be near 0 [see M. Karplus, *J. Chem. Phys.*, **30**, 11 (1959)].

CHART II



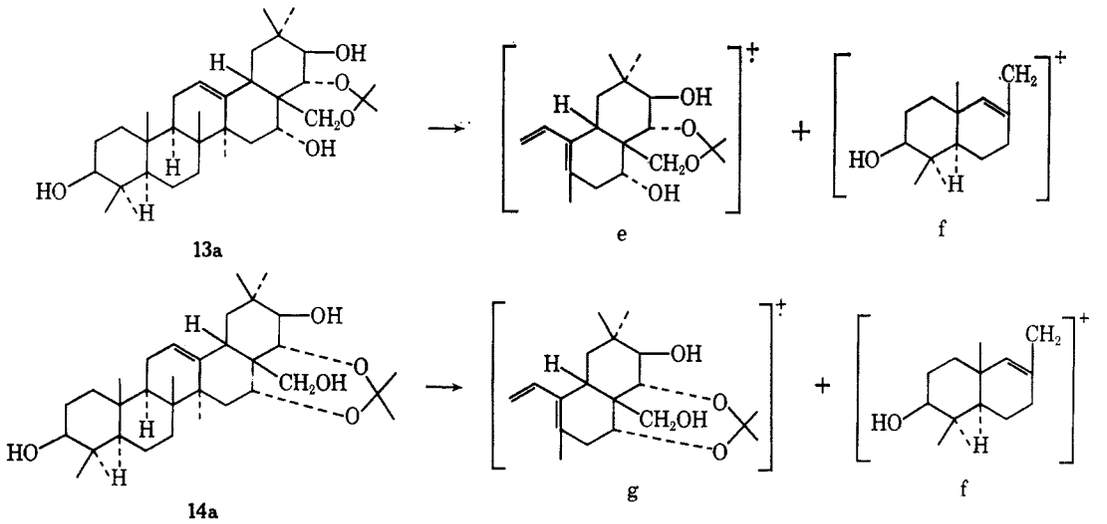

epoxide must have been formed by intramolecular SN2 displacement, as depicted by structures **1h** → **12a**.[19]

Acetonidation of jegosapogenol with *p*-toluenesulfonic acid–acetone gave two monoacetonides, **13a** and **14a** (see Experimental Section for the mass spectra and Chart III).

On acetylation with acetic anhydride–pyridine, **13a** yielded a monoacetate, **13b**, whereas **14a** furnished a mixture of a diacetate, **14b**, and a triacetate, **14c**, under

(19) If structure **11a** were the correct one for jegosapogenol, its triacetate would be **11b**, which cannot yield an epoxide analogous to **12a**.

CHART III




the same conditions. Oxidation of **13a** with the chromium trioxide–pyridine complex[20] afforded a 3,16-diketo derivative, **13c**, which showed only a six-membered carbonyl band in the infrared spectrum. On acetonidation with perchloric acid–acetone, followed by acetylation, jegosapogenol furnished a product which proved to be different from **13b**, **14b**, or **14c**. Its nmr spectrum gave peaks at $\tau$ 8.53 [s, 6 H, OC(O)$(CH_3)_2$] and 6.53 (s, 1 H). The chemical shift and shape of the latter peak is consistent with the proton at C-21 in the epoxide derivatives (see Table I), and thus this product should be considered to be 16$\alpha$,21$\alpha$-epoxyacetonyl acetate **15**.

Lead tetraacetate oxidation of jegosapogenol in acetic acid gave rise to **16a**, which did not exhibit an aldehyde carbonyl absorption in its infrared spectrum. On acetylation, this compound formed a triacetate, **16b**, and on methoxylation with *p*-toluenesulfonic acid–methanol, followed by acetylation, it afforded a trimethoxy monoacetate, **17**. Oxidation of **16a** with Jones reagent yielded a ketolactone, **18**, showing an infrared lactone carbonyl band at 1761 $cm^{-1}$ in addition to a six-membered ketone absorption at 1704 $cm^{-1}$. This compound exhibited a signal (1 H, at C-21) at $\tau$ 4.82 in the nmr spectrum and had an absorption maximum at 203 m$\mu$ in the uv spectrum. Apparently, lead tetraacetate oxidation of jegosapogenol produced initially a dialdehyde, which underwent immediate acid-catalyzed intramolecular acetal formation to **16a**, as depicted in formula E. Sodium borohydride reduction of **18** and subsequent acetylation gave a diacetyl lactone, **19**, which showed both lactonic (1758 $cm^{-1}$) and ester carbonyl (1740 $cm^{-1}$) bands in the infrared spectrum. (See Chart IV.)

After we had proposed structure **1a**[1] for jegosapogenol, a striking similarity between this triterpene and barringtogenol C was noticed. Barua, *et al.*,[21] proposed structure **29** for barringtogenol C, a new triterpenoid sapogenin from the fruits of *Barringtonia acutangula* Gaertn, on the basis of an extensive chemical degradation.[22] However, Tschesche, *et al.*,[23] recently reported that the nmr spectrum of barringtogenol D (**30**, the 16$\alpha$,21$\alpha$-epoxy derivative of barringtogenol C) triacetate shows a singlet at $\tau$ 6.35 for the proton at C-21. If the acetoxyl group at C-22 were $\beta$ axial, some degree of coupling between H-21 and H-22 should be observed, since the dihedral angle approximates 45° (Dreiding models). In order to confirm this point, we attempted to prepare from 16$\alpha$,21$\alpha$-epoxytriacetyl jegosapogenol (**12a**) 16$\alpha$,21$\alpha$-epoxy-3$\beta$,22$\beta$,28-triacetate (**22b**).

Alkaline hydrolysis of **12a** yielded an alcohol, **12b**, which, on tritylation, led to a trityl ether, **12c**. Oxidation with chromium trioxide–pyridine complex converted **12c** into a monoketo derivative, **20a**, and the latter was detritylated and then acetylated with acetic anhydride–pyridine at room temperature to a monoacetate, **20c**. Successive oxidation of **20c** with Jones reagent and hydrolysis yielded a diketo derivative, **21a**. Reduction of **21a** with sodium borohydride, followed by acetylation, afforded the desired compound, **22b**. This compound proved to be different from **12a** by melting point and infrared spectrum, and hence must be epimeric at C-22. The nmr spectrum of **22b** exhibited two doublets ($J$ = 6 Hz) at $\tau$ 4.73 and 6.25, due to the protons at C-22 and C-21, respectively. Double-resonance experiments confirmed that these protons are in fact coupled to each other. These results suggested that the C-22 hydroxyl group of the barringtogenols should be $\alpha$ equatorial and that barringtogenol C should be jegosapogenol. Through the courtesy of Professor Tschesche, samples of barringtogenol C and D and barringtogenol D triacetate were obtained and were found to be identical with the corresponding derivatives of jegosapogenol (melting point, mixture melting point, and infrared spectrum). Thus, the structures of barringtogenol C (aescinidin)[24] and barringtogenol D should be revised to **1a** and **12b**, respectively. (See Chart V.)

The triterpene alcohol, protoaescigenin,[25] is ob-

(20) G. I. Poos, G. E. Arth, R. E. Beyler, and L. H. Sarett, *J. Amer. Chem. Soc.*, **75**, 422 (1953).

(21) A. K. Barua, S. K. Chakraborti, P. Chakrabarti, and P. C. Maiti, *J. Indian Chem. Soc.*, **40**, 483 (1963); A. K. Barua and P. Chakrabarti, *Sci. Cult.* (Calcutta), **30**, 332 (1964); *Tetrahedron*, **21**, 381 (1965).

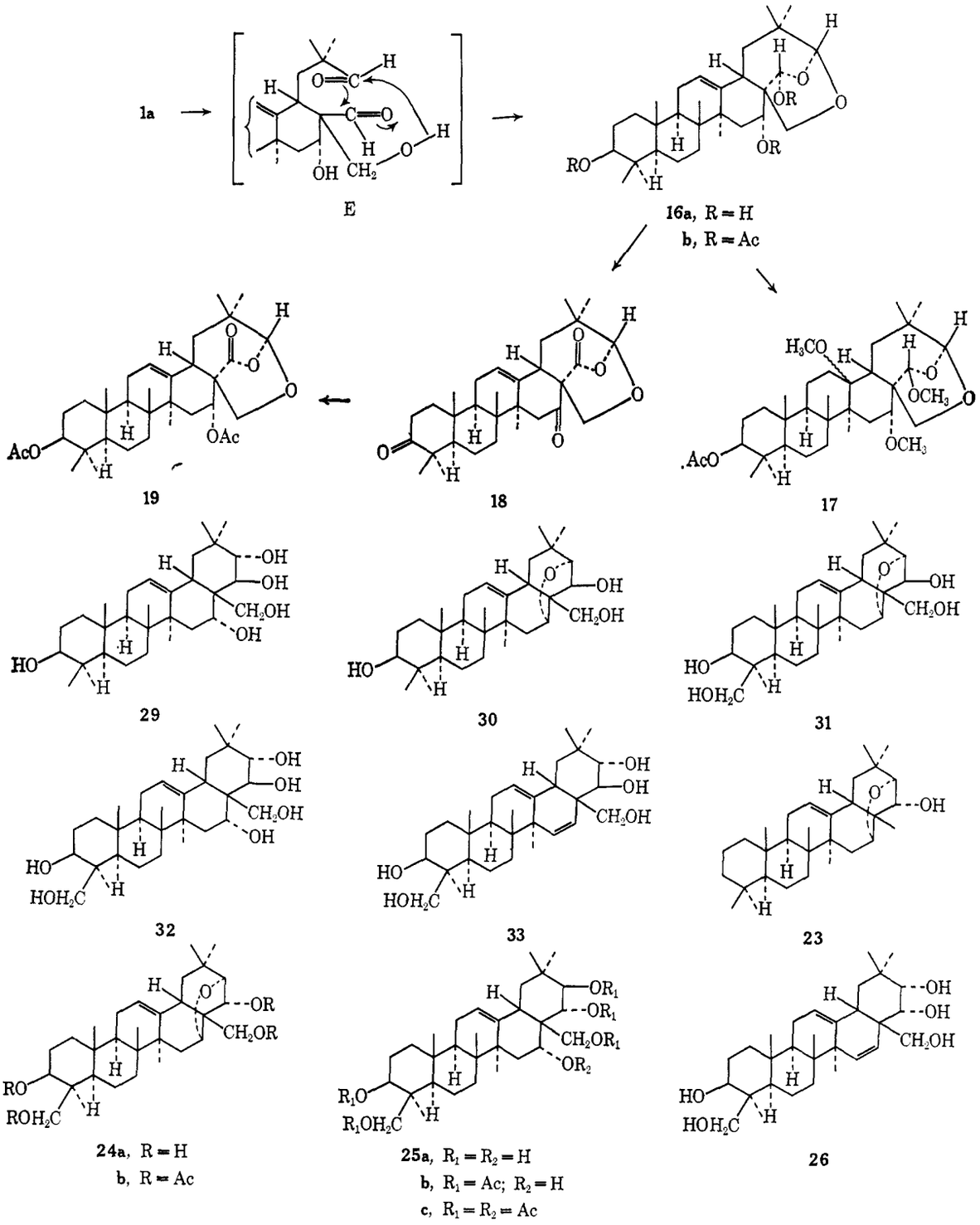
(22) The only difference between the proposed constitution of this compound and that of jegosapogenol lies in the configuration of the $\alpha$-glycol system in ring E. The *trans*-diaxial (21$\alpha$,22$\beta$) assignment for barringtogenol C was based mainly on the slow rate of reaction of this compound with lead tetraacetate.

(23) R. Tschesche and G. Wulff, *Tetrahedron Lett.*, 1569 (1965).

(24) R. Kuhn and I. Löw, *ibid.*, 891 (1964); *Tetrahedron*, **22**, 1899 (1966).

(25) R. Kuhn and I. Löw, *Ann.*, **669**, 183 (1963).

CHART IV




tained by the acid hydrolysis of aescin, a saponin from the seeds of the chestnut *Aesculus hippocastanum* L. On prolonged heating, aescigenin[26] is produced as an artifact. Isoaescigenin[27] is also present in the hydrolysate, and is formed when either protoaescigenin or aescigenin is refluxed with aqueous hydrochloric acid. The structures of aescigenin, protoaescigenin, and isoaescigenin were previously shown, on the basis of numerous chemical reactions, to be **31**, **32**, and **33**, respectively.[28] However, from nmr spectral as well as chemical evidence[29] presented previously, the structures of aescigenin and protoaescigenin should be revised to **24a** and

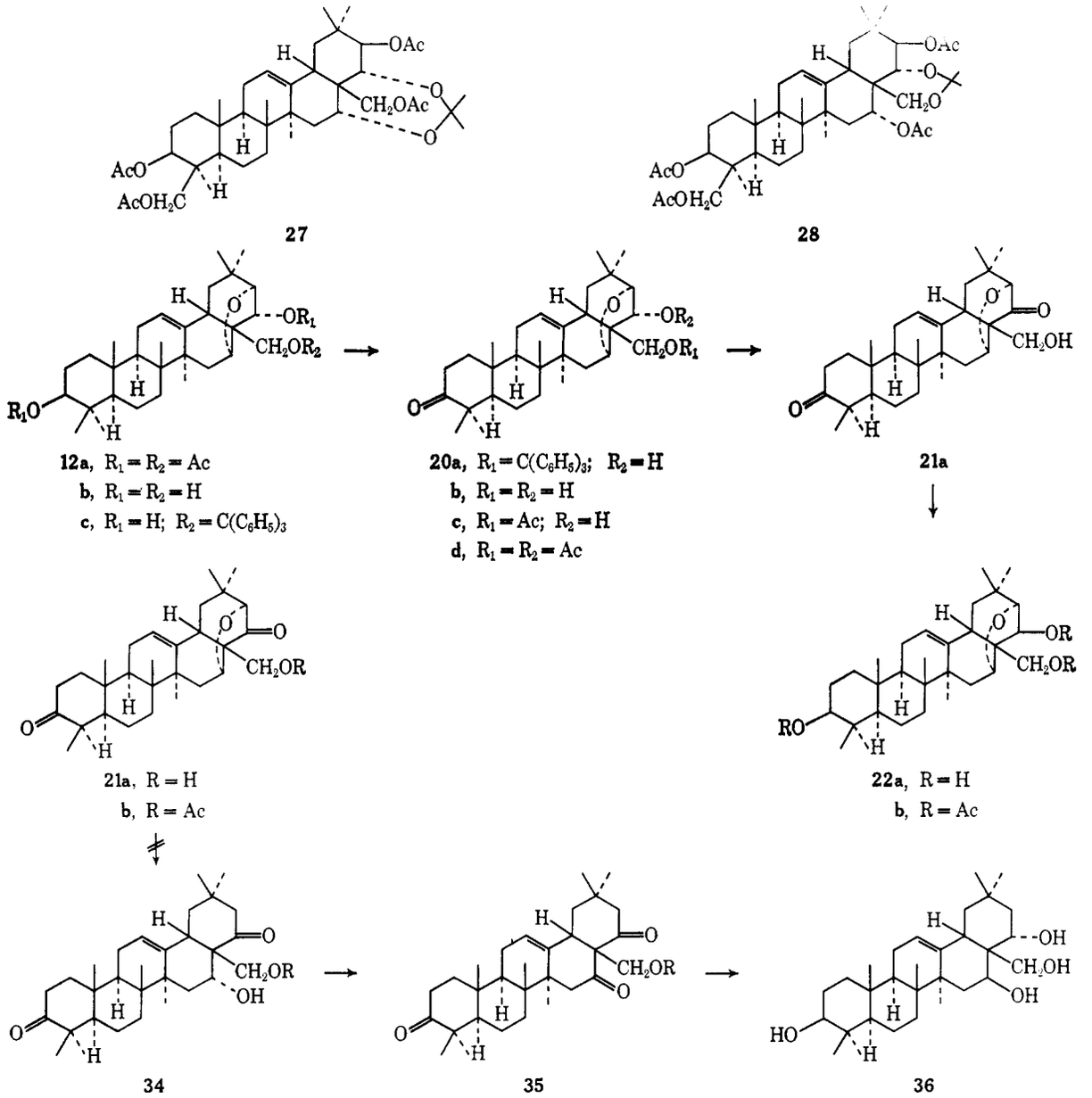
(26) G. Cainelli, A. Melera, D. Arigoni, and O. Jeger, *Helv. Chim. Acta*, **40**, 2390 (1957).

(27) J. B. Thomson, *Tetrahedron*, **22**, 351 (1966).

(28) It is pertinent to note that these triterpenes, together with barringtogenol C and D, were interrelated chemically[21-27] with methyl oleanolate, whose structure has been eventually established by X-ray analysis [see C. H. Carlisle and A. M. Abd El Rahim, *Chem. Ind.* London), 279 (1954)].

(29) The original assignment of the $\beta$ configuration to the 22-hydroxy group of aescigenin was based solely on molecular rotational data (see ref 26). Tschesche, *et al.*,[23] recently showed that aescigenin tetraacetate (**24b**) gives a singlet at $\tau$ 6.35 due to the proton at C-21 in the nmr spectrum, and thus H-22 must be $\beta$ axial (see also discussion above). Furthermore, the epoxy alcohol **23**, derived from barringtogenol D (**12b**), was shown by Barua, *et al.*,[21] to be identical with the corresponding derivatives from aescigenin or protoaescigenin. The nmr spectra of the acetonides **27** and **28** derived from protoaescigenin show an AB quartet (see Table I) with $J$ = 9 and 11 Hz, respectively, indicating that H-21 and H-22 are *trans* diaxial (see also ref 1).

CHART V




**25a**, respectively. The nmr spectra of isoaescigenin (originally assumed to be **33**) pentaacetate and its derivatives show an AB quartet in the $\tau$ 5 region. The magnitude of the small coupling constant ($J \cong 3$ Hz) between H-21 and H-22 does not enable a differentiation to be made among the three possibilities, *viz.*, (a) H-21$\beta$ (equatorial) [OH-21$\alpha$ (axial)] and H-22$\alpha$ (equatorial) [OH-22$\beta$ (axial)], (b) H-21$\beta$ (equatorial) [OH-21$\alpha$ (axial)] and H-22$\beta$ (axial) [OH-22$\alpha$ (equatorial)], and (c) H-21$\alpha$ (axial) [OH-21$\beta$ (equatorial)] and H-22$\alpha$ (equatorial) [OH-22$\beta$ (axial)].[30]

However, since H-22 of aescigenin was known to be $\alpha$ equatorial (see unrevised structure **31**), that of isoaescigenin derived from it was assumed to possess the same configuration ($\alpha$ equatorial).[31] However, now that the 22-OH has been established as being $\alpha$ equatorial (hence, the 22-H, as $\beta$ axial), the only possible structure for isoaescigenin is **26**.[32,33]

Finally, we take this opportunity to report our unsuccessful attempts to convert jegosapogenol chemically into chichipegenin (**36**),[34] triterpene from the cactus *Lemaireocereus chichipe*, *via* the following route: **21** → **34** → **35** → **36**.

For the fission of the ether ring in the epoxy diketone **21**, a key step for this scheme, the following two methods were applied.

One was the reduction with zinc–acetic acid

(30) Dreiding models indicated that all these dihedral angles between H-21 and H-22 are approximately equal.

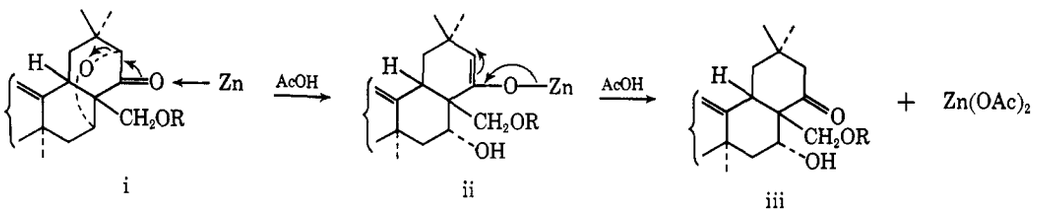
(31) The *trans*-diaxial configuration [21$\alpha$-OH,22$\beta$-OH (21$\beta$-H,22$\alpha$-H)] was assigned for the $\alpha$-glycol system in isoaescigenin on the basis of the slow rate of its reaction with sodium metaperiodate (see ref 27).

(32) It should be noted that all the relevant structural features can be accommodated by this formula (see ref 27).

(33) Recently, a similar line of reasoning was presented to establish the identity of barringtogenol C and theasapogenol B [see I. Yoshioka, T. Nishimura, A. Matsuda, and I. Kitagawa, *Tetrahedron Lett.*, 5979 (1966); I. Yoshioka, T. Nishimura, A. Matsuda, K. Imai, and I. Kitagawa, *ibid.*, 637 (1967); N. Sugiyama, H. Aoyama, T. Sayama, and K. Yamada, *J. Chem. Soc. Jap.*, **88**, 1316 (1967)].

(34) A. Sandoval, A. Manjarrez, P. R. Leeming, G. H. Thomas, and C. Djerassi, *J. Amer. Chem. Soc.*, **79**, 4468 (1957).

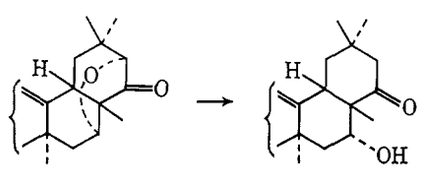
CHART VI




i ii iii

(Chart VI).[35] When **21a** was treated with zinc–acetic acid at room temperature for 13 hr, only the acetate **21b** was obtained. Refluxing of **21b** with zinc in ethanol containing a few drops of concentrated sulfuric acid yielded recovered starting material. Heating of **21b** with zinc in acetic acid with a few drops of concentrated hydrochloric acid in a sealed tube for 6 hr also resulted in the recovery of starting compound.

The other method was to reduce the epoxy diketone **21b** with aluminum amalgam.[36] However, when **21b** was allowed to react with aluminum amalgam in ether




**37** **38**

saturated with water at room temperature for 1 day, only starting material was recovered. Refluxing of **21b** with aluminum amalgam in dioxane for 8 hr did not cleave the ether ring, and only a small amount of product, whose keto group at C-22 was supposed to have been reduced to the alcohol, was obtained besides the starting material.

## Experimental Section

Melting points were taken on a Kofler hot-stage apparatus and are uncorrected. Infrared spectra were recorded on a Hitachi Model EPI-S spectrometer or a Perkin-Elmer Model 337 grating spectrophotometer in potassium bromide disks unless otherwise specified. Ultraviolet spectra were determined on a Shimazu Model SV-50 spectrophotometer in 95% ethanol solutions. Rotations were measured on a Zeiss polarimeter "0.01" in chloroform solutions. Optical rotatory dispersion was performed with a Jasco ORD/UV-5 spectropolarimeter. Unless otherwise noted, 100 mHz and 60 mHz nmr spectra were obtained in deuterochloroform solutions (about 10%) with Varian HR-100 and A-60 spectrometers, respectively, using TMS as an internal standard. Double-resonance experiments were carried out on the HR-100 after the method of L. F. Johnson, "Varian Technical Information Bulletin," Vol. III, No. 3, 1962, p 5. The mass spectra were determined at 70 eV with a CEC Model 21-103 mass spectrometer equipped with a direct inlet system.[37] Silica gel for column chromatography refers to Mallinckrodt silicic acid. For tlc, Merck silica gel G was used and the spots were identified by exposure to iodine vapor. Alumina used for column chromatography was either Woelm neutral, activity grade I, or Merck standardized, activity grade II–III. All extracts were dried over anhydrous sodium sulfate or anhydrous magnesium sulfate before evaporation.

**Isolation of Jegosapogenol.**—The dried skins (2.0 kg) of *Styrax japonica* Sieb. *et* Zucc. were ground and extracted four times each with 60 l. of hot methanol. The methanol extracts were combined, concentrated, and allowed to stand overnight. The pale green precipitates were filtered by suction and washed two times with 4 l. of ether to afford crude jegosaponin, which was heated under reflux with 8 l. of 50% ethanol containing 750 ml of concentrated hydrochloric acid for 6 hr. On cooling, crude jegosapogenin, which precipitated out, was filtered by suction and taken up in chloroform. The chloroform solution was filtered, dried, and evaporated. The residue was heated under reflux for 3 hr with 3 l. of 80% aqueous ethanol containing 180 g of sodium hydroxide. After cooling, the precipitated solid was crystallized from ethanol, yielding 100 g of jegosapogenol, mp 275° dec.

**Preparation of Pure Jegosapogenol (1a).**—Jegosapogenol is best purified through its acetate, followed by alkaline hydrolysis. The tetraacetate **1c** (1.361 g, see below) was refluxed with 5% methanolic sodium hydroxide (25 ml) for 3 hr. The solution was concentrated *in vacuo* and diluted with water, and the precipitate was crystallized from 95% ethanol, yielding 500 mg of pure jegosapogenol (1a): mp 326–330° dec; $[\alpha]_D$ 30° (*c* 0.64, pyridine); mass spectrum *m/e* (rel intensity) 490 (6, $M^+$), 282 (47, a), 264 (65, a − $H_2O$), 246 (72, a − $2H_2O$), 215 [100, a − ($2H_2O$ + $CH_2OH$)], 207 (35, b), and 197 [43, a − ($3H_2O$ + $CH_2OH$)]. Jegosapogenol was shown to be identical with barringtogenol C by direct comparison of their infrared spectra.

*Anal.* Calcd for $C_{30}H_{50}O_5$: C, 73.43; H, 10.27; O, 16.30. Found: C, 73.41; H, 10.18; O, 16.51.

**Pentaacetate 1b.**—Jegosapogenol (2.0 g) in acetic anhydride (50 ml) was heated under reflux for 1.5 hr. The solution was concentrated *in vacuo* to remove the excess acetic anhydride and extracted with chloroform. The chloroform layer was washed with water, dried, and evaporated. The oily residue (3.0 g) was chromatographed on 20 g of Woelm alumina. Elution with benzene gave 1.187 g of the pentaacetate **1b**, which was recrystallized from ethanol–water: mp 154–156°; $[\alpha]_D$ 28° (*c* 1.16); ir (Nujol) 1724 $cm^{-1}$ (ester C=O); nmr $\tau$ (100 mHz, benzene) 7.85, 8.18, 8.21, 8.22, and 8.23 (s, 15 H, $OCOCH_3$).

*Anal.* Calcd for $C_{40}H_{60}O_{10}$: C, 68.54; H, 8.63; O, 22.83; 5AcO, 30.70. Found: C, 68.21; H, 8.57; O, 22.01; 5AcO, 30.78.

**Tetraacetate 1c.**—Jegosapogenol (10 g) in acetic anhydride (30 g) and pyridine (200 ml) was set aside at room temperature for 2 days. After removal of the solvent *in vacuo*, the product was extracted with benzene, and the benzene solution was washed successively with 1% hydrochloric acid, 5% aqueous sodium hydroxide, and water, then dried and evaporated. The crude product (11.34 g) obtained was chromatographed on 200 g of Woelm alumina, and eluted with benzene to give 5.20 g of the tetraacetate **1c**, which was recrystallized from ethanol–water: mp 234°; $[\alpha]_D$ 33° (*c* 1.13); ir ($CHCl_3$) 1739 $cm^{-1}$ (ester C=O); nmr $\tau$ (100 mHz) 7.94 (3 H), 7.95 (3 H), and 7.98 (6 H) (s, four $OCOCH_3$), and 8.54 (3 H), 8.93 (3 H), 9.03 (3 H), and 9.11 (12 H) (s, seven C—$CH_3$); mass spectrum *m/e* (rel intensity) 658 (2, $M^+$), 390 (19, c − $H_2O$), 348 (20, c − AcOH), 330 [3, c − ($H_2O$ + AcOH)], 288 (8, c − 2AcOH), 270 [16, c − ($H_2O$ + 2AcOH)], 257 [52, c − ($H_2O$ + AcOH + $CH_2OAc$)], 249 (23, d), 228 (31, c − 3AcOH), 215 [100, c − (2AcOH + $CH_2$-OAc)], and 197 [76, c − ($H_2O$ + 2AcOH + $CH_2OAc$)].

*Anal.* Calcd for $C_{38}H_{56}O_9$: C, 69.27; H, 8.87; O, 21.86; 4AcO, 26.13. Found: C, 69.58; H, 8.65; O, 21.22; 4AcO, 25.84.

**Triacetate 1d.**—Jegosapogenol (8.0 g) in acetic anhydride (10 ml) and pyridine (80 ml) was kept at room temperature for 1 day. The solution was diluted with water and the product was

(35) We anticipated that mechanistically, this reduction proceeds as indicated above (i → ii → iii) and is similar to the reduction of α-acetoxy ketones with zinc–acetic acid to the corresponding ketones [see S. W. Pelletier, N. Adityachaudhury, M. Tomaz, J. J. Reynolds, and R. Mechoulam, *J. Org. Chem.*, **30**, 4234 (1965)].

(36) This method was used very successfully in the cleavage of the epoxy ketone **37** to the keto alcohol **38** (see ref 26).

(37) J. F. Lynch, J. M. Wilson, H. Budzikiewicz, and C. Djerassi, *Experientia*, **19**, 211 (1963).

extracted with chloroform. The chloroform layer was washed with 5% hydrochloric acid and water, and evaporated. The crystalline residue was washed several times with ether to furnish 5.95 g of the triacetate **1d**: mp 245–247°; $[\alpha]_D$ 11° (*c* 1.33); ir ($CHCl_3$) 1739 $cm^{-1}$ (ester C=O); nmr $\tau$ (100 mHz) 7.88 (3 H) and 7.94 (6 H) (s, three OCOC**H**$_3$), and 8.57, 8.98, 8.99, 9.02, 9.09, 9.11, and 9.12 (s, 21 H, seven C—C**H**$_3$).

*Anal.* Calcd for $C_{36}H_{56}O_8$: C, 70.10; H, 9.15. Found: C, 70.04; H, 9.15.

**Tetrabenzoate 1e.**—Jegosapogenol (10 g) was treated with 10 g of benzoyl chloride and 500 ml of pyridine at room temperature for 20 hr. After addition of methanol, the solvent was evaporated *in vacuo* and the residue was taken up in methylene chloride. The methylene chloride layer was washed successively with dilute hydrochloric acid, dilute aqueous sodium carbonate, and water, then dried and evaporated. The crude product was chromatographed on 200 g of Woelm alumina. Elution with benzene–ether (9:1) and crystallization from methanol yielded 9.24 g of the tetrabenzoate **1e**: mp >310°; $[\alpha]_D$ 21° (*c* 0.95); ir ($CHCl_3$) 1724 $cm^{-1}$ (ester C=O); nmr $\tau$ 1.8–3.0 (m, 20 H, benzenoid protons).

*Anal.* Calcd for $C_{58}H_{66}O_9$: C, 76.79; H, 7.33. Found: C, 76.54; H, 7.17.

**Tribenzoate 1f.**—Jegosapogenol (1.0 g) in benzoyl chloride (3.0 ml) and pyridine (100 ml) was kept standing at room temperature overnight. The solution was treated with methanol, evaporated *in vacuo*, and extracted with methylene chloride. After working up in the usual way, 1.6 g of crude product was chromatographed on 45 g of Woelm alumina and eluted with ether to give 760 mg of the tribenzoate **1f**, which, after recrystallization from methanol, showed mp 271–273°; $[\alpha]_D$ 82° (*c* 0.22); ir ($CHCl_3$) 1724 (ester C=O) and 1605 $cm^{-1}$ (benzenoid); nmr $\tau$ 1.8–2.8 (m, 15 H, benzenoid protons).

*Anal.* Calcd for $C_{51}H_{62}O_8$: C, 76.28; H, 7.78. Found: C, 76.57; H, 7.79.

**Monoketomonohydroxytribenzoate 2a.**—To a solution of 4 g of the tribenzoate **1f** in 500 ml of acetone was added, at 0°, 2.8 ml of Jones reagent (equivalent to 720 mg of chromium trioxide). After dilution of the solution with water, the product was extracted with methylene chloride. The methylene chloride solution was washed with aqueous sodium carbonate and water, dried, and evaporated, yielding 1.8 g of the monoketomonohydroxytribenzoate **2a**: mp 285–287° dec; ir ($CHCl_3$) 3546 (OH) 1712 (C=O), and 1608 $cm^{-1}$ (benzenoid); nmr $\tau$ 1.8–2.8 (m, 15 H, benzenoid protons).

*Anal.* Calcd for $C_{51}H_{60}O_8$: C, 76.97; H, 7.55. Found: C, 76.71; H, 7.69.

**Diketotribenzoate 2b.**—The monoketomonohydroxytribenzoate **2a** (1.5 g) in acetone (20 ml) was treated at 0° with 0.5 ml of Jones reagent (equivalent to 125 mg of chromium trioxide) for 40 min. Usual work-up afforded 0.965 g of product which was chromatographed on 40 g of silica gel. Elution with methylene chloride gave 402 mg of the diketotribenzoate **2b**: mp 178–181°; ir ($CHCl_3$) 1712 $cm^{-1}$ (C=O); nmr $\tau$ 1.8–2.8 (m, 15 H, benzenoid protons), 4.30 (s, 1 H, CHOBz at C-22), 4.37 (m, 1 H, double bond at C-12), and 5.30 (m, 3 H, CHOBz at C-3 and C**H**$_2$OBz at C-28).

*Anal.* Calcd for $C_{51}H_{58}O_8$: C, 76.77; H, 7.32. Found: C, 76.95; H, 7.40.

**Trityl Ether 1g.**—Jegosapogenol (2.0 g) and trityl chloride (6.0 g) in pyridine (50 ml) were heated under reflux for 6 hr. The solvent was evaporated *in vacuo* to dryness, and the residue was taken up in chloroform. The chloroform solution was washed with water, dried, and evaporated. The product was chromatographed on 100 g of Merck alumina in benzene. Elution with chloroform–methanol (20:1) and crystallization from hexane–ether yielded 1.8 g of the trityl ether **1g**: mp 276–278°; nmr $\tau$ 2.62 (m 15 H, benzenoid protons), 4.76 (m, 1 H, double bond at C-12), 5.51 (m, 1 H, CHOH at C-16), 6.22 (s, 2 H, C**H**$_2$OCPh$_3$ at C-28), and 6.80 and 7.20 (AB q, 2 H, $J$ = 9 Hz, CHOH at C-21 and C-22).

*Anal.* Calcd for $C_{49}H_{64}O_5$: C, 80.29; H, 8.80; O, 10.91. Found: C, 80.11; H, 8.95; O, 11.08.

**Triketotribenzoate 2c.**—The tribenzoate **1f** (289 mg) was treated with chromium trioxide (140 mg) in acetic acid (50 ml) and the solution was kept standing overnight. The usual work-up yielded 280 mg of crude product, which was chromatographed on 10 g of Woelm alumina. Elution with ether gave 108 mg of the triketotribenzoate **2c**, which, after recrystallization from methanol, showed mp 281°; ir ($CHCl_3$) 1721 (C=O), 1669 (conjugated C=O), and 1603 $cm^{-1}$ (benzenoid); uv $\lambda_{max}$ 232 m$\mu$ ($\epsilon$ 68,000); nmr $\tau$ 1.8–2.8 (m, 15 H, benzenoid protons), 4.16 (s 1 H, double bond at C-12), 4.32 (s, 1 H, CHOBz at C-22), 5.23 (t, 1 H, $J$ = 7 Hz, CHOBz at C-3), and 5.18 and 5.48 (AB q, 2 H, $J$ = 12 Hz, C**H**$_2$OBz at C-28).

*Anal.* Calcd for $C_{51}H_{56}O_9$: C, 75.34; H, 6.94. Found: C, 75.42; H, 7.13.

**Monoketopentaacetate 3a.**—The pentaacetate (569 mg) was oxidized at room temperature overnight with chromium trioxide (40 mg) in 5 ml of 85% aqueous acetic acid and 30 ml of glacial acetic acid. After decomposition of the excess chromium trioxide with methanol, the product was isolated as usual (462 mg) and then chromatographed on 14 g of Woelm alumina. Elution with benzene–ether (9:1) afforded 301 mg of an $\alpha,\beta$-unsaturated ketone, **3a**, which, after recrystallization from water-saturated ether, had mp 233–236°; uv $\lambda_{max}$ 242 m$\mu$ ($\epsilon$ 9900); ir ($CHCl_3$) 1748 (ester C=O) and 1667 $cm^{-1}$ (conjugated C=O); nmr $\tau$ 4.30 (s, 1 H, double bond at C-12), 4.63 (s, 3 H, CHOAc at C-16, C-21, and C-22), 5.47 (t, 1 H, $J$ = 8 Hz, CHOAc at C-3), 6.29 (s, 2 H, C**H**$_2$OAc at C-28), and 7.72, 7.92, 7.94, 7.97, and 8.04 (s, 15 H, five OCOC**H**$_3$).

**Oxidation of the Tetraacetate with Chromium Trioxide.**—The tetraacetate **1c** (1.028 g) was treated with chromium trioxide (200 mg) in glacial acetic acid (40 ml) at room temperature overnight. After dilution with water, the solution was extracted with ether and the product (994 mg) was isolated as usual. This was chromatographed on 30 g of Woelm alumina [elution with benzene–ether (9:1)] and crystallized from 95% ethanol to afford 347 mg of the keto tetraacetate **4a**: mp 283–285°; $[\alpha]_D$ −30° (*c* 1.43); ir ($CHCl_3$) 1745 (ester C=O) and 1724 $cm^{-1}$ (C=O); nmr $\tau$ 7.94, 7.95, 7.98, and 8.01 (s, 12 H, four OCOC**H**$_3$); ORD (dioxane) $[\alpha]_{589}$ −30°, $[\alpha]_{324}$ −1290° tr, $[\alpha]_{275}$ +1470° pk.

*Anal.* Calcd for $C_{38}H_{56}O_9$: C, 69.48; H, 8.59. Found: C, 69.50; H, 8.86.

Elution with ethyl acetate gave 245 mg of crystals, which, after recrystallization from 95% ethanol, provided 40 mg of the 11,16-diketo tetraacetate **3b**: mp 295°; uv $\lambda_{max}$ 241 m$\mu$; ir ($CHCl_3$) 1739 (C=O) and 1667 $cm^{-1}$ (conjugated C=O); nmr $\tau$ 7.93 (9 H) and 8.00 (3 H) (s, four OCOC**H**$_3$).

*Anal.* Calcd for $C_{38}H_{54}O_{10}$: C, 68.03; H, 8.11. Found: C, 68.00; H, 8.40.

**Selenium Dioxide Oxidation of the Tetraacetate 1c.**—A solution of 1.987 g of the tetraacetate in 100 ml of glacial acetic acid was heated under reflux with 1.3 g of selenium dioxide for 12 hr. The solution was diluted with water and the product was extracted with ether. The ether extract was washed with water, dried, and evaporated to afford 1.708 g of crude product which was chromatographed on 60 g of Woelm alumina. Elution with benzene–ether gave 0.867 g of product, which was recrystallized from hexane–ether to show mp 153–157°, identical with the pentaacetate **1b**. Elution with ether–ethyl acetate and ethyl acetate gave 749 mg of $\Delta^{11:12,13:18}$-diene as an amorphous solid, mp 147–153°, which had uv absorption maxima at 242, 250, and 260 m$\mu$.

**Reduction of the Keto Tetraacetate 4a with Sodium Borohydride.**—To a solution of 740 mg of the keto tetraacetate in 25 ml of methanol and 10 ml of dioxane was added 300 mg of sodium borohydride. The solution was stirred at room temperature for 2.5 hr and diluted with water, and the product was extracted with chloroform. The chloroform extract was washed with water, dried, and evaporated to yield 740 mg of crude product, which was chromatographed on 20 g of Merck alumina. Elution with benzene–ether (4:1 to 1:1) gave 530 mg of product, which was shown to be identical with the tetraacetate **1c** by mixture melting point, ir, and nmr spectra.

**Retro Aldol Reaction of the Keto Tetraacetate 4a.**—To a solution of 1.0 g of the keto tetraacetate in 20 ml of dioxane was added 20 ml of ice-cooled 5% methanolic sodium hydroxide, and the solution was kept in the refrigerator overnight. The reaction mixture was poured onto aqueous sulfuric acid solution containing crushed ice. The product was extracted with chloroform, and the chloroform layer was washed with water, dried, and evaporated, leaving 650 mg of a residue which showed absorption maxima at 242 and 300 m$\mu$ in the uv spectrum. This was chromatographed on 10 g of silica gel and the chloroform fractions 4–6 (135 mg, one spot on tlc) were combined and crystallized from chloroform to give the nor ketone **5**: mp 245–246°; $[\alpha]_D$ −25° (*c* 0.78); ir 1705 $cm^{-1}$ (C=O); nmr $\tau$ (60 MHz, pyridine)

8.71, 8.75, 8.85, 8.89, 8.94, 9.03, and 9.15 (s, 21 H, seven C—$CH_3$).

*Anal.* Calcd for $C_{29}H_{46}O_4 \cdot H_2O$: C, 73.07; H, 10.15. Found: C, 73.35; H, 10.55.

This compound consumed 0.67 equiv of periodic acid on titration.

**Alkali Treatment of the Nor Ketone 5.**—A solution of 600 mg of the nor ketone and 800 mg of sodium hydroxide in 40 ml of dioxane and 20 ml of methanol was left at room temperature overnight. The solution was diluted with water and the product was extracted with chloroform. Washing of the chloroform extract with water, drying, and evaporation yielded 520 mg of product, which exhibited two absorption maxima at 247 (corresponding to **6a**) and 300 mμ (corresponding to **7a**). By refluxing of this compound with 10 ml of 1% methanolic sodium hydroxide, the former band (247 mμ) was shifted to 300 mμ.

The compound **7a** (400 mg) was acetylated with acetic anhydride–pyridine (0.5–10 ml) at room temperature overnight. The product was isolated in the usual manner and chromatographed on 4 g of silica gel. Elution with chloroform and crystallization from ether–hexane afforded 52 mg of the monoacetate **7b**: mp 215°; $[\alpha]_D$ 37° (*c* 2.01); uv $\lambda_{max}$ 300 mμ (ε 12,400); ir ($CHCl_3$) 3448 (OH), 1718 (ester C=O), 1661 (conjugated C=O), and 1629 and 1600 $cm^{-1}$ (double bond); nmr τ 3.75 (m, 1 H, double bond at C-12), 5.47 (t, 1 H, *J* = 7 Hz, CHOAc at C-3), 6.48 (m, 1 H, CHOH at C-21), and 7.94 (s, 3 H, $OCOCH_3$).

*Anal.* Calcd for $C_{31}H_{46}O_4$: C, 77.13; H, 9.67. Found: C, 77.45; H, 9.44.

**Oxidation of Compounds 6a and 7a with Chromium Trioxide–Acetic Acid.**—The product (1.3 g) obtained by alkali treatment of the nor ketone **5** was dissolved in acetic acid (30 ml) and treated with 471 mg of chromium trioxide. After standing at room temperature overnight, the solution was diluted with water and extracted with chloroform. The product (490 mg) was isolated in the usual manner and chromatographed on 50 g of silica gel. Crystallization of the first chloroform effluent (65 mg) from methanol–acetone gave 27 mg of **8a** as needles: mp 188–191°; $[\alpha]_D$ 19° (*c* 1.10); ir ($CHCl_3$) 1706 (C=O), 1686 (conjugated C=O), and 1623 $cm^{-1}$ (double bond); nmr τ 3.37 (d, 1 H, *J* = 3 Hz, at C-22), 4.33 (m, 1 H, double bond at C-12), and 6.40 (m, 1 H, allylic proton at C-18).

*Anal.* Calcd for $C_{29}H_{40}O_3$: C, 79.77; H, 9.23. Found: C, 79.58; H, 8.91.

The uv spectrum of this compound showed an absorption maximum at 250 mμ, which, on addition of a trace of alkali, was shifted to 300 mμ.

**Keto Tetrabenzoate 4b.**—The tetrabenzoate (150 mg) in pyridine (1.5 ml) was treated with chromium trioxide–pyridine (200 mg–2.0 ml) complex. The mixture was kept standing at room temperature overnight, diluted with water, and extracted with chloroform. The chloroform solution was washed with dilute hydrochloric acid and water, dried, and evaporated. The residue was taken up in acetone and filtered on alumina. The filtrate was concentrated and crystallized from methanol to give 102 mg of the keto tetrabenzoate **4b**: mp >300°; ir 1730 $cm^{-1}$ (C=O).

*Anal.* Calcd for $C_{58}H_{64}O_9$: C, 76.97; H, 7.13; O, 15.91. Found: C, 76.75; H, 7.15; O, 15.61.

**Retro Aldol Reaction of the Keto Tetrabenzoate 4b.**—A solution of the keto tetrabenzoate in 50 ml of dioxane was treated with 20 ml of 10% aqueous sodium hydroxide at room temperature under a nitrogen stream for 3 days. The reaction mixture was diluted with water, the product was extracted with chloroform, and the chloroform extract was washed with water, dried, and evaporated *in vacuo*. After washing several times with ether, the product was recrystallized from methanol–methylene chloride, whereupon 750 mg of **6b** was obtained: mp 277–278° dec; $[\alpha]_D$ 1°; uv $\lambda_{max}$ 231 (ε 20,800), 249 (sh), 273 (sh), and 283 (sh) mμ; ir ($CHCl_3$) 3534 (OH), 1706 (C=O), and 1639 $cm^{-1}$ (double bond); nmr τ 1.8–2.7 (m, 5 H, benzenoid protons), 3.27 (q, 1 H, *J* = 2 and 3 Hz at C-22), 4.48 (m, 1 H, double bond at C-12), and 5.25 (t, 1 H, *J* = 7 Hz, CHOBz at C-3).

*Anal.* Calcd for $C_{36}H_{48}O_4$: C, 79.37; H, 8.88. Found: C, 79.29; H, 9.10.

**Manganese Dioxide Oxidation of Compound 6b.**—A solution of 445 mg of the compound in 40 ml of chloroform was vigorously stirred with 2.0 g of active manganese dioxide at room temperature overnight. The solution was filtered, and the filtrate was washed with water and evaporated to afford 390 mg of product. Purification by chromatography on 10 g of silica gel and recrystallization from methanol yielded 194 mg of **8b**: mp 259–261°; $[\alpha]_D$ 17°; ir ($CHCl_3$) 1721 (ester C=O) and 1689 $cm^{-1}$ (conjugated C=O).

This compound showed uv $\lambda_{max}$ 232 (ε 22,800), 236 (sh), 247 (sh), and 278 (sh) mμ, and by addition of a trace of alkali, a new peak was generated at 300 mμ.

**Dehydration of the Tetraacetate 1c with Thionyl Chloride–Pyridine.**—The tetraacetate (6.23 g) was heated under reflux with thionyl chloride (12 ml) and pyridine (200 ml) for 3 hr. Water was added to the reaction mixture and the product was extracted with ether. The ether extract was washed with dilute hydrochloric acid and water, dried, and evaporated, yielding 6.34 g of product. This was chromatographed on 120 g of Merck alumina, and elution with benzene to benzene–ether (3:1) gave 4.99 g of product. Recrystallization from methanol yielded 2.78 g of the olefin **10**: mp 230–232°; $[\alpha]_D$ −4.6° (*c* 1.15); ir 1740 $cm^{-1}$ (ester C=O); nmr τ 7.93, 7.97, 7.99, and 8.01 (s, 12 H, four $OCOCH_3$).

*Anal.* Calcd for $C_{38}H_{56}O_8$: C, 71.22; H, 8.81. Found: C, 71.45; H, 8.91.

**Triacetylmonomesylate 1h.**—The triacetate **1d** (2.0 g) in pyridine (20 ml) was treated with methanesulfonyl chloride (1.0 ml) at room temperature. After 6 hr, the solution was diluted with water and extracted with chloroform, and the chloroform layer was washed with dilute hydrochloric acid and water, dried, and evaporated. Recrystallization of the crude product from methanol gave 1.88 g of the monomesylate **1h**: mp 168–169°; $[\alpha]_D$ 46° (*c* 0.75); ir 1735 $cm^{-1}$ (ester C=O); nmr τ 7.00 (s, 3 H, $OSO_2CH_3$ at C-21), and 7.87, 7.93, and 7.95 (s, 9 H, three $OCOCH_3$).

*Anal.* Calcd for $C_{37}H_{58}O_{10}S$: C, 63.94; H, 8.41. Found: C, 63.66; H, 8.58.

**Epoxy Compound 12a. Method A.**—The triacetylmonomesylate **1h** (212 mg) was refluxed with pyridine (10 ml) for 1.5 hr. The solution was diluted with water and extracted with chloroform, and the chloroform extract was washed with dilute hydrochloric acid and water, dried, and evaporated. The product was chromatographed on 5 g of Merck alumina. Crystallization of the benzene fractions (169 mg) from acetone gave the epoxide **12a**: mp 235–236°; $[\alpha]_D$ 58° (*c* 1.11); ir 1740 $cm^{-1}$ (ester C=O); nmr τ 7.95 (s, 9 H, three $OCOCH_3$); mass spectrum[23] *m/e* (rel intensity) 598 (2, $M^+$), 538 (8), 478 (1), 348 (83), 288 (73), 249 (20), 228 (100), 215 (72), 190 (100), and 189 (46).

This compound was shown to be identical with barringtogenol D triacetate by direct comparison (melting point, mixture melting point, and infrared spectrum).

*Anal.* Calcd for $C_{36}H_{54}O_7$: C, 72.21; H, 9.09. Found: C, 72.18; H, 9.21.

**Method B.**—The triacetate **1d** (478 mg) in methanesulfonyl chloride (1 ml) and pyridine (10 ml) was heated under reflux for 2 hr. The product was worked up as above and the crude product (474 mg) was chromatographed on 10 g of Merck alumina. Elution with benzene gave 438 mg of **12a**.

**Lithium Aluminum Hydride Reduction of the Triacetylmonomesylate 1h.**—To a suspension of 140 mg of lithium aluminum hydride in 60 ml of dry ether was added 500 mg of the compound in 30 ml of dry dioxane, and the mixture was stirred at room temperature for 5 hr. After the excess reagent was destroyed with water-saturated ether, the complex was treated with saturated aqueous sodium sulfate solution. The ether layer was separated, dried, and evaporated to yield 362 mg of product, which, after crystallization from methanol, showed mp >300°. Identity with the epoxytriol **12b** (see below) was achieved by direct comparison (infrared spectrum). On acetylation, this compound gave rise to the epoxytriacetate **12a** (melting point and nmr spectrum).

**Acetonidation of Jegosapogenol. Method A. Catalyzed with *p*-Toluenesulfonic Acid.**—Jegosapogenol (1.0 g) in 140 ml of dry acetone containing 200 mg of *p*-toluenesulfonic acid was heated under reflux for 15 hr. The solution was evaporated and the product was taken up in chloroform. The chloroform solution was evaporated and the residue (1.0 g) was chromatographed on 25 g of Woelm alumina. Elution with benzene–ether [(3:1) to (1:1)] yielded, after recrystallization from acetone, 280 mg of the acetonide **13a**: mp 259–263°; $[\alpha]_D$ 101° (*c* 0.43); nmr τ 8.53 [s, 6 H, $OC(O)(CH_3)_2$]; mass spectrum *m/e* (rel intensity) 530 (4, $M^+$), 454 [3, M − ($H_2O$ + $Me_2C$=O)], 441 [9, M − $Me_2C$(OH)$OCH_2$], 424 {14, M − [$H_2O$ + $Me_2C(O)OCH_2$]}, 322 (100, e), 246 [57, e − ($H_2O$ + $Me_2C$=O)], 215 {57, e − [$H_2O$ + $Me_2C(OH)OCH_2$]}, 207 (58, f), and 197 {25, e − [$2H_2O$ + $Me_2C$(OH)$OCH_2$]}.

*Anal.* Calcd for $C_{33}H_{54}O_5$: C, 74.67; H, 10.26. Found: C, 74.85; H, 10.29.

Elution with ether–methanol (9:1) and crystallization from acetone yielded 90 mg of the acetonide **14a**: mp 206–207°; $[\alpha]_D$ 102° (*c* 0.34); nmr $\tau$ 8.31 and 8.49 [s, 6 H, OC(O)($CH_3$)$_2$]; mass spectrum *m/e* (rel intensity) 530 (0.6, $M^+$), 512 (51, M − $H_2O$), 454 [6, M − ($H_2O$ + $Me_2C$=O)], 436 [15, M − (2$H_2O$ + $Me_2C$=O)], 246 [100, g − ($H_2O$ + $Me_2C$=O)], 233 [88, g − ($CH_2OH$ + $Me_2C$=O)], 228 [52, g − (2$H_2O$ + $Me_2C$=O)], 215 [54, g − ($H_2O$ + $CH_2OH$ + $Me_2C$=O)], 207 (57, f), and 197 [41, g − (2$H_2O$ + $CH_2OH$ + $Me_2C$=O)].

*Anal.* Calcd for $C_{33}H_{54}O_5 \cdot H_2O$: C, 72.22; H, 10.29. Found: C, 72.07; H, 10.39.

**Acetylation of the Acetonide 13a.**—The acetonide (600 mg) in acetic anhydride (1 ml) and pyridine (10 ml) was set aside at room temperature overnight. The solution was diluted with water and extracted with chloroform, and the chloroform layer was washed with dilute hydrochloric acid and water, dried, and evaporated. The product (600 mg) was chromatographed on 20 g of Woelm alumina, and elution with benzene–ether (3:1) gave 230 mg of the monoacetate **13b** as an amorphous powder: nmr $\tau$ 7.94 (s, 3 H, OCOC**H**$_3$).

**Acetylation of the Acetonide 14a.**—The acetonide (230 mg) in acetic anhydride (1.5 ml) and pyridine (8 ml) was kept standing at room temperature for 4 days. The solution was diluted with water and the product was extracted with chloroform. The chloroform layer was washed with dilute hydrochloric acid and water, dried, and evaporated, yielding 226 mg of product. This was chromatographed on 5 g of Woelm alumina and eluted with benzene to give 36 mg of the triacetate **14c** as an amorphous powder: nmr $\tau$ 7.90, 7.91, and 7.94 (s, 9 H, three OCOC**H**$_3$).

Elution with benzene–ether [(6:1) to (1:1)] gave 60 mg of the diacetate **14b**, which, after crystallization from ethanol, showed mp 222–225°; nmr $\tau$ 4.66 (m, 1 H, double bond at C-12), 5.47 (t, 1 H, $J$ = 8 Hz, C**H**OAc at C-3), 5.82 and 6.05 (AB q, 2 H, $J$ = 11 Hz, C**H**$_2$OAc at C-28), 6.00 and 6.10 (AB q, 2 H, $J$ = 10 Hz, C**H**OH at C-21 and C**H**O- at C-22), 6.44 (m, 1 H, C**H**O- at C-16), and 7.90 and 7.95 (s, 6 H, two OCOC**H**$_3$).

**Oxidation of the Acetonide 13a by Chromium Trioxide–Pyridine Complex.**—The acetonide (235 mg) in pyridine (2.5 ml) was oxidized with chromium trioxide–pyridine (250 mg–2.5 ml) at room temperature overnight. The reaction mixture was diluted with water and extracted with chloroform. The chloroform layer was washed with dilute hydrochloric acid and water, dried, and evaporated, yielding 230 mg of product. This was filtered in chloroform on 4 g of Woelm alumina and the filtrate was concentrated to dryness. Crystallization of the residue from methanol gave 120 mg of **13c**: mp 275–277°; ir ($CHCl_3$) 1705 cm$^{-1}$ (C=O); nmr $\tau$ 4.49 (m, 1 H, double bond at C-12), 5.64 and 6.22 (AB q, 2 H, $J$ = 12 Hz, C**H**$_2$O- at C-28), 5.88 (d, 1 H, $J$ = 9 Hz, C**H**O- at C-22), 6.42 (d, 1 H, $J$ = 9 Hz, C**H**OH at C-21), 8.52 [s, 6 H, OC(O)($CH_3$)$_2$], and 8.60, 8.74, 8.86, 8.89, 8.92, 8.98, and 9.04 (s, 21 H, seven C—C**H**$_3$).

*Anal.* Calcd for $C_{33}H_{50}O_5$: C, 75.24; H, 9.57. Found: C, 75.07; H, 9.71.

**Method B. Catalyzed with Perchloric Acid.**—To a solution of 2.0 g of jegosapogenol in 300 ml of dry acetone was added dropwise 30 drops of 60% perchloric acid until the solution became clear. The solution was kept at room temperature for 2 days, then concentrated *in vacuo*, diluted with water, and neutralized with aqueous sodium carbonate. The product (847 mg) was isolated by extraction with ether and chromatographed on 25 g of Woelm alumina. Elution with benzene–ether (9:1) gave 395 mg of product, which, after acetylation, was purified through chromatography. Crystallization from methanol gave the acetonide **15**: mp 227–229°; $[\alpha]_D$ 26° (*c* 1.07); ir 1735 cm$^{-1}$ (ester C=O); nmr $\tau$ 7.97 (s, 3 H, OCOC**H**$_3$) and 8.53 [s, 6 H, OC(O)($CH_3$)$_2$].

*Anal.* Calcd for $C_{35}H_{54}O_5$: C, 75.77; H, 9.81. Found: C, 75.91; H, 10.01.

**Lead Tetraacetate Oxidation of Jegosapogenol.**—A suspension of 3 g of jegosapogenol and 7.5 g of lead tetraacetate in 180 ml of acetic acid was stirred at room temperature overnight. The resulting precipitate was collected and dissolved in ether, and the ether solution was washed with dilute aqueous sodium carbonate and water, dried, and evaporated, yielding 2.402 g of product, which was recrystallized from aqueous acetone to give 1.215 g of the hemiacetal **16a**: mp 206–207°; $[\alpha]_D$ −14° (*c* 0.48).

*Anal.* Calcd for $C_{30}H_{48}O_5 \cdot H_2O$: C, 71.11; H, 9.95. Found: C, 71.24; H, 10.29.

Acetylation of this compound with acetic anhydride–pyridine afforded the acetate **16b**: mp 201–203°; $[\alpha]_D$ −16° (*c* 0.74); ir ($CHCl_3$) 1727 cm$^{-1}$ (ester C=O); nmr $\tau$ 3.13 [s, 1 H, O—C(O)**H** at C-22], 4.58 (m, 1 H, double bond at C-12), 5.30 [s, 1 H, O—C(O)**H** at C-21], 5.53 (m, 2 H, C**H**OAc at C-3 and C-16), 5.82 and 6.67 (AB q, 2 H, $J$ = 10 Hz, C**H**$_2$O- at C-28), and 7.86, 7.97, and 7.98 (s, 9 H, three OCOC**H**$_3$).

**Methoxylation of the Hemiacetal 16a.**—A solution of 220 mg of the hemiacetal and 90 mg of *p*-toluenesulfonic acid in 100 ml of methanol was refluxed for 2 hr. The solution was concentrated and diluted with water, and the product was isolated (178 mg) by extraction with chloroform. This was chromatographed on 5 g of Woelm alumina, and the product (93 mg), eluted with ether, was acetylated with acetic anhydride (0.3 ml), and pyridine (3 ml). The acetate thus obtained was filtered in chloroform on alumina and crystallized from methanol, giving 20 mg of **17**: mp 233–234°; ir ($CHCl_3$) 1727 cm$^{-1}$ (ester C=O); nmr $\tau$ 6.43, 6.46, and 6.47 (s, 9 H, three OC**H**$_3$), 7.96 (s, 3 H, OCOC**H**$_3$), and no signal corresponding to H-12 on the double bond.

**Oxidation of the Hemiacetal 16a.**—To a stirred solution of 100 mg of the hemiacetal in 5 ml of acetone was added dropwise 0.2 ml of Jones reagent (equivalent to 50 mg of chromium trioxide) under ice cooling. After 15 min, the solution was diluted with water and the product was extracted with chloroform, the chloroform solution was washed with aqueous sodium carbonate and water, dried, and evaporated. Recrystallization of the residue (79 mg) from acetone gave **18**: mp 290–300° dec; $[\alpha]_D$ −6° (*c* 0.92); ir ($CHCl_3$) 1761 (lactone C=O) and 1704 cm$^{-1}$ (C=O); uv $\lambda_{max}$ 203 m$\mu$ ($\epsilon$ 10,800). The mass spectrum of this compound showed the molecular ion peak at *m/e* 482.

*Anal.* Calcd for $C_{30}H_{42}O_5$: C, 74.65; H, 8.77. Found: C, 74.62; H, 9.08.

**Reduction of the Keto Lactone 18.**—A solution of 173 mg of the keto lactone and 600 mg of sodium borohydride in 20 ml of methanol and 20 ml of dioxane was stirred at room temperature for 20 hr. The solution was diluted with water and the product was extracted with methylene chloride. The methylene chloride layer was washed with water, dried, and evaporated to afford 130 mg of product, which, after acetylation, was chromatographed on 5 g of Woelm alumina. Elution with methylene chloride gave 30 mg of the diacetyl lactone **19**: mp 243–245°; $[\alpha]_D$ 47° (*c* 0.60); ir ($CHCl_3$) 1758 (lactone C=O), 1740 (ester C=O), and 1730 cm$^{-1}$ (ester C=O); nmr $\tau$ 4.64 (m, 1 H, double bond at C-12), 4.83 (m, 1 H, C**H**OAc at C-16), 4.86 (s, 1 H, O—C(O)**H** at C-21), 5.50 (t, 1 H, $J$ = 8 Hz, C**H**OAc at C-3), 6.06 and 6.28 (AB q, 2 H, $J$ = 10 Hz, C**H**$_2$O at C-28), and 7.95 and 8.03 (s, 6 H, OCOC**H**$_3$).

*Anal.* Calcd for $C_{34}H_{50}O_7$: C, 71.55; H, 8.83. Found: C, 71.89; H, 8.73.

**Epoxytriol 12b.**—The epoxytriacetate **12a** (4.81 g) was refluxed with 5% methanolic sodium hydroxide (100 ml) for 2 hr. The solution was concentrated and diluted with water, and the resulting precipitate (3.52 g) was filtered and recrystallized from methanol to afford **12b**: mp >300°; $[\alpha]_D$ 22° (*c* 0.70, dioxane).

This compound was shown to be identical with barringtogenol D by direct comparison of their infrared spectra.

*Anal.* Calcd for $C_{30}H_{48}O_4$: C, 76.22; H, 10.24; O, 13.54. Found: C, 76.26; H, 10.12; O, 13.80.

**Tritylation of the Epoxytriol 12b.**—The epoxytriol (1.20 g) was refluxed with trityl chloride (3.60 g) and pyridine (30 ml) for 8 hr. The solution was diluted with water and the product was extracted with chloroform. The chloroform layer was washed with water, dried, and evaporated. The residue was chromatographed on 200 g of Merck alumina. Elution with ether–methanol (9:1) and crystallization from methanol gave 1.22 g of the trityl ether **12c**: mp 183–185°; $[\alpha]_D$ 70° (*c* 1.40); nmr $\tau$ 2.66 (m, 15 H, benzenoid protons).

*Anal.* Calcd for $C_{49}H_{62}O_4$: C, 82.31; H, 8.74; O, 8.95. Found: C, 82.20; H, 8.95; O, 8.98.

**Oxidation of the Epoxy Trityl Ether 12c by Chromium Trioxide–Pyridine.**—The epoxy trityl ether (1.22 g) in pyridine (10 ml) was treated with chromium trioxide–pyridine (1.5 g:15 ml) complex and the mixture was stirred at room temperature overnight. The product (1.36 g) was isolated by extraction with chloroform as usual and chromatographed on 40 g of Merck alumina. The product, eluted with benzene to benzene–ether (1:1), was crystallized from methanol to yield 1.00 g of **20a**: mp 238–241°; $[\alpha]_D$ 87° (*c* 0.67); ir 1700 cm$^{-1}$ (C=O); nmr $\tau$ 2.62 (m, 15 H, benzenoid protons).

*Anal.* Calcd for $C_{49}H_{60}O_4$: C, 82.54; H, 8.48; O, 8.98. Found: C, 82.28; H, 8.34; O, 8.93.

**Acid Hydrolysis of the Epoxyketo Trityl Ether 20a.**—The epoxyketo trityl ether (925 mg) in ethanol (40 ml) was heated under reflux with 10 ml of 5% aqueous hydrochloric acid for 1.5 hr. The reaction mixture was diluted with water and the product (983 mg) was isolated by extraction with chloroform and chromatographed on 30 g of Merck alumina. Elution with chloroform to chloroform–methanol (20:1) yielded 666 mg of **20b**, which, after recrystallization from ether–chloroform, showed mp 230–233°; $[\alpha]D$ 70° (*c* 0.59); ir 1703 $cm^{-1}$ (C=O).

*Anal.* Calcd for $C_{30}H_{46}O_4$: C, 76.55; H, 9.85; O, 13.60. Found: C, 76.73; H, 9.87; O, 13.65.

**Acetylation of the Compound 20b.**—A mixture of 3.2 g of the compound, 15 ml of pyridine, and 0.7 ml of acetic anhydride was set aside at room temperature overnight. After the usual work-up, the product was chromatographed in chloroform on 50 g of silica gel. The fractions 4–15 (chloroform), which were homogeneous on tlc, were combined and crystallized from methanol to yield 1.478 g of the monoacetate **20c**: mp 186–187°; $[\alpha]D$ 24° (*c* 1.01); ir 1730 (ester C=O) and 1700 $cm^{-1}$ (C=O); nmr $\tau$ 7.88 (s, 3 H, $OCOCH_3$).

*Anal.* Calcd for $C_{32}H_{48}O_5$: C, 74.96; H, 9.44; O, 15.60. Found: C, 74.74; H, 9.33; O, 15.60.

Rechromatography of the mother liquor of the fractions 4–15 and the fractions 2–3 (chloroform) gave an additional 200 mg of **20c**.

The fraction 1 (chloroform) gave the diacetate **20d**, which, after recrystallization from methanol, showed mp 218–219°; $[\alpha]D$ −22° (*c* 2.22); ir 1740 (ester C=O) and 1700 $cm^{-1}$ (C=O); nmr $\tau$ 7.96 (s, 6 H, two $OCOCH_3$).

*Anal.* Calcd for $C_{34}H_{50}O_6$: C, 73.61; H, 9.09; O, 17.31. Found: C, 73.56; H, 9.23; O, 17.25.

**Oxidation of the Compound 20c.**—To a solution of 165 mg of the compound in 10 ml of acetone was added, at 0°, 0.4 ml of Jones reagent (equivalent to 108 mg of chromium trioxide). The solution was stirred at room temperature for 2.5 hr and methanol was added to decompose the excess reagent. The solution was basified with dilute sodium bicarbonate and the product was extracted with chloroform. The chloroform layer was washed with water, dried, and evaporated to give 157 mg of product. This was chromatographed on 10 g of Merck alumina, and elution with benzene–ether (1:1) gave 41 mg of **21a**, which, after recrystallization from methanol, showed mp 228–230°; $[\alpha]D$ −21° (*c* 1.02); ir 1753 (five-membered C=O) and 1703 $cm^{-1}$ (C=O).

*Anal.* Calcd for $C_{30}H_{44}O_4$: C, 76.88; H, 9.46; O, 13.66. Found: C, 76.56; H, 9.36; O, 13.42.

**Reduction of the Compound 21a with Sodium Borohydride.**—To a solution of 100 mg of the compound in 5 ml of methanol and 1 ml of chloroform was added 50 mg of sodium borohydride, and the mixture was stirred for 2 hr. The solution was diluted with water and the product was extracted with chloroform. The chloroform layer was washed with water, dried, and evaporated to afford 110 mg of product. Recrystallization from acetone gave 83 mg of **22a**: mp 258–259°; $[\alpha]D$ 26° (*c* 0.42, dioxane).

*Anal.* Calcd for $C_{30}H_{48}O_4$: C, 76.22; H, 10.24; O, 13.54. Found: C, 76.44; H, 10.16; O, 13.66.

**Acetylation of Compound 22a.**—The compound (74 mg) in acetic anhydride (0.2 ml) and pyridine (2 ml) was left at room temperature for 2.5 days. Usual work-up yielded 96 mg of product, which, after recrystallization from acetone, furnished 29 mg of the acetate **22b**: mp 215–216°; $[\alpha]D$ 26° (*c* 0.92); ir 1730 $cm^{-1}$ (ester C=O); nmr $\tau$ 7.90, 7.96, and 7.99 (s, 9 H, three $OCOCH_3$), and 8.53 (3 H), 8.94 (3 H), 9.06 (6 H), and 9.13 (9 H) (s, seven C-$CH_3$).

*Anal.* Calcd for $C_{36}H_{54}O_7$: C, 72.21; H, 9.09; O, 18.70. Found: C, 72.12; H, 8.96; O, 18.54.

**Registry No.**—**1a**, 13844-01-4; **1b**, 14694-67-8; **1c**, 13844-00-3; **1d**, 14257-18-2; **1e**, 20852-69-1; **1f**, 20852-70-4; **1g**, 20852-71-5; **1h**, 14162-52-8; **2a**, 20852-73-7; **2b**, 20852-74-8; **2c**, 20852-75-9; **3a**, 20852-76-0; **3b**, 20852-77-1; **4a**, 13843-99-7; **4b**, 20930-46-5; **5**, 20852-79-3; **6b**, 20852-80-6; **7b**, 20852-81-7; **8a**, 20852-82-8; **8b**, 20852-83-9; **10**, 20852-84-0; **12a**, 13862-93-6; **12b**, 19882-11-2; **12c**, 20852-86-2; **13a**, 20852-87-3; **13b**, 20852-88-4; **13c**, 20852-89-5; **14a**, 20852-90-8; **14b**, 20852-91-9; **14c**, 20852-92-0; **15**, 18178-99-9; **16a**, 20852-94-2; **16b**, 20852-95-3; **17**, 20852-96-4; **18**, 20852-97-5; **19**, 20930-47-6; **20a**, 20852-98-6; **20b**, 20852-99-7; **20c**, 20853-00-3; **20d**, 20853-01-4; **21a**, 14257-19-3; **22a**, 1258-99-7; **22b**, 864-98-2; **24a**, 17806-68-7; **24b**, 20853-06-9; **25a**, 20853-07-0; **25b**, 15914-79-1; **25c**, 20853-09-2; **26**, 20853-10-5; **27**, 20853-11-6; **28**, 20853-12-7.

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