Malabaricane Triterpenes from a Fijian Collection of the Sponge *Jaspis stellifera*

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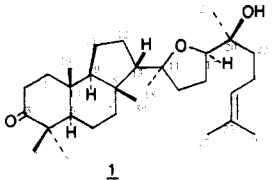
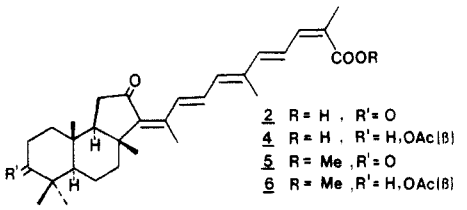
Three new triterpenes belonging to the rare malabaricane class have been isolated from the sponge *Jaspis stellifera* collected in Fiji. The compounds have been identified by a combination of spectral evidence and chemical degradations as (13*Z*,15*E*,17*E*,22*E*,24*Z*)-3,12-dioxomalabarica-13,15,17,22,24-pentaen-26-oic acid (**2**), (13*Z*,15*E*,17*E*,22*Z*,24*Z*)-3,12-dioxomalabarica-13,15,17,22,24-pentaen-22,26-olide (**3**), and (13*Z*,15*E*,17*E*,22*E*,24*Z*)-3β-acetoxy-12-oxomalabarica-13,15,17,22,24-pentaen-26-oic acid (**4**). The relative and absolute stereochemistries were solved by a combination of ^1H and ^{13}C NMR and CD studies.

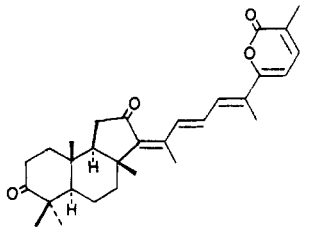
Although sponges have proven to be a particularly fruitful source of new sesqui-, di-, and sesterterpenes[1] and also of sterols,[2] no triterpenes have been isolated from sponges with the exception of squalene.[1] The isolation of novel C26-methylated sterols from the sponge *Jaspis stellifera* has been reported recently.[2,3] We now describe the isolation of three new triterpenes, possessing the rare malabaricane skeleton, from *Jaspis stellifera* collected in Fiji. Malabaricane triterpenes, exemplified by malabaricol (**1**), have been obtained from a single natural source, the wood of the tree *Ailanthus malabarica*.[4,5]



1



2 R = H, R' = O
4 R = H, R' = H,OAc(β)
5 R = Me, R' = O
6 R = Me, R' = H,OAc(β)



3

Jaspis stellifera is a chocolate-colored sponge common on the reef flats of the Great Barrier Reef and Fiji. Internally the color of the sponge varies from a butter color to an intense bright yellow. The yellow pigments, extractable from the freeze-dried sponge with dichloromethane, constitute between 1% and 8% of the dry sponge.

The crude dichloromethane extract of *Jaspis* was rapidly chromatographed on silica gel to remove sterols and fats, and the intensely colored yellow fractions were immediately treated with diazomethane. Separation of this methylated mixture by high-pressure LC on silica gel gave **5** (the methyl ester of **2**), **3**, and **6** (the methyl ester of **4**) in yields of 23%, 3%, and 4%, respectively, based on the crude extract.

High-resolution mass spectroscopy of **5** established the molecular formula $C_{31}H_{42}O_4$, and the UV absorption at 395 nm (ε 44 600) and 412 (41 000) suggested the presence of a conjugated polyene system. The ^{13}C NMR spectrum of **5** showed resonances at δ 218.0 (s), 207.7 (s), 167.7 (s), 145.5 (s), 142.9 (d), 142.5 (s), 141.2 (d), 138.5 (s), 134.8 (d), 133.8 (d), 130.5 (d), 126.2 (d), and 125.4 (s), indicative of the presence of two ketonic carbonyls, one ester carbonyl, and five double bonds. Compound **5** must therefore be tricyclic, and the UV spectrum demanded that all the double bonds and at least one carbonyl be conjugated.

The ^1H NMR spectrum of **5** revealed olefinic proton resonances at δ 8.28 (1 H, d, J = 15 Hz), 7.47 (1 *H*, dd, J = 11, 15 Hz), 6.99 (1 H, dd, J = 11, 15 Hz), 6.55 (1 H, d, J = 11 Hz), 6.49 (1 H, d, J = 15 Hz), and 6.41 (1 H, d, J = 11 Hz) and methyl signals at δ 2.07 (3 H) and 2.01 (6 H) typical of the ^1H NMR spectra of *E*-orientated carotenoids.[6] The remainder of the analyzable portion of the ^1H NMR spectrum comprised resonances at δ 3.78 (3 H, s, OCH_3) and 2.73 (2 H, m) and four methyl singlets at δ 1.41, 1.12, 1.06, and 0.86. Because the ^{13}C NMR spectrum of **5** revealed only three singlets in the aliphatic region, **5** must contain a *gem*-dimethyl grouping.

Reduction of **5** with zinc powder and acetic acid gave the colorless dihydro derivative **7** in high yield. The UV absorption at 310 nm was consistent with the presence of a conjugated tetraene, and ^1H NMR olefinic resonances at δ 6.50 (1 H, dd, J = 11, 15 Hz), 6.45 (1 H, dd, J = 11, 15 Hz), 6.24 (1 H, d, J = 8, 15 Hz), 6.06 (1 H, d, J = 11 Hz), 5.93 (1 H, d, J = 11 Hz), and 5.78 (1 H, dd, J = 15 Hz) together with the presence of only two vinyl methyl resonances at δ 1.90 and 1.88 and the appearance of new resonances at δ 3.25 (1 H, dq, J = 8, 7, 7, 7 Hz), 2.66 (1 H, s), and 1.31 (3 H, d, J = 7 Hz) strongly suggested the conversion of the partial structure **9** to **10**. The extremely low-field positions of the two resonances at δ 8.28 and 7.47

(1) L. Minale in "Marine Natural Products", Vol. 1, P. J. Scheuer, Ed., Academic Press, New York, 1978.
(2) C. Djerassi, N. Theobald, W. C. M. C. Kokke, C. S. Pak, and R. M. K. Carlson *Pure Appl. Chem.*, **51**, 1815 (1979).
(3) N. Theobald, R. J. Wells, and C. Djerassi, *J. Am. Chem. Soc.*, **100**, 7677 (1978).
(4) A. Chawla and S. Dev, *Tetrahedron Lett.*, 4837 (1967).
(5) (a) R. R. Sobti and S. Dev, *Tetrahedron Lett.*, 2215 (1968); (b) W. F. Patou, I. C, Paul, A. G. Bajaj, and S. Dev, *ibid.*, 4153 (1979).
(6) G. Englert in "Carotenoids", O. Isler, Ed., Birkhaeuser Verlag, Basel, Switzerland, 1971, pp 204-243.

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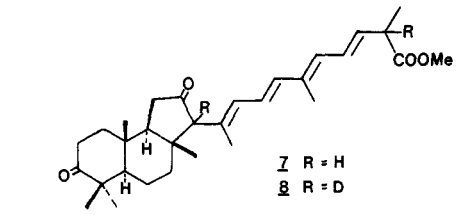
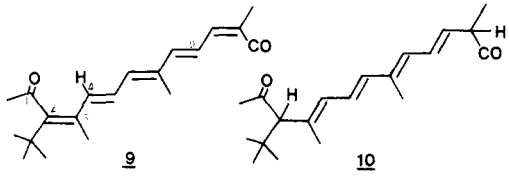
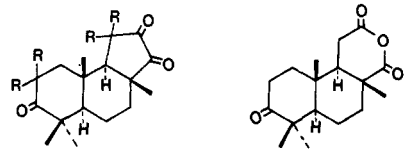


7 R = H
8 R = D



9 10



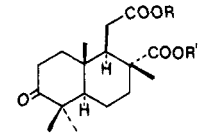
11 R = H
13 R = D

12

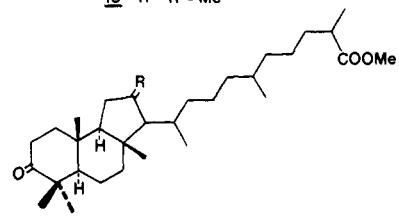
in the ^1H NMR spectrum of **5** suggested that they were in the deshielding region of the carbonyl groups, and therefore the two terminal double bonds of the polyene system must have the configurations shown in partial structure **9**. A recently reported example of similar deshielding of the proton on C4 in partial structure **9** by a carbonyl group reports δ 8.0 as the resonance frequency of a proton affected by a carbonyl in a similar conjugated system.[7] Also, from numerous examples in the carotenoid field, a proton on C9 in partial structure **9** would only be deshielded if the orientation of the C10–C11 double bond was *Z*. The assignment of the *E* configuration about the two central trisubstituted double bonds was indicated by resonances near δ 13 and 16 in the ^{13}C NMR spectrum of **5**. This was in close agreement with the values obtained for the central methyl groups in the ^{13}C NMR spectra of all *trans*-carotenoids.[6] Irradiation at δ 3.25 in the NMR of **7** collapsed the δ 5.78 resonance to a doublet (J = 15 Hz) and also collapsed the methyl doublet at δ 1.31 to a singlet. Further confirmation was obtained by repeating the reduction of **5** with zinc and acetic acid-d_1. The ^1H NMR of the product **8** revealed the δ 5.78 resonance as a doublet and the δ 1.31 resonance as a singlet, and the δ 3.25 and 2.66 resonances were absent. The IR spectrum of **7** showed two absorption maxima at ν_{max} 1745 and 1710 cm^{-1} compared to maxima at ν_{max} 1710 and 1690 cm^{-1} found for **5**, which suggested that the conjugated ester and five-membered-ring carbonyl functions present in **5** had been converted to nonconjugated carbonyls in **7**.

Incorporation of both a *gem*-dimethyl group and the partial structure **9** in **5** could not be explained on the basis of a regular head to tail isoprenoid precursor, but the general structure **5**, obtained from a squalene-derived precursor, fitted all spectral evidence, and further chemical degradations were designed by using structure **5** as a working hypothesis.

Treatment of **5** in dichloromethane with ozone at −78 °C followed by a dimethyl sulfide workup gave a mixture of the triketone **11** and the anhydride **12** in moderate yield. The high-resolution mass spectrum of **11** established the formula $C_{17}H_{24}O_3$ and showed a major fragment ion at m/e 206 ($C_{14}H_{22}O$), an expected fragment of **11**. The ^1H NMR spectrum of **11** showed the presence of four quaternary methyl groups, and 270-MHz ^1H NMR showed most of the expected coupling. Analysis of the spectrum was simplified by preparation of the tetradeuterio derivative **13**. IR absorption maxima at 1765, 1750, and 1710 cm^{-1} supported the presence of 1,2-diketone and six-membered ketone functions, respectively. The formula of **12** was found to be $C_{17}H_{24}O_4$ by high-resolution mass spectroscopy, with the same dominant m/e 206 ($C_{14}H_{22}O$) fragment ion as that found in the mass spectrum of **11**. IR absorption maxima at 1806 and 1760 cm^{-1} required a six-membered anhydride functionality,[8] which was confirmed by treatment with methanol to give a half-ester **14** and further treatment of **14** with diazomethane to yield the dimethyl ester **15**.



14 R or R' = Me, R' or R = H
15 R = R' = Me



16 R = O, C13 α or β
17 R = O, C13 β or α
18 R = H_2

Hydrogenation of **5** in methanol with 10% palladium on charcoal at atmospheric pressure overnight gave, in addition to the two expected decahydro derivatives **16** and **17** (stereochemistry at C13 unknown), a major product which, from spectral evidence, could be assigned the structure **18**. The molecular formula of **18** was obtained by high-resolution mass spectroscopy, and the ^{13}C NMR and IR spectra demonstrated the presence of the C3 keto group and the ester function but the absence of a five-membered-ring ketone function. Comparison of the ^1H NMR chemical shifts of the quaternary methyl groups of **18** (δ 0.72, 0.84, 0.98, and 1.14) in benzene-d_6 with those reported for **1** (δ 0.77, 0.83, 0.97, and 1.13) in the same solvent support the assignment of the same AB and BC ring stereochemistry for both compounds. This was further corroborated by comparison of the ^{13}C NMR chemical shifts of C5, C8, C9, C10, and C13 in **1** [59.5 (d), 58.2 (d), 55.5 (d), 44.1 (s), 36.6 ppm (s)] and **18** [58.8 (d), 58.2 (d), 54.5 (d), 42.3 (s), 35.0 ppm (s)].

The molecular formula of **3** was established as $C_{30}H_{38}O_4$ by high-resolution mass spectroscopy and was shown not to be a methyl ester by ^1H NMR. That **3** was indeed a natural product and not an artifact formed during treatment of chromatographic fractions with diazomethane was confirmed by the isolation of pure **3** by slow evaporation of a dichloromethane solution of a fraction obtained during chromatography of the initial extract of the sponge.

^{13}C NMR spectroscopy confirmed that **3** contained the same ketonic carbonyl functions present in **5** and established the presence of five double bonds, but resonances at δ 163.1 (s) and 159.3 (s) suggested that **3** was an enol lactone. The UV absorption of **3** at 396 nm (ϵ 29 200) and

(7) S. J. Wratten and D. J. Faulkner, *Tetrahedron Lett.*, 961 (1978).

(8) L. J. Bellamy, "The Infra Spectra of Complex Molecules", Vol. 1, 3rd ed., Chapman and Hall, London, 1975, p 144.

417 (23750) suggested the presence of a similar conjugated system to that of **5**, but the ^1H and ^{13}C NMR spectra demonstrated that one of the olefinic protons present in **5** was absent in **3**. Analysis of ^1H NMR spectrum of **3** showed olefinic proton resonances at δ 8.33 (1 H, d, J = 15 Hz), 6.97 (1 H, dd, J = 11, 15 Hz), 7.30 (1 H, d, J = 11 Hz), 7.20 (1 H, d, J = 7 Hz), and 6.30 (1 H, d, J = 7 Hz) which could be rationalized by the replacement of the proton on C22 by an oxygen to form the enol lactone shown in **3**. This assignment was supported by ^{13}C NMR and, in particular, mass spectral data.

The high-resolution mass spectrum of **3** showed prominent ions at m/e 353 ($C_{24}H_{33}O_2$), corresponding to a C20–C22 cleavage, m/e 313 ($C_{21}H_{29}O_2$), due to a C16–C17 cleavage, and m/e 149 ($C_9H_9O_2$) due to the enol–lactone portion of the same C16–C17 cleavage. All other spectral data, when compared to those of **5**, fully supported a common skeleton from C1 to C21 in both **3** and **5**. Ozonolysis of **3** gave, after a dimethyl sulfide workup, **11** and **12**, identical in all respects with the ozonolysis products of **5**.

Spectral data for the third metabolite **4**, isolated as the methyl ester **6**, suggested that the 3-ketone group of **5** was replaced by a 3β-acetoxyl group in **6**. Thus in the ^{13}C NMR spectrum the δ 218.0 resonance was replaced by resonances at δ 170.9 (s) and 80.7 (d), and in the ^1H NMR spectrum signals at δ 4.62 (1 H, m, $W_{h/2}$ = 16 Hz) and 1.98 (3 H, s) could be attributed to an equatorial acetoxyl group at C3. Hydrolysis of **6** with sodium carbonate in methanol and treatment of the product with diazomethane followed by oxidation with Jones reagent gave a product identical with **5** by IR and ^1H NMR and mass spectra.

Comparison of the ^{13}C NMR spectra of **6** with that of lanosterol[9] revealed a close similarity between the C4, C5, C10, and C19 resonances. Although lanosterol cannot be regarded as a perfect model compound for *Jaspis* triterpenes, the close agreement of carbon resonances with those of **5** supports ^1H NMR comparison of **18** and **1** in the assignment of AB trans stereochemistry.

The absolute configuration of **5** was established by a CD study on **18** which showed an ϵ_{max} of 1.82 at 295.1 nm. We have found significant variation of *Jaspis stellifera* metabolites and will report, in a subsequent paper, the isolation of polyene derivatives of malabaracan-28-oic acids from a collection of *J. stellifera* from the southern end of the Great Barrier Reef.

Experimental Section

General Methods. All solvents used were analytical grade. ^1H NMR spectra were measured at 100 MHz on a JEOL MH-100 instrument, and some measurements were repeated at 270 MHz on a Brucker instrument. Where 270-MHz spectra were obtained, an asterisk appears before δ in the experimental data. ^{13}C NMR spectra were measured at 15.04 MHz on a JEOL FX60 spectrometer. Tetramethylsilane was used as internal standard for all NMR measurement. Mass spectra and high-resolution data were obtained by using a VG-Micromass 70/70 instrument, UV data were obtained on a Varian Spectroscan spectrometer, IR data were measured on a Hitachi 285 instrument, and rotations were measured on a JASCO DIP-4 polarimeter. High-pressure LC separations were carried out on a Whatman Magnum 9 10/50 column packed with Partisil; eluting solvents which appear later refer to separation on this column.

Extraction of *Jaspis stellifera*. Freeze-dried, powdered *Jaspis stellifera* collected near Suva, Fiji (100 g), was slowly percolated with dichloromethane (2 L) until the extract was only pale yellow. Concentration of the combined extracts under vacuum gave a yellow-brown gum (5 g). A 2-g sample of this extract was dissolved in dichloromethane (100 mL), applied to a silica gel bed (Merck Type H for TLC; 100 g) dry packed into a Büchner funnel, and run by application of vacuum to the receiving flask. Sequential elution with dichloromethane, dichloromethane–ethyl acetate mixtures, and ethyl acetate (250 mL each) gave bright yellow fractions in the dichloromethane–ethyl acetate (2:1) and ethyl acetate fractions. These were concentrated, excess ethereal diazomethane was added, and, after a few minutes, the solvent was removed under vacuum to give a mixture (800 mg) of **3**, **5**, and **6** contaminated with sterol and lipid. High-pressure LC of this mixture using diethyl ether–hexane (7:3) as the eluting solvent gave pure **5** (470 mg), **3** (80 mg), and **6** (60 mg) after 20 separate injections (10-min separation time per injection). The methyl esters of the natural products resisted attempted crystallization, and attempts to crystallize derivatives were not pursued due to the paucity of material.

Methyl (13*Z*,15*E*,17*E*,22*E*,24*Z*)-3,12-Dioxomalabarica-13,15,17,22,24-pentaen-26-oate (5): $[\alpha]^{20}_D$ +31.0° (c 1.0, $CHCl_3$); UV (methanol) 395 nm (ϵ 44600), 412 (41000); IR (CCl_4) 2950, 2850, 1710, 1690, 1610, 1570, 1380, 1370, 1200, 1160, 1150, 970 cm^{-1}; ^1H NMR ($CDCl_3$) δ 8.28 (1 H, d, J = 15 Hz), 7.47 (1 H, dd, J = 11, 15 Hz), 6.99 (1 H, dd, J = 11, 15 Hz), 6.55 (1 H, d, J = 11 Hz), 6.49 (1 H, d, J = 15 Hz), 6.41 (1 H, d, J = 11 Hz), 3.78 (3 H, s), 2.73 (2 H, m), 2.07 (3 H, s), 2.01 (6 H, br s), 1.41 (3 H, s), 1.12 (3 H, s), 1.06 (3 H, s), 0.86 (3 H, s); ^{13}C NMR ($CDCl_3$) δ 218.0 (s), 205.7 (s), 167.7 (s), 145.5 (s), 142.9 (d), 142.5 (s), 141.2 (d), 138.5 (s), 134.8 (d), 133.8 (d), 130.5 (d), 126.2 (d), 125.4 (s), 51.2 (q), 47.7 (d), 46.6 (s), 45.2 (d), 44.6 (s), 37.1 (t), 36.7 (t), 34.6 (s), 33.3 (t), 31.2 (t), 29.0 (q), 24.5 (q), 23.3 (q), 20.8 (q), 19.5 (t), 19.2 (q), 15.8 (q), 12.9 (q); high-resolution mass measurement m/e 478.3072, $C_{31}H_{42}O_4$ requires m/e 478.3083.

(13*Z*,15*E*,17*E*,22*Z*,24*Z*)-3,12-Dioxomalabarica-13,15,17,22-24-pentaen-22,26-olide (3) crystallized from dichloromethane as yellow prisms: mp 266–268 °C; $[\alpha]^{20}_D$ +45.7 (c 0.8, $CHCl_3$); UV (methanol) 396 nm (ϵ 29200), 417 (23750); IR ($CHCl_3$) 2980, 2950, 2900, 1730 (sh), 1710, 1690 (sh), 1610, 1390, 1380, 1180, 1120 cm^{-1}; ^1H NMR ($CDCl_3$) δ 8.33 (1 H, d, J = 15 Hz), 7.30 (1 H, d, J = 11 Hz), 7.20 (1 H, d, J = 7 Hz), 6.97 (1 H, dd, J = 11, 15 Hz), 6.30 (1 H, d, J = 7 Hz), 2.12 (3 H, s), 2.08 (3 H, s), 2.04 (3 H, s), 1.40 (3 H, s), 1.12 (3 H, s), 1.05 (3 H, s), 0.87 (3 H, s); ^{13}C NMR ($CDCl_3$) δ 218.9 (s), 205.6 (s), 163.1 (s), 159.3 (s), 146.7 (s), 141.7 (s), 139.5 (d), 136.7 (d), 131.0 (d), 130.8 (d), 128.3 (s), 124.1 (s), 102.4 (d), 47.9 (d), 46.8 (s), 45.4 (d), 44.8 (s), 37.2 (t), 36.7 (t), 34.8 (s), 33.4 (t), 31.4 (t), 29.2 (q), 25.2 (t), 24.6 (q), 23.5 (q), 19.4 (q), 16.8 (q), 15.9 (q), 12.8 (q); high-resolution mass measurement m/e 462.2766 ($C_{30}H_{38}O_4$ requires m/e 462.2770), 353.2481 ($C_{24}H_{33}O_2$ requires 353.2480), 313.2160 ($C_{21}H_{29}O_2$ requires 313.2167), 149.0606 ($C_9H_9O_2$ requires 149.0603).

Methyl (13*Z*,15*E*,17*E*,22*E*,24*Z*)-3β-acetoxy-12-oxomalabarica-13,15,17,22,24-pentaen-26-oate (6) was isolated as a bright yellow foam: $[\alpha]^{20}_D$ −135.7 (c 1, $CHCl_3$); UV (methanol) 395 nm (ϵ 56400), 412 (52700); IR ($CHCl_3$) 2950, 2920, 1730, 1690, 1610, 1570, 1375, 1360, 1240, 1160, 1150, 970 cm^{-1}; ^1H NMR ($CDCl_3$) δ 8.18 (1 H, d, J = 15 Hz), 7.50 (1 H, m), 7.00 (1 H, m), 6.50 (3 H, m), 4.62 (1 H, m), 3.78 (3 H, s), 2.04 (6 H, s), 2.01 (3 H, s), 1.98 (3 H, s), 1.39 (3 H, s), 1.02 (3 H, s), 0.91 (3 H, s), 0.87 (3 H, s); ^{13}C NMR ($CDCl_3$) δ 206.4 (s), 170.9 (s), 168.0 (s), 146.6 (s), 143.3 (d), 142.1 (s), 141.4 (d), 138.5 (s), 135.0 (d), 134.1 (d), 131.8 (d), 126.3 (d), 125.5 (s), 80.7 (d), 51.4 (q), 50.2 (d), 46.6 (d), 44.7 (s), 38.1 (s), 36.8 (t), 36.7 (t), 35.5 (s), 33.1 (t), 29.6 (t), 29.1 (q), 25.1 (t), 24.7 (q), 22.4 (q), 21.2 (q), 20.9 (q), 18.3 (q), 16.9 (q), 13.0 (q); high-resolution mass measurement m/e 522.3358 ($C_{33}H_{46}O_5$ requires m/e 522.3343), 409.2721 ($C_{27}H_{37}O_3$ requires 409.2741), 357.2430 ($C_{23}H_{33}O_3$ requires 357.2428).

Methyl (14*E*,16*E*,20*E*,23*E*)-3,12-Dioxomalabarica-14,16,20,23-tetraen-26-oate (7). A mixture of acetic acid (10 mL), the ester **5** (25 mg), and zinc powder (1 g) was stirred at room temperature for 2 h. The reaction mixture was filtered, the solids were washed with diethyl ether (100 mL), and the combined filtrates were washed with water (2 × 100 mL), 5% aqueous sodium carbonate (2 × 50 mL), and water (20 mL). Evaporation of the dried ($MgSO_4$) ethereal layer gave **7** as a colorless foam: UV (methanol) 310 nm (ϵ 25000); IR (KBr disk) 2980, 2950, 2880, 1745, 1710, 1610, 1575, 1380, 1160, 1150, 970, 780 cm^{-1}; ^1H NMR ($CDCl_3$) δ 6.50 (1 H, dd, J = 11, 15 Hz), 6.45 (1 H, dd, J = 11,

(9) G. Lukacs, F. Khuong-Hu, C. R. Bennett, B. L. Buckwalter, and E. Wenkert, *Tetrahedron* Lett., 3515 (1972).

15 Hz), 6.24 (1 H, d, J = 15 Hz), 6.06 (1 H, d, J = 11 Hz), 5.93 (1 H, d, J = 11 Hz), 5.78 (1 H, dd, J = 8, 15 Hz), 3.69 (3 H, s), 3.25 (1 H, dq, J = 8, 7, 7, 7 Hz), 2.74 (2 H, m), 2.66 (1 H, s), 1.90 (3 H, s), 1.88 (3 H, s), 1.31 (3 H, d, J = 7 Hz), 1.11 (3 H, s), 1.07 (6 H, s), 0.88 (3 H, s); mass spectrum, m/e 480 (M^+).

Methyl (14*E*,16*E*,20*E*,23*E*)-13,25-dideutero-3,12-dioxomalabarica-14,16,20,23-tetraen-26-oate (8) was prepared from the ester **5** (20 mg), acetic acid-d_1 (10 mL), and zinc dust (1 g) under the same conditions used for the preparation of **7**. The dideuterio compound **8** was obtained as a pale yellow foam: UV as for **7**; IR ($CHCl_3$ film) 2350, 1745, 1710 cm^{-1}; ^1H NMR ($CDCl_3$) δ 6.49 (1 H, dd, J = 11, 15 Hz), 6.48 (1 H, dd, J = 11, 15 Hz), 6.23 (1 H, d, J = 15 Hz), 6.06 (1 H, d, J = 11 Hz), 5.93 (1 H, d, J = 11 Hz), 5.78 (1 H, d, J = 15 Hz), 3.69 (3 H, s), 2.76 (1 H, dd, J = 6, 12 Hz), 2.70 (1 H, dd, J = 6, 12 Hz), 1.90 (3 H, s), 1.88 (3 H, s), 1.29 (3 H, s), 1.12 (3 H, s), 1.07 (6 H, s), 0.88 (3 H, s); mass spectrum, m/e 482 (M^+).

Ozonolysis of the Methyl Ester 5. Ozone was bubbled for 0.5 h into a solution of **5** (120 mg) in dichloromethane (25 mL) cooled to −78 °C. Excess ozone was removed by bubbling nitrogen into the solution for a further 5 min, and dimethyl sulfide (0.5 mL) was added to the mixture, which was allowed to stand at 20 °C overnight. The solvents were removed under vacuum and the resulting gum was separated by high-pressure LC on silica gel with dichloromethane–ethyl acetate (6:4) as eluting solvent. Concentration of high-pressure LC fractions yielded the diketone **11** (12 mg) and the anhydride **12** (30 mg).

Compound 11 was obtained as a colorless foam: IR (CCl_4) 2980, 2950, 2880, 1765, 1750, 1710, 1470, 1380, 1370, 1150, 1120, 1020 cm^{-1}; ^1H NMR ($CDCl_3$) δ 2.70 (1 H, m), 1.32 (3 H, s), 1.14 (3 H, s), 1.08 (3 H, s), 0.92 (3 H, s); high-resolution mass measurements m/e 276.1732 ($C_{17}H_{24}O_3$ requires m/e 276.1725), 206.1675 ($C_{14}H_{22}O$ requires 206.1671).

Compound 12 was obtained as a colorless foam: IR (CCl_4) 3050, 2950, 2920, 1806, 1760, 1710, 1460, 1380, 1370, 1150, 1030 cm^{-1}; ^1H NMR ($CDCl_3$) δ 2.70 (1 H, d, J = 11 Hz), 1.50 (3 H, s), 1.28 (1 H, d, J = 5 Hz), 1.13 (3 H, s), 1.07 (3 H, s), 0.91 (3 H, s); high-resolution mass measurement m/e 292.1673 ($C_{17}H_{24}O_4$ requires m/e 292.1674), 206.1670 ($C_{14}H_{22}O$ requires 206.1671).

Preparation of the Monomethyl Ester 14. A solution of **12** in methanol was allowed to stand overnight. Removal of the solvent under vacuum gave **14** as a colorless foam in quantitative yield: IR 3500–2500 (br), 1740, 1710, 1470 cm^{-1}; ^1H NMR ($CDCl_3$) δ 8.0 (1 H, vbr), 3.72 (3 H, s), 2.8 (1 H, m), 2.45 (2 H, m), 1.23 (3 H, s), 1.18 (3 H, s), 1.08 (3 H, s), 1.00 (3 H, s); high resolution mass measurement m/e 324.1946 ($C_{18}H_{28}O_5$ requires m/e 324.1934).

Preparation of the Dimethyl Ester 15. A solution of **14** (13 mg) in diethyl ether (3 mL) was treated with an excess of an ethereal solution of diazomethane. After a few minutes the solvents were removed under vacuum to give **15** as a colorless foam: IR (CCl_4) 3000, 2950, 1740, 1730, 1710 cm^{-1}; ^1H NMR ($CDCl_3$) δ 3.73 (3 H, s), 3.70 (3 H, s), 2.78 (1 H, m), 2.42 (2 H, m), 1.64 (1 H, m), 1.10 (6 H, s), 1.05 (3 H, s), 0.97 (3 H, s); mass spectrum, 338 (M^+), 323, 306, 279, 260, 142.

Ozonolysis of the Lactone 3. A solution of **3** (20 mg) in dichloromethane (20 mL) was treated with ozone and worked up as above to yield, after separation by high-presure LC, **11** (5 mg) and **12** (8 mg) which were identical by IR, ^1H NMR, and mass spectra with the compounds isolated from the ozonolysis of **5**.

Hydrogenation of 5. A mixture of **5** (90 mg), 10% Pd/C (20 mg), and methanol (20 mL) was stirred in an atmosphere of hydrogen for 18 h. The mixture was filtered, the solvent removed under vacuum, and the residual gum separated by high-pressure LC using hexane–ethyl acetate (7:3) to give two isomeric decahydro derivatives, **16** (25 mg) and **17** (18 mg), together with a single isomer of **18** (30 mg).

Compound 16 was obtained as a colorless foam: IR (CCl_4) 2980, 2950, 2880, 1740, 1710, 1460, 1380, 1370, 1160, 1090 cm^{-1}; ^1H NMR ($CDCl_3$) δ 3.67 (3 H, s), 1.18 (3 H, d, J = 7 Hz), 1.11 (6 H, s), 1.10 (6 H, d, J = 7 Hz), 1.06 (3 H, s), 0.88 (3 H, s); high-resolution mass measurement m/e 488.3848 ($C_{31}H_{52}O_4$ requires m/e 488.3864), 473.3616 ($C_{30}H_{49}O_4$ requires 473.3629), 247.1688.

Compound 17 was obtained as a colorless foam: IR (CCl_4) 2980, 2950, 2880, 1740, 1710, 1460, 1380, 1370, 1160, 1090 cm^{-1}; ^1H NMR ($CDCl_3$) δ 3.68 (3 H, s), 1.18 (3 H, d, J = 6 Hz), 1.11 (6 H, s), 1.08 (6 H, d, J = 6 Hz), 1.05 (3 H, s), 0.88 (3 H, s); high-resolution mass measurement m/e 488.3848 ($C_{31}H_{52}O_4$ requires m/e 488.3863); mass spectrum, m/e 488, 473, 247.

Compound 18 was obtained as a colorless gum: IR (CCl_4) 2980, 2950, 2900, 1740, 1710, 1460, 1380, 1370, 1150, 1120 cm^{-1}; ^1H NMR ($CDCl_3$) δ 3.68 (3 H, s), 1.15 (3 H, d, J = 7 Hz), 1.07 (3 H, s), 1.02 (3 H, s), 0.97 (3 H, s), 0.85 (6 H, d, J = 6 Hz), 0.78 (3 H, s); ^{13}C NMR ($CDCl_3$) δ 220.8 (s), 177.3 (s), 58.8 (d), 58.2 (d), 54.4 (d), 51.4 (q), 46.8 (s), 46.0 (d), 42.3 (s), 39.5, 38.2, 37.4, 36.8, 35.6, 35.3, 35.0 (s), 34.1, 33.8, 32.7, 32.0, 29.3, 28.2, 24.7, 24.3, 23.7 (q), 20.0 (t), 19.7 (2C, q), 19.4 (q), 18.3 (q), 17.1 (q); mass spectrum, m/e 474, 459, 399, 389, 220, 205, 125; high-resolution mass measurement m/e 474.4062 ($C_{31}H_{54}O_3$ requires m/e 474.4071); ^1H NMR (C_6D_6) δ 0.72 (3 H, s), 0.84 (3 H, s), 0.98 (3 H, s), 1.14 (3 H, s) [lit.[4] for **1**: ^1H NMR (C_6D_6), 0.77 (3 H, s), 0.83 (3 H, s), 0.97 (3 H, s), 1.13 (3 H, s)].

Conversion of the Acetoxy Compound 6 into the Diketone 5. A mixture of **6** (20 mg) and anhydrous sodium carbonate (100 mg) in methanol (10 mL) was stirred at 20 °C for 2 h. The mixture was filtered, excess ethereal diazomethane was added to the filtrate, and the solvents were removed under vacuum after the mixture was allowed to stand a few minutes. The residual gum was dissolved in acetone and excess Jones reagent added. After 5 min, the excess reagent was destroyed by addition of 2-propanol, the mixture was filtered, and the solvents were removed under vacuum. High-pressure LC of the residue (hexane–ethyl acetate, 7:3) gave 8 mg of a product with identical IR, ^1H NMR, and mass spectral characteristics as those found for **5**.

Malabaricol (1): ^{13}C NMR ($CDCl_3$) δ 217.2 (s), 131.4 (s), 124.6 (d), 85.6 (s), 82.3 (d), 72.7 (s), 59.5 (d), 58.2 (d), 55.5 (d), 47.4 (s), 44.1 (s), 39.7 (t), 38.2 (t), 37.8 (t), 36.8 (t), 36.6 (s), 34.2 (t), 26.6, 26.1, 25.7 (3 C), 24.4, 23.9, 22.2, 21.1, (2 C), 20.8, 17.6 (q), 15.5 (q).

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