structure: 66.6 (C_2); 58.2 (C_6); 50.5 (C_8); 43.8 (C_1); 32.0 (C_3); 22.7; 22.1 (C_4, C_5); 17.9 (C_9).

***cis*-2-Thiabicyclo[6.1.0]nonan-7α-ol 2,2-Dioxide (18).** A ~3:2 mixture of **18** and **19** (0.70 g) was chromatographed (silica gel, ethyl ether/methanol = 100/6) to give 0.30 g (75%) of **18** as the slower eluting component; crystallized from hexane/benzene (0.18 g, 60%), mp 108-109 °C. ^{13}C NMR: δ 66.3 (C_7); 55.0 (C_3); 36.4 (C_6); 34.3 (C_1); 25.5 (C_8); 23.4 (C_4); 18.1 (C_5); 5.1 (C_9). ^1H NMR (acetone-d_6): δ 4.36 (m, 1 H, C_7H); 3.40-3.10 (m, 2 H, C_3H_2); 2.85 (s, 1 H, OH); 2.50 (ddd, J = 8.2, 8.2, 6.7 Hz, 1 H, C_1H); 2.20-1.50 (m, 8 H); 1.30 (m, 1 H). Anal. Calcd for $C_8H_{14}SO_3$: C, 50.50; H, 7.42; S, 16.85. Found: C, 51.00; H, 7.51; S, 16.97.

***trans*-2-Thiabicyclo[6.1.0]nonan-7α-ol 2,2-Dioxide (19).** Mp 168-169 °C (0.16 g, 67%, benzene). ^{13}C NMR: δ 63.4 (C_7); 57.9 (C_3); 38.8 (C_6); 27.6 (C_1); 25.1, 25.0 (C_4, C_8); 20.9 (C_5); 4.2 (C_9). ^1H NMR (acetone-d_6): δ 4.20 (m, 1 H, C_7H); 3.30; 3.00 (m's, 1 H each, C_3H_2); 2.55 (ddd, J = 8.5, 5.2, 5.2 Hz, 1 H, C_1H); 2.40-1.50 (m, 8 H); 1.15; 1.05 (m's, 1 H each, C_9H_2). In $CDCl_3$, the latter multiplets resonate at δ 1.40 and 1.10 and, in the presence of a praseodymium shift reagent [Pr(hfc)$_3$], the 1.10 resonance is shifted upfield more strongly than the 1.40 multiplet. On this basis the corresponding H's (at C_9) can be assigned to the α and β side, respectively. Anal. Calcd for $C_8H_{14}SO_3$: C, 50.50; H, 7.42; S, 16.85. Found: C, 50.02; H, 7.53; S, 17.03.

***trans*-2-Thiabicyclo[4.3.0]nonan-5β-ol 2,2-Dioxide (24).** Base treatment of **13** (0.40 g, 2.1 mmol, for conditions see **16**) yielded a 80/20 trans/cis epimer mixture from which the title compound was separated by chromatography (silica gel, ethyl ether/methanol = 100/6) as the slower eluting component, mp 139-140 °C (benzene; 0.22 g, 70%). ^{13}C NMR: δ 72.5 (C_5); 62.2 (C_1); 50.9 (C_6); 50.4 (C_3); 32.9 (C_4); 29.0 (C_7); 21.7; 20.5 (C_8, C_9). ^1H NMR: δ 3.62 (m, 1 H, HCO); 3.08 (s, OH); 3.03 (m, 1 H); 2.78 (m, 1 H); 2.34-1.96 (m, 7 H); 1.79 (m, 2 H); 1.40 (m, 1 H).

Deoxygenation of alcohols 13 and 17 was performed by way of the Barton-McCombie procedure via the *S*-methyl dithiocarbonate ester derivatives.[14] ***cis*-2-Thiabicyclo[4.3.0]nonan-5β-ol 2,2-Dioxide Xanthate Ester.** Mp 140-141 °C (EtOH). ^{13}C NMR: δ 215.8; 76.5; 60.6; 46.9; 45.7; 26.6; 25.1; 23.2; 21.9; 19.1. ***cis*-2-Thiabicyclo[4.3.0]nonan-5α-ol 2,2-Dioxide Xanthate Ester.** Mp 129-130 °C (MeOH). ^{13}C NMR: δ 215.9; 77.7; 62.7; 45.6; 43.8; 25.5; 25.4; 22.1; 19.0.

Each of the above xanthates (0.40 g, 1.5 mmol) was reacted with tributylstannane (0.65 g, 2.25 mmol, toluene, 12 mL, AIBN, reflux, 7 h) to give after solvent evaporation and flash chromatography (silica gel, ethyl ether/petroleum ether = 2/1) ***cis*-2-thiabicyclo[4.3.0]nonane 2,2-dioxide** (0.20 g, 77%) identical with the sulfone obtained by *m*-CPBA oxidation of authentic *cis*-2-thiabicyclo[4.3.0]nonane,[1c] mp 72 °C (hexane/benzene). ^{13}C NMR: δ 63.2 (C_1); 48.0 (C_3); 40.7 (C_6); 29.7 (C_5); 24.6 (C_7): 23.7 (C_9); 21.4, 21.0 (C_4, C_8).

Acknowledgment. This work was supported by funds provided by MURST and CNR-Rome. We wish to thank Professor M. Camaggi for assistance with the numerical calculations.

Supplementary Material Available: MMX force fields, minimized geometries, and strain energies of conformations A-E (5 pages). Ordering information is given on any current masthead page.

Cyclization of Epoxyneocembrene Derivatives to Secotrinervitanes[1]

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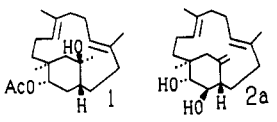
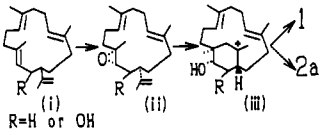
Four stereoisomers of epoxyneocembrene derivatives **5-8** were treated with BF_3·OEt_2 as potential model reactions for the proposed biogenesis of secotrinervitane-type diterpenoids (Scheme I). Two of them (**5** and **6**) afforded secotrinervitane derivatives, while the remaining isomers **7** and **8** gave no cyclization products (Table I). The natural product, secotrinervitene-2β,3α-diol (**2a**) was synthesized from **5** in *dl*-form.

When disturbed, soldiers of the naste termite (Nasititermitinae) are known to eject from their frontal gland a viscous defensive secretion. Recently, several diterpenoids have been isolated from the secretion and identified as 3α-acetoxy-15β-hydroxy-7,16-secotrinervita-7,11-diene (**1**) and its analogue **2a**, respectively. The former (**1**) was isolated by J. C. Braekman from *Nasutitermes princeps* soldiers collected in Papua, New Guinea,[2] while the latter (**2a**) was characterized by G. D. Prestwich as a secretion component of *Longipedtermes longipes* soldiers in Malaysia.[3]



These natural products belong to the secotrinervitane class of diterpenoids, which are structurally unique by virtue of their bicyclic IN-OUT ring system. X-ray crystallographic analysis of both compounds has unequivocally revealed that the termini of the macrocyclic ring are disposed on the cyclohexane ring with 1,4-trans diequatorial orientation. The cyclohexane ring possesses the chair conformation in the crystalline state. The secotrinervitane class is believed to arise biogenetically from epoxyneocembrene (ii, R = H or OH). The carbon skeleton (iii) of the secotrinervitane class is generated by cyclization at the isopropenyl group onto the epoxide ring to the bridging cyclohexane ring as shown in Scheme I. The parent hydrocarbon, neocembrene (i, R = H) is well-known as a termite trail pheromone[4] used by the workers of a Nastitermes species.

Scheme I



(1) Cyclization of Polyenes. 49. For part 48, see ref 6.
(2) Braeckman, J. D.; Daloze, D.; Dupont, A.; Pasteels, J.; Tursch, B.; Declercz, J. P.; Germain, G.; van Meerssche, M. *Tetrahedron Lett.* **1980**, *21*, 2761.
(3) Prestwich, G. D.; Tempesta, M. S.; Turner, C. *Tetrahedron Lett.* **1984**, *25*, 1531.
(4) Isolation: (a) Birch, A. J.; Brown, W. V.; Corrie, J. E. T.; Moore, B. P. *J. Chem. Soc., Perkin Trans. 1* **1972**, 2653. (b) Paril, V. D.; Nayak, U. R.; Dev, S. *Tetrahedron* **1973**, *29*, 341. Synthesis: Kitahara, Y.; Kato, T.; Kobayashi, T. *Chem. Lett.* **1976**, 219.

0022-3263/91/1956-4520$02.50/0

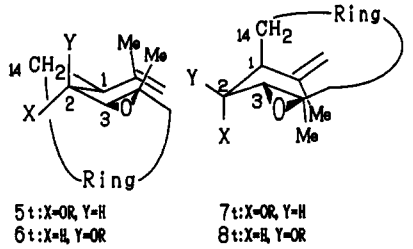


Figure 2.

come of these π-cyclizations. Earlier experiments in our laboratory,[11] through X-ray crystallographic analysis and spectral evidence, had shown that the starting allyl alcohols **3** and **4** have the partial conformation shown in Figure 1. In the ^1H NMR spectra of **3** and **4**, a positive NOE was observed between C_2-H and C_4-Me in each compound. A clear NOE was also observed between these protons in 400-MHz NOESY experiments on both epoxy alcohols **5a** and **7a**, indicating that the conformation remains unchanged by the introduction of the epoxide ring. Plausible partial conformations of the epoxy alcohols **5a** and **7a** and their isomers **6a** and **8a** can be depicted as shown in Figure 1.

On the basis of conformational analysis of the ground state of the epoxy alcohols, we can examine the transition state of the cyclization through the inspection of Dreiding models. Assuming that the transition state is chairlike, the C_1–C_{14} bond at one terminus of the macrocyclic ring is equatorial in **5t** and **6t**, as shown in Figure 2. These transition states can be derived with small changes in the conformations of the macrocyclic rings of the ground states of **5a** and **6a** in Figure 1. Orbital overlap of the π-electrons of the isopropenyl group with the C_4 position seems to be possible without any steric congestion, as was indeed observed in the reaction of **5** and its isomer **6** when treated with BF_3·OEt_2. In the cases of **7** and its isomer **8**, the transition state for π-cyclization may be destabilized by an energetically unstable axial orientation of the C_1–C_{14} terminus bond as shown in Figure 2. In addition, a large conformational change is needed to derive the transition states **7t** and **8t** from the ground states of **7a** and **8a** in Figure 1. Thus, the π-cyclization is disfavored with **7** and its epimer **8**. The stereochemical differences observed in the cyclization of the derivatives of the four epoxy alcohols **5–8** are therefore rationalizable.

From a biosynthetical point of view, it is of interest to note that all the natural products possessing the secotrinervitane and trinervitane skeletons have the trans orientation with respect to the C_1 and C_4 positions. The conformational preference of the transition state for cyclization may be dominated by the conformation of the ground state of the epoxy alcohols in both the laboratory and in the termite itself.

Experimental Section

Column chromatography was performed on silica gel 60 (Merck). ^1H NMR spectra were determined at 90 or 400 MHz. ^{13}C NMR spectra were determined at 23 MHz. TLC was performed on precoated TLC plates, silica gel $60F_{254}$ (Merck).

(1*RS*,2*SR*,3*SR*,6*E*,10*E*,14*SR*)-2,3-Epoxy-14-(2-propenyl)-3,7,11-trimethyl-6,10-cyclotetradecadien-1-yl Acetate (5b). To a solution of epoxy alcohol[7] **5a** (470 mg, 1.54 mmol) in pyridine (2 mL) were added acetic anhydride (1 mL) and a catalytic amount of (dimethylamino)pyridine, and the resulting solution was stirred at rt overnight. After methanol (1 mL) was added, the mixture was poured into water and extracted with ether (20 mL × 3). The combined organic layers were successively washed with 5 M aqueous $CuSO_4$, water, and then brine. After the layers were dried over Na_2SO_4, the solvent was removed in vacuo. Purification by silica gel column chromatography (EtOAc/hexane = 1/15) gave acetate **5b** (535 mg, 100%) as a colorless oil: IR (CCl_4) 2950, 1745, 1240 cm^{-1}; ^1H NMR δ ($CDCl_3$) 5.0 (2 H, m), 4.77 (1 H, dd, J = 7.4, 2.3 Hz), 4.73 (1 H, m), 4.61 (1 H, m), 2.67 (1 H, d, J = 7.4 Hz), 2.00 (3 H, s), 1.7–1.5 (9 H, m), 1.31 (3 H, s); ^{13}C NMR ($CDCl_3$) δ 169.0 (s), 147.1 (s), 136.2 (s), 133.3 (s), 125.0 (d), 122.9 (d), 111.5 (t), 77.7 (d), 68.0 (d), 62.3 (s), 44.9 (d), 39.1 (t), 38.0 (t), 34.5 (t), 25.0 (t), 24.0 (t), 23.2 (t), 20.8 (q), 20.1 (q), 17.7 (q), 17.3 (q), 16.3 (q); MS m/z 346 (M^+, 17), 304, 261, 135, and 107 (100); HRMS calcd for $C_{22}H_{34}O_3$ 346.2489, found 346.2485.

(±)-3α-Hydroxysecotrinerviten-2β-yl Acetate (2b). To a stirred solution of epoxy acetate **5b** (116 mg, 0.33 mmol) in ether (3 mL) was added BF_3·OEt_2 (0.082 mL) at −20 °C under N_2. The mixture was stirred at the same temperature for 17 h. Saturated aqueous $NaHCO_3$ (10 mL) was added, and then the mixture was extracted with ether (15 mL × 3). After being washed with brine, the combined organic layers were dried over Na_2SO_4. Removal of the solvent in vacuo and purification by silica gel column chromatography (EtOAc/hexane = 1/10) gave **2b** (95 mg/ 82%) as colorless needles: mp 78–79 °C (hexane); IR ($CHCl_3$) 2970, 1730, 1380 cm^{-1}; ^1H NMR ($CDCl_3$) δ 5.20 (1 H, m), 4.80 (1 H, b s), 4.75 (1 H, m), 4.72 (1 H, d, J = 1.5 Hz), 4.53 (1 H, dd, J = 11.3, 8.4 Hz), 3.64 (1 H, d, J = 8.4 Hz), 2.89 (1 H, b d, J = 8.5 Hz), 2.13 (3 H, s), 1.63 (3 H, s), 1.57 (3 H, t, J = 1.4 Hz), 0.87 (3 H, s); ^{13}C NMR ($CDCl_3$) δ 171.5 (s), 144.4 (s), 133.5 (s), 132.9 (s), 128.3 (d), 127.4 (d), 107.4 (t), 77.5 (d), 75.8 (d), 46.9 (t), 42.7 (d), 39.7 (t), 39.4 (s), 36.6 (t × 2), 25.1 (t × 2), 21.9 (q), 19.7 (q), 15.0 (t), 14.2 (q), 13.8 (q); MS m/z 346 (M^+, 1), 328, 285 (100), 119. Anal. Calcd for $C_{22}H_{34}O_3$: C, 76.26; H, 9.89. Found: C, 76.28; H, 9.94.

(±)-Secotrinervitene-2β,3α-diol (2a). To a stirred solution of monoacetate **2b** (54 mg, 0.16 mmol) in ether (3 mL) was added $LiAlH_4$ (10 mg) at 0 °C, and the mixture was stirred at the same temperature for 10 min. EtOAc (1 mL) and saturated aqueous NH_4Cl (0.5 mL) were added to the mixture, and the resulting suspension was filtered through silica gel. The solvent was removed in vacuo, and the residue was purified by silica gel column chromatography (EtOAc/hexane = 1/5) to give diol **2a** (44 mg, 93%) as colorless prisms: mp 164–166 °C (benzene); IR (KBr) 3340, 3090, 2925, 1650, 1465, 892 cm^{-1}; ^1H NMR ($CDCl_3$) δ 5.20 (1 H, b d, J = 9.0 Hz), 4.7 (1 H, m), 4.73 (1 H, b s), 4.65 (1 H, b s), 3.47 (1 H, d, J = 8.6 Hz), 3.14 (1 H, dd, J = 8.6, 10.7 Hz), 2.93 (1 H, d, J = 10.7 Hz), 1.64 (3 H, s), 1.62 (3 H, s), 0.84 (3 H, s); ^{13}C NMR ($CDCl_3$) δ 145.7 (s), 134.0 (s), 132.9 (s), 128.0 (d), 127.4 (d), 106.2 (t), 78.1 (d), 74.7 (d), 47.6 (t), 44.5 (d), 39.7 (t), 38.8 (s), 36.6 (t × 2), 25.2 (t × 2), 21.8 (t), 18.8 (q), 15.3 (q), 14.4 (q); MS m/z 304 (M^+, 8), 286, 175, 136, and 81 (100). Anal. Calcd for $C_{20}H_{32}O_2$: C, 78.90; H, 10.59. Found: C, 78.57; H, 10.60%.

(1*SR*,2*SR*,3*SR*,6*E*,10*E*,14*SR*)-, (1*SR*,2*RS*,3*RS*,6*E*,10-*E*,14*SR*)-, and (1*RS*,2*RS*,3*RS*,6*E*,10*E*,14*SR*)-2,3-Epoxy-14-(2-propenyl)-3,7,11-trimethyl-6,10-cyclotetradecadien-1-yl Acetate (6b–8b). Acetates **6b–8b** were prepared in a manner similar to that given previously for **5b**.

6b from **6a**[7] as a colorless oil in 96% yield: IR (CCl_4) 2935, 1745, 1241 cm^{-1}; ^1H NMR ($CDCl_3$) δ 5.1 (2 H, m), 4.76 (1 H, dd, J = 2.4, 1.5 Hz), 4.65 (1 H, d, J = 2.4 Hz), 4.45 (1 H, dd, J = 10.2, 7.2 Hz), 3.00 (1 H, d, J = 7.2 Hz), 1.90 (3 H, s), 1.58 (9 H, s), 1.22 (3 H, s); ^{13}C NMR ($CDCl_3$) δ 168.5 (s), 144.1 (s), 139.6 (s), 134.0 (s), 126.0 (d), 122.8 (d), 115.0 (t), 75.6 (d), 73.2 (d), 61.6 (s), 50.8 (d), 39.1 (t), 35.1 (t), 33.9 (t), 24.9 (t), 24.5 (t), 23.7 (t), 21.0 (q), 19.7 (q), 18.6 (q), 18.4 (q), 15.0 (q); MS m/z 346 (M^+, 4), 328, 125 (100), 81; HRMS calcd for $C_{22}H_{34}O_3$ 346.2489, found 346.2499.

7b from **7a**[7] as colorless prisms in 99% yield: mp 50–51 °C (MeOH); IR (CCl_4) 2940, 1745, 1240, 890 cm^{-1}; ^1H NMR ($CDCl_3$) δ 5.0 (2 H, m), 4.83 (1 H, m), 4.73 (1 H, dd, J = 9.0, 7.1 Hz), 4.71 (1 H, m), 2.72 (1 H, d, J = 9.0 Hz), 2.38 (1 H, q, J = 7.1 Hz), 1.97 (3 H, s), 1.67 (3 H, t, J = 0.8 Hz), 1.63 (3 H, s), 1.59 (3 H, t, J = 0.9 Hz), 1.30 (3 H, s); ^{13}C NMR ($CDCl_3$) δ 169.7 (s), 143.5 (s), 134.2 (s), 133.5 (s), 125.4 (d), 124.6 (d), 114.9 (t), 71.7 (d), 63.1 (d), 61.4 (s), 46.9 (d), 39.5 (t), 36.2 (t), 34.7 (t), 27.1 (t), 23.7 (t), 22.5 (t), 20.5 (q), 19.1 (q), 18.0 (q), 16.5 (q), 15.2 (q); MS m/z 346

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(M^+, 8), 304, 149, 81, 43 (100). Anal. Calcd for $C_{22}H_{34}O_3$: C, 76.26; H, 9.89; Found: C, 75.92; H, 9.80.

8b from **8a**[7] as a colorless oil in 91% yield: IR (CCl_4) 2940, 1747, 1235 cm^{-1}; ^1H NMR ($CDCl_3$) δ 5.1 (2 H, m), 4.98 (1 H, dd, J = 5.6, 3.9 Hz), 4.78 (1 H, dd, J = 2.0, 1.3 Hz), 4.73 (1 H, m), 2.86 (1 H, d, J = 5.5 Hz), 1.99 (3 H, s), 1.73 (3 H, t, J = 1.0 Hz), 1.59 (6 H, s), 1.31 (3 H, s); ^{13}C NMR δ ($CDCl_3$) 169.1 (s), 146.2 (s), 135.1 (s), 134.9 (s), 124.8 (d), 124.3 (d), 112.0 (t), 73.2 (d), 63.3 (d), 61.0 (s), 46.3 (d), 39.6 (t), 39.0 (t), 35.8 (t), 24.3 (t), 23.9 (t), 23.5 (t), 20.5 (q), 20.2 (q), 17.6 (q), 17.1 (q), 15.5 (q); MS m/z 346 (M^+, 3), 125 (100), 81, 43; HRMS calcd for $C_{22}H_{34}O_3$ 346.2489, found 346.2492.

Reaction of Compounds 6b–8b with BF_3·OEt_2. To a stirred solution of each of the acetates **6b–8b** (100 mg, 0.29 mmol) in ether (3 mL) was added BF_3·OEt_2 (0.036 mL) at −20 °C under N_2, and stirring was continued at the same temperature for 2 h. Saturated aqueous $NaHCO_3$ (10 mL) was added, and the mixture was extracted with ether (15 mL × 3). After being washed with brine, the combined organic layers were dried over Na_2SO_4. After removal of the solvent, each of the reaction products was analyzed by ^1H NMR spectroscopy, and each spectrum showed no methyl signal near δ 1–0.8.

***tert*-Butyldimethylsilyl (1*RS*,2*SR*,3*SR*,6*E*,10*E*,14*SR*)-2,3-Epoxy-14-(2-propenyl)-3,7,11-trimethyl-6,10-cyclotetradecadien-1-yl Ether (5c).** To a solution of epoxy alcohol **5a** (45 mg, 0.15 mmol) in DMF (2 mL) was added imidazole (24 mg) and *tert*-butylchlorodimethylsilane (27 mg), and the mixture was stirred at rt for 4 days. The mixture was diluted in ether (50 mL), and the organic layer was washed with water and brine. After the layer was dried over Na_2SO_4, solvent was removed in vacuo. The residue was passed through a silica gel column with EtOAc/hexane (1/60) to give TBDMS ether **5c** (55 mg, 89%) as a colorless oil: IR (CCl_4) 2932, 1544, 1386, 1248, 1114 cm^{-1}; ^1H NMR ($CDCl_3$) δ 5.05 (2 H, m), 4.76 (1 H, m), 4.63 (1 H, m), 3.43 (1 H, dd, J = 8.8, 1.8 Hz), 2.79 (1 H, d, J = 8.8 Hz), 2.32 (1 H, m), 1.68 (3 H, s), 1.62 (3 H, s), 1.59 (3 H, s), 1.25 (3 H, s), 0.91 (9 H, s), 0.13 (3 H, s), 0.04 (3 H, s); ^{13}C NMR ($CDCl_3$) δ 147.0 (s), 135.4 (s), 134.0 (s), 125.1 (d), 123.1 (d), 111.7 (t), 74.4 (d), 68.2 (d), 60.8 (s), 46.5 (d), 39.1 (t), 38.5 (t), 35.3 (t), 26.1 (q × 3), 24.6 (t), 24.2 (t), 23.9 (t), 20.5 (q), 18.4 (s), 17.8 (q), 17.0 (q), 16.4 (q), −3.8 (q), −5.1 (q); MS m/z 418 (M^+, 2), 400, 360, 145, 75 (100); HRMS calcd for $C_{26}H_{46}O_2Si$ 418.3269, found 418.3259.

(1*SR*,2*SR*,3*SR*,6*E*,10*E*,14*SR*)-, (1*SR*,2*RS*,3*RS*,6*E*,10*E*,14*SR*)-, and (1*RS*,2*RS*,3*RS*,6*E*,10*E*,14*SR*)-2,3-Epoxy-14-(2-propenyl)-3,7,11-trimethyl-6,10-cyclotetradecadien-1-yl *tert*-Butyldimethylsilyl Ether (6c–8c). The TBDMS ethers **6c–8c** were prepared in a manner similar to that given previously for **5c**.

6c from **6a** as a colorless oil (71%): IR (CCl_4) 2932, 1464, 1250, 1132, 1086, 892 cm^{-1}; ^1H NMR ($CDCl_3$) δ 5.15 (2 H, m), 4.82 (1 H, m), 4.71 (1 H, m), 3.65 (1 H, dd, J = 7.2, 7.6 Hz), 2.78 (1 H, d, J = 7.2 Hz), 1.74 (3 H, s), 1.61 (6 H, s), 1.39 (3 H, s), 0.89 (9 H, s), 0.11 (6 H, s); ^{13}C NMR ($CDCl_3$) δ 145.4 (s), 133.2 (s), 130.5 (s), 126.6 (d), 122.9 (d), 113.7 (t), 72.4 (d), 63.0 (d), 60.9 (s), 51.8 (d), 39.3 (t), 35.4 (t), 34.8 (t), 26.3 (t), 26.0 (q × 3), 24.4 (t), 23.4 (t), 20.4 (q), 19.6 (q), 18.5 (s), 17.8 (q), 15.0 (q), −2.9 (q), −4.8 (q); MS m/z 418 (M^+, 3), 400, 145, 81 (100); HRMS calcd for $C_{26}H_{46}O_2Si$ 418.3269, found 418.3263.

7c from **7a** as a colorless oil (65%): IR (CCl_4) 2936, 1464, 1250, 1124, 1084, 890 cm^{-1}; ^1H NMR ($CDCl_3$) δ 5.05 (2 H, m), 4.89 (1 H, m), 4.78 (1 H, m), 3.38 (1 H, dd, J = 9.2, 5.1 Hz), 2.87 (1 H, d, J = 9.2 Hz), 1.73 (3 H, s), 1.61 (3 H, s), 1.55 (3 H, s), 1.25 (3 H, s), 0.89 (9 H, s), 0.12 (3 H, s), 0.04 (3 H, s); ^{13}C NMR ($CDCl_3$) δ 145.1 (s), 134.5 (s), 133.9 (s), 125.5 (d), 125.4 (d), 114.5 (t), 73.6 (d), 67.1 (d), 61.1 (s), 48.5 (d), 39.8 (t), 37.1 (t), 35.8 (t), 28.0 (t), 26.0 (q × 3), 25.7 (t), 24.4 (t), 23.5 (q), 20.7 (q), 18.3 (s), 16.4 (q), 15.5 (q), −3.0 (q), −5.1 (q); MS m/z 418 (M^+, 2), 400, 360, 178, 145, 75 (100); HRMS calcd for $C_{26}H_{46}O_2Si$ 418.3269, found 418.3255.

8c from **8a** as a colorless oil (78%): IR (CCl_4) 2932, 1250, 1106, 892 cm^{-1}; ^1H NMR ($CDCl_3$) δ 5.09 (2 H, m), 4.84 (2 H, m), 4.04 (1 H, dd, J = 4.8, 4.0 Hz), 2.69 (1 H, d, J = 4.0 Hz), 1.73 (3 H, s), 1.63 (3 H, s), 1.54 (3 H, s), 1.37 (3 H, s), 0.86 (9 H, s), 0.06 (6 H, s); ^{13}C NMR ($CDCl_3$) δ 146.2 (s), 134.5 (s), 134.1 (s), 125.6 (d), 124.7 (d), 113.2 (t), 70.7 (d), 66.1 (d), 61.1 (s), 47.1 (d), 39.3 (t), 37.6 (t), 36.2 (t), 26.2 (q × 3), 26.0 (t), 24.9 (t), 23.8 (t), 20.6 (q), 18.4 (s), 17.7 (q), 16.3 (q), 16.0 (q), −3.8 (q), −5.1 (q); MS m/z 418 (M^+, 5), 400, 178, 145, 75 (100); HRMS calcd for $C_{26}H_{46}O_2Si$ 418.3269, found 418.3258.

Benzyl (1*RS*,2*SR*,3*SR*,6*E*,10*E*,14*SR*)-2,3-Epoxy-14-(2-propenyl)-3,7,11-trimethyl-6,10-cyclotetradecadien-1-yl Ether (5d). To a suspension of NaH (16 mg) in benzene (4 mL) was added a solution of epoxy alcohol **5a** (100 mg, 0.33 mmol) in benzene (1 mL) at 0 °C under N_2, and the mixture was stirred for 10 min. Benzyl bromide (0.044 mL) and *n*-Bu_4NI (6 mg) were added to the solution, and stirring was continued at rt for 3 days. Saturated aqueous NH_4Cl (10 mL) was added to the solution, and it was poured into water. The mixture was extracted with ether. After drying over Na_2SO_4, the solvent was removed in vacuo. The residue was passed through a silica gel column with EtOAc/hexane (1/20) to give benzyl ether **5d** (113 mg, 87%) as a colorless oil: IR (CCl_4) 2916, 1454, 1386, 1070, 890 cm^{-1}; ^1H NMR ($CDCl_3$) δ 7.30 (5 H, s), 5.10 (2 H, m), 4.91 (1 H, d, J = 12.8 Hz), 4.66 (2 H, m), 4.46 (1 H, d, J = 12.8 Hz), 3.24 (1 H, dd, J = 9.8, 1.2 Hz), 2.84 (1 H, d, 9.8 Hz), 1.63 (9 H, s), 1.23 (3 H, s); ^{13}C NMR ($CDCl_3$) δ 147.4 (s), 139.3 (s), 135.4 (s), 133.7 (s), 128.1 (d × 2), 127.7 (d), 127.4 (d × 2), 127.1 (d), 122.8 (d), 112.0 (t), 80.8 (d), 72.2 (t), 67.5 (d), 58.4 (s), 46.1 (d), 39.0 (t), 38.3 (t), 34.7 (t), 24.4 (t), 23.9 (t), 23.5 (t), 19.7 (q), 17.6 (q), 17.3 (q), 16.5 (q); MS m/z 394 (M^+, 1), 376, 302, 212, 104, 90 (100), 81; HRMS calcd for $C_{27}H_{38}O_2$ 394.2873, found 394.2865.

Benzyl (1*SR*,2*RS*,3*RS*,6*E*,10*E*,14*SR*)-2,3-Epoxy-14-(2-propenyl)-3,7,11-trimethyl-6,10-cyclotetradecadien-1-yl Ether (7d). **7d** was prepared from **7a** in a manner similar to that given previously for **5d** as a colorless oil (57%): IR (CCl_4) 2936, 1454, 1086, 1028, 890 cm^{-1}; ^1H NMR ($CDCl_3$) δ 7.29 (5 H, s), 5.09 (2 H, m), 4.88 (1 H, d, J = 12.0 Hz), 4.80 (2 H, m), 4.45 (1 H, d, J = 12.0 Hz), 3.06 (1 H, dd, J = 8.8, 2.8 Hz), 2.87 (1 H, d, J = 8.8 Hz), 1.77 (3 H, s), 1.69 (3 H, s), 1.60 (3 H, s), 1.20 (3 H, s); ^{13}C NMR ($CDCl_3$) δ 144.9 (s), 139.2 (s), 134.6 (s), 133.9 (s), 128.0 (d × 2), 127.8 (d × 2), 127.2 (d), 125.5 (d), 124.9 (d), 114.3 (t), 78.9 (d), 72.6 (t), 66.6 (d), 58.8 (s), 47.5 (d), 39.6 (t), 36.8 (t), 35.3 (t), 27.8 (t), 24.3 (t), 23.0 (t), 20.0 (q), 18.7 (q), 16.8 (q), 15.7 (q); MS m/z 394 (M^+, 2), 302, 147, 104, 90 (100), 81; HRMS calcd for $C_{27}H_{38}O_2$ 394.2873, found 394.2871.

(1*RS*,2*SR*,3*SR*,6*E*,10*E*,14*SR*)-2,3-Epoxy-14-(2-propenyl)-3,7,11-trimethyl-6,10-cyclotetradecadien-1-yl Methoxymethyl Ether (5e). To a solution of epoxy alcohol **5a** (97 mg, 0.32 mmol) in CH_2Cl_2 (6 mL) was added diisopropylethylamine (0.17 mL) and methoxymethyl chloride (0.09 mL), and the mixture was stirred at rt for 2 days. The solution was poured into water and extracted with ether (15 mL × 3). The combined organic layers were washed with brine and dried over Na_2SO_4. The solvent was removed in vacuo, and the residue was passed through a silica gel column with EtOAc/hexane (1/20) to give **5e** (105 mg, 95%) as a colorless oil: IR (CCl_4) 2956, 1386, 1154, 1094, 1024, 892 cm^{-1}; ^1H NMR ($CDCl_3$) δ 5.08 (2 H, m), 4.87 (1 H, d, J = 7.2 Hz), 4.75 (1 H, m), 4.67 (1 H, m), 4.49 (1 H, d, J = 7.2 Hz), 3.36 (1 H, dd, J = 9.2, 2.4 Hz), 3.25 (3 H, s), 2.75 (1 H, d, J = 9.2 Hz), 1.73 (3 H, s), 1.60 (6 H, s), 1.23 (3 H, s); ^{13}C NMR ($CDCl_3$) δ 146.6 (s), 135.2 (s), 133.6 (s), 125.1 (d), 122.9 (d), 112.0 (t), 96.1 (t), 77.3 (d), 66.9 (d), 59.1 (s), 55.6 (q), 45.5 (d), 39.0 (t), 38.2 (t), 35.1 (t), 24.4 (t), 23.8 (t), 23.6 (t), 20.1 (q), 17.7 (q), 17.0 (q), 16.4 (q); MS m/z 348 (M^+, 2), 316, 303, 117, 93, 81, 45 (100); HRMS calcd for $C_{22}H_{36}O_3$ 348.2666, found 348.2656.

(1*SR*,2*SR*,3*SR*,6*E*,10*E*,14*SR*)- and (1*SR*,2*RS*,3*RS*,6*E*,10*E*,14*SR*)-2,3-Epoxy-14-(2-propenyl)-3,7,11-trimethyl-6,10-cyclotetradecadien-1-yl Methoxymethyl Ether (6e and 7e). **6e and 7e were prepared in a manner similar to that given previously for 5e.**

6e from **6a** as a colorless oil (70%): IR (CCl_4) 2932, 1440, 1152, 1100, 1036, 892 cm^{-1}; ^1H NMR ($CDCl_3$) δ 5.16 (2 H, m), 4.85 (1 H, m), 4.72 (1 H, m), 4.69 (1 H, d, J = 6.7 Hz), 4.53 (1 H, d, J = 6.7 Hz), 3.57 (1 H, dd, J = 9.0, 7.1 Hz), 3.36 (3 H, s), 2.90 (1 H, d, J = 7.1 Hz), 1.72 (3 H, s), 1.60 (6 H, s), 1.40 (3 H, s); ^{13}C NMR ($CDCl_3$) δ 145.5 (s), 134.2 (s), 133.0 (s), 126.2 (d), 122.3 (d), 113.5 (t), 95.5 (t), 75.7 (d), 61.9 (d), 61.0 (s), 55.7 (q), 50.6 (d), 39.1 (t), 34.9 (t), 34.1 (t), 25.5 (t), 24.3 (t), 23.8 (t), 19.8 (q), 19.3 (q), 18.4 (q), 14.9 (q); MS m/z 348 (M^+, 4), 316, 145, 117, 93, 81, 45 (100); HRMS calcd for $C_{22}H_{36}O_3$ 348.2666, found 348.2650.

7e from **7a** as a colorless oil (99%): IR (CCl_4) 2932, 1152, 1094, 1028, 892 cm^{-1}; ^1H NMR ($CDCl_3$) δ 5.06 (2 H, m), 4.90 (2 H, m), 4.87 (1 H, d, J = 7.2 Hz), 4.42 (1 H, d, J = 7.2 Hz), 3.34 (1 H, dd, J = 9.4, 6.4 Hz), 3.28 (3 H, s), 2.77 (1 H, d, J = 9.4 Hz), 1.77 (3 H, s), 1.64 (3 H, s), 1.59 (3 H, s), 1.23 (3 H, s); ^{13}C NMR ($CDCl_3$) δ 144.7 (s), 134.4 (s), 133.7 (s), 125.5 (d), 124.9 (d), 114.5 (t), 95.9 (t), 76.2 (d), 66.2 (d), 59.7 (s), 55.5 (q), 47.4 (d), 39.6 (t), 36.7 (t), 35.2 (t), 27.7 (t), 24.1 (t), 22.9 (t), 19.6 (q), 18.4 (q), 16.6 (q), 15.5 (q); MS m/z 348 (M^+, 3), 316, 302, 147, 93, 81, 45 (100); HRMS calcd for $C_{22}H_{36}O_3$ 348.2666, found 348.2649.

General Procedure for Cyclization Reaction. To a stirred solution of epoxy silyl ether **5c** (116 mg, 0.28 mmol) in ether (5 mL) was added BF_3·OEt_2 (0.17 mL) at −20 °C under N_2, and the mixture was stirred for 5 h at the same temperature. After being quenched with saturated aqueous $NaHCO_3$ (10 mL), the mixture was extracted with ether (15 mL × 3) and the combined organic layers were washed with brine. The solution was dried over Na_2SO_4, and the solvent was removed in vacuo. The residue was passed through a silica gel column with EtOAc/hexane (1/60) to elute first **9c** (67 mg, 58%) and then **2c** (38 mg, 33%).

9c as colorless oil: IR (CCl_4) 2956, 2860, 1464, 1200 cm^{-1}; ^1H NMR ($CDCl_3$) δ 5.44 (1 H, b t, J = 7.2 Hz), 4.80 (1 H, b d, J = 9.8 Hz), 3.55 (1 H, dd, J = 7.4, 3.8 Hz), 3.26 (1 H, d, J = 3.8 Hz), 1.56 (6 H, s), 1.26 (3 H, s), 1.11 (3 H, s), 0.92 (9 H, s), 0.07 (6 H, s); ^{13}C NMR ($CDCl_3$) δ 134.6 (s), 133.6 (s), 128.6 (d), 127.7 (d), 87.7 (s), 85.4 (d), 82.2 (d), 51.1 (t), 46.8 (s), 44.1 (d), 39.5 (t), 38.8 (t), 34.9 (t), 30.0 (q), 25.8 (q × 3), 25.5 (t), 24.7 (t), 23.3 (t), 18.6 (s), 18.4 (q), 15.3 (q), 15.1 (q), −5.0 (q × 2); MS m/z 418 (M^+, 4), 403, 389, 361, 269, 185, 121, 73 (100); HRMS calcd for $C_{26}H_{46}O_2Si$ 418.3264, found 418.3245.

2c as a colorless oil: IR (CCl_4) 3620, 2932, 2856, 1652, 1436, 1150 cm^{-1}; ^1H NMR ($CDCl_3$) δ 5.21 (1 H, m), 4.7 (3 H, m), 3.31 (1 H, m), 3.07 (1 H, m), 1.57 (6 H, s), 0.93 (9 H, s), 0.77 (3 H, s), 0.07 (6 H, s); ^{13}C NMR ($CDCl_3$) δ 144.1 (s), 133.1 (s), 132.5 (s), 127.8 (d), 127.0 (d), 109.2 (t), 78.6 (d), 75.6 (d), 46.9 (t), 41.9 (d), 39.5 (t), 39.1 (t), 36.8 (t), 36.4 (t), 26.5 (q × 3), 25.4 (t), 24.9 (t), 19.7 (q), 18.1 (s), 15.0 (t), 14.2 (q), 13.6 (q), −3.3 (q), −5.0 (q); MS m/z 418 (M^+, 2), 400, 147, 109, 75 (100); HRMS calcd for $C_{26}H_{46}O_2Si$ 418.3269, found 418.3246.

10c from **6c** as a colorless oil (70%): IR (CCl_4) 3604, 2936, 1464, 1252, 1134, 1038, 884 cm^{-1}; ^1H NMR ($CDCl_3$) δ 5.22 (1 H, b t, J = 7.0 Hz), 4.80 (2 H, m), 4.56 (1 H, m), 3.84 (1 H, d, J = 3.6 Hz), 3.71 (1 H, dd, J = 10.0, 3.6 Hz), 1.56 (6 H, s), 0.95 (12 H, s), 0.06 (6 H, s); ^{13}C NMR ($CDCl_3$) δ 144.8 (s), 133.6 (s), 132.6 (s), 128.2 (d), 127.5 (d), 107.1 (t), 77.2 (d), 73.1 (d), 46.3 (t), 43.2 (d), 40.4 (s), 39.6 (t), 37.5 (t), 36.7 (t), 26.0 (q × 3), 25.4 (t), 25.2 (t), 24.0 (q), 22.9 (t), 18.4 (s), 15.3 (q), 14.2 (q), −4.0 (q × 2); MS m/z 418 (M^+, 2), 400, 302, 109, 81, 75 (100); HRMS calcd for $C_{26}H_{46}O_2Si$ 418.3269, found 418.3255.

11 from **7c** as a colorless oil (52%): IR (CCl_4) 3624, 2936, 1464, 1116, 1062, 886 cm^{-1}; ^1H NMR ($CDCl_3$) δ 5.54 (1 H, b t, J = 8.0 Hz), 5.0 (3 H, m), 4.66 (1 H, b d, J = 2.4 Hz), 3.92 (1 H, d, J = 9.6 Hz), 3.53 (1 H, dd, J = 9.6, 2.0 Hz), 3.01 (1 H, m), 1.75 (3 H, s), 1.64 (6 H, s), 1.59 (3 H, s), 0.96 (9 H, s), 0.16 (6 H, s); ^{13}C NMR ($CDCl_3$) δ 144.8 (s), 133.2 (s × 3), 128.0 (d), 126.8 (d), 122.2 (d), 116.2 (t), 78.7 (d × 2), 43.9 (d), 39.0 (t), 35.9 (t), 28.4 (t), 26.8 (t), 26.3 (q × 3), 25.1 (t), 21.3 (q), 18.5 (s), 15.6 (q × 2), 11.3 (q), −3.2 (q), −5.1 (q); MS m/z 400 ($M^+ - H_2O$, 2), 360, 145, 93, 75 (100).

12 from **8c** as a colorless oil (70%): IR (CCl_4) 3650, 2932, 1464, 1084, 888 cm^{-1}; ^1H NMR ($CDCl_3$) δ 5.54 (1 H, b t, J = 8.0 Hz), 5.0 (2 H, m), 4.84 (1 H, m), 4.66 (1 H, m), 3.95 (1 H, m), 3.79 (1 H, dd, J = 6.4, 3.2), 1.65 (6 H, s), 1.63 (3 H, s), 4.53 (3 H, s), 0.95 (9 H, s), 0.15 (3 H, s), 0.10 (3 H, s); ^{13}C NMR ($CDCl_3$) δ 145.1 (s), 133.8 (s), 133.5 (s), 132.8 (s), 128.0 (d), 127.1 (d), 121.8 (d), 115.3 (t), 79.5 (d), 77.5 (d), 42.8 (d), 39.5 (t), 36.0 (t), 28.3 (t), 26.5 (t), 26.1 (q × 3), 24.9 (t), 21.5 (q), 18.6 (s), 15.6 (q), 15.3 (q), 12.0 (q), −3.0 (q), −5.1 (q); MS m/z 418 (M^+, 1), 400, 332, 145, 75 (100); HRMS calcd for $C_{26}H_{46}O_2Si$ 418.3269, found 418.3248.

9d and **2d** were obtained from **5d**.

9d: colorless needles (32%); mp 105 °C (EtOH); IR (CCl_4) 2936, 2864, 1652, 1464, 1140 cm^{-1}; ^1H NMR ($CDCl_3$) δ 7.27 (5 H, s), 5.43 (1 H, b t, J = 7.2 Hz), 4.82 (1 H, b d, J = 10.2 Hz), 4.55 (1 H, d, J = 12.0 Hz), 4.46 (1 H, d, J = 12.0 Hz), 3.61 (1 H, d, J = 3.2 Hz), 3.45 (1 H, dd, J = 7.7, 3.2 Hz), 2.91 (1 H, b t, J = 10.8 Hz), 1.57 (3 H, s), 1.51 (3 H, s), 1.31 (3 H, s), 1.10 (3 H, s); ^{13}C NMR ($CDCl_3$) δ 138.9 (s), 134.8 (s), 133.8 (s), 128.5 (d), 128.1 (d), 127.7 (d × 2), 127.2 (d × 2), 127.1 (d), 89.5 (d), 87.6 (s), 82.7 (d), 72.2 (t), 51.0 (t), 46.7 (s), 42.8 (d), 39.5 (t), 38.8 (t), 33.2 (t), 30.2 (q), 25.4 (t × 2), 23.5 (t), 18.4 (q), 15.2 (q), 15.0 (q); MS m/z 394 (M^+, 7), 303, 245, 227, 175, 149, 121, 91 (100); HRMS calcd for $C_{27}H_{38}O_2$ 394.2873, found 394.2862.

2d: colorless oil (20%); IR (CCl_4) 3596, 3032, 2920, 1464, 1050, 892 cm^{-1}; ^1H NMR ($CDCl_3$) δ 7.26 (5 H, s), 5.25 (2 H, m), 4.63 (4 H, m), 3.49 (1 H, d, J = 9.2 Hz), 2.95 (1 H, dd, J = 11.2, 9.2 Hz), 1.57 (6 H, s), 0.79 (3 H, s); ^{13}C NMR ($CDCl_3$) δ 146.2 (s), 138.8 (s), 133.7 (s), 132.8 (s), 128.4 (d), 127.9 (d), 127.7 (d), 127.5 (d × 2), 127.2 (d × 2), 106.0 (t), 84.1 (d), 76.3 (d), 74.0 (t), 47.2 (s), 44.5 (d), 39.6 (t), 38.6 (t), 36.7 (t), 36.6 (t), 25.1 (t), 25.0 (t), 22.0 (q), 19.8 (t), 15.2 (q), 14.4 (q); MS m/z 394 (M^+, 3), 376, 302, 148, 104, 90 (100); HRMS calcd for $C_{27}H_{38}O_2$ 394.2873, found 394.2866.

13 from **7d** as a colorless oil (22%): IR (CCl_4) 3068, 2932, 2856, 1728, 1464, 1104, 892 cm^{-1}; ^1H NMR ($CDCl_3$) δ 7.35 (5 H, s), 5.12 (1 H, b t, J = 7.3 Hz), 4.90 (1 H, m), 4.70 (1 H, d, J = 12.0 Hz), 4.6 (2 H, m), 4.13 (1 H, d, J = 12.0 Hz), 4.11 (1 H, d, J = 3.7 Hz), 1.67 (3 H, s), 1.57 (6 H, s), 1.04 (3 H, d, J = 6.8 Hz); ^{13}C NMR ($CDCl_3$) δ 212.4 (s), 146.7 (s), 138.3 (s), 135.8 (s), 133.9 (s), 128.2 (d × 2), 128.1 (d × 2), 127.6 (d), 126.0 (d), 124.8 (d), 113.0 (t), 82.3 (d), 72.1 (t), 45.8 (d), 39.4 (t), 38.5 (d), 35.7 (t), 34.1 (t), 26.0 (t), 24.7 (t), 24.5 (t), 20.4 (q), 15.5 (q), 15.2 (q), 13.9 (q); MS m/z 394 (M^+, 1), 303, 288, 105, 91 (100), 81; HRMS calcd for $C_{27}H_{38}O_2$ 394.2873, found 394.2855.

9e and **2e** were obtained from **5e**.

9e as a colorless oil (49%): IR (CCl_4) 2928, 1454, 1152, 1096, cm^{-1}; ^1H NMR ($CDCl_3$) δ 5.42 (1 H, b t, J = 6.5 Hz), 4.82 (1 H, d, J = 9.1 Hz), 4.75 (1 H, m), 4.58 (1 H, d, J = 9.1 Hz), 3.6 (2 H, m), 3.35 (3 H, s), 1.58 (6 H, s), 1.31 (3 H, s), 1.11 (3 H, s); ^{13}C NMR ($CDCl_3$) δ 134.7 (s), 133.7 (s), 128.7 (d), 127.8 (d), 97.3 (t), 88.2 (d), 87.4 (s), 83.9 (d), 55.6 (q), 50.9 (t), 46.7 (s), 42.4 (d), 39.4 (t), 36.8 (t), 33.9 (t), 30.4 (q), 25.4 (t × 2), 23.6 (t), 18.4 (q), 15.3 (q), 15.1 (q); MS m/z 348 (M^+, 8), 316, 286, 229, 147, 121, 81, 45 (100); HRMS calcd for $C_{22}H_{36}O_3$ 348.2666, found 348.2625.

2e as a colorless oil (27%): IR (CCl_4) 3464, 2928, 2852, 1652, 1464, 1136, 892 cm^{-1}; ^1H NMR ($CDCl_3$) δ 5.2 (2 H, m), 4.76 (1 H, d, J = 6.4 Hz), 4.67 (2 H, m), 4.58 (1 H, d, J = 6.4 Hz), 3.41 (3 H, s), 3.40–2.80 (2 H, m), 1.67 (3 H, s), 1.58 (3 H, s), 0.77 (3 H, s); ^{13}C NMR ($CDCl_3$) δ 146.0 (s), 133.9 (s), 132.7 (s), 128.0 (d), 127.7 (d), 106.1 (t), 98.2 (t), 86.0 (d), 75.9 (d), 55.8 (q), 47.5 (t), 43.7 (d), 39.8 (t), 39.0 (s), 37.0 (t), 36.7 (t), 25.2 (t × 2), 22.2 (q), 19.2 (t), 15.2 (q), 14.2 (q); MS m/z 348 (M^+, 3), 316, 286, 203, 175, 135, 109, 81, 45 (100); HRMS calcd for $C_{22}H_{36}O_3$ 348.2666, found 348.2645.

10e from **6e** as colorless prisms (41%): mp 87 °C (benzene); IR (CCl_4) 3472, 2940, 1658, 1440, 1150, 1040, 888 cm^{-1}; ^1H NMR ($CDCl_3$) δ 5.27 (1 H, b t, J = 6.7 Hz), 4.8 (2 H, m), 4.73 (1 H, d, J = 6.5 Hz), 4.62 (1 H, m), 4.53 (1 H, d, J = 6.5 Hz), 3.8 (2 H, m), 3.40 (3 H, s), 1.57 (6 H, s), 0.91 (3 H, s); ^{13}C NMR ($CDCl_3$) δ 145.1 (s), 133.6 (s), 132.5 (s), 128.2 (d), 127.5 (s), 106.8 (t), 98.9 (t), 86.8 (d), 71.9 (d), 56.1 (q), 46.0 (t), 42.4 (d), 40.5 (s), 39.6 (t), 37.2 (t), 36.6 (t), 25.4 (t), 25.2 (t), 23.6 (q), 23.4 (t), 15.2 (q), 14.1 (q); MS m/z 348 (M^+, 8), 316, 303, 286, 175, 163, 81 (100); HRMS calcd for $C_{22}H_{36}O_3$ 348.2666, found 348.2663.

Desilylation of (±)-2β-(*tert*-Butyldimethylsiloxy)secotrinerviten-3α-ol (2c). To a solution of **2c** (34 mg, 0.08 mmol) in THF (2 mL) was added a solution of tetrabutylammonium fluoride in THF (1.0 M, 0.12 mmol), and the mixture was stirred at rt for 27 h. After being diluted with ether (50 mL), the mixture was washed with water and brine. The solvent was removed in vacuo, and the residue was passed through a silica gel column with EtOAc/hexane (1/10) to give diol **2a** (12 mg, 49%).

Desilylation of (±)-2α-(*tert*-Butyldimethylsiloxy)secotrinerviten-3α-ol (10c) and (1*RS*,2*SR*,3*SR*,6*E*,10*E*,13*E*)- and (1*RS*,2*RS*,3*SR*,6*E*,10*E*,13*E*)-2-(*tert*-Butyldimethylsiloxy)-3-(2-propenyl)-6,10,14-trimethyl-6,10,13-cyclotetradecatrien-1-ol (11 and 12). **10a** (R = H) was obtained from **10c** in a manner similar to that given previously for **2a** as colorless prisms (48%): mp 124 °C (benzene); IR (CCl_4) 3584, 2928, 1380, 1090, 896 cm^{-1}; ^1H NMR ($CDCl_3$) δ 5.25 (1 H, b t, J = 8.3 Hz), 5.00 (1 H, b s), 4.78 (2 H, m), 3.80 (2 H, m), 1.57 (6 H, s), 0.87 (3 H, s); ^{13}C NMR ($CDCl_3$) δ 145.8 (s), 133.6 (s), 133.0 (s), 128.2 (d), 127.1 (d), 109.3 (t), 74.6 (d), 72.7 (d), 45.6 (t), 43.2 (d), 40.6 (s), 39.6 (t), 37.4 (t), 36.5 (t), 25.4 (t), 25.3 (t), 24.3 (q), 22.6 (t), 15.3 (q), 14.2 (q); MS m/z 304 (M^+, 36), 286, 151 (100), 81; HRMS

calcd for $C_{20}H_{32}O_2$ 304.2400, found 304.2400.

11a from **11** as colorless needles (90%): mp 117 °C (benzene); IR (CCl_4) 3632, 3584, 2936, 1642, 1210 cm^{-1}; ^1H NMR ($CDCl_3$) δ 5.43 (1 H, b t, J = 8.3 Hz), 4.8 (3 H, m), 4.72 (1 H, d, J = 2.4 Hz), 3.82 (1 H, d, J = 9.5 Hz), 3.45 (1 H, dd, J = 9.5, 3.0 Hz), 1.77 (3 H, s), 1.63 (6 H, s), 1.55 (3 H, s); ^{13}C NMR ($CDCl_3$) δ 144.8 (s), 133.9 (s), 133.3 (s), 131.8 (s), 128.7 (d), 127.2 (d), 122.0 (d), 115.6 (t), 80.1 (d), 75.5 (d), 45.2 (d), 39.0 (t), 36.5 (t), 28.7 (t), 26.9 (t), 24.8 (t), 21.6 (q), 15.7 (q), 15.5 (q), 11.4 (q); MS m/z 304 (M^+, 4), 286, 234, 203, 109, 95, 81 (100). Anal. Calcd for $C_{20}H_{32}O_2$: C, 78.90; H, 10.59. Found: C, 78.72; H, 10.53.

12a from **12** as colorless needles (58%): mp 89 °C (benzene-/hexane); IR (CCl_4) 3624, 2924, 1442, 1386, 1062, 1006, 900 cm^{-1}; ^1H NMR ($CDCl_3$) δ 5.52 (1 H, b t, J = 8.0 Hz), 5.0 (2 H, m), 4.85 (1 H, m), 4.70 (1 H, m), 4.04 (1 H, d, J = 3.1 Hz), 3.76 (1 H, dd, J = 7.9, 3.1 Hz), 1.70 (3 H, s), 1.65 (6 H, s), 1.55 (3 H, s); ^{13}C NMR ($CDCl_3$) δ 145.1 (s), 134.0 (s), 133.5 (s), 133.0 (s), 127.8 (d), 127.3 (d), 122.0 (d), 115.5 (t), 80.0 (d), 77.1 (d), 44.0 (d), 39.6 (t), 36.2 (t), 28.5 (t), 26.6 (t), 24.6 (t), 21.6 (q), 15.8 (q), 15.3 (q), 11.8 (q); MS m/z 304 (M^+, 4), 286, 271, 203, 137, 121, 109, 95, 84 (100); HRMS calcd for $C_{20}H_{32}O_2$ 304.2400, found 304.2403.

Supplementary Material Available: ^1H NMR for compounds **2a-e, 5b-e, 6b, 6c, 6e, 7b-e, 8b, 8c, 9c-e, 10a, 10c, 10e, 11, 11a, 12, 12a,** and **13** (29 pages). Ordering information is given on any current masthead page.

Improved Preparation of the Clathrate Host Compound Tri-*o*-thymotide and Related Trisalicylide Derivatives

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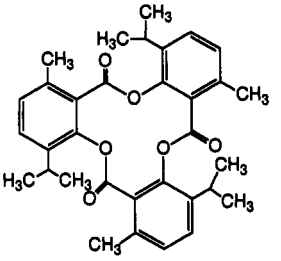
In order to improve the relatively low yield (ca. 35%) previously observed in the synthesis of tri-*o*-thymotide (TOT, **1**) from *o*-thymotic acid (**2**), the cyclodehydration was studied using a variety of conditions. The low yield is due to the formation of di-*o*-thymotide (DOT, **3**), previously reported, and at least three other products (**4-6**), which apparently result from the acid-catalyzed decarboxylation of **2** and subsequent condensation with thymol (**7**). Using pyridine as a solvent, side-product formation is inhibited. Under appropriate conditions, namely, neat $POCl_3$ at 50 °C, the yield of **1** is 93%. Other salicylic acid derivatives also give high yields of the corresponding "trimers" under these conditions, thus providing a general, improved preparation of a family of potential clathrate host substances.

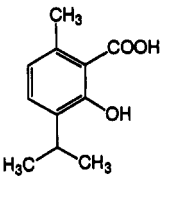
Introduction

The study of clathrate inclusion phenomena continues to command the attention of chemists and technologists because of the intrinsic scientific interest in clathrate formation and properties (bringing two different substances together in a crystalline array and generating new and different properties compared to either of the components) and also because of the many potential applications of such systems.[1-4] The well-known host substance tri-*o*-thymotide (TOT, **1**) has been especially well-studied:[5] cage- and channel-type inclusion complexes and six additional clathrate types have been recognized;[6-11] most TOT (**1**) complexes are chiral[11] (i.e., they have enantiomorphic space groups). Some of the specific applications for which TOT (**1**) clathrates have been used include the following: (a) media for chemical reactions of included guests,[6] as well as asymmetric reactions;[12] (b) agents for optical resolutions and configuration determination of guest species;[13] (c) chromatography supports;[14] (d) host species for studying guest molecular motion;[15] (e) matrix isolation of labile species;[16] (f) separation of terpenes (menthone, carvacrol, etc.) in essential oils;[17] (g) separation of specific hydrocarbons from complex mixtures;[18] (h) a medium for effecting second harmonic generation (nonlinear optical effect).[19]

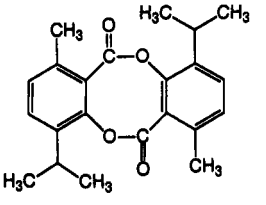
Except for the reported synthesis[20] of **1** in 1952 and a very recent stepwise strategy for preparing nonsymmetrical trimers,[21] no studies on the synthesis of **1** have been described. We herein report a study of the original cyclodehydration reaction and describe the side products pro-



Tri-*o*-Thymotide (TOT, 1)



o-Thymotic acid (2)



Di-*o*-Thymotide (DOT, 3)

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