a residue (308 mg) which was separated by PLC on SiO_2 plates (C_6H_6–EtOAc, 9:1, as eluent) into two components, **2** (most polar, 270 mg) and **3** (35 mg).

Compound **2** is a syrup: IR (film) 3550, 3100, 1735, 1600, 1250, 940, 895 cm^{-1}; NMR)100 MHz, $CDCl_3$) δ 6.34 (1 H, q, J_{XA} = 18, J_{XB} = 10 Hz, H-14), 5.36–4.88 (3 H, m, H-6 and H-15 protons), 4.99 (2 H, s, H-16), 3.86 (2 H, AB system, J = 11 Hz, H-18), 2.06 and 2.01 (3 H each, s, two -OAc), 1.26 (3 H, s, H-17), 0.92 and 0.85 (3 H each, s, H-20 and H-19 protons, respectively); mass spectrum M^+ m/e 406.

Compound **3**: mp 118–120 °C (aqueous EtOH); $[\alpha]^{20}_D$ −31° (c 0.18, $CHCl_3$); IR (KBr) no -OH absorption, 3100, 1745, 1600, 1255, 920, 900 cm^{-1}; NMR (100 MHz, $CDCl_3$) δ 6.34 (1 H, q, J_{XA} = 18, J_{XB} = 10 Hz, H-14), 5.54–4.90 (3 H, m, H-6 and H-15 protons), 4.99 (2 H, s, H-16), 3.83 (2 H, AB system, J = 11 Hz, H-18), 2.13, 2.07, and 2.00 (3 H each, s, three -OAc), 1.58 (3 H, s, H-17), 0.96 and 0.85 (3 H each, s, H-20 and H-19 protons, respectively); mass spectrum $[M - 60]^+$ m/e 388. Anal. Calcd for $C_{26}H_{40}O_6$: C, 69.61; H, 8.99. Found: C, 69.73; H, 8.89.

Lactone 4. The diacetate **2** (250 mg) was treated with an excess of osmium tetroxide in Et_2O–dioxane (1:1) solution yielding quantitatively a product which without further characterization was treated with HIO_4 in aqueous ethanol solution affording 210 mg of **4**: mp 145–147 °C (aqueous EtOH); $[\alpha]^{20}_D$ −88.7° (c 0.40, $CHCl_3$); IR (KBr) 1740, 1720, 1235 cm^{-1}; NMR (100 MHz, $CDCl_3$) δ 5.07 (1 H, sextet, $J_{aa'} = J_{aa''}$ = 11, $J_{ae'}$ = 4 Hz, H-6), 3.86 (2 H, AB system, J = 11 Hz, H-18), 2.60 (2 H, m, H-12), 2.26 (1 H, q, J_{gem} = 12, $J_{ea'}$ = 4 Hz, equatorial H-7), 2.06 and 2.03 (3 H each, s, two -OAc), 1.49 (3 H, s, H-17), 0.98 and 0.87 (3 H each, s, H-20 and H-19 protons, respectively); mass spectrum $[M - 60]^+$ m/e 320. Anal. Calcd for $C_{21}H_{32}O_6$: C, 66.30; H, 8.48. Found: C, 66.42; H, 8.57.

X-Ray Structure Determination of 4. $C_{21}H_{32}O_6$ (4) crystallizes in the space group $P2_1$ with two molecules in a cell of dimensions a = 10.790 (1), b = 10.055 (1), c = 9.458 (1) Å, and β = 93.95 (1)°. The molecular weight is 380 g mol^{-1} and the calculated density is 1.23 g cm^{-3}. The intensity of 3144 independent reflections with $\theta \leq 30°$ were measured on a computer-controlled diffractometer using graphite-monochromated Mo Kα radiation (0.7107 Å). No crystal decomposition was observed during the data collection. After correction for Lorentz and polarization effects, 1707 reflections were considered observed with the criterion $I > 2\sigma(I)$. The structure was solved by using the multisolution tangent formula.[7] It was necessary to take into account the amplitude error[8] to obtain a substantial fragment of the molecule among several E-map solutions. The rest of the molecule was found on a difference map after a "hard" least-squares correction ($\sin\theta/\lambda < 0.4$) of the first fragment. The hydrogen atoms, found on a difference map, were included in the last weighted anisotropic least-squares refinements (isotropic for H atoms). Final unweighted and weighted disagreement indices are R = 0.051 and Rw = 0.066, respectively.[9]

Monobenzoate 5. Benzoyl chloride (200 mg) was added to a solution of **1** (300 mg) in dry pyridine (5 mL) and the mixture kept for 2 h at 0 °C, poured into water, and extracted with chloroform. Vacuum distillation of the solvent left a residue from which the compound **5** (280 mg) was chromatographically isolated [PLC on SiO_2, C_6H_6–EtOAc (9:1)]: mp 139–143 °C (aqueous EtOH); $[\alpha]^{20}_D$ −16.6° (c 0.58, $CHCl_3$); IR (KBr) 3540, 3500, 3300, 3100, 3080, 1700, 1600, 1285, 915, 890, 715 cm^{-1}; NMR (60 MHz, $CDCl_3$) δ 8.40–7.30 (5 H, m, phenyl protons), 4.20 (2 H, AB system, J = 11 Hz, H-18), 3.85 (1 H, m, H-6). Anal. Calcd for $C_{27}H_{38}O_4$: C, 76.02; H, 8.98. Found: C, 75.90; H, 8.89.

Application of Horeau's Method[4] to 5. A mixture of (±)-α-phenylbutyric anhydride (0.37 mmol) and **5** (36 mg) in pyridine solution (2 mL) was kept at room temperature during 20 h: α_1 = −0.106, α_2 = −0.201; $\alpha_1 - (1.1\alpha_2)$ = +0.115. Configuration: 6R.

Dibenzoate 6. Reaction of a pyridine solution of compound **1** with a large excess of benzoyl chloride for 24 h at room temperature yielded **6**: mp 62–65 °C (EtOH); $[\alpha]^{20}_D$ −13.8° (c 0.53, $CHCl_3$); IR (KBr) 3520, 3100, 3080, 1720, 1600, 1275, 940, 890, 710 cm^{-1}; NMR (60 MHz, $CDCl_3$) δ 8.40–7.20 (10 H, m, phenyl protons), 4.20 (2 H, s, H-18), no signal at 4.00–3.00. Anal. Calcd for $C_{34}H_{42}O_5$: C, 76.95; H, 7.98. Found: C, 77.01; H, 7.94.

Application of the "Benzoate Rule":[5] **6**, $[M]_D$ −73.6° **5**, $[M]_D$ −70.7°; $\Delta[M]_D$ = −2.9. Absolute stereochemistry: 6R.

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Registry No.—**1**, 62279-93-0; **2**, 62264-72-6; **3**, 62264-73-7; **4**, 62264-74-8; **5**, 62264-75-9; **6**, 62264-76-0; benzoyl chloride, 98-88-4.

Supplementary Material Available. A list of atomic parameters, bond distances, and angles (3 pages). Ordering information is given on any current masthead page.

References and Notes

(1) Part 34 in the series "Studies on Diterpenes from *Sideritis* Genus". For part 33 see M. C. Garcia-Alvarez and B. Rodriguez, *Phytochemistry*, **15**, 1994 (1976).
(2) C. von Carstenn-Lichterfelde, B. Rodríguez, and S. Valverde, *Experientia*, **31**, 757 (1975).
(3) A. I. Scott, "Interpretation of the Ultraviolet Spectra of Natural Products", Pergamon Press, Oxford, 1964, p 46.
(4) A. Horeau and A. Nouaille, *Tetrahedron Lett.*, 1939 (1971).
(5) J. R. Brewster, *Tetrahedron*, **13**, 106 (1961).
(6) F. Piozzi, P. Venturella, A. Bellino and R. Mondelli, *Tetrahedron*, **24**, 4073 (1968).
(7) P. Main, M. M. Woolfson, J. Declercq, and G. Germain, MULTAN, Physics Department, University of York, York, England, 1974.
(8) H. B. Bürgi and J. D. Dunitz, *Acta Crystallogr., Sect. A*, **27**, 117 (1971).
(9) J. M. Stewart, F. A. Kundell, and J. C. Baldwin, "The X-Ray 70 System", Computer Science Center, University of Maryland, College Park, Md., 1970.

Structure, Chemistry, and Absolute Configuration of 1(*S*)-Bromo-4(*R*)-hydroxy-(−)-selin-7-ene from a Marine Red Alga *Laurencia* Sp.

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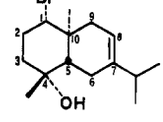
As part of a program aimed at assessing the diversity of halogen-based terpene synthesis in the red seaweed *Laurencia* (Rhodomelaceae), we have investigated the metabolites from a number of unrecorded species from this genus indigenous to the Gulf of California.[1-3] One collection of an apparently unrecorded *Laurencia*[4] has now yielded a bromine-containing derivative of the selinane type (**1**), which is a previously unknown ring system from this source.

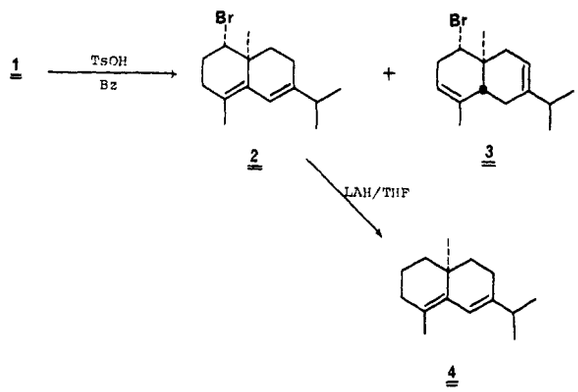


1

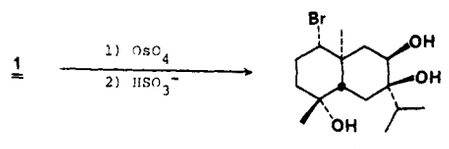
1(*S*)-Bromo-4(*R*)-hydroxy-(−)-selin-7-ene (**1**), an oil, $[\alpha]^{22}_D$ +52.6° (c 4.62, $CHCl_3$), was obtained in high yield (10% extract) from silica gel chromatography of the chloroform–methanol extract of the fresh alga. High-resolution mass spectral analysis of **1** established a molecular formula of $C_{15}H_{25}OBr$ and illustrated a facile loss of water. Intense infrared absorption at 3450 cm^{-1} further confirmed that **1** was an alcohol. The lack of acetylation upon treatment with acetic anhydride in pyridine (25 °C), the presence of a quaternary carbon resonance at 70.4 ppm in the ^{13}C NMR (relative to Me_4Si = 0), and a singlet at δ 1.16 in the ^1H NMR spectrum indicated the hydroxyl to be tertiary and located at a methyl-bearing carbon. The ^{13}C NMR spectrum of **1** further indicated a secondary bromine-containing carbon (doublet at 68.5 ppm) and a single trisubstituted olefin (singlet at 142.0 and doublet at 116.4 ppm) to be present in the molecule, which indicated that **1** is bicyclic. The ^1H NMR spectrum gave considerable insight into the structure of **1**. A symmetrical one-proton heptet at δ 2.16 and a six-proton doublet at δ 1.0 indicated that **1** contained an isopropyl group. Also, a complex signal at δ 2.43, appearing as a double quartet (actually a dddd

with J = 13, 13, 13, 4 Hz), was assignable to the axial methylene proton at C-2 based upon analogous bands rigorously defined for iriediol,[2] oppositol,[5] and bromosphaerol.[6] This ring proton suffers deshielding, presumably from both the adjacent equatorial bromine at C-1 and the axial hydroxyl at C-4. This proton appears to be recognizable in rigid *cis*-1,4-cyclohexane bromohydrin systems and moves to usually obscured high field when either bromine or hydroxyl are eliminated.

Consideration of gross spectral characteristics allowed the preliminary conclusion that this metabolite possessed the selinane ring system; however, unambiguous assignments could not be made based upon spectral analysis. Treatment of 1 with *p*-toluenesulfonic acid in benzene gave the isomeric bromodienes 2 and 3 in good yield. Diene 2 was isolated by thick layer chromatography and was converted by $LiAlH_4$ dehalogenation to the diene 4 which had spectral characteristics (NMR, IR, UV, and $[\alpha]_D$) identical with those published for (−)-(δ)-selinene.[7] These conversions allowed an unequivocal assignment of 1 to the selinane group and also defined the absolute stereochemistry at the angular methyl carbon, C-10, as α.

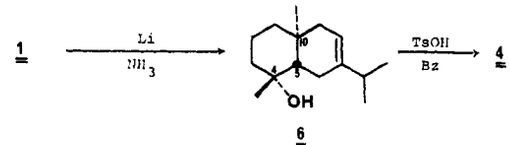


To fix the position of the double bond in 1, the C-7, C-8 cis diol was prepared by treatment with OsO_4 in diethyl ether. The NMR spectrum of 5 clearly shows the existence of the C-8



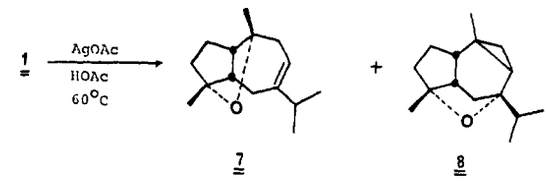
alcohol methine proton at δ 4.02, appearing as a double doublet, J = 12, 4 Hz. These data indicate an axial proton coupled to an adjacent methylene pair. These criteria can be met only by an equatorial hydroxyl specifically at C-8, proving that 1 contains a Δ^7 olefin rather than Δ^6.

Lithium in ammonia reduction of 1 gave the debromo alcohol 6, which was spectrally identical but of opposite rotation, $[\alpha]_D$ +57.1°, with the corresponding compound, $[\alpha]_D$ −62.1 ± 3°, derived from oplodiol.[8] Hence the chiral centers at C-4, -5, and -10 have the same relative configuration as in oplodiol, but are of opposite absolute configuration. To confirm these conclusions, 6 was also converted to (−)-δ-selinene (4) by

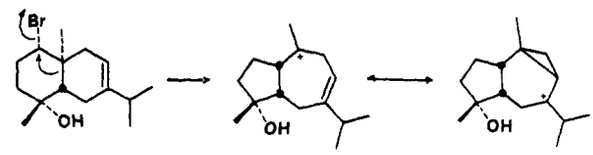


treatment with *p*-toluenesulfonic acid in benzene. These data indicate that 1 contains the trans ring juncture as drawn. NMR evidence to fix the stereochemistry at C-5 can also be obtained from the triol 5. In this compound, the C-5 proton is resolved at δ 1.93 as a doublet of doublets with J = 12, 5 Hz. These coupling constants and multiplicities confirm that the C-5 proton is axial and is flanked by a methylene pair.

The remaining stereochemistry of 1, not rigorously defined by the chemistry outlined above, is at the bromine-bearing carbon, C-1. The axial coupling constants for the methine proton at C-1 (dd, J = 12, 4 Hz) and the analogy to similar *Laurencia* metabolites allow a reasonable assignment of the bromine to an equatorial position. In further support of this assignment and also of the gross structure of 1 are the products obtained from the reaction of 1 with AgOAc in HOAc at 60 °C for 2 h. Under these conditions a high yield of two rearranged ethers, 7 and 8, is obtained.



The structures of 7 and 8 are assigned based upon interpretation of ^{13}C and ^1H NMR, MS, and infrared data, as well as the conversion of 7 to guaiazulene with Pd/C.[9] A bridged ether analogous to 7 has recently been described which is formed from treatment of the perhydroazulene lactone eremanthine with NBS in aqueous dioxane.[10] Molecular models reveal that ether formation between the carbon atoms indicated in 7 requires a cis ring fusion. The formation of these products is consistent with a concerted elimination of an equatorial bromine, migration of the anti bridgehead bond, and subsequent trapping of the carbonium ion by a proximate hydroxyl before and after participation of the Δ^7 olefinic bond.



Natural compounds containing the bicyclic cyclohexane-1,4-bromohydrin system, now exemplified by compound 1, the irieols,[2] oppositol,[5] and bromosphaerol,[6] appear to be common in some red seaweeds.[11] Based upon the biomimetic studies of Sutherland et al.,[12] the bromohydrin system in 1 is probably produced by a bromonium ion induced transannular cyclization of a germacrene intermediate, and the related structures from other medium-size ring intermediates.

Experimental Section

NMR spectra were recorded on Varian HR-220 or EM-360 spectrometers; chemical shifts are expressed as δ values in parts per million relative to tetramethylsilane = 0. Infrared spectra were obtained on a Perkin-Elmer 137 sodium chloride spectrophotometer and UV spectra were recorded on a Perkin-Elmer 124 double beam spectrophotometer. Optical rotations were recorded on a Perkin-Elmer 1410 polarimeter.

Mass spectra were obtained on a Hewlett-Packard 5930A mass spectrometer. High-resolution mass spectra were measured by Dr. Kai Fang, Department of Chemistry, UCLA.

Isolation of 1(*S*)-Bromo-4(*R*)-hydroxy-(−)-selin-7-ene (1). Crude extract (20.0 g) obtained from the chloroform–methanol (1:1) extraction of the fresh alga (~2.5 kg) was applied to a column containing 250 g of silica gel (Grace Chemical). This was eluted with a solvent gradient system from petroleum ether to benzene to ethyl ether. The majority of 1 was found in five fractions which were eluted with 100% benzene. These fractions were combined (2 g) and rechromatographed to give on benzene–petroleum ether (9:1) elution a pure sample of 1 (1.25 g): high-resolution mass spectrum M^+ *m/e* 300.1085 for $C_{15}H_{25}O^{79}Br$ (calcd, 300.1089); ^{13}C NMR (20 MHz,

benzene-d_6, relative to Me_4Si) 142.0 (s), 116.4 (d), 70.4 (s), 68.5 (d), 48.1 (d), 43.1 (t), 42.5 (t), 38.6 (s), 34.9 (d), 30.5 (t), 29.6 (q), 24.6 (t), 21.9 (q), 21.3 (q), and 14.2 ppm (q); ^1H NMR (220 MHz, $CDCl_3$, relative to Me_4Si) δ 5.32 (1 H, bd, J = 6 Hz), 4.00 (1 H, dd, J = 12, 4 Hz), 2.43 (1 H, dddd, J = 13, 13, 13, 4 Hz), 2.16 (1 H, heptet, J = 7 Hz), 1.64 (1 H, m), 1.16 (3 H, s), 1.09 (3 H, s), and 1.00 ppm (6 H, d, J = 7 Hz).

Dehydration of 1. Compound 1 (70 mg) was dissolved in benzene (10 mL) and a catalytic amount of *p*-toluenesulfonic acid monohydrate was added (~5 mg). The mixture was refluxed for 30 min, after which time diethyl ether (75 mL) was added and the organic phase neutralized with $NaHCO_3$. The ether phase was separated and dried with anhydrous $MgSO_4$, and the ether was removed in vacuo to yield a light, mobile oil (50 mg). Silica gel TLC showed the production of two relatively nonpolar products, one UV active at R_f 0.7 (petroleum ether) and one non-UV-active at R_f 0.8. Preparative layer chromatography (petroleum ether) gave pure samples of **2** and **3** in a 3:2 ratio. For compound **2:** NMR (60 MHz, CCl_4) δ 6.00 (1 H, s), 4.03 (1 H, dd, J = 12, 5 Hz), 1.67 (3 H, s), 1.05 (6 H, d, J = 7 Hz), 1.03 (3 H, s); UV λ_{max} (CH_2Cl_2) 240, 247, 257 nm; mass spectrum m/e 282/284 (M^+), $C_{15}H_{23}Br$. For compound **3:** NMR (220 MHz, CCl_4) δ 5.39 (1 H, bs), 5.27 (1 H, bs), 4.23 (1 H, dd, J = 11, 5 Hz), 1.66 (3 H, s), 1.02 (6 H, d, J = 8 Hz), 0.86 (3 H, s); mass spectrum M^+ m/e 282/284 (1:1) for $C_{15}H_{23}Br$.

(−)-δ-Selinene (4) from 2. A solution of 20 mg of **2** in 5 mL of anhydrous THF containing excess $LiAlH_4$ was refluxed in a nitrogen atmosphere for 4 h. Standard hydrolytic workup gave 5 mg of (−)-δ-selinene (**4**): NMR (60 MHz, CCl_4) δ 6.02 (1 H, s), 1.67 (3 H, s), 1.05 (6 H, d, J = 7 Hz), 0.92 (3 H, s); UV λ_{max} (CH_3OH) 237, 244, 255 nm; IR (film) ν 2900, 1645, 1620, 1385, 1375, 1295, 1270, 1215, 1175, 1065, 1030, 995, 955, 876, and 805 cm^{-1}; $[\alpha]^{22}_D$ −188° (c 0.08, $CHCl_3$); mass spectrum M^+ m/e 204 for $C_{15}H_{24}$.

1(*S*)-Bromo-4(*R*),7(*R*),8(*R*)-trihydroxy-(−)-selinane (5). A solution of 57 mg of **1** and 50 mg of OsO_4 in 5 mL of anhydrous ether containing 5 drops of pyridine was stirred for 48 h at 25 °C. The reaction was quenched by adding 15 mL of pyridine followed by 20 mL of a 5% solution of $NaHSO_3$. After stirring for 2 h, the reaction mixture was extracted with ether. The ether solution was washed five times with 5% HCl solution and once with saturated $NaHCO_3$ solution, and dried over $MgSO_4$. Filtration and evaporation gave a single product (50 mg), an oil (**5**): NMR (220 MHz, $CDCl_3$) δ 4.02 (1 H, dd, J = 12, 4 Hz), 3.92 (1 H, dd, J = 12, 5 Hz), 2.39 (1 H, dddd, J = 13, 13, 13, 4 Hz), 1.93 (1 H, dd, J = 12, 5 Hz), 1.23 (3 H, s), 1.18 (3 H, s), 1.04 (3 H, d, J = 8 Hz), 0.99 (3 H, d, J = 8 Hz); mass spectrum m/e 291/293 (M^+ − 43), 273/275 M^+ − (43 + H_2O), 255/257 M^+ − (43 + 2H_2O), 237 M^+ − (43 + Br).

4(*R*)-Hydroxy-(−)-selin-7-ene (6). To a solution of excess Li in liquid ammonia (dry ice–acetone bath) and diethyl ether, 30 mg of **1** in 2 mL of ether was added with stirring. After 2 h, NH_4Cl was added slowly and the reaction mixture was allowed to warm to room temperature. When the ammonia had evaporated, the reaction mixture was washed with 5% HCl followed by saturated $NaHCO_3$, dried ($MgSO_4$), filtered, and evaporated to give, after thick layer chromatography, 20 mg of **6** as a colorless oil: $[\alpha]^{21}_D$ +57.1° (c 1.37, dioxane); NMR (220 MHz, $CDCl_3$) δ 5.32 (1 H, bs), 2.22 (1 H, hep, J = 7 Hz), 1.17 (3 H, s), 1.02 (6 H, d, J = 7 Hz), 0.96 (3 H, s); IR (film) ν 3350, 2900, 1625, 1140 cm^{-1}; mass spectrum m/e 204 (M^+ − H_2O) $C_{15}H_{24}$, 189 (M^+ − H_2O − CH_3) $C_{14}H_{21}$.

Conversion of 6 to (−)-δ-Selinene. A solution of 20 mg of **6** in 5 mL of benzene containing a catalytic amount of *p*-toluenesulfonic acid monohydrate was refluxed for 1 h. Workup yielded two olefins as judged by NMR, one of which was **4**. The mixture was dissolved in 2 mL of acetic acid containing 2 drops of H_2SO_4 and stirred for 30 min. Workup gave 15 mg of a single olefin, **4**, which was identical with that produced from **2**.

Silver Acetate Rearrangement of 1. A solution of 100 mg of **1** in glacial acetic acid was added slowly with stirring to a suspension of excess AgOAc in glacial acetic acid. The reaction mixture was stirred at 60 °C for 2 h and filtered, and the filtrate was washed with ether. The ether–acetic acid was washed with water, followed by $NaHCO_3$, dried over $MgSO_4$, filtered, and evaporated to give a yellow oil. TLC of the reaction mixture indicated two major products which were less polar than **1**. TLC (ether–petroleum ether, 1:1 v/v), R_f 0.4 (**7**) and R_f 0.5 (**8**). Thick layer chromatography gave pure samples of **7** (30 mg) and **8** (20 mg). For compound **7:** ^{13}C NMR (20 MHz, $CDCl_3$) 143.0 (s), 117.7 (d), 86.1 (s), 80.0 (s), 50.3 (d), 49.1 (d), 42.8, 37.2, 36.3, 27.5, 27.1, 24.2, 21.9, 21.7, 17.2 ppm; ^1H NMR (220 MHz, $CDCl_3$) δ 5.23 (1 H, dd, J = 5, 5 Hz), 1.26 (3 H, s), 1.23 (3 H, s), 1.02 (6 H, d, J = 8 Hz); mass spectrum m/e 220 (M^+) $C_{15}H_{24}O$. For compound **8:** ^{13}C NMR (20 MHz, $CDCl_3$) 92.0, 86.1, 53.0, 42.1, 35.7, 31.2, 30.7, 31.0, 27.3, 27.1, 26.2, 25.0, 24.5, 24.2, 17.4 ppm; ^1H NMR (220 MHz, $CDCl_3$) δ 1.20 (3 H, s), 0.95 (3 H, s), 0.94 (3 H, d, J = 7 Hz), 0.92 (3 H, d, J = 7 Hz), 0.45 (1 H, bs), 0.43 (1 H, dd, J = 7, 3 Hz); mass spectrum m/e 220 (M^+) $C_{15}H_{24}O$.

Guaiazulene. A solution of 20 mg of **7** in xylene was refluxed in the presence of 10% Pd on charcoal for 48 h. Filtration and evaporation left a blue residue. TLC (petroleum ether) purification of this mixture gave approximately 1 mg of a blue hydrocarbon which was determined to be identical with guaiazulene by TLC and visible spectra.

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Registry No.—**1,** 62264-66-8; **2,** 62264-67-9; **3,** 62264-68-0; **4,** 28624-23-9; **5,** 62288-63-5; **6,** 62264-69-1; **7,** 62264-70-4; **8,** 62264-71-5.

References and Notes

(1) B. M. Howard and W. Fenical, *Tetrahedron Lett.*, 1687 (1975).
(2) W. Fenical, B. Howard, K. B. Gifkins, and J. Clardy, *Tetrahedron Lett.*, 3983 (1975).
(3) W. Fenical and J. N. Norris, *J. Phycol.*, **11,** 104 (1975).
(4) A voucher specimen from this collection has been deposited, along with other unknown *Laurencia* species, in the National Herbarium, Smithsonian Institution, Washington, D.C. For chemical extraction, freshly collected algae were preserved and stored in methanol prior to workup.
(5) S. S. Hall, D. J. Faulkner, D. J. Fayos, and J. Clardy, *J. Am. Chem. Soc.*, **95,** 7187 (1973).
(6) E. Fattorusso, in "NATO Conference on Marine Natural Products", D. J. Faulkner and W. H. Fenical, Ed., Plenum Press, New York, N.Y., 1977, pp 165–178.
(7) M. L. Maheshwari, T. C. Jain, R. B. Bates, and B. C. Bhattacharyya, *Tetrahedron* **19,** 1079 (1963).
(8) H. Minato and M. Ishikawa, *J. Chem. Soc. C,* 423 (1967).
(9) Guaiazulene was identified by comparison of spectral features with those of an authentic sample isolated and rigorously identified from *Laurencia obtusa*.
(10) M. Garcia, A. J. R. Da Silva, P. M. Baker, B. Gilbert, and J. Rabi, *Phytochemistry* **15,** 331 (1976).
(11) While this work was in progress, we became aware that Dr. R. J. Wells, Roche Research Institute of Marine Pharmacology, Australia, had isolated a closely related compound, 1-bromo-6-chloro-4-hydroxyselinane, also from a *Laurencia* species.
(12) E. D. Brown, M. D. Solomon, J. K. Sutherland, and A. Torre, *Chem. Commun.*, 111 (1967).

Carbonyl Homologation with α-Substitution. A New Synthesis of 4,4-Disubstituted 2-Cyclopentenones

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One of the most difficult tasks in organic synthesis is the creation of a quaternary carbon center. Since ketones are among the most accessible compounds in organic chemistry, a procedure for the geminal alkylation at a carbonyl carbon with functionally dissimilar substituents would be very attractive. We have recently described a new approach to this problem which involved the conversion of ketone carbonyl groups into either the pyrrolidine enamines **4** or the morpholine enamines **5** of the homologous aldehydes, and the necessary reagents for effecting these conversions were diethyl lithiopyrrolidinomethylphosphonate (**2**) or diethyl lithiomorpholinomethylphosphonate (**3**), respectively.[1,2] The inherent advantage of these procedures for carbonyl homologation is that the enamines **4** and **5,** which are useful functional derivatives of the corresponding aldehydes, are obtained