was added cyclohexanone (3.8 mL, 3.6 g, 36.7 mmol) and aluminum isopropanoxide (0.432 g, 2.12 mmol). The reaction was distilled slowly for 1 h (5 mL distillate was collected which was replaced with toluene) and then refluxed for 3 h. The cooled solution was diluted with potassium–sodium tartrate solution (25 mL) and water (25 mL) and then extracted with toluene (3 × 50 mL). After drying (Na_2SO_4), the solvent was evaporated under vacuum to give an oil which was chromatographed (alumina, III, 30 g, toluene). The collected product showed no 4.50 ppm (CHOH) absorption in the ^1H NMR spectrum but did contain cyclohexanone as an impurity.[12] This product was dissolved in toluene (3 mL) and dimethyl sulfoxide (2.7 mL) before lithium acetylide–ethylenediamine complex (2.3 g, 2.5 mmol) was added. After the solution was stirred at room temperature under nitrogen for 20 h, ammonium chloride (3 g) was cautiously added, followed by dropwise addition of water (10 mL). Additional water (50 mL) was added and the solution was extracted with methylene chloride. The residue remaining after drying (Na_2SO_4) and evaporating the solvent was chromatographed (alumina, III, 50 g, toluene–5% EtOAc/toluene): NMR (CCl_4) δ 0.82 (s, 3, CH_3), 1.65 (s, 3, $=CCH_3$), 2.44 (s, 1, $\equiv CH$), 3.56 (s, 3, OCH_3), 7.1 ppm (s, 1, $=CH$).

To the above product in methanol (25 mL) was added 3 N hydrochloric acid (15 mL) and the resulting solution was heated for 15 min on the steam bath. Solid sodium bicarbonate was added to neutralize the hydrochloric acid. The solution was evaporated, diluted with water (50 mL), extracted with methylene chloride, and dried ($MgSO_4$). The solvent was removed under vacuum and the residue was chromatographed (alumina, III, 50 g) to give 212 mg (46% yield) of pure steroid **6a**: mp 122–124 °C; IR (CH_2Cl_2) 3260 ($C\equiv CH$) and 1685 cm^{-1} ($=CC=C$); NMR (CCl_4) δ 0.79 (s, 3, CH_3), 1.95 (s, 3, $=CCH_3$), 2.42 (s, 1, $\equiv CH$), 5.80 ppm (s, 1, $=CH$).

Anal. Calcd for $C_{19}H_{26}O_2$: C, 79.68; H, 9.15. Found: C, 79.75; H, 9.12.

Acknowledgment. This work was supported under Contract N01-HD-4-2860 with the National Institutes of Child Health and Human Development.

Registry No.—**2b,** 4192-93-2; **3b,** 63976-96-5; **3c,** 63976-97-6; **3d,** 63976-98-7; **3f,** 63976-99-8; **4a,** 63977-00-4; **4b,** 63977-01-5; **5a,** 63977-02-6; **5b,** 63977-03-7; **5b** epimeric alcohol derivative, 63977-04-8; **5b** epimeric alcohol derivative 2, 63977-05-9; **5b** dihydro alcohol derivative, 63977-06-0; **5c,** 63977-07-1; **5d,** 63977-08-2; **5e,** 63977-09-3; **5e** dihydro derivative, 63977-10-6; **5e** dihydro ketone derivative, 63988-55-6; **5e** dihydro ethynylated derivative, 639777-11-7; **6a,** 63977-12-8; **6b,** 63977-13-9; **6b** 20 alcohol derivative, 63977-14-0.

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(12) Efforts to remove the cyclohexanone by heating under vacuum resulted in rearomatization of the dihydro intermediate. Attempted steam distillation of the cyclohexanone from the crude reaction resulted in hydrolysis of the 3-*O*-methyl ether.

Halogenated Alicyclic Monoterpenes from the Red Algae *Placamium*

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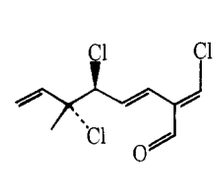
The red algae *Placamium violaceum* (Farlow) and *P. cartilagineum* (Dixon), collected from the vicinity of Monterey Bay, Calif., yield a number of halogenated alicyclic terpenes. The structures of placamene D (**4**), placamene D′ (**5**), and placamene E (**8**) have been elucidated by a combination of spectroscopic and chemical experiments. Additional structural details and chemical properties are discussed for other *Placamium* alicycles including placamene B (**2**), violacene (**3**), and placamene C (**9**). Their composite structures suggest several biosynthetic generalizations about these and other halogenated monoterpenes known from *Placamium*.

The red alga *Placamium* has been under study in our lab because it is a source of unique monterpenes.[1,2] Recent work by ourselves and others has shown that both acyclic and cyclic halogenated monoterpenes are elaborated by *Placamium* (order Gigartinales),[3–5] and as well by other red algae including *Microcladia* (order Ceramiales)[6] and *Chondrococcus* (order Cryptonemiales).[7,8]

Our investigation of the natural products chemistry of *Placamium* was first prompted by an observation that extracts of *Placamium cartilagineum* (Dixon) and *Placamium violaceum* (Farlow) collected from Four-Mile Beach (Santa Cruz County, Calif.) showed toxicity in two bioassays. A nonpolar chromatographic fraction from either of these *Placamium* species was highly toxic to goldfish,[9] and these extracts exhibited LC_{50} growth inhibition against mosquito larvae at 0.03 and 0.09 ppm dilutions, respectively.[10] Subsequent isolation work yielded cartilagineal (**1**) as a major component from *P. cartilagineum*[1] and placamene B (**2**) as a major component from *P. violaceum*.[2] In both *Placamium* species we observed another major haloterpene component,[2] violacene (**3**),[11] whose structure has been recently revised after



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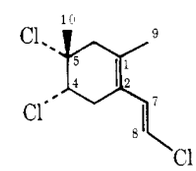

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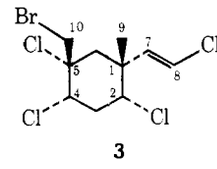

3

x-ray study.[12] Interestingly, both placamene B (**2**) and violacene (**3**) are highly toxic to goldfish, and they display significant growth inhibition against mosquito larvae. In order to further explore the toxic metabolites from *Placamium*, we extended out study of *P. violaceum* to several other collection sites in the Monterey Bay area. This yielded new halogenated

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Table I. ^{13}C NMR Data at 25.15 MHz[a]

	3[c]			4[c]	5[c]	6[c]		7[c]			8[c]	9[c]		
C	δ (ppm)		J (Hz)	δ (ppm)	δ (ppm)	δ (ppm)		δ (ppm)		J (Hz)	δ (ppm)	δ (ppm)		J (Hz)
1	42.0	(s)			43.4	39.3	(s)	43.4	(s)		142.6	67.4	(s)	
2	64.1	(d)	140[a]	65.1	65.5	67.3	(d)	67.9	(d)	155[a]	49.8	52.4	(d)	125
3	38.3	(t)	134	43.5	44.1	38.2	(t)	29.7	(t)	126	39.0	35.0	(t)	132
4	59.0	(d)	140[a]	58.2	49.4	59.9	(d)	32.7	(t)	133	65.5	65.1	(d)	142
5	71.3	(s)		140.9	140.7	72.1	(s)	143.1	(s)		72.2	71.2	(s)	
6	48.8	(t)	125[a]	45.5	45.2	41.5	(t)	44.5	(t)	133	44.2	57.1	(t)	134
7	135.4	(br d)	156	133.3	133.5	23.4	(t)	136.2	(d)	160	133.0	131.3	(d)	161
6	119.5	(dd)	10/193	120.8	120.6	8.0	(q)	119.1	(dd)	9/194	119.2	120.7	(dt)	7/7/194
9	27.4	(q)	129	26.3	26.1	27.0	(q)	26.0	(q)	126	112.7	28.0	(q)	128
10	38.8	(t)	163	113.6	116.1	39.5	(t)	111.4	(t)	155	30.9	31.9	(q)	129

[a] Potential error in J value ±5 due to overlapping multiplets. [b] For carbon numbering, see Schemes I and IV. [c] Registry no.: **3**, 54279-01-5; **4**, 62560-51-4; **5**, 63883-43-2; **6**, 63886-49-9; **7**, 63866-50-2; **8**, 63866-51-3; **9**, 62532-55-2.

monoterpenes, and we now report these structures.

An Overview from GC/MS Data. Haloterpenes **1–3** possess distinctly different carbon skeletons and each exhibits a diagnostic mass spectral fragmentation pattern. The principal fragments from **1–3** can be designated as type I, II, or III, respectively. An acyclic octa-1,5,7-triene, such as cartilagineal (**1**), displays a type I fragmentation, giving a base peak cluster at 89/91 due to a $[C_4H_6Cl]^+$. Alternatively, the trialkyl-substituted ring system as in plocamene B (**2**) exhibits intense type II fragmentation by a way of a $[C_{10}H_{11}Cl]^+$ = 167/169 to an aromatic nucleus $[C_{10}H_{11}]^+$ = 131. Finally, the *gem*-alkyl-substituted system as in violacene (**3**) cannot easily aromatize, but instead displays an $M^+ - CH_3$ fragment and successive M^+ – halogens, type III fragmentation.

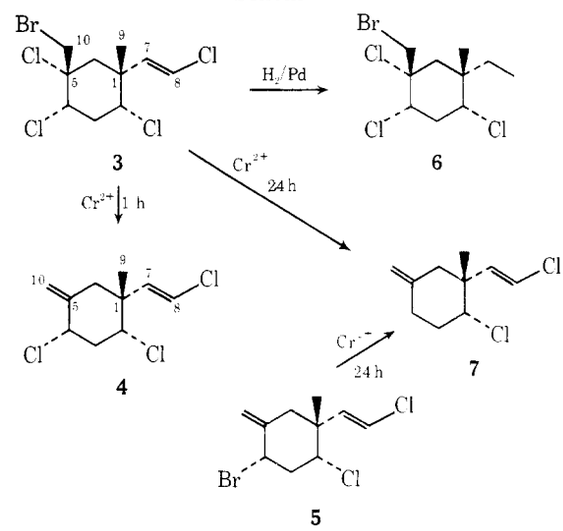
GC–MS of various *P. cartilagineum* and *P. violaceum* extracts revealed unknown components with types II and III fragmentation. Peaks displaying type III fragments were especially noticeable from *P. violaceum* and *P. cartilagineum* from Santa Cruz, Monterey and San Mateo counties. Four isomeric $C_{10}H_{13}X_3$ components could be identified in various collections whose appearance was highly dependent upon species and location.[13] As one example, the relative amounts of two $C_{10}H_{13}Cl_3$ isomers, plocamene D and plocamane E, varied from 91:9, 78:28 to 25:75 from *P. violaceum* at Four Mile Beach, Davenport Landing, and Pigeon Point, respectively.

Results and Discussion

Two new components, plocamene D and plocamane D′, exhibiting type III mass spectral fragments were isolated. Plocamene D (**4**) of molecular formula $C_{10}H_{13}Cl_3$ (M^+ = 238/240/242) was most easily purified from the *P. violaceum* extract from Four-Mile Beach. A monocyclic ring was established by the four vinyl carbons in the ^{13}C NMR (Table I). In the ^1H NMR (360 MHz, $CDCl_3$), the 13 protons of plocamene D appeared as separate resonances: δ 1.22 (3 H, s, CH_3), 2.11 (1 H, d, J = 14.2 Hz, H_{6a}), 2.10 (1 H, q, J = 12.5 Hz, H_{3a}), 2.58 (1 H, dt, J = 12.5, 4.0 Hz, H_{3e}), 2.61 (1 H, d, J = 14.2 Hz, H_{6e}), 3.83 (1 H, dd, J = 12.4, 3.8 Hz, H_{2a}), 4.34 (1 H, br d, J = 12.4, 3.8 Hz, H_{4a}), 5.00 and 5.41 (1 H each, s, H_{10} and $H_{10'}$), 6.02 (1 H, d, J = 13.7 Hz, H_8), 6.10 (1 H, d, J = 13.7 Hz, H_7). The several subfeatures recognizable from this data, a quaternary CH_3, a $>CCH_2C<$ unit, a –(Cl)CHCH$_2$CH(Cl)– group, a $>C{=}CH_2$, and a –CH=CH– residue, could best be combined in the gross structure **4**. Diequatorial Cl's at C_2 and C_4 were indicated by the large J_{a-a} couplings.

Plocamene D′ (**5**), M^+ = 282/284/286 ($C_{10}H_{13}Cl_2Br$), was isolated from *P. violaceum* from Asilomar Beach. The ^{13}C NMR shifts for **5** were similar to those of **4** (Table I), except that one of the halogen-bearing carbons in **5** was shielded by 9 ppm relative to its counterpart in **4**. Likewise, the only difference in the ^1H NMR between **4** and **5** was that the H_4 broadened doubled doublet in **5** was deshielded relative to that in **4**. These two observations indicated that the gross structure of **5** differed from **4** by only a Br substituent at C_4.

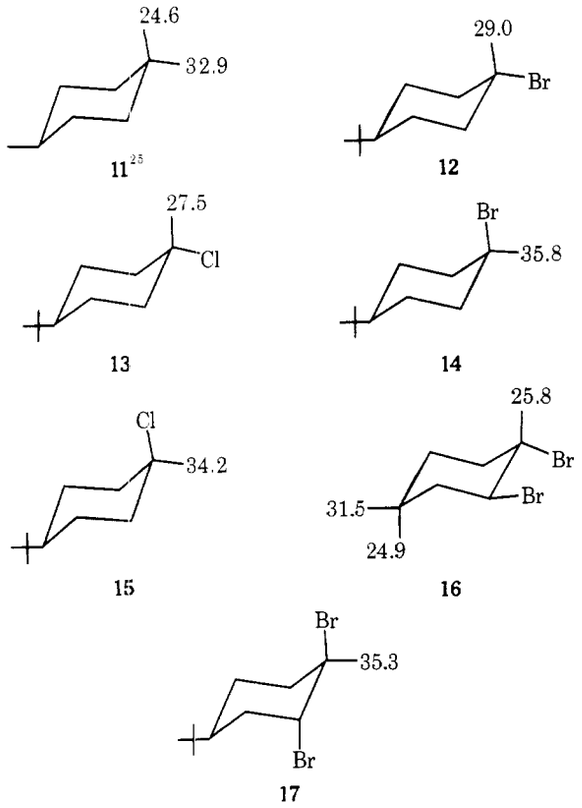
Scheme I



The assignment of the *gem*-methyl, *trans*-chlorovinyl stereochemistry at C_1 in **4** and **5** was approached by a correlation based upon ^{13}C NMR chemical shifts. This seemed reasonable because methyl shifts are sensitive to configurational changes, and a particularly relevant example is afforded by the methyl shift differences of 5–6 ppm observed by Wenkert for pairs of pimaradienes epimeric at a $-C(C_2H_3)CH_3$ position.[14] To provide some background for interpreting carbon shifts in polyfunctional six-membered rings, two violacene derivatives **6** and **7**, prepared by hydrogenation and reductive dehalogenation (Scheme I), were examined in order to determine the sensitivity of their ^{13}C methyl shifts to substituent changes. Comparison of the methyl shifts between **3** vs. **6** and **7** (Table I) revealed that an anticipated homoallyl shielding effect[15] was negligible and that the δ effect though larger than expected was still small.[16] The closeness of the methyl carbon shifts of **7** (26.0) to that of **4** (26.3) and **5** (26.1) indicated that the C_1 configuration of these latter two must be identical to that of **3**. The chemical interconversions shown in Scheme I provided further confirmation on this point, and yielded the absolute stereochemical assignments shown.

GC/MS data of a *P. violaceum* extract from Pigeon Point revealed that it was especially rich in a component, plocamene E (**8**), with type II fragmentation. Interestingly, a second collection of this alga (1.3 kg, wet wt) from a single rock at that location gave a crude oil whose ^1H PFT NMR showed plocamene E as the only haloterpene component. After purifi-

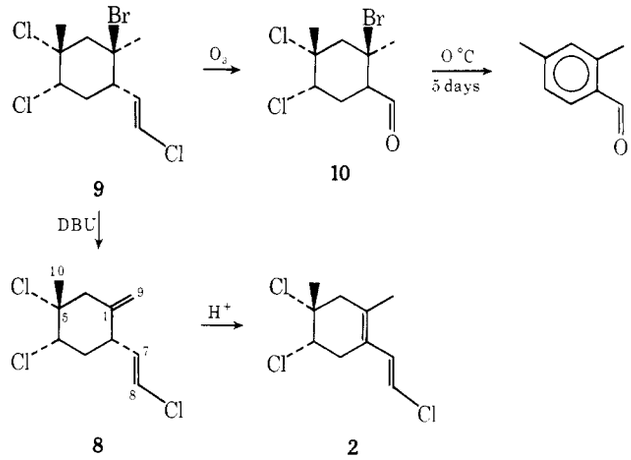
Scheme II



cation by HPLC, this compound displayed a mass spectrum parent *m/e* 238/240/242 ($C_{10}H_{13}Cl_3$). A single ring was indicated by the four vinyl and two quaternary carbons in the ^{13}C NMR (Table I). The ^1H NMR (360 MHz, $CDCl_3$) exhibited additional structural features including a single quaternary methyl (δ 1.73, s), an isolated methylene (δ 2.41, br d, J = 14.8 Hz; δ 2.77 d, J = 14.7 Hz) and *exo*-methylene (δ 4.84 and 4.90), and a –(Cl)CHCH$_2$CH(CH=CHCl)–: δ 2.05 (q, J = 12.8 Hz, H_{3a}), 2.11 (dt, J = 12.6, 4.5, 4.5 Hz, H_{3e}), 2.79 (m in Bz-d_6 spin decoup at H_9 converted this peak into an eight-line multiplet with J = 14, 9.5 Hz, H_{2a}), 3.95 (dd, J = 11.2, 4.5 Hz, H_{4a}), 5.94 (dd, J = 13.4, 7.9 Hz, H_7), and 6.04 (d, J = 13.4 Hz, H_8). These J values were characteristic of a six-membered ring of gross structure **8** with diequatorial substituents at C_2 and C_4. The choice of the attachment of the *exo*-methylene to position C_1 or C_5 was confirmed as the former by an observed long-range coupling from the *exo*-methylene H's to H_{2a} and H_{6a} which was collapsed by spin decoupling at the *exo*-methylene.

The problem of the C_5 CH_3 stereochemistry in **8** was resolved with the aid of ^{13}C chemical shifts, and it was assigned as equatorial. Axial and equatorial cyclohexyl quaternary methyls exhibit different and characteristic carbon shifts.[17] For example, an axial–equatorial methyl-shift difference of 8 ppm is observed for a noninverting 1,1-dimethylcyclohexane **11**, with Me(e) = δ 33 and Me(a) = δ 25. A similar large difference, Me(a) – Me(e) = 7 ppm, is observed for a cyclohexyl methyl gem to a halogen (Cl or Br) as shown by **12–15** in Scheme II. In order to apply this shift correlation to compounds such as **2** and **8**, the effects due to additional γ substituents must first be estimated. The comparative data among compound sets **12** and **16** and **14** and **17**, along with data from several other model compounds that will be discussed elsewhere, show that the shielding imparted by an added γ halogen gauche to an axial methyl or an equatorial methyl is δ 4 or 1, respectively. Thus, a characteristic methyl shift can be estimated for a 1-methyl-1,2-dihalocyclohexane as δ 33–35 Me(e) and δ 23–25 Me(a). In view of this analysis, the methyl shift of **8** (δ 30.9) falls into a range that is consistent

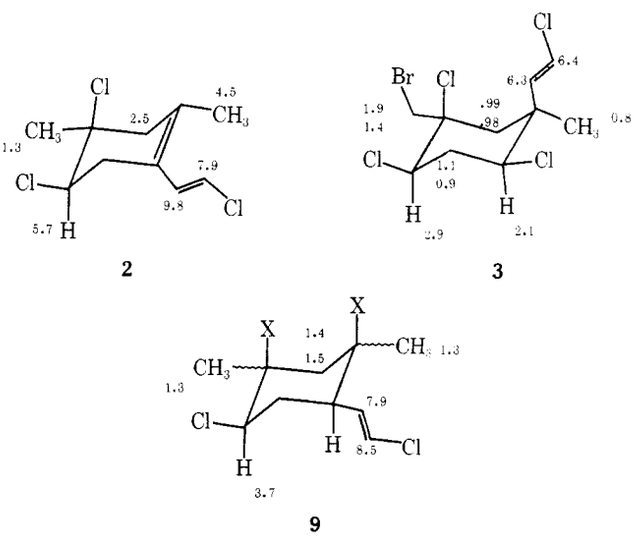
Scheme III



with an equatorial assignment. In addition, our earlier suggestion of an equatorial type methyl in **2** (δ 30.3)[2] is further substantiated by this analysis.

The final compound isolated, plocamene C (**9**), was a major component of the Pigeon Point oil, but it was present in only low concentration in the Four-Mile Beach oil. The ^{13}C and ^1H NMR of **9** showed many similarities to **8** with differences in the mass spectrum (M^+ 318, $C_{10}H_{14}Cl_3Br$), the ^{13}C NMR spectrum (two vinyl carbons), and the ^1H NMR spectrum (s Me's δ 1.67 and 1.95) which indicated that the structure of **9** differed from **8** by only an HBr. The closeness of the CH_3 ^1H δ values in **9** to those in 1,1-chloromethylcyclohexane (δ 1.58) and 1,1-bromomethylcyclohexane (δ 1.80)[18] indicated also that chlorines were at both C_5 and C_8 in **9**. The use of a relaxation reagent Gd(fod)$_3$[19] provided evidence for the placement of the single Br at C_1. Ozonalysis of **9** yielded aldehyde **10** (Scheme III) with methyls at δ 1.64 and 2.0 ($CDCl_3$) representing a methyl gem to a chlorine and bromine, respectively. Addition of Gd(fod)$_3$ caused the low-field signal to broaden considerably owing to an efficient relaxation between it and the lanthanide reagent, whereas the high-field methyl remained sharp. While our work on this structure was in progress, a publication appeared on the x-ray of (1*R*,2*S*,4*S*,5*R*)-1-bromo-*trans*-2-chlorovinyl-4,5-dichloro-1,5-dimethylcyclohexane (**9′**)[4a] which had the same molecular formula and similar ^1H NMR properties as **9**. Differences in their melting points (**9** = 78.5–79 °C, and **9′** = 43.5–44.5 °C) and chemical behavior at first suggested that **9** and **9′** might be isomers, but further careful comparison between **9** and an authentic sample

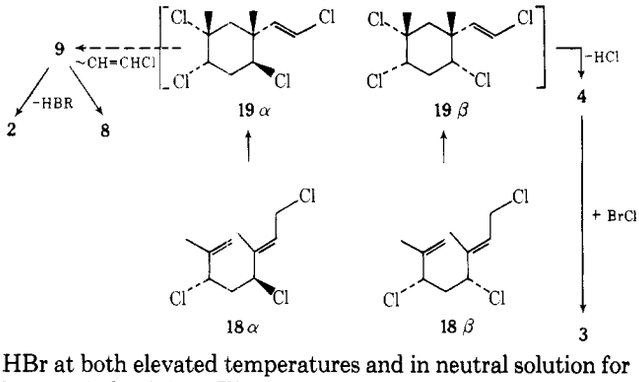
Scheme IV. Proton T_1 Data



of 9′ revealed that they were identical.[20] Before the above comparison was completed, we explored the use of T_1 data to set the 9 C_1 and C_5 halogen substitution and stereochemistry. Relaxation rates for both ^1H and ^{13}C are sensitive to a number of factors including steric environment.[21] Proton T_1's were available for 2 and 3[22] and were measured for 9 and tabulated in Scheme IV. Dipole relaxation is a dominant mechanism in the data of 2 and 3 as shown by the expected T_1 increase for protons in 2 along the series CH_3 (1.3), $-CH_2-$ (H_{6e} = 2.5) and C=C(H)– (9.8). Although the structurally different methyls in 2 display different T_1 values, a similar expected difference did not carry over into the methyl T_1 values of 9.

The chemical relationships established in Scheme III led to the absolute stereochemical assignments for both plocamene B (2) and plocamene E (8). In our hands, 9 was inert to loss of HBr in the presence of acid.[4a] On the other hand, basic treatment of 9 with 1,5-diazobicyclo[5.4.0]undec-5-ene (DBU) in refluxing dioxane yielded 8 which could then be rearranged to the more stable 2 by acid catalysis.

The chemical and stereostructural features of the alicyclic compounds established above provide some insight into their possible biogenesis. Comparison among the six-membered ring substituent stereochemistries of plocamene C (9) and plocamene D (4) along with the relative stereochemistries known for acyclic epimers 18α and 18β, also isolated from *P. violaceum*,[3b] suggests a hypothetical set of structures 19α and 19β as a relay to both rearranged and nonrearranged sets of alicycles 9 and 4.[26] Plocamene C (9) is quite stable to loss of



HBr at both elevated temperatures and in neutral solution for long periods of time. The structural similarities then between 9 vs. plocamene B (2) and plocamene E (8) suggest that the latter two are derived from the former by some type of biological dehydrohalogenation. The contrasting process of biological halogenation seems also to be occurring in that enzymatic chlorobromination undoubtedly converts 4 into 3.

Experimental Section

The NMR spectra were recorded on a JEOL PS 100 PFT spectrometer operating on 100 MHz for ^1H and 25.1 MHz for ^{13}C. The 360-MHz ^1H NMR spectra were recorded at the Stanford Magnetic Resonance Laboratory. Optical rotations were measured on a Perkin-Elmer 141 polarimeter with a 1-dm cell (5 mL). GC/MS data were recorded on a Finnigan 4000 system equipped with a ⅛ in. × 3 ft glass column packed with 3% OV-17 on Chromasorb G and temperature programmed 120–190 °C at 2 °C/min. Routine low-resolution mass spectra data were recorded on a Hitachi Perkin-Elmer RMU-6E mass spectrometer. High-performance liquid chromatography (HPLC) was done on a Waters ALC 201 using Porasil columns ⅜ in. × 8 ft. All solvents were reagent grade and distilled for HPLC use. Spectral-grade solvents were used for NMR (Me_4Si standard) and optical rotation determinations. Low-boiling petroleum ether was used in all instances.

Collections and Extractions. *Plocamium violaceum* was collected interdially from several locations (wet weight and yield of extract) including: Davenport Landing, Santa Cruz County, Oct. 16, 1974 and Nov. 12, 1974 (1 kg, 2.33 g, 0.23% yield); Four-Mile Beach, Santa Cruz County, Nov. 11, 1974 (0.7 kg, 2.06 g, 0.29% yield); Pigeon Point, San Mateo County, Oct. 15, 1974 and Nov. 14, 1974 (1 kg, 2.68 g, 0.23% yield); Pigeon Point, Nov. 2, 1975 (1.3 kg, 1.10 g, 0.08% yield); and Asilomar Beach, Monterey County, July 27, 1975 (320 g, 0.9 g, 0.28% yield).

The freshly collected algae were either directly extracted or held frozen until extraction. All samples were cold extracted twice with $CHCl_3$ and once with EtOH (95%) over a period of 3–7 days. The combined extract was then chromatographed through silica gel (Grace grade 62, 60–200 mesh, activated) using petroleum ether followed by petroleum ether/benzene (1:1). The resulting semipurified oil was then subjected to HPLC using petroleum ether/benzene (95:5).

Isolations. Following the procedure above, Plocamene C, D, D′, and E were isolated.

Plocamene D (4) was obtained as clear mobile oil, HPLC fraction no. 18 (20-mL fractions, 39 mg), from Four-Mile Beach: $[\alpha]^{20}_D$ −4.1° (*c* 0.73, $CHCl_3$); MS *m/e* 238, 240, 242, (M^+), 223, 225 ($M^+ - CH_3$), 203, 205, 207 ($M^+ - Cl$), 167, 169 ($M^+ - Cl$, HCl), 131 ($M^+ - Cl$, HCl, HCl); 91 base $(C_7H_7)^+$ and NMR discussed in the text.

Plomacene D′ (5) was obtained as a clear mobile oil, HPLC fraction no. 10 (40 mg), from Asilomar Beach: MS *m/e* 282, 284, 286 (M^+), 267 269 ($M^+ - CH_3$), 247, 249, 251 ($M^+ - Cl$), 203, 205, 207 ($M^+ - Br$), 167, 169 ($M^+ - Br$, Cl, H), 91 base $(C_7H_7)^+$; ^1H NMR ($CDCl_3$ 100 MHz) δ 1.26 (s, CH_3), 2.1–2.8 (m, 2 H), 2.18 (d, 1 H, *J* = 15 Hz), 2.71 (d, 1 H, *J* = 15 Hz), 3.87 (dd, 1 H, *J* = 4, 12 Hz), 4.53 (br d, 1 H, *J* = 4, 12 Hz), 5.10 (br s, 1 H), 5.46 (br s, 1 H), 6.03 (d, 1 H, *J* = 12 Hz), 6.15 (d, 1 H, *J* = 12 Hz).

Plocamene E (8) was obtained as a clear mobile oil, HPLC fraction no. 21–24 (359 mg), from Pigeon Point: $[\alpha]^{20}_D$ −105° (*c* 4.57, $CHCl_3$); MS *m/e* 238, 240, 242 (M^+), 203, 205, 207 ($M^+ - Cl$), 167, 169 ($M^+ -$ Cl, HCl), 131 base ($M^+ -$ Cl, HCl, HCl) and NMR discussed in the text.

Plocamene C (9) was isolated from collections at Pigeon Point (283 mg) and both Davenport Landing collections, HPLC fraction no. 17–19 (83 mg), and it was recrystallized (ETOH) to a mp 78.5–79 °C (uncorrected). The absolute methyl carbon shifts were derived by relating ^{13}C peaks to ^1H peaks by the graphical off-resonance decoupling method.[23] In addition to NMR discussed in the text: ^1H NMR (360 MHz, $CDCl_3$) δ 1.67 (s, CH_3), 1.95 (s, CH_3), 2.03 (dt, 1 H, *J* = 3.8, 13.5 Hz), 2.15 (dt, 1 H, *J* = 12.1, 13.5 Hz), 2.69 (d, 1 H, *J* = 15.1 Hz), 2.89 (m, 1 H, *J* = 3.8, 7.7, 12.1 Hz), 2.95 (d, 1 H, *J* = 15.1 Hz), 3.89 (dd, 1 H, *J* = 3.8, 12.1 Hz), 6.05 (dd, 1 H, *J* = 7.7, 13.3), 6.16 (d, 1 H, *J* = 13.3 Hz); $[\alpha]^{20}_D$ −84° (*c* 0.32, $CHCl_3$); MS *m/e* 318, 320, 322, 324 (M^+), 282, 284, 286 (M^+ – HCl), 238, 240, 242 (M^+ – HBr), 203, 205, 207 (M^+ – H, Br, Cl), 167, 169 (M^+ – Br, 2Cl, 2 H), 131 base (M^+ – Br, 3 Cl, 3 H). Plocamene C ((9) was compared by GC/MS to an authentic sample of compound (9′) provided by Professor D. J. Faulkner. Their retention times and mass spectra were identical. Plocamene C (9) was found to be thermally quite stable in that a GLC before and after melting were identical.

Hydrogenation of Violacene (3) to 6. Violacene (3), 100 mg, and 5 mg of Pd on carbon (10%) in 20 mL of EtOH were hydrogenated until 1 equiv of H_2 was absorbed (ca. 12 h) to yield quantitatively the dihydro compound 6: ^1H NMR ($CDCl_3$) δ 0.92 (t, CH_3, *J* = 7.3 Hz), 1.01 (s, CH_3), 1–2 (m, 2 H), 1.89 (d, 1 H, *J* = 16.1 Hz), 2.28 (d, 1 H, *J* = 16.1 Hz), 2.42 (dt, 1 H, *J* = 4.3, 11.7), 2.64 (q, 1 H, *J* = 11.7 Hz), 3.51 (d, 1 H, *J* = 10.7 Hz), 3.81 (dd, 1 H, *J* = 4.4, 11.7 Hz), 3.93 (d, 1 H, *J* = 10.7 Hz), 4.32 (dd, 1 H, *J* = 4.4, 11.7 Hz); MS *m/e* 320, 322, 324, 326 (M^+).

Violacene (3) to Plocamene D (4) and 7. Violacene (3), 10 mg (in 2 mL of DMF), and an equivalent amount of Cr^{2+} ion (in DMF/H_2O solution)[24] were stirred for a period of 1 h at room temperature under a stream of N_2. The reaction mixture was worked up to yield a 1:1 mixture of starting material and plocamene D (4) whose PFT NMR spectral properties were identical to those described in the text. When this reaction was carried out for a longer period of time (24 h), upon workup 7 was the exclusive product: ^1H NMR (360 MHz, $CDCl_3$) δ 1.18 (3 H, s, CH_3), 1.88 (2 H, complex m, H_4), 2.06 (1 H, d, *J* = 14 Hz, H_6), 2.13 (1 H, m, H_3), 2.43 (1 H, complex m, H_3), 2.49 (1 H, d, *J* = 14 Hz, H_6), 3.90 (1 H, dd, *J* = 10, 4 Hz, H_{2a}), 4.70 and 4.81 (1 H each, s, H_{10} and $H_{10'}$), 6.04 (1 H, d, *J* = 14 Hz, H_7), 6.09 (1 H, d, *J* = 14 Hz, H_8); mass spectrum 204, 206, 208 (M^+), 169, 171 (M^+ – Cl), 91 base (C_7H_7).

Plocamene D′ (5) to 7. Following the above procedure, plocamene D′ (5) (20 mg) was converted to the compound 7. Its spectral properties were identical to those mentioned above.

Plocamene C (6) to Plocamene E (5). Plocamene C (6) (10 mg) in a nitrogen atmosphere and dry dioxane (10 mL) was reacted with a slight excess of 1.5 diazobicyclo[5.4.0]undec-5-ene (DBU) at reflux for 24 h. After workup, the resulting product displayed PFT NMR spectral properties that were identical to those described above from plocamene E (5).

Plocamene E (5) to Plocamene B (2). Plocamene E (5) (10 mg)

and a catalytic amount of *p*-toluenesulfonic acid (HOTS) were dissolved in benzene (10 mL) under nitrogen. After a 2-h reflux, the resulting product displayed PFT NMR spectral properties that were identical to those of plocamene B (**2**).

Ozonolysis of Plocamene C (6) to Aldehyde (10). Plocamene C (**6**) (20 mg) in ethyl acetate (10 mL) was ozonized at −78 °C. The reaction mixture was worked up with dimethyl sulfide, and the resulting aldehyde displayed the following: NMR, 100 MHz ($CDCl_3$), δ 1.66 (s, CH_3), 2.00 (s, CH_3), 2.18 (m, 2 H), 2.70 (d, 1 H, J = 15.5 Hz), 2.89, (d, 1 H, J = 15.5 Hz), 3.51 (br m, 1 H), 3.84 (dd, 1 H, J = 4, 7.9 Hz), 8.92 (s, 1 H). Upon standing at room temperature overnight or at 0 °C for 5 days, the aldehyde **10** aromatized to 2,5 benzaldehyde.[2]

Treatment of Aldehyde (8) with Gd(fod)$_3$. To aldehyde **8** (15 mg) in $CDCl_3$ was added $Gd(fod)_3$ (6 mM solution in $CDCl_3$) in 100-μL portions until line broadening became apparent (450 μL). Final molar ratio of 8 to $Gd(fod)_3$ = 1.0:0.049.

Relaxation Time Measurements. The Fourier transform T_1 measurements were done using the standard 180°–τ–90° pulse sequence. The delay time (τ) was greater than $4T_1$ for the most rapidly relaxing protons. Dilute samples were prepared in benzene-d_6 with added Me_4Si. All samples were degassed (five freeze–pump–thaw cycles) and then sealed.

Carbon NMR of Model Compounds. The ^{13}C NMR data for **11** was taken from the literature.[25] Compounds **12–17** were prepared by addition of HX or X_2 (X = Cl, Br) to the corresponding olefins. ^{13}C NMR data were obtained on 80% solutions in $CDCl_3$. Unseparated epimeric mixtures of **12** and **14**, and **13** and **15** were used.

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(26) Added in Proof. Wells[27] just recently reported mertense (**20**) which is related to gross structure 19β. The stereochemistry suggested at both the *gem*-methyl/chlorovinyl and the *gem*-methyl/chloride for **20** may be in error. Based upon ^{13}C methyl chemical shifts, the former methyl in **20** at δ 26.1 is similar to the shift and stereochemistry in **3–5** and the shift of the latter, δ 20.1, is consistent with an axial placement as discussed in the text.
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