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SESQUITERPENE METABOLITES FROM *LAURENCIA FILIFORMIS*

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Abstract—The major lipid components of *Laurencia filiformis* have been shown to be aplysistatin (1) and 6β-hydroxyaplysistatin (2). The structure and absolute configuration of these sesquiterpenes has been confirmed by X-ray diffraction methods. An interesting thermal rearrangement of 2 is described.

As part of a programme to investigate the natural products from marine sources of the Western Australian coast, we had the opportunity of examining samples of *Laurencia filiformis* collected at Point Peron. Previous work[1,2] on the varieties of *L. filiformis* has shown the presence of sequiterpenes based on the laurene, selinane[1] and chamigrene skeletons.[2] We now report that the local variety contains aplysistatin (1), previously isolated[3] from the sea-hare *Aplysia angasi*, and 6β-hydroxyaplysistatin. Chemical and X-ray crystallographic evidence for the structure and configuration of these sesquiterpenes is presented.

The methylene chloride extract of a fresh sample of *L. filiformis* yielded a white crystalline solid which, from tlc, appeared to contain two compounds. Rapid filtration of the mixture through silicic acid afforded aplysistatin (1, 0.4%) and 6β-hydroxyaplysistatin (2, 1.6%). Although the spectral characteristics of 1 corresponded to those reported,[3] discrepancies in the m.p., optical rotation and crystal properties were significant and did not allow us to exclude the possibility that we were dealing with a stereoisomer of 1. For this reason, and others given in the X-ray section of this note, we undertook an X-ray diffraction analysis of 1. As shown below the structure of 1 was identical with that reported for aplysistatin (1). The discrepancies between the published parameters and those found by us for 1 have been resolved by direct comparison with an authentic sample[4] of aplysistatin (1) (Experimental).

The spectral characteristics of the major component (2), $C_{15}H_{21}BrO_4$ were essentially similar to those of aplysistatin except that the IR spectrum showed absorption from an OH group (3500 cm^{-1}) and the NMR spectrum showed that two tertiary Me groups had suffered a deshielding influence (δ0.96–1.24 and δ1.29–1.65). Furthermore a signal at δ4.99 (br d, J 5.8 Hz) was assigned to an allylic methine proton. This signal was shown to have coupling (J 5.8 Hz) to the vinylic proton and to a tertiary methine proton (C–5H) thus locating the OH group at C–6. Assuming that 2 had a conformation similar to that of aplysistatin, this indicated a β-stereochemistry for the OH group. The compound could be oxidized to the conjugated ketone (3) ($\nu_{max}^{CCl_4}$: 1790 and 1700 cm^{-1}) and hydrogenated to the dihydro derivative (4) which appeared as a single stereoisomer. The structure assigned to 2 was subsequently confirmed by X-ray diffraction analysis (*vide infra*).

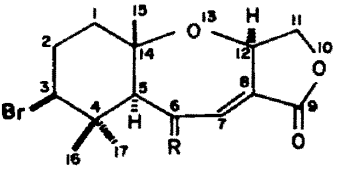
Of the three forms of *L. filiformis* described,[5] *L. filiformis* f. heteroclada contains[1] sesquiterpenes based on the laurene and selinane skeleton. An unspecified form of *Laurencia* probably collected in Australia contains chamigrene sesquiterpenes.[2] In view of the present work it would appear that all three forms have been examined and are chemotaxonomically distinct. The isolation[3] of aplysistatin from the sea hare, *A. angasi*, collected in the South Pacific Ocean (Australia), as well as *L. filiformis* indicates that the sea hare may graze on this alga.

A chance observation led us to thermolyse a sample of 6β-hydroxy aplysistatin (2). Heating 2 in a glass ampoule at 129° *in vacuo* for 10 min, yielded a mixture containing mainly one compound which could be isolated (30%) as a crystalline material after tlc and hplc separation. The molecular composition of 5, $C_{15}H_{16}O_2$, indicated that 2 had lost the elements of HBr and two molecules of H_2O. Although the butenolide group had been retained (IR: 1770 cm^{-1}) the NMR spectrum of 5 clearly showed resonance signals for three aromatic Me's (δ2.23, 2.26, 2.27), two aromatic protons (δ6.96) and for two vinylic protons of an *E*-disubstituted double bond (δ6.26 and δ7.80, J 16 Hz). A signal at δ 7.26 showing coupling to a 2 proton signal at δ4.86 was assigned to a β-proton of an α,β-unsaturated CO group flanked by an oxymethylene group, consistent with the presence of a 2(5H)-furanone group.

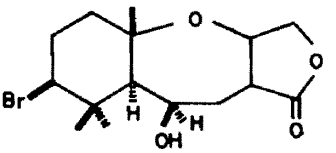
The low field chemical shift for one of the vinylic protons (δ7.80) was attributed to the deshielding influence of the butenolide CO and, *mutatis mutandis*, is expected by analogy with that observed in other vinylogously conjugated[6,7] α-substituted-Δ-α,β-butenolides. This conclusion is supported by the results obtained using $Eu(fod)_3$ as a LSR which caused this proton to shift downfield at a greater rate than the other proton to which it is mutually coupled. Evidence in favour of a 1, 2, 3, 4-tetrasubstituted benzene came from the IR(CS_2) spectrum of 5 which showed strong absorption bands at 810 cm^{-1} expected for such a system.[8] These results lead to structure 5 for the thermolysis product of 6β-hydroxy-aplysistatin. The formation of 5 can be rationalized by assuming heat induced loss of Br, Me migration and loss of H^+. The HBr thus generated could catalyse dehydration of the 6β-OH group and opening of the cyclic ether. Isomerisation of the double bonds followed by dehydration would lead to 5.

In this context it is interesting to note that a number of monocyclofarnesanes have been isolated from marine algae and their associated herbivores.[9,10] In particular the cyclohexadiene (6), the corresponding aromatic compound (7), a probable artifact of 6, have been isolated[10] from a variety of *Laurencia nidifica*, and dactyloxene A, B and

C,[9,11] from the sea hare *Aplysia dactylonela*, all contain 1,2,3,4-tetrasubstituted carbocyclic ring. Although a biosynthetic scheme linking all these compounds has been proposed,[12] the question of whether all the steps indicated are enzyme catalysed remains to be answered. The presence of aryl carotenes containing 1,2,3- and 1,2,5-trimethylphenyl end groups in algae and sponges is also well documented.[13]



1. R = H, H
2. R = OH, H
3. R = O



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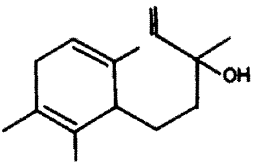

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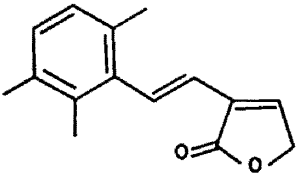

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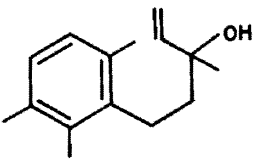

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EXPERIMENTAL

General experimental details have been reported.[14] In addition C^{13}-NMR spectra were obtained at 20.1 MHz with a Bruker WP 80FT instrument.

Extraction of L. filiformis. A fresh sample of the red alga (119 g, dry weight) collected from Point Peron, Western Australia in August 1979, was extracted with a soln of CH_2Cl_2:MeOH (1:1). The CH_2Cl_2 layer, obtained after addition of ~10% by volume of water, on standing yielded a white crystalline solid (2 g) which was shown by tlc (CH_2Cl_2:EtAc; 3:1) to be a two component mixture. Rapid filtration of the mixture through silicic acid with light petroleum and $CHCl_3$ resolved the mixture into fractions of 1 and 2. Aplysistatin (1) crystallized from MeOH as plates, m.p. 161.5–162.5° $[\alpha]_{589}^{25}$ −28° (*c*, 0.6; MeOH). (Found: C, 54.65; H, 6.68. Calc. for $C_{15}H_{21}BrO_3$: C, 54.77; H, 6.43%). [Although the parameters reported for aplysistatin differed significantly, m.p. 173°; $[\alpha]_{589}^{25}$ −379°, a sample of authentic 1, provided by Prof. Pettit, in our hands showed m.p. 161.5–162.5, $[\alpha]_{589}^{25}$ −32° (*c*, 0.03; MeOH). The m.p. was undepressed on admixture with our sample].

Aplysistatin 1 from *L. filiformis* showed the following spectral properties: λ_{max}^{EtOH} (nm): 242 (ε 2300); $\nu_{max}^{CCl_4}$: 1780, 1690 cm^{-1}. MS (*m/z*, %): 330/328 (M^+, 1), 300/298 (4), 286/284 (8), 249 (5), 218/216 (8), 204/202 (33), 189/187 (19), 139 (24), 123 (100), 107 (39), NMR ($CDCl_3$, 90 MHz) δ: 0.96 and 1.18 (s, 16-, 17-H_3), 1.29 (s, 15-H_3), 3.86 (dd, J 7.0 and 9.0 Hz, 11α-H), 3.89 (m, 3-H), 4.48 (t, J 9.0 and 9.0 Hz, 11β-H), 5.14 (m, 12-H), 6.94 (m, 7-H); C^{13} NMR ($CDCl_3$, 20.1 MHz) δ: 17.99, 21.81, 30.86 (q, 16-, 17-, 15-C), 27.33 (t, 6-C), 32.57, 37.86 (t, 1- and 2-C), 41.11 (s, 4-C), 51.41 (d, 5-C), 65.19, 66.96 (d, 3- and 12-C), 69.97 (t, 11-C), 79.20 (s, 14-C), 132.32 (s, 8-C), 143.02 (d, 7-C), 169.27 (s, 9-C). 6β-*Hydroxyaplysistatin* (2) crystallized from MeOH as rods, m.p. 153.5–155.5°, $[\alpha]_{589}^{25}$ −130° (c, 0.4, MeOH). (Found: C, 52.25; H, 6.10; Br, 23.40. $C_{15}H_{21}O_4Br$ requires: C, 52.19; H, 6.13; Br, 23.14%). ν_{max}^{mull}: 3500, 1765, 1695 (w) cm^{-1}; λ_{max}^{EtOH} (nm): 237 (ε, 2500). NMR ($CDCl_3$; 90 MHz) δ: 1.24 and 1.29 (s, 16-, 17-H_3), 1.65 (s, 15-H_3), 3.90 (m, 3-H), 3.97 (dd, J 7.0, 9.0 Hz, 11-αH), 4.56 (dd, J 8.0, 9.0 Hz, 11-βH), 4.99 (br d, J 5.8 Hz, 6-H), 5.10 (dd, J 2.4, 8.0 Hz, 12-H), 6.96 (dd, J 2.4, 5.8 Hz, 7-H). C^{13}-NMR ($CDCl_3$; 20.1 MHz) δ: 19.36, 25.62, 31.03 (q, 16-, 17-, 15-C), 32.62, 39.51 (t, 1-, 2-C), 41.90 (s, 4-C), 55.23 (d, 5-C), 65.82, 66.61 (d, 3-, 12-H), 68.32 (d, 6-C), 70.03 (t, 11-C), 79.60 (s, 14-C), 134.25 (s, 8-C), 142.00 (d, 7-C), 169.55 (s, 9-C). MS (*m/z*, %): 265 (M^+-Br, 1), 247 (4), 229 (5), 207/205 (11), 189/187 (5), 181 (70), 159 (11), 139 (65), 125 (100), 109/107 (30).

Oxidation of 6β-*hydroxyaplysistatin* (2). A soln of 2 (23 mg) in CH_2Cl_2 (10 ml) was treated with pyridinium chromate (186 mg) for 15 min. The compound recovered was purified by preparative tlc to yield the *ketone* (4, 18 mg), which crystallized from MeOH as needles, m.p. 163–165°, $[\alpha]_{589}^{25}$ +33° (*c*, 0.5, MeOH). (Found: C, 52.72; H, 5.83. $C_{15}H_{19}O_4Br$ requires: C, 52.49; H, 5.58%). NMR ($CDCl_3$, 90 MHz) δ: 1.11, 1.28 (s, 16-, 17-H_3), 1.46 (s, 15-H_3), 2.91 (bs, 5-H), 3.83 (m, 3-H), 4.05 (dd, J 7.0, 9.0 Hz, 11-αH), 4.67 (br t, J 9.0 Hz, 11-βH), 5.30 (m, 12-H), 6.84 (br d, J 3.0 Hz, 7-H). $\nu_{max}^{CCl_4}$: 1790, 1700 cm^{-1}; λ_{max}^{EtOH} (nm): 235 (ε, 7900). MS (*m/z*, %): 344/342 (M^+, 5%), 301/299 (2), 263 (21), 245 (17), 227 (6), 219 (12), 205 (100), 191 (19), 181 (20), 139 (99).

Hydrogenation of 2. A soln of 2 (20 mg) in EtOH (10 ml) was hydrogenated over Pd/C (10%; 6 mg). The *dihydro compound* (4, 20 mg) crystallized from MeOH as rods, m.p. 126.5° $[\alpha]_{589}^{25}$ −18° (*c* 0.6, $CHCl_3$). (Found: C, 51.82; H, 6.96. $C_{15}H_{23}O_4Br$ requires: C, 51.88; H, 6.68%). NMR ($CDCl_3$; 90 MHz) δ: 1.26, 1.36 (s, 16-, 17-H_3), 1.55 (s, 15-H_3), 3.80–4.23 (m, 2H), 4.37–4.60 (m, 3H). $\nu_{max}^{CHCl_3}$: 3500, 1770 cm^{-1}; MS (*m/z*, %): 267 (M^+-Br, 19%), 249 (9), 207 (11), 204/202 (9), 189/187 (17), 183 (43), 181 (17), 145 (19), 141 (21), 127 (64), 123 (100).

Thermolysis of 2. Heating a sample of 2 *in vacuo* at 129° for 10 min yielded a product which was shown to be mainly the rearranged compound 5. Preparative tlc (CH_2Cl_2:EtAc, 3:1) fol-

lowed by hplc (silica, $CHCl_3$: hexane, 1:1) yielded a pure sample of the 2-*oxofuran* (5) as a crystalline compound, m.p. 59–61°, which decomposed on standing. (Found: M^+, 228.1152. $C_{15}H_{16}O_2$ requires: M^+, 228.1150). NMR ($CDCl_3$, 90 MHz) δ: 2.23, 2.26, 2.27 (s, aromatic Me's), 4.86 (m, oxymethylene protons), 6.26 (d, J 16 Hz) and 7.80 (d, J 16 Hz) (vinylic protons), 6.96 (s, aromatic protons), 7.26 (br s, vinylic proton). $\nu_{max}^{CS_2}$: 1770, 810 (aromatic protons),[8a] 760 cm^{-1} (conjugated double bond)[8b]; λ_{max}^{EtOH} (nm): 277 (ϵ, 12600) 220 (ϵ, 20500). MS (*m/z*, %): 228.1152 (M^+, 100), 213 (21), 200.0870 ($C_{13}H_{12}O_2$ requires: 200.0837, 21), 183.1174 ($C_{14}H_{15}$ requires: 183.1174, 69), 169 (34), 156 (38), 147 (17), 141 (66), 128 (34).

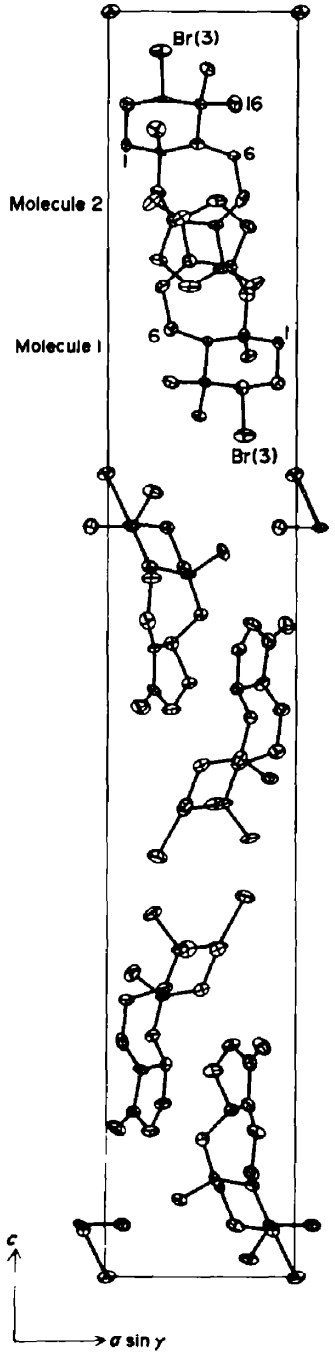


Fig. 1. Unit cell contents of (1) projected down b. Non-hydrogen atoms only are shown with 20% thermal ellipsoids.

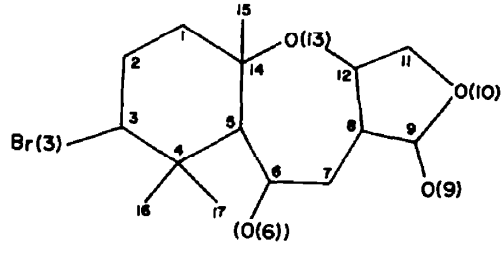
CRYSTALLOGRAPHY

Crystal data: (1). $C_{15}H_{21}BrO_3$, $M = 329.2$, trigonal, space group $P3_1$ (C_3^2, No. 144), $a = 7.590(1)$, $c = 43.990(4)$ Å, $U = 2197.5(5)$ Å^3. $D_m = 1.49(1)$, D_c ($Z = 6$) = 1.49 g. cm^{-3}. $F(000) = 1020$. $\mu_{Mo} = 27.7$ cm^{-1}. Crystal dimensions: $0.43 \times 0.17 \times 0.25$ mm.

(2). $C_{15}H_{21}BrO_4 \cdot CH_3OH \equiv C_{16}H_{25}BrO_5$, $M = 377.3$, orthorhombic, space group $P2_12_12_1$ (D_2^4, No. 19), $a = 15.422(2)$, $b = 11.012(3)$, $c = 10.456(2)$ Å, $U = 1775(1)$ Å^3, $D_m = 1.40(1)$, D_c ($Z = 4$) = 1.41 g. cm^{-3}. $F(000) = 784$. $\mu_{Mo} = 23.0$ cm^{-1}. Crystal dimensions: $0.13 \times 0.40 \times 0.17$ mm.

Structure determination. Unique data sets, with equivalent Friedel pairs were measured to $2\theta_{max}$ 50° for both structures on a Syntex $P2_1$ four-circle diffractometer in conventional $\hat{\omega}$-scan mode (1), $2\theta/\theta$-scan mode (2), yielding 2274 (1), 1815 (2) independent reflections; of these 1046 (1), 804 (2) with $I > 3\sigma(I)$ were considered "observed" and used in the structure solutions (heavy atom method) and refinement after absorption correction. Monochromatic Mo K_α radiation was used ($\lambda = 0.71069$ Å), T being 295 (1) K. Refinement by 9×9 block diagonal least squares, C, O, Br thermal motion being refined anisotropically. Hydrogen atoms were located from difference maps and "improved" by calculation to trigonal or tetrahedral estimates and constrained with U_H (isotropic) = 1.25 < U_{ii} (parent carbon) >. Residuals at convergence were (R, R', S): 0.042, 0.048, 1.4(1); 0.038, 0.042, 1.2(2). (For the alternative chirality, residuals were 0.057, 0.046, 4.0(1); 0.050, 0.055, 2.5(2)). Computation was carried out using the X-ray 76 program system[18] implemented on a Perkin–Elmer 8/32 computer by S. R. Hall. Neutral atom scattering factors were employed, C, O, Br corrected for anomalous dispersion (f', f'').[15–17]

Atom numbering for the C atom skeleton is as follows, following that defined previously.[3]



Structural commentary

Structure determination of 1 and 2 shows the two compounds to be formulated as above, the molecular structure of 1 being identical with that obtained for aplysistatin by the previous structure determination.[3] In the initial crystallization attempts for 1, suitable material for X-ray work was only obtained from methanol solution; this was found to be of different cell symmetry ($P3_1$) to that previously obtained ($P2_12_12_1$) and so the analysis was proceeded with. Subsequent crystallization attempts have failed to yield further material in a state other than microcrystalline from all other solvents including acetone/hexane as used in the previous study. It appears that the two studies have yielded two different, unsaturated, crystalline phases of aplysistatin. The assignment of absolute configuration in the present two determinations was straightforward in spite of the difficulties imposed by the very long cell dimension

Table 1. Atomic fractional coordinates

Compound/Molecule	(2)			(1)/1			(1)/2		
Atom	x	y	z	x	y	z	x	y	z
C(1)	0.3828(6)	0.1214(8)	0.4105(9)	0.9014(20)	0.4004(20)	0.7398(3)	0.0945(20)	0.4978(22)	0.8952(3)
H(1A)	0.370(-)	0.086(-)	0.491(-)	1.025(-)	0.533(-)	0.741(-)	-0.032(-)	0.507(-)	0.894(-)
H(1B)	0.417(-)	0.195(-)	0.427(-)	0.913(-)	0.317(-)	0.755(-)	0.080(-)	0.403(-)	0.880(-)
C(2)	0.2998(6)	0.1591(8)	0.3418(9)	0.8974(22)	0.3118(25)	0.7081(3)	0.0995(23)	0.4131(23)	0.9270(3)
H(2A)	0.263(-)	0.091(-)	0.329(-)	0.911(-)	0.399(-)	0.692(-)	0.079(-)	0.484(-)	0.944(-)
H(2B)	0.266(-)	0.217(-)	0.395(-)	1.013(-)	0.284(-)	0.706(-)	-0.012(-)	0.268(-)	0.930(-)
C(3)	0.3217(5)	0.2186(9)	0.2168(8)	0.7096(21)	0.1162(22)	0.7048(3)	0.2899(25)	0.4068(24)	0.9304(3)
H(3)	0.358(-)	0.288(-)	0.235(-)	0.694(-)	0.032(-)	0.723(-)	0.326(-)	0.357(-)	0.914(-)
Br(3)	0.21283(7)	0.2824(1)	0.1416(1)	0.7231(1)	-0.0102(3)	0.66667(-)	0.2762(4)	0.2668(4)	0.96891(4)
C(4)	0.3722(5)	0.1383(7)	0.1227(9)	0.5122(20)	0.1287(21)	0.7085(3)	0.4870(21)	0.6145(23)	0.9273(3)
C(16)	0.3990(6)	0.2169(10)	0.0072(10)	0.3315(25)	-0.0929(25)	0.7087(3)	0.6689(25)	0.5782(27)	0.9274(3)
H(16A)	0.347(-)	0.250(-)	-0.035(-)	0.330(-)	-0.164(-)	0.691(-)	0.673(-)	0.516(-)	0.948(-)
H(16B)	0.433(-)	0.285(-)	0.031(-)	0.341(-)	-0.167(-)	0.726(-)	0.661(-)	0.488(-)	0.913(-)
H(16C)	0.428(-)	0.170(-)	-0.055(-)	0.207(-)	-0.092(-)	0.710(-)	0.795(-)	0.703(-)	0.927(-)
C(17)	0.3166(6)	0.0327(9)	0.0691(11)	0.4831(23)	0.2405(26)	0.6818(3)	0.5223(24)	0.7594(26)	0.9548(3)
H(17A)	0.300(-)	-0.022(-)	0.138(-)	0.594(-)	0.380(-)	0.682(-)	0.410(-)	0.792(-)	0.954(-)
H(17B)	0.266(-)	0.059(-)	0.026(-)	0.483(-)	0.181(-)	0.664(-)	0.524(-)	0.708(-)	0.973(-)
H(1 C)	0.347(-)	-0.022(-)	0.008(-)	0.360(-)	0.250(-)	0.683(-)	0.644(-)	0.894(-)	0.952(-)
C(5)	0.4550(5)	0.0966(7)	0.1978(8)	0.5274(19)	0.2262(22)	0.7406(3)	0.4709(23)	0.6933(24)	0.8961(3)
H(5)	0.483(-)	0.168(-)	0.235(-)	0.561(-)	0.155(-)	0.755(-)	0.443(-)	0.588(-)	0.882(-)
C(6)	0.5242(5)	0.0361(8)	0.1116(8)	0.3317(22)	0.2296(24)	0.7505(3)	0.6633(21)	0.8955(23)	0.8870(3)
H(6A)	0.515(-)	0.079(-)	0.031(-)	0.344(-)	0.354(-)	0.743(-)	0.648(-)	1.007(-)	0.895(-)
H(6B)				0.221(-)	0.121(-)	0.739(-)	0.777(-)	0.903(-)	0.899(-)

O(6)	0.5086(4)	-0.0892(5)	0.0898(6)						
H(6)	0.548(-)	-0.120(-)	0.026(-)						
C(7)	0.6154(5)	0.0549(7)	0.1589(9)	0.2866(23)	0.2078(26)	0.7836(3)	0.7066(22)	0.9174(23)	0.8534(3)
H(7)	0.660(-)	0.041(-)	0.094(-)	0.135(-)	0.151(-)	0.789(-)	0.856(-)	1.025(-)	0.846(-)
C(8)	0.6406(5)	0.0906(8)	0.2737(9)	0.4284(22)	0.2473(22)	0.8042(3)	0.5688(22)	0.8175(22)	0.8321(2)
C(9)	0.7309(6)	0.1079(9)	0.3138(9)	0.3874(25)	0.2414(23)	0.8379(3)	0.6094(27)	0.8552(24)	0.7986(3)
O(9)	0.7950(4)	0.1156(7)	0.2484(7)	0.2306(17)	0.1773(17)	0.8504(2)	0.7725(18)	0.9456(17)	0.7858(2)
O(10)	0.7336(4)	0.1102(6)	0.4426(7)	0.5732(18)	0.3394(17)	0.8513(2)	0.4312(20)	0.7668(18)	0.7837(2)
C(11)	0.6489(6)	0.0825(9)	0.4952(10)	0.7397(24)	0.4356(27)	0.8312(3)	0.2669(25)	0.6994(25)	0.8046(3)
H(11A)	0.635(-)	0.129(-)	0.574(-)	0.810(-)	0.584(-)	0.830(-)	0.206(-)	0.789(-)	0.806(-)
H(11B)	0.643(-)	-0.004(-)	0.527(-)	0.859(-)	0.413(-)	0.837(-)	0.141(-)	0.565(-)	0.799(-)
C(12)	0.5837(5)	0.1048(8)	0.3889(8)	0.6508(20)	0.3378(21)	0.8061(3)	0.3434(21)	0.6829(20)	0.8359(3)
H(12)	0.555(-)	0.184(-)	0.384(-)	0.677(-)	0.223(-)	0.796(-)	0.311(-)	0.542(-)	0.839(-)
O(13)	0.5193(3)	0.0130(5)	0.3965(5)	0.7345(14)	0.4914(14)	0.7776(2)	0.2642(13)	0.7568(14)	0.8583(2)
C(14)	0.4378(5)	0.0363(7)	0.3323(8)	0.7182(20)	0.4228(20)	0.7453(3)	0.2746(19)	0.7031(20)	0.8896(2)
C(15)	0.3987(5)	-0.0897(7)	0.3266(9)	0.7446(24)	0.6080(24)	0.7291(3)	0.2556(27)	0.8655(24)	0.9076(3)
H(15A)	0.346(-)	-0.086(-)	0.282(-)	0.856(-)	0.725(-)	0.739(-)	0.135(-)	0.870(-)	0.902(-)
H(15B)	0.438(-)	-0.143(-)	0.279(-)	0.771(-)	0.612(-)	0.709(-)	0.243(-)	0.836(-)	0.929(-)
H(15C)	0.389(-)	-0.130(-)	0.406(-)	0.625(-)	0.622(-)	0.732(-)	0.370(-)	0.998(-)	0.905(-)
Solvent									
C	1.0153(10)	0.0716(18)	0.2460(16)						
H(A)	1.080(-)	0.085(-)	0.265(-)						
H(B)	1.004(-)	0.101(-)	0.161(-)						
H(C)	1.011(-)	-0.020(-)	0.236(-)						
O	0.9629(5)	0.1106(10)	0.3391(7)						
H	0.920(-)	0.170(-)	0.280(-)						

Table 2. Molecular non-hydrogen atom geometries. The three values in each entry are for (2) and molecules 1,2 of (1) respectively

Atoms		Parameter
Distances/Å		
	C(1)-C(2)	1.53(1), 1.54(2), 1.55(2)
	C(1)-C(14)	1.51(1), 1.50(2), 1.49(2)
	C(2)-C(3)	1.50(1), 1.46(2), 1.48(3)
	C(3)-C(4)	1.54(1), 1.56(3), 1.54(2)
	C(3)-Br(3)	1.982(8), 1.96(2), 1.97(1)
	C(4)-C(5)	1.57(1), 1.57(2), 1.53(2)
	C(4)-C(16)	1.54(1), 1.55(2), 1.54(3)
	C(4)-C(17)	1.55(1), 1.53(2), 1.57(2)
	C(5)-C(6)	1.55(1), 1.56(3), 1.55(2)
	C(5)-C(14)	1.58(1), 1.49(2), 1.56(3)
	C(6)-C(7)	1.51(1), 1.49(2), 1.51(2)
	C(6)-O(6)	1.42(1)
	C(7)-C(8)	1.32(1), 1.32(2), 1.32(2)
	C(8)-C(9)	1.47(1), 1.51(2), 1.50(2)
	C(8)-C(12)	1.50(1), 1.48(2), 1.50(2)
	C(9)-O(9)	1.21(1), 1.17(2), 1.21(2)
	C(9)-O(10)	1.35(1), 1.36(2), 1.34(2)
	O(10)-C(11)	1.45(1), 1.41(2), 1.43(2)
	C(11)-C(12)	1.52(1), 1.54(2), 1.52(2)
	C(12)-O(13)	1.42(1), 1.41(2), 1.41(2)
	O(13)-C(14)	1.45(1), 1.50(2), 1.45(1)
	C(14)-C(15)	1.51(1), 1.50(2), 1.53(3)
Angles/deg.		
	C(14)-C(1)-C(2)	112.7(7), 112(1), 112(1)
	C(1)-C(2)-C(3)	109.9(7), 109(1), 110(1)
	C(2)-C(3)-C(4)	114.9(8), 114(2), 115(2)
	C(2)-C(3)-Br(3)	108.0(5), 109(1), 108(1)
	Br(3)-C(3)-C(4)	112.3(6), 114(1), 113(1)
	C(3)-C(4)-C(5)	105.2(7), 106(1), 105(1)
	C(3)-C(4)-C(16)	108.3(7), 107(1), 108(2)
	C(3)-C(4)-C(17)	112.5(7), 111(1), 113(1)
	C(5)-C(4)-C(16)	109.8(7), 109(1), 109(1)
	C(5)-C(4)-C(17)	114.3(7), 115(1), 116(2)
	C(16)-C(4)-C(17)	106.6(8), 108(1), 106(1)
	C(4)-C(5)-C(6)	113.3(7), 114(1), 114(1)
	C(4)-C(5)-C(14)	115.6(7), 114(1), 117(1)
	C(6)-C(5)-C(14)	117.0(7), 114(1), 111(1)
	C(5)-C(6)-C(7)	113.1(7), 116(1), 114(1)
	C(5)-C(6)-O(6)	113.3(7)
	O(6)-C(6)-C(7)	110.2(7)
	C(6)-C(7)-C(8)	127.9(8), 122(1), 124(1)

Table 2. (*Contd*)

C(7)-C(8)-C(9)	125.3(8), 122(1), 124(1)
C(7)-C(8)-C(12)	126.1(7), 129(1), 128(1)
C(9)-C(8)-C(12)	108.2(7), 108(1), 107(1)
C(8)-C(9)-O(9)	128.8(9), 129(1), 128(1)
C(8)-C(9)-O(10)	108.5(8), 106(1), 109(1)
O(9)-C(9)-O(10)	122.7(9), 126(1), 123(1)
C(9)-O(10)-C(11)	110.3(7), 115(1), 110(1)
O(10)-C(11)-C(12)	106.5(8), 104(1), 108(1)
C(11)-C(12)-C(8)	100.6(7), 104(1), 101(1)
C(11)-C(12)-O(13)	107.9(7), 108(1), 110(2)
C(8)-C(12)-O(13)	112.4(7), 114(1), 112(1)
C(12)-O(13)-C(14)	117.1(6), 117(1), 117(1)
C(5)-C(14)-C(1)	108.5(7), 111(1), 109(1)
C(5)-C(14)-O(13)	110.0(6), 111(1), 112(1)
C(5)-C(14)-C(15)	114.7(7), 119(1), 115(1)
C(1)-C(14)-O(13)	110.3(7), 106(1), 107(1)
C(1)-C(14)-C(15)	111.6(7), 109(1), 111(1)
O(13)-C(14)-C(15)	101.6(6), 100(1), 103(1)

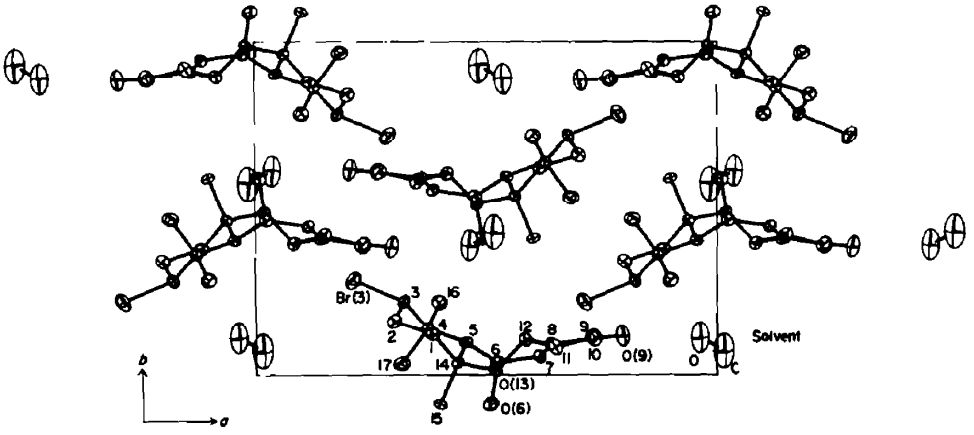


Fig. 2. Unit cell contents of (2) projected down *c*.

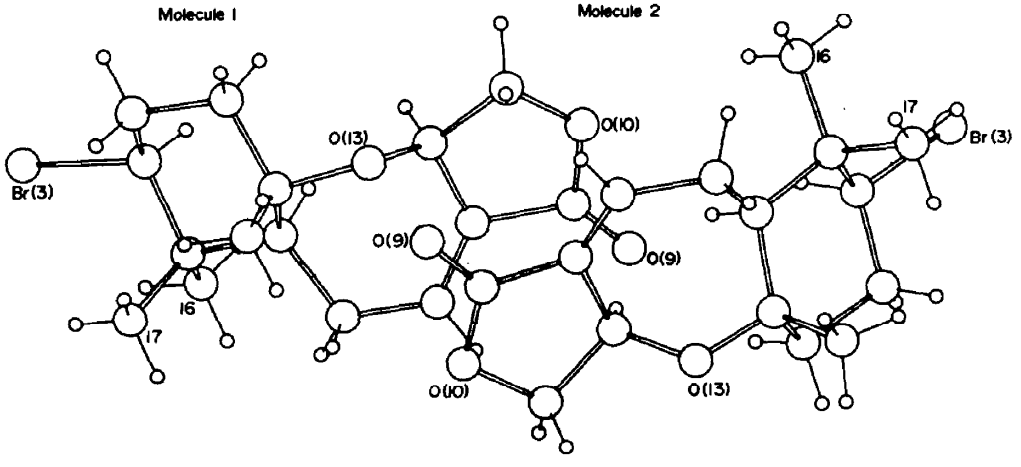


Fig. 3. Projection of the two molecules of the asymmetric unit of (1).

Table 3. Least squares planes. In order to enable comparison of the conformations of the three independent molecules, non-hydrogen atom deviations, δ, from a least squares plane defined by C(8–12), O(10) are given. δ and σ are in Å. The plane equation is in the form $pX + qY + rZ = s$, where the frame (X, Y, Z) Å is defined with X parallel to a, Z in the ac plane

Compound/molecule	(2)	(1)/1,2
$10^4 p$	-0591	-5201, -4806
$10^4 q$	9979	8446, 8677
$10^4 r$	0275	-1270, 1268
s	0.592	-4.392, 8.660
σ	0.12	0.09, 0.10
δC(8)	0.10	0.07, 0.06
δC(9)	-0.02	0.00, 0.01
δO(10)	-0.08	-0.07, -0.09
δC(11)	0.13	0.11, 0.12
δC(12)	-0.13	-0.10, -0.11
Non defining atoms		
δC(1)	-0.51	-0.29, -0.26
δC(2)	-0.98	-0.76, -0.74
δC(3)	-1.58	-1.47, -1.46
δBr(3)	-2.36	-2.26, -2.25
δC(4)	-0.62	-0.62, -0.64
δC(16)	-1.43	-1.58, -1.57
δC(17)	0.50	0.49, 0.48
δC(5)	-0.11	-0.12, -0.16
δC(6)	0.64	0.62, 0.61
δC(7)	0.50	0.45, 0.43
δO(9)	-0.03	0.07, 0.03
δO(13)	0.81	0.85, 0.86
δC(14)	0.50	0.58, 0.60
δC(15)	1.85	1.96, 1.99

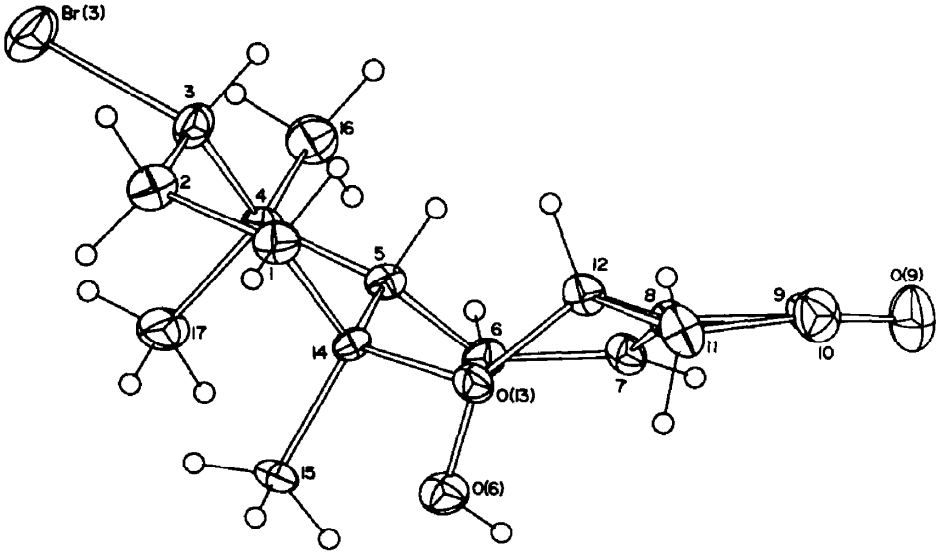


Fig. 4. Projection of a molecule of (2). Hydrogen atoms are shown as circles of arbitrary radius 0.1 Å.

found in the present phase of **1**, and the chiralities of **1** and **2** were found to be in conformity with each other and with that of the previous determination as well.

In **1**, the unit cell is trigonal in symmetry, the asymmetric unit containing two discrete molecules of the same chirality. In **2**, the asymmetric unit of the orthorhombic cell contains one molecule. The geometrical parameters of the two structures are in substantial agreement among the three molecules, the precision of the determination of **2** being rather better than that of **1**, a consequence of more intense and extensive data measured by a more suitable scan technique. Bond lengths are as expected. A number of features of interest are found among the angular parameters; this will be discussed in terms of the more precise geometry of **2**. The following features are noted:

(1) Within the lactone ring the angle at C(12) is smaller than the remainder, presumably because this angle is less sterically constrained than those at C(8, 9, 10). The exocyclic angles at C(9) are different (C(8)–C(9)–O(9), 129; C(10)–C(9)–O(9), 123°); this appears to be a consequence of the proximity of O(9) to C(7) (3.00(1) Å).

(2) The 6-membered ring has a "chair" conformation. Inequivalences are observed in Br–C(3)–C(2, 4) (108.0(5), 112.3(6)°), and probably result from the close contacts between Br and methyls 16 and 17, Br...H distances to each of the two Me's being found at 2.7_9, 2.8_7 Å. Br–C(16, 17) are 3.27(1), 3.28(1) Å, well below the van der Waals sum of $\sim 3.9_5$ Å, and this interaction in turn may be responsible for the inequivalence of C(3)–C(4)–C(16, 17), (108.3(7), 112.5(7)°), reflected in a similar inequivalence between C(5)–C(4)–C(16, 17) (109.8(7), 114.3(7)°). There is also an observed inequivalence of O(6)–C(6)–C(5, 7) (113.3(7), 110.2(7)°), but examination of the O(6) environment, shows the presence of a close transannular contact of H(15B), 2.3_3 Å and this appears to be the probable interaction responsible in this case.

In **2**, the OH group lies close to the methanol O atom (O...O(6) ($1\frac{1}{2}-x, \bar{y}, \frac{1}{2}+z$), 2.67(1) Å) comprising the only intermolecular contact of note in the two structures.

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Note added in proof: The alga has now been identified as *Laurencia filiformis* (C. Agardh) Montagne nearest to forma *filiformis* (H. B. S. Womersley determinavit). We are indebted to Professor H. B. S. Womersley, University of Adelaide for the identification.