mL) was added tributyltin hydride (8 μL, 0.03 mmol) and AIBN (7.7 mg, 0.04 mmol). The reaction mixture was then placed in a preheated oil bath (85 °C). After the mixture was refluxed for 12 h, the reaction was incomplete as determined by gas chromatography (**29a**/**28a** = 2/1); therefore, additional portions of tributyltin hydride (1.2 μL, 0.0045 mmol) and AIBN (1.5 mg, 0.009 mmol) were added to the solution. After 4 h at 85 °C, more tributyltin hydride (1.2 μL, 0.0045 mmol) and AIBN (1.5 mg, 0.009 mmol) were added. After refluxing 12 h, the reaction mixture was concentrated, and the residue was purified by medium-pressure liquid chromatography (100% hexanes) to give **29a** as a colorless oil (15.3 mg, 40%): ^{1}H NMR ($CDCl_3$) *E* isomer δ 5.81 (1 H, m), 2.57-2.13, (4 H, m), 2.00-0.99 (10 H, m); *Z* isomer δ 5.66 (1 H, m); IR ($CHCl_3$) 2920, 2850, 1440, 1320 cm^{-1}; MS, *m/e* 262, 135, 95, 79, 67. HRMS Calcd for $C_{10}H_{15}I$: 262.0219. Found: 262.0217. Anal. Calcd for $C_{10}H_{15}I$: C, 45.82; H, 5.77. Found: C, 45.87; H, 5.89.

2-(Iodomethylene)-1-methylbicyclo[3.4.0]nonane (29b) (*E*/*Z* Mixture). Compound **29b** was prepared following the procedure for **27b** using tertiary iodide **28b** (52 mg, 0.118 mmol), tributyltin hydride (5.4 μL, 0.02 mmol), and AIBN (5.9 mg, 0.036 mmol). A colorless oil (**29b**, 20.5 mg, 40%) was obtained after medium-pressure liquid chromatography (100% pentanes): ^{1}H NMR ($CDCl_3$) *E* isomer δ 5.77 (1 H, m), 2.50-2.33 (2 H, m), 1.86-1.15 (11 H, m), 1.05 (3 H, s); *Z* isomer δ 6.03 (1 H, m); ^{1}H NMR (benzene-d_6) *E* isomer δ 5.64 (1 H, m), 2.44-2.16 (2 H, m), 1.56-0.88 (11 H, m), 0.81 (3 H, s); *Z* isomer δ 5.55 (1 H, m); IR ($CHCl_3$) 2920, 2840, 1445, 1200 cm^{-1}. Anal. Calcd for $C_{11}H_{17}I$: C, 47.84; H, 6.21. Found: C, 47.91; H, 6.49.

2-(Iodomethylene)spiro[4.5]decane (31a) (Mixture of *E* and *Z* Isomer) and *trans*-2-Methylene-7-iodospiro[4.5]decane (32a). A solution of iodide **30a** (33 mg, 0.12 mmol) and hexabutylditin (6 μL, 0.012 mmol) in degassed benzene (0.4 mL) was irradiated with a sunlamp (GE, 275 W, distance from tube = 10 cm) for 15 min. Evaporation of the solvent gave a crude oil which was purified by flash chromatography (100% hexanes) to afford the *E* and *Z* isomers of **31a** in 40% yield (13.3 mg) and **32a** in 7% yield (2.3 mg): ^{1}H NMR ($CDCl_3$) *E* isomer of **31a** δ 5.85 (1 H, t, *J* = 3 Hz), 2.36 (2 H, td, *J* = 7, 3 Hz), 1.78 (2 H, t, *J* = 6 Hz), 1.69-1.25 (12 H, m); ^{1}H NMR ($CDCl_3$) **32a** δ 4.89 (1 H, s), 4.80 (1 H, s), 4.26 (1 H, tt, *J* = 11, 4 Hz), 2.37 (2 H, m), 1.70-1.30 (10 H, m).

2-(Iodoethylene)spiro[4.5]decane (31b) (Mixture of *E* and *Z* Isomer) and *trans*-2-Ethylene-7-iodospiro[4.5]decane (32b). A solution of crude iodide **30b** (706 mg, 2.1 mmol) and hexamethylditin (180 μL, 0.21 mmol, 1.15 M in benzene) in degassed benzene (1.2 mL) was irradiated with a sunlamp (GE, 275 W, distance from tube = 10 cm) for 80 min. The photolysis temperature was kept at 40 °C. The resulting mixture was concentrated to give a crude brown oil. Flash chromatography (100% hexanes) afforded a pale-yellow oil which was a mixture of **32b** and the *E* and *Z* isomers of **31b** (432 mg, 70% overall from **30b**). The undesired elimination product (4-hexynylcyclohex-1-ene) was isolated in 6% yield (20 mg): ^{1}H NMR ($CDCl_3$) *E* isomer of **31b** δ 2.73 (3 H, t, *J* = 2 Hz), 2.43 (2 H, td, *J* = 7 Hz), 1.90 (2 H, t, *J* = 7 Hz), 1.80-1.18 (12 H, m); *Z* isomer of **31b** δ 2.56 (3 H, s); ^{13}C NMR ($CDCl_3$) *E* isomer of **31b** δ 155.2 (s), 93.1 (s), 48.1 (s), 45.9 (t), 40.4 (t), 34.5 (t), 31.4 (q), 25.9 (t), 23.3 (t), 22.7 (t); IR (thin film) **31b** mixture 2928, 2857, 1636, 1446 cm^{-1}; MS **31b** mixture, *m/e*, 290, 163, 95, 81. HRMS (**31b** mixture) Calcd for $C_{12}H_{19}I$: 290.0531. Found: 290.0531. ^{1}H NMR ($CDCl_3$) **32b** δ 5.23 (1 H, m), 4.28 (1 H, tt, *J* = 13, 4 Hz), 2.42 (1 H, br d, *J* = 13 Hz), 2.27 (2 H, m), 2.18 (1 H, br d, *J* = 13 Hz), 1.99 (1 H, t, *J* = 13 Hz), 1.87 (1 H, m), 1.66-1.25 (8 H, m), 1.60 (3 H, d, *J* = 1 Hz); IR (thin film) **32b** 2020, 2953, 1670, 1447 cm^{-1}; MS **32b**, *m/e*, 290, 240, 197, 163. HRMS (**32b**) Calcd for $C_{12}H_{19}I$: 290.0531. Found: 290.0533.

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Supplementary Material Available: Full details on the general aspects of the work, the preparation of all cyclization precursors, and the characterization of products by syntheses of authentic samples and by chemical transformations (38 pages). Ordering information is given on any current masthead page.

Xestovanin A and Secoxestovanin A, Triterpenoid Glycosides with New Carbon Skeletons from the Sponge *Xestospongia vanilla*

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Contribution from the Departments of Chemistry and Oceanography, University of British Columbia, Vancouver, British Columbia, Canada V6T 1W5. *Received January 18, 1989*

Abstract: Xestovanin A (**1**) and secoxestovanin A (**2**), two new triterpenoid glycosides, have been isolated from extracts of the Northeastern Pacific marine sponge *Xestospongia vanilla*. The structures of **1** and **2** were solved by extensive spectroscopic analysis and chemical transformations. Xestovanin A (**1**) gave the hexaacetate **5** on treatment with acetic anhydride and pyridine. Reaction of **1** with hot aqueous potassium hydroxide gave the organic soluble elimination product **6**. Acidic hydrolysis of the water soluble material from the elimination reaction gave D-fucose and L-rhamnose. Secoxestovanin A (**2**) gave the same elimination product **6** on treatment with hydroxide. *X. vanilla* is only the second sponge known to contain triterpenoid glycosides. The aglycones of **1** and **2** both have new triterpenoid carbon skeletons. Xestovanin A (**1**) shows antifungal activity against *Pythium ultimum*.

Marine sponges are an extremely rich source of sesqui-, di-, and sesterterpenoids.[1] The reported occurrence of squalene-derived triterpenoids in sponges is, by contrast, currently limited to a relatively small number of compounds in only a few different species. The first examples were a family of isomalabaricane triterpenoids isolated from the Pacific Ocean sponge *Jaspis stellifera*[2a] and the Indian Ocean sponge *Stelletta* sp.[2b] Subsequently, a Red Sea sponge, *Siphonochalina siphonella*, yielded triterpenoids representing three new carbon skeletons all formed by novel modes of squalene cyclization.[3] Recently, sarsinosides A_1, B_1, and C_1, a family of norlanostane oligoglycosides,[4] and

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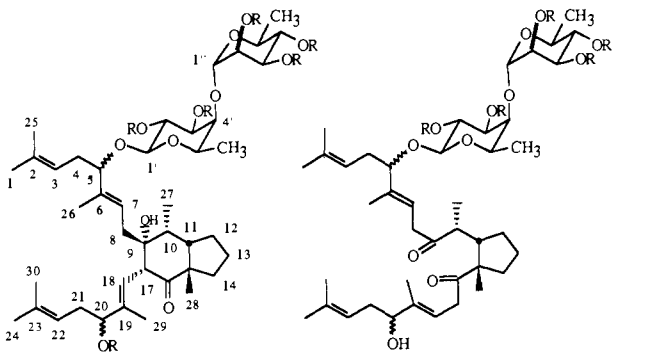
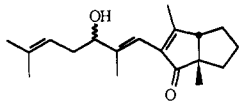
pouosides A–E, a family of triterpenoid glycosides, whose aglycones have a carotenoid-like carbon skeleton,[5] have been isolated from the Pacific Ocean sponge *Asteropus sarasinosum*. Prior to the discovery of the sarasinosides and pouosides in *A. sarasinosum*, the only known marine sources of triterpenoid glycosides were echinoderms.[6] We now wish to report the isolation of xestovanin A (**1**) and secoxestovanin A (**2**), two squalene-derived triterpenoid glycosides, from the Northeastern Pacific sponge *Xestospongia vanilla*. Both xestovanin A (**1**) and secoxestovanin A (**2**) have new cyclic triterpenoid carbon skeletons.



1 R=H
5 R=Ac

2 R=H



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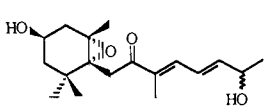

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Samples of *X. vanilla* were collected by hand using SCUBA in exposed surge channels along the shoreline of the Deer Group of islands in Barkley Sound, British Columbia. Freshly collected sponge was homogenized with methanol in a Waring blender. Concentration of the methanol extract in vacuo gave an aqueous suspension that was exhaustively extracted with dichloromethane. Purification of the dichloromethane soluble material by Sephadex LH20 chromatography (9:1 MeOH/CH_2Cl_2) gave a series of early eluting fractions containing crude mixtures of triterpenoid glycosides and a series of late eluting fractions containing, among other things, the previously reported metabolites xestenone (**3**)[7] and xestodiol (**4**).[8] Fractionation of the triterpenoid glycoside mixtures by C_{18} reversed-phase flash chromatography[9] (i, 3:1 MeOH/H_2O; ii, 3:2 acetone/H_2O) gave pure xestovanin A (**1**) and secoxestovanin A (**2**) as colorless glasses.

The molecular formula of xestovanin A (**1**) was determined by mass spectrometry. A parent ion was observed at m/z 787 ($C_{42}H_{68}O_{12}$ + Na) daltons in the FABMS of **1**. The highest mass ion in the HREIMS of **1** was an $M^+ - H_2O$ fragment observed at m/z 746.4592 daltons corresponding to an elemental composition of $C_{42}H_{66}O_{11}$ (ΔM −1.3 mmu). All 42 carbons were observed in the ^{13}C NMR spectrum of xestovanin A (**1**) (Experimental Section) and an APT experiment[10] revealed 61 protons attached to carbon atoms. Xestovanin A (**1**) gave the hexaacetate **5** (^1H NMR $CDCl_3$ δ 2.01 (s, 6 H), 2.32 (s, 3 H), 2.57 (s, 3 H), 2.75 (s, 3 H), 2.14 (s, 3 H)) when treated with acetic anhydride in pyridine. An OH stretching vibration (3385 cm^{-1}) in the IR spectrum of hexaacetate **5** and the presence of six hydroxyl proton resonances showing vicinal coupling (DMSO-d_6 δ 4.48, d; 4.67, d; 4.57, d; 4.64, d; 4.92, d; 5.03, d) and one hydroxyl proton resonance lacking vicinal coupling (δ 4.40, s) in the ^1H NMR spectrum of **1** (Table I) indicated that a tertiary alcohol in **1** had not been acetylated. The acetylation reaction, in conjunction with the ^1H NMR data for **1**, established that the seven protons not attached to carbon atoms in xestovanin A were part of alcohol functionalities.

Five of the nine sites of unsaturation required by the molecular formula of xestovanin A (**1**) could be readily identified from its ^{13}C NMR spectrum. A downfield singlet (δ 212.8) revealed a saturated ketone (IR 1701 cm^{-1}), and eight olefinic resonances (δ 139.4, 133.7, 132.1, 131.3, 126.3, 121.3, 121.2, 120.1) revealed four carbon carbon double bonds. The lack of evidence for additional unsaturated functional groups indicated that xestovanin A (**1**) was tetracyclic.

The observation of ketal methine carbon resonances at δ 101.2 and 98.6 ppm in the ^{13}C NMR spectrum of xestovanin A (**1**) (Experimental Section) suggested the presence of two monosaccharide residues in the molecule. A ^1H COSY NMR experiment (Table I), carried out on **1** in DMSO-d_6 so that scalar couplings to the alcohol protons could be observed, confirmed the existence of the sugar residues, and it demonstrated that both monosaccharides were 6-deoxyhexoses. Subtracting the 12 carbons of the two hexose residues from the total of 42 carbons present in xestovanin A indicated a bicyclic C_{30} aglycone. The ^1H NMR spectrum of **1** contained resonances that could be assigned to four aliphatic and six olefinic methyls (Table I). Two of the aliphatic methyl resonances were assigned to the 6-deoxyhexose fragments. The remaining eight methyl residues, which had to be assigned to the aglycone, are the number required by a triterpenoid skeleton. It was apparent, therefore, that xestovanin A was a triterpenoid glycoside. The EIHRMS spectrum of **1**, which showed fragment ions at m/z 436.3337 ($C_{30}H_{44}O_2$ ΔM −0.4 mmu) and 418.3196 ($C_{30}H_{42}O$ ΔM −4.0 mmu) daltons corresponding to loss of the two sugar residues plus one and two water molecules, respectively, supported this hypothesis.

A pair of ten carbon fragments (substructures A and B) of the aglycone could be routinely identified from the ^1H COSY, double resonance, and NOE NMR data collected on **1** in DMSO-d_6 (Table I). These substructures are nearly identical with the side chain previously found in xestenone (**3**).[7] Scalar coupling observed between H20 (δ 3.90) and the neighboring alcohol proton and the lack of such a coupling into H5 (δ 4.44) established the presence of alcohol and ether functionalities at C20 and C5, respectively. Negative NOEs observed between H5 and H7 and between H20 and H18 provided connectivities between the two independent scalar-coupled spin systems in each ten-carbon fragment and also established the E configuration for both the C6–C7 and C18–C19 olefins. The observation of negative NOEs was attributed to slow tumbling of xestovanin A (**1**) in the viscous solvent DMSO.[11] The corresponding NOEs (H7 to H5 and H18 to H20) recorded on the hexacetate **5** in $CDCl_3$ were positive (Table II, Supplementary Material).

The remaining portion of the aglycone had to contain ten carbon atoms, had to incorporate ketone (IR 1701 cm^{-1}; ^{13}C NMR δ 212.8 ppm), tertiary alcohol (^{13}C NMR δ 82.1, s), secondary methyl (^1H NMR δ 0.95, d, J = 6.2 Hz, 3 H), and tertiary methyl (δ 1.35, s, 3 H) functionalities and had to be bicyclic. Combining the assumption that xestovanin A (**1**) had an unrearranged triterpenoid carbon skeleton and the fact that a companion metabolite, xestenone (**3**), contained a cyclopentane ring, we were able to construct two candidate structures C and D for the aglycone.

A number of pieces of spectral evidence indicated that the aglycone had structure C. The ketone stretching frequency of 1701 cm^{-1} was consistent with a cyclohexanone. The ^1H COSY spectrum of hexaacetate **5** contained correlations which established a connectivity sequence starting with the protons on Me27 and continuing uninterrupted around to the methylene protons on C14 (Table II, Supplementary Material). This data provided support

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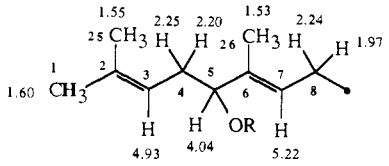
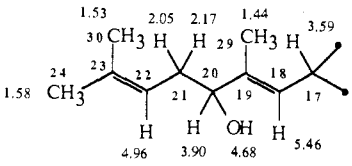
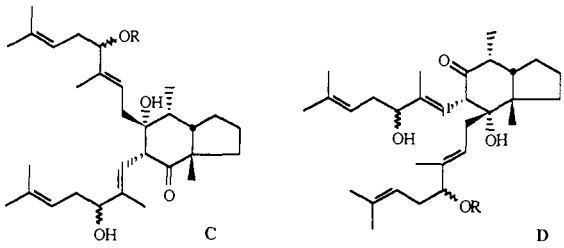


Fragment A



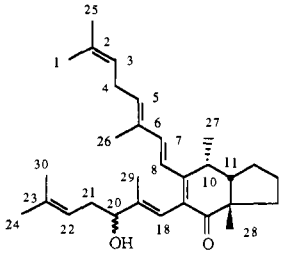
Fragment B



C D

for the presence of the cyclopentane ring in xestovanin A (**1**). A scalar coupling, observed in the ^{1}H COSY (DMSO-d_6) spectrum of **1** between the tertiary alcohol proton (δ 4.40, br s; C90H) and the methine proton (δ 3.59; H17) on one terminus of fragment B, could be assigned to a W coupling between a proton on an axial alcohol and an adjacent axial methine proton on a cyclohexane ring in a chair-like conformation. Irradiation of the tertiary methyl protons (δ 1.35; Me28) in the hexaacetate **5** induced NOEs in the methine proton adjacent to the secondary methyl (δ 2.27; H10), in the methine proton on the terminus of fragment B (δ 3.60; H17), and in the ring junction methine proton (δ 1.99; H11). The NOE results were in concert with the methyl group having 1,3-diaxial relationships with the methines at δ 2.27 and 3.60, and, in conjunction with the observed W coupling, they established the relative stereochemistry around the bicyclic system as shown. Irradiation of the secondary methyl protons (δ 0.95; Me27) of **1**, in a SINEPT experiment[12] optimized for a $J_{C,H}$ of 7 Hz, gave strong polarization transfer through three-bond coupling to the tertiary carbinol carbon at δ 82.1 (C9). A second SINEPT experiment, utilizing the same $J_{C,H}$ of 7 Hz, showed polarization transfer from the methine proton on the terminus of fragment B 3.59; H17) to the tertiary carbinol carbon at δ 82.1 (C9) and to the ketone carbon at δ 212.8 (C16). The SINEPT results are only consistent with the constitution of candidate structure C.

Further support for the proposed constitution of the aglycone came from detailed spectroscopic analysis of the double elimination product **6**, obtained by treatment of xestovanin A (**1**) with hot aqueous potassium hydroxide. Compound **6** gave a parent ion



6

at m/z 436.3336 daltons in the EIHRMS for a molecular formula of $C_{30}H_{44}O_2$ (ΔM −0.5 mmu). The ^{13}C NMR spectrum of **6** (Experimental Section) showed resonances for 12 olefinic carbons (6 CH, 6C), an unsaturated ketone (δ 204.4; IR 1651 cm^{-1}), and a carbinol methine (δ 76.8 CH). The presence of a conjugated ketone in **6** indicated that dehydration of the β-hydroxy ketone in **1** had occurred during the treatment with hydroxide. A pair of ^{1}H NMR resonances at δ 6.58 (d, J = 16.4 Hz) and 6.29 (d, J = 16.4 Hz) in the spectrum of **6** were assigned to H7 and H8, respectively, and a resonance at δ 5.65 (t, J = 7.4 Hz), which upon irradiation induced an NOE in the resonance at δ 6.58 (H7), was assigned to H5 (Table III, Supplementary Material). The presence of the C5-C6, C7-C8 diene in **6** indicated that 1,4-elimination of the C5 alkoxy substituent (i.e., the disaccharide) in xestovanin A (**1**) had also occurred during the hydroxide treatment. A ^{1}H COSY spectrum of **6**, in conjunction with the demonstration of a NOE between H18 (δ 6.13) and H20 (δ 4.18) (Table III, Supplementary Material), showed that the functionality on the side-chain carbons from C18 to C24 was identical in xestovanin A (**1**) and the double elimination product **6**. NOEs observed between H7 and H10 and between the protons on Me28 and H11 in **6** confirmed the attachment of the side chain containing the C5 alkoxy substituent (i.e., fragment A) at C9 in xestovanin A (**1**) and confirmed the cis fusion of the bicyclic ring system. All the other data recorded for the double elimination product **6** was also consistent with the structure shown.

The water-soluble material formed in the treatment of xestovanin A (**1**) with potassium hydroxide was hydrolyzed with aqueous trifluoroacetic acid. The resulting monosaccharides were reacted first with (+)- or (−)-2-octanol in trifluoroacetic acid and then with pyridine/acetic anhydride. Analysis of the resulting acetylated 2-octyl glycosides by capillary GC led to the identification of L-rhamnose and D-fucose.[13] It was possible to assign NMR resonances to all the rhamnose and fucose protons in xestovanin A (**1**) by analysis of the ^{1}H COSY data collected in DMSO-d_6 (Table I). The fucose H4′ methine and the two anomeric protons, H1′ and H1″, failed to show vicinal couplings to adjacent hydroxyl protons indicating the presence of ether linkages at C4′, C1′, and C1″. A 7.3 Hz vicinal coupling between the fucose anomeric proton (H1′) and H2′ revealed that the fucose had the β-anomeric configuration. Irradiation of the fucose anomeric proton in the hexaacetate **5** induced NOEs in H3′ and H5′ as well as in H5, the ether methine proton on fragment A of the aglycone (Table II, Supplementary Material). Therefore, the fucose had to be attached to the aglycone through a β-glycosidic linkage to C5. A NOE observed between H4′ and H1″ demonstrated that rhamnose was linked to the fucose via a 1,4-glycosidic linkage. The one-bond carbon–hydrogen coupling constant between the rhamnose anomeric carbon and its attached proton was found to be 171.4 Hz, which showed that rhamnose had the α-anomeric configuration.[14]

The above arguments established the constitution of xestovanin A to be that shown in **1**. In addition, the absolute configurations of the chiral centers in the disaccharide portion of the molecule are as depicted. The chiral centers in the bicyclic portion of the aglycone (C9, C10, C11, C15, C17) are shown with the correct configurations relative to each other; however, since their absolute configurations have not been determined, the set of configurations shown for these centers is arbitrary. It was not possible to draw any conclusions about the configurations at C5 and C20.

Secoxestovanin A (**2**), like xestovanin A (**1**), showed a parent ion in the FABMS at m/z 787 ($C_{42}H_{68}O_{12}$ + Na) daltons and a M$^+$ − H_2O fragment at m/z 746.4579 ($C_{42}H_{66}O_{11}$ ΔM −2.6 mmu) daltons as the highest mass ion in the EIHRMS. A comparison of the ^{1}H and ^{13}C data obtained from secoxestovanin A (**2**) to that of xestovanin A (**1**) showed that the two molecules had nearly identical structures (Table I and Experimental Section). In particular, the resonances assigned to the fucose and rhamnose

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Table I. ^{1}H NMR Data (400 MHz: DMSO-d_6) for Xestovanin A (**1**) and Secoxestovanin A (**2**)

	1	**1**: COSY correlations	**2**	**2**: COSY correlations
C				
1	1.60, s	H3	1.62, s	H3
3	4.93, t (7.0)	Me1, Me25, H4, H4′	4.97, t (6.9)	Me1, Me25, H4, H4′
4	2.20, m; 2.25, m	H3, H5	2.20, m; 2.24, m	H3, H5
5	4.04, dd (5.9, 8.7)	H4, H4′	4.01, dd (5.9, 8.3)	H4, H4′
7	5.22, br d (8.1)	H8, H8′, Me26	5.39, t (7.0)	H8, H8′, Me26
8	2.24, m; 1.97, m	H7	3.19 (2 H), m	H7
9OH	4.40, s	H17		
10	2.07, dq (5.5, 6.2)	Me27, H11	2.81, dq (10.0, 6.9)	Me27, H11
11	1.86, m	H10	1.81, dt (10.0, 7.5)	H10, H12, H12′
12	1.83, m		1.66, m; 1.43, m	H11
13	1.32, m			
14	2.43, ddd (13.0, 5.5, 8.0)			
17	3.59, d (9.9)	H18, C9OH	3.22, m (2H)	H18
18	5.46, br d (9.6)	H17, Me29	5.44, t (6.8)	H17, Me29
20	3.90, dt (4.1, 7.5)	H21, H21′, C20OH	3.83, m	H21, H21′, C20OH
20OH	4.68, d (4.1)	H20	4.65, d (4.2)	H20
21	2.05, m; 2.17, m	H20, H22	2.10, t (6.7, 2H)	H20, H22
22	4.96, t	H21, Me24, Me30	5.08, t (6.9)	H21, Me24, Me30
24	1.58, s	H22	1.55, s	H22
25	1.55, s	H3	1.55, s	H3
26	1.53, s	H7	1.55, s	H7
27	0.95, d (6.2)	H10	0.91, d (6.9)	H10
28	1.35, s		1.33, s	
29	1.41, s	H18	1.55, s	H18
30	1.53, s	H22	1.62, s	H22
1′	3.97, d (7.3)	H2′	3.96, d (7.7)	H2′
2′	3.28, ddd (9.6, 7.3, 4.3)	H1′, C2′OH	3.25, m	H1′, C2′OH
2′OH	4.92, d (4.3)	H2′	4.79, d (4.7)	H2′
3′	3.31, ddd (9.6, 4.0, 1.8)	H4′, C3′OH	3.36, m	H4′, C3′OH
3′OH	5.03, d (4.0)	H3′	4.95, d (4.3)	H3′
4′	3.61, br d (1.8)	H5′	3.57, m	H3′
5′	3.39, br q (6.3)	H4′, H6′	3.47, m	H6′
6′	1.15, d (6.3)	H5′	1.12, d (6.1)	H5′
1″	5.10, d (2.0)	H2″	5.08, d (1.2)	H2″
2″	3.76, ddd (4.2, 3.1, 2.0)	H1″, H3″, C2″OH	3.77, m	H1″, H3″, C2″OH
2″OH	4.57, d (4.2)	H2″	4.54, d (4.3)	H2″
3″	3.46, ddd (9.3, 5.7, 3.1)	H2″, H4″, C3″OH	3.47, m	H2″, H4″, C3″OH
3″OH	4.48, d (5.7)	H3″	4.48, d (6.5)	H3″
4″	3.18, dt (9.2, 5.8)	H3″, H5″, C4″OH	3.19, m	H3″, H5″, C4″OH
4″OH	4.64, d (5.8)	H4″	4.62, d (5.7)	H4″
5″	3.56, dq (9.2, 6.2)	H4″, H6″	3.57, m	H4″, H6″
6″	1.10, d (6.2)	H5″	1.10, d (6.1)	H5″

fragments of **1** were virtually duplicated in the spectra of **2** indicating that the two molecules contained identical disaccharide substructures. The ^{13}C NMR spectrum of **2** contained eight olefinic resonances (Experimental Section) and two ketone carbonyl resonances (δ 211.4, 212.6) which accounted for six of the nine sites of unsaturation required by the molecular formula. Two of the three remaining sites of unsaturation could be attributed to the rings of the fucose and rhamnose residues. Therefore, the aglycone of secoxestovanin A (**2**) had to be monocyclic. The presence of a second ketone functionality in **2**, combined with the absence of a tertiary alcohol functionality and the requirement of a monocyclic aglycone, suggested that secoxestovanin A (**2**) was simply the retroaldol product of xestovanin A (**1**). All the spectral data for **2**, including ^{1}H COSY, NOE, and ^{13}C NMR experiments, supported this hypothesis (Table I and Experimental Section). Treatment of secoxestovanin A (**2**) with hot aqueous potassium hydroxide also gave **6**. The conversion of both xestovanin A (**1**) and secoxestovanin A (**2**) to the same product **6** provided chemical confirmation of the proposed structural relationship between **1** and **2**.

Xestovanin A (**1**) and secoxestovanin A (**2**) are new members of an emerging group of squalene-derived triterpenoids[2-5] with new carbon skeletons[15] that have been isolated from marine sponges. *X. vanilla* is only the second sponge which has been found to contain triterpenoid glycosides.[4,5] The structural similarity between the xestovanins (**1** and **2**) and xestenone (**3**) implies that the latter metabolite is a degraded triterpenoid, not a degraded diterpenoid as previously reported.[7] Xestovanin A (**1**) shows antifungal activity.[16]

Experimental Section

Isolation of Xestovanin A (1) and Secoxestovanin A (2) from *X. vanilla*. *X. vanilla* was collected in Barkley Sound, British Columbia in May and June of 1988. Freshly collected sponge material (1 kg dry wt) was homogenized with methanol in a Waring blender. Concentration of the methanol extracts in vacuo gave an aqueous suspension that was diluted with water (500 mL) and extracted with dichloromethane (3 × 300 mL). Concentration of the combined dichloromethane layers in vacuo gave a highly colored crude oil (47 g). A portion of the oil (4.7 g) was fractionated by chromatography on Sephadex LH 20 (9:1 MeOH/CH_2Cl_2) to give a series of early eluting fractions which contained complex mixtures of triterpenoid glycosides (350 mg). The triterpenoid glycosides were partially separated by isocratic reversed phase flash chromatography (eluent 3:1 MeOH/H_2O). A second reversed phase flash chromatography (eluent 3:2 acetone/H_2O) gave pure samples of xestovanin A (**1**) (40 mg; 4×10^{-2}% of dry wt of sponge) and secoxestovanin A (**2**) (4 mg; 4×10^{-3}% dry wt).

Xestovanin A (**1**): colorless glass; FTIR (film) 1701 cm^{-1}; ^{1}H NMR (see Table I); ^{13}C NMR (100 MHz, DMSO-d_6) δ 212.8 (C), 139.4 (C), 133.7 (C), 132.1 (C), 131.3 (C), 126.3 (CH), 121.3 (CH), 121.2 (CH), 120.1 (CH), 101.2 (CH:1″), 98.6 (CH:1′), 82.1 (C), 81.9 (CH), 76.7 (CH), 76.6 (CH), 74.6 (CH), 71.9 (CH), 70.8 (CH), 70.7 (CH), 69.9 (CH), 69.8 (CH), 68.9 (CH), 55.0 (CH), 54.6 (C), 50.9 (CH), 36.4

(15) We propose the names xestovanane and secoxestovanane for the new carbon skeletons of **1** and **2**.

(16) In a standard disc assay (1/4 in. disc), xestovanin A (**1**) inhibits *Pythium ultimum* at a level of <50 μg/disc.

(CH_2), 34.3 (CH_2), 34.1 (CH_2), 33.9 (CH), 31.4 (CH_2), 27.0 (CH_2), 25.5 (CH_3), 25.4 (CH_3), 25.3 (CH_3), 21.5 (CH_2), 17.9 (CH_3), 17.8 (CH_3), 17.7 (CH_3), 17.2 (CH_3), 13.2 (CH_3), 10.8 (CH_3), 10.2 (CH_3); FABMS M^+ 787 ($C_{42}H_{68}O_{12}$ + Na); EIHRMS $M^+ - H_2O$ 746.4592 ($C_{42}H_{66}O_{11}$ ΔM -1.3 mmu); EILRMS 746, 728, 659, 582, 531, 436, 418, 385, 367, 349, 337, 301, 163, 147, 135, 121, 109.

Secoxestovanin A (2): colorless glass; ^1H NMR (see Table I); ^{13}C NMR (100 MHz, DMSO-d_6) δ 212.6 (C), 211.4 (C), 140.1 (C), 136.6 (C), 132.1 (C), 131.4 (C), 121.4 (CH), 121.4 (CH), 120.2 (CH), 117.3 (CH), 101.2 (CH), 99.1 (CH), 81.3 (CH), 76.7 (CH), 75.6 (CH), 74.3 (CH), 71.9 (CH), 70.8 (CH), 70.6 (CH), 70.0 (CH), 69.4 (CH), 68.9 (CH), 56.3 (C) 52.9 (CH), 46.8 (CH), 41.2 (CH_2), 38.4 (CH_2), 34.1 (CH_2), 31.8 (CH_2), 31.7 (CH_2), 25.9 (CH_3), 25.7 (CH_3), 25.6 (CH_3), 22.7 (CH_2), 17.8 (CH_3), 17.8 (2 × CH_3), 17.2 (CH_3), 16.4 (CH_3), 12.0 (CH_3), 10.6 (CH_3); FABMS M^+ 787 ($C_{42}H_{68}O_{12}$ + Na); EIHRMS $M^+ - H_2O$ 746.4579 ($C_{42}H_{66}O_{11}$ ΔM -2.6 mmu).

Hexaacetate 5. Xestovanin A (**1**) (20 mg) was added to acetic anhydride (1 mL) and pyridine (1 mL), and the mixture was stirred overnight at room temperature. The acetylation reagents were removed in vacuo to give a quantitative yield of the hexaacetate **5**: FTIR (film) 3384, 2965, 2936, 2876, 1752, 1710, 1440, 1371, 1244, 1224 cm^{-1}; ^1H NMR (see Table II); FABMS 1039 ($C_{54}H_{80}O_{18}$ + Na); EILRMS $M^+ - H_2O$ 998, 956, 938, 869, 503, 436, 417, 273.

Double Elimination Product 6. Xestovanin A (**1**) (40mg) was heated with stirring for 1 h at 50 °C with methanol (3 mL) and 0.05 M KOH (3 mL). The reaction mixture was cooled, diluted with 10 mL of water, neutralized with dilute HCl, and extracted with ether (3 × 25mL). The ether layers were combined, dried over sodium sulfate, and evaporated in vacuo. The resulting residue was purified by radial silica gel chromatography (3:2 hexane/ether) to give the double elimination product **6** (7 mg). **6**: FTIR (film) 3410, 2965, 2928, 2875, 1651, 1594, 1556, 1447, 1374 cm^{-1}; ^1H NMR (see Table III); ^{13}C NMR (100 MHz, $CDCl_3$) δ 204.4 (C), 142.7 (C), 139.5 (CH), 135.9 (CH), 134.7 (C), 134.0 (C), 132.7 (C), 131.0 (C), 130.9 (C), 124.4 (CH), 121.5 (CH), 120.5 (CH), 120.2 (CH), 76.8 (CH), 52.5 (C), 48.4 (CH), 36.1 (CH_2), 34.3 (CH_2), 31.3 (CH), 27.8 (CH_2), 27.0 (CH_2), 25.9 (CH_3), 25.8 (CH_3), 25.7 (CH_3), 21.6 (CH_2), 19.1 (CH_3), 18.1 (CH_3), 17.8 (CH_3), 14.0 (CH_3), 12.2 (CH_3); EIHRMS M^+ 436.3336 ($C_{30}H_{44}O_2$ ΔM -0.5 mmu).

Secoxestovanin A (**2**) (10 mg) was treated with aqueous potassium hydroxide as described above. The elimination product **6** formed from **2** in this reaction was identical by TLC and ^1H NMR comparison with that formed from xestovanin A (**1**) under the same conditions.

Identification of Fucose and Rhamnose.[13] The water soluble material from the elimination reaction of xestovanin A (**1**) described above was taken to dryness by lyophilization. Aqueous trifluoracetic acid (3 M, 10 mL) was added to the residue, and the resulting solution was heated at 90 °C for 2 h. Removal of the water and trifluoroacetic acid in vacuo gave a gum (3 mg for each reaction) that was reacted separately with (+)- and (-)-2-octanol (250 μL) and trifluroacetic acid (1 drop) at 100 °C overnight. Removal of the reagents in vacuo gave a mixture of 2-octylglycosides that were acetylated at room temperature with acetic anhydride and pyridine. Removal of the acetylation reagents under high vacuum gave a mixture of acetylated 2-octylglycosides. The mixture was dissolved in $CHCl_3$ and analyzed by capillary GC (DB-17 column; temperature program: 180°C for 2 min/increase at 5 °C per min/220 °C final temperature). The retention times and relative intensities were compared to those observed for the acetylated 2-octylglycosides of D- and L-fucose and L-rhamnose standards. The observed retention times were as follows: ((+)-2-octanol with L-fucose) 10.17, 11.00 min; ((+)-2-octanol with D-fucose) 9.91, 10.47, 10.65, 11.48 min; ((+)-2-octanol with L-rhamnose) 9.38, 9.55, 10.25 min; ((-)-2-octanol with L-rhamnose) 9.26, 10.04 min; ((+)-2-octanol with hydrolysis products) 9.36, 9.54, 9.91, 10.24, 10.47, 10.65, 11.48 min; ((-)-2-octanol with hydrolysis products) 9.26, 10.03, 10.17, 10.95.

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Supplementary Material Available: Tables II and III containing ^1H NMR data for the acetate **5** and the elimination product **6** (3 pages). Ordering information is given on any current masthead page.

Palladium-Catalyzed Selective Hydrogenolysis of Alkenyloxiranes with Formic Acid. Stereoselectivity and Synthetic Utility

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Abstract: Selective hydrogenolysis of alkenyloxiranes to give homoallylic alcohols was carried out using formic acid in the presence of palladium-phosphine catalyst. The selectivity of the reaction depends on a nature and an amount of phosphine ligands. The reaction proceeds stereoselectively, because the hydride derived from formic acid attacks the allyl groups intramolecularly from a palladium side of π-allylpalladium hydride intermediates. The stereoselectivity of hydride attack, which induces the ring opening of alkenyloxiranes, can be controlled by the olefin geometry of alkenyloxiranes. Thus, inversion of configuration at the oxirane carbon by the hydride attack was observed in the reaction of (*E*)-alkenyloxiranes, whereas configuration at the oxirane carbon was retained with (*Z*)-alkenyloxiranes owing to the anti-syn isomerization of the π-allylpalladium system prior to the hydride attack. On the basis of these observations, both (*S*)- and (*R*)-6,10-dimethyl-2-undecanones were synthesized with high enantiomeric purities starting from one enantiomer, (2*S*,3*S*)-6,6-(2,2-dimethylpropylenedioxy)-2,3-epoxy-2-methyl-1-heptanol.

Regio- or stereoselective epoxide-opening reaction is one of the most useful and promising synthetic methods for the preparation of optically active acyclic hydroxy compounds, because a wide variety of chiral epoxides are easily available with high enantiomeric purity by the Sharpless asymmetric epoxidation of allylic alcohols.[2,3] Although a number of ring-opening reactions of

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