2-Hydroxy-luisol A, a New Quinone-derived Tetraol from a Marine *Streptomyces* sp. and Oxidation Products of Luisol A*

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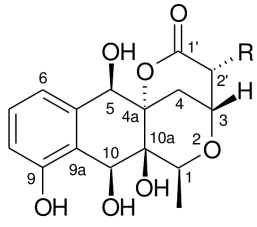
In addition to luisol A (**1a**), luisol B (**2**), and aloesaponarin II, the marine streptomycete B7617 produced a new derivative of **1a**, 2-hydroxy-luisol A (**1b**). In an attempt to increase the biological activity, luisol A (**1a**) was oxidized and delivered with Jones reagent or by Swern oxidation the derivatives **3a/3b** and **4a/4b**, respectively, but none of these compounds showed antimicrobial or cytotoxic activities. All structure elucidations are based on 2D NMR analyses or were derived by comparison with published data.

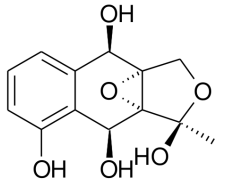
Key words: Luisol, Marine Streptomycetes

Introduction

In the course of our screening program for new antibiotics, aloesaponarin II [1], luisol A (**1a**) [2], luisol B (**2**) [2] and the new tetraol, 2-hydroxyluisol A (**1b**), were isolated from the marine actinomycete isolate B7617. Compounds **1a** and **1b** are tetraline derivatives related to granaticin [2] and particularly to MM44785 [3], nanaomycin E [4] and kalafungin [5], which are based on the same hydroxy-tetrahydropyrane system. Luisol B (**2**) [2] and the fungal metabolite arthrinone [6] are the only natural products possessing an epoxynaphtho[2,3c]furan skeleton.



1a: R = H
1b: R = OH



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Results and Discussion

The marine actinomycete B7617 isolated from the sediment of a littoral site near Punta Arenas, Tierra del Fuego (Chile), was found to be closely related with *Streptomyces rectiviolaceus*. The strain was cultivated in M_2 medium with 50 % seawater and worked up by ethyl acetate and solid phase extraction (Fig. S1 in the Supplementary Material; see note at the end of the article for availability). Chromatographic separation of the resulting crude extracts guided by chemical screening revealed a new metabolite termed 2-hydroxyluisol A (**1b**), and the previously reported metabolites luisol A (**1a**), luisol B (**2**), and aloesaponarin II.

The major compound **1a** was isolated as a colorless amorphous solid, which gave a brown coloration on spraying with anisaldehyde/sulfuric acid. The ^{13}C NMR spectrum indicated 16 signals, and the ESI mass spectrum delivered an $[M+Na]^+$ ion at $m/z = 345$. The ^1H NMR spectrum showed signals of a 1,2,3-trisubstituted benzene ring and of a CH_3-CH(O) fragment. These data identified [7] compound **1a** as luisol A, previously isolated from an estuarine *Streptomyces* sp. by Fenical *et al.* [2]; in a similar way, a second compound was identified as luisol B (**2**).

Compound **1b** was obtained as colorless gum. The molecular formula $C_{16}H_{18}O_8$ was deduced from the

* Art. No. XLV on Marine Bacteria. For XLIV, see: M. Ali Abdalla, E. Helmke, H. Laatsch. C. Fujianmycin, A Bioactive Angucyclinone from a Marine Derived *Streptomyces* sp. B6219. *Nat. Prod. Commun.* **2010**, *5*, 1917.

Table 1. ^{1}H (300 MHz) NMR data of luisol A (**1a**) and luisol derivatives in [D$_6$]DMSO and CDCl$_3$ (δ values, J in Hz).

No.	**1a** in [D$_6$]DMSO	**1b** in [D$_6$]DMSO	**3a** in CDCl$_3$	**3b** in [D$_6$]DMSO	**4a** in CDCl$_3$	**4b** in CDCl$_3$
2α'	2.88 (dd, 19.0, 5)	4.16 (d, 4.7)	2.98 (*A*BX, 19.5 br)	2.98 (*A*BX, 19.0, 5.0)	2.88 (d br, 19.5)	2.90 (*AB*X br, 19.0)
2β'	2.71 (d, 19.0)	–	2.80 (A*B*X, 19.5, 5.4)	2.71 (A*B*X br, 19.2)	2.82 (dd, 19.5, 5.1)	2.78 (*AB*X, 19.0, 5.1)
1	3.76 (q, 6.1)	3.60 (q, 6.1)	4.35 (q, 6.0)	3.92 (q, 5.9)	3.97 (q, 6.1)	3.97 (q, 6.0)
1-Me	1.34 (d, 6.1)	1.27 (d, 6.1)	1.48 (d, 6.0)	1.34 (d, 5.9)	1.32 (d, 6.2)	1.18 (d, 6.0)
3	4.38 (m)	4.23 (t, 4.3)	4.50 (m)	4.32 (m)	4.50 (m)	4.49 (m)
4α	1.71 (d, 13.6)	1.90 (d, 14.1)	2.20 (A*B*X, 14.6, 1.4)	1.88 (*AB*X, 14.0, 1.3)	2.28 (m)	2.11 (*AB*X br, 15)
4β	2.94 (dd, 13.0. 5)	2.85 (dd, 14.3. 5.1)	2.58 (*AB*XY, 14.6, 4.6, 2.3)	2.73 (*AB*X, 14.2, m)	2.36 (m)	2.60 (*AB*X 15.0, m)
5	4.34 (s)	4.27 (s)	–	4.58 (s)	–	–
6	6.88 (d, 7.6)	6.82 (d, 7.9)	7.60 (dd, 8.0, 1.3)	7.05 (d br, 7.3)	8.02 (dd, 8.1, 1.1)	7.90 (dd, 7.7, 1.2)
7	7.21 (t, 7.8)	7.15 (t, 7.8)	7.66 (t, 8.0)	7.62 (dd, 8.4, 7.3)	7.53 (t, 8.2)	7.50 (dd, 8.1, 7.7)
8	6.85 (d, 7.6)	6.78 (d, 7.9)	7.29 (dd, 7.4, 1.3)	6.95 (d br, 8.4)	7.32 (dd, 8.2, 1.3)	7.39 (dd, 8.1, 1.2)
10	4.64 (s)	4.50 (s)	–	–	6.14 (s)	6.35 (s)
OH	9.60, 5.60, 5.18 (3 s br)	5.95 (s, br, 1H)	11.15 (s)	11.20 (s), 6.40 (s br)	4.52 (s br)[a]	3.8 (s br)[a]
9/10-OAc					2.29 (s), 2.06 (s)	2.24 (s), 2.14 (s)

[a] Shifts strongly depend on measurement conditions.

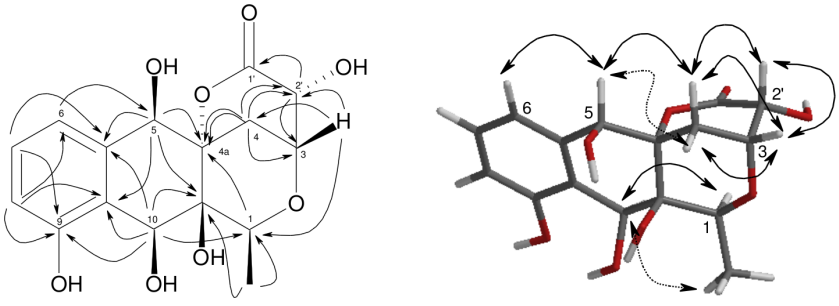
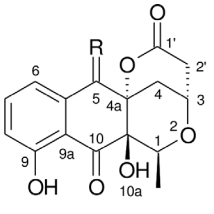


Fig. 1. HMBC correlations (→, left) and nO interactions (right) of 2-hydroxy-luisol A (**1b**); the conformation of **1b** as obtained by DFT calculations [8].

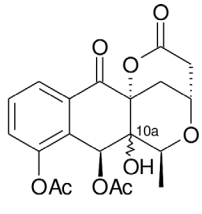
pseudo-molecular ion at $m/z = 361$ [M+Na]$^+$ by high-resolution ESI MS, *i. e.* **1b** has one oxygen atom more than **1a**. The ^{13}C NMR spectrum was very similar to that of **1a** with the only difference being the methylene signal of C-2′ at δ = 35.5 converted into an oxymethine signal at δ = 66.7. This agrees well with the hitherto unknown 2-hydroxy-luisol A (**1b**), which was fully confirmed by the ^{1}H and 2D NMR data (see Fig. 1 and Table 1).

The relative configuration was deduced from NOESY correlations: proton H-5 showed a strong nO effect with H-6, and H-10 coupled with H-1, so that both H-1 and H-10 should be in a *cis*-orientation as in **1a**. The proton H-2′ (δ = 4.16) showed besides the expected correlations with H-3 (δ = 4.23) a cross signal with H$_\alpha$-4, so that 2′-OH clearly adopted an α-configuration. The same signal of H$_\alpha$-4 (but not of H$_\beta$-4) was strongly coupled with H$_\alpha$-5, confirming the *pseudo*equatorial position in both cases (Fig. 1). Therefore the same relative configuration as for **1a** can be assumed for **1b**, with an additional (R^*)-hydroxy group at C-2′.

Oxidation of luisol A (**1a**) with Jones reagent afforded a light-yellow solid with the molecular formula



3a: R = O
3b: R = αH, βOH



4a: αOH
4b: βOH

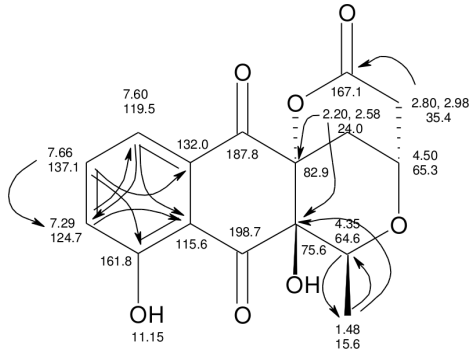
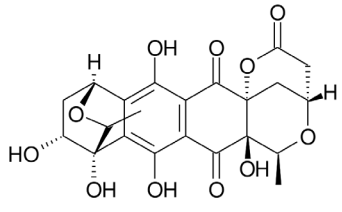


Fig. 2. HMBC correlations (→) of oxidation product **3a**.

No.	**1a**[a]	**1b**[a]	**3a**[b]	**3b**[a]	**4a**[b]	**4b**[b]
1′	169.2	172.7	167.1	168.2	167.6	167.3
2′	35.5	66.7	35.4	34.8	35.5	35.5
1	70.1	69.9	64.6	64.6	65.0	68.0
1-Me	15.9	15.6	15.6	16.1	13.8	14.9
3	65.5	69.8	65.3	65.3	66.2	65.4
4	28.0	28.1	24.0	26.5	25.0	24.6
4a	80.6	80.5	82.9	80.8	78.5	81.0
5	72.8	72.0	187.8[c]	71.0	188.2	188.4
5a	136.5	136.3	132.0	141.5	130.5	130.9
6	121.4	121.9	119.5	121.5	126.1	129.7
7	128.9	128.6	137.1	137.0	130.4	130.0
8	115.6	115.3	124.7	117.0	129.18	125.3
9	156.7	156.5	161.8	160.8	149.8	149.2
9a	122.1	121.2	115.6	113.5	129.22	129.2
10	67.5	67.0	198.7[c]	200.9	63.9	67.0
10a	71.9	71.5	75.6	72.9	72.0	74.5
9-OAc					169.8[d], 21.0	168.4, 21.2
10-OAc					169.7[d], 20.7	169.7, 21.3

Table 2. ^{13}C (75 MHz) NMR data of luisol A (**1a**) and luisol derivatives in [D$_6$]DMSO (δ values, J in Hz).

[a] [D$_6$]DMSO; [b] CDCl$_3$; [c] no HMBC cross signal between H-6 and CO-5 visible; assignment of CO-5/10 by means of chemical shifts; [d] acetate shifts may be exchanged.



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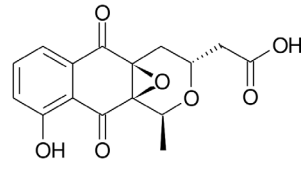

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$C_{16}H_{14}O_7$ (EI HRMS). In the ^{1}H NMR spectrum, the oxymethine signals H-5 and H-10 in **1a** had disappeared, and an additional signal of a chelated hydroxy group at δ = 11.16 was visible. The two additional carbonyl signals at δ = 187.8 and 198.7 did not show HMBC cross signals, however, their values agree well with the expected ^{13}C NMR shift difference of $\Delta\delta \sim$ 10 between chelated and non-chelated CO groups and confirmed structure **3a** (Fig. 2). Further ^{13}C NMR assignments (Table 2) were derived from 2D spectra and confirmed by comparison with **1a**. The proton H-1 showed a strong nO effect with the H$_\alpha$-2′ signal, thereby confirming retention of the previous (rel-(1*S*, 3*R*, 4a*S*, 5*R*, 10*S*, 11*R*)) configuration. Compound **3a** is a sub-structure of the antibiotics MM 44785 [3] and granaticin D (**5**) from *Streptomyces* sp. GW 37/655 [9], respectively, and could also be expected as a natural product by an intramolecular cyclization of the (hitherto unknown) nanaomycin E stereoisomer **6**.

Oxidation of **1a** with pyridinium dichromate afforded the partially oxidized colorless solid **3b** with the formula $C_{16}H_{16}O_7$. Its proton NMR spectrum was similar to that of **3a**, however, the carbonyl signal at high field corresponding to C-5 in **3a** was lacking, and instead an oxymethine singlet at δ = 4.58 was visible;

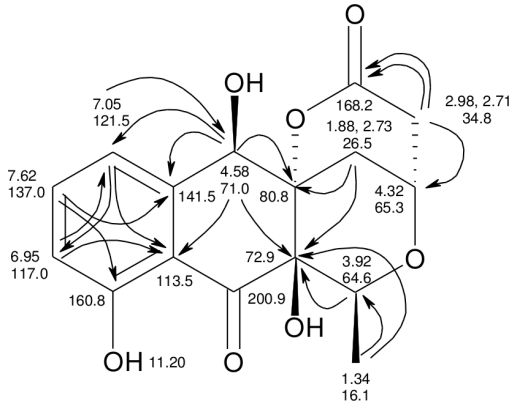

Fig. 3. HMBC correlations (→) of oxidation product 3b.

the signal of 9-OH remained nearly unchanged with respect to **3a** (δ = 11.20). The HMBC correlations of H-5, especially with C-6, along with the carbon shifts distinguished between **3a** and the isomer with the carbonyl group at C-5, and finally led to the structure **3b** (Fig. 3) with an unchanged configuration assumed with respect to **1a**.

Swern oxidation of **1a** with DMSO in acetic anhydride delivered two isomeric keto-diacetates as amorphous solids with the molecular formula $C_{20}H_{20}O_9$.

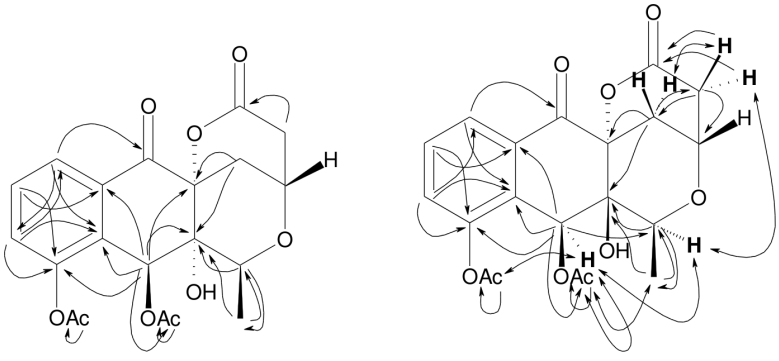

Fig. 4. HMBC (→) and selected NOESY (⇆) correlations (distance > 3 bonds) of oxidation products **4a** (left) and **4b** (right).

The ^{13}C NMR spectrum of both compounds displayed four carbonyl signals, among which three were assigned to esters or lactones, and the signals at $\delta \sim 188$ were attributed to conjugated ketones. There was a strong downfield shift of the H-6 dd signal from δ = 6.88 in **1a** to 8.00 and 7.90, respectively, indicating an influence of a carbonyl group at C-5 in both isomers similar as in **3a**. This was further proven by the respective HMBC correlations of H-6 with signals at $\delta \sim 188$; correspondingly, only the oxymethine singlet of H-10 was found in both isomers. Each of the two further carbonyl and methyl signals were due to two acetate groups in both products.

In both isomers, C-9 showed a substantial upfield shift ($\delta \sim 149$) with respect to the previous compounds (see Table 2), indicating an acetylation of 9-OH. The HMBC spectrum showed cross signals between the methine singlets of H-10 and an acetate carbonyl ($\sim$ 169), proving that the second acetoxy group was attached to C-10 in both oxidation products, and identifying them as diastereomers (Fig. 4). The isomers differed in the shifts of the oxymethine protons H-10 and the 10-acetate methyls (δ = 6.17/6.35 and 2.06/2.14). The strongest ^{13}C shift differences were observed for C-1, 4a, 10, and 10a.

The nO interactions were nearly identical for both isomers: the proton H_α-1 showed a strong nO effect with H_α-2′ and H_α-10, indicating unchanged configurations at C-1 and C-10. Besides with H_α-2′ and H-3, the proton H_β-2′ coupled only with H_α-4. Unexpectedly, there was no nO interaction between the acetate groups, and only a very weak cross signal between 1-Me and 10-OAc, indicating an axial orientation of 10-OAc and an equatorial position of 1-Me: this confirmed that both oxidation products are C-10a epimers. DFT calculations [8] delivered for C-10 and C-10a in the 4a,10a-*cis* fused isomer lower ^{13}C shifts than for the *trans* isomer. According to the experimental ^{13}C values, we therefore tentatively assume, that the more polar diacetate has the relative configuration **4a**, and the other one is **4b**.

Biological activity

Antibacterial and antifungal activities were determined using the agar diffusion method. In spite of the structural similarity of compounds **1a**–**3b** with antibiotics of the nanaomycin group and other naphthoquinones, they were inactive against *Bacillus subtilis*, *Streptomyces viridochromogenes* (Tü 57), *Staphylococcus aureus*, *Escherichia coli*, *Candida albicans*, *Mucor miehei*, and the micro-algae *Chlorella vulgaris*, *Chlorella sorokiniana* and *Scenedesmus subspicatus* up to a concentration of 100 μg mL^{-1}.

Experimental Section

NMR spectra were measured on Varian Unity 300 (^{1}H, 300.145 MHz), Varian Inova 500 (499.876 MHz) and Varian Inova 600 (599.740 MHz) spectrometers. Electron spray ionization mass spectrometry (ESI HRMS) was done on a Finnigan LCQ ion trap mass spectrometer. High-resolution mass spectra (HRMS) were recorded by ESI MS on an Apex IV 7 Tesla Fourier-Transform Ion Cyclotron Resonance Mass Spectrometer (Bruker Daltonics, Billerica, MA, USA). EI mass spectra were recorded on a Finnigan MAT 95 spectrometer (70 eV, Thermo Electron Corp., Bremen, Germany) using perfluorokerosene as the reference substance for EI HRMS. UV/Vis spectra were recorded on a Varian Cary 3E UV/Vis spectrometer. IR spectra were recorded on a Perkin-Elmer 1600 Series FT-IR spectrometer (KBr pellets). Flash chromatography was carried out on silica gel (230–400 mesh); R_f values were measured on silica gel TLC cards Polygram SIL G/UV$_{254}$ (Macherey-Nagel & Co., Düren, Germany). Size-exclusion chromatography was done on Sephadex LH-20 (Lipophilic Sephadex, Amersham Bioscience Ltd. purchased from

Sigma-Aldrich Chemie, Steinheim, Germany). XAD-16 adsorber resin was obtained from Rohm and Haas (Frankfurt, Germany).

M_2^+ Medium

Malt extract (10 g), yeast extract (4 g) and glucose (4 g) were dissolved in 500 mL of tap water and 500 mL of artificial sea water and adjusted to pH = 7.8 with 2 N NaOH and sterilized for 30 min at 121 °C. After sterilization, a pH of 7.0 was attained.

Taxonomic characteristics of strain B7617

Strain B7617 has been isolated from the sediment of a littoral site near Punta Arenas (Tierra del Fuego, Chile) using chitin agar containing 50 % natural seawater and an incubation temperature of 8 °C. The reference culture of B7617 is kept on yeast extract-malt extract agar in the Collection of Marine Actinomycetes at the Alfred Wegener Institute for Polar and Marine Research in Bremerhaven.

The almost complete 16S rRNA gene sequence of the strain B7617 (accession no. DQ026660) showed 99 % similarity with *Streptomyces rectiviolaceus*. The strain formed a beige substrate mycelium and a very sparse aerial mycelium. The mycelium showed about 4 μm long spikes (see Fig. S2 in the Supplementary Material). Melanin pigment was neither produced on peptone-yeast extract-iron agar nor on tyrosine agar [10]. The optimum growth temperature was at about 20 °C. The strain showed good growth at 10 °C but did not grow at 36 °C. Growth was obtained in media from 0 % up to 7 % seawater salinity. Starch and casein were degraded, chitin was not hydrolyzed [11]. Nitrate reductase was not produced.

Fermentation, extraction and isolation

The strain B7617 was cultivated in a 15 L shaking culture (linear shaker) using M_2 medium with 50 % artificial seawater at 28 °C for 4 d. The brown fermentation broth was filtered under pressure. The mycelium was extracted with ethyl acetate and finally with acetone to yield a light-yellow extract A, while the water phase was subjected to XAD-16 adsorption. The resin was washed with tap water (20 L) and finally eluted with methanol (10 L), and the eluate was evaporated under reduced pressure to yield an oily extract B. Extract A was washed with cyclohexane and separated by PTLC (CH_2Cl_2/5 % MeOH), to deliver 3 mg of aloesaponarin II. Separation of extract B on Sephadex LH-20 (CH_2Cl_2/50 % MeOH) and afterwards preparative HPLC with MeCN/80 % H_2O led to luisol A (**1a**, 300 mg), luisol B (**2**, 7 mg), and 2-hydroxy-luisol A (**1b**, 4 mg).

*Luisol A (**1a**)*

Colorless solid, R_f = 0.58 (CH_2Cl_2/15 % MeOH). – NMR data see Tables 1 and 2. – MS ((+)-ESI): m/z (%) = 345 (8) $[M+Na]^+$, 667 (100) $[2M+Na]^+$. – MS ((–)-ESI): m/z (%) = 321 (100) $[M–H]^-$, 643 (98) $[2M–H]^-$.

*2-Hydroxy-luisol A (**1b**)*

Colorless gum, R_f = 0.42 (CH_2Cl_2/15 % MeOH). – UV/Vis (MeOH): $\lambda_{max}(\lg\varepsilon)$ = 280 (2.72), 219 (sh, 3.30) nm. – $[\alpha]_D^{21}$ = −4.4° (c = 0.045, MeOH). – IR (KBr): ν = 3355 (br, OH), 2258, 2130, 1745 (CO), 1647, 1594, 1466, 1385, 1278, 1154, 1105, 995, 953, 826, 765, 733 cm^{-1}. – NMR data: see Tables 1 and 2 and Fig. S3 and S4 in the Supplementary Material. – MS ((+)-ESI): m/z (%) = 361 (3) $[M+Na]^+$, 699 (100) $[2M+Na]^+$. – MS ((–)-ESI): m/z = 337 $[M–H]^-$. – HRMS ((+)-ESI): m/z = 361.08939 (calc. 361.08940 for $C_{16}H_{18}O_8Na$, $[M+Na]^+$).

*Oxidation of luisol A (**1a**)*

a) Luisol A (**1a**, 12 mg, 0.037 mmol) was dissolved in acetone (5 mL), and Jones reagent (2 ml) [solution of chromium trioxide (26.72 g) in 23 mL of sulfuric acid and 100 mL of precooled water] was added under stirring at r. t. The reaction mixture was stirred overnight, filtered off from undissolved particles and extracted with dichloromethane and ether. The organic phase was concentrated under vacuum and separated by PTLC (CH_2Cl_2/5 % MeOH) to yield **3a** (8.8 mg, 75.7 %).

b) To a solution of luisol A (**1a**, 10 mg, 0.031 mmol) in 5 mL acetone, 40 mg of pyridinium chlorochromate was added. The reaction mixture was stirred for 3 h followed by extraction with dichloromethane and separated by preparative TLC to afford **3b** (4 mg, 42 %).

c) To a solution of luisol A (**1a**, 25 mg, 0.078 mmol) in DMSO (1.5 mL), acetic anhydride (0.6 mL) was added at r. t., and the mixture was stirred for 3 h. Distilled water (50 mL) was added to the reaction mixture, and the latter was extracted with dichloromethane. The organic phase was separated by preparative TLC to yield **4a** (5.8 mg, 18.4 %) and **4b** (4 mg, 12.7 %).

[(1S,3R*,4aR*,10aR*)-4a,9,10a-Trihydroxy-1-methyl-5,10-dioxo-3,4,4a,5,10,10a-hexahydro-1H-benzo[g]isochromen-3-yl]-acetic acid 4a-lactone (**3a**)*

Light-yellow solid, R_f = 0.38 (CH_2Cl_2/5 % MeOH). – UV/Vis (MeOH): $\lambda_{max}(\lg\varepsilon)$ = 336 (3.63), 260 (sh, 3.62), 241 (sh, 3.93) nm. – IR (KBr): ν = 3438, 2924, 2854, 2361, 2341, 1734, 1717, 1654, 1560, 1541, 1457, 1385, 1280, 1230, 1174, 1077, 1096, 1054, 996, 852, 802, 779, 714 cm^{-1}. – NMR data: see Tables 1 and 2 and Fig. S5 in the Supplementary Material. – MS ((+)-ESI): m/z (%) = 318 (16) $[M]^+$, 230 (100), 215 (20), 202 (18). – HRMS (EI): m/z = 318.0740 (calcd. 318.0739 for $C_{16}H_{14}O_7$, $[M]^+$).

[(1S,3R*,4aS*,10R*,10aR*)-4a,9,10,10a-Tetrahydroxy-1-methyl-10-oxo-3,4,4a,5,10,10a-hexahydro-1H-benzo[g]-isochromen-3-yl]-acetic acid-4a-lactone (**3b**)*

Colorless solid, R_f = 0.31 (CH_2Cl_2/5 % MeOH). – UV/Vis (MeOH): $\lambda_{max}(\lg\varepsilon)$ = 318 (3.56), 247 (3.93). – IR (KBr): ν = 3416, 2922, 2852, 2361, 1736, 1653, 1617, 1578, 1542, 1385, 1350, 1321, 1296, 1248, 1166, 1137, 1097, 1080, 1051, 1024, 1001, 961, 883, 837, 818, 759, 726, 695, 679, 556 cm^{-1}. – ^1H NMR (MeOD, 300 MHz): δ = 7.58 (dd, *J* = 8.4, 7.5 Hz, 1 H, H-7), 7.02 (dd, *J* = 7.5, 1.1 Hz, 1 H, H-8), 6.92 (dd, *J* = 8.4, 1.1 Hz, 1 H, H-6), 4.61 (s, 1 H, H-5), 4.40 (m, 1 H, H-3), 4.07 (q, *J* = 6.0 Hz, 1 H, H-1), 2.93, 2.82 (*AB*X, *J* = 14.3, 1.6 Hz, 2 H, H-2′), 2.96, 1.88 (ABX br, *J* = 14.3, 1.6 Hz, 2 H, H_2-4), 1.46 (d, *J* = 6.0 Hz, 3 H, 1-CH_3); for spectra in [D_6]DMSO: see Tables 1 and 2 and Fig. S6 in the Supplementary Material. – MS ((+)-EI; 70 eV): *m*/*z* (%) = 320 (100) $[M]^+$, 302 (10), $[M–H_2O]^+$, 284 (16), 276 (32), 258 (24), 230 (33), 208 (16), 191 (92), 149 (18), 129 (24), 121 (28), 73 (36), 57 (44), 43 (50), 41 (52). – HRMS (EI): *m*/*z* = 320.0896 (calcd. 320.0896 for $C_{16}H_{16}O_7$, $[M]^+$).

[(1S,3R*,4aR*,10S*,10aS*)-9,10-Diacetoxy-4a,10a-dihydroxy-1-methyl-5-oxo-3,4,4a,5,10,10a-hexahydro-1H-benzo[g]isochromen-3-yl]-acetic acid-4a-lactone (**4a**)*

Amorphous, colorless solid, R_f = 0.38 (CH_2Cl_2/5 % MeOH). – UV/Vis (MeOH): $\lambda_{max}(\lg\varepsilon)$ = 280 sh, 238 (3.81). – IR (KBr): ν = 3433, 2925, 2854, 1743, 1716, 1634, 1603, 1458, 1373, 1285, 1231, 1179, 1096, 1056, 1026, 913, 799, 710 cm^{-1}. – NMR data: see Tables 1 and 2 and Fig. S7 in the Supplementary Material. – MS ((+)-ESI): *m*/*z* (%) = 427 (100) $[M+Na]^+$, 831 (10) $[M+Na]^+$. – HRMS ((+)-ESI): *m*/*z* = 427.0996 (calcd. 427.1000 for $C_{20}H_{20}O_9Na$, $[M+Na]^+$).

[(1S,3R*,4aR*,10S*,10aR*)-9,10-Diacetoxy-4a,10a-dihydroxy-1-methyl-5-oxo-3,4,4a,5,10,10a-hexahydro-1H-benzo[g]isochromen-3-yl]-acetic acid-4a-lactone (**4b**)*

Amorphous, colorless solid, R_f = 0.46 (CH_2Cl_2/5 % MeOH). – UV/Vis (MeOH): $\lambda_{max}(\lg\varepsilon)$ = 285 (sh, 3.45), 237 (4.12). – IR (KBr): ν = 3475, 2924, 2852, 1756, 1715, 1602, 1464, 1435, 1372, 1345, 1315, 1286, 1232, 1177, 1107, 1085, 1057, 1024, 986, 930, 860, 778, 744, 707, 688, 598 cm^{-1}. – NMR data: see Tables 1 and 2 and Fig. S8 in the Supplementary Material. – HRMS ((+)-ESI): *m*/*z* = 427.09995 (calcd. 427.09995 for $C_{20}H_{20}O_9Na$, $[M+Na]^+$).

Supporting information

Work-up procedure, high-resolution SEM image of *Streptomyces* sp. B7617, ^1H NMR spectra of **1b**, **3a**, **3b**, **4a**, and **4b** are available as Supporting Information (online only).

Acknowledgements

We thank R. Machinek for the NMR measurements, Dr. H. Frauendorf for the mass spectra and F. Lissy and A. Kohl for technical assistance. Financial support of this work by a grant from the Bundesministerium für Bildung und Forschung (BMBF, grant 03FO233A) is gratefully acknowledged.

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Supporting information

2-Hydroxy-luisol A, a New Quinone-derived Tetraol from a Marine *Streptomyces* sp. and Oxidation Products of Luisol A

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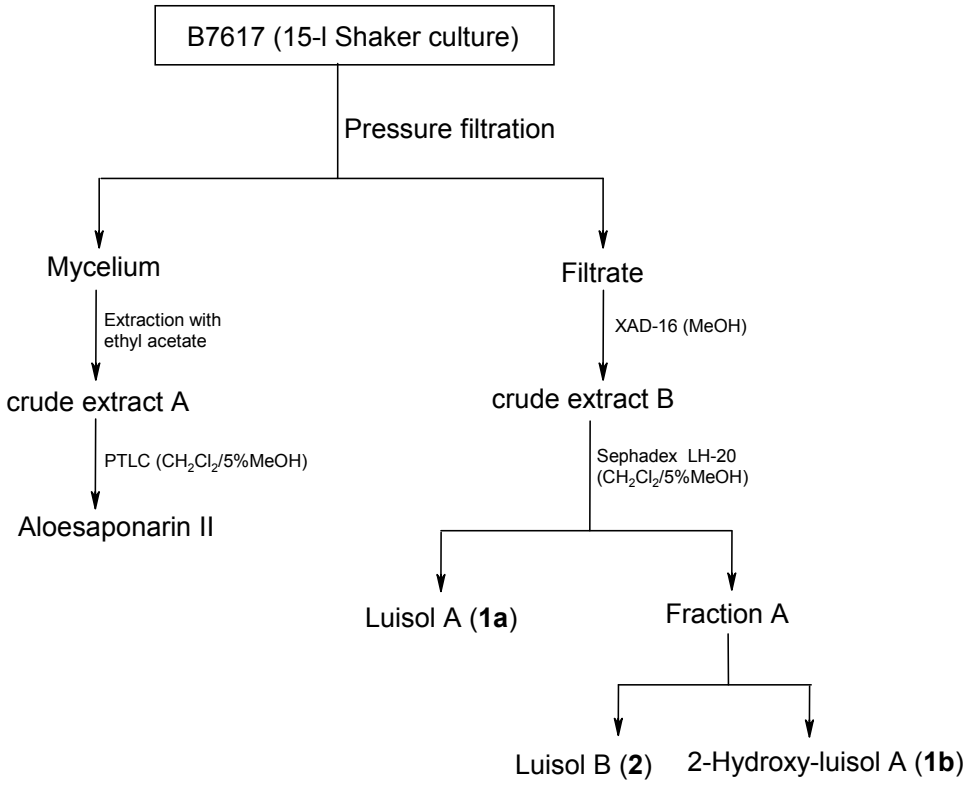

Figure S1. Work up of the marine *Streptomyces* sp. B7617.

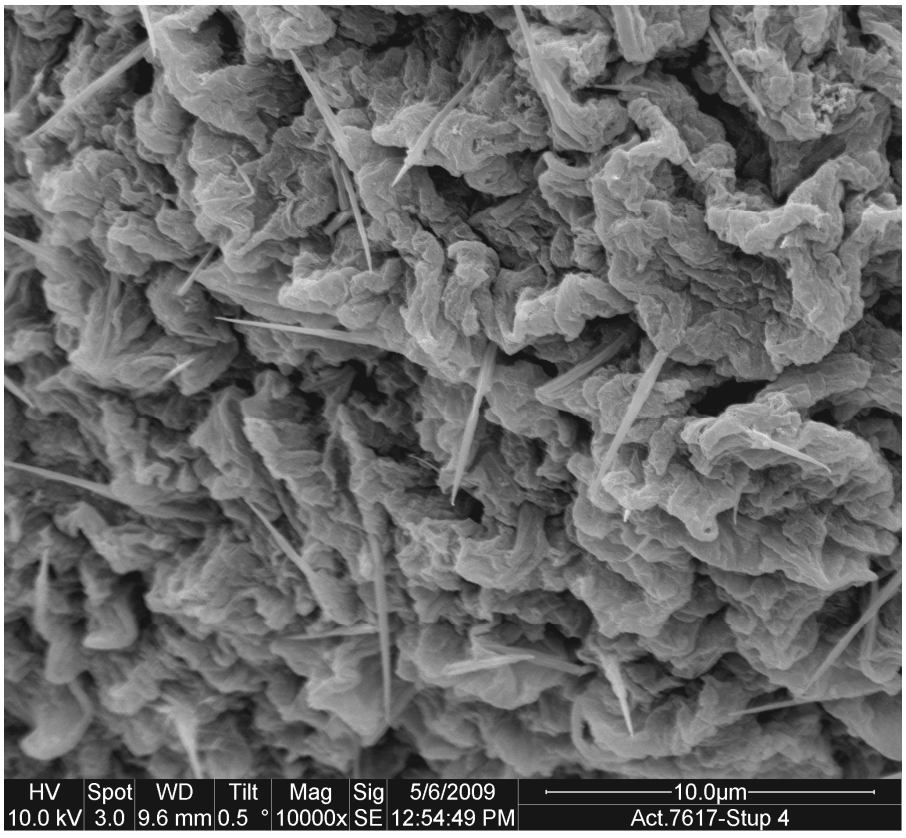

Figure S2. High-resolution SEM image of *Streptomyces* sp. B7617.

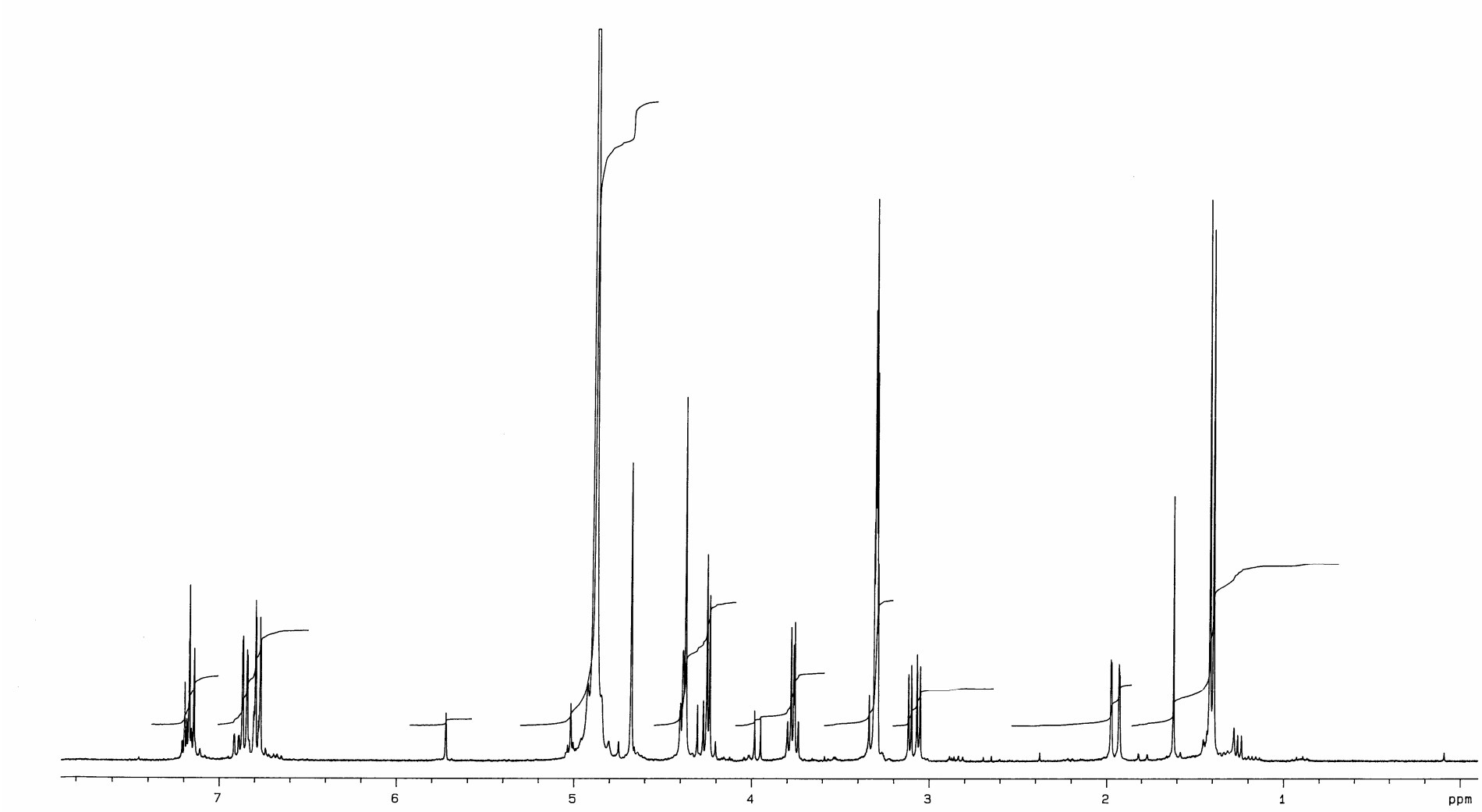

Figure S3. ^{1}H NMR spectrum of 2-hydroxyluisol A (**1b**) in [D_4]MeOD.

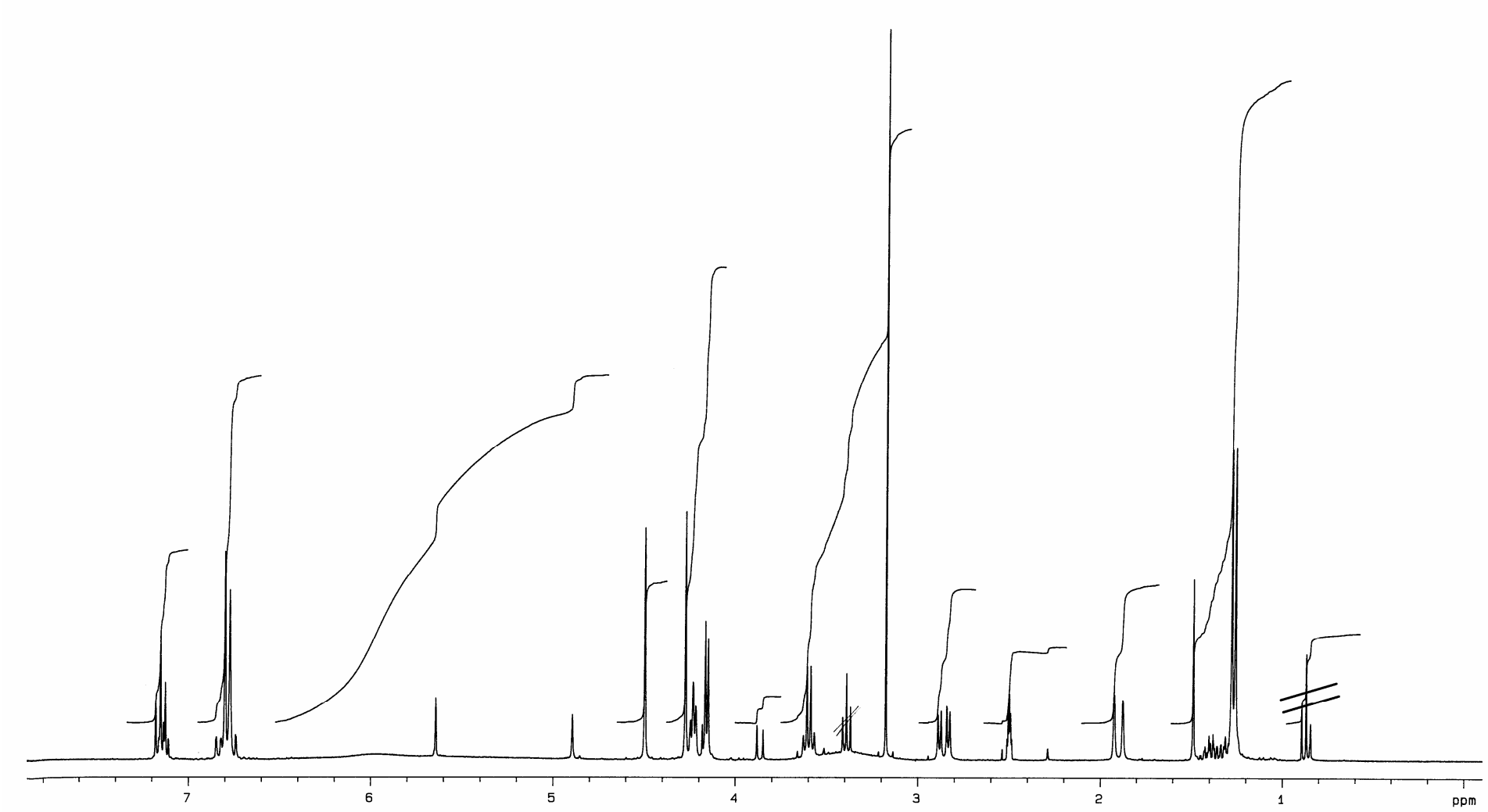

Figure S4. ^{1}H NMR spectrum of 2-hydroxyluisol A (**1b**) in [D_6]DMSO.

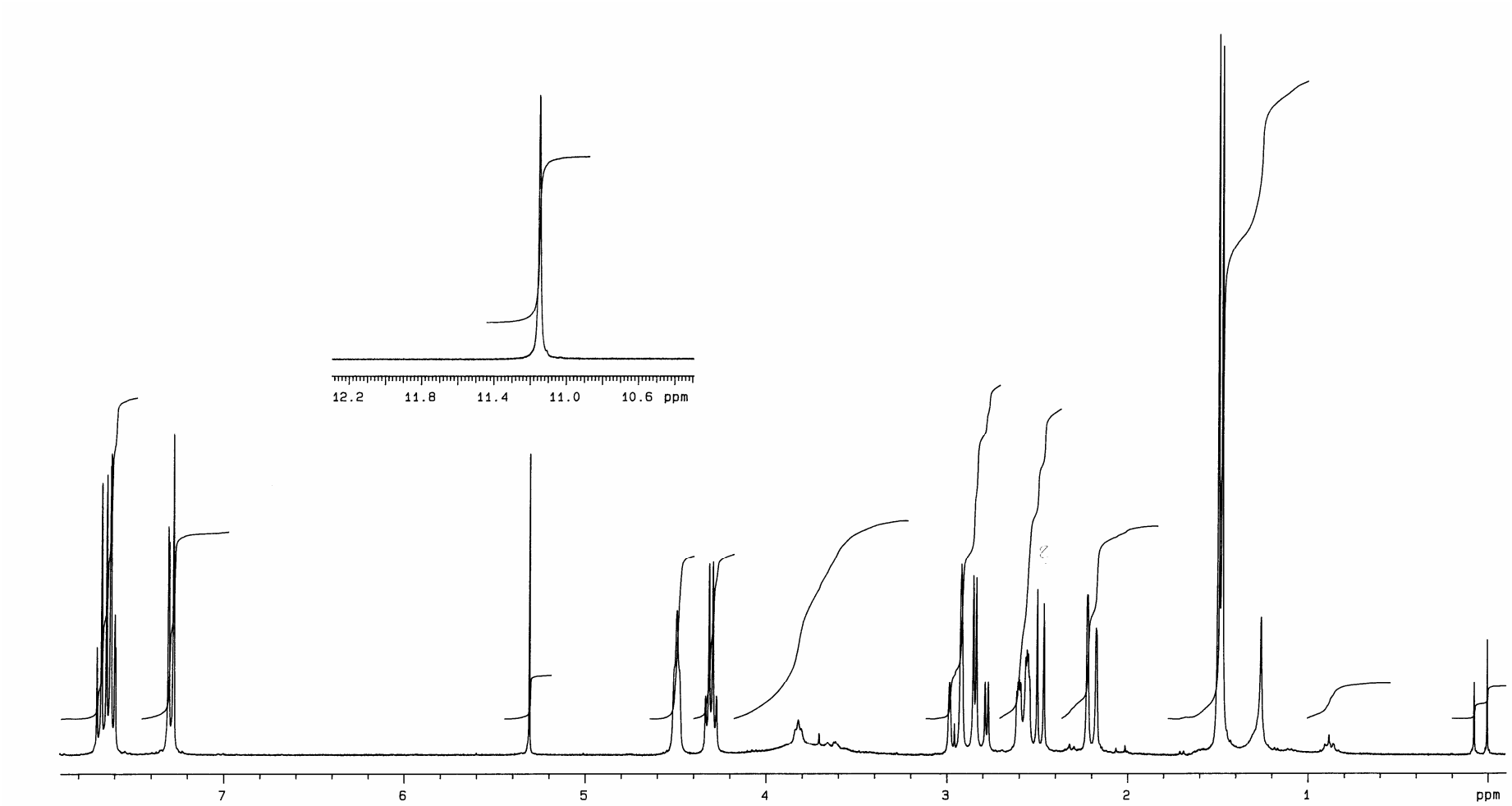

Figure S5. ^{1}H NMR spectrum of [(1*S**,3*R**,4a*R**,10a*R**)-4a,9,10a-Trihydroxy-1-methyl-5,10-dioxo-3,4,4a,5,10,10a-hexahydro-1H-benzo[g]isochromen-3-yl]-acetic acid 4a-lactone (**3a**) in $CDCl_3$.

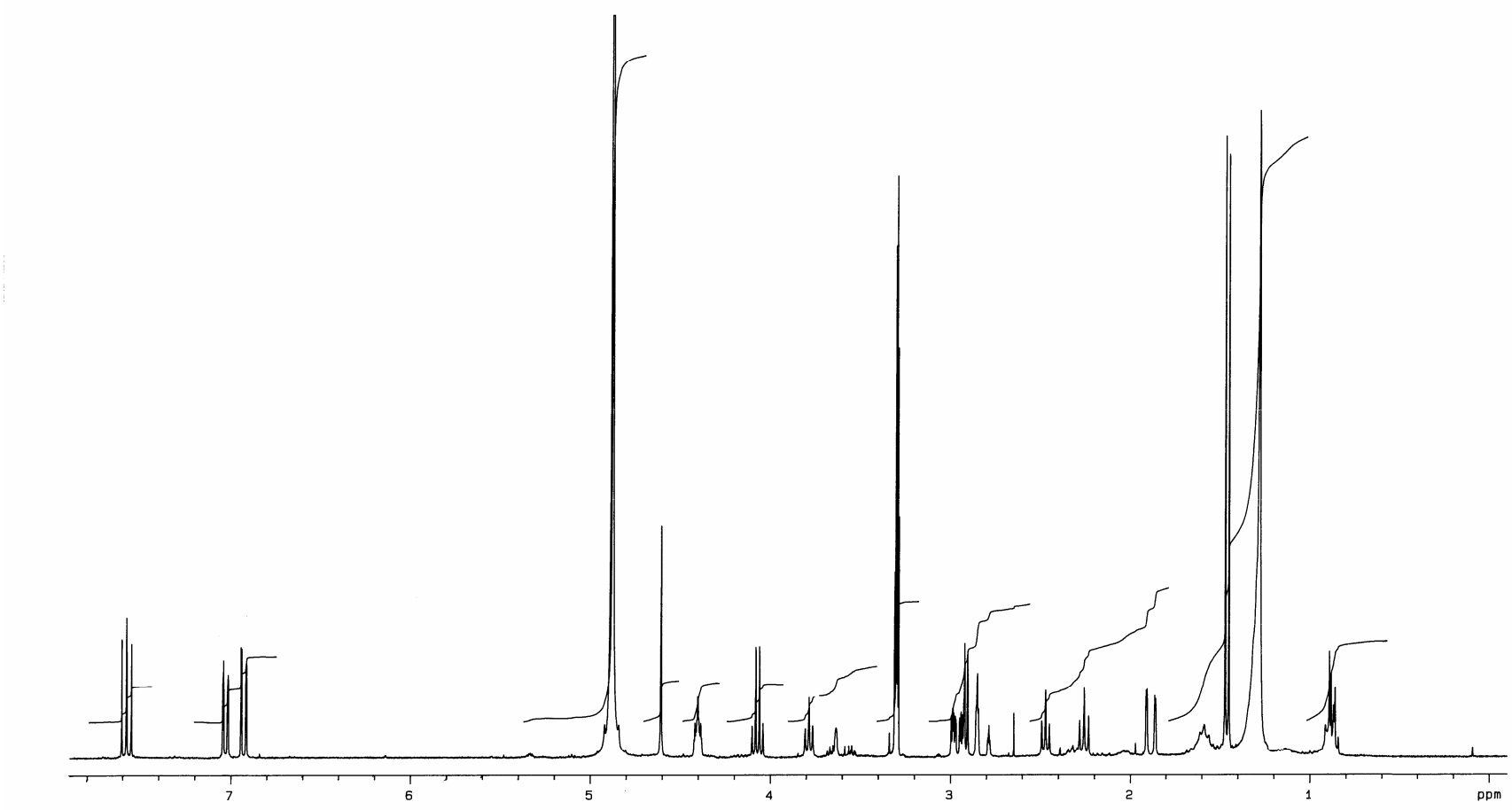

Figure S6. ^{1}H NMR spectrum of [(1*S**,3*R**,4a*S**,5*R**,10a*R**)-4a,5,9,10a-tetrahydroxy-1-methyl-10-oxo-3,4,4a,5,10,10a–hexahydro-1H-benzo[g]isochromen-3-yl]-acetic acid-4a-lactone (**3b**) in [D_4]MeOD.

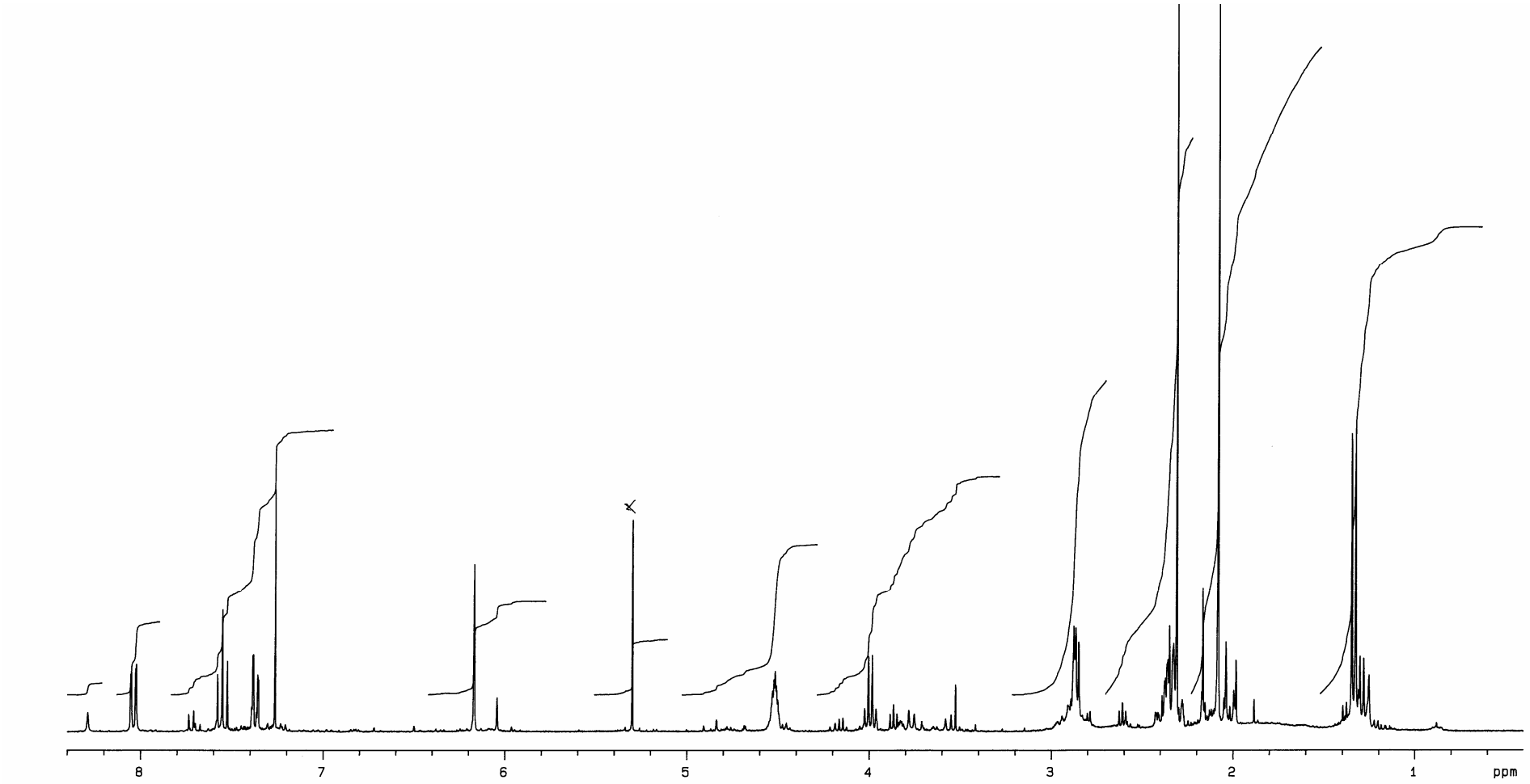

Figure S7. ^{1}H NMR spectrum of [(1*S**,3*R**,4a*R**,10*S**,10a*R**)-9,10-diacetoxy-4a,10a-dihydroxy-1-methyl-5-oxo-3,4,4a,5,10,10a–hexahydro-1H-benzo[g]isochromen-3-yl]-acetic acid-4a-lactone (**4a**) in $CDCl_3$.

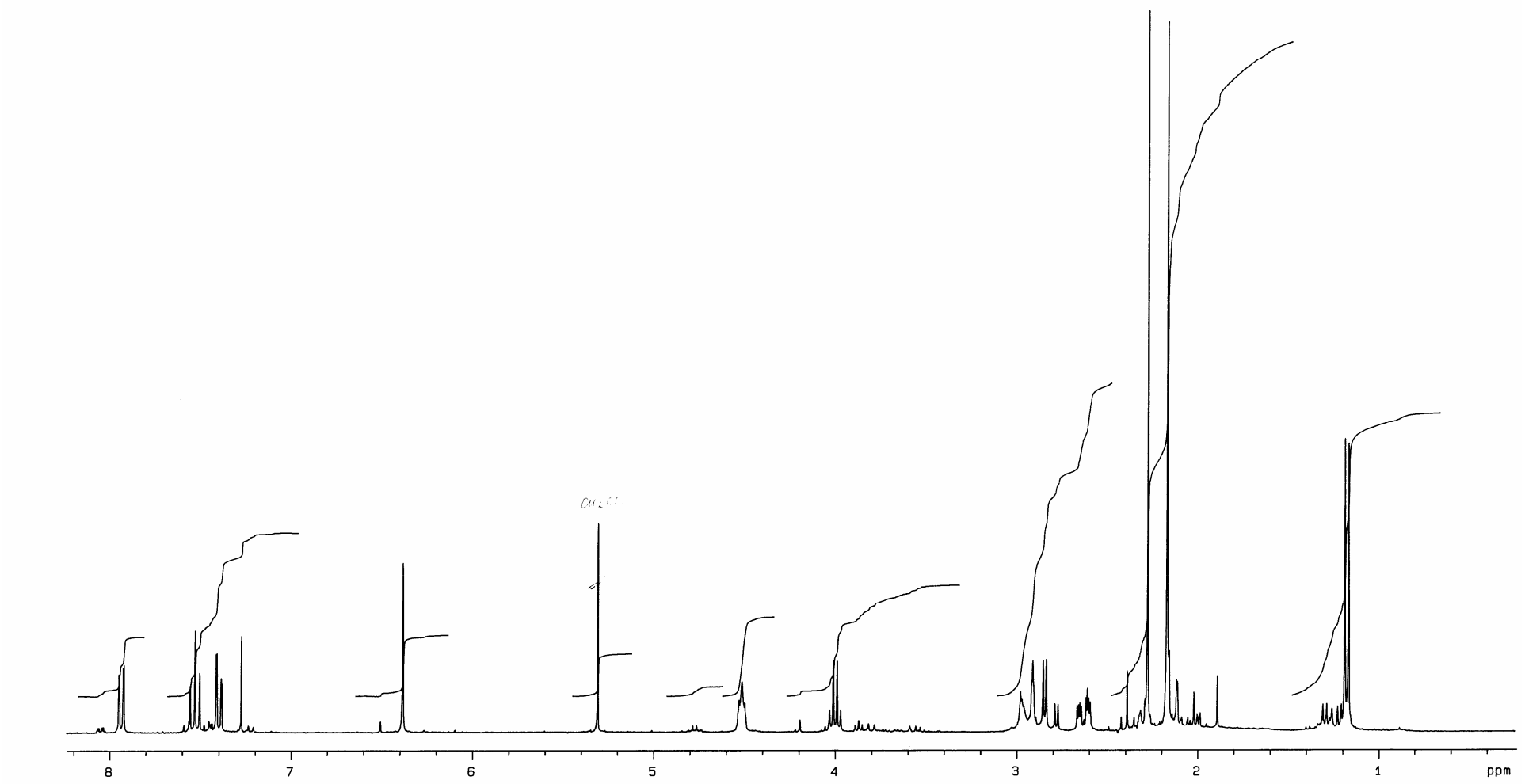

Figure S8. ^{1}H NMR spectrum of [(1*S**,3*R**,4a*R**,10*S**,10a*R**)-9,10a-diacetoxy-4a,10-dihydroxy-1-methyl-5-oxo-3,4,4a,5,10,10a–hexahydro-1H-benzo[g]isochromen-3-yl]-acetic acid-4a-lactone (**4b**) in $CDCl_3$.