Eleven New Eudesmane Derivatives from *Laggera pterodonta*

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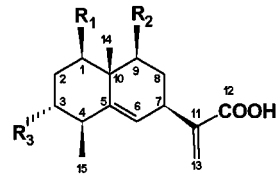
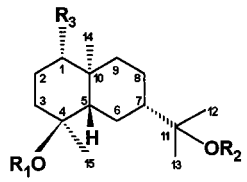
A phytochemical investigation of *Laggera pterodonta* afforded, in addition to several known compounds, three new eudesmane sesquiterpenes (**1**−**3**) and eight new eudesmane glucosides (pterodontosides A−H; **4**−**11**). The structures of **1**−**11** were elucidated by highfield 1D and 2D NMR techniques as well as by chemical methods.

Laggera pterodonta (DC.) Benth. (Compositae), which is called "Chou Ling Dan", is widely distributed in southwestern regions in the People's Republic of China, especially in Yunnan and Sichuan Provinces. This herb is commonly cultivated domestically and has been traditionally employed as a medicine because it has antiinflammatory and antibacterial properties and has been used as a cure for angina, bronchitis, influenza, and malaria. Externally applied, this plant has been of use in treating scabies, burns, bites by poisonous snakes, injuries from falls, fractures, and contusions and strains.[1] On the basis of previous biological testing, *L. pterodonta* has been found to possess antileukemic activity,[1] as well as expectorant and antibronchitis effects.[1] Phytochemically, several eudesmane derivatives and flavones have been isolated from this plant.[2−5]

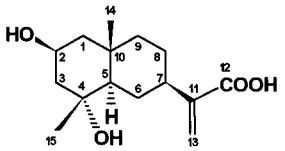
In the present work, a thorough investigation of the *n*-BuOH extract of *L. pterodonta* has led to the isolation of 18 compounds, of which three (**1**−**3**) are new eudesmanoic acids and eight are new eudesmanoic glucosides (pterodontosides A−H; **4**−**11**). Seven known compounds were obtained, namely, 2α,3*β*-dihydroxypterodontic acid,[3] tormentic acid,[6,7] 3-hydroxycoumarin, D-mannitol, pterodontriol B,[2] palmitic acid *β*-D-glucoside, and thapsic acid *β*-D-glucoside, which were identified by comparing their physical properties and NMR spectra with those in the literature or by direct comparison with authentic samples. Details of the isolation and structure determination of the novel compounds **1**−**11** are discussed in this paper.



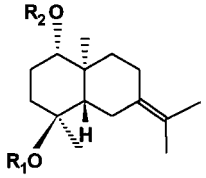
1 R_1=R_2=OH, R_3=H
2 R_1=R_3=OH, R_2=H
4 R_1=O−β−D−Glc, R_2=R_3=H
5 R_1=R_3=H, R_2= O−β−D−Glc
4a R_1=OH, R_2=R_3=H



6 R_1=β−D−Glc, R_2=R_3=H
7 R_1=R_3=H, R_2=β−D−Glc
8 R_1=β−D−Glc, R_2=H, R_3=OH
9 R_1=R_2=H, R_3= O−β−D−Glc
6a/7a R_1=R_2=R_3=H
8a/9a R_1=R_2=H, R_3=OH



3



10 R_1=β−D−Glc, R_2=H
11 R_1=H, R_2= β−D−Glc

Results and Discussion

The EIMS and FABMS data of **1**, together with its ^{13}C-NMR spectrum and elemental analysis, indicated a molecular formula of $C_{15}H_{22}O_4$. The observation of $[M - H_2O]^+$ and $[M - 2\ H_2O]^+$ peaks in the mass spectrum showed the presence of at least two hydroxyl groups, a conclusion confirmed by the IR spectrum (see Experimental Section). The latter further suggested the presence of a conjugated carboxyl functionality, which was supported by the UV spectrum (206, 215, 263 nm) and by the ^{13}C-NMR signals at 169.58 (C=O), 146.77 (C), and 123.11 (CH_2) ppm. The sharp singlet at δ_H 1.52 in the ^{1}H-NMR spectrum suggested an eudesmane derivative, especially in view of the strong similarity of the NMR spectral data of **1** with those of 1*β*-hydroxypterodontic acid, previously found in this same species.[3] The main difference between the spectra of these compounds was the presence of an additional ^{1}H-NMR signal at δ_H 4.21 (dd, J = 12.0, 3.2 Hz) and a ^{13}C-NMR signal at 81.36 ppm (CH), in the case of compound **1**. Therefore, it was inferred that the structure of **1** corresponds to that of 1*β*-hydroxypterodontic acid but with a second hydroxyl group present, which must be located at C-9, in view of the ^{1}H-NMR signal multiplicity observed and the downfield ^{13}C-NMR shifts of C-8 and C-10 of **1** in comparison to the analogous data of 1*β*-hydroxypterodontic acid.[3] The coupling constants clearly indicated that H-9 is axial, so the OH-9 group is *β* oriented. Compound **1** was therefore assigned as 1*β*,9*β*-dihydroxy-4α*H*-eudesma-5,11(13)-dien-12-oic acid.

The IR, UV, and MS data of **2** were very similar to those of **1**, which suggested that it was a dihydroxylated eudesmane acid. Comparison of their NMR data (see Experimental Section) revealed that **2** retained most of the structural features of **1** with the exception of the OH-9 group; however, the ^{1}H-NMR signal at δ_H 4.22 (ddd, J = 5.1, 5.0, 5.0 Hz) strongly suggested that the second hydroxyl group was axial and had to be located at C-3. This conclusion was confirmed by the H-4 signal, which appeared as a broadened double quadruplet at δ_H 2.93 (J = 7.0, 5.0 Hz). The downfield shift of C-2 and C-4, when compared with those of **1**, also

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supported the presence of an OH-3α group. Accordingly, compound **2** was assigned as 1*β*,3α-dihydroxy-4α*H*-eudesma-5,11(13)-dien-12-oic acid.

Compound **3** was also a dihydroxylated eudesmane acid (NMR and MS data) but lacked a C=C bond. One of the OH groups was tertiary (quaternary carbon ^{13}C-NMR signal at 70.9 ppm). This resonance and the ^{1}H-NMR singlet at δ_H 1.79 (Me-15) suggested that this OH group was at C-4. The other hydroxyl was secondary (CH signal at 67.8 ppm) and gave rise to a broad triplet at δ_H 4.56 (J = 3.3 Hz). The small coupling constants indicated an equatorial hydrogen. Because this signal was coupled with two methylene groups that were most likely at C-1 and C-3, on the basis of their shape and coupling constants, the remaining hydroxyl group was thus located at C-2*β*. Compound **3** is therefore 2*β*-hydroxyillicic acid. The stereochemistry of C-4 was supported by a clear NOE observation between Me-14 and Me-15.

The ^{13}C-NMR spectrum of **4** (see Experimental Section) showed 21 signals, of which six resonated in the oxygenated carbon zone (60−90 ppm). One methine signal at 102.4 ppm suggested an anomeric carbon. This and the high number of oxygenated carbons gave support to **4** being a sesquiterpene glycoside. The FABMS showed a base peak at *m*/*z* 232, 180 amu below the probable molecular peak at *m*/*z* 412, which was in good agreement with the loss of an hexose moiety. Aside from the sugar signals, the ^{1}H-NMR spectrum of **4** was similar to that of 1*β*-hydroxypterodontic acid.[3] This suggested that **4** was a glycosyl derivative of the latter compound. As confirmation of this, acid hydrolysis of **4** provided glucose (identified by paper chromatography) and an aglycon **4a**, which was identical with 1-hydroxypterodontic acid by mp, NMR, and MS. Diagnostic changes of C-1, C-2, and C-10 between these two analogues in their ^{13}C-NMR spectra disclosed the fact that the glycosyl group of **4** was connected to C-1. The coupling constant of the anomeric hydrogen (J = 7.7 Hz) indicated a *β*-D-glucoside. Compound **4** (pterodontoside A) was consequently assigned as 1*β*-(*β*-D-glucopyranosyloxy)-4α*H*-eudesma-5,11(13)-dien-12-oic acid.

The NMR spectral data of **5** (see Experimental Section) were almost superimposable with those of **4** and indicated their isomeric nature. The shape of the signal of the hydrogen geminal to the glucosyloxy moiety (δ_H 3.88, dd, J = 12.2, 3.0 Hz) showed that this hydrogen was axial and necessarily located at C-9, which was in agreement with the downfield shift of C-9 of **5**. The similarity of the NMR data of **5** with those of the known compound pterodontic acid [3] permitted the assignment of **5** (pterodontoside B) as 9*β*-(*β*-D-glucopyranosyloxy)-4α*H*-eudesma-5,11(13)-dien-12-oic acid.

Compounds **6**−**11** (pterodontosides C−H) were not acids but still displayed the eudesmane skeleton, as judged by their ^{1}H-NMR spectra. These data further indicated that the six compounds were glucosides, a conclusion confirmed in some cases by acid hydrolysis to glucose and a eudesmane aglycon. In two cases, **6** and **7**, this aglycon (**6a**/**7a**) was the known *ent*-eudesmane derivative pterodondiol,[2] as established by comparison with an authentic sample (IR, NMR, mp and $[\alpha]_D$). The coupling constant of the anomeric hydrogen (J = 7.2 Hz in both cases) indicated that they were *β*-glucosides. By comparison of the ^{13}C-NMR data of both compounds (see Experimental Section) with those of pterodondiol,[2] characteristic shifts in some specific signals were noticed. In **6**, for instance, a marked downfield shift (*ca.* 10 ppm, from δ_C 71.5 in ptorodondiol to δ_C 81.3 in **6**) was observed for the signal of C-4, while the signals of C-3 and C-5 were somewhat shifted (1−4 ppm) to higher field. This suggested that the glucosyl group was bound to the OH-4. In the same way, the characteristic shifts in the signals of C-11, C-12, C-13 in the ^{13}C-NMR spectrum of **7** indicated that the glucosyl group was bound to OH-11. Therefore, compounds **6** and **7** (pterodontosides C and D) were assigned as 4*β*-(*β*-D-glucopyranosyloxy)-*enantio*-eudesm-11-ol and 11-(*β*-D-glucopyranosyloxy)-*enantio*-eudesm-4*β*-ol, respectively.

The eudesmane glycosides **8** and **9** had in common the fact that they both yielded glucose and aglycon **8a**/**9a**, the known *ent*-eudesmane derivative pterodontriol B,[2] by acid hydrolysis. By proceeding in the same way as described for compounds **6** and **7**, the characteristic differences in the ^{1}H- and ^{13}C-NMR signals between each glucoside and aglycon were examined (see Experimental Section). The glucosyl group of **8** was deduced as being located at OH-4 by the characteristic ^{13}C-NMR shifts of C-3, C-4, and C-5. A *γ*-effect from Me-15 resulted in the anomeric carbon occurring at somewhat high field (*δ* 98.14). Comparison of the ^{1}H- and ^{13}C-NMR data of **9** with those of **8** indicated that the glucosyl group of **9** was situated at the hydroxyl bound to C-1, with the anomeric carbon (C-1″) appearing at *δ* 106.5. Therefore, compounds **8** and **9** (pterodontosides E and F) were structurally determined as 4*β*-(*β*-D-glucopyranosyloxy)-*enantio*-eudasma-1α,11-diol and 1α-(*β*-D-glucopyranosyloxy)-*enantio*-eudasma-4*β*,11-diol, respectively.

In contrast with the aforementioned compounds, the ^{13}C-NMR data of glucosides **10** and **11** showed the presence of two quaternary olefinic carbon signals and two downfield-shifted methylenes (C-6 and C-8) (see Experimental Section), and the absence of any ^{1}H-NMR signals attributable to H-7 and H-11 suggested the presence of an olefinic bond in their molecules. The two ^{1}H-NMR olefinic methyl singlets at ca. *δ* 1.45 and 1.75 ppm, which could thus be assigned to Me-12 and Me-13, provided support to these assignments. A combination of the results of ^{1}H−^{13}C COSY and NOESY experiments on these two substances (pterodontosides G and H) led to the assignments as 4*β*-(*β*-D-glucopyranosyloxy)-*enantio*-eudasm-7(11)-en-1α-ol and 1α-(*β*-D-glucopyranosyloxy)-*enantio*-eudasm-7(11)-en-4*β*-ol, respectively. The NMR data indicated that the aglycon of 10 and 11 exhibited close similarities with those of **8** and **9**, respectively. The depicted structures for 10 and 11 are therefore the only likely ones, and these compounds may be biogenetically derived from **8** and **9** by enzymatic dehydration.

Experimental Section

General Experimental Procedures. Melting points were recorded on a Kofler hot-stage instrument and are uncorrected. IR spectra were obtained on a Perkin-Elmer 577 instrument using KBr pellets. UV spectra were determined in MeOH, employing a Shimadzu UV-210 A instrument. EIMS data were obtained on a Finnigan-4510 spectrometer at 70 eV. FABMS spectra were recorded on a VG ZAB-HS spectrometer. Optical

rotations were measured with a Perkin-Elmer 241 polarimeter. ^{1}H- and ^{13}C-NMR spectra were obtained on a Bruker AM 400 spectrometer with TMS as internal reference. Elemental analysis measurements were obtained by a EA-1106 elemental analyzer. Preparative TLC was performed on Si GF_{254} and RP-18 plates (Merck).

Plant Material. Whole plants of *Laggera pterodonta* (DC.) Benth. (Compositae) were collected in November 1994, at Mapo, Qiubei County, Yunnan Province, People's Republic of China, and identified by Mr. Z. W. Lin. A voucher specimen (no. 941122CLD) is deposited in the Laboratory of Phytochemistry, Kunming Institute of Botany.

Extraction and Isolation. The air-dried aerial parts of the whole plants (10.2 kg, dry wt) were powdered and extracted twice with hot 95% alcohol (at 70 °C, 2 h each time). The residue (486 g), obtained by removal of the solvent *in vacuo*, was defatted thoroughly with petroleum ether (60−90 °C) and then successively extracted with EtOAc (1000 mL × 4) and *n*-BuOH (1000 mL × 4). The *n*-BuOH layers were combined and evaporated to dryness to give a residue (122 g), 82 g of which were mixed with Si gel (200−300 mesh, 100 g) and then subjected to column chromatography over 3600 g Si gel (200−300 mesh), using as solvents $CHCl_3$ containing gradually increasing proportions of MeOH (50:1−0:1, 500 mL each eluate). Sixteen fractions (fractions A through P) were obtained (by TLC monitoring), which were further purified by repeated column chromatography (Si gel and RP-18 support material) and preparative TLC (Si GF_{254} and RP-18 plates). Fraction A (6.0 g) afforded 86 mg of 3-hydroxycoumarin; fraction B (11.3 g) gave 86 mg of tormentic acid. From fraction F (3.2 g), 18 mg of thapsic acid *β*-D-glucoside was purified. Compound **2** (46 mg) was obtained from fraction G (2.4 g). Fractions H and I were combined (8.3 g) and afforded, apart from 17 mg of **1** as well as 14 mg of **3**, 23 mg of **6** and 16 mg of **7**. Fraction J (2.5 g) finally afforded 144 mg of 2α,3*β*-dihydroxypterodontic acid. Fractions K and L were combined (3.6 g), and 15 mg of **10** and 21 mg of **11** were purified, together with 11 mg of **8** and 14 mg of **9**. Fraction O (4.7 g) was subjected to separation over a silica H column and gave 45 mg of **4** and 24 mg of **5**. A large amount of D-mannitol (*ca* 2.6 g) was obtained from fraction P.

The known compounds were identified by comparing their physical and spectroscopic properties (mp, MS, IR, and NMR) with literature values,[2,3,6,7] and some were compared directly with authentic samples.

1*β*,9*β*-Dihydroxy-4α*H*-eudesma-5,11(13)-dien-12-oic acid (1): obtained as colorless prisms (MeOH); mp 210−211 °C; $[\alpha]^{20}_D$ −36.6° (*c* 0.32, MeOH); UV (MeOH) λ_{max} (log ϵ) 206 (4.13), 215 (3.75), 263 (3.47) nm; IR (dry film) ν_{max} 3398, 3369, 2970, 2938, 2875, 1691, 1641, 1480, 1344, 1066, 1008 cm^{-1}; ^{1}H NMR (C_5D_5N, 400 MHz) δ 6.52 (1H, br s, H-13′), 5.69 (1H, br s, H-13), 5.48 (1H, br s, H-6), 4.21 (1H, dd, J = 12.0, 3.2 Hz, H-9), 3.89 (1H, dd, J = 11.6, 4.3 Hz, H-1), 3.86 (1H, m, H-7), 2.50 (1H, m, H-8), 2.48 (2H, m, H-2 and H-4), 2.08 (1H, ddd, J = 11.6, 11.6, 4.0 Hz, H-2′), 2.00 (1H, ddd, J = 11.6, 11.6, 11.6 Hz, H-8′), 1.69 (2H, m, H-3 and H-3′), 1.52 (3H, s, Me-14), 1.22 (3H, d, J = 7.6 Hz, Me-15); ^{13}C NMR (C_5D_5N, 100 MHz) δ 169.58 (s, C-12), 147.38 (s, C-5), 146.77 (s, C-11), 125.53 (d, C-6), 123.11 (t, C-13), 81.36 (d, C-9), 79.36 (d, C-1),44.27 (s, C-10), 38.41 (d, C-4), 37.70 (d, C-7), 30.34 (t, C-3), 30.34 (t, C-8), 26.45 (t, C-2), 24.02 (q, C-15), 14.99 (q, C-14); EIMS (70 eV) m/z $[M]^+$ 266 (2), $[M - H_2O]^+$ 248 (53), $[M - 2 \times H_2O]^+$ 230 (67), 220 (31), 215 (45), 206 (31), 202 (48), 188 (54), 177 (36), 163 (43), 145 (54), 133 (41), 117 (58), 105 (54), 95 (68), 55 (100); FABMS (pos) m/z $[M + H]^+$ 267 (12), 249 (42), 231 (100), 213 (18), 203 (19), 189 (17), 175 (28), 159 (48), 148 (34), 131 (28), 119 (90), 105 (59), 91 (56); *anal.* C 67.67%, H 8.27%, calcd for $C_{15}H_{22}O_4$, C 67.65%, H 8.22%.

1*β*,3α-Dihydroxyeudesma-5,11(13)-dien-12-oic acid (2): obtained as colorless gum (MeOH); $[\alpha]^{21}_D$ −21.6° (*c* 1.2, MeOH); UV (MeOH) λ_{max} (log ϵ) 204.5 (4.02), 215 (3.90), 255.5 (3.58), 269.5 (3.44), 271 (3.43) nm; IR (dry film) ν_{max} 3375, 3409, 2964, 2935, 2870, 1690, 1639, 1480, 1346, 1314, 1064, 1005 cm^{-1}; ^{1}H NMR (C_5D_5N, 400 MHz) δ 6.56 (1H, d, J = 1.2 Hz, H-13′), 5.73 (1H, br s, H-13), 5.68 (1H, br s, H-6), 4.22 (1H, ddd, J = 5.0, 5.1, 5.0 Hz, H-3), 3.73 (1H, dd, J = 11.5, 4.3 Hz, H-1), 3.72 (1H, m, H-7), 2.93 (1H, br dq, J = 7.0, 5.0 Hz, H-4), 2.55 (1H, m, H-8), 2.49 (1H, m, H-2), 2.43 (1H, m, H-2′), 2.33 (1H, m, H-9′), 1.69 (1H, m, H-8′), 1.56 (1H, m, H-9), 1.50 (3H, d, J = 6.9 Hz, Me-15), 1.47 (3H, s, Me-14); ^{13}C NMR (C_5D_5N, 100 MHz) δ 169.76 (s, C-12), 147.43 (s, C-5), 147.08 (s, C-11), 127.97 (d, C-6), 122.94 (t, C-13), 77.20 (d, C-1), 69.86 (d, C-3), 46.60 (d, C-4), 40.50 (s, C-10), 39.44 (d, C-7), 38.76 (t, C-9), 36.69 (t, C-2), 27.15 (t, C-8), 21.59 (q, C-14), 16.88 (q, C-15); EIMS (70 eV) m/z $[M]^+$ 266 (8), $[M - H_2O]^+$ 248 (45), 233 (14), 230 (74), 220 (24), 215 (13), 213 (17), 202 (100), 185 (11), 184 (12), 174 (24), 169 (33), 158 (47), 143 (22), 130 (12), 128 (19), 116 (30), 105 (35); *anal.* C 67.57%, H 8.18%, calcd for $C_{15}H_{22}O_4$, C 67.75%, H 8.22%.

2*β*-Hydroxyillicic acid (3): obtained as colorless needles (MeOH); mp 198−199 °C; $[\alpha]^{22}_D$ −44.4° (*c* 0.9, MeOH); UV (MeOH) λ_{max} (log ϵ) 206.5 (4.10), 266 (3.47) nm; IR (dry film) ν_{max} 3423, 3340 br (OH), 2918, 1680, 1435, 1278, 1172, 1140, 951, 905, 828 cm^{-1}; ^{1}H NMR (C_5D_5N, 400 MHz) δ 6.52 (1H, d, J = 1.1 Hz, H-13′), 5.72 (1H, s, H-13), 4.56 (1H, br t, J = 3.3 Hz, H-2), 2.98 (1H, tt, J = 12.5, 3.4 Hz, H-7), 2.75 (1H, br d, J = 12.4 Hz, H-6), 2.59 (1H, br d, J = 13.5 Hz, H-1′), 2.19 (1H, dd, J = 13.7, 3.6 Hz, H-1), 1.96 (1H, br d, J = 14.0 Hz, H-3′), 1.85 (1H, m, H-5), 1.84 (1H, m, H-8′), 1.79 (3H, s, Me-15), 1.72 (2H, m, H-6′ and H-8), 1.54 (3H, s, Me-14), 1.54 (1H, m, H-9′), 1.49 (1H, dd, J = 13.9, 3.6 Hz, H-3), 1.32 (1H, ddd, J = 12.6, 12.6, 4.3 Hz, H-9); ^{13}C NMR (C_5D_5N, 100 MHz) δ 170.04 (s, C-12), 148.39 (s, C-11), 121.52 (t, C-13), 70.86 (s, C-4), 67.82 (d, C-2), 55.56 (d, C-5), 50.23 (t, C-1), 47.82 (t, C-3), 45.92 (t, C-9), 41.39 (d, C-7), 34.75 (s, C-10), 27.63 (t, C-8), 27.36 (t, C-6), 25.63 (q, C-15), 20.84 (q, C-14); EIMS (70 eV) m/z $[M]^+$ 268 (7), 250 (44), 217 (15), 204 (15), 167 (23), 149 (47), 121 (43), 87 (100); FABMS (pos) m/z $[M + H]^+$ 269 (5), 251 (23), 233 (100), 223 (14); *anal.* C 67.22%, H 9.02%, calcd for $C_{15}H_{24}O_4$, C 67.16%, H 8.96%.

Pterodontoside A [1*β*-(*β*-D-glucopyranosyloxy)-4α*H*-eudesma-5,11(13)-dien-12-oic acid] (4): obtained as colorless needles (MeOH); mp 248−249 °C (dec); $[\alpha]^{19}_D$ −75.0° (*c* 1.8, MeOH); UV (MeOH) λ_{max} (log ϵ) 206 (4.15), 224 (3.75), 263.5 (3.47), 294 (3.11) nm; IR (dry film) ν_{max} 3553 br (OH), 3400 br (OH), 2956, 2925, 2890, 2844, 1682, 1618, 1458, 1449, 1425, 1398, 1357, 1295, 1264, 1157, 1094, 1043, 1006, 944, 870, 628 cm^{-1}; ^{1}H NMR (C_5D_5N, 400 MHz) δ 6.50 (1H, d, J = 1.4 Hz, H-13′), 5.63 (1H, br s, H-13), 5.47 (1H, br s, H-6), 4.89

(1H, d, J = 7.7 Hz, H-1″), 4.54 (1H, dd, J = 11.7, 2.4 Hz, H-6″$_a$), 4.39 (1H, dd, J = 11.7, 5.2 Hz, H-6″$_b$), 4.27 (1H, m, H-4″), 4.24 (1H, m, H-5″), 4.00 (1H, t, J = 8.4 Hz, H-2″), 3.95 (1H, m, H-3″), 3.64 (1H, dd, J = 11.6, 4.0 Hz, H-1), 3.60 (1H, m, H-7), 2.38 (1H, m, H-4), 2.25 (1H, ddt, J = 10.8, 4.0, 3.5 Hz, H-2), 2.06 (1H, m, H-8), 2.04 (1H, m, H-2″), 1.94 (1H, m, H-9′), 1.56 (1H, m, H-8′), 1.52 (2H, m, H-3 and H-3′), 1.50 (1H, m, H-9), 1.24 (3H, s, Me-14), 1.10 (1H, d, J = 7.6 Hz, Me-15); ^{13}C NMR (C_5D_5N, 100 MHz) δ 169.66 (s, C-12), 147.80 (s, C-5), 147.51 (s, C-11), 126.18 (d, C-6), 122.72 (t, C-13), 102.37 (d, C-1″), 85.92 (d, C-1), 78.78 (d, C-5″), 78.32 (d, C-3″), 75.29 (d, C-2″), 72.06 (d, C-4″), 63.18 (t, C-6″), 40.06 (s, C-10), 39.01 (d, C-4), 38.23 (t, C-9), 30.26 (t, C-3), 26.77 (t, C-8), 23.37 (q, C-15), 23.02 (t, C-2), 22.05 (q, C-14); EIMS (70 eV) m/z [M − Glc]$^+$ 240 (0.8), 232 (27), 217 (4), 204 (5), 187 (7), 175 (6), 161 (11), 145 (16), 131 (17), 119 (23), 105 (39), 91 (56), 55 (100); FABMS (pos) m/z [M + H]$^+$ 413 (7), 251 (14), 233 (100), 215 (12), 205 (4), 187 (15), 145 (19); *anal.* C 61.24%, H 7.91%, calcd for $C_{21}H_{32}O_8$, C 61.17%, H 7.77%.

Pterodontoside B [9*β*-(*β*-D-glucopyranosyloxy)-4α*H*-eudesma-5,11(13)-dien-12-oic acid] (5): obtained as a colorless powder (MeOH); mp 255−256 °C (dec); $[\alpha]^{23}_D$ −3.4° (*c* 0.3, MeOH); UV (MeOH) λ_{max} (log ϵ) 206 (4.09), 223 (3.62), 265 (3.43) nm; IR (dry film) ν_{max} 3350 br (OH), 2894, 2830, 1689, 1620, 1534, 1530, 1397, 1205, 1265, 1162, 1096, 1075, 1022, 939, 840, 618 cm^{-1}; ^{1}H NMR (C_5D_5N, 400 MHz) δ 6.44 (1H, d, J = 1.6 Hz, H-13′), 5.58 (1H, br s, H-13), 5.45 (1H, br s, H-6), 4.97 (1H, d, J = 7.7 Hz, H-1″), 4.50 (1H, dd, J = 11.8, 2.7 Hz, H-6″$_a$), 4.36 (1H, dd, J = 11.7, 5.0 Hz, H-6″$_b$), 4.27 (1H, m, H-4″), 4.25 (1H, m, H-5″), 4.05 (1H, t, J = 8.6 Hz, H-2″), 3.98 (1H, m, H-3″), 3.88 (1H, dd, J = 12.2, 3.0 Hz, H-9), 3.58 (1H, m, H-7), 2.94 (1H, m, H-4), 2.50 (1H, m, H-8), 1.74 (1H, m, H-2), 1.56 (3H, m, H-3/H-3′ and H-8′), 1.50 m (1H, m, H-1′), 1.42 (1H, m, H-2′), 1.36 (3H, s, Me-14), 1.26 (1H, m, H-1), 1.15 (3H, d, J = 7.6 Hz, Me-15); ^{13}C NMR (C_5D_5N, 100 MHz) δ 169.53 (s, C-12), 147.47 (s, C-5), 146.75 (s, C-11), 123.53 (d, C-6), 122.62 (t, C-13), 106.54 (d, C-1″), 87.79 (d, C-9), 78.72 (d, C-5″), 78.11 (d, C-3″), 75.88 (d, C-2″), 71.94 (d, C-4″), 63.72 (t, C-6″), 40.23 (s, C-10), 38.43 (d, C-7), 38.42 (t, C-1), 37.91 (d, C-4), 33.85 (t, C-3), 33.03 (t, C-8), 23.79 (q, C-15), 21.17 (q, C-14), 17.52 (t, C-2); EIMS (70 eV) m/z [M]$^+$ 412 (0.5), 394 (1), 250 (4), 232 (54), 205 (64), 189 (17), 164 (31), 149 (66), 123 (43), 109 (42), 57 (100); FABMS (pos) m/z [M + H]$^+$ 413 (9), 251 (25), 233 (68), 205 (100), 189 (10), 161 (33), 149 (33), 135 (23), 123 (43), 105 (29), 81 (34); *anal.* C 61.26%, H 7.88%, calcd for $C_{21}H_{32}O_8$, C 61.17%, H 7.77%.

Pterodontoside C [4*β*-(*β*-D-glucopyranosyloxy)-*enantio*-eudesm-11-ol] (6): obtained as a white powder (MeOH); mp 187−188 °C; $[\alpha]^{20}_D$ +4.5° (*c* 1.2, MeOH); IR (dry film) ν_{max} 3398 br, 2996, 2908, 2858, 1640 br, 1473, 1390, 1333, 1269, 1217, 1189, 1172, 1080, 1022, 988, 935, 903 cm^{-1}; ^{1}H NMR (C_5D_5N, 400 MHz) δ 5.09 (1H, d, J = 7.2 Hz, H-1″), 4.51 (1H, dd, J = 11.8, 2.2 Hz, H-6″$_a$), 4.38 (1H, dd, J = 11.8, 5.1 Hz, H-6″$_b$), 4.31 (1H, m, H-4″), 4.29 (1H, m, H-5″), 4.03 (1H, t, J = 8.5 Hz, H-2″), 3.93 (1H, m, H-3″), 2.26 (1H, dd, J = 12.3, 3.4 Hz, H-5), 2.02 (2H, m, H-6′ and H-8), 1.98 (2H, m, H-3 and H-3′), 1.84 (1H, m, H-8′), 1.80 (1H, m, H-7), 1.53 (3H, s, Me-13), 1.52 (1H, m, H-6), 1.51 (3H, s, Me-12), 1.46 (2H, m, H-2 and H-2′), 1.38 (3H, s, Me-15), 1.27 (2H, m, H-1 and H-9′), 1.21 (1H, m, H-9), 1.10 (1H, m, H-1), 0.95 (3H, s, Me-14); ^{13}C NMR (C_5D_5N, 100 MHz) δ 98.62 (d, C-1″), 81.32 (s, C-4), 79.01 (d, C-5″), 78.01 (d, C-3″), 75.77 (d, C-2″), 72.13 (d, C-4″), 71.78 (s, C-11), 63.11 (t, C-6″), 48.39 (d, C-5), 42.96 (d, C-7), 42.76 (t, C-9), 42.11 (t, C-1), 40.37 (t, C-3), 34.70 (s, C-10), 30.57 (q, C-13), 29.75 (q, C-12), 21.86 (t, C-6), 21.86 (t, C-8), 20.85 (t, C-2), 19.74 (q, C-15), 19.43 (q, C-14); EIMS (70 eV) m/z [M − Glc]$^+$ 240 (2), 222 (8), 204 (17), 189 (14), 161 (25), 149 (75), 137 (30), 123 (28), 109 (45), 97 (38), 81 (58), 69 (100); FABMS (pos) m/z [M + H]$^+$ 403 (4), 241 (3), 223 (13), 205 (100), 189 (16), 177 (6), 175 (7), 173 (5), 149 (55), 137 (16), 123 (50), 105 (24), 95 (21), 81 (36), 59 (11), 55 (36); *anal.* C 62.78%, H 9.56%, calcd for $C_{21}H_{38}O_7$, C 62.69%, H 9.45%.

Pterodontoside D [11-(*β*-D-glucopyranosyloxy)-*enantio*-eudesm-4*β*-ol] (7): obtained as a white powder (MeOH); mp 193−194 °C; $[\alpha]^{20}_D$ +3.3° (*c* 0.9, MeOH); IR (dry film) ν_{max} 3410 br, 2998 br, 2909, 2862, 1638 br, 1472 br, 1392, 1330, 1210, 1190, 1175, 1115, 1083, 1017, 998, 940, 905, 627, 615 cm^{-1}; ^{1}H NMR (C_5D_5N, 400 MHz) δ 5.01 (1H, d, J = 7.2 Hz, H-1″), 4.50 (1H, dd, J = 11.7, 2.5 Hz, H-6″$_a$), 4.36 (1H, t, J = 8.4 Hz, H-6″$_b$), 4.29 (1H, m, H-4″), 4.27 (1H, m, H-5″), 3.92 (1H, m, H-3″), 2.27 (1H, dd, J = 12.4, 3.4 Hz, H-5), 2.01 (1H, m, H-6′), 1.99 (1H, m, H-8′), 1.94 (1H, m, H-8), 1.93 (1H, m, H-3′), 1.84 (1H, m, H-7), 1.72 (1H, m, H-6), 1.70 (1H, m, H-3), 1.58 (1H, s, Me-13), 1.56 (3H, s, H-12), 1.40 (2H, m, H-2 and H-2′), 1.40 (3H, s, Me-15), 1.28 (1H, m, H-1′), 1.21 (1H, m, H-9′), 1.18 (1H, m, H-9), 1.12 (1H, m, H-1), 0.96 (3H, s, Me-14); ^{13}C NMR (C_5D_5N, 100 MHz) δ 98.06 (d, C-1″); 79.69 (s, C-11), 78.84 (d, C-5″), 77.68 (d, C-3″), 75.69 (d, C-2″), 73.83 (s, C-4), 72.00 (d, C-4″), 63.00 (d, C-3″), 48.39 (d, C-5), 42.64 (t, C-9), 42.52 (d, C-7), 42.12 (t, C-1), 40.34 (t, C-3), 34.58 (s, C-10), 26.93 (q, C-13), 25.85 (q, C-12), 22.71 (q, C-15), 21.75 (t, C-6), 21.75 (t, C-8), 20.42 (t, C-2), 19.21 (q, C-14); EIMS (70 eV) m/z [M − Glc]$^+$ 240 (4), 222 (6), 204 (19), 189 (14), 161 (16), 149 (64), 137 (35), 123 (30), 121 (22), 109 (35), 97 (35), 95 (39), 81 (50), 69 (95), 55 (100); FABMS (pos) m/z [M + H]$^+$ 403 (8), 241 (4), 223 (15), 205 (100), 189 (15), 179 (5), 175 (7), 161 (23), 149 (45), 135 (28), 123 (52), 107 (28), 95 (27), 81 (37), 59 (12); *anal.* C 62.75%, H 9.58%, calcd for $C_{21}H_{38}O_7$, C 62.69%, H 9.45%.

Pterodontoside E [4*β*-(*β*-D-glucopyranosyloxy)-*enantio*-eudesma-1α,11-diol] (8): obtained as a white powder (MeOH); mp 203−204 °C; $[\alpha]^{22}_D$ +22.5° (*c* 0.9, MeOH); IR (dry film) ν_{max} 3335 br, 2964, 2924, 2866, 1517, 1495, 1492, 1358, 1260, 1190, 1169, 1123, 1091, 1080, 1057, 1043, 964, 919, 620 br cm^{-1}; ^{1}H NMR (C_5D_5N, 400 MHz) δ 4.82 (1H, d, J = 7.7 Hz, H-1″), 4.43 (1H, dd, J = 11.7, 2.2 Hz, H-6″$_a$), 4.32 (1H, dd, J = 11.8, 5.0 Hz, H-6″$_b$), 4.27 (1H, m, H-4″), 4.20 (1H, m, H-5″), 3.94 (1H, d, J = 8.1 Hz, H-2″), 3.85 (1H, m, H-3″), 3.54 (1H, dd, J = 10.3, 4.9 Hz, H-1), 2.52 (1H, m, H-6′), 2.33 (1H, dd, J = 12.6, 3.6 Hz, H-5), 2.04 (1H, m, H-3), 2.03 (1H, m, H-8), 2.01 (1H, m, H-8′), 1.99 (1H, m, H-3′), 1.93 (2H, m, H-9 and H-9′), 1.84 (1H, m, H-7), 1.83 (2H, m, H-2 and H-2′), 1.49 (3H, s, Me-13), 1.45 (3H, s, Me-12), 1.34 (3H, s, Me-15), 1.20 (3H, s, Me-14), 1.10 (1H, m, H-6); ^{13}C NMR (C_5D_5N, 100 MHz) δ 98.14 (d, C-1″), 79.64 (d, C-1), 79.47 (s, C-4), 78.97 (d, C-5″), 78.68 (d, C-3″), 75.85 (d, C-2″), 73.98 (s, C-11), 71.86 (d, C-4″), 62.99 (t, C-6″), 47.17 (d, C-5), 42.66 (d, C-7), 42.17 (t, C-9), 39.94 (s, C-10), 38.42 (t, C-3), 30.59 (q, C-13), 29.75 (q, C-12), 29.58 (t, C-2), 21.71 (t, C-6), 21.58 (t, C-8),

19.45 (q, C-15), 14.86 (q, C-14); EIMS (70 eV) *m/z* [M − Glc]$^+$ 256 (1.5), 238 (15), 221 (91), 203 (100), 187 (18), 180 (35), 163 (81), 147 (76), 133 (24), 121 (46), 109 (51), 107 (47), 59 (58); FABMS (pos) *m/z* [M + H]$^+$ 419 (4), 257 (4), 240 (8), 221 (23), 203 (100), 189 (26), 177 (23), 175 (28), 161 (65), 147 (69), 135 (42), 119 (70), 105 (80), 95 (76), 69 (72), 55 (82); *anal.* C 60.37%, H 9.16%, calcd for $C_{21}H_{38}O_8$, C 60.29%, H 9.09%.

Pterodontoside F [1α-(β-D-glucopyranosyloxy)-*enantio*-eudesma-4β,11-diol] (9): obtained as a white powder (MeOH); mp 196.5−197.5 °C; $[\alpha]^{20}_D$ +24.5° (*c* 1.3, MeOH); IR (dry film) ν_{max} 3341 br, 2967, 2928, 2865, 1514, 1496, 1392, 1357, 1263, 1189, 1168, 1120, 1092, 1085, 1058, 1035, 966, 952, 923, 610 br cm^{-1}; ^{1}H NMR (C_5D_5N, 400 MHz) δ 5.01 (1H, d, *J* = 7.6 Hz, H-1″), 4.43 (1H, dd, *J* = 11.8, 2.3 Hz, H-6″$_a$), 4.33 (1H, dd, *J* = 11.8, 4.9 Hz, H-6″$_b$), 4.29 (1H, m, H-4″), 4.22 (1H, m, H-5″), 3.95 (1H, t, *J* = 8.2 Hz, H-2″), 3.85 (1H, m, H-3″), 3.66 (1H, dd, *J* = 10.5, 4.8 Hz, H-1), 2.58 (1H, m, H-6′), 2.20 (1H, ddd, *J* = 11.0, 11.0, 4.4 Hz, H-3), 2.10 (1H, dd, *J* = 12.5, 3.8 Hz, H-5), 2.04 (1H, m, H-3′), 2.02 (1H, m, H-8), 1.99 (1H, m, H-8′), 1.94 (2H, m, H-9 and H-9′), 1.84 (3H, m, H-2/H-2′ and H-7), 1.68 (1H, m, H-6), 1.47 (3H, s, Me-13), 1.43 (3H, s, Me-12), 1.42 (3H, s, Me-15), 1.22 (3H, s, Me-14); ^{13}C NMR (C_5D_5N, 100 MHz) δ 106.54 (d, C-1″), 90.72 (d, C-1), 78.96 (d, C-5″), 78.02 (d, C-3″), 75.54 (d, C-2″), 73.99 (s, C-11), 71.82 (d, C-4″), 62.98 (t, C-6″), 48.40 (d, C-5), 42.57 (d, C-7), 42.17 (t, C-9), 39.71 (s, C-10), 39.31 (t, C-3), 30.58 (q, C-13), 29.58 (q, C-12), 28.68 (t, C-2), 21.70 (t, C-6), 21.56 (t, C-8), 19.44 (q, C-15), 14.64 (q, C-14); EIMS (70 eV) *m/z* [M − Glc]$^+$ 256 (3), 238 (23), 221 (100), 203 (96), 187 (18), 180 (20), 163 (88), 147 (82), 133 (36), 121 (47), 109 (49), 107 (51), 69 (56), 59 (65); FABMS (pos) *m/z* [M + H]$^+$ 419 (5), 257 (5), 240 (7), 221 (26), 203 (100), 189 (20), 177 (20), 175 (32), 161 (67), 147 (92), 135 (43), 133 (53), 119 (76), 105 (93), 95 (78), 69 (98); *anal.* C 60.38%, H 9.13%, calcd for $C_{21}H_{38}O_8$, C 60.29%, H 9.09%.

Pterodontoside G [4β-(β-D-glucopyranosyloxy)-*enantio*-eudesm-7(11)-en-1α-ol] (10): obtained as a white powder (MeOH); mp 185−186 °C; $[\alpha]^{21}_D$ +1.0° (*c* 2.0, MeOH); IR (dry film) ν_{max} 3320 br, 3085, 3009, 2940, 2800, 1690, 1678, 1618, 1450, 1306, 1200, 1085, 1025, 842, 760 cm^{-1}; ^{1}H NMR (C_5D_5N, 400 MHz) δ 5.03 (1H, d, *J* = 7.6 Hz, H-1″), 4.48 (1H, dd, *J* = 11.8, 2.5 Hz, H-6″$_a$), 4.31 (1H, dd, *J* = 11.7, 5.7 Hz, H-6″$_b$), 4.26 (1H, m, H-4″), 4.21 (1H, m, H-5″), 4.03 (1H, t, *J* = 8.3 Hz, H-2″), 3.89 (1H, m, H-3″), 3.40 (1H, m, H-8′), 3.38 (1H, dd, *J* = 10.8, 4.6 Hz, H-1), 2.66 (1H, m, H-6′), 2.34 (1H, m, H-9′), 2.14 (1H, m, H-3′), 2.06 (1H, m, H-3), 1.82 (2H, m, H-2 and H-2′), 1.75 (s, 3H, Me-13), 1.72 (1H, m, H-5), 1.70 (1H, m, H-8), 1.65 (3H, s, Me-15), 1.45 (3H, s, Me-12), 1.25 (1H, m, H-9), 1.24 (3H, s, Me-14); ^{13}C NMR (C_5D_5N, 100 MHz) δ 132.18 (s, C-11), 120.87 (s, C-7), 98.02 (d, C-1″), 79.07 (d, C-1), 78.97 (d, C-3″), 78.74 (s, C-4), 77.98 (d, C-5″), 75.67 (d, C-2″), 72.05 (d, C-4″), 63.25 (t, C-6″), 53.20 (d, C-5), 42.48 (t, C-9), 40.02 (s, C-10), 38.29 (t, C-3), 29.38 (t, C-2), 25.71 (t, C-6), 25.28 (t, C-8), 20.51 (q, C-15), 20.24 (q, C-12), 19.09 (q, C-13), 13.55 (q, C-14); EIMS (70 eV) *m/z* [M]$^+$ 400 (0.2), 238 (3), 220 (23), 205 (40), 202 (58), 187 (44), 174 (16), 159 (30), 146 (22), 144 (37), 129 (13), 118 (42), 101 (36), 90 (74), 73 (57), 55 (100); FABMS (pos) *m/z* [M + H]$^+$ 401 (3), 239 (16), 221 (100), 206 (23), 205 (20), 202 (58), 188 (43), 187 (20), 159 (35), 144 (43), 129 (17), 118 (36), 101 (26), 81 (28), 57 (20); *anal.* C 63.12%, H 9.06%, calcd for $C_{21}H_{36}O_7$, C 63.00%, H 9.00%.

Pterodontoside H [1α-(β-D-glucopyranosyloxy)-*enantio*-eudesm-7(11)-en-4β-ol] (11): obtained as a white powder (MeOH); mp 190−191 °C; $[\alpha]^{20}_D$ +0.85° (*c* 1.6, MeOH); IR (dry film) ν_{max} 3332 br, 3080, 3012, 2950, 2812, 1688, 1612, 1455, 1206, 1086, 1022, 850, 788 cm^{-1}; ^{1}H-NMR (C_5D_5N, 400 MHz) δ 4.90 (1H, d, *J* = 7.7 Hz, H-1″), 4.52 (1H, dd, *J* = 11.8, 2.3 Hz, H-6″$_a$), 4.39 (1H, dd, *J* = 11.7, 5.1 Hz, H-6″$_b$), 4.27 (1H, m, H-3″), 4.23 (1H, m, H-5″), 3.96 (1H, t, *J* = 8.2 Hz, H-2″), 3.94 (1H, m, H-3″), 3.61 (1H, dd, *J* = 10.8, 4.6 Hz, H-1), 3.52 (1H, br d, *J* = 12.6 Hz, H-8′), 2.66 (1H, m, H-9′), 2.52 (1H, m, H-6′), 1.92 (4H, m, H-2/H-2′, H-3′ and H-5), 1.89 (1H, m, H-8), 1.85 (1H, m, H-6), 1.80 (1H, m, H-3), 1.74 (3H, s, Me-13), 1.45 (3H, s, Me-12), 1.38 (3H, s, Me-15), 1.26 (1H, m, H-9), 1.22 (3H, s, Me-14); ^{13}C NMR (C_5D_5N, 100 MHz) δ 132.35 (s, C-11), 120.25 (s, C-7), 106.54 (d, C-1″), 89.87 (d, C-1), 78.88 (d, C-3″), 78.17 (d, C-5″), 75.86 (d, C-2″), 70.58 (s, C-4), 63.05 (t, C-6″), 54.79 (d, C-5), 42.03 (t, C-9), 42.02 (t, C-3), 39.98 (s, C-10), 28.29 (t, C-2), 25.72 (t, C-6), 25.14 (t, C-8), 22.95 (q, C-15), 20.25 (q, C-12), 19.08 (q, C-13), 13.83 (q, C-14); EIMS (70 eV) *m/z* [M − Glc]$^+$ 238 (2), 220 (30), 205 (45), 202 (46), 187 (48), 174 (32), 159 (25), 146 (23), 144 (54), 129 (32), 118 (23), 101 (57), 90 (64), 73 (82), 57 (100); FABMS (pos) *m/z* [M + H]$^+$ 401 (8), 239 (24), 221 (100), 220 (22), 206 (36), 205 (28), 202 (47), 188 (32), 187 (30), 159 (28), 144 (35), 118 (19), 101 (15), 90 (20), 82 (16), 55 (32); *anal.* C 63.08%, H 9.06%, calcd for $C_{21}H_{36}O_7$, C 63.00%, H 9.00%.

Acid Hydrolysis of Glucosides 4, and 6−9. A quantity of 4 M HCl (3 mL) was added to a solution of 10 mg of each glucoside in 3 mL of MeOH, refluxed at 70 °C for 4 h, with 6 mL of H_2O added, the MeOH evaporated off under a vacuum at 60 °C, and the residue extracted with Et_2O (5 mL × 3). The dried Et_2O layers were combined and evaporated, thus yielding the aglycons, which were subjected to physical and spectroscopic data measurements. The aqueous layer in each case was neutralized with Na_2CO_3 to pH 7.0, and the sugar moiety was examined by paper chromatography (comparing with authentic sugar samples).

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