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GERMACRANOLIDES, GUAIANOLIDES AND EUDESMANOLIDES FROM *GREENMANIELLA RESINOSA*

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Key Word Index—*Greenmaniella resinosa*; Compositae; sesquiterpene lactones; germacranolides; guaianolides; eudesmanolides; bisabolene derivative.

Abstract—The aerial parts of *Greenmaniella resinosa* afforded, in addition to known compounds, 22 new ones: nine germacranolides, seven eudesmanolides, five guaianolides and a bisabolene derivative. The structures were elucidated by spectroscopic methods and by some chemical transformations including partial synthesis. The chemotaxonomic situation of *Greenmaniella* and the biogenetic relationships of the compounds are discussed briefly.

INTRODUCTION

Greenmaniella Sharp. (Compositae, tribe Heliantheae), a monotypic genus confined to the Monterrey area of north-eastern Mexico, was originally described as a *Zaluzania* in the subtribe Helianthinae. It was placed later with some reservations in the subtribe Verbesininae [1] but subsequently transferred to the subtribe Neurolininae [2, 3]. As nothing is known on the chemistry of *Greenmaniella G. resinosa* we have investigated.

RESULTS AND DISCUSSION

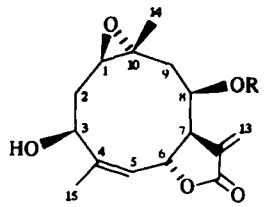
The aerial parts of *G. resinosa* afforded as main constituents the germacranolides tagitinin C (**3a**) [4–6], tagitinin E (**1b**) [6], tagitinin F (**5a**) [4–6] and 1-desoxyorizabin (**4a**) [7] as well as the eudesmanolide pinnatifidin (**9a**) [8]. Furthermore, the germacranolides **1a**, **2**, **3b**, **4b**, **4c**, **4d**, **5b**, **5c**, **6** and **14**, the eudsmanolides **7a**, **7b**, **7e**, **8a**, **8b**, **9b** and **9c**, the guaianolides **10**, **11**, **12a**, **12b** and **13** as well as the known lactones ivalin [9], ovatifolin [10], desacetyltulipinolide-1β,10-epoxide [11] and 8-epi-dentatin A (**7c**) [12] and the bisabolen-diol **15** were isolated.

The structure of **1a** followed from the ^{1}H NMR spectrum (Table 1) which was very similar to that of **1b**. The presence of the corresponding propionate followed from the typical ABX_3 signals of a chiral propionate.

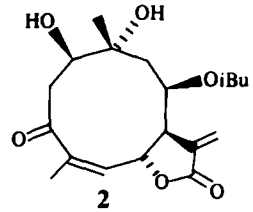
The ^{1}H NMR spectrum of **2** was obtained from a sample which was a mixture with a second lactone (Table 1). All efforts to separate this mixture were unsuccessful. It eventually emerged that we were dealing with an equilibrium mixture of two lactones which changed with temperature. Integration of the exomethylene proton signals indicated a 1:1.125 mixture at 25° and a 1.2:1 mixture at 77°. Spin decoupling allowed the assignment of all signals of both lactones. All data only agreed with the presence of ketone **2**, which we have named resinosolide. The ^{1}H NMR data of the second lactone indicated the presence of the hemiacetal **4c**. Treatment of the mixture with a trace of acid in methanol afforded the acetal **4e**; its ^{1}H NMR spectrum (Table 1) was close to that of **4c**, but also to that of **4d**, which differed from **4c** only by the replacement of the 1-hydroxy by a methoxy group. Spin decoupling allowed the assignment of all signals of **4c–4e**. The data of **4c** indicated that this lactone was an isomer of orizabin [13]. In the spectrum of orizabin the H-1 signal is a slightly broadened doublet but in the spectra of **4c–4e** this signal is replaced by a double doublet. The stereochemistry was determined by NOE difference spectroscopy. Clear effects were observed between H-14, H-8, H-1, OMe and H-2α, between H-7 and H-8, between H-9β and H-6 as well as between OMe, H-1 and H-9β (always first proton saturated). Also, the ^{13}C NMR data of **4d** agreed with the proposed structure (Experimental). It is noteworthy that in the case of **4d** no trace of the corresponding *O*-methyl derivative of **2** could be observed. Only one 1β-hydroxy derivative has been reported so far from a *Viguiera* species [14]. The configuration of a second lactone from a *Calea* species (compound **7** in ref. [15]) has to be corrected to 1α-hydroxy.

A further contribution to the elucidation of the stereochemistry of these lactones is the result of the acid catalysed transformation of **1b** to **4f**. The ^{1}H NMR spectrum (Table 1) and inspection of a model indicated that in compound **4f** the configuration at C-3 and C-10 was opposite to that of **4a–4e**. Most likely **4f** was formed by protonation of the epoxide followed by attack of the 3-hydroxy group which led to inversion at C-10. The ^{1}H NMR data are typically different from those of **4a–4e** and related lactones.

The ^{1}H NMR spectrum of **3b** (Table 1) was very close to that of **3a**. The changed nature of the ester group followed from the typical signals of a methyl butyrate. The structure of **4b** clearly followed from the ^{1}H NMR spectrum (Table 1) which was close to that of **4a** though small differences led to overlapping of some signals. Addition of deuteriobenzene allowed the assignment of all signals by spin decoupling. Similarly, the ^{1}H NMR data of **5b** and **5c** (Table 1) were close to those of **5a** indicating the



1a R = COEt **1b** R = *i*-Bu



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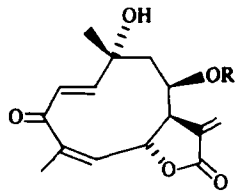
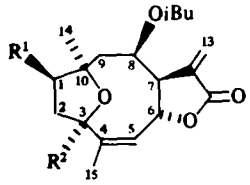
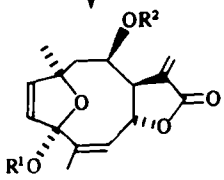


3a R = *i*-Bu **3b** R = MeBu
3c R = *i*-Bu,1Z

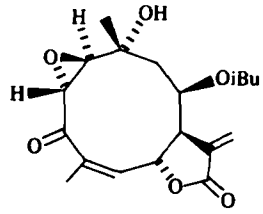


	4a	**4b**	**4c**	**4d**	**4e**	**4f**
R^1	H	H	OH	OMe	OH	OH
R^2	OH	OMe	OH	OH	OMe	H

3,10 epi



	5a	**5b**	**5c**
R^1	H	Me	H
R^2	*i*-Bu	*i*-Bu	MeBu



6

presence of the corresponding 3-*O*-methyl ether and the 8-*O*-methyl butyrate, respectively. As followed from the couplings of H-8 the conformation of **5a–5c** differed from that of **4a–4e**.

The ^{1}H NMR spectrum of **6** (Table 1) was in part similar to that of **3a**. However, the pair of lowfield doublets (H-1 and H-2) was replaced by a pair of narrowly split doublets at δ 3.68 and 3.22 (J = 2.5 Hz). Furthermore the H-5 signal was shifted downfield (δ 6.36). Spin decoupling allowed the assignment of all the signals. Therefore, in agreement with the molecular formula, the presence of the epoxide **6** was proposed. A very similar compound with a 8-*O*-angelate group was prepared by oxidation of tifruticin, itself obtained by epoxidation of desoxyfruticin [5]. The ^{1}H NMR spectra, however, were clearly different. NOE difference spectroscopy with **6** indicated that only the configurations at C-1 and C-2 were different in these closely related lactones. Clear NOEs were observed between H-14 and H-2, between H-15 and H-5, between H-7, H-8 and H-1, between H-2, H-9β, H-6 and H-14 as well as between H-6 and H-2. Inspection of a model indicated that these effects and the couplings agreed with the proposed stereochemistry and with a conformation where the ketone was nearly in plane with the conjugated double bond. This explained the downfield shift of the H-5 signal. In the case of dehydrotifruticin steric hindrance leads to a conformation where the keto group is not in plane with the double bond. Epoxidation of **3a** afforded a single epoxide which is identical with the natural product. Inspection of a model indicated that in the case of **3a** in its preferred conformation the attack of peracid should be favoured from one side by steric effects and by the 10-hydroxy group.

Obviously all these germacranolides are biogenetically related. Oxidation of **1b** followed by hydrolysis of the epoxide would lead to **2** which by elimination of water would give a mixture of the *E,Z*-isomers **3a** and **3c**. Inspection of a model of **3c** shows that it can be easily transformed into **5a** and, accordingly, **3c** was not observed. Epoxidation of **3a** would give **6**. The lactone **4a** could be formed by hydrogenation of either **5a** or **3a**. The *O*-methyl ethers **4b** and **5b** may be artifacts as methanol was used for extraction. This also could be considered in the case of **4d** as the corresponding 8-*O*-angelate was prepared from the corresponding dienone [5] by methanol addition.

The structure of **7a** and **7e** followed from the ^{1}H NMR spectra (Table 2) which were similar to those of reynosin [16] and balchanin [17], respectively. The presence of an 8β-isobutyryloxy group could be deduced from the typical signals of the isobutyrate residue and the couplings of H-8. The spectrum of **7c** was close to that of **7a** but, as expected, the H-8 signal was shifted upfield. Lactone **7c** has been reported previously [12] but no NMR data were

Table 1. ^{1}H NMR spectral data of compounds **1**, **2**, **3b**, **4b**, **4c**, **4d**, **4e**, **4f**, **5b**, **5c** and **6** ($CDCl_3$, 400 MHz, δ values)

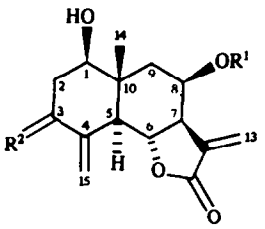
	1*	2	3b	4b	4c	4d	4e	4f†	5b	5c	6
H-1 } H-1' }	2.79 *dd*	4.19 *dd*	6.91 *d*	2.02 *m* 1.80 *m*	4.51 *dd*	4.02 *dd*	4.37 *dd*	3.92 *d*	5.68 *d*	5.81 *d*	3.22 *d*
H-2 H-2'	2.46 *ddd* 1.75 *ddd*	2.88 *dd* 2.66 *dd*	6.23 *d*	2.22 *m* 2.02 *m*	2.52 *dd* 2.11 *dd*	2.60 *dd* 1.50 *dd*	2.49 *dd* 2.04 *dd*	2.03 *ddd* 2.35 *dd*	6.27 *d*	6.31 *d*	3.68 *d*
H-5	5.32 *dq*	5.73 *dq*	5.86 *dq*	5.66 *dq*	5.64 *dq*	5.61 *dq*	5.73 *dq*	5.40 *ddq*	5.68 *dq*	5.69 *dq*	6.36 *dq*
H-6	6.66 *dd*	5.30 *dd*	5.39 *br d*	5.34 *ddq*	5.43 *ddq*	5.39 *ddq*	5.38 *ddq*	6.43 *br t*	5.75 *ddq*	5.90 *ddq*	5.63 *ddq*
H-7	2.84 *dddd*	3.23 *dddd*	3.53 *br s*	4.20 *dddd*	4.12 *dddd*	4.08 *dddd*	4.22 *dddd*	2.86 *dddd*	3.68 *ddd*	3.42 *ddd*	3.28 *dddd*
H-8	5.18 *ddd*	5.40 *ddd*	5.37 *ddd*	5.56 *m*‡	5.62 *ddd*	5.59 *dt*	5.64 *dt*	5.48 *br d*	5.22 *dt*	5.08 *t*	5.38 *dd*
H-9	2.73 *dd*	1.97 *dd*	2.47 *dd*	1.84 *dd*	2.15 *dd*	1.73 *dd*	2.05 *dd*	2.34 *dd*	2.31 *dd*	2.36 *dd*	2.12 *dd*
H-9'	1.32 *dd*	1.86 *dd*	1.98 *dd*	1.95 *dd*	1.78 *dd*	2.14 *br dd*	1.79 *dd*	1.53 *br d*	2.20 *dd*	2.28 *dd*	1.96 *dd*
H-13	6.38 *d*	6.34 *d*	6.35 *d*	6.22 *d*	6.26 *d*	6.24 *d*	6.26 *d*	6.32 *d*	6.28 *d*	6.30 *d*	6.35 *d*
H-13'	5.76 *d*	5.76 *d*	5.80 *d*	5.57 *d*	5.60 *d*	5.57 *d*	5.61 *d*	5.59 *d*	5.65 *d*	5.69 *d*	5.84 *d*
H-14	1.50 *s*	1.32 *s*	1.54 *s*	1.45 *s*	1.51 *s*	1.53 *s*	1.48 *s*	1.36 *s*	1.43 *s*	1.41 *s*	1.28 *s*
H-15	1.82 *d*	2.00 *br s*	1.96 *d*	1.73 *t*	1.82 *t*	1.81 *t*	1.73 *t*	1.64 *br s*	1.88 *t*	1.93 *t*	1.95 *t*
OCOR	2.33 ABX_3	2.43 *qq*	2.62 *tq*	2.38 *qq*	2.42 *qq*	2.40 *qq*	2.41 *qq*	2.57 *qq*	2.48 *qq*	2.32 *tq*	2.49 *qq*
	1.11 *t*	1.07 *d*	1.58 *m*	1.03 *d*	1.07 *d*	1.06 *d*	1.05 *d*	1.14 *d*	1.13 *d*	1.58 *m*	1.12 *d*
		1.05 *d*	1.40 *m*	1.02 *d*	1.05 *d*	1.04 *d*	1.04 *d*	1.13 *d*	1.11 *d*	1.42 *m*	1.11 *d*
			0.84 *t*							0.86 *t*	
			1.04 *d*							1.10 *d*	
OMe	—	—	—	3.20 *s*		3.38 *s*	3.10 *s*		3.29 *s*		

*H-3 4.44 *br dd*.

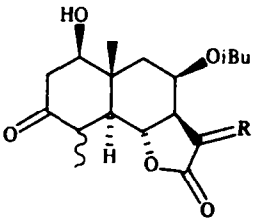
†H-3 4.80 *br dd*.

‡In $CDCl_3$–C_6D_6 H-8 5.46 *dt*.

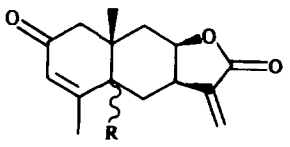
J (Hz): compound **1**: 1,2 = 4.5; 1,2' = 10; 2,2' = 15; 2,3 = 4; 2',3 = 2.5; 5,6 = 11; 5,15 = 1.5; 6,7 = 2; 7,8 = 7,13 = 2.5; 7,13' = 2; 8,9 = 4.5; 8,9' = 2.5; 9,9' = 15; compound **2**: 1,2 = 3.5; 1,2' = 7.5; 2,2' = 15; 5,6 = 8.5; 5,15 = 1.3; 6,7 = 7,8 = 2.5; 7,13 = 2; 7,13' = 1.8; 8,9 = 4.5; 8,9' = 10; 9,9' = 15; compound **3b**: 1,2 = 16; 5,6 = 9; 5,15 = 1.5; 7,8 = 3; 7,13 = 2; 7,13' = 1.7; 8,9 = 6; 8,9' = 9; 9,9' = 14; compounds **4b**–**4e**: 1,2 = 6; 1,2' = 10; 2,2' = 12.5; 5,6 = 3.5; 5,15 = 6,15 = 1.5; 6,7 = 3; 7,13 = 2.5; 7,13' = 2; 7,8 = 8,9 = 5.5; 8,9' = 11; 9,9' = 14.5; compound **4f**: 1,2α = 4; 2α,2β = 15; 2α,3 = 10; 2β,3 = 6; 3,15 = 5,15 = 1; 5,6 = 6,7 = 6; 7,8 ~ 1; 7,13 = 3.5; 7,13' = 3; 8,9β = 7.5; 9α,9β = 15; compounds **5b** and **5c**: 1,2 = 6; 5,6 = 5; 6,7 = 3; 7,8 = 1; 7,13 = 2.5; 7,13' = 2; 8,9 = 4; 8,9' = 5; 9,9' = 15; compound **6**: 1,2 = 2.5; 5,6 = 7; 5,15 = 6,15 = 1.3; 6,7 = 1; 7,8 = 2.5; 7,13 = 1.8; 7,13' = 1.5; 8,9 = 4; 8,9' = 10; 9,9' = 15.



	7a	7b	7c	7d	7e
R^1	*i*-Bu	*i*-Bu	H	*i*-Bu	*i*-Bu
R^2	H_2	β-OH, H	H_2	=O	H_2 Δ3



	8a	8b	8c
R	CH_2	CH_2	CH_3,H
R	4β-H	4α-H	4α-H



9a R = α-H
9b R = α-OH
9c R = β-OH

Table 2. ^{1}H NMR spectral data of compounds **7a–7e**, **8a–8c**, **9b** and **9c** ($CDCl_3$, 400 MHz, δ values)

	7a	7b	7c	7d	7e	8a*	8b†	8c	9b	9c
H-1	3.53 *dd*	3.57 *dd*	3.50 *dd*	3.90 *ddd*	3.68 *dd*	3.71 *dd*	3.76 *dd*	3.71 *dd*	2.64 *br d* 2.15 *d*	2.48 *d* 2.37 *d*
H-2	1.83 *br ddd*	2.26 *ddd*	1.83 *m*	2.93 *dd*	2.40 *m*	2.75 *dd*	2.68 *m*	2.66 *m*	—	—
H-2′	1.62 *ddd*	1.57 *ddd*	1.64 *m*	2.46 *dd*		2.59 *m*				
H-3	2.36 *ddd*	4.11 *br dd*	2.35 *ddd*	—	5.37 *br s*	—	—	—	5.84 *br s*	5.87 *br s*
H-3′	2.14 *ddd*		2.14 *ddd*	—		—	—	—		
H-5	2.25 *br d*	2.13 *br d*	2.24 *br d*	2.61 *dt*	2.43 *br d*	1.66 *dd*	2.01 *dd*	1.89 *dd*	—	—
H-6	4.51 *t*	4.57 *t*	4.62 *t*	4.56 *t*	4.42 *t*	4.48 *t*	4.51 *t*	4.78 *t*	2.11 *dd* 1.63 *dd*	2.13 *dd* 2.41 *dd*
H-7	2.83 *dddd*	2.82 *dddd*	2.72 *dddd*	2.90 *dddd*	2.78 *dddd*	2.82 *dddd*	2.80 *dddd*	2.01 *m*	3.43 *br dddd*	3.22 *br dddd*
H-8	5.76 *ddd*	5.75 *ddd*	4.66 *br s*	5.81 *ddd*	5.76 *ddd*	5.78 *ddd*	5.78 *ddd*	5.56 *ddd*	4.58 *ddd*	4.74 *ddd*
H-9	1.59 *br d*	2.34 *dd*	2.32 *dd*	2.42 *dd*	1.98 *m*	2.42 *dd*	2.35 *dd*	2.33 *dd*	2.25 *dd*	1.88 *dd*
H-9′	2.32 *dd*	1.58 *dd*	1.54 *dd*	1.68 *dd*	2.40 *m*	1.58 *br d*	1.59 *br d*	1.62 *dd*	2.00 *br d*	1.81 *dd*
H-13	6.16 *d*	6.17 *d*	6.35 *d*	6.22 *d*	6.16 *d*	6.19 *d*	6.19 *d*	1.29 *d*	6.18 *d*	6.36 *d*
H-13′	5.44 *d*	5.46 *d*	5.53 *d*	5.52 *d*	5.43 *d*	5.47 *d*	5.48 *d*		5.65 *d*	5.76 *d*
H-14	0.99 *s*	0.97 *s*	1.07 *s*	1.11 *s*	1.07 *s*	1.30 *s*	1.28 *s*	1.27 *s*	1.13 *s*	1.09 *s*
H-15	5.03 *br s* 4.96 *br s*	5.36 *br s* 5.13 *br s*	5.02 *br s* 4.95 *br s*	6.20 *d* 5.84 *d*	1.89 *br s*	1.32 *d*	1.32 *d*	1.33 *d*	2.00 *d*	2.07 *d*
OCOR	2.54 *qq*	2.54 *qq*	—	2.56 *dd*	2.54 *qq*	2.56 *qq*	2.57 *qq*	2.56 *qq*	—	—
	1.15 *d*	1.15 *d*	—	1.17 *d*	1.16 *d*	1.17 *d*	1.18 *d*	1.21 *d*		
	1.14 *d*	1.14 *d*		1.16 *d*	1.15 *d*	1.16 *d*	1.17 *d*	1.20 *d*		

*H-4 2.59 *m*.

†H-4 2.86 *br dq*.

J (Hz): compounds **7a** and **7c**: 1,2 = 4.5; 1,2′ = 11; 2,2′ = 2′,3′ = 3,3′ = 12; 2,3 = 1.5; 5,6 = 6,7 = 11; 7,8 = 7,13′ = 8,9 = 3; 7,13 = 3.5; 8,9′ = 2; 9,9′ = 15; compound **7b**: 1,2 = 4.5; 1,2′ = 2,2′ = 2′,3 = 12; 2,3 = 5; 5,6 = 6,7 = 11; 7,8 = 7,13′ = 8,9 = 3; 7,13 = 3.5; 8,9′ = 2; 9,9′ = 15; compound **7d**: 1,2 = 6; 1,2′ = 10; 2,2′ = 17; 5,6 = 6,7 = 10.5; 5,15 = 5,15′ = 2; 7,8 = 3; 7.13 = 8,9′ = 3.5; 7,13′ = 3; 8,9 = 2.5; 9,9′ = 15; compound **7e**: 1,2 = 6; 1,2′ = 9; H-5–H-9 and H-13 see **7a**; compounds **8a** and **8b**: 2,2′ = 15.5; 5,6 = 6,7 = 10.5; 7,8 = 7,13 = 8,9 = 3; 7,13′ = 8,9′ = 2.5; 9,9′ = 15 (compound **8a**: 1,2 = 5.5; 1,2′ = 11.5; 4,5 = 10; 4,15 = 7; compound **8b**: 1,2 = 4,5 = 7; 1,2′ = 10; 4,15 = 7.5); compound **8c**: 1,2 = 4,5 = 7; 1,2′ = 10; 4,15 = 7.5; 5,6 = 6,7 = 11; 7,11 = 11,13 = 7.5; 7,8 = 8,9′ = 3; 8,9 = 2.5; 9,9′ = 15.

presented. Therefore we have added the relevant data in Table 1. The spectrum of **7e** was similar to that of the corresponding angelate [18].

The ^{1}H NMR spectrum of **7b** (Table 1) was very close to that of **7a**. The presence of an additional hydroxy group at C-3 was deduced from the broadened double doublet at δ4.11. The positions of the oxygen functions were established by spin decoupling and the configurations at C-1 and C-3 followed from the observed couplings. Those of H-3 differed clearly from those of trichomatolide B, a related 3α-hydroxy compound [19].

The ^{1}H NMR spectra of **8a** and **8b** (Table 2) were similar indicating that these lactones may be epimers. This assumption was supported by spin decoupling which led to clear sequences for H-5 through H-9. Although some signals were overlapped the presence of a secondary methyl group at C-4 could be shown by decoupling. A double doublet at δ3.71 and 3.76, respectively, indicated a secondary hydroxy group which could be placed at C-1. As the methyl singlets were shifted downfield (δ1.30 and 1.28, respectively) in agreement with the molecular formula ($C_{19}H_{26}O_6$) the presence of guaianolides with a 1,10-epoxide was proposed. An alternative possibility was the presence of the eudesmanolides **8a** and **8b**. However, the chemical shift of H-14 would be unusual for this type of sesquiterpene lactone. As only minute amounts were isolated no reactions could be undertaken. However, a very weak ^{13}C NMR spectrum was obtained which did not show signals for epoxide carbons. Thus the structures of **8a** and **8b** were favoured. The ^{1}H NMR spectra in deuteriobenzene gave further information, especially the couplings of H-4, which clearly indicated that the epimer **8a** had *trans*-diaxial protons at C-4 and C-5 while a 6 Hz coupling in the case of **8b** required the *cis*-relationship of these protons. Accordingly, H-4 showed a *W*-coupling with H-2 which gave rise to an unresolved multiplet in the case of **8b**. The presence of eudesmanolides were further supported by a *W*-coupling of H-14 with H-9α in both epimers. Finally the structure of **8b** was established by a partial synthesis of **8c**. Manganese dioxide oxidation of **7b** afforded the ketone **7d** which was stereospecifically hydrogenated to **8c**. The ^{1}H NMR spectrum (Table 2) of the latter was nearly identical with that of **8b** except for the signals of H-7, H-11 and H-13. Obviously the unusual shift of H-14 was due to deshielding effects of the 3-keto group and of the 8β-oxygen function. The fragmentation pattern in the mass spectra of **8a** and **8b** also supported the presence of eudesmanolides. In particular the fragment *m/z* 251 was probably formed by loss of ring A and this was followed by elimination of isobutyric acid leading to *m/z* 163 ($C_{10}H_{11}O_2$). Biogenetically **8a** and **8b** probably are formed from **1b** which, by proton attack of the epoxide, could be transformed to an eudesmanolide cation. Loss of H-3 could lead then to the enols of **8a** and **8b** which are derivatives of artecalin [20]. However, the ^{1}H NMR data of the latter compound (**8b**) could not be compared with those of **8a** as only a 60 MHz spectrum in deuterioacetone is reported in the literature [21].

The structures of **9b** and **9c** followed from the ^{1}H NMR spectra (Table 2). All signals could be assigned by spin decoupling. While the spectrum of **9b** was very close to that of pinnatifidin (**9a**) [8] that of **9c** differed remarkably. The couplings of H-8 were changed and H-6β was shifted downfield. The stereochemistry was determined by NOE difference spectroscopy which gave clear effects between H-14, H-9α, H-9β and H-2β as well as between H-8, H-7 and H-2α. Inspection of a model showed that these effects required the presence of a *cis*-decalin derivative where the B ring was in a boat conformation. Thus **9b** and **9c** were epimeric 5-hydroxypinnatifidins.

The ^{1}H NMR spectrum of **10** (Table 3) indicated the presence of a hydroperoxide (δ8.45 *s*) of a guaianolide where all signals could be assigned by spin decoupling. The stereochemistry followed from the couplings and from a strong NOE between H-14 and H-6 indicating a conformation with a quasi-axial 10-methyl group which agreed with the couplings of H-8. The presence of a hydroperoxide was supported by the mass spectrum. After loss of isobutyric acid (*m/z* 276) elimination of hydrogen peroxide was observed (*m/z* 242).

The ^{1}H NMR data of **11** (Table 3) showed that again a guaianolide was present. Most signals were close to those of dehydroleucodin derivatives [22]. However, as a signal for H-3 was missing in agreement with the molecular formula and the IR band at 3620 cm^{-1} a 3-hydroxy derivative was present. A similar tiglate, but lacking the 1,10-double bond, was reported previously [23].

The ^{1}H NMR spectra of **12a** and **12b** (Table 3) indicated that epimers were most likely present again. Spin decoupling showed that a 3-ketoguaianolide with a 8β-isobutyryloxy group should be proposed. In agreement with the molecular formula the chemical shift of the methyl signals indicated hydroxy groups at C-4 and C-10. This was established by the ^{13}C NMR spectrum of **12a** (Experimental). The configurations at C-4 and C-10 were determined by NOE difference spectroscopy. In the case of **12a** saturation of H-14 gave clear NOEs with H-9α, H-9β and H-2β while H-15 showed a NOE with H-5. Surprisingly in the ^{1}H NMR spectrum of **12b** some signals were broadened (H-6 and H-7) which were sharpened at elevated temperature. Obviously the changed stereochemistry led to some flexibility of the conformation. The stereochemistry followed from the results of NOE difference spectroscopy. Clear effects were observed between H-14, H-9β, H-6, H-2β and H-1, between H-15 and H-6 and between H-7, H-5 and H-8. A weak NOE between H-14 and H-15 supported the proposed conformational flexibility.

The ^{1}H NMR spectrum of **13** (Table 3) indicated that an anhydro derivative of **12a/b** was present. Accordingly, the signal of H-6 was a broadened doublet at δ 5.41 which was sharpened by irradiation at δ 2.00 (H-15) and 3.32 (H-1). All signals were assigned by spin decoupling and the stereochemistry was determined by the observed NOEs between H-14 and H-9β as well as between H-7 and H-8.

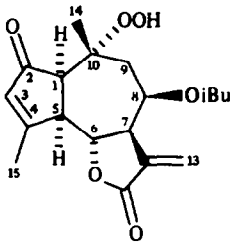
The ^{1}H NMR spectrum of **14** (Table 3) was in part

Table 3. ^{1}H NMR spectral data of compounds **10**, **11**, **12a**, **12b**, **13** and **14** ($CDCl_3$, 400 MHz, δ values)

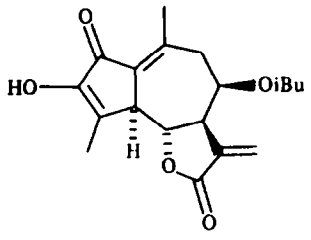
	10*	**11**	**12a** (C_6D_6)	**12b** (60°)	**13**	**14**
H-1	2.91 *d*	—	1.97 *ddd*	2.97 *ddd*	3.32 *m*	2.86 *dd*
H-2	—	—	2.11 *dd*	2.59 *dd*	2.60 *m*	2.20 *m*
H-2′	—	—	1.80 *dd*	2.28 *dd*		1.56 *m*
H-3	5.45 *br s*	—	—	—	—	2.42 *ddd* 2.29 *br dd*
H-4	—	—	—	—	—	—
H-5	3.19 *ddq*	3.39 *br d*	1.91 *t*	2.71 *dd*	—	5.36 *br d*
H-6	4.67 *dd*	4.03 *t*	4.79 *t*	4.40 *dd*	5.41 *br d*	5.27 *t*
H-7	3.11 *dddd*	3.12 *dddd*	3.52 *dddd*	3.85 *dddd*	3.44 *br ddd*	2.77 *dddd*
H-8	5.71 *ddd*	5.68 *dt*	5.51 *ddd*	5.64 *ddd*	4.81 *br dd*	4.59 *br d*
H-9	2.29 *dd*	2.86 *dd*	2.15 *dd*	2.31 *dd*	2.37 *dd*	1.14 *br d*
H-9′	2.06 *dd*	2.75 *br d*	1.22 *dd*	1.82 *dd*	2.10 *br dd*	3.01 *dd*
H-13	6.34 *d*	6.24 *d*	6.25 *d*	6.27 *d*	6.37 *d*	6.37 *d*
H-13′	5.60 *d*	5.49 *d*	5.16 *d*	5.47 *d*	5.66 *d*	5.57 *d*
H-14	1.20 *s*	2.41 *s*	0.54 *s*	1.35 *s*	1.09 *s*	4.68 *d* 3.78 *d*
H-15	2.26 *t*	2.23 *br s*	1.48 *s*	1.52 *s*	2.00 *dd*	1.85 *br s*
OCOR	2.48 *qq*	2.48 *qq*	2.22 *qq*	2.48 *qq*	2.54 *qq*	2.13 *s*
	1.11 *d*	1.10 *d*	1.01 *d*	1.11 *d*	1.15 *d*	
	1.09 *d*	1.09 *d*	0.96 *d*	1.09 *d*	1.14 *d*	

*OOH 8.45 *s*.

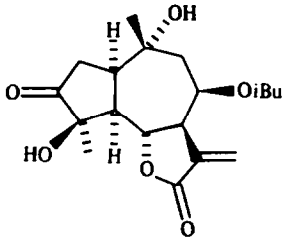
J (Hz): compound **10**: 1,5 = 6; 3,15 = 5,15 = 1; 5,6 = 11; 6,7 = 9.5; 7,8 = 2.5; 7,13 = 3.5; 7,13′ = 3; 8,9 = 3; 8,9′ = 5; 9,9′ = 15; compound **11**: 5,6 = 10; 7,8 = 1; 7,13 = 3; 7,13′ = 2.5; 8,9 = 6; 8,9′ = 1; 9,9′ = 15; compound **12a**: 1,2 = 5.5; 1,2′ = 11; 1,5 = 5,6 = 6,7 = 9.5; 2,2′ = 17; 7,8 = 7,13 = 3,5; 7,13′ = 3; 8,9 = 8.5; 8,9′ = 5; 9,9′ = 15; compound **12b**: 1,2 = 9; 1,2′ = 1,5 = 7.5; 2,2′ = 18.5; 5,6 = 11; 6,7 = 8.5; 7,8 = 3; 7,13 = 3.5; 7,13′ = 3; 8,9 = 5; 8,9 = 9; 9,9′ = 15; compound **13**: 6,7 = 11; 1,15 = 6,15 = 1.5; 7,13 = 7,13′ = 8,9′ = 3; 8,9 = 3.5; 9,9′ = 14.5; compound **14**: 1,2 = 2; 1,2′ = 11; 2,3 = 3,3′ = 12; 2′,3 = 2,3′ = 5; 5,6 = 6,7 = 10; 7,8 ~ 1; 7,13 = 3.5; 7,13′ = 3; 8,9 = 6.5; 9,9′ = 15; 14,14′ = 11.



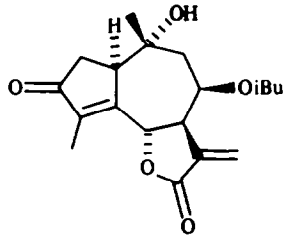
10



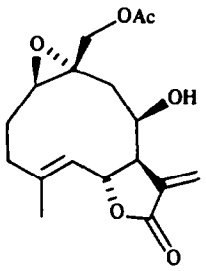
11



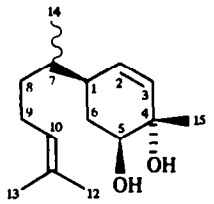
12a 12b 4 *epi*



13



14



15

similar to that of ovatifolin [10]. However, the replacement of the 1,10-double bond by an epoxide was indicated by an upfield shift of H-14 and the chemical shift of H-1 (δ 2.86, *dd*) which required the presence of an epoxide. The ^{1}H NMR data were close to those of the corresponding 8-*O*-methacrylate [24].

The structure of **15** could also be deduced from the ^{1}H NMR spectrum (Experimental). All signals were assigned by spin decoupling which led to the proposed sequence. The observed couplings and inspection of a model indicated the probable presence of a derivative of α-zingiberene, a hydrocarbon also isolated from *Calea* species, which are probably related to *Greenmaniella* [25, 26]. The proposed configuration at C-5 agreed with the couplings and for biogenetic reasons a *trans*-diol was assumed.

The non-polar fractions afforded heptadeca-1,7*E*,9*E*,15*E*-tetraen-11,13-diyne (centaur X_4) [27], geranylcymol [28] and caryophyllen epoxide.

The chemistry of *Greenmaniella* shows clear relationships to the genus *Calea* [29, 30]. The lactones like tagitinin E are biogenetically close to furanoheliangolides and therefore the chemistry of *Neurolaena* [31] and *Brasilia* [32], which are also placed in the subtribe Neurolininae [3], also indicates a relationship. However, the constituents of *Zaluzania* [33], *Schistocarpha* [34] and *Bebbia* [34], which have been placed in this subtribe [2], clearly differ and therefore their placement in other subtribes [3] would be supported by the chemistry. It is clear that the removal of *Greenmaniella resinosa* from *Zaluzania*, where it was originally placed, is strongly supported by the chemistry. Further investigations of related genera may solve some of the remaining problems.

EXPERIMENTAL

The air-dried aerial parts (600 g, voucher Turner 15625) were extracted with MeOH–Et_2O–petrol (1:1:1) at room temp. The extract obtained was separated as reported previously [35] first by CC (silica gel) into four fractions (CC 1–CC 4) which were further separated by HPLC (RP 8, *ca* 100 bar; H 1: MeOH–H_2O, 7:3; H 2: MeOH–H_2O, 3:2; H 3: MeOH–H_2O, 11:9) and/or by repeated prep. TLC (silica gel, PF 254; P 1: Et_2O–petrol, 3:1; P 2: $CHCl_3$–C_6H_6–Et_2O, 1:1:1; P 3: $CHCl_3$–MeOH, 30:1; P 4: petrol). Finally the following compounds were obtained (in parentheses condition of isolation and R_f or R_t values): CC 1: 35 mg geranylcymol (P 4, R_f 0.85), 20 mg squalene (P 4, R_f 0.8) and 20 mg centaur X_4 (P 4, R_f 0.70). CC 2: 80 mg caryophyllene-poxide. CC 3: 3 mg **1a** (H 2, R_t 1.8 min, P 3, R_f 0.62), 200 mg **1b** (H 2, R_t 3.1 min, P 3, R_f 0.70), 15 mg **2**, **4c** (H 3, R_t 4.1 min),

400 mg **3a** (H 2, R_t 3.0 min), 2 mg **3b** (H 2, R_t 5.5 min), 300 mg **4a** (H 2, R_t 7.9 min, P 1, R_f 0.60), 1.5 mg **4b** (P 1, R_f 0.75), 150 mg **4d** (H 1, R_t 4.4 min), 300 mg **5a** (H 1, R_t 5.0 min, P 1, R_f 0.28), 3 mg **5b** (H 1, R_t 4.0 min, P 1, R_f 0.60), 2 mg **5c** (H 2, R_t 7.9 min, P 2, R_f 0.50), 8 mg **6** (H 2, R_t 3.1 min, P 3, R_f 0.50), 2 mg **7a** (H 1, R_t 5.0 min, P 2, R_f 0.50), 2 mg **7e** (H 1, R_t 5.7 min), 5 mg **9b** (H 2, R_t 1.8 min, P 3, R_f 0.32), 3 mg **9c** (H 2, R_t 1.2 min, P 3, R_f 0.50), 1 mg **10** (H 3, R_t 5.7 min), 2.5 mg **8a** (H 3, R_t 6.9 min), 1 mg **8b** (H 3, R_t 6.7 min, P 3, R_f 0.35), 2 mg **11** (P 3, R_f 0.70), 10 mg **12a** (H 3, R_t 3.2 min, P 3, R_f 0.45), 1 mg **13** (H 3, R_t 5.8 min), 1.5 mg **14** (H 2, R_t 1.8 min, P 3, R_f 0.45), 2 mg **15** (H 1, R_t 2.8 min, P 2, R_f 0.60), 50 mg ovatifolin (H 2, R_t 4.7 min), 10 mg ivalin (H 2, R_t 3.2 min) and 1 mg desacetyl-tulipinolide-1β,10α-epoxide. CC 4: 500 mg **9a** (crystallization), 3 mg **7b** (H 3, R_t 6.7 min, P 3, R_f 0.50), 1.5 mg **7c** (H 3, R_t 2.9 min, P 3, R_f 0.50), 1.5 mg **12b** (H 3, R_t 4.5 min, P 3, R_f 0.50).

Desacyltagitinin E-8-O-*propionate* (**1a**). Colourless crystals, mp 125°; IR $\nu_{max}^{CHCl_3}$ cm^{-1}: 3600 (OH), 1765 (γ-lactone), 1730 (CO_2R); MS *m/z* (rel. int.): 262.121 [M − RCO_2H]$^+$ (2.5) (calc. for $C_{15}H_{18}O_4$: 262.121), 244 [262 − H_2O]$^+$ (3), 57 [C_2H_5CO]$^+$ (100).

Transformation of **1b** *to* **4f**. Compound **1b** (30 mg) in 3 ml C_6H_6 was refluxed for 30 min with 10 mg *p*-toluene sulphonic acid. After shaking with $NaHCO_3$ soln prep. TLC of the reaction products ($CHCl_3$–MeOH, 30:1) afforded 15 mg **4f**, colourless crystals, mp 173°; IR $\nu_{max}^{CHCl_3}$ cm^{-1}: 3625 (OH), 1760 (γ-lactone), 1730 (CO_2R); MS *m/z* (rel. int.): 350.173 [M]$^+$ (0.7) (calc. for $C_{19}H_{26}O_6$: 350.173), 262 [M − RCO_2H]$^+$ (11), 244 [262 − H_2O]$^+$ (9), 226 [244 − H_2O]$^+$ (6), 211 [226 − Me]$^+$ (10), 71 [C_3H_7CO]$^+$ (100); $[\alpha]_D^{24°}$ − 141° ($CHCl_3$; *c* 0.79).

Resinosolide (**2**). Colourless gum; IR $\nu_{max}^{CCl_4}$ cm^{-1}: 3590 (OH), 1780 (γ-lactone), 1730 (CO_2R), 1700 (C=CC=O); MS *m/z* (rel. int.): 366.168 [M]$^+$ (0.15) (calc. for $C_{19}H_{26}O_7$: 366.168), 348 [M − H_2O]$^+$ (0.9), 330 [348 − H_2O]$^+$ (1), 278 [M − RCO_2H]$^+$ (6), 260 [278 − H_2O]$^+$ (5), 242 [260 − H_2O]$^+$ (2), 71 [C_3H_7CO]$^+$ (100). To 5 mg of the mixture in 2 ml MeOH was added 5 mg *p*-toluene solphonic acid. After standing for 12 hr at 20° usual work-up afforded 5 mg **4e**; colourless crystals, mp 176°; MS *m/z* (rel. int.): 380.184 [M]$^+$ (2) (calc. for $C_{20}H_{28}O_7$: 380.184), 349 [M − OMe]$^+$ (2), 292 [M − RCO_2H]$^+$ (37), 71 [C_3H_7CO]$^+$ (100).

Desacyltagitinin C-8-O-[2-*methylbutyrate*] (**3b**). Colourless oil; IR $\nu_{max}^{CHCl_3}$ cm^{-1}: 3610 (OH), 1765 (γ-lactone), 1730 (CO_2R); MS *m/z* (rel. int.): 362.173 [M]$^+$ (0.1) (calc. for $C_{20}H_{26}O_6$: 362.173), 260 [M − RCO_2H]$^+$ (7), 242 [260 − H_2O]$^+$ (3), 85 [RCO]$^+$ (44), 57 [85 − CO]$^+$ (100).

Desoxytagitinin B-3-O-*methyl ether* (**4b**). Colourless oil; IR $\nu_{max}^{CCl_4}$ cm^{-1}: 1775 (γ-lactone), 1735 (CO_2R); MS *m/z* (rel. int.): 364.189 [M]$^+$ (6) (calc. for $C_{20}H_{28}O_6$: 364.189), 332 [M − MeOH]$^+$ (7), 276 [M − RCO_2H]$^+$ (17), 261 [276 − Me]$^+$ (18), 232 [276 − CO_2]$^+$ (57), 71 [C_3H_7CO]$^+$ (100).

2β-*Methoxydesoxytagitinin B* (**4d**). Colourless oil; IR $\nu_{max}^{CCl_4}$ cm^{-1}: 3590 (OH), 1775 (γ-lactone), 1725 (CO_2R); MS *m/z* (rel. int.): 380.184 [M]$^+$ (0.7) (calc. for $C_{20}H_{28}O_7$: 380.184), 362 [M − H_2O]$^+$ (1.4), 330 [362 − MeOH]$^+$ (1), 292 [M − RCO_2H]$^+$ (11), 260 [292 − MeOH]$^+$ (9), 71 [C_3H_7CO]$^+$ (100); ^{13}C NMR (C_6D_6, C-1–C-15): 86.5 *d*, 41.3 *t*, 103.6 *s*, 140.5 *s*, 129.2 *d*, 70.8 *d*, 57.9 *d*, 75.2 *d*, 35.7 *t*, 81.7 *s*, 137.3 *s*, 169.5 *s*, 121.9 *t*, 22.4 *q*, 27.1 *q*; OCOR: 175.6 *s*, 34.3 *d*, 18.7 *q*, 19.2 *q*; $[\alpha]_D^{24°}$ − 124° ($CHCl_3$; *c* 1.3).

Tagitinin F-3-O-*methyl ether* (**5b**). Colourless oil; IR $\nu_{max}^{CCl_4}$ cm^{-1}: 1770 (γ-lactone), 1735 (CO_2R); MS *m/z* (rel. int.): 362.173 [M]$^+$ (2.2) (calc. for $C_{20}H_{26}O_6$: 362.173), 331 [M − OMe]$^+$ (8), 274 [M − RCO_2H]$^+$ (14), 259 [274 − Me]$^+$ (12), 71 [C_3H_7CO]$^+$ (100); $[\alpha]_D^{24°}$ − 84° ($CHCl_3$; *c* 0.3).

Desacyltagitinin F-8-O-[2-*methylbutyrate*] (**5c**). Colourless oil; IR $\nu_{max}^{CHCl_3}$ cm^{-1}: 3580 (OH), 1760 (γ-lactone), 1730 (CO_2R); MS *m/z* (rel. int.): 362.173 [M]$^+$ (0.6) (calc. for $C_{20}H_{26}O_6$: 362.173), 260 [M − RCO_2H]$^+$ (12), 242 [260 − H_2O]$^+$ (6), 85 [C_4H_9CO]$^+$ (51), 57 [85 − CO]$^+$ (100).

1β,2α-*Epoxytagitinin C* (**6**). Colourless, amorphous material, mp 110°; IR $\nu_{max}^{CHCl_3}$ cm^{-1}: 3630 (OH), 1770 (γ-lactone), 1735 (CO_2R), 1690 (C=CC=O); MS *m/z* (rel. int.): 364.152 [M]$^+$ (0.1) (calc. for $C_{19}H_{24}O_7$: 364.152), 276 [M − RCO_2H]$^+$ (1.5), 248 [276 − CO]$^+$ (3), 233 [248 − Me]$^+$ (6), 123 (82), 71 [C_3H_7CO]$^+$ (100); ^{13}C NMR ($CDCl_3$, C-1–C-15): 58.1 *d*, 65.5 *d*, 193.5 *s*, 137.1 *s*, 141.5 *d*, 75.1 *d*, 49.6 *d*, 73.0 *d*, 42.3 *t*, 70.0 *s*, 135.5 *s*, 168.8 *s*, 125.0 *t*, 26.0 *q*, 20.2 *q*; OCOR: 176.1 *s*, 34.1 *d*, 18.6 *q* (2 ×); $[\alpha]_D^{24°}$ − 69° ($CHCl_3$; *c* 0.53). To 20 mg **1b** in 1 ml $CHCl_3$ 20 mg *m*-chloroperbenzoic acid and 20 mg $NaHCO_3$ were added. After 16 hr HPLC (H3, R_t 4.7 min) afforded 10 mg **6**, identical with the natural compound and unreacted material.

8β-*Isobutyryloxyreynosin* (**7a**). Colourless oil; IR $\nu_{max}^{CCl_4}$, cm^{-1}: 3600 (OH), 1775 (γ-lactone), 1735 (CO_2R); MS *m/z* (rel. int.): 334.178 [M]$^+$ (1.6) (calc. for $C_{19}H_{26}O_5$: 334.178), 246 [M − RCO_2H]$^+$ (22), 228 [246 − H_2O]$^+$ (37), 71 [C_3H_7CO]$^+$ (100).

8β-*Isobutyryloxyridentin B* (**7b**). Colourless oil; IR $\nu_{max}^{CHCl_3}$ cm^{-1}: 3600 (OH), 1760 (γ-lactone), 1730 (CO_2R); MS *m/z* (rel. int.): 350.173 [M]$^+$ (8) (calc. for $C_{19}H_{26}O_6$: 350.173), 262 [M − RCO_2H]$^+$ (2.5), 244 [262 − H_2O]$^+$ (4.5), 229 [244 − Me]$^+$ (2), 71 [C_3H_7CO]$^+$ (100); $[\alpha]_D^{24°}$ − 2° ($CHCl_3$; *c* 0.45). Compound **7b** (3 mg) in 3 ml MeOH was stirred with 30 mg MnO_2 for 1 hr at room temp. Prep. TLC ($CHCl_3$–MeOH, 50:1) gave 1.5 mg **7d** (R_f 0.4) which was hydrogenated in MeOH with $Pd/BaSO_4$ (5%). The reaction product was purified by HPLC (H 3, R_t 7.8 min); colourless oil; MS *m/z* (rel. int.): 253 [M − $C_5H_7O_2$]$^+$ (10), 165 [253 − RCO_2H]$^+$ (62), 71 [RCO]$^+$ (100).

8β-*Isobutyryloxybalchanin* (**7e**). Colourless oil; IR $\nu_{max}^{CHCl_3}$ cm^{-1}: 3610 (OH), 1765 (γ-lactone), 1730 (CO_2R); MS *m/z* (rel. int.): 334.178 [M]$^+$ (8) (calc. for $C_{19}H_{26}O_5$: 334.178), 246 [M − RCO_2H]$^+$ (32), 228 [246 − H_2O]$^+$ (11), 217 [246 − CHO]$^+$ (12), 71 [C_3H_7CO]$^+$ (100).

8β-*Isobutyryloxyartecalin* (**8a**). Colourless crystals, mp 228°; IR $\nu_{max}^{CHCl_3}$ cm^{-1}: 3580 (OH), 1770 (γ-lactone), 1730 (CO_2R); MS *m/z* (rel. int.): 350.173 [M]$^+$ (0.7) (calc. for $C_{19}H_{26}O_6$: 350.173), 332 [M − H_2O]$^+$ (0.5), 262 [M − RCO_2H]$^+$ (5), 251 [M − $C_5H_7O_2$]$^+$ (26), 163.075 [251 − RCO_2H]$^+$ (25), 145 [163 − H_2O]$^+$ (56), 117 [145 − CO]$^+$ (71), 71 [C_3H_7CO]$^+$ (100); ^{13}C NMR (C_6D_6, C-1–C-15): 76.4 *d*, 50.2 *t*, 205.8 *s*, 52.5 *d*, 44.1 *d*, 77.4 *d*, 46.3 *d*, 65.2 *d*, 40.6 *t*, 42.8 *s*, 134.9 *s*, 173.5 *s*, 118.2 *t*, 30.1 *q*, 13.7 *q*; OCOR: 175.5 *s*, 34.3 *d*, 19.2 *q*, 18.8 *q*; $[\alpha]_D^{24°}$ − 5° ($CHCl_3$; *c* 0.21).

8β-*Isobutyryloxy-4-epiartecalin* (**8b**). Colourless gum; IR $\nu_{max}^{CHCl_3}$ cm^{-1}: 3580 (OH), 1770 (γ-lactone), 1730 (CO_2R); MS *m/z* (rel. int.): 350.173 [M]$^+$ (0.7) (calc. for $C_{19}H_{26}O_6$: 350.173), 332 (0.7), 251 (24), 244 [332 − RCO_2H]$^+$ (5), 163 (82), 145 (60), 117 (82), 71 (100).

5α-*Hydroxypinnatifidin* (**9b**). Colourless crystals, mp 201°; IR $\nu_{max}^{CHCl_3}$ cm^{-1}: 3600 (OH), 1765 (γ-lactone), 1670 (C=CC=O); MS *m/z* (rel. int.): 262.121 [M]$^+$ (7) (calc. for $C_{15}H_{18}O_4$: 262.121), 247 [M − Me]$^+$ (3.5), 244 [M − H_2O]$^+$ (3), 229 [244 − Me]$^+$ (2), 111 (71), 61 (100); $[\alpha]_D^{24°}$ + 166° ($CHCl_3$; *c* 0.08).

5β-*Hydroxypinnatifidin* (**9c**). Colourless crystals, mp 175°; IR $\nu_{max}^{CHCl_3}$ cm^{-1}: 3630 (OH), 1765 (γ-lactone), 1670 (C=CC=O); MS *m/z* (rel. int.): 262.121 [M]$^+$ (18) (calc. for $C_{15}H_{18}O_4$: 262.121), 244 (2), 98 (100); $[\alpha]_D^{24°}$ + 51° ($CHCl_3$; *c* 0.39).

2-*Oxo*-10α-*peroxi*-8β-*isobutyryloxyguaia*-3, 11(13)-*dien*-12,6α-*olide* (**10**). Colourless gum; IR $\nu_{max}^{CHCl_3}$ cm^{-1}: 3590 (OOH), 1770 (γ-lactone), 1730 (CO_2R); MS *m/z* (rel. int.): 364.152 [M]$^+$ (1.4) (calc. for $C_{19}H_{24}O_7$: 364.152), 346 [M − H_2O]$^+$ (1.4), 276 [M − RCO_2H]$^+$ (5), 258 [276 − H_2O]$^+$ (6), 242 [276 − H_2O_2]$^+$ (4), 71 [C_3H_7CO]$^+$ (100).

3-*Hydroxy*-8β-*isobutyryloxydehydroleucodin* (**11**). Colourless crystals, mp 124°; IR $\nu_{max}^{CHCl_3}$ cm^{-1}: 3620 (OH), 1760 (γ-lactone),

1720 (CO_2R); MS *m/z* (rel. int.): 346.142 $[M]^+$ (42) (calc. for $C_{19}H_{22}O_6$: 346.142), 258 $[M-RCO_2H]^+$ (54), 71 $[C_3H_7CO]^+$ (100); $[\alpha]_D^{24°}$ +71° ($CHCl_3$; *c* 0.07).

*4β,10α-Dihydroxy-3-oxo-8β-isobutyryloxyguaia-*11(13)*-en-*12,6α*-olide* (**12a**). Colourless, amorphous material, mp 105°; IR $\nu_{max}^{CHCl_3}$ cm^{-1}: 3600 (OH), 1765 (γ-lactone), 1735 (C=O, CO_2R); MS *m/z* (rel. int.): 366.168 $[M]^+$ (0.9) (calc. for $C_{19}H_{26}O_7$: 366.168), 348 $[M-H_2O]^+$ (0.5), 278 $[M-RCO_2H]^+$ (1.5), 260 $[278-H_2O]^+$ (2.5), 242 $[260-H_2O]^+$ (1.4), 177 (37), 109 (66), 71 (44), 69 (100); ^{13}C NMR ($CDCl_3$, C-1–C-15): 45.4 *d*, 47.1 *t*, 214.2 *s*, 77.3 *s*, 53.3 *d*, 76.5 *d*, 47.7 *d*, 65.4 *d*, 39.4 *t*, 71.3 *s*, 135.0 *s*, 171.8 *s*, 120.8 *t*, 32.1 *q*, 22.9 *q*; OCOR: 176.4 *s*, 34.0 *d*, 19.2 *q*, 18.8 *q*; $[\alpha]_D^{24°}$ +40° ($CHCl_3$; *c* 0.38).

*4α,10α-Dihydroxy-3-oxo-8β-isobutyryloxyguaia-*11(13)*-en-*12,6α*-olide* (**12b**). Colourless, amorphous material, mp 115°; IR $\nu_{max}^{CHCl_3}$ cm^{-1}: 3605 (OH), 1760 (γ-lactone), 1735 (C=O, CO_2R); MS *m/z* (rel. int.): 366.168 $[M]^+$ (0.1) (calc. for $C_{19}H_{26}O_7$: 366.168), 278 $[M-RCO_2H]^+$ (1), 260 $[278-H_2O]^+$ (1), 71 $[C_3H_7CO]^+$ (100).

*3-Oxo-10α-hydroxy-8β-isobutyryloxyguaia-*4,11(13)*-dien-*12,6α*-olide* (**13**). Colourless gum: IR $\nu_{max}^{CCl_4}$ cm^{-1}: 3460 (OH), 1780 (γ-lactone), 1735 (CO_2R), 1710 (C=CC=O); MS *m/z* (rel. int.): 348.157 $[M]^+$ (5) (calc. for $C_{19}H_{24}O_6$: 348.157), 278 $[M-O{=}C{=}CMe_2]^+$ (22), 260 $[M-RCO_2H]^+$ (24), 242 $[260-H_2O]^+$ (7), 71 $[C_3H_7CO]^+$ (100); $[\alpha]_D^{24°}$ +25° ($CHCl_3$; *c* 0.14).

1α,10β-Epoxyovatifolin (**14**). Colourless crystals, mp 124°; IR $\nu_{max}^{CHCl_3}$ cm^{-1}: 3600 (OH), 1760 (γ-lactone), 1740 (OAc); MS *m/z* (rel. int.): 262.121 $[M-HOAc]^+$ (15) (calc. for $C_{15}H_{18}O_4$: 262.121), 244 $[262-H_2O]^+$ (8), 111 (96), 95 (100).

*4α,5β-Dihydroxybisabola-*2,10*-diene* (**15**). Colourless oil; IR $\nu_{max}^{CHCl_3}$ cm^{-1}: 3580, 3400 (OH); MS *m/z* (rel. int.): 238.193 $[M]^+$ (1.5) (calc. for $C_{15}H_{26}O_2$: 238.193), 220 $[M-H_2O]^+$ (4), 202 $[220-H_2O]^+$ (2), 151 $[220-C_5H_9]^+$ (17), 109 $[C_8H_{13}]^+$ (56), 69 $[C_5H_9]^+$ (100); ^1H NMR ($CDCl_3$): 2.31 (*br q*, H-1), 5.66 (*dd*, H-2), 5.62 (*br dd*, H-3), 3.79 (*dd*, H-5), 1.83 (*ddd*, H-6), 1.70 (*ddd*, H-6'), 1.59 (*m*, H-7), 1.40 (*dddd*, H-8), 1.23 (*dddd*, H-8'), 2.03 (*br dddd*, H-9), 1.95 (*br dddd*, H-9'), 5.10 (*br t*, H-10), 1.69 (*br s*, H-12), 1.61 (*br s*, H-13), 0.88 (*d*, H-14), 1.32 (*s*, H-15) [*J* (Hz): 1,2 = 2; 1,3 = 1.5; 1,6 = 1,6' = 1,7 = 6; 5,6 = 7; 5,6' = 2.5; 6,6' = 9,9' = 14; 8,9 = 8,9' = 8',9' = 9,10 = 9',10 = 7].

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