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GERMACRANOLIDES FROM *GOCHNATIA VERNONIOIDES*

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Key Word Index—*Gochnatia vernonioides*; Compositae; sesquiterpene lactones; germacranolides; melampolide, elephantopin derivative, bisabolene derivatives

Abstract—The aerial parts of *Gochnatia vernonioides* afforded, in addition to dehydrocostus lactone, zaluzanin C and desacetyllaurenobiolide angelate, 14 further sesquiterpene lactones, ten 8, 12- and three 6, 12-germacranolides as well as one eudesmanolide and three bisabolene derivatives. The structures were elucidated by spectroscopic methods and by comparing the data with those of closely related compounds. 8α-Angeloyloxytaraxic acid underwent an unusual autocatalysed cyclisation while the usual Cope rearrangement was not observed.

INTRODUCTION

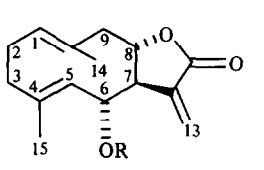
From the large genus *Gochnatia* (Compositae, tribe Mutisieae, subtribe Gochnatiinae) triterpenes [1, 2], guaianolides from two species [3, 4] and germacra-8,12-olides from one species [2] have been isolated. We have now studied the constituents of *G. vernonioides* H. B. K. from Peru. The results are discussed in this paper.

RESULTS AND DISCUSSION

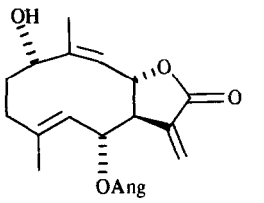
The above ground parts of *G. vernonioides* afforded a complex mixture of sesquiterpene lactones, which could only be separated by a combination of TLC and HPLC. This led to the isolation of dehydrocostus lactone [5], zaluzanin C [6], desacetyllaurenobiolide angelate (**1**) [2] and 14 other lactones, the germacran-8,12-olides **2**–**10**, the melampolide **11**, desacylelephantopin angelate (**12**), the two acids **13** and **14** as well as the eudesmanolide **16**. Furthermore, three aldehydes (**17**–**19**) derived from bisabolene were present.

The ^{1}H NMR spectral data of **2** and **3** (Table 1) showed that the compounds were angelates. Most of the signals were close to those from **1**, which was isolated from an *Actinoseris* species belonging to the same subtribe, and of the epoxides obtained from laurenobiolide by epoxidation [5]. The differences in the spin couplings $J_{5,6}$ indicated that **2** and **3** differed only in their stereochemistry at C-4 and C-5. The ^{1}H NMR spectrum of **4** (Table 1), which was similar to that of **3**, broadened at room temperature, showed that the angelate in **3** was replaced by a phenyl acetate residue. In agreement with this assumption the MS of **4** showed an ion at *m/z* 91, obviously due to tropylium, as the base peak, and the molecular formula was $C_{23}H_{26}O_5$. While most couplings were identical with those of **3**, the presence of the phenyl acetate moiety caused some differences.

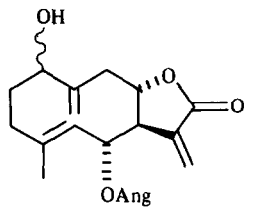
The ^{1}H NMR spectrum of **5** (Table 1) was similar to that of tulirinol, its configuration being established by X-ray analysis [6]. The replacement of the acetate by an angelate residue clearly followed from the typical



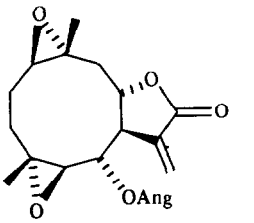
1 R = Ang
2 4α, 5β-epoxide, R = Ang
3 4β, 5α-epoxide, R = Ang
4 4β, 5α-epoxide, R = Phenac



5
6 4α, 5β-epoxide



7 1α OH
8 1α OH, 4α, 5β-epoxide
9 1β OH, 4α, 5β-epoxide



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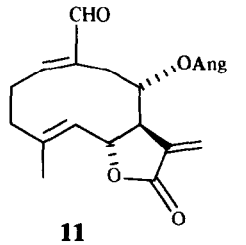

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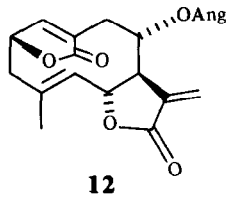

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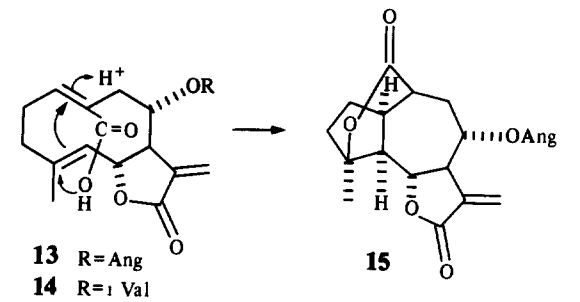
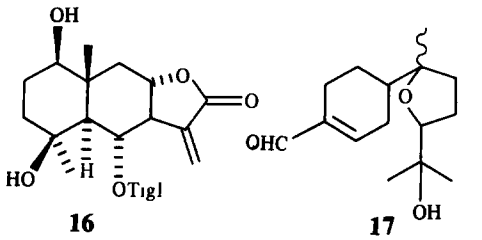
^{1}H NMR signals and a small down field shift of the H-6 signal. The stereochemistry and the conformation was established by NOE difference spectroscopy. Clear effects



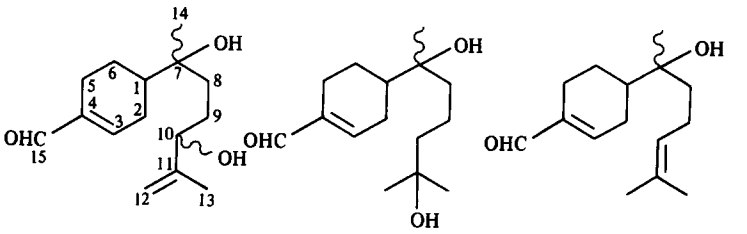
13 R=Ang
14 R=i Val

15



16

17



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19

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Table 1. ^{1}H NMR spectral data of **2–10** (400 MHz, $CDCl_3$, TMS as internal standard)

	2	3 (60°)	4 (60°)	5	6	7	8	9	10
H-1	5.35 *br dd*	5.37 *br dd*	5.32 *br dd*	4.43 *dd*	4.87 *dd*	3.90 *m*	4.27 *m*	4.54 *br dd*	2.86 *br dd*
H-5	2.78 *d*	2.74 *d*	2.69 *d*	4.90 *br d*	2.73 *d*	4.95 *d*	2.80 *d*	2.75 *m*	2.98 *d*
H-6	4.91 *dd*	5.42 *dd*	5.27 *dd*	5.48 *dd*	5.23 *dd*	5 34 *m*	4.98 *dd*	5.00 *dd*	4.99 *dd*
H-7	3.17 *m*	3.10 *dddd*	2.98 *dddd*	3.10 *dddd*	3.28 *dddd*	3.10 *m*	3.24 *m*	3.19 *dddd*	3.15 *dddd*
H-8	4.15 *ddd*	4.56 *ddd*	4.48 *ddd*	4.65 *dd*	4.96 *dd*	4.06 *m*	4.27 *m*	4.26 *ddd*	4.27 *br dd*
H-9	2 71 *br d*	2.89 *br dd*	2.84 *br dd*	} 5.34 *br d*	} 5.49 *br d*	2.95 *m*	2.94 *br d*	3.10 *br d*	2.62 *br d*
H-9′	2.25 *br dd*		1.91 *br dd*			2.4 *m*	2 42 *dd*	2.45 *dd*	
H-13	6.36 *d*	6.38 *d*	6.14 *d*	6.27 *d*	6.28 *d*	6.34 *d*	6.36 *d*	6 37 *d*	6.36 *d*
H-13′	5.75 *d*	5.80 *d*	5.26 *d*	5.75 *d*	5 64 *d*	5 86 *d*	5.77 *d*	5.78 *d*	5.75 *d*
H-14	1.83 *br d*	1 79 *br s*	1.75 *br s*	1.83 *d*	1.86 *d*	{ 5.19 *br s* / 5.15 *br s*	{ 5.37 *br s* / 5.27 *br s*	{ 5.46 *br s* / 5.34 *br s*	1.49 *s*
H-15	1.32 *s*	1.45 *s*	1.32 *s*	1.94 *br s*	1.57 *s*	1.84 *br s*	1.49 *s*	1.51 *s*	1.44 *s*
OR	6.10 *qq*	6.08 *qq*	7.35 *m*	6.14 *qq*	6.16 *qq*	6.14 *qq*	6.14 *qq*	6.15 *qq*	6.14 *qq*
	1.96 *dq*	1.98 *dq*	7.20 *m*	2.00 *dq*	2.01 *dq*	2.00 *dq*	1 99 *dq*	1.99 *dq*	1.97 *dq*
	1.91 *dq*	1.92 *dq*	3.67 *d*	1.90 *dq*	1.93 *dq*	1.92 *dq*	1 94 *dq*	1.96 *dq*	1 92 *dq*
			3.60 *d*						

J (Hz): Compound **2**. 1, 2 ≈ 7; 5, 6 = 6, 7 = 9.5; 7, 8 = 4.5; 7, 13 = 3; 7, 13′ = 2 5; 8, 9 = 2; 8, 9′ = 11; 9, 9′ = 13; compounds **3** and **4**: 1, 2 ≈ 8; 5, 6 = 4; 6, 7 = 11.5; 7, 8 = 3; 7, 13 = 2.5; 7, 13′ = 2; 8, 9 = 3.5; 9, 9′ = 13; compounds **5** and **6**: 1, 2 = 5.5; 1, 2′ = 11; 5, 6 = 11; 6, 7 = 10; 7, 8 = 9.5; 7, 13 = 3.5; 7, 13′ = 3; 8, 9 = 10; compound **7**: 7, 13 = 3; compound **8**: 5, 6 = 10; 6, 7 = 9.5; 7, 13 = 3; 7, 13′ = 2.8; 8, 9′ = 12; 9, 9 = 14; compound **9**: 1, 2 = 5.5; 1, 2′ = 9.5, 5, 6 = 10; 6, 7 = 10.5; 7, 8 = 4; 7, 13 = 3; 7, 13′ = 2.5; 8, 9 = 2.5; 8, 9′ = 11; 9, 9′ = 13.5; compound **10**: 1, 2 = 11; 5, 6 = 9.5; 6, 7 = 10; 7, 8 = 3 5; 7, 13 = 7, 13′ = 2.5; 8, 9′ = 9; 9, 9′ = 14; OAng: 3′, 4′ = 7; 3′, 5′ = 4′, 5′ = 1.5.

were observed between H-14 and H-9, H-15 and H-6, H-8, H-1 and H-6, H-5 and H-7, and H-9 and H-7. Therefore **5** has a preferred conformation with the C-4 methyl above and the C-10 methyl below the plane.

The ^{1}H NMR spectral data of **6** (Table 1) were close to those of **5**; however, the presence of a 4,5-epoxide replaced the broadened H-5 signal at δ4.90 to a sharp doublet at δ2.73 while the H-15 signal was shifted to δ1.57. The stereochemistry at C-4 and C-5 followed from the coupling $J_{5,6}$, especially if compared with those of **2** and **3**.

The ^{1}H NMR spectrum of **7** (Table 1) was very close to that of the corresponding methacrylate [5]. Again the nature of the changed ester group clearly followed from the typical ^{1}H NMR signals. If the ^{1}H NMR spectrum of **8** (Table 1) was compared with that of **7** it was obvious that the 4,5-double bond was replaced by an epoxide. The stereochemistry could be deduced by comparing the coupling $J_{5,6}$ with that observed in the spectrum of **2**. Similar differences in the spectra of **8** and **9** (Table 1) allowed the assignment of the configuration at C-1, especially if compared with the data of the corresponding epimeric methacrylates with a 4,5-double bond [5] and with those of epimers obtained from laurenobiolide [6, 7].

The structure of **10** also could be deduced by comparing the ^{1}H NMR spectral data (Table 1) with those of the corresponding acetate obtained by epoxidation of laurenobiolide [5]. The sequences were confirmed as in all other spectra by spin decoupling.

The ^{1}H NMR spectrum of **11** (Table 2) displayed the typical signals of a methylene lactone, an angelate and a conjugated aldehyde. The configuration of the double bond followed from the chemical shift of the aldehyde proton. Spin decoupling again allowed the assignment of all signals which were somewhat similar to those of acanthospermal derivatives [8]. However, the couplings of H-8 indicated a changed configuration at this centre. The relative position of the angelate followed from the chemical shifts of H-6 and H-8, and indicated that the position of the lactone ring in **11**–**14** differed from that in **1**–**10**. This was further established from the Cotton effects observed in the CD spectra by application of the Geissman rule [9].

The structure of **12** could easily be deduced from the ^{1}H NMR spectrum (Table 2) which as expected was very close to that of desoxyelephantopin [10], the 8-angeloyloxy residue being replaced by a methacrylate residue.

The ^{1}H NMR spectra of **13** and **14** (which could not be obtained free from the former) were extremely broadened at room temperature. Only at 110° in deuteriobenzene in a sealed tube could all signals of **13** be assigned by spin decoupling. The results indicated that again a 6,12-lactone was present with an angelate residue at C-8. The configuration at this center was deduced from the couplings observed, while the *Z*-configuration of the 1,10-double bond followed from the chemical shift of H-1 (δ5.88 in $CDCl_3$). The nature of the ester groups followed from the typical ^{1}H NMR signals. The structure of **13** was further supported by the ^{13}C NMR spectrum (see Experimental) which displayed several highly broadened signals at room temperature. The C-9 signal was especially broad; at 80° in deuteriobenzene this signal was detectable, but still broad.

To get a clearer ^{1}H NMR spectrum of **13**, we tried to transform it by Cope rearrangement to an elemanolide. However, heating at 200° gave the dilactone **15** as shown from careful ^{1}H NMR measurements. The spectrum showed that both double bonds had disappeared and spin decoupling allowed the assignment of all signals leading to a sequence which included all protons except those of the C-4 methyl group and the angelate residue. The chemical shift of the methyl group, however, obviously requires an oxygen function at the methyl bearing carbon. Thus the only possible structure of **15** is that shown. The stereochemistry of the compound was established by NOE difference spectroscopy. Clear effects were visible between H-1 and H-7, H-6 and H-8, and H-2β and H-10. The observed W-coupling between H-5 and H-10 strongly supported the stereochemistry. The ^{13}C NMR spectrum (see Experimental) agreed with the proposed structure and it appears that **15** most likely is formed by proton attack as illustrated. The determination of the stereochemistry of **15** also established that of both **13** and **14**, whereas the Cotton effect of **13** would point to an opposite configuration at C-6 if the Geissman rule [9] was applied. However, there are plenty of exceptions.

The structure of **16** again clearly followed from the ^{1}H NMR spectrum (Table 2) as it was very similar to those of the corresponding angelate, senecioate and methacrylate [5].

The presence of conjugated aldehydes in **17**–**19** could easily be deduced from the ^{1}H NMR spectra (Table 3) because of their characteristic low field signals; their chemical shifts further indicated an *E*-configuration of the double bond. The presence of hydroxyl groups in all three compounds followed from the IR spectra. Though **17**–**19** showed no molecular ions it was very likely that they were isomers as chemical ionization showed for all three compounds an ion with *m/z* 235, most probably formed by loss of water from the M + 1 ion. In the MS of **17** the fragments *m/z* 237 [M − Me], 193 [M − C(OH)Me$_2$], 175 [193 − H_2O], 143 [M − C_7H_9O] and 59 [HO=CMe$_2$] were observed. These, together with the ^{1}H NMR data, agreed with the proposed structure and excluded an isomeric structure with a tetrahydropyran ring. Biogenetic considerations also support the proposed structure of **17** which was most likely derived from **20**, which is also the common precursor of **18** and **19**.

The ^{1}H NMR spectra of **18** and **19** showed that these compounds had a second double bond, an α,α-disubstituted one in **18** and a *trans*-disubstituted in **19**. Spin decoupling allowed the assignment of most signals in the spectra of the diols. However, the absolute and the relative stereochemistry at C-7 and C-10 could not be determined.

The chemistry of *G. vernonioides* showed once more that sesquiterpene lactones, especially germacra-dien-8,12-olides, are widespread in this genus. The significance of this awaits further investigations in other genera of the subtribe.

EXPERIMENTAL

The air dried plant material (540 g), collected in January 1983 in Peru, voucher RMK 9156, was extracted and separated in the usual fashion [11]. The polar CC fractions (Et$_2$O–petrol, 1:1) gave by TLC (CH_2Cl_2–C_6H_6–Et$_2$O, 5:5:1) 6 mg dehydrocostus lactone, 11 mg zaluzanin C and 4 mg **1**. The next CC fraction (Et$_2$O–petrol, 3:1) gave after repeated TLC (Et$_2$O–petrol, 1:2, two developments) and HPLC (RP 8, MeOH–H_2O, 3:2) 5 mg **2** (R_f 10.8 min), 1.5 mg **5** (R_f 16.0 min), 3.0 mg **6** (R_f 7 min), 1.5 mg **9** (R_f 5.6 min), 3 mg **10** (R_f 5 min), 2 mg **16** (R_f 4.0 min) and 2 mg **17** (R_f 7.6 min). The most polar CC fraction (Et$_2$O–MeOH, 3:1) was separated again by CC into four fractions (Et$_2$O and

Table 2. ^{1}H NMR spectral data of **11–16** (400 MHz, $CDCl_3$, TMS as internal standard)

	11	12	13 62°	13 C_6D_6, 110°	14 C_6D_6, 110°	15* C_6D_6	16
H-1	6.57 *ddd*	7.03 *br s*	5.88 *m*	5.25 *m*	5.22 *m*	1.60 *br t*	3.50 *dd*
H-5	5.09 *br d*	5.44 *br s* (H-2) 4.77 *br d*	4.91 *br d*	4.63 *br d*	4.62 *br d*	1.38 *ddd*	1.92 *br d*
H-6	4.66 *dd*	5.17 *dd*	5.02 *br dd*	4.93 *br dd*	4.90 *br dd*	3.52 *dd*	5.80 *dd*
H-7	2.86 *dddd*	2.90 *m*	3.03 *m*	2.78 *m*	2.80 *m*	2.57 *dddd*	2.87 *dddd*
H-8	5.26 *ddd*	4.67 *br d*	5.22 *m*	5.46 *m*	5.59 *m*	5.01 *ddd*	4.05 *ddd*
H-9	2.94 *br d*	3.02 *br d*	2.91 *br d*	2.96 *br d*	2.89 *m*	2.85 *ddd* (β)	2.55 *dd*
H-9′		2.77 *dd*	2.56 *m*	2.25 *m*	2.25 *m*	1.06 *ddd* (α)	1.49 *dd*
H-13	6.24 *d*	6.24 *d*	6.24 *br d*	6.36 *d*	6.43 *d*	6.24 *dd*	6.08 *d*
H-13′	5.71 *d*	5.60 *d*	5.63 *br d*	5.59 *br d*	5.68 *br d*	5.56 *dd*	5.26 *d*
H-14	9.56 *br s*	—	—	—	—	—	1.05 *s*
H-15	1.90 *br s*	1.86 *d*	1.70 *br s*	1.60 *br s*	1.60 *br s*	1.22 *s*	1.26 *s*
OR	6.26 *qq*	6.16 *qq*	6.12 *br q*	5.84 *br q*	0.94 *d*	5.80 *qq*	6.96 *qq*
	2.07 *dq*	1.97 *dq*	1.90 *br d*	1.90 *br d*	0.93 *d*	2.00 *dq*	1.88 *dq*
	2.01 *dq*	1.90 *dq*	1.89 *br s*	1.83 *br s*		1.85 *dq*	1.83 *dq*

*H-2β, 0.83 *ddd*; H-2α, 1.30 *dddd*; H-3α, 1.22 *dd*; H-3β, 1.73 *ddd*; H-10, 2.00 *m* (in $CDCl_3$, 2.68 *t*)

J (Hz): Compound **11**: 1,2 = 7; 1,2′ = 9; 1,9 = 1.5, 5,6 = 6, 7 = 7, 8 = 10; 7,13 = 7, 13′ = 3; 8,9 = 2.5, 8,9′ = 4.5; 9,9′ = 16; compound **12**: 5,6 = 10.5; 5,15 = 1.5; 6,7 = 8; 7,13 = 3.5; 7,13′ = 3; 8,9′ = 9, 9′ = 12, compounds **13** and **14**: 5,6 = 10; 6,7 = 9; 7,13 = 3.5; 7,13′ = 3; 9,9′ = 13; compound **15**: 1,2α = 1, 5 = 6; 2α,2β = 13; 2α,3α = 11; 2α,3β = 4.5; 2β,3α = 4; 2β,3β = 9; 5,6 = 6.5; 5,10 ~ 0.5; 7,8 = 10; 7,13 = 3.5; 7,13′ = 3; 8,9α = 4.5; 8,9β = 5; 9α,9β = 14; 9α,10 = 9β,10 = 5; 13,13′ ~ 0.5; compound **16**: 1α,2α = 1α, OH = 4.5; 1α,1β = 10; 5α,6β = 6β,7 = 10; 7,8β = 8β, 9α = 12; 7,13 = 3; 8β,9β = 4, 9α,9β = 12; OAng· 3′,4′ = 7; 3′,5′ = 4′,5′ = 1.5.

Table 3. ^{1}H NMR spectral data of **17–19** (400 MHz, $CDCl_3$, TMS as internal standard)

	17	18	19
H-2	2.04 *m*	2.04 *m*	2.05 *m*
H-3	6.82 *br dd*	6.80 *br dd*	6.80 *br dd*
H-5	2.49 *m*	2.54 *br dd*	2.53 *br dd*
H-5′		2.43 *m*	2.43 *m*
H-8	2.0–1.65 *m*	1.65 *m*	2.28 *dd*
H-9			2.22 *dd* 5.68 *dd*
H-10	3.69 *dd*	4.08 *ddd*	5.74 *d*
H-12	1.22 *s*	4.97 *ddq* 4.87 *ddq*	1.33 *s*
H-13	1.13 *s**	1.74 *br s*	
H-14	1.18 *s**	1.17 *s*	1.16 *s*
H-15	9.44 *s*	9.44 *s*	9.43 *s*

*May be interchangeable.

J (Hz). 2,3 = 5; 2′,3 = 3, 2,5 ~ 1.5; 5,5′ = 17; 5,6 = 5; compound **17**: 9,10 = 10; 9′,10 = 5; compound **18**: 9,10 = 6, 10,12 = 12, 13 ~ 1.5; 10, OH = 10, compound **19**: 8,8′ = 14; 8,9 = 6.5, 8′,9 = 7; 9,10 = 15.

Et_2O–MeOH, 4:1). The first fraction gave by HPLC (RP 8, MeOH–H_2O, 3:2) 3 mg **2** (R_t 10.0 min), 2 mg **3** (R_t 13.7 min), 4 mg **4** (R_t 17.0 min), 1.5 mg **9** (R_t 5.6 min) and 1 mg **11** (R_t 10.3 min). The next portion gave by HPLC (RP 8, MeOH–H_2O, 11:9) 1 mg **8** (R_t 5.3 min), crude **17** (R_t 9.6 min), which gave by TLC (CH_2Cl_2–C_6H_6–Et_2O, 1:1:1, (I), several developments) 6 mg **17**, 3 mg **13** (R_t 13.5 min), 1 mg **7** (R_t 11.5 min) and a mixture (R_t 15.6 min) which gave by TLC (CH_2Cl_2–C_6H_6–Et_2O, 1:1:1, several developments) 2 mg **2** (R_f 0.7) and 3 mg sakuranetin. The third fraction gave by HPLC (RP 8, MeOH–H_2O, 3:2) 1 mg **18** (R_t 4.8 min) and a mixture which gave by TLC (mixture I, several developments) and HPLC of the three main zones (RP 8, MeOH–H_2O, 3:2), 2 mg **12** (R_t 12.4 min), 3 mg **18** (R_t 4.9 min), 3 mg **19** (R_t 4.8 min), 4 mg **13** (R_t 13.0 min) and 1.5 mg **14** (R_t 11.1 min) containing still **13**. HPLC of the next CC fraction gave a mixture (R_t 9.8 min), which by TLC (mixture I) gave 15 mg **13**, 1 mg **14** (containing still **13**) and 1 mg **18**. The most polar CC fractions gave by HPLC (RP 8, MeOH–H_2O, 3.2) 5 mg **13** and 5 mg sakuranetin. All compounds, except **14** which still contained **13**, were homogeneous by 400 MHz ^{1}H NMR and by TLC. Known compounds were identified by comparing the 400 MHz ^{1}H NMR spectra with those of authentic material. Probably due to the small amounts the lactones could not be induced to crystallize.

6α-*Angeloyloxy*-4α,5β-*epoxygermacra*-1(10)E,11-*dien*-8α,12-*olide* (**2**). Colourless oil; IR $\nu_{max}^{CHCl_3}$ cm^{-1}: 1770 (γ-lactone), 1720 (C=CCO_2R); MS *m/z* (rel int.): 246.126 $[M-RCO_2H]^+$ (3) (calc. for $C_{15}H_{18}O_3$: 246.126), 83 $[C_4H_7CO]^+$ (100), 57 $[83-CO]^+$ (67), CI (isobutane): 347 $[M+1]^+$ (17), 247 $[347-RCO_2H]^+$ (100), 229 $[247-H_2O]^+$ (64); CD (MeCN): $\varepsilon_{280} = -0.17$.

6α-*Angeloyloxy*-4β,5α-*epoxygermacra*-1(10)E,11-*dien*-8α,12-*olide* (**3**). Colourless oil, IR $\nu_{max}^{CHCl_3}$ cm^{-1}: 1780 (γ-lactone), 1725 (C=CCO_2R); MS *m/z* (rel int.): 346.178 $[M]^+$ (0.1) (calc. for $C_{20}H_{26}O_5$: 346.178), 246 $[M-RCO_2H]^+$ (1), 83 $[C_4H_7CO]^+$ (100), 55 $[83-CO]^+$ (58); CD (MeCN): $\varepsilon_{280} = -0.57$.

6α-*Phenylacetoxy*-4β,5α-*epoxygermacra*-1(10)E,11-*dien*-8α,12-*olide* (**4**). Colourless oil; IR $\nu_{max}^{CHCl_3}$ cm^{-1} 1770 (γ-lactone), 1740 (CO_2R), MS *m/z* (rel int.): 382.178 $[M]^+$ (0.1) (calc. for $C_{23}H_{26}O_5$: 382.178), 246 $[M-RCO_2H]^+$ (4), 119 $[RCO]^+$ (10), 91 $[119-CO]^+$ (100); CI (isobutane). 383 $[M+1]^+$ (42), 247 (44); CD (MeCN): $\varepsilon_{280} = -0.53$

6α-*Angeloyloxy*-1α-*hydroxy*-*germacra*-4E,9Z,11-*trien*-8α,12-*olide* (**5**). IR $\nu_{max}^{CHCl_3}$ cm^{-1}: 3600 (OH), 1760 (γ-lactone), 1715 (C=CCO_2R); MS *m/z* (rel. int.). 246.126 $[M-RCO_2H]^+$ (2)

(calc. for $C_{15}H_{18}O_3$: 246.126), 228 [246 − H_2O]$^+$ (2), 213 [228 − Me]$^+$ (2), 83 [C_4H_7CO]$^+$ (100), 55 [83 − CO]$^+$ (68); CI (isobutane): 347 [M + 1]$^+$ (12), 247 [347 − RCO_2H]$^+$ (88), 229 [247 − H_2O]$^+$ (100), 101 [RCO_2H + 1]$^+$ (13).

6α-Angeloyloxy-4α,5β-epoxy-1α-hydroxygermacra-9Z,11-dien-8α,12-olide (**6**). Colourless oil; IR $\nu_{max}^{CHCl_3}$ cm^{-1}: 3600 (OH), 1765 (γ-lactone), 1715 (C=CCO_2R); MS *m/z* (rel. int.): 262 121 [M − RCO_2H]$^+$ (2) (calc for $C_{15}H_{18}O_4$: 262.121), 83 [C_4H_7CO]$^+$ (100), 55 [83 − CO]$^+$ (77); CI (isobutane): 363 [M + 1]$^+$ (3), 263 [363 − RCO_2H]$^+$ (8), 235 [263 − CO]$^+$ (100).

6α-Angeloyloxy-1α-hydroxy-germacra-4E,10(14),11-trien-8α,12-olide (**7**) IR $\nu_{max}^{CHCl_3}$ cm^{-1}: 3600 (OH), 1770 (γ-lactone), 1720 (C=CCO_2R); MS *m/z* (rel. int.): 246.126 [M − RCO_2H]$^+$ (2) (calc for $C_{15}H_{18}O_3$: 246 126), 228 [246 − H_2O]$^+$ (8), 213 [228 − Me]$^+$ (5), 83 [C_4H_7CO]$^+$ (100), 57 [83 − CO]$^+$ (70)

6α-Angeloyloxy-4α,5β-epoxy-1α-hydroxy-germacra-10(14),11-dien-8α,12-olide (**8**) IR $\nu_{max}^{CHCl_3}$ cm^{-1}. 3600 (OH), 1760 (γ-lactone), 1720 (C=CCO_2R); MS (CI, isobutane) *m/z* (rel. int.): 363 [M + 1]$^+$ (42), 263 [363 − RCO_2H]$^+$ (89), 245 [263 − H_2O]$^+$ (100)

6α-Angeloyloxy-4α,5β-epoxy-1β-hydroxy-germacra-10(14),11-dien-8α-12-olide (**9**). IR $\nu_{max}^{CHCl_3}$ cm^{-1}: 3600 (OH), 1770 (γ-lactone), 1720 (C=CCO_2R); MS (CI, isobutane) *m/z* (rel int.): 363 [M + 1]$^+$ (40), 263 [363 − RCO_2H]$^+$ (34), 235 [263 − CO]$^+$ (100)

6α-Angeloyloxy-1β,10α,4α,5β-diepoxygermacra-11-en-8α,12-olide (**10**). Colourless oil, IR $\nu_{max}^{CHCl_3}$ cm^{-1}: 1760 (γ-lactone), 1715 (C=CCO_2R); MS *m/z* (rel. int.). 362 173 [M]$^+$ (0.2) (calc. for $C_{20}H_{26}O_6$: 362.173), 263 [M − RCO_2]$^+$ (2), 245 [263 − H_2O]$^+$ (0 5), 83 [C_4H_7CO]$^+$ (100), 55 [83 − CO]$^+$ (68).

8α-Angeloyloxy-14-al-germacra-1(10)E,4E,11-trien-8α,12-olide (**11**) IR $\nu_{max}^{CHCl_3}$ cm^{-1}: 1775 (γ-lactone), 1730 (CHO, C=CCO_2R); MS (CI, isobutane) *m/z* (rel int.). 345 [M + 1]$^+$ (18), 245 [345 − RCO_2H]$^+$ (100).

8-Desacyl-desoxyelephantopin angelate (**12**). Colourless oil; IR $\nu_{max}^{CHCl_3}$ cm^{-1}: 1760 (γ-lactone), 1720 (C=CCO_2R); MS *m/z* (rel int.): 258.089 [M − RCO_2H]$^+$ (4) (calc. for $C_{15}H_{14}O_4$: 258 089), 83 [C_4H_7CO]$^+$ (100), 55 [83 − CO]$^+$ (96)

8α-Angeloyloxytaraxic acid (**13**) Colourless crystals, mp 170–172°; IR $\nu_{max}^{CHCl_3}$ cm^{-1}: 3600–2700, 1710 (CO_2H), 1760 (γ-lactone), 1720 (C=CCO_2R); MS *m/z* (rel. int.): 260.105 [M − RCO_2H]$^+$ (6) (calc for $C_{15}H_{16}O_4$. 260.105), 242 [260 − H_2O]$^+$ (6), 214 [242 − CO]$^+$ (8), 83 [C_4H_7CO]$^+$ (96), 55 [83 − CO]$^+$ (100), ^{13}C NMR ($CDCl_3$, 25°, C-1 to C-15): δ150 4*, 26.0, 37.7*, 142.5*, 127.2, 78.4, 52 7*, 73.8*, ~ 43 very broad, 126.8*, 135 3, 166 9, 124.1*, 172 3*, 17 1*; OAng: 170.0, 126 1, 139.6, 20 4, 15.8 (*broad singlets in the broad band decoupled spectra) C_6D_6, 80° (C-1 to C-15): 149.3, 26.4, 40.0, 141.8, 127.5*, 78.2, 53 1, 74.4, 42 9, (~ 127.5)*, 136 6, 166 9, 123.0, 169.4, 17.0 (*overlapped by C_6D_6 signals), CD (MeCN): $\Delta\varepsilon_{266} = -1.14$. 5 mg **13** in 0 5 ml C_6D_6 were heated in a sealed NMR tube for 90 min at 200° After cooling the ^{1}H NMR spectrum of **13** was completely changed to that of **15**, colourless crystals, mp 228–230° (Et_2O–petrol); IR $\nu_{max}^{CCl_4}$ cm^{-1}: 1770 (γ-lactone), 1730 (δ-lactone, CO_2R), MS *m/z* (rel int.): 342 147 [M − H_2O]$^+$ (0.2) (calc. for $C_{20}H_{22}O_5$: 342.147), 261 [M − OAng]$^+$ (15), 243 [261 − H_2O]$^+$ (4), 215 [243 − CO]$^+$ (13), 83 [C_4H_7CO]$^+$ (86), 55 [83 − CO]$^+$ (100); ^{13}C NMR (C_6D_6, C-1 to C-15): 39.7, 30.1, 38 1, 89.1, 44.7, 72.0, 50 1, 74.8, 37.7, 46.2, 137.2, 168.6, 123.1, 170.1, 21 7; OAng: 165.5, 127.3, 139.7, 20.6, 15.9.

8α-Isovaleryloxytaraxic acid (**14**). Colourless oil, not free from **13**; IR $\nu_{max}^{CHCl_3}$ cm^{-1}: 3500–2700, 1720 (CO_2H), 1760 (γ-lactone), 1720 (CO_2R); MS *m/z* (rel. int.): 260.105 [M − RCO_2H]$^+$ (5) (calc. for $C_{15}H_{16}O_4$: 260.105), 242 [260 − H_2O]$^+$ (6), 214 [242 − CO]$^+$ (11), 85 [C_4H_9CO]$^+$ (30), 57 [85 − CO]$^+$ (100).

Desacyltanapsin-6-O-angelate (**16**). Colourless oil, IR $\nu_{max}^{CHCl_3}$ cm^{-1}. 3580 (OH), 1770 (γ-lactone), 1715 (C=CCO_2R); MS *m/z* (rel. int.). 264.136 [M − RCO_2H]$^+$ (1.5) (calc for $C_{15}H_{20}O_4$: 264.136), 246 [264 − H_2O]$^+$ (4), 228 [246 − H_2O]$^+$ (4), 83 [C_4H_7CO]$^+$ (100), 55 [83 − CO]$^+$ (88); CD (MeCN): $\Delta\varepsilon_{280} = -0.25$

7,10-Epoxy-11-hydroxy-bisabol-2-en-15-al (**17**) Colourless oil, IR $\nu_{max}^{CHCl_3}$ cm^{-1}. 3630 (OH), 2720, 1675, 1640 (C=CCHO), MS *m/z* (rel. int.): 237.149 [M − Me]$^+$ (6) (calc. for $C_{14}H_{11}O_3$: 237 149), 193 [M − C(OH)Me_2]$^+$ (24), 175 [193 − H_2O]$^+$ (30), 143 [M − C_7H_9O]$^+$ (100), 59 [HO=CMe_2]$^+$ (96); CI (isobutane): 235 [M + 1 − H_2O]$^+$ (100)

7,10-Dihydroxy-bisabola-2,11-dien-15-al (**18**). Colourless oil, IR $\nu_{max}^{CHCl_3}$ cm^{-1}: 3600 (OH), 1670 (C=CCHO); MS (CI, isobutane): 235 [M + 1 − H_2O]$^+$ (100), 217 [235 − H_2O]$^+$ (42).

7,11-Dihydroxy-bisabola-2,9E-dien-15-al (**19**). Colourless oil; IR $\nu_{max}^{CHCl_3}$ cm^{-1}: 3590 (OH), 2720, 1680, 1640 (C=CCHO); MS (CI, isobutane) *m/z* (rel. int.): 253 [M + 1]$^+$ (3), 235 [253 − H_2O]$^+$ (23), 83 (100).

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