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EUDESMANOLIDES, 5,10-BIS-*EPI*-EUDESMANES AND OPLOPANONE DERIVATIVES FROM *AMBROSIA ARTEMISIOIDES*

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Key Word Index—*Ambrosia artemisioides*, Compositae, sesquiterpenes; eudesmanolides, 5,10-bis-*epi*-eudesmanes, oplopanone derivatives

Abstract—The aerial parts of *Ambrosia artemisioides* afforded in addition to known compounds nine new eudesmanolides, twelve 5,10-bis-*epi*-eudesmanes and five oplopanone derivatives. The structures were elucidated by high field NMR techniques

INTRODUCTION

The genus *Ambrosia* (Compositae, tribe Heliantheae, subtribe Ambrosiinae) with more than 40 species is concentrated in southwestern North America. Many species already have been studied chemically, they usually contain pseudoguaianolides [1]. We now have studied *A. artemisioides* Meyen et Walp. ex Meyen, a narrow endemic species from southern Peru and northern Chile. The results are presented in this paper.

RESULTS AND DISCUSSON

The extract of the aerial parts gave in addition to known compounds (see Experimental) the oplopanone derivatives **1a**–**1e**, the eudesmanolides **2a**–**2i** and the 5,10-bis-*epi*-eudesmane derivatives **3a**–**3e** and **3g**–**3l**.

The ^{1}H NMR spectrum of **1a** (Table 1) was in part close to that of anhydrooplopanone [2]. However, typical signals of an angelate group indicated additional substitution. The corresponding low field signal (δ5.23 *ddd*) was coupled with a proton which gave a broadened double doublet at δ2.28, which only could be assigned to H-9. Therefore, the position of the ester group was determined. The configuration at all chiral centres followed from the observed NOE's and consideration of a model. Thus, clear effects were observed between H-1, H-2, H-4 and H-10′, between H-3, H-2′, H-11 and H-15 as well as between H-6′, H-4 and H-13. Inspection of the ^{1}H NMR spectrum of **1b** (Table 1) clearly showed that a keto derivative of a double bond isomer of anhydrooplopanone was present As no olefinic proton signal was visible and H-10 now appeared as a doublet at δ2.14, the position of the double bond was elucidated. Spin decoupling starting with the H-2 protons indicated the whole sequence For a compound without a function at C-1 we propose the name *iso*-anhydrooplopanone

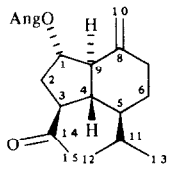
The ^{1}H NMR spectral data of **1c** (Table 1) showed that an angelate was again present. Spin decoupling indicated that an oplopanone derivative with an additional keto group at C-7 must be present. The observed couplings showed that **1c** had the same stereochemistry as **1a** and **1b**. The ^{1}H NMR data of **1d** (Table 1) were nearly identical with those of **1c**, only those of the ester groups being different. Thus, this diketone was the corresponding cinnamate. Similarly the ^{1}H NMR data of **1e** showed that we were dealing with the 1α-anisoyloxy derivative

The ^{1}H NMR spectrum of **2a** (Table 2) clearly showed that an alantolactone derivative was present as followed from the typical signals of H-7, H-8 and H-13. Signals at δ2.68 and 2.56 further indicated an epoxide. A *W*-coupling of the lower double doublet with H-3α required a 4α,15-epoxide. Thus, **2a** was the 4α,15-epoxide of isoalantolactone. The ^{1}H NMR spectrum of **2b** (Table 2) was in part close to that of **2a**. However, an additional low field signal at δ3.41 was visible and the epoxide proton signals now both were simple doublets. Accordingly, H-3α was replaced by a hydroxy group. This was further established by partial synthesis from isotelekin.

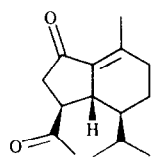
The ^{1}H NMR spectra of **2c**–**2f** (Table 2) were close to that of *iso-allo*-alantolactone [3] The missing olefinic methyl singlet was replaced by pairs of broadened doublets indicating substitution at C-15 by oxygen functions Their nature easily could be deduced from the corresponding ester signals Only in the case of **2c** such signals were absent and the chemical shift as well as the molecular formula indicated the presence of a 15-hydroxy group

The ^{1}H NMR spectrum of **2g** (Table 2) showed that a hydroperoxide (δ8.15 *br s*) with an additional acetoxy group was present. The position of the oxygen functions followed from the chemical shifts of H-3 and H-15 while the configuration at C-3 was indicated by the observed small vicinal couplings of H-3. The same couplings were visible in the spectrum of **2h** (Table 2). All data agreed well with the presence of a 3α,15-dihydroxy derivative of *allo*-alantolactone. The ^{1}H NMR data of **2i** (Table 2) clearly showed that this lactone was the corresponding 3-keto derivative Accordingly, the H-2 signals and that of H-6α were shifted downfield.

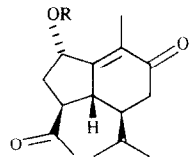
The ^{1}H NMR spectrum of **3e** (Table 3) was in part close to that of β-chaenocephalol cinnamate (**3f**) [4], an eudesmane derivative epimeric at C-5 and C-10 also present in the extract. The data clearly showed that only the signals of the ester residues differed.



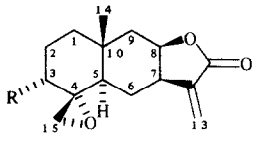
1a



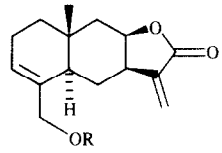
1b



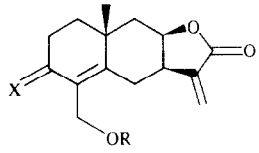
1c **1d** **1e**
R Ang Cinn A*



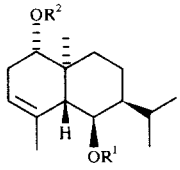
2a **2b**
R H OH



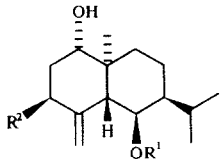
2c **2d** **2e** **2f**
R H Ac Cinn Cinn *cis*



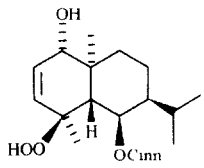
2g **2h** **2i**
R Ac H H
X αOOH,H αOH,H O



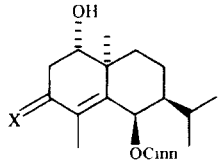
3a **3b** **3c** **3d**
R^1 H A Cinn B*
R^2 Cinn H H H



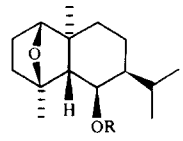
3e **3f** **3g**
R^1 Ang Cinn Cinn
R^2 H H OOH



3h



3i X = βOOH,H
3j X = O



3k R = Cinn
3l R = A

* A *p*-methoxybenzoyl
B β-D-glucopyranosyl

The ^{1}H NMR spectra of **3a–3c** (Table 3) showed that derivatives of eudesm-3-ene with oxygen functions at C-1 and C-6 were present The nature of these functions easily could be deduced from the corresponding signals and the relative positions of the ester groups followed from the chemical shifts The observed NOE's showed that again 5,10-bis-*epi*-eudesmanes were present. Thus, clear effects were observed between H-14 and H-6α, between H-1 and H-5 as well as between H-5, H-1 and H-11 These effects further indicated the configurations at C-1, C-6 and C-7 which already followed from the couplings. The ^{1}H NMR spectrum of **3d** (Table 3) showed that the 6-*O*-β-D-glucopyranoside of the 1α,6β-dihydroxy derivative was present as followed from the couplings of the sugar moiety and the similarity of the signals of the sesquiterpene part with those of **3a–3c**,

The ^{1}H NMR spectra of **3g–3i** (Table 3) indicated that most likely isomeric hydroperoxides were present, probably formed by an ene-reaction of **3c** with singlet oxygen from the sterically less hindered side Accordingly, the stereochemistry was identical in all three compounds as followed from NOE experiments Thus, in the case of **3h** clear effects were observed between H-15, H-14 and H-6, between H-1, H-2 and H-5 as well as between H-6, H-14, H-15 and H-12 Similarly, the stereochemistry of **3i** followed from the observed NOE's Clear effects were obtained between H-6, H-15, H-7 and H-12, between H-1 and H-2 as well as between H-3, H-2' and H-15 The ^{1}H NMR spectrum of **3g** was close to that of β-chaenocephalol cinnamate (**3f**) The position and the configuration of the hydroperoxide group followed from the couplings and the chemical shifts of H-15

The ^{1}H NMR spectrum of **3j** (Table 3) indicated the presence of the corresponding 3-keto derivative of **3i** The couplings showed that the stereochemistry was the same as in **3i**

Table 1 ^{1}H NMR spectral data of compounds **1a**-**1e** (400 MHz, $CDCl_3$, δ-values)

H	1a*	1b	1c	1d	1e
1	5 23 *ddd*	—	5 92 *br d*	6 09 *br d*	6 03 *br d*
2	2 31 *ddd*	2 57 *dd*	2 25 *br dd*	2 20 *br dd*	2 35 *dd*
2′	1 90 *m*	2 23 *dd*	1 97*ddd*	2 00 *ddd*	2 03 *ddd*
3	2 85 *ddd*	2 78 *ddd*	3.00 *ddd*	3 07 *ddd*	3 07 *ddd*
4	1 85 *dd*	2 97 *m*	3 09 *ddq*	3 12 *ddq*	3 15 *ddq*
5	1 34 *dddd*	1 16 *dddd*	1.85 *dddd*	1 95 *dddd*	1 94 *dddd*
6	1 74 *dddd*	1 69 *dddd*	2.46 *dd*	2 48 *dd*	2 49 *dd*
6′	1 11 *dddd*	1.28 *dddd*	2 15 *dd*	2 17 *dd*	2 19 *dd*
7	2 38 *ddd*	2 34 *br dd*	—	—	—
7′	1 96 *m*	2 18 *m*	—	—	—
10	4 74 *ddd* 4 60 *ddd*	2 14 *d*	1 72 *d*	1 75 *d*	1 74 *d*
11	1 50 *dqq*	1 53 *dqq*	1 46 *dqq*	1 47 *dqq*	1.47 *dqq*
12	0 93 *d*	0 97 *d*	0 94 *d*	0 94 *d*	0.96 *d*
13	0.68 *d*	0 78 *d*	0 81 *d*	0.81 *d*	0 82 *d*
15	2.20 *s*	2 30 *s*	2 30 *s*	2 31 *s*	2 29 *s*
OR	6.04 *qq*	—	6.14 *qq*	7 71 *d*	7 95 *d*
	1 94 *dq*		1.98 *dq*	7 54 *m*	6 93 *d*
	1 86 *dq*		1.87 *dq*	7 41 *m*	3 87 *s*
				6 42 *d*	

*H-9 2.28 *br dd*

J[Hz] Compound **1a** 1,2 = 8 5, 1,2′ = 6 5, 1,9 = 10, 2,2′ = 13 5, 2,3 = 6 5, 2′,3 = 11 5, 3,4 = 10, 4,5 = 10, 4 9 = 5,6′ = 6,6′ = 6′,7′ = 12 5, 5,6 = 5,11 = 6,7 = 2 5, 6,7′ = 5, 6′,7 = 4, 7,7′ = 13 5, 7′,10 = 7′,10′ = 9,10 = 9,10′ = 10,10′ = 1 5, 11,12 = 11,13 = 6 5; compound **1b** 2,2′ = 17 5, 2,3 = 8, 2′,3 = 11 5, 3,4 = 10; 4,5 = 9 5, 4,10 = 5,6 = 5,11 = 6,7 = 2, 5,6′ = 6,6′ = 6′,7′ = 12 5, 6,7′ = 6′,7 = 6 5, 7,7′ = 19, 11,12 = 11,13 = 6 5; compounds **1c**–**1e** 1,2′ = 6, 2,2′ = 14, 2,3 = 6, 2′,3 = 12, 3,4 = 4,5 = 10, 4,10 = 5,11 = 2.5, 5,6 = 3 5, 5,6′ = 13 5, 6,6′ = 16 5, 11,12 = 11,13 = 6 5

The ^{1}H NMR spectra of **3k** and **3l** (Table 3) only differed in the signals of the ester parts. The molecular formula of both compounds required a third ring as the ^{1}H and also the ^{13}C NMR data (see Experimental) indicated the absence of a double bond in the sesquiterpene part Doublets at δ3.89 and 3.91, respectively, and the chemical shift of H-15 required an oxygen ring and spin decoupling led to sequences with the proposed arrangement of substitution pattern of an eudesmane. The stereochemistry was determined by NOE experiments. In the case of **3k** irradiation of H-14 gave clear effects with H-6, H-1 and H-7 while saturation of H-6 caused NOE's with H-7, H-14 and H-15.

The isolation of eudesmane derivatives from this *Ambrosia* species with quite unusual overall morphology is interesting. So far eudesmanolides have been reported from only two species [5, 6], in one case together with the usual pseudoguaianolides [7]. Two further species only contain costic and illicic acid. All these species previously were placed in the genus *Franseria* which has been combined with *Ambrosia*. It is remarkable that all eudesmanolides belong to the 10β-methyl series while the eudesmane derivatives all are epimeric at C-5 and C-10.

EXPERIMENTAL

The air-dried aerial parts (300 g, voucher Dillon *et al* 4760, deposited in the Field Museum of National History, collected 20 km WNW of Tacna, S Peru) was extracted with Et_2O–MeOH–petrol (1·1 1) and the extract obtained was separated as reported previously [8] Known compounds were identified by comparing the 400 MHz ^{1}H NMR spectra with those of authentic materials Conditions of final separation of the new compounds are given in parenthesis HPLC [RP 8 *ca* 100 bar, HP1 MeOH–H_2O (9 1), HP2 MeOH–H_2O (17 3), HP3 MeOH–H_2O (4 1), HP4 MeOH–H_2O (7 3), HP5 MeOH–H_2O (13 7), HP6. MeOH–H_2O (3 2), HP7 MeOH–H_2O, (1 1)] TLC [silica gel PF 254, T1 Et_2O–petrol (1 4), T2. Et_2O–petrol (1 1), T3 C_6H_6–CH_2Cl_2–Et_2O (9 9 2), T4 $CHCl_3$–MeOH (19 1), T5 C_6H_6–CH_2Cl_2–Et_2O (4 5.1); T6 toluene–CH_2Cl_2–Et_2O (4 5 1), T7 Et_2O–petrol (3 2), T8 Et_2O–petrol (2 3)] Thus, as known compounds 95 mg caryophyllene, 10 mg ar-curcumene, 30 mg caryophyllene-1β,10α-epoxide, 5 mg γ-curcumene endoperoxide, 2 mg spathulenol, 4 mg sitosterol, 4 mg stigmasterol, 135 mg costic acid, 6 mg 11,13-dihydrocostic acid [9], 10 mg cyperol [10], 34 mg isoalantolactone [11], 32 mg 11,13-dihydroalantolactone [12], 2 mg inunal [3], 500 mg isotelekin [3], 40 mg apigenin, 40 mg kaempferol, 5 mg eriodictyol, 3 mg aromadendrin, 4 mg aromadendrin-3-*O*-methyl ether and 14 mg scopoletin were isolated and the following new ones: 64 mg **1a** (T1, R_f 0 7), 2 mg **1b** (HP2, R_t 6 9 min), 37 mg **1c** (T3, R_f 0 5), 2 mg **1d** (T5, R_f 0.4), 1 mg **1e** (HP4, R_t 22 6 min), 250 mg **2a** (T7, R_f 0 4), 30 mg **2b** (HP5, R_t 4 0 min), 1 65 g **2c** (HP6, R_t 8 8 min), 930 mg **2d** (T7, R_f 0 3), 39 mg **2e** (T6, R_f 0 9), 3 mg **2f** (T5, R_f 0 6), 2 mg **2g** (T7, R_f 0.1), 63 mg **2h** (HP7, R_t 11 7 min), 2 mg **2i** (T4, R_f 0 5), 9 mg **3a** (T8, R_f 0.5) 2 mg **3b** (HP4, R_t 56 min), 22 mg **3c** (HP2, R_t 18 2 min), 22 mg **3d** (HP6, R_t 8 3 min), 1 mg **3e** (T2, R_f 0 6), 3 mg **3f** (HP3, R_t 19 min), 3 mg **3g** (HP4, R_t 20.5 min), 4 mg **3h** (HP4, R_t 19 3 min), 14 mg **3i** (HP4, R_t 33 3 min), 11 mg **3j** (HP4, R_t 43 2 min), 260 mg **3k** (T1, R_f 0 6) and 12 mg **3l** (HP2, R_t 15 6 min).

Table 2 ^{1}H NMR spectral data of **2a–2i** (400 MHz, $CDCl_3$, δ-values)

H	2a	2b	2c	2d	2e	2f	2g	2h	2i
1α	1 21 *m*	1 68 *m*	1 32 *m*	1 36 *m*	1 36 *m*	1 33 *m*	*	1 79 *m*	2 09 *ddd*
1β	1 60 *m*	1 37 *m*	1 48 *m*	1 52 *m*	1 53 *m*	1 50 *m*	*	1 40 *m*	1 79 *ddd*
2α	} 1 70 *m*	} 1 85 *m*	} 2 15–	} 2 15–	} 2 10–	} 2 10–	*	1 73 *m*	2 50 *ddd*
2β			2 05 *m*	2 05 *m*	2 00 *m*	2 00 *m*	*	1 95 *m*	2 65 *ddd*
3	{ 1 88 *dddd* 1 34 *br ddd*	3 41 *dd*	5 69 *br s*	5 80 *br s*	5 86 *br s*	5 77 *br s*	4 43 *br s*	4 27 *br s*	
5	1 57 *m*	2 26 *dd*	2 15–	2 10 *br d*	2 16 *br d*	2 09 *br* *	--	-	
6α	1 63 *m*	1 53 *ddd*	2 03 *m*	1 90 *ddd*	1 97 *ddd*	1 84 *ddd*	2 10 *m*	2 89 *dd*	3 19 *dd*
6β	0 95 *ddd*	0 96 *ddd*	1 28 *ddd*	1 31 *ddd*	1 36 *m*	1 30 *m*	2 90 *dd*	2 04 *ddd*	2 26 *dd*
7	2 90 *br ddd*	2 92 *br ddd*	3 05 *br ddd*	3 03 *br ddd*	3 05 *br ddd*	2 93 *br ddd*	3 08 *m*	3 20 *ddddd*	2 29 *ddddd*
8	4 48 *ddd*	4 48 *ddd*	4 63 *ddd*	4 54 *ddd*	4 55 *ddd*	4 52 *m*	4 50 *ddd*	4 56 *ddd*	4 63 *ddd*
9α	1 51 *br dd*	1 56 *br dd*	1 47 *br dd*	1 49 *br dd*	1 51 *br dd*	1 48 *br dd*	1 91 *dd*	1 86 *d*	1 99 *dd*
9β	2 20 *dd*	2 20 *dd*	2 18 *dd*	2 20 *dd*	2 21 *dd*	2 17 *dd*	1 82 *dd*		1 83 *dd*
13	6 11 *d*	6 11 *d*	6 13 *d*	6 16 *d*	6 16 *d*	6 14 *d*	6 29 *d*	6 26 *d*	6 38 *d*
13′	5 56 *d*	5 55 *d*	5 62 *d*	5 64 *d*	5 64 *d*	5 59 *d*	5 68 *d*	5 65*d*	5 74 *d*
14	1 00 *s*	0 98 *s*	0 89 *s*	0 92 *s*	0 96 *s*	0 89 *s*	1 16 *s*	1 09 *s*	1 28 *s*
15	2 68 *dd*	2 80 *d*	4 10 *br d*	4 48 *br d*	4 67 *br d*	} 4 52 *m*	} 4 72 *br s*	4 45 *br d*	4 42 *br d*
15′	2 56*dd*	2 64 *d*	3 98 *br d*	4 43 *br d*	4 57 *br d*			4 16 *br d*	4 32 *br d*
OR				2 07 *s*	7 70 *d*	7 57 *m*	8 15 (OOH)		
					7 54 *m*	7 35 *m*			
					7 40 *m*	7 09 *d*			
					6 46 *d*	5 97 *d*			

*Obscured

J[Hz] Compounds **2a** to **2f** 5,6α = 2 5, 5,6β = 6α,6β = 6β,7 = 12 5, 6α, 7 = 7, 7,8 = 8,9α = 5, 7,13 = 1 2, 7,13′ = 1, 8,9β = 2, 9α,9β = 16, compound **2a** 3α,15 = 2, 15,15′ = 4 5, compound **2b** 2α,3 = 2β,3 = 3, 15,15′ = 4, compounds **2c** to **2e** 15,15′ = 11.5, compound **2g** 6α,6β = 13 5, 6α,7 = 7, 7,8 = 8,9α = 8, 7,13 = 2 5, 7,13′ = 2, 8,9β = 5, 9α,9β = 14, compound **2h** 3,6β = 1 5, 6α,6β = 13 5, 6α,7 = 7,8 = 8,9α = 8,9β = 7, 6β,7 = 11 5, 7,13 = 2 5, 7,13′ = 2, 15,15′ = 11 5, compound **2i** 1α,1β = 13, 1α,2α = 1β,2β = 5 5, 1α,2β = 14, 1β,2α = 2 5, 2α,2β = 18, 6α,6β = 12 5, 6α,7 = 7, 6β,7 = 10 5, 7,8 = 8 5, 7,13 = 3, 7,13′ = 2 5, 8,9α = 5, 8,9β = 11 5, 9α,9β = 14, 15,15′ = 12

Table 3 ^{1}H NMR spectral data of

H	3a	3b	3c	3d	3e	3f
1	4 91 *dd*	3 68 *dd*	3 66 *dd*	3 49 *dd*	3 49 *dd*	3 52 *dd*
3	5 35 *br s*	5 33 *br s*	5 32 *br s*	5 23 *br s*	{ 2 28 *ddd* 2 08 *ddd*	2 30 *ddd* 2 13 *ddd*
5	2 20 *br d*	2 63 *br d*	2 56 *br d*	2 45 *br d*	2 33 *br d*	2 38 *br d*
6	4 23 *dd*	5 45 *dd*	5 34 *dd*	4 39 *dd*	5 31 *dd*	5 36 *dd*
11	1 75 *m*	2 01 *m*	1 99 *m*	2 24 *m*	1 98 *m*	2 04 *m*
12	1 06 *d*	0 98 *d*	1 01 *d*	1 05 *d*	0 96 *d*	1 01 *d*
13	0 96 *d*	0 95 *d*	0 95 *d*	0 97 *d*	0 96 *d*	0 96 *d*
14	1 07 *s*	0 97 *s*	0 94 *s*	0 84 *s*	0 86 *s*	0 87 *s*
15	1 89 *br s*	1 73 *br s*	1 68 *br s*	1 90 *br s*	{ 4 97 *br s* 4 31 *br s*	{ 4 85 *br s* 4 36 *br s*
OR	7 66 *d*	8 02 *d*	7 68 *d*	4 44 *d*	6 03 *qq*	7 65 *d*
	7 52 *m*	6 93 *d*	7 53 *m*	3 33 *dd*	1 97 *dq*	7 52 *dq*
	7 39 *m*	3 86 *s*	7 39 *m*	3 22 *m* (3H)	1 83 *dq*	7 37 *m*
	6 43 *d*		6 43 *d*	3 86 *dd*		6 40 *d*
				3 64 *dd*		

*H-2 5 75 *dd*, †H-2 2 33 *dd* and 1 99 *ddd*, ‡H-2 2 72 *dd* and 2 61 *dd*; §H-7 2 18 *m*, ||H-7 2 22 *m*

J[Hz] 11,12 = 11,13 = 7, compound **3a** 1,2 = 6 5, 1,2′ = 10, 5,6 = 8 5, 6,7 = 4 5; compounds **3b** to **3d** 1,2 = 7, 1,2′ = 10, 5,6 = 11 5, 6,7 = 5, compounds **3e** to **3g;** 1,2 = 4 5, 1,2′ = 11 5, 2,3 = 2 5, 2,3′ = 2′,3 = 5, 2′,3′ = 3,3′ = 13, 5,6 = 11 5, 6,7 = 5, compound **3h** 1,2 = 1 5, 1,3 = 2 5, 2,3 = 10, 5,6 = 7 5, 6,7 = 3 5, compound **3i** 1,2 = 4 5, 1,2′ = 12, 2,2′ = 14, 2′,3 = 5 5, compound **3j** 1,2 = 6, 1,2′ = 12, 1,OH = 5, 2,2′ = 17 5, compounds **3k** and **3l** 1,2 = 5, 5,6 = 12, 6,7 = 7, OAng 3,4 = 7, 3.5 = 4,5 = 1 5, OCinn 2,3 = 16, OA 2,3 = 8, OGlu 1,2 = 8, 2,3 = 3,4 = 9, 5,6 = 2 5,6′ = 5 5, 6,6′ = 11 5

1α-*Angeloyloxyanhydrooplopanone* (**1a**) Colourless oil, IR $\nu_{max}^{CHCl_3}$ cm^{-1}. 1715, 1660 (C=CCO$_2$R), 1710 (C=O), MS *m/z* (rel. int.) 318 [M]$^+$ (0 02), 218.167 [M−RCO$_2$H]$^+$ (21) ($C_{15}H_{22}O$), 175 [M−C_3H_7]$^+$ (100), 133 (20), 83 [RCO]$^+$ (46), 55 (42).

1-*Oxo*-iso-*anhydrooplopanone* (**1b**). Colourless oil, IR $\nu_{max}^{CHCl_3}$ cm^{-1} 1705 (C=O), 1660 (C=CC=O); MS *m/z* (rel int.) 234.162 [M]$^+$ (32) ($C_{15}H_{22}O_2$), 219 (12), 191 (40), 164 (48), 149 (21), 73 (43), 61 (100)

1α-*Angeloyloxy*-7-*oxo*-iso-*anhydrooplopanone* (**1c**). Colourless oil, IR $\nu_{max}^{CHCl_3}$ cm^{-1}· 1715 (CO$_2$R), 1705 (C=O), 1670 (C=CC=O); MS *m/z* (rel int) 332 199 [M]$^+$ (0 9) (calc for $C_{20}H_{28}O_4$: 332.199), 289 (0.4), 232 (70), 189 (35), 147 (43), 83 (100), 55 (55)

1α-*Cinnamoyloxy*-7-*oxo*-iso-*anhydrooplopanone* (**1d**) Colourless oil, IR $\nu_{max}^{CHCl_3}$ cm^{-1} 1720, 1640 (C=CCO$_2$R), 1670 (C=CC=O), MS *m/z* (rel. int) 380 199 [M]$^+$ (1 6) (calc for $C_{24}H_{28}O_4$· 380 199), 232 (49), 189 (20), 147 (24), 131 [RCO]$^+$ (100), 103 (21)

1α-[*Anisoyloxy*]-7-*oxo*-iso-*anhydrooplopanone* (**1e**). Colourless oil, IR $\nu_{max}^{CHCl_3}$ cm^{-1}: 1705 (C=O), 1660 (C=CC=O); MS *m/z* (rel. int.). 384.193 [M]$^+$ (1 3) (calc. for $C_{23}H_{28}O_5$: 384.193), 232 (35), 189 (13), 177 (23), 147 (13), 135 [RCO]$^+$ (100).

4α,15-*Epoxy*-iso-*alantolactone* (**2a**) Colourless oil, IR $\nu_{max}^{CHCl_3}$ cm^{-1} 1760 (γ-lactone), MS *m/z* (rel int.) 248.141 [M]$^+$ (10) (calc for $C_{15}H_{20}O_3$ 248 141), 233 (100).

3α-*hydroxy*-4α,15-*epoxy*-iso-*alantolactone* (**2b**). Colourless oil, IR $\nu_{max}^{CHCl_3}$ cm^{-1} 3580 (OH), 1760 (γ-lactone), MS *m/z* (rel. int.) 264.136 [M]$^+$ (30) (calc for $C_{15}H_{20}O_4$. 264.136), 249 (5), 234 (100), 118 (71), 91 (79) To 10 mg isotelekin in 2 ml $CHCl_3$ in the presence of $NaHCO_3$ 10 mg *m*-chloroperbenzoic acid was added Usual work-up after 1 hr gave an epoxide (70% yield) identical with the natural compound.

15-*Hydroxy*-iso-allo-*alantolactone* (**2c**) Colourless oil, IR $\nu_{max}^{CHCl_3}$ cm^{-1} 3610 (OH), 1760 (γ-lactone); MS *m/z* (rel. int.)· 248 141 [M]$^+$ (12) (calc for $C_{15}H_{20}O_3$ 248.141), 230 (15), 175 (38), 131 (21), 119 (22), 105 (25), 91 (29), 73 (68), 61 (100)

15-*Acetoxy*-iso-allo-*alantolactone* (**2d**). Colourless oil, IR $\nu_{max}^{CHCl_3}$ cm^{-1} 1765 (γ-lactone, OAc), MS *m/z* (rel int) 248 [M−ketene]$^+$ (10), 230 [M−HOAc]$^+$ (64), 215 (26), 185 (26), 149 (26), 131 (25), 119 (67), 105 (39), 99 (100), 91 (44)

15-*Cinnamoyloxy*-iso-allo-*alantolactone* (**2e**) Colourless oil, IR $\nu_{max}^{CHCl_3}$ cm^{-1} 1760 (γ-lactone), 1700, 1635 (C=CCO$_2$R); MS *m/z* (rel. int) 378 183 [M]$^+$ (1) (calc for $C_{24}H_{26}O_4$. 378 183), 360 (1), 230 (46), 192 (24), 145 (32), 131 [RCO]$^+$ (100), 119 (59), 105 (42), 91 (39)

15-[2Z-*Cinnamoyloxyl*]-iso-allo-*alantolactone* (**2f**) Colourless oil; IR $\nu_{max}^{CHCl_3}$ cm^{-1} 1760 (γ-lactone), 1700 (C=CCO$_2$R), MS *m/z* (rel int.) 378 183 [M]$^+$ (0 8) (calc for $C_{24}H_{26}O_4$ 378.183), 360 (1 3), 230 (52), 147 (16), 131 [RCO]$^+$ (100), 119 (48), 103 (33)

15-*Acetoxy*-3α-*hydroperoxy*-allo-*alantolactone* (**2g**). Colourless oil; IR $\nu_{max}^{CHCl_3}$ cm^{-1} 1755 (γ-lactone, OAc); MS *m/z* (rel. int) 289 [M−OOH]$^+$ (1), 262 [M−HOAc]$^+$ (2 5), 149 (33), 99 (44), 61 (100)

3α,15-*Dihydroxy*-allo-*alantolactone* (**2h**). Colourless oil, IR $\nu_{max}^{CHCl_3}$ cm^{-1} 3510 (OH), 1770 (γ-lactone), MS *m/z* (rel. int.) 246.126 [M−H_2O]$^+$ (21) (calc. for $C_{15}H_{18}O_3$ 246 126), 233 (100), 217 (51), 119 (34), 105 (48), 91 (65), 73 (63), 63 (88).

15-*Hydroxy*-3-*oxo*-allo-*alantolactone* (**2i**) Colourless oil, IR $\nu_{max}^{CHCl_3}$ cm^{-1} 3510 (OH), 1770 (γ-lactone), MS *m/z* (rel int) 262 121 [M]$^+$ (11) (calc for $C_{15}H_{18}O_4$ 262 121), 244 (7), 217 (100), 151 (59), 91 (64), 55 (71)

1α-*Cinnamoyloxy*-6β-*hydroxy*-5,10-*bis*-epi-*eudesm*-3-*ene* (**3a**) Colourless oil, IR $\nu_{max}^{CHCl_3}$ cm^{-1} 3600 (OH), 1700, 1640 C=CCO$_2$R); MS *m/z* (rel int. 368 235 [M]$^+$ (0 1) (calc for $C_{24}H_{32}O_3$ 368 235), 220 (38), 205 (13), 202 (15), 177 (17), 159 (54), 131 (100).

1α-*Hydroxy*-6β-*anisoyloxy*-5,10-*bis*-epi-*eudesm*-3-*ene* (**3b**). Colourless oil, IR $\nu_{max}^{CHCl_3}$ cm^{-1}. 3500 (OH), 1695, 1605 (CO$_2$R); MS *m/z* (rel int) 220 [M−RCO$_2$H]$^+$ (33), 202 (4), 177 (79), 159 (27), 135 [RCO]$^+$ (100), 107 (11).

6β-*Cinnamoyloxy*-1α-*hydroxy*-5,10-*bis*-epi-*eudesm*-3-*ene* (**3c**)

3a–3l (400 MHz, $CDCl_3$, δ-values)

3g	3h	3i*	3j‡	3k§	3l‖
3 75 *dd*	4 07 *br s*	3 69 *dd*	3 87 *ddd*	3 89 *d*	3.91 *d*
4 52 *dd*	5 61 *dd*	4 39 *d*	—	1 55 *m* 1 38 *m*	1.55 *m* 1 37 *m*
2 79 *br d*	2.62 *d*	—	—	1 86 *br d*	1.93 *br* d
5.40 *dd*	5.39 *dd*	6 20 *br s*	6 37 *br s*	5 52 *dd*	5 62 *dd*
2 05 *m*	1 91 *m*	1.39 *m*	1 48 *m*	1 81 *m*	1 85 *m*
1·01 *d*	1.02 *d*	1.11 *d*	1 11 *d*	0.92 *d*	0 91 *d*
0.98 *d*	0 97 *d*	0 92 *d*	0 96 *d*	0 90 *d*	0.89 *d*
0 87 *s*	1 08 *s*	1 10 *s*	1 23 *s*	1 23 *s*	1 26 *s*
5.21 *br s* 4 75 *br s*	1.19 *s*	1.86 *br s*	1.91 *s*	1 32 *s*	1.28 *s*
7.65 *d*	7.76 *d*	7.60 *d*	7.64 *d*	7 69 *d*	8 00 *d*
7.51 *m*	7 56 *m*	7 51 *m*	7 52 *m*	7 50 *m*	6.93 *m*d
7.38 *m*	7 40 *m*	7.38 *m*	7 39 *m*	7 39 *m*	3.87 *s*
6 38 *d*	6 44 *d*	6.37 *d*	6 37 *d*	6.44 *d*	
7.81 *br s*	8.16 *br s*	8.00 *br s*	1 73 *d*		
(OOH)	(OOH)	(OOH)	(OH)		

Colourless oil, IR $\nu_{max}^{CHCl_3}$ cm^{-1} 3520 (OH), 1700, 1640 (C=CCO$_2$R), MS *m/z* (rel. int) 220 [M − RCO$_2$H]$^+$ (48), 202 (5), 187 (2), 177 (100), 159 (29), 147 (5), 131 (76), 103 (20)

1α,6β-*Dihydroxy*-5,10-*bis*-epi-*eudesm*-3-*ene*-6-O-[β-D-*glucopyranoside*] (**3d**) Colourless gum, IR $\nu_{max}^{CHCl_3}$ cm^{-1} 3580 (OH), MS *m/z* (rel int) 220 [M − sugar]$^+$ (56), 202 (6), 177 (100), 159 (29), 145 (14), 119 (21), 107 (29)

6β-*Angeloyloxy*-1α-*hydroxy*-5,10-*bis*-epi-*eudesm*-4(15)-*ene* (**3e**) Colourless oil, IR $\nu_{max}^{CHCl_3}$ cm^{-1} 3500 (OH), 1700 (C=CCO$_2$R), MS *m/z* (rel int) 320 235 [M]$^+$ (4) (calc for $C_{20}H_{32}O_3$ 320 235), 277 (0 5), 220 (31), 202 (11), 177 (34), 159 (36), 83 [RCO]$^+$ (100), 55 (67)

6β-*Cinnamoyloxy*-1α-*hydroxy*-3β-*hydroperoxy*-5,10-*bis*-epi-*eudesm*-4(15)-*ene* (**3g**) Colourless oil, IR $\nu_{max}^{CHCl_3}$ cm^{-1} 3510 (OH), 1690, 1630 (C=CCO$_2$R), MS *m/z* (rel int) 382 214 [M − H$_2$O]$^+$ (0 9) (calc for $C_{24}H_{30}O_4$ 382 214), 339 (0 5), 251 (1 5), 234 (7), 191 (8), 131 [RCO]$^+$ (100), 103 (22)

6β-*Cinnamoyloxy*-1α-*hydroxy*-4β-*hydroperoxy*-5,10-*bis*-epi-*eudesm*-2-*ene* (**3h**) Colourless oil, IR $\nu_{max}^{CHCl_3}$ cm^{-1} 3530 (OH), 1700, 1640 (C=CCO$_2$R), MS *m/z* (rel int) 382 214 [M − H$_2$O]$^+$ (0 2) (calc for $C_{24}H_{30}O_4$ 382 214), 367 [M − OOH]$^+$ (0 5), 339 (0 1), 234 (5 5), 131 [RCO]$^+$ (100), 103 (22)

6β-*Cinnamoyloxy*-1α-*hydroxy*-3β-*hydroperoxy*-5,10-*bis*-epi-*eudesm*-4-*ene* (**3i**) Colourless oil, IR $\nu_{max}^{CHCl_3}$ cm^{-1} 3510 (OH), 1695, 1635 (C=CCO$_2$R), MS *m/z* (rel int) 382 214 [M − H$_2$O]$^+$ (0 5) (calc for $C_{24}H_{30}O_4$ 382 214) 367 (0 4), 339 (0 4), 234 (4 5), 131 [RCO]$^+$ (44), 103 (13), 73 (69) 61 (100)

6β-*Cinnamoyloxy*-1α-*hydroxy*-5,10-*bis*-epi-*eudesm*-4-*en*-3-*one* (**3j**) Colourless oil, IR $\nu_{max}^{CHCl_3}$ cm^{-1} 3520 (OH), 1710 (C=CCO$_2$R, C=CC=O), MS *m/z* (rel int) 382 214 [M]$^+$ (3) (calc for $C_{24}H_{30}O_4$ 382 214), 234 (18), 191 (35), 131 [RCO]$^+$ (100) 103 (14)

6β-*Cinnamoyloxy*-5,10-*bis*-epi-*eudesmane*-1β,4β-*epoxide* (**3k**) Colourless oil, IR $\nu_{max}^{CHCl_3}$ cm^{-1} 1710, 1630 (C=CCO$_2$R), MS *m/z* (rel int) 368 235 [M]$^+$ (4) (calc for $C_{24}H_{32}O_3$ 368 235), 220 (57), 131 [RCO]$^+$ (100), 119 (28), 93 (38), 81 (44), ^{13}C NMR ($CDCl_3$, C-1 to C-15) 84 5, 23 7, 41 9, 82 5, 53 2, 72 0, 43 3, 21 2, 28 9, 48 4, 27 4, 23 6, 19 9, 17 1, 23 6, OCOR 166 6, 118 3, 144 9, 134 4, 128 1 (2C), 128 9 (2C), 130 3

6β-*Anisoyloxy*-5,10-*bis*-epi-*eudesmane*-1β,4β-*epoxide* (**31**) Colourless oil, IR $\nu_{max}^{CHCl_3}$ cm^{-1} 1700, 1600 (C=CCO$_2$R), MS *m/z* (rel int) 372 230 [M]$^+$ (0 6) (calc for $C_{23}H_{32}O_4$ 372 230), 220 (8), 205 (5), 177 (8), 159 (9), 135 [RCO]$^+$ (100), 107 (13)

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