*Phytochemistry*, Vol. 21, No. 1, pp. 181–186, 1982.
Printed in Great Britain.

0031–9422/82/010181–06 $03.00/0


# UNUSUAL DITERPENES FROM *BRICKELLIA EUPATORIEDES**

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(*Received* 12 *May* 1981)

**Key Word Index**—*Brickellia eupatoriedes*; Compositae; Eupatorieae; diterpenes; labdane derivatives; rearranged pimarene derivatives.

**Abstract**—While the roots of *Brickellia eupatoriedes* contained several unusual rearranged pimarene derivatives, the aerial parts afforded labdane derivatives, only one of them having been isolated before. The structure and stereochemistry of the new diterpenes could be elucidated by spectroscopic methods and a few chemical transformations. The absolute configuration of the rearranged diterpenes was proposed following the results of CD measurements.

The aerial parts of *Brickellia eupatoriedes* (L.) Shinner afforded in addition to germacrene D, lupeol and its acetate and stigmasterol several labdane derivatives, one of these, the angelate **1** being isolated before from other *Brickellia* species [1]. All diterpenes, except one, were acids, which could be separated in part after esterification with diazomethane. Only the major constituents, **12** and **14**, could be isolated as acids. The $^1$H NMR data of **3** and **5** showed that the corresponding acids only differed from **1** by the ester group at C-3, which were *trans*- and *cis*-cinnamates. From the $^1$H NMR data of **7** and the mixture of **9** and **11** (Table 1) the presence of 13,14-dihydro derivatives could be deduced. The stereochemistry at C-13, however, could not be determined. **12** and **14** were highly oxygenated labdane derivatives of molecular formula $C_{39}H_{54}O_{10}$, which could be separated after

Table 1. $^1$H NMR spectral data of compounds **3**, **5**, **7**, **9**, **11**, **13**, **15**, **15a** and **16**

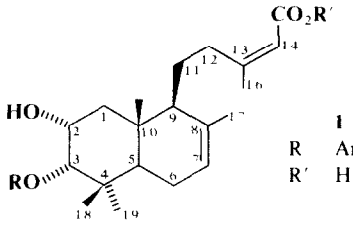
| | **3** | **5** | **7** | **9** | **11** | **13*** | **15*** | **15a*** | **16** |
|---|---|---|---|---|---|---|---|---|---|
| H-2 | 4.21 *br d* | 4.12 *br d* | 4.18 *br d* | 4.12 *br d* | | 5.35 *br d* | 5.35 *br d* | 5.35 *br d* | 4.13 *m*† |
| H-3 | 5.07 *br d* | 4.98 *br d* | 5.04 *br d* | 5.04 *br d* | 4.97 *br d* | 5.09 *br d* | 5.09 *br d* | 5.10 *br d* | |
| H-7 | 5.45 *br s* | 5.41 *br s* | 5.39 *br s* | 5.45 *br s* | 5.40 *br s* | 4.95 *br s* | 4.86 *br s* | 3.72 *br s* | 2.39 *ddd* |
| H-12 | | | | | | | | | |
| H-14 | 5.66 *br s* | 5.66 *br s* | 2.31 *dd*<br>2.13 *dd* | 2.31 *dd*<br>2.13 *dd* | | 5.80 *br s* | 5.74 *br s* | 5.71 *br s* | 5.40 *br t* |
| H-15 | — | — | — | — | | — | — | — | 4.13 *br d* |
| H-16 | 1.93 *br s* | 1.93 *br s* | 0.94 *d* | 0.96 *d* | | 1.91 *d* | 1.89 *d* | 1.91 *d* | 1.68 *br s* |
| H-17<br>H-17′ | 1.84 *br s* | 1.81 *br s* | 1.67 *br s* | 1.84 *br s* | 1.81 *br s* | 1.23 *s* | 1.26 *s* | 1.42 *s* | 4.87 *br s*<br>4.54 *br s* |
| H-18 | 1.05 *s* | 1.00 *s* | 1.02 *s* | 1.00 *s* | | 1.02 *s* | 1.00 *s* | 1.01 *s* | 0.99 *s* |
| H-19 | 0.93 *s* | 0.86 *s* | 0.89 *s* | 0.96 *s* | 0.95 *s* | 0.99 *s* | 0.98 *s* | 0.93 *s* | 0.91 *s* |
| H-20 | 0.86 *s* | 0.79 *s* | 0.82 *s* | 0.79 *s* | | 0.78 *s* | 0.77 *s* | 0.89 *s* | |
| COOR | 6.51 *d* | 6.04 *d* | 6.12 *qq* | 6.50 *d* | 6.03 *d* | 6.40 *d* | 5.95 *d* | — | — |
| | 7.73 *d* | 7.02 *d* | 2.02 *dq* | 7.71 *d* | 7.02 *d* | 7.69 *d* | 6.92 *d* | — | — |
| | 7.57 *m* | 7.56 *m* | 1.93 *dq* | 7.56 *m* | 7.56 *m* | 7.50 *m* | 7.50 *m* | — | — |
| | 7.40 *m* | 7.40 *m* | | 7.40 *m* | 7.40 *m* | 7.38 *m* | 7.38 *m* | — | — |
| OMe | 3.68 *s* | 3.68 *s* | 3.67 *s* | 3.67 *s* | 3.67 *s* | 3.68 *s* | 3.68 *s* | 3.68 *s* | — |

*OAng 6.02 *qq*, 1.95 *dq*, 1.81 *dq*; OCOC(OH) (Me) Et 1.8 *m*, 0.94 *t*, 1.23 *s*.

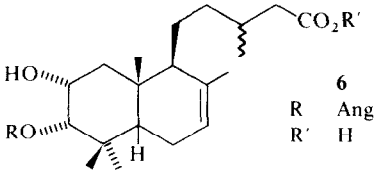
†In $C_6D_6$ 3.88 *dddd* ($J$ = 4).

$J$ (Hz): 1α,2β = 12; 2β,3β = 2; 14,16 = 1.3; compounds **7**–**11**: 13,14 = 6; 14,14′ = 14; 13,16 = 7; *trans* Cinn: 2′,3′ = 15; *cis* Cinn: 2′,3′ = 11; OAng: 3′,4′ = 7; 3′,5′ = 4′,5′ = 1.5; OCOC(OH) (Me) Et: 3′,4′ = 7; compound **16**: 6,7 = 4; 6′,7 = 2.5; 7,7′ = 13; 14,15 = 7.

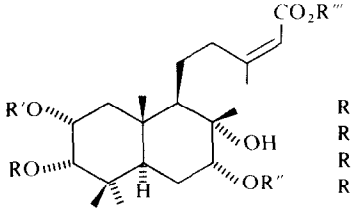
*Part 382 in the series "Naturally Occurring Terpene Derivatives". For Part 381 see Bohlmann, F., Kramp, W., Jakupovic, J., Robinson, H. and King, R. M. (1982) *Phytochemistry* **21**, (in press).



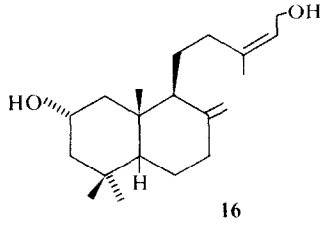
| | 1 | 2 | 3 | 4 | 5 |
|---|---|---|---|---|---|
| R | Ang | *trans* Cinn | *trans* Cinn | *cis* Cinn | *cis* Cinn |
| R′ | H | H | Me | H | Me |



| | 6 | 7 | 8 | 9 | 10 | 11 |
|---|---|---|---|---|---|---|
| R | Ang | Ang | *trans* Cinn | *trans* Cinn | *cis* Cinn | *cis* Cinn |
| R′ | H | Me | H | Me | H | Me |



| | 12 | 13 | 14 | 15 | 15a |
|---|---|---|---|---|---|
| R | Ang | | | Ang | Ang |
| R′ | | | | | |
| R″ | *trans* Cinn | | | *cis* Cinn | H |
| R‴ | H | Me | H | Me | Me |



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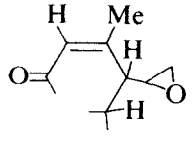
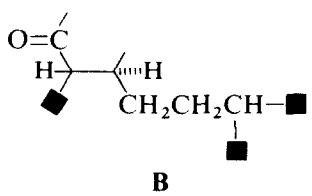
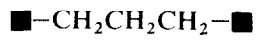
esterification. The $^1$H NMR data (Table 1) indicated the nature of the ester residues. Both contained an angelate and a 2-hydroxy-2-methylbutyrate residue, while one was a *trans*- and the other a *cis*-cinnamate. An additional hydroxyl group was best placed at C-8, since a downfield shifted methyl singlet was visible. As the H-20 signal showed no downfield shift the 8-methyl group most probably was axial. The couplings of the low field signals showed that two ester groups were α-orientated at C-2 and C-3, while the third one most probably was an axial orientated group at C-7. Partial hydrolysis led to **15a** with a free 7α-hydroxyl group, while the cinnamate signals were missing. Further saponification was unsuccessful. Therefore the relative position of the two remaining ester groups could not be determined. The only neutral diterpene was most probably **16**. Its $^1$H NMR data (Table 1) was close to those of similar labdanes. While the nature of the C-9 side-chain clearly followed from the $^1$H NMR data, the position of the second hydroxyl was deduced from the coupling pattern, which was identical with an alcohol from a *Baccharis* species [2]. As the signal showed four small couplings the axial orientation between two methylene groups was established, a situation only given at C-2. The absolute configuration of all labdanes was assigned only from biogenetic considerations; as **1** co-occurred with a labdane [1], it was very likely that all compounds belong to this series. The roots afforded **32** [3] and a complex mixture of diterpenes, which, however, were not labdanes but rearranged pimarene derivatives. The least polar compound had molecular formula $C_{20}H_{30}O_2$. The IR spectrum indicated the presence of a conjugated ketone, while an epoxide was indicated by the typical signals around 2.8 ppm (2.61 *ddd*, 2.77 *ddd*, 2.88 *dd*) (Table 2). An olefinic signal at 5.80 (*dq*) was coupled with an olefinic methyl. An allylic coupling with a broadened triplet at 1.72 ppm, which was further coupled with the epoxide proton (2.77 *ddd*) led to the partial structure **A**:



**A**



**B**



**C**

Table 2. $^1$H NMR spectral data of compounds **17**–**23** (400 MHz, $CDCl_3$, TMS as int. standard)

| | **17** | **18** | **19** | **20** | **21** | **22** | **23*** |
|---|---|---|---|---|---|---|---|
| H-1α | 2.90 *br d* | 2.67 *br ddd* | 2.85 *m* | 2.98 *ddd* | 2.85 *br d* | 2.95 *ddd* | |
| H-1β | 0.92 *ddd* | 0.89 *ddd* | 0.91 *ddd* | 0.93 *m* | 1.01 *ddd* | 0.96 *m* | |
| H-2α | 1.60 *ddd* | 1.6 *m* | 1.57 *ddd* | 1.65 *m* | 1.6 *m* | 1.70 *m* | |
| H-2β | 1.40 *m* | 1.4 *m* | 1.38 *m* | — | 1.38 *m* | — | |
| H-3α | 1.38 *m* | | | 4.59 *dd* | 1.2 *m* | 4.59 *dd* | |
| H-3β | 1.13 *ddd* | 1.15 *ddd* | 1.15 *ddd* | 1.65 *m* | 1.20 *m* | 1.70 *m* | |
| H-5 | 0.82 *dd* | 0.85 *m* | 0.82 *dd* | 0.85 *m* | 0.83 *m* | 0.9 *m* | |
| H-6α | 1.20 *ddd* | 1.30 *ddd* | 1.31 *ddd* | 1.25 *m* | 1.35 *m* | 1.4 *m* | |
| H-6β | 1.65 *ddd* | 1.65 *m* | 1.65 *ddd* | 1.65 *m* | 1.6 *m* | 1.7 *m* | |
| H-7α | 2.48 *dddd* | 2.5 *m* | 2.49 *dddd* | 2.51 *m* | 2.15 *m* | 2.55 *m* | |
| H-7β | 1.23 *dddd* | 1.25 *m* | 1.25 *dddd* | 1.25 *m* | 1.35 *m* | 1.4 *m* | |
| H-8 | 2.15 *dddd* | 2.13 *dddd* | 2.16 *dddd* | 2.15 *m* | 2.3 *m* | 2.1 *m* | — |
| H-9 | 1.80 *d* | 1.91 *d* | 1.85 *d* | 1.79 *d* | 2.24 *d* | 1.85 *d* | — |
| H-12 | 5.80 *dq* | 6.47 *d* | 5.96 *dq* | 5.82 *dq* | 6.02 *t* | 6.08 *dq* | 6.50 *d* |
| H-14 | 1.72 *br dd* | 2.5 *m* | 1.91 *br ddd* | 1.72 *br dd* | — | 1.93 *br dd* | |
| H-15 | 2.77 *ddd* | 2.93 *ddd* | 2.83 *m* | 2.83 *ddd* | 2.83 *dd* | 2.85 *m* | 2.93 *ddd* |
| H-16 | 2.88 *dd* | 2.78 *dd* | | 2.88 *dd* | 3.01 *dd* | | 2.79 *dd* |
| H-16′ | 2.61 *dd* | 2.73 *dd* | 2.59 *dd* | 2.62 *dd* | 2.80 *dd* | 2.61 *dd* | 2.76 *dd* |
| H-17 | 1.92 *dd* | 9.68 *s* | 4.73 *br d*<br>4.62 *dt* | 1.93 *dd* | 4.80 *dd*<br>4.65 *dd* | 4.76 *br d*<br>4.64 *br d* | 9.70 *s* |
| H-18 | 0.84 *s* | 0.85 *s* | 0.84 *s* | 0.92 *s* | 0.85 *s* | 0.89 *s* | 0.85 *s* |
| H-19 | 0.83 *s* | 0.84 *s* | 0.83 *s* | 0.88 *s* | 0.82 *s* | 0.92 *s* | 0.84 *s* |
| H-20 | 1.02 *s* | 1.08 *s* | 1.03 *s* | 1.05 *s* | 1.99 *s* | 1.08 *s* | 0.96 *s* |
| OCOR | — | — | 2.11 *s* | 6.03 *qq* | 2.11 *s* | 2.12 *s* | |
| | | | | 1.98 *dq* | | 6.16 *qq* | |
| | | | | 1.89 *dq* | | 1.99 *dq* | |
| | | | | | | 1.89 *dq* | |

* Missing signals were overlapping with those of **18**.

*J* (Hz): 1α,1β = 13; 1α,2α = 3.5; 1α,2β = 13; 1β,2α ~ 3; 1β,2β ~ 3; 2α,2β = 13; 2α,3α ~ 3; 2α,3β ~ 3; 2β,3α = 13; 2β,3β = 3.5; 3α,3β = 13; 5β,6α = 12; 5β,6β = 2; 6α,6β = 13; 6α,7α = 3; 6α,7β = 12; 6β,7α = 3; 6β,7β = 3; 7α,7β = 13; 7α,8α = 3.5; 7β,8α = 12; 8α,9β = 12.5; 8α,14 = 9; 12,14 = 12,17 = 1.5; 14,15 = 8.5; 15,16 = 3.5; 15,16′ = 3; 16,16′ = 5; **19**, **21**, **22**: 12,17 = 1.5; 17,17′ = 16.

As the $^1$H NMR spectrum further showed the presence of three tertiary methyl groups the ring skeleton of **17** was very likely. Spin decoupling allowed the assignment of the remaining sequences **B** and **C**, which only could be combined to **17**. The stereochemistry at C-8, C-9 and C-14 followed from the couplings observed. The CD curve of **17** showed opposite Cotton effects as that of the steroid **30** [4] indicating different stereochemistry at the carbon α to the conjugated keto group. Therefore the absolute configuration presented in **17** was very likely. The molecular formula and the $^1$H NMR data of **18** (Table 2) clearly showed that this diterpene was an aldehyde derived from **17** by oxidation of the olefinic methyl group. Consequently the signal of H-12 was shifted downfield and showed a doublet splitting only. Since at first the nature of the oxygen functions was not clear, the diterpene, which was accompanied by a small amount of a second one, was heated with acetic anhydride. This resulted in the formation of two products formed by opening of the epoxide ring. The $^1$H NMR data (Table 3) showed that **27** and **28** were present. While the stereochemistry of **27** at C-15 and C-16 followed from the couplings that of **28** could not be determined with certainty. Both diacetates obviously were formed from **18**, while the second compound was destroyed. As the configuration at C-15 in **27** was settled also that of the epoxide was very likely, as **27** probably was formed via **34**. After addition of diazomethane to **18** and **23** two separable pyrazolines were obtained. While one was the adduct of **18**, the second one was that of **23** with additional addition to the aldehyde group. All data agreed with the presence of **29**, while those of the natural compound led to the structure **23**, though this diterpene could not be separated from **18**. Having established the structures of **17** and **18** the $^1$H NMR data of **19**–**22** (Table 2) easily led to the proposed structures. The data of **19** were similar to those of **17**, however, the olefinic methyl was replaced by $CH_2OAc$ (4.73 *br d*, 4.62 *ddd* and 2.11 *s*). Furthermore, the signals of H-15 and H-16 were slightly shifted. From the $^1$H NMR spectrum of **20**, which could not be separated completely from impurities, the presence of an angelate was obvious. A double doublet at 4.59 ppm and a downfield shift of the H-18 signal indicated a 3α-position of this ester group. The other signals again were similar to those of **17**. The $^1$H NMR data of **22** (Table 2) were close to those of **19** and **20** indicating a 17-acetoxy derivative of **20**. The molecular formula of **21** showed that a diterpene was present containing one more oxygen than **19**. The missing coupling $J_{14,15}$ indicated that a hydroxyl group was at C-14. Consequently the H-12 signal was a triplet

Table 3. $^1$H NMR spectral data of compounds **24**–**29** (400 MHz, $CDCl_3$, TMS as int. standard)

| | **24** | **25** | **26** ($C_6D_6$) | **27** | **28** | **29*** |
|---|---|---|---|---|---|---|
| H-1$\beta$ | 2.84 *m* | 2.83 *br d* | 3.39 *ddd* | 2.78 *ddd* | 2.94 *m* | 2.31 *br d* |
| H-5 | 0.85 *m* | 0.85 *m* | 0.85 *dd* | 0.82 *m* | 0.85 *m* | 0.84 *dd* |
| H-8 | 2.15 *m* | 2.15 *m* | 1.98 *ddd* | 2.10 *m* | 2.03 *m* | |
| H-9 | 1.92 *d* | 1.90 *d* | 2.14 *d* | 1.93 *d* | 1.81 *d* | |
| H-12 | 5.96 *dt* | 5.98 *dt* | 5.59 *br s* | 5.92 *d* | 5.92 *d* | 2.69 *dd* |
| H-14 | | | | 2.70 *ddd* | 2.94 *m* | 1.6 *m* |
| H-15 | 2.84 *m* | 2.80 *ddd* | 3.30 *ddd* | 4.88 *ddd* | 4.61 *ddd* | 3.40 *ddd* |
| H-16 | | 2.87 *dd* | 3.51 *ddd* | 3.85 *dd* | 4.25 *dd* | 3.00 *dd* |
| H-16′ | 2.59 *dd* | 2.61 *dd* | 3.20 *dd* | 3.74 *dd* | 4.04 *dd* | 2.78 *dd* |
| H-17 | 4.74 *br d* | 4.75 *br d* | 4.00 *dd* | 6.25 *s* | 6.72 *br s* | 3.15 *dd* |
| H-17′ | 4.63 *br d* | 4.62 *dt* | 3.72 *br d* | | | |
| H-18 | 1.60 *br s* | 1.31 *s* | 0.89 *s* | 0.83 *s* | 0.84 *s* | 0.84 *s* |
| H-19 | 1.56 *br s* | 1.23 *s* | 0.87 *s* | 0.81 *s* | 0.81 *s* | 0.80 *s* |
| H-20 | 0.92 *s* | 0.92 *s* | 1.14 *s* | 1.00 *s* | 1.00 *s* | 0.90 *s* |
| OH | | - | 1.17 *d* | - | — | - - |
| OAc | 2.12 *s* | 2.12 *s* | — | 2.10, 2.12 *s* | 2.07, 2.10 *s* | |

* H-21 4.99 *dd*, 4.59 *dd* ($J_{12,21}$ = 4 and 10 Hz; $J_{21,21'}$ = 18 Hz; H-22 2.89 *dd*, 2.75 *dd* ($J_{1',22}$ = 3 Hz; $J_{22,22'}$ = 4.5 Hz).

*J*(Hz): Compounds **24**, **25**: 8,9 = 12; 12,14 = 12,17 = 1.5; 14,15 = 9; 15,16 = 3.5; 15,16′ = 3; 17,17′ = 16; compound **26**: 1$\alpha$,1$\beta$ = 13; 1$\alpha$,2$\alpha$ = 5; 1$\alpha$,2$\beta$ = 3; 5,6$\alpha$ = 12; 5,6$\beta$ = 2.5; 6$\alpha$,7$\beta$ = 7$\alpha$,7$\beta$ = 13; 6$\beta$,7$\beta$ = 3.5; 7$\beta$,8 = 12; 7$\alpha$,8 = 4; 8,9 = 12; 12,17 = 1.5; 15,16 = 5; 15,16′ = 10; 15,OH = 5; 16,16′ = 10; 17,17′ = 14; compound **27**: 8,14 = 14,15 = 9; 12,14 = 2; 15,16 = 5; 15,16′ = 16,16′ = 10; compound **28**: 8,14 = 14,15 = 9; 12,14 = 3; 12,17 = 1; 14,15 = 9; 15,16 = 4; 15,16′ = 8; 16,16′ = 12.5; compound **29**: 14,15 = 9; 15,16 = 4; 15,16′ = 2.5; 16,16′ = 5.

and the H-15 signal was slightly shifted downfield, while a downfield shift of H-9 required a 14$\beta$-hydroxyl group. The structures of **24** and **25** could not be established rigorously. However, all data, especially the chemical shifts of the methyl signals (Table 2), could only be explained if diterpenes with a rearranged ring A were present. The $^1$H NMR data and the molecular formula of **26** (Table 3) showed that a diterpene was present, which had in addition to a conjugated keto group three further oxygen functions. Spin decoupling in $C_6D_6$ showed that H-12 was coupled with a double doublet and a broadened doublet at 3.93 and 3.65, respectively, while a threefold doublet at 3.22 ppm was coupled with a double doublet at 3.13 and a threefold doublet at 3.48 ppm indicating the proposed situation at C-15 to C-17. The $\beta$-orientation of the C-14 hydroxyl was supported by a downfield shift of H-8$\beta$, while the stereochemistry at C-15 directly followed from the couplings observed.

Obviously all diterpenes from the roots are formed from the same precursor, which could be the oxygenated pimarene **33**, which may be directly transformed to **17**, which surely then could be further transformed to the other diterpenes. So far only one compound with this carbon skeleton was reported, which was named cleistanthol (**31**) [5]. We therefore propose the name cleistanthane for this carbon skeleton.

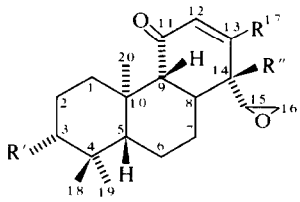
The compounds isolated from *B. eupatoriedes* again showed that the chemistry of this large genus is not uniform. So far most species have afforded labdane and/or dehydronerolidol derivatives [6, 7] as well as several flavones [8, 9] and a few *p*-hydroxyacetophenone derivatives [6]. Only one species so far gave a clerodane [1]. Surely further investigation is necessary to see whether the rearranged pimarenes are of chemotaxonomic importance.

## EXPERIMENTAL

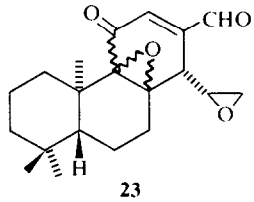
The air-dried plant material (voucher deposited in the U.S. National Herbarium) was extracted with $Et_2O$–petrol, (1:2) and the resulting extracts were separated first by CC (Si gel) and further by TLC (Si gel). Known compounds were identified by comparing the IR and $^1$H NMR spectra with those of authentic material. The aerial parts (200 g) afforded 20 mg germacrene D, 10 mg lupeol and 5 mg of its acetate, 10 mg stigmasterol, 9.5 mg **1**, 4 mg **16** ($Et_2O$–petrol, 4:1), 6 mg **32** and 100 mg of polar acids from which only **12** and **14** could be isolated as a mixture. After addition of $CH_2N_2$ and TLC ($Et_2O$–petrol, 4:1, × 3) 3 mg **3**, 3 mg **5**, 2 mg **7**, 4 mg **9**, 4 mg **11** and 65 mg **13** and **15** were obtained. The roots (70 g) gave 9 mg **17** ($Et_2O$–petrol, 1:1), 27 mg **18** ($Et_2O$–petrol, 2:1) containing 2 mg **23**, 6 mg **19** ($Et_2O$–petrol, 2:1), 5 mg **20** ($Et_2O$–petrol, 2:1), 8 mg **21** ($Et_2O$–petrol, 3:1), 6.5 mg **22** ($Et_2O$–petrol, 3:1), 1 mg **24** ($Et_2O$–petrol, 2:1), 3.5 mg **25** ($Et_2O$–petrol, 2:1) and 3 mg **26** ($Et_2O$–petrol, 3:1).

*Methyl-3α-trans-cinnamoyloxy-2α-hydroxy-13,14Z-dehydrocativate* (**3**). Colourless gum, IR $\nu_{max}^{CCl_4}$ cm$^{-1}$: 3600 (OH), 1715 (C=CCO$_2$R); MS *m/z* (rel. int.): 480.288 [M]$^+$ (0.5) ($C_{30}H_{40}O_5$), 448 [M − MeOH]$^+$ (1), 367 [M − $CH_2C(Me)$=$CHCO_2Me$]$^+$ (16), 219 [367 − $RCO_2H$]$^+$ (30), 201 [219 − $H_2O$]$^+$ (27), 131 [RCO]$^+$ (100).

*Methyl-3α-cis-cinnamoyloxy-2α-hydroxy-13,14Z-dehydrocativate* (**5**). Colourless gum, IR $\nu_{max}^{CCl_4}$ cm$^{-1}$: 3600 (OH), 1715 (C=CCO$_2$R); MS *m/z* (rel. int.): 480 [M]$^+$ (0.3), 367 (11), 219 (28), 201 (23), 133 (100).



| | 17 | 18 | 19 | 20 | 21 | 22 |
|---|---|---|---|---|---|---|
| R | Me | CHO | $CH_2OAc$ | Me | $CH_2OAc$ | $CH_2OAc$ |
| R′ | H | H | H | OAng | H | OAng |
| R″ | H | H | H | H | OH | H |



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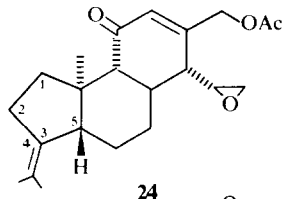

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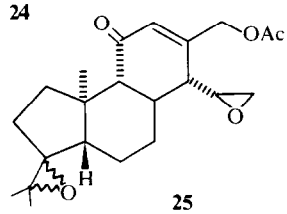

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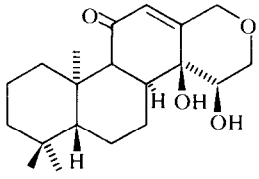

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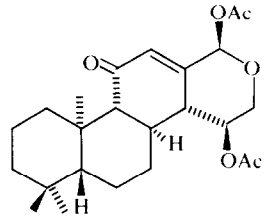

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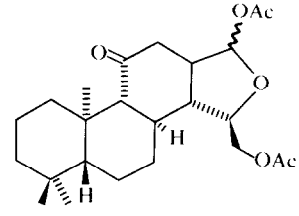

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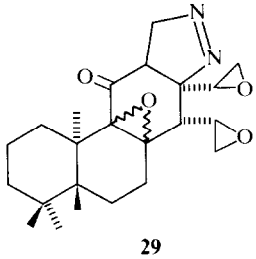

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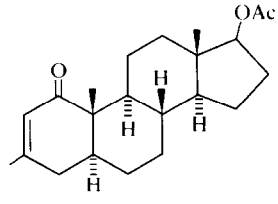

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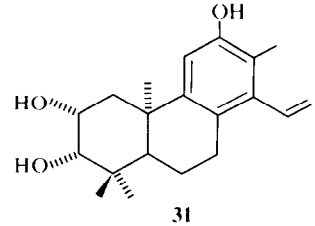

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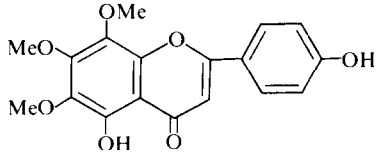

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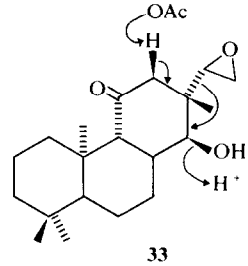

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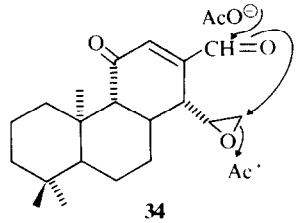

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*Methyl-3α-angeloyloxy-2α-hydroxycativate* (**7**). Colourless gum, IR $\nu_{max}^{CCl_4}$ cm$^{-1}$: 3600 (OH), 1738 ($CO_2R$), 1715 (C=CCO$_2$R); MS *m/z* (rel. int.): 434 [M]$^+$ (0.5), 334 [M $-RCO_2H$]$^+$ (3), 319 [334 $-Me$]$^+$ (7), 301 [319 $-H_2O$]$^+$ (10), 83 [$C_4H_7CO$]$^+$ (100), 55 [83 $-CO$]$^+$ (87).

*Methyl-3α-*trans- *and* cis-*cinnamoyloxy-2α-hydroxycativate* (**9** *and* **11**). Colourless gum, not free from **3** and **5**, IR $\nu_{max}^{CCl_4}$ cm$^{-1}$: 3600 (OH), 1725 ($CO_2R$, C=CCO$_2$R).

2α,3α-[*Angeloyloxy- and 2-hydroxy-2-methylbutyryloxy*]-7α-trans- *and* cis-*cinnamoyloxycativic acid* (**12** *and* **14**). Colourless gum, which was not separated, MS *m/z* (rel. int.): 682 [M]$^+$ (0.5), 664 [M $-H_2O$]$^+$ (2), 534 [M $-RCO_2H$]$^+$ (8), 516 [534 $-H_2O$]$^+$ (3), 434 [534 $-$AngOH]$^+$ (7), 416 [434 $-H_2O$]$^+$ (2), 398 [416 $-H_2O$]$^+$ (1), 131 [$C_6H_5CH$=CHCO]$^+$ (85), 83 [$C_4H_7CO$]$^+$ (100), 55 [83 $-CO$]$^+$ (81). To the mixture diazomethane in $Et_2O$ was added. TLC ($Et_2O$ petrol, 3:2, several times) afforded **13** and a mixture of **13** and **15** ($^1$H NMR see Table 1). IR $\nu_{max}^{CCl_4}$ cm$^{-1}$: 3350 (OH), 1730, 1645 (C=CCO$_2$R).

2β,15-*Dihydroxy-labda-*8(17),13-*diene* (**16**). Colourless gum, IR $\nu_{max}^{CCl_4}$ cm$^{-1}$: 3640 (OH), 900 (C=CH$_2$); MS *m/z* (rel. int.): 306 [M]$^+$ (0.5), 291 [M $-Me$]$^+$ (10), 273 [291 $-H_2O$]$^+$ (17), 255 [273 $-H_2O$]$^+$ (8), 93 (100), 81 (95).

15,16-*Epoxycleistanth-*12-*en-*11-*one* (**17**). Colourless crystals, mp 125–128°, IR $\nu_{max}^{CCl_4}$ cm$^{-1}$: 1685 (C=CC=O); MS *m/z* (rel. int.): 302.225 [M]$^+$ (25) ($C_{20}H_{30}O_2$), 287 [M $-Me$]+ (30), 271 [M $-CH_2OH$]$^+$ (21), 164 (15), 151 (70), 135 (32), 123 (100), 109 (93);

$$[\alpha]_{24}^{\lambda} = \frac{589}{+3.5} \quad \frac{578}{+4.0} \quad \frac{546}{+5.4} \quad \frac{436\text{ nm}}{+23.5} \quad (CHCl_3;\ c\ 0.43).$$

CD (MeCN) $\Delta_{\varepsilon 342}$ +1.3 (**30**: $\Delta_{\varepsilon 336}$ −1.5).

15,16-*Epoxy-*11-*oxo cleistanth-*12-*en-*17-*al* (**18**). Colourless gum, IR $\nu_{max}^{CCl_4}$ cm$^{-1}$: 2710, 1700 (C=CCHO), 1690 (C=CCO); MS *m/z* (rel. int.): 316.204 [M]$^+$ (18) ($C_{20}H_{28}O_3$), 301 [M $-Me$]$^+$ (8), 285 [316 $-CH_2OH$]$^+$ (17), 123 (42), 107 (44), 95 (48), 81 (57), 69 (73), 55 (100);

$$[\alpha]_{24}^{\lambda} = \frac{589}{+189} \quad \frac{578}{+205} \quad \frac{546}{+263} \quad \frac{436\text{ nm}}{+1624} \quad (CHCl_3;\ c\ 0.3).$$

10 mg **18** were heated for 10 min in 1 ml $Ac_2O$ and 0.1 ml pyridine. Usual work-up and TLC ($Et_2O$- petrol, 2:1) afforded 2.5 mg **27** and 2 mg **28**. **27**: Colourless gum, IR $\nu_{max}^{CCl_4}$ cm$^{-1}$: 1755, 1225 (OAc), 1685 (C=CCO); MS *m/z* (rel. int.): 418.236 [M]$^+$ (6) ($C_{24}H_{34}O_6$), 358 [M $-$AcOH]$^+$ (62), 298 [358 $-$AcOH]$^+$ (48), 283 [298 $-Me$]$^+$ (12), 147 (100).

**28**. Colourless gum, IR $\nu_{max}^{CCl_4}$ cm$^{-1}$: 1750, 1225 (OAc), 1680 (C=CCO); MS *m/z* (rel. int.): 418.236 [M]$^+$ (8) ($C_{24}H_{34}O_6$), 358 [M $-$HOAc]$^+$ (100), 345 [M $-CH_2OAc$]$^+$ (10), 316 [358 $-$ketene]$^+$ (17), 298 [358 $-$HOAc]$^+$ (24), 285 [345 $-$HOAc]$^+$ (33), 207 (64), 69 (88), 55 (87).

17-*Acetoxy-*15,16-*epoxycleistanth-*12-*en-*11-*one* (**19**). Colourless gum, IR $\nu_{max}^{CCl_4}$ cm$^{-1}$: 1750, 1230 (OAc), 1685 (C=CCO); MS *m/z* (rel. int.): 360.230 [M]$^+$ (12) ($C_{22}H_{32}O_4$), 345 [M $-Me$]$^+$ (8), 329 [M $-CH_2OH$]$^+$ (30), 318 [M $-$ketene]$^+$ (12), 300 [M $-$HOAc]$^+$ (24), 121 (100).

3α-*Angeloyloxy-*15,16-*epoxycleistanth-*12-*en-*11-*one* (**20**). Colourless gum. IR $\nu_{max}^{CCl_4}$ cm$^{-1}$: 1720 (C=CCO$_2$R), 1680 (C=CCO); MS *m/z* (rel. int.): 400.261 [M]$^+$ (2) ($C_{25}H_{36}O_4$), 300 [M $-$AngOH]$^+$ (42), 285 [300 $-Me$]$^+$ (15), 269 [300 $-CH_2OH$]$^+$ (12), 83 [$C_4H_7CO$]$^+$ (100).

17-*Acetoxy-*14β-*hydroxy-*15,16-*epoxycleistanth-*12-*en-*11-*one* (**21**). Colourless gum, IR $\nu_{max}^{CCl_4}$ cm$^{-1}$: 3520 (OH), 1750, 1230 (OAc), 1680 (C=CCO); MS *m/z* (rel. int.): 376.225 [M]$^+$ (4) ($C_{22}H_{32}O_5$), 333 [M $-$COMe]$^+$ (32), 316 [M $-$HOAc]$^+$ (18), 298 [316 $-H_2O$]$^+$ (14), 121 (100).

$$[\alpha]_{24}^{\lambda} = \frac{589}{-7.3} \quad \frac{578}{-8.0} \quad \frac{546}{-10.0} \quad \frac{436\text{ nm}}{-17.7} \quad (CHCl_3;\ c\ 0.3)$$

17-*Acetoxy-*3α-*angeloyloxy-*15,16-*epoxycleistanth-*12-*en-*11-*one* (**22**). Colourless gum, IR $\nu_{max}^{CCl_4}$ cm$^{-1}$: 1750 (OAc), 1720 (C=CCO$_2$R); MS *m/z* (rel. int.): 358 [M $-$AngOH]$^+$ (2), 83 [$C_4H_7CO$]$^+$ (100).

11-*Oxo-*8,9,15,16-*diepoxycleistanth-*12-*en-*17-*al* (**23**). Colourless gum, not free from **18**. MS *m/z* (rel. int.): 330.183 [M]$^+$ (8) ($C_{20}H_{26}O_4$), 315 [M $-Me$]$^+$ (6), 55 (100); reaction with $CH_2N_2$ in $Et_2O$ afforded after TLC **29**; IR $\nu_{max}^{CCl_4}$ cm$^{-1}$: 1700 (C=O); MS *m/z* (rel. int.): 386.221 [M]$^+$ (1) ($C_{22}H_{30}N_2O_4$), 358 [M $-N_2$]$^+$ (0.5), 318 [358 $-CH_2O$]$^+$ (15), 317 [358 $-CH_2OH$]$^+$ (15), 69 (87), 55 (100).

17-*Acetoxy-*15,16-*epoxyisocleistanth-*12-*en-*11-*one* (**24**). Colourless gum, not free from **20**. IR $\nu_{max}^{CCl_4}$ cm$^{-1}$: 1750 (OAc), 1685 (C=CCO); MS *m/z* (rel. int.): 358 [M]$^+$ (0.5) ($C_{22}H_{30}O_4$), 298 [M $-$HOAc]$^+$ (3), 267 [298 $-CH_2OH$]$^+$ (8), 135 (100).

17-*Acetoxy-*3,4,15,16-*diepoxyisocleistanth-*12-*en-*11-*one* (**25**). Colourless gum, IR $\nu_{max}^{CCl_4}$ cm$^{-1}$: 1750 (OAc), 1680 (C=CCO); MS *m/z* (rel. int.): 374.209 [M]$^+$ (37) ($C_{22}H_{30}O_5$), 359 [M $-Me$]$^+$ (60), 343 [M $-CH_2OH$]$^+$ (12), 317 [359 $-$ketene]$^+$ (15), 301 [343 $-$ketene]$^+$ (14), 299 (359 $-$HOAc)$^+$ (6), 55 (100).

14β,15β-*Dihydroxy-*16,17-*oxidocleistanth-*12-*en-*11-*one* (**26**). Colourless gum. IR $\nu_{max}^{CCl_4}$ cm$^{-1}$: 3560 (OH), 1690 (C=CCO); MS *m/z* (rel. int.): 334.214 [M]$^+$ (2) ($C_{20}H_{30}O_4$), 316 [M $-H_2O$]$^+$ (10), 274 [M $-$HOCHCH$_2$O]$^+$ (100).

*Acknowledgements*—We thank Dr. Hutton of Elkins for the plant material and the Deutsche Forschungsgemeinschaft for financial support.

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