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# GERMACRANOLIDES AND DITERPENES FROM *VIGUIERA* SPECIES*

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**Key Word Index**—*Viguiera bishopii*; *V. procumbens*; *V. dentata*; *V. pazensis*; *V. lanceolata*; *V. incana*; Compositae; diterpenes; dehydrotrachylobanic acid; dehydrostachenic acid; sesquiterpene lactones; heliangolides; falcarinol acetate.

**Abstract**—The investigation of six *Viguiera* species afforded in addition to known compounds two new diterpenes, the 9,11-dehydro derivatives of trachylobanic and stachenic acid, two new heliangolides closely related to viguiestenin, and the acetate of falcarinol. The chemotaxonomic situation is discussed briefly.

## INTRODUCTION

From the large genus *Viguiera* (Compositae, tribe Heliantheae, subtribe Helianthinae) [1] so far only a few species have been investigated chemically. From three species heliangolides with a furanone ring were reported [2–4], a further species contained a simple heliangolide [5], while others mainly gave different types of diterpenes [6]. One species contained flavones, chalcones and aurones [7]. We have now studied the constituents of six further species. Again all contain diterpenes, two of them being new. One species, *V. procumbens*, afforded in minute amounts two new heliangolides closely related to viguiestenin [5].

## RESULTS AND DISCUSSION

The roots of *Viguiera bishopii* H. Robins afforded α-pinene (**1**), *ent*-kaurenic acid (**6**), *ent*-manool (**13**), stachen-19-oic acid (**16**) [8], 9,11-dehydro-*ent*-kaurenic acid (**17**) 17α-hydroxy-*ent*-kaurane (**18**), trachylobanic acid (**19**) [9] and two further diterpenic acids, which could only be separated from the acid mixture as their methyl esters using silver nitrate coated thin-layer plates. As shown by the molecular formulae, both have two hydrogens less than the other acids isolated. The less polar methyl ester shows $^1$H NMR signals (see Table 1) very similar in part to those of the ester of **19**. However, an olefinic signal can be observed (5.67, *d*, *J* = 5.5). Double resonance experiments also after addition of Eu(fod)$_3$ allow the assignments of the sequence of the protons around the olefinic double bond, which clearly indicate that the substance is the 9,11-dehydro compound **20** (see Table 1). Inspection of a model shows that the observed upfield shifts of the 14β-H and 15α-H signals are due to the shielding effect of the 9,11-double bond. The angles, 15α, 16 being nearly 90°, practically no coupling can be observed. The Eu(fod)$_3$-induced shifts furthermore allow the assignments of the methyl shifts and those of 3-H. 17-H is shifted downfield by the 9,11-double bond, if compared with the shift in **19**. The second methyl ester shows $^1$H NMR signals very similar to those of the ester of **16**. The presence of a 9,11-double bond is indicated by the observed couplings of 11-H. Again a model shows that the observed couplings are in good agreement with the corresponding angles. Therefore **22** must be assigned to the natural acid. The aerial parts contain bicyclogermacrene (**3**), modhephene (**10**) [10], biformene (**12**), **13**

Table 1. $^1$H NMR data for the diterpenoids **21** and **23** (270 MHz, CDCl$_3$, TMS as internal standard)

| | | **21** | **23** |
|---|---|---|---|
| 3α-H | 2.21 *ddd* | 3.76 *d*(*br*) | 2.19 *d*(*br*) |
| 3β-H | 1.03 *ddd* | 2.26 *m* | 1.04 *ddd* |
| 11-H | 5.67 *d* | 5.88 *d* | 5.16 *dd* |
| 12-H | 1.40 *dd* | 1.49 *dd* | 2.19 *dd* |
| 13-H | — | — | 1.95 *m* |
| 14α-H | 1.20 *d* | 1.35 *d* | |
| 14β-H | 0.72 *d* | 0.94 *d* | |
| 15α-H | 0.81 *d*(*br*) | 0.98 *d* | 5.25 *d* |
| 15β-H | 1.40 *dd* | 1.49 *dd* | |
| 16-H | 1.11 *dd* | 1.19 *dd* | 6.16 *d* |
| 17-H | 1.25 *s* | 1.33 *s* | 1.23 *s* |
| 18-H | 1.19 *s* | 2.10 *s* | 1.10 *s* |
| 20-H | 0.90 *s* | 1.78 *s* | 0.86 *s* |
| OMe | 3.64 *s* | 4.86 *s* | 3.66 *s* |

*J* (Hz): **21**: 2α,3α ~ 3; 2α,3β = 13; 2β,3α ~ 3; 2β,3β = 3.5; 3α,3β = 13; 11,12 = 5.5; 12,16 = 7; 14,14′ = 11; 15,16 = 2; 15,15′ = 11; **23**: 2α,3β = 13; 2β,3β = 4; 3α,3β = 13; 11,12 = 2.5; 11,12′ = 3.5; 12,12′ = 17.5; 15,16 = 5.2.

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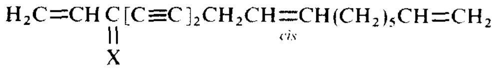
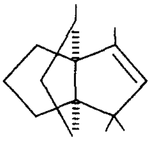
* Part 293 in the series "Naturally Occurring Terpene Derivatives"; for Part 292 see: Bohlmann, F., Gupta, R. K., Jakupovic, J., King, R. M. and Robinson, H. *Liebigs Ann. Chem.* (in press).



$H_2C{=}CH\,\underset{\underset{X}{\|}}{C}[C{\equiv}C]_2CH_2\underset{cis}{CH{=}CH}(CH_2)_5CH{=}CH_2$

**7** X = O
**8** X = OH, H
**9** X = OAc, H



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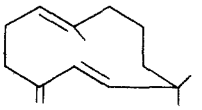

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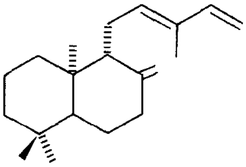

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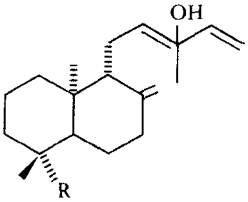
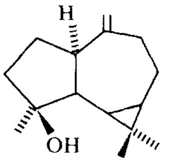


**13** R = Me
**14** R = $CO_2H$



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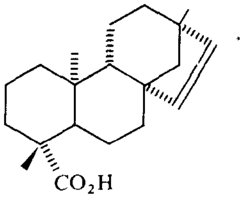

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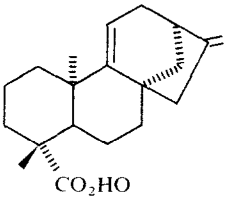

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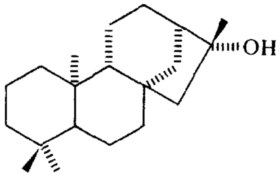
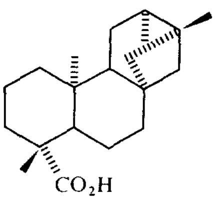
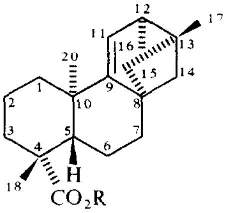


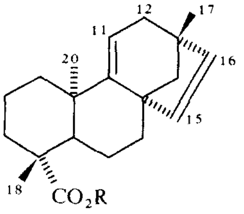
**18**



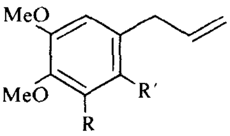
**19**



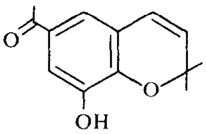
**20** R = H
**21** R = Me



**22** R = H
**23** R = Me



**24** R = OMe, R′ = H
**25** R = H, R′ = OMe



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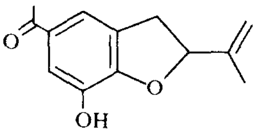
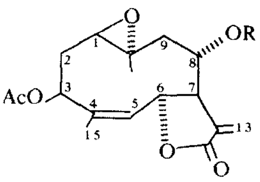


**27**



**28** R = Mebu
**29** R = iVal
**30** R = iBu

Table 2. $^1$H NMR data of sesquiterpene lactones **28** and **29** (270 MHz, $CDCl_3$)

| | **28** | | **29** |
|---|---|---|---|
| 1-H | | 2.86 *d*(*br*) | |
| 2-H | | 2.58 *ddd* | |
| 2′-H | | 1.8 *m* | |
| 3-H | | 5.26 *m* | |
| 5-H | | 5.28 *d*(*br*) | |
| 6-H | 6.12 *d*(*br*) | | 6.11 *d*(*br*) |
| 7-H | | 2.86 *m* | |
| 8-H | | 5.20 *m* | |
| 9-H | | 2.75 *dd* | |
| 9′-H | | 1.37 *d*(*br*) | |
| 13-H | | 6.37 *d* | |
| 13′-H | | 5.78 *d* | |
| 14-H | 1.52 *s* | | 1.49 *s* |
| 15-H | | 1.91 *d* | |
| OAc | | 2.16 *s* | |
| OCOR | 2.35 *tq* | | 2.18 *d*(*br*) |
| | 1.14 *d* | | 2.05 *m* |
| | 0.89 *t* | | 0.94 *d* |

*J* (Hz): 1,2 ~ 10; 5,6 = 11; 5,15 ~ 1; 7,8 ~ 1.5; 7,13 = 2; 8,9 = 5; 9,9′ = 15; Mebu: 2′,3′ = 2′,5′ = 3′,4′ = 7; iVal: 2′,3′ = 3′,4′ = 3′,5′ = 7.

and the corresponding acid **14**, spathulenol (**15**) [11], **16**, **22**, elimicin (**24**) and γ-asarone (**25**).

The roots of *V. procumbens* (Pers.) Blake contain falcarinone **7** [12], falcarinol (**8**) [12], *ent*-kaurenic acid, **17** and **19**, while the aerial parts gave also **7**, **8**, *ent*-kaurenic acid, **17**, **19** as well as germacrene D (**2**), α-farnesene (**4**), pentadec-1-ene (**5**) and humulene (**11**). From the polar fraction further minute amounts of two sesquiterpene lactones were isolated, their structures most probably being **28** and **29**. The corresponding isobutyrate **30** is viguiestenin [5], its structure being recently revised [13]. The $^1$H NMR data are very similar to those reported for **30** [5] and those of desacetylviguiestenin [13]. Though these two lactones could not be separated, the structures are nevertheless reasonably certain. The roots and the aerial parts of *V. dentata* (Cav.) Spreng. in addition to linoleic acid only afforded **6** and **17**. The roots of *V. pazensis* Rusby again contain **7**, **8** and **19**, while the aerial parts afforded **6**–**8** and **19** as well as **26** and **27**. The roots of *V. lanceolata* Britt. also contain **6**–**8** and **19**, while the aerial parts only afforded **6**–**8**.

The roots of *B. incana* (Pers.) Blake contain **8** and the corresponding acetate **9**, not isolated before. Its structure clearly follows from the comparison with the acetate formed from **8**. The aerial parts only gave **6** and **8**. Summarizing the results on *Viguiera* obtained up to now, it is clear that diterpenic acids are widespread in this genus. Furthermore acetylenes such as **7** and heliangolides seem to be characteristic. This is true also for *Helianthus*, which is placed in the same subtribe.

## EXPERIMENTAL

The air dried plant material, collected in Bolivia, was extracted with $Et_2O$–petrol 1:2 and the resulting extracts were separated first by column chromatography ($SiO_2$, act. grade II) and further by repeated TLC ($SiO_2$, GF 254). Known compounds were identified by comparison of the IR and $^1$H NMR spectra.

Viguiera bishopii (*voucher RMK* 7574). The roots (250 g) afforded 30 mg **1**, 20 mg **6**, 50 mg **13**, 20 mg **16**, 20 mg **17**, 30 mg **18**, 20 mg **19**, 30 mg **20** and 20 mg **22** (**20** and **22** were isolated as the methyl esters and separated by $AgNO_3$-coated TLC-plates, $Et_2O$–petrol 1:10). The aerial parts (350 g) gave 5 mg **3**, 5 mg **10**, 5 mg **12**, 40 mg **13**, 5 mg **14**, 5 mg **15**, 25 mg **16**, 25 mg **22**, 5 mg **24** and 5 mg **25**.

Viguiera procumbens (*voucher RMK* 7512). The roots (115 g) afforded 105 mg **6**, 15 mg **7**, 55 mg **8**, 45 mg **17** and 195 mg **19**, while the aerial parts (440 g) gave 10 mg **2**, 5 mg **4**, 15 mg **5**, 10 mg **6**, 5 mg **7**, 2 mg **8**, 5 mg **11**, 45 mg **17**, 5 mg **19** and 4 mg **28** and **29** (*ca* 3:1) ($Et_2O$–petrol 3:1).

Viguiera dentata (*voucher RMK* 7354). The roots (70 g) afforded 50 mg linoleic acid, 155 mg **6** and 75 mg **17**, while the aerial parts (70 g) gave 5 mg linoleic acid, 30 mg **6** and 15 mg **17**.

Viguiera pazensis (*voucher RMK* 7552). The roots (30 g) afforded 5 mg **7**, 10 mg **8** and 20 mg **19**, while the aerial parts (430 g) gave 5 mg **6**, 5 mg **7**, 13 mg **8**, 8 mg **19**, 2 mg **26** and 1 mg **27**.

Viguiera lanceolata (*voucher RMK* 7427). The roots (250 g) afforded 20 mg **6**, 20 mg **7**, 15 mg **8** and 10 mg **19**, while the aerial parts (520 g) gave 15 mg **6**, 10 mg **7** and 5 mg **8**.

Viguiera incana (*voucher RMK* 7790, *collected in Ecuador*). The roots (50 g) afforded 17 mg **8** and 4 mg **9** ($Et_2O$–petrol 1:10), while the aerial parts (150 g) afforded 20 mg **6** and 15 mg **8**.

*Falcarinol acetate* (**9**). Colourless oil, IR $\nu_{max}^{CCl_4}$ cm$^{-1}$: 2260 ($C\equiv C$), 1750, 1230 (OAc), 3080, 920 ($CH{=}CH_2$); MS: $M^+$ *m/e* 284.178 (5%) ($C_{19}H_{24}O_2$); 159 (81) (M − ketene, $n(CH_2)_4CH{=}CH_2$); 91 (100) ($C_7H_7^+$); $^1$H NMR ($CDCl_3$): 5.53 (*d*, 1-H), 5.37 (*d*, 1′-H), 5.83 (*ddd*, 2-H), 5.90 (*s*(*br*), 3-H), 3.03 (*d*(*br*), 8-H), 5.5–5.3 (*m*, 9, 10-H), 2.05 (*m*, 11, 16-H), 1.38 *m* (12—14-H), 5.80 (*ddt*, 16-H), 5.00 (*ddt*, 17*t*-H), 4.94 (*ddt*, 17*c*-H). The compound was identical with a sample prepared by acetylation of **8** (30 min, 70°, $Ac_2O$).

*Methyl*-9,11-*dehydrotrachylobanoate* (**21**). Colourless crystals, mp 75° (petrol), IR $\nu_{max}^{CCl_4}$ cm$^{-1}$: 1725, 1140 (axial $CO_2R$); 3050, 1620, 840 ($C{=}CH$); MS: $M^+$ *m/e* 314.225 (100%) ($C_{21}H_{30}O_2$); 299 (85) (M − ˙Me); 235 (19) (M − ˙$CO_2Me$); 239 (54) (299 − $HCO_2Me$).

$$[\alpha]^{\lambda}_{24^\circ} = \frac{589 \qquad 578 \qquad 546 \qquad 436\,\text{nm}}{-109.4 \quad -114.1 \quad -130.9 \quad -232.6}$$

($c = 1.2, CHCl_3$).

*Methyl*-9,11-*dehydrostachen*-19-*oate* (**23**). Colourless crystals, mp 132° (petrol), IR $\nu_{max}^{CCl_4}$ cm$^{-1}$: 1730, 1160 (axial $CO_2R$); 3050 ($CH{=}CH$); MS: $M^+$ *m/e* 314.225 (100%) ($C_{21}H_{30}O_2$); 299 (48) (M − ˙Me); 255 (24) (M − ˙$CO_2Me$); 239 (59) (299 − $HCO_2Me$).

$$[\alpha]^{\lambda}_{24^\circ} = \frac{589 \qquad 578 \qquad 546 \qquad 436\,\text{nm}}{+1.8 \quad +1.8 \quad +2.7 \quad +10.9}$$

($c = 0.6, CHCl_3$).

8α-[2-*Methylbutyryloxy*]- *and isovaleryloxy*-8-*desacylviguestenin* (**28** *and* **29**). Inseparable as a colourless gum, MS: $M^+$ *m/e* 406.199 (1%) ($C_{22}H_{30}O_7$); 391 (2) (M − ˙Me); 321 (15) (M − RCO˙); 305 (5) (M − $RCO_2^{\cdot}$); 304 (7) (M − $RCO_2H$); 261 (100) (321 − AcOH); 244 (42) (304 − AcOH); 85 (32) ($C_4H_9CO^+$); 57 (78) (85 − CO); 43 (77) ($MeCO^+$).

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## REFERENCES

1. Stuessy, T. F. (1977) *The Biology and Chemistry of the Compositae* (Heywood, V. H., Harborne, J. B. and Turner, B. L. eds.) p. 621. Academic Press, London.
2. Romo de Vivar, A., Guerrero, C., Diaz, E., Bratoeff, E. and Jimenez, L. (1976) *Phytochemistry* **15**, 525.
3. Guerrero, C., Santana, M. and Romo, J. (1976) *Rev. Latinoamer. Quim.* **7**, 41.
4. Romo de Vivar, A., Delgado, G., Guerrero, C., Resenduz, J. and Ortega, A. (1978) *Rev. Latinoamer. Quim.* **9**, 171.
5. Guerrero, C. Ortega, A. Diaz, E. and Romo de Vivar, A. (1973) *Rev. Latinoamer. Quim.* **4**, 118.
6. Bohlmann, F., Zdero, C. and Mahanta, P. K. (1977) *Phytochemistry* **16**, 1073.
7. Shimokoriyama, M. and Geissman, T. A. (1960) *J. Org. Chem.* **25**, 1956.
8. Bohlmann, F. and Le Van, N. (1976) *Chem. Ber.* **109**, 1446.
9. Pyrek, S. (1970) *Tetrahedron* **26**, 5029.
10. Zalkow, L. H., Harris, R. N. III and Van Derveer, D. (1978) *Chem. Comm.* 420.
11. Moth, O., Repcak, M. and Sedmera, P. (1978) *Arch. Pharm.* 311.
12. Bohlmann, F., Burkhardt, T. and Zdero, C. (1973) *Naturally Occurring Acetylenes*. Academic Press, London.
13. Baruah, N. C., Sharma, R. P., Madhusadanan, K. P., Thyagarajan, G., Herz, W. and Murari, R. (1979) *J. Org. Chem.* **44**, 1831.