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A NEW TYPE OF GERMACRANOLIDE FROM *VERNONIA* SPECIES*

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Key Word Index—*Vernonia* species; Compositae; new germacranolides; enol lactones; new guaianolides.

Abstract—From several South African *Vernonia* species, a considerable number of sesquiterpene lactones has been isolated. Together with known compounds, seven members of a new type with an enol lactone ring have been found, their structures being elucidated by spectroscopic methods and some chemical transformations. Furthermore two new derivatives of costunolide are present in two species, and three new guaianolides have been found. From some species, however, no lactones could be isolated. Together with a new bisabolene derivative, a known eremophilone has been isolated, probably for the first time, from a member of the tribe Vernonieae.

INTRODUCTION

The literature already contains a considerable number of reports on constituents of the large genus *Vernonia*, mainly due to the fact that it is rich is sesquiterpene lactones [1]. However several other types of natural products are also present, especially flavones [2], several triterpenes and sterols [3], acetylenes [4] as well as vernolic acid and similar compounds [5]. South African *Vernonia* species so far have not been investigated chemically. We therefore have collected nine species from Natal to see whether the constituents are similar or not to previously investigated species which are mainly American.

RESULTS AND DISCUSSION

Vernonia dregeana Sch. Bip. only contains the triterpenes **1**, **2**, **4** and lupenone. **1** is also present in *V. capensis* (Houtt.) Druce. *V. neocorymbosa* Hilliard et Burtt, also affords only triterpenes.

Table 1. ^{1}H-NMR data of **9***

H	C_6D_6		H	C_6D_6	
1α	*ddd*	2.13	9	*m*	1.97
2α	*ddd*	1.86		*m*	1.45
2β	*ddd*	1.63	13	*d*	6.12
3β	*dd(br)*	4.34	13′	*d*	4.84
5α	*dddd*	2.61	14	*dd*	5.52
6β	*dd*	3.35	14′	*dd*	5.17
7α	*ddddd*	2.01	15	*s(br)*	4.57
8	*m*	1.45	15′	*s(br)*	4.49

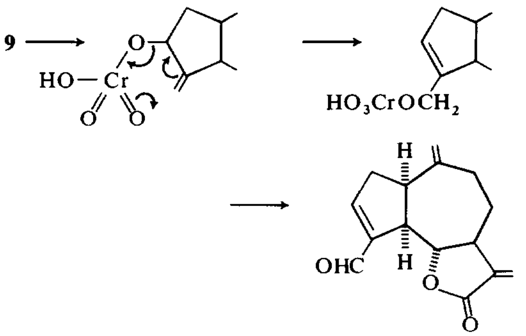
J (Hz): 1α,2α = 4; 1α,2β = 8; 1α,5α = 10; 2α,3β = 6; 2β,3β = 6; 2α.2β = 14; 3β,15 = 2; 5α,6β = 9; 5α,15 = 2; 6β,7α = 9; 7α,8α = 3; 7α,8β = 10: 7α,13 = 3.5.

* ^{1}H-NMR spectra always measured at 270 MHz, TMS as internal standard, δ-values, normally in $CDCl_3$.

The roots of *V. anisochaetoides* Sonder. afford aplotaxene and the thiophenacetylene **7** [4], while the aerial parts contain aplotaxene, **3** and **5** together with a lactone. The ^{1}H-NMR data show that we are dealing with an isomer of zaluzanin C (**8**) with 3α-configuration of the hydroxyl (**9**). Therefore the 6β-H is less deshielded than in **8**. Oxidation affords dehydrozaluzanin C (**11**) together with the unusual oxidation product **9a**†. The roots of *V. natalensis* Sch. Bip. contain the lactone **13**, previously isolated from a *Eupatorium* species [6]. The roots of *V. hirsuta* (DC.) Sch. Bip. var. *flanaganii* Phill. afford the pentaynene **8** [4], the eremophilone **14**, the known sesquiterpene lactones **10**, **12** and **15** together with two derivatives of **15**, which have the structures **16** and **17**. The position of the ester group follows from the chemical shift of the remaining olefinic methyl group (see Table 2) and furthermore by comparison of the NMR data with those of the corresponding methylacrylate [11]. Finally, we have isolated the bisabolene derivative **18**, its structure being elucidated by NMR techniques, especially by systematic decoupling experiments (see Table 3). Also the mass spectrum is in good agreement with the structure. The aerial parts also

* Part 133 in the series 'Naturally Occurring Terpene Derivatives'; for part 132 see Bohlmann, F. and Zdero, C. (1978) *Phytochemistry* **17**, 487.

† Formation of **9a** probably proceeeds by a cyclic mechanism as follows



9a

A somewhat similar reaction with additional epoxidation has been observed with a secondary allylic alcohol, which leads to an epoxy ketone. (Kupchan, S. M., Maruyama, M., Hemingway, R. J., Hemingway, J. C., Shibuya, S. and Fujita, T. (1973) *J. Org. Chem.* **38**, 2189).

Table 2. ^{1}H-NMR data of **16** and **17***

	16 (C_6D_6)	**17** (C_6D_6)
1-H	*m* 4.48	*m* 4 47
3β-H	*ddd* 2.41	*ddd* 2.36
5-H	*d* 4 43	*d* 4.42
6-H	*dd* 3.95	*dd* 3.92
7-H	*m* 2.1	*m* 2.1
13-H	*d* 6.21	*d* 6.20
13′-H	*d* 4.89	*d* 4.91
14-H	*s(br)* 1.05	*s(br)* 1.03
15-H	*ABq* 4.53	*s* 4 46
OCOR	*qq* 5.76	*d* 0.87
	d 2.13	*d* 0 88
	d 1.43	

J(Hz): 2α,3β = 2; 2β,3β = 4; 3α,3β = 12; 5,6 = 10; 6,7 = 9; 7,13 = 3.5; OCOR (**16**); *J* = 1; (**17**)· *J* = 7.

contain **12** and **15** together with germacrene D (**19**) and the triterpenes **1** and **2**.

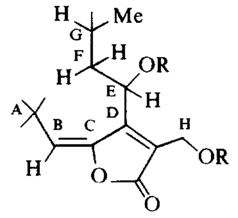
The roots of *V. hirsuta* (DC.) Sch. Bip. var. *hirsuta* contain also the lactones **10**, **12**, **15**, **16** and **17** as well as the isomer of **12**, the guaianolide **20**. The aerial parts afford **19** and **1** together with three further lactones, which are closely related to each other, differing only in the ester

Table 3. ^{1}H-NMR data of **18***

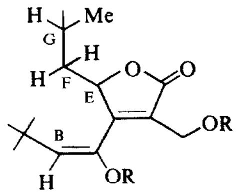
2-H	*s(br)* 5.88	12-H	*d* 1.98
4-H	*m* 2.35	13-H	*d* 2 23
6-H	*m* 2.54	14-H	*d* 0.60
7-H	*ddq* 2.76	15-H	*s(br)* 1.95
8-H	*dd* 4.35	OH	*d* 3.72
10-H	*qq* 6 31		

**J* (Hz): 6,7 = 7; 7,14 = 7; 7,8 = 2; OH = 5; 10,12 = 10,13 = 1.2.

part. The less polar compound is a 2-methylacrylate, while in the second the ester group is epoxidized and in the third an allylic hydroxyl is introduced. These assumptions clearly follow from the ^{1}H-NMR data. Furthermore all three lactones have a hydroxyl and an acetate group. High resolution ms shows that there must be a further oxygen function, which turns out to be part of a semi ketal. Reaction with *p*-toluenesulfonic acid in methanol therefore affords in all cases corresponding ketals; however, this was partially accompanied by the hydrolysis of the acetate. Extensive ^{1}H-NMR studies of all these compounds show that they are enol lactones with the two possible partial structures **I** and **II**:



I



II

The proton at B give rise to a singlet and that at E to a *dd*, which couples with two protons at F, which give rise to a *ddd* (see Table 4). These two protons themselves couple with a proton at G, which is coupled with methyl protons. The signals of two further methylene groups are not coupled with the rest of the hydrogens. To decide between **I** and **II**, we saponified the ketal. Only small amounts of the expected diol could be obtained. However, the NMR spectrum clearly shows that only **I** is possible as the enol lactone still is present and the corresponding signal for the proton at the hydroxyl bearing carbon can be observed [*dd* 5.12 (*J* = 6 and 12 (H, OH), with D_2O *d*(*J* = 6)]. Also the ^{13}C-NMR spectrum is in good agreement with this arrangement (see Table 5).

Table 4. ^{1}H-NMR

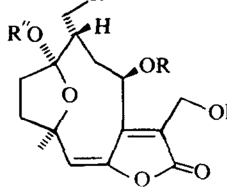
H	**21** + Eu(fod)$_3$		**22**	**23**	**24**	**25**
2, 3	*s* 2.09	*s* 2.24	*s* 2.07	*m* 2.3–2.0	*m* 1.8–2.2	*m* 1.8–2.2
5	*s* 5.88	*s* 6.16	*s* 5.91	*s* 5.96	*s* 5.86	*s* 5.88
8α	*d(br)* 6.28	*d(br)* 8.15	*d(br)* 6.36	*d(br)* 6 42	*d(br)* 6.30	*d(br)* 6.25
9α	*dd* 2 32	*dd* 2.57	*dd* 2.25	*dd* 2.42	*dd* 2 44	*dd* 2.41
9β	*ddd* 1.87	*ddd* 2.01	*ddd* 1.85	*ddd* 1.87	*ddd* 1 80	*ddd* 1.76
10β	*m* 2.08	*m* 2.24	*m* 2.07	*m* 2.0	*m* 1.95	*m* 1.92
13	*d* 5.10	*d* 6.48	*s* 4.97	*d* 5.13	*dd* 4.63§	*d* 5.10
13′	*d* 5.01	*d* 5.94		*d* 5.02	*dd* 4.53‖	*d* 5.02
14	*d* 0.95	*d* 1.00	*d* 0.92	*d* 0.95	*d* 0.90	*d* 0.88
15	*s* 1.48	*s* 1.70	*s* 1.57	*s* 1.53	*s* 1.49	*s* 1.49
OCOR	*s(br)* 6.25	*s(br)* 6 58	*d* 3.22†	*d* 6.33	*s(br)* 6.32	*s(br)* 6.28
	dq 5.61*	*dq* 5 77*	*d* 2.73†	*s(br)* 5.76	*dq* 5.64	*dq* 5.61*
	t 1.92	*s(br)* 2.15	*s* 1.59	*d* 4.27‡	*t* 1.94	*t* 1.92*
				t 4.11‡		
OAc	*s* 2.08	*s* 2.66	*s* 2.07	*s* 2 09	—	*s* 2.07
OMe	—	—	--	—	*s* 3.27	*s* 3.27

J(Hz)· 8α,9β = 8; 9α,9β = 16; 9α,10α = 12, 9β,10α = 1.5; 10,14 = 7; 13,13′ = 13
* *J* = 1; † *J* = 6.5, ‡ *J* = 7, § *J* = 13,3.5 (OH), ‖ *J* = 13,8 (OH); ¶ *J* = 7,11 (OH); ** *J* 13,13′ = 13; *J* H, OH = 3.5,8; †† *J* = 12,4.

Table 5. ^{13}C-NMR signals of **21** (δ-values in ppm, $CDCl_3$, 67.5 MHz, TMS as internal standard†

C-1	*s* 108.3	C-12	*s* 170.1
C-2*	*t* 38.7	C-13	*t* 55.7
C-3*	*t* 38.0	C-14	*q* 18.2
C-4	*s* 81.2	C-15	*q* 28.3
C-5	*d* 126.4	Meacr	*s* 167.0
C-6	*s* 150.1		*s* 136.3
C-7	*s* 146.5		*t* 126.5
C-8	*d* 68.8		*q* 17.1
C-9	*t* 36.1	Ac	*s* 167.1
C-10	*d* 41.5		*q* 20.7
C-11	*s* 130.1		

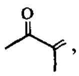
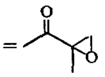
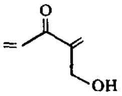
† Assignments are made by comparison with those of a large series of similar compounds; however, some assignments, as those marked with * may be interchangeable.



	21*	22	23	24	25	26
R	Meacr†	EMeacr	HOMeacr	Meacr	Meacr	EMeacr
R'	Ac	Ac	Ac	H	Ac	Ac
R''	H	H	H	Me	Me	Me
R'''	H	H	H	H	H	H

	27	28	29	30	31
R	HOMeacr	H	Meacr	EMeacr	Meacr
R'	Ac	H	H	H	Ac
R''	Me	Me	H	H	H
R'''	H	H	H	H	OH

* The numbering is given for 6,7-lactone, though the alternative formulation as a 7,8-lactone by changing the stereochemistry at all centres would be possible. The same is true for glaucolide A (**38**) [1a], which is structurally related to **21**.

† Meacr = , EMeacr = , HOMeacr = 

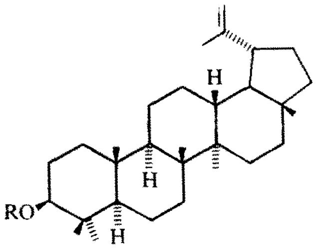
To complete the partial structure **I**, only the ketal-carbon, the two methylenes and the carbon with the second methyl and the oxygen function has to be added. The last one must be at A. Therefore the only possible structures for natural products are **21–23**. The stereochemistry at the asymmetric centres are in agreement with the observed coupling constants. Also the low downfield position of 8α-H can be explained from the model, as it comes very near to the ketal oxygen. The angle between 8α- and 9α-H is nearly 90° and therefore 8α-H displays only a doublet. Only the stereochemistry at C-10 is not certain, though the given one should be preferred, since it is based on the observed coupling constants for 9-H and the probable relationship to glaucolide A (**38**) [1a]. For the lactone without an oxygen function at C-8 and a free C-13-hydroxyl group, we propose the name hirsutinolide.

Perhaps both types **21** and **38**, are formed from the diepoxide **32** via the rearranged lactone **33**, which on hydrolysis would afford **35**. Elimination of water would give **34**, which directly could be transformed to **21**, or **35** could be oxidized first at C-1 and then by elimination of water would produce **36**. Also glaucolide A (**38**) [1a], which is widespread in the genus *Vernonia* probably is formed via **33** by hydrolysis, oxidation and acetylation. The proposed biogenetic route would be an indication that we are dealing with 6,7- rather than 7,8-lactones.

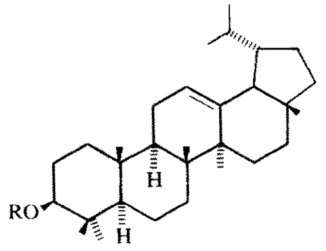
The roots of *V. angulifolia* DC. afford **3** and **4** as well as traces of a diynetriene alcohol, while the aerial parts contain **19**, **3**, **4**, the lactones **21**, **22** and two further

data of **21***

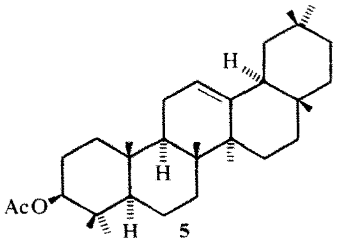
26	27	28	29	30	31
m 2.2–1.8	*m* 2.25–1.9	*m* 2.2–1.8	*s* 2.08	*s* 2.09	
s 5.91	*s* 5.92	*s* 5.83	*s* 5.85	*s* 5.88	*s* 5.86
d(br) 6.37	*d(br)* 6.41	*dd* 5.14¶	*d(br)* 6.33	*d(br)* 6.39	*d(br)* 6.33
dd 2.31	*dd* 2.42	*dd* 2.33	*dd* 2.34	*dd* 2.26	*m* 2.3
ddd 1.77	*ddd* 1.82	*ddd* 1.78	*ddd* 1.83	*ddd* 1.86	} *m* 1.9
m 2.1	*m* 2.1	*m* 2.1	*m* 1.92	*m* 1.93	
s 4.96	*d* 5.08	*d* 4.57	*d* 4.64**	*d* 4.58	*d* 5.11
	d 5.00	*d* 4.44	*dd* 4.55**	*d* 4.50	*d* 4.99††
d 0.87	*d* 0.89	*d* 0.89	*d* 0.95	*d* 0.93	{ *dd* 3.74†† *dd* 3.60††
s 1.59	*s* 1.57	*s* 1.63	*s* 1.46	*s* 1.57	*s* 1.52
d 3.22	*d* 6.33	—	*s(br)* 6.28	*d* 3.21	*s(br)* 6.24
d 2.72	*d* 5.75	—	*dq* 5.63	*d* 2.74	*dq* 5.63
s 1.61	*d* 4.27‡ 3.61‡	—	*t* 1 92	*s* 1.58	*t* 1.93
s 2.07	*s* 2.09	—	—	—	*s* 2.07
s 3.25	*s* 3.30	*s* 3.29	—	—	—



1: R = H **2**: R = Ac



3: R = H **4**: R = Ac



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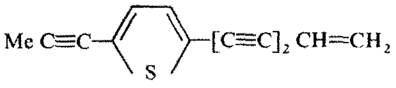
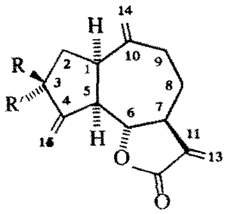
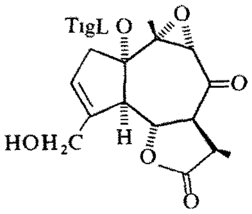
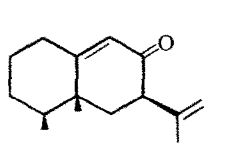


6

Me[C≡C]$_5$CH=CH$_2$ **7**



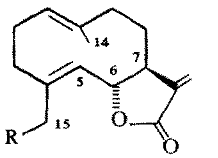


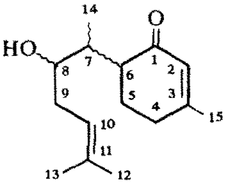


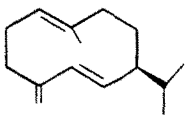
	8(6)	**9**	**10**(7)	**11**(6)	**12**(8)
R =	OH	H	OSen	>O	H
R′ =	H	OH	H		H

13(9)

14(10)





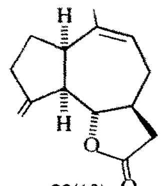


15 **16** **17**

R = H(12) OSen OiVal

18

19



20(13)

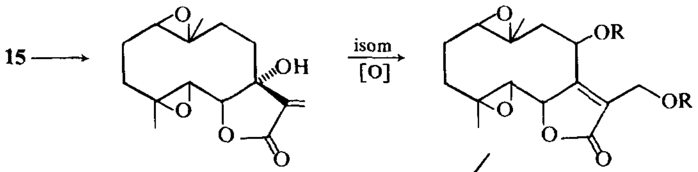
similar compounds with a free 13-hydroxy group. The structures therefore are **29** and **30**.

A further enol lactone has been isolated from the aerial parts of *V. novebaracensis* (L.) Michx. collected in Guatemala. However this compound could be prepared in pure form only after acetylation of a tertiary hydroxyl group. The ^{1}H-NMR spectrum of the crude lactone shows that the lactone moiety has undergone no change, with an acetylated 13-hydroxy- and a methylacrylic acid ester group at C-8. As the ^{1}H-NMR signals of the diacetate in deuteriobenzene are mainly first order, they can easily be interpreted (see Table 6). The use of a shift reagent also solved the remaining problem, whether the doublet at 5.00 is due to an olefinic proton or to a secondary acetate. The observed small shift clearly indicates that this signal is that of an olefinic proton. However, two possible structures, one with a 1,2- and one with a 1,10-double bond, are still possible. From biogenetical considerations the first possibility however is more likely. Therefore the structure of the

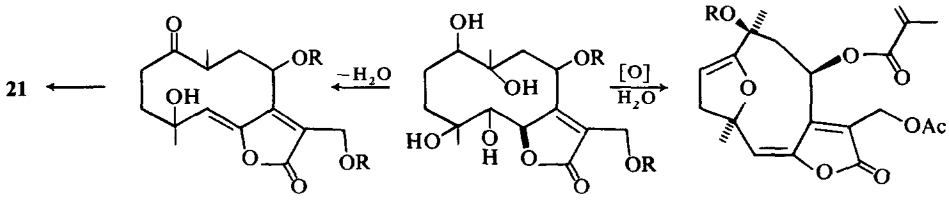
Table 6. ¹H-NMR data of **36**–**39**

	36 C_6D_6 (76°)	**37** (C_6D_6)	Δ†	$CDCl_3$	**39** C_6D_6 (76°)	**40** $CDCl_3$ (57°)
2-H	*s*(*br*) 5.05	*dd* 4.64	0.08	*dd* 5.00		
3α-H	*m* 2.4–2.2	*dd* 2.43	0.02	*d* 2.92	*m* 2.0	*m* 2.2–2.0
3β-H		*dd* 2.34	0.10			
5-H	*s* 5.62	*s* 5.54	0.11	*s* 5.98	*s* 5.52	*s* 5.92
8α-H	*m* 6.25	*dd* 6.23	0.90	*d*(*br*) 6.14	*dd* 6.43	*s*(*br*) 6.48
9α-H	*dd* 2.56	*dd* 2.77	0.11	*dd* 2.82	*dd* 2.39	*dd* 2.61
9β-H	*m* 2.2	*d*(*br*) 2.20	0.14	*d*(*br*) 2.32	*m* 2.08	*ddd* 2.45
13-H	*d* 5.08	*d* 4.95	0.65	*s* 4.90	*d* 5.19	*d* 5.22
13′-H	*d* 4.98	*d* 4.86	0.50		*d* 5.02	*d* 4.95
14-H	*s* 1.54	*s* 1.50	0.06	*s* 1.62	*s* 1.25	*s* 1.58
15-H	*s* 1.38	*s* 1.13	0.09		*s* 1.15	*s* 1.25
OCOR	*s*(*br*) 6.19	*s*(*br*) 6.13	0.20	*s*(*br*) 6.21	*s*(*br*) 6.22	*s*(*br*) 6.26
	dq 5.27	*dq* 5.20*	0.08	*dq* 5.66	*dq* 5.26	*dq* 5.67
	t 1.79	*t* 1.75	0.13	*t* 1.92	*t* 1.79	*t* 1.95
OAc	*s* 1.77	*s* 1.64	0.26	*s* 2.06	*s* 1.68	*s* 2.06
	—	*s* 1.59	0.18	*s* 1.98	—	—
OMe	—	—		—	*s* 3.42	—

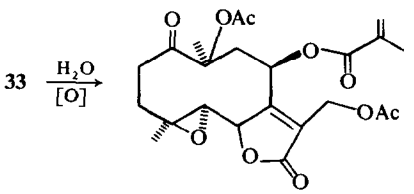
J (Hz) 2,3 = 2.5; 8α, 9α = 6; 8α, 9β = 2; 9α, 9β = 16; 13, 13′ = 13.
* *J* = 1; † Δ-values after addition of *ca* 0.1 equivalents of Eu(fod)$_3$.



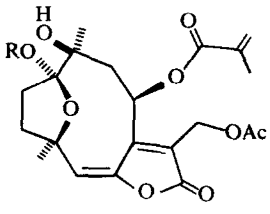
32 **33**



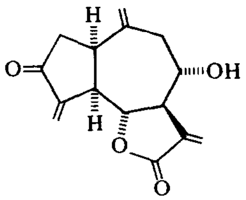
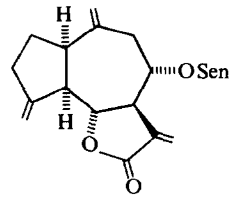
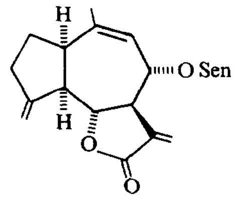
34 **35** **36**: R = H **37**: R = Ac



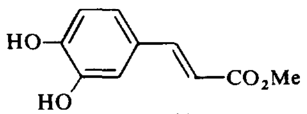
38



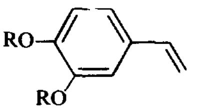
39: R = Me **40**: R = H

41 **42** **43**



44



45: R = H **46**: R = Ac

Table 7. ^{1}H-NMR data of **41** and **43**

	41			**43** (C_6D_6)	
	$C_6D_6/CDCl_3$	+Eu(fod)$_3$	Δ†		Δ†
1α H	*m* 2.53	*dd(br)* 3.71	1.18		
2-H	*m* 2.18*	*d* 4.35	2.17		
5α-H	*dddd* 2.66	*dddd* 4.07	1.41	*m* 2.32	0.31
6β-H	*dd* 3.42	*dd* 5.04	1.62	*dd* 3.37	0.55
7α-H	*m* 1.76	*ddd* 3.44	1.68	*dddd* 2.84	0.70
8β-H	*ddd(br)* 3.10	*ddd(br)* 4.72	1.62	*d(br)* 5.36	1.21
9α-H	*m* 1.76	*dd* 2.91	1.15	*s(br)* 5.40	1.01
9β-H	*dd* 2.27	*dd* 3.27	1.00		
11β-H	*dq* 2.16	*dq* 4.22	2.06		
13-H	*d* 1.34	*d* 2.71	1.37	*d* 6.26	0.95
				d 5.61	0.79
14-H	*s(br)* 4.67	*s* 5.71	1.04	*s(br)* 1.41	0.17
14′-H	*s(br)* 4.50	*s* 5.27	0.77		
15-H	*d* 6.19	*d* 8.04	1.85	*s(br)* 5.26	0.14
15′-H	*d* 5.64	*d* 6.68	1.04	*s(br)* 4.99	0.02

J (Hz) **41**: 1,2 = 6; 1,5 = 10; 5,6 = 9.5; 5,15 = 2.5; 6,7 = 9.5, 7,8 = 10; 7,11 = 10; 8,9α = 10; 8,9β = 5; 9α,9β = 13, 11,13 = 7.

* in $CDCl_3$ 2α *dd* 2.65 (*J* = 18, 7.5), 2β *dd* 2.52 (*J* = 18.3). **43** 5α,6β = 6β,7α = 7α,8β = 9.5; 7α,13 = 3.5; 7α,13′ = 3; 8β,9 = 10.

† Δ-values after addition of Eu(fod)$_3$.

natural product most probably is **36**, which we have named 8β-(2-methylacryloyloxy)-isohirsutinolid-13(O)-acetate, and the compounds of the acidic hydrolysis should be **39** and **40**. **36** is closely related to **21**. The position of the acetate at C-13 only is given by analogy. Together with **36** and **5** the catechol derivatives **44** and **45** have been isolated. The position of the hydroxy groups in **45** has been established by comparison of the NMR-signals with those of the diacetate, prepared by acetylation of **45** (see Table 8).

The roots of *V. novebaracensis* contain besides zaluzanin C (**8**) and its dehydro derivative **11** a further lactone; its spectroscopic properties show, that it is the known ketone **41**, previously prepared by hydrogenation and reduction of cynaropikrin (**14**). Melting point and optical rotation are in good agreement with those given for this compound. The ^{1}H-NMR data (Table 7) clearly establishes the identity with **41**.

The roots of *V. oligocephala* (DC.) Walp. contain besides **42** [1] the isomer **43**, as shown by the ^{1}H-NMR data (see Table 7). The 8α-position of the senecioyloxy group and the position of the double bonds clearly follow from the observed coupling constants and the shifts after addition of Eu(fod)$_3$. As the data are furthermore in good agreement with those of vanillosmin [3], where the 1α-H configuration is established, the stereochemistry at C-1 is also most likely. The aerial parts afford besides **21** a lactone (**31**) with a further oxygen function, which must be located at C-15 as shown by the expected splittings of the corresponding NMR signals (see Table 4).

The investigation of the South African *Vernonia* species again shows that highly oxidized germacranolides are probably typical for this large genus. However there are several species where these lactones are missing or other lactones predominate. All isolated guaianolides have 1α, 5α, 6β, 7α-H configuration with a 6,7-lactone ring. It is remarkable that the only species investigated from Guatemala affords a lactone very similar to those from South Africa. Acetylenes are relatively rare. The occurrence of the eremophilone **14** is surprising, as these compounds are normally only present in the tribe Senecioneae. The overall pictures still is not very clear, but, as not even ten percent of the known species have been investigated up to now, more work on both the chemical and botanical aspects is necessary.

Table 8. ^{1}H-NMR data of **45** and **46**

	45	**46**
3-H	*s(br)* 6.98	*d* 7.23
5-H	*s(br)* 6.79	*dd* 7.28
6-H		*d* 7.15
7-H	*dd* 6.59	*dd* 6.66
8*t*-H	*dd* 5.54	*d(br)* 5.70
8*c*-H	*dd* 5.03	*d(br)* 5.28
OAc	—	*s* 2.30
		s 2.29

J (Hz): 3,5 = 1.6; 5,6 = 8.5; 7,8*t* = 17; 7,8*c* = 11; 8,8 = 1.

EXPERIMENTAL

IR: CCl_4 or $CHCl_3$. NMR: Bruker WH 270 (in all cases the interpretation was supported by extensive double resonance experiments); MS: Varian MAT 711, 70 eV; optical rotation, $CHCl_3$. The air dried plant material collected in February 1977 in Natal (except *V. novebaracencis*, which was collected in Guatemala by Dr. R. King) was extracted with Et_2O–petrol at room temp. and the resulting extracts have been separated first by chromatography (Si gel, act. grade II) and further by repeated TLC (Si gel, GF 254) using Et_2O–petrol mixtures. Known compounds were identified by comparison of their NMR- and IR-spectra with those of authentic samples.

Vernonia dregeana *Sch. Bip.* (voucher 77/83). 15 g roots afforded 20 mg **2** and 20 mg **4** and 75 g aerial parts 30 mg **2**, 15 mg lupenone, 15 mg **4** and 50 mg **1**

Vernonia capensis (*Houtt.*) *Bruce* (*voucher 77/177*) 30 g aerial parts afforded 12 mg **1**.

Vernonia neocorymbosa *Hilliard et Burtt.* (*voucher 77/104*). 850 g roots yielded 95 mg of a complex triterpene mixture and 175 g aerial parts 60 mg of triterpenes.

Vernonia anisochaetoides *Sonder* (*voucher 77/92*). 35 g roots afforded 85 mg aplotaxene, 8 mg **6** and 300 g aerial parts 6 mg aplotaxene, 110 mg **4**, 50 mg **3** and 35 mg **9** (Et_2O-petrol, 3:1).

Vernonia natalensis *Sch. Bip.* (*voucher 77/55*). 90 g roots yielded 6 mg **13**.

Vernonia hirsuta (*DC*). *Sch. Bip. var.* flanagani *Phill.* (*voucher 77/36*). 520 g roots afforded 3 mg **7**, 3.1 g **12**, 0.6 g **15**, 120 mg **10**, 12 mg **16** (Et_2O-petrol, 1:1), 12 mg **17** (Et_2O-petrol, 1:1) (separated completely only by a Sephadex column, MeOH as solvent) and 25 mg **18** (Et_2O-petrol, 1:1). 120 g aerial parts yielded 1 mg **19**, 100 mg **2**, 30 mg **1**, 50 mg **12** and 25 mg **15**.

Vernonia hirsuta (*DC.*) *Sch. Bip. var.* hirsuta (*voucher 77/40*). 84 g roots afforded 25 mg **20**, 150 mg **12**, 9 mg **15**, 37 mg **10**, 1 mg **16** and 1 mg **17**. 135 g of aerial parts yielded 15 mg **19**, 45 mg **1**, 35 mg **21** (Et_2O), 6 mg **22** (Et_2O) and 23 mg **23** (Et_2O–MeOH, 10:1).

Vernonia angulifolia *DC.* (*voucher 77/250*). 180 g roots afforded 60 mg **4**, 5 mg **3** and 0.2 mg of a diynetrienol, while 300 g aerial parts yielded 20 mg **19**, 20 mg **4**, 18 mg **3**, 12 mg **21**, 18 mg **22**, 12 mg **29** (Et_2O) and 11 mg **30** (Et_2O).

Vernonia novebaracensis (*L.*) *Michx.* (*voucher RMK 7151*). 30 g roots afforded 10 mg **11**, 5 mg **8**, 5 mg **4** and 20 mg **41** (Et_2O–petrol, 1:1). 500 g aerial parts yielded 3 mg **19**, 75 mg **5**, 15 mg **44**, 15 mg **45** and 50 mg **36** (Et_2O-petrol, 3:1).

Vernonia oligocephala (*DC.*) *Walp.* (*voucher 77/179*). 19 g roots afforded 5 mg **43** (Et_2O–petrol, 1:) and 10 mg **42**, while 11 g aerial parts yielded 4 mg **21** and 3 mg **31** (Et_2O–MeOH, 20:1).

3β-H-Zaluzanin C (**9**). Colourless oil, IR ($CHCl_3$): OH 3600; γ-lactone 1760 cm^{-1}. MS: M^+ *m/e* 246.126 (36%) (calc. for $C_{15}H_{18}O_3$ 246.126): $-^{\cdot}CH_3$ 231 (9): $-H_2O$ 228 (17); $-CO$ 218 (20); C_3H_7 43 (100).

$$[\alpha]^{\lambda}_{24^\circ} = \frac{589 \quad 578 \quad 546 \quad 436\,\text{nm}}{-55.6 \quad -58.5 \quad -68.1 \quad -120^\circ} (c = 0.24)$$

10 mg **9** were stirred in 3 ml CH_2Cl_2 for 12 hr with 50 mg CrO_3–Py complex. The usual workup yielded 2 mg **11**, identical with authentic material, and the aldehyde **9a** (2 mg). ^{1}H-NMR: 3-H *dd* 6.98 (*J* = 3, 2.5); 6β-H *dd* 3.91 (J = 10, 9.5); 13-H *d* 6.16 and 5.42 (J = 3.5); 14-H *s(br)* 5.03 and 4.91; 15-H *s* 9.79.

15-Senecioyloxy costunolide (**16**). Colourless crystals, mp 146° (Et_2O-petrol), IR ($CHCl_3$): γ-lactone 1760; $C{=}CCO_2R$ 1715, 1650 cm^{-1}. MS: M^+ *m/e* 330.183 (9%) (calc. for $C_{20}H_{26}O_4$ 330.183); $-C_4H_7CO_2H$ 230 (73): 230 $-^{\cdot}CH_3$ 215 (15); 230 $-CO$ 202 (16); $C_4H_7CO^+$ 83 (100).

15-Isovaleryloxy costunolide (**17**). Colourless crystals, mp 122° (Et_2O–petrol), IR: γ-lactone 1765; CO_2R 1730 cm^{-1}. MS: M^+ *m/e* 332.198 (8%) (calc. for $C_{20}H_{28}O_4$ 332.199); $-C_4H_9CO_2H$ 230 (70); $C_4H_9CO^+$ 85 (100).

$$[\alpha]^{\lambda}_{24^\circ} = \frac{589 \quad 578 \quad 546 \quad 436\,\text{nm}}{+67.4 \quad +71.2 \quad +82.3 \quad +138.0^\circ} (c = 0.27)$$

1,9-Dioxo-8-hydroxy-bisabolene (**18**). Colourless oil, IR: OH (hydrogen bonded) 3460; C=C—C=O 1670; 1635 cm^{-1}. MS: M^+ *m/e* 250.157 (8%) (calc. for $C_{15}H_{22}O_3$ 250.157); $-H_2O$ 232 (1); $-Me_2C{=}CHCO^{\cdot}$ 167 (53): 167 $-H_2O$ 149 (18); $-Me_2C{=}CHCOCH(OH)CH(CH_3)^{\cdot}$ 109 (97); $Me_2C{=}CHCO^+$ 83 (100).

$$[\alpha]^{\lambda}_{24^\circ} = \frac{589 \quad 578 \quad 546 \quad 436\,\text{nm}}{+21.3 \quad +22.3 \quad +27.1 \quad +65.6^\circ} (c = 0.1)$$

8β-(2-Methylacryloyloxy)-hirsutinolide-13(O)-acetate (**21**). Colourless oil, IR (CCl_4): OH 3610; γ-enol lactone 1780; $C{=}CCO_2R$ 1720, 1640; OAc 1750, 1230 cm^{-1}. UV (Et_2O) λ_{max} = 282 nm. MS: M^+ *m/e* 406.163 (8%) (calc. for $C_{21}H_{26}O_8$ 406.163); $-AcOH$ 346 (1); 346 $-CO$ 318 (2); 346 $-C_3H_5CO_2H$ 260 (25); $C_3H_5CO^+$ 69 (100).

$$[\alpha]^{\lambda}_{24^\circ} = \frac{589 \quad 578 \quad 546 \quad 436\,\text{nm}}{+19.5 \quad +24.5 \quad +41.2 \quad +167.5^\circ} (c = 1.0)$$

To 20 mg **21** in 2 ml MeOH 10 mg *p*-toluenesulfonic acid was added. After 15 min the soln was neutralized and the reaction mixture separated by TLC (Et_2O). 15 mg **24** and 3 mg **25** were obtained. **24**: colourless oil IR (CCl_4)OH 3610; lactone 1770; $C{=}CCO_2R$ 1715, 1650 cm^{-1}. MS: M^+ *m/e* 378 ($C_{20}H_{26}O_7$) (2%); $C_3H_5CO^+$ 69 (100). **25**: colourless oil, IR ($CHCl_3$): lactone 1765; OAc 1750; $C{=}CCO_2R$ 1710, 1650 cm^{-1}. MS: M^+ *m/e* 420 ($C_{22}H_{28}O_8$) (22%); $-AcOH$ 360 (1); 360 $-C_3H_5CO_2H$ 274 (11); $C_3H_5CO^+$ 69 (100). 10 mg of **24** in 5 ml MeOH was reacted with 100 mg K_2CO_3 in 0.5 ml H_2O for 30 min. After TLC (Et_2O–CH_2Cl_2, 1:1) 2 mg **28** was obtained.

8β-(2-Methyl-2,3-epoxypropionyloxy)-hirsutinolide-13(O)acetate (**22**). Colourless oil, IR ($CHCl_3$): OH 3620; lactone 1770; CO_2R 1740 cm^{-1}. MS: M^+ *m/e* 422.158 (7%) (calc. for $C_{21}H_{26}O_9$ 422.157); $-RCO_2H$ 320 (17); 320 $-AcOH$ 260 (21); $MeCO^+$ 43 (100).

$$[\alpha]^{\lambda}_{24^\circ} = \frac{589 \quad 578 \quad 546 \quad 436\,\text{nm}}{+18.3 \quad +21.1 \quad +30.8 \quad +33.9^\circ} (c = 2.05)$$

10 mg of **22** on reaction with MeOH (see above) afforded 8 mg **26**, colourless oil, IR (CCl_4): lactone 1775; OAc 1750, 1230; CO_2R 1730 cm^{-1}. MS: M^+ *m/e* 436 ($C_{22}H_{28}O_9$) (15%); $-RCO_2^{\cdot}$ 335 (5); $-RCO_2H$, AcOH 274 (32); $MeCO^+$ 43 (100).

8β-(2-Hydroxymethylacryloyloxy)-hirsutinolide-13(O)-acetate (**23**). Colourless crystals, mp 72° (Et_2O–petrol), IR ($CHCl_3$): OH 3420; lactone 1765; OAc 1740; $C{=}CCO_2R$ 1720, 1650 cm^{-1}. UV (Et_2O) λ_{max} 284 nm. MS: M^+ *m/e* 422.157 (4%) (calc. for $C_{21}H_{26}O_9$ 422.158); $-AcOH$ 362 (2); $-RCO_2H$ 260 (11); 260 $-H_2O$ 242 (10); $MeCO^+$ 43 (100).

$$[\alpha]^{\lambda}_{24^\circ} = \frac{589 \quad 578 \quad 546 \quad 436\,\text{nm}}{+111.2 \quad +116.5 \quad +138.5 \quad +302.5^\circ} (c = 1.3)$$

10 mg **23** was reacted with MeOH as above. After TLC (Et_2O) 8 mg **27** was obtained. Colourless oil, IR (CCl_4): OH 3520; lactone 1770; OAc 1750; CO_2R 1730 cm^{-1}. MS: M^+ *m/e* 436.173 (42%) (calc. for $C_{22}H_{28}O_9$ 436.173); $-RCO_2H$, AcOH 274 (34); $HOCH_2C({=}CH_2)CO^+$ 85 (100); $MeCO^+$ 43 (95).

8β-(2-Methylacryloyloxy)hirsutinolide (**29**). Colourless crystals, mp 184° (Et_2O–petrol) IR ($CHCl_3$): OH 3600; lactone 1760; CO_2R 1735 cm^{-1}. MS: M^+ *m/e* 364.152 (calc. for $C_{19}H_{24}O_7$ 364.152).

$$[\alpha]^{\lambda}_{24^\circ} = \frac{589 \quad 578 \quad 546 \quad 436\,\text{nm}}{-6.9 \quad +5.7 \quad +7.4 \quad +7.5^\circ} (c = 1.1)$$

8β(2-Methyl-2,3-epoxypropionyloxy)hirsutinolide (**30**). Colourless crystals, mp 170° (Et_2O–petrol) IR ($CHCl_3$): OH 3600; lactone 1760; CO_2R 1735 cm^{-1}. MS: M^+ *m/e* 380.145 (13%) (calc. for $C_{19}H_{24}O_8$ 380.147); $-RCO_2H$ 278 (15); $C_3H_7^+$ 43 (100).

$$[\alpha]^{\lambda}_{24^\circ} = \frac{589 \quad 578 \quad 546 \quad 436\,\text{nm}}{+0.7 \quad +2.9 \quad +5.8 \quad +34.2^\circ} (c = 1.1)$$

*8β-(2-*Methylacryloyloxy)-*15*-hydroxyhirsutinolide (**31**). Colourless oil, IR: OH 3620; lactone 1765; $C{=}CCO_2R$ 1720, 1640 cm^{-1}. MS: M^+ *m/e* 422.158 (4%) (*calc.* for $C_{21}H_{26}O_9$ 422.158); $-AcOH$ 362 (3); 362 $-C_3H_5CO_2$ 276 (6); 276 $-^{\cdot}CH_3$ 261 (7); 276 $-H_2O$ 258 (6); $C_3H_5CO^+$ 69 (100).

8β-(2-Methylacryloyloxy)isohirsutinolide (**36**). Colourless, impure isolated oil, IR (CCl_4): OH (H bonded) 3580; lactone 1775; OAc 1745, 1240; $C{=}CCO_2R$ 1720, 1645 cm^{-1}. 40 mg was acetylated with Ac_2O–Py–4-pyrrolidinopyridine [15] (12 hr, room temp.). TLC (Et_2O–petrol, 3:1) afford 20 mg **37**, colourless oil, IR (CCl_4): lactone 1775; OAc 1750, 1240; $C{=}CCO_2R$ 1725, 1630; C=C—OR 1670 cm^{-1}. MS: M^+ *m/e* 446.158 (1%) (calc. for $C_{23}H_{26}O_9$ 446.158); $-AcOH$ 386 (2); 386 $-H_2C{=}C{=}O$ 344 (12); 344 $-CO$ 318 (37); $C_3H_5CO^+$ 69 (100). To 10 mg **37** in 2 ml MeOH 10 mg *p*-toluenesulfonic acid was added. After 15 min the soln was neutralized. The reaction mixture after TLC (Et_2O–petrol, 3:1) afford 3.5 mg **39** and 5 mg **40**, **39**: colourless oil, IR (CCl_4): OH (H bonded) 3580; lactone 1770; OAc, $C{=}CCO_2R$ 1735, 1650 cm^{-1}. MS: M^+ *m/e* 436

($C_{22}H_{28}O_9$) (8%); —·OMe 405 (5); —AcOH, RCO_2H 290 (10); $C_3H_5CO^+$ 69 (95); $MeCO^+$ 43 (100). **40**: colourless oil, IR (CCl_4): OH (H bonded) 3560; lactone 1770; OAc, $C{=}CCO_2R$ 1735, 1650 cm^{-1}. MS: M^+ *m/e* 422 ($C_{21}H_{26}O_9$) (12%); —AcOH 362 (2); 362 —$C_3H_5CO_2H$ 276 (11); C_3H_5CO 69 (82); $MeCO^+$ 43 (100).

8α-Hydroxy-11β,13-dihydrodehydrozaluzanin (**41**). Colourless crystals, mp 168° (Et_2O–petrol), IR: OH 3620; lactone 1770; C=C—C=O 1725, 1640 (5-ring) cm^{-1} MS: M^+ *m/e* 262.120 (4%) (calc. for $C_{15}H_{18}O_4$ 262.121); —H_2O 244 (10) —CO 234 (7); $C_3H_7^+$ 43 (100).

$$[\alpha]^{\lambda}_{24^\circ} = \frac{589 \quad 578 \quad 546 \quad 436\,\text{nm}}{+169{\cdot}5 \quad +176.5 \quad +206 \quad +441^\circ}(c = 0.57)$$

8α-Senecioyloxyvanillosmin (**43**). Colourless oil, IR: lactone 1780; $C{=}CCO_2R$ 1725, 1650 cm^{-1}. MS: M^+ *m/e* 328.167 (4%) (calc. for $C_{20}H_{24}O_4$ 328.167); —$C_4H_7CO_2H$ 228 (12); $C_4H_7CO^+$ 83 (100).

4-Vinylcatechol (**45**). Colourless oil, IR· OH 3620, 3550; aromate 1600, 1520 cm^{-1}. MS: M^+ *m/e* 136.051 (100%) (calc. for $C_8H_8O_2$ 136.052). 10 mg **45** was heated for 30 min with Ac_2O to 70°. After TLC (Et_2O–petrol, 1:10) 12 mg **46** was obtained.

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