Sesquiterpenoids. Part XVII.[1] *X*-Ray Crystallographic Determination of the Stereochemistry and Conformation of Dihydromikanolide, a Germacranolide Diepoxide †

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The stereochemistry of dihydromikanolide (1,10:2,3-diepoxy-6,8-dihydroxygermacr-4-ene-12,15-dioic acid di-γ-lactone) has been defined by *X*-ray analysis of the crystal structure. The conformation of the ten-membered ring is similar to that in pregeijerene and related to one of the less favourable conformations of cyclodecane. The *trans* double bond of the ring has a torsion angle of 163°. The unsaturated α,γ-fused γ-lactone at C(4)—(6) is almost planar, whereas the β,γ-*trans*-fused γ-lactone at C(7)–(8) adopts a normal envelope conformation. The crystals are monoclinic, $a = 10{\cdot}451(6)$, $b = 7{\cdot}122(4)$, $c = 9{\cdot}233(5)$ Å, $\beta = 99{\cdot}77(3)°$, $Z = 2$, space group $P2_1$. The structure was solved by direct methods from intensity data collected on a diffractometer, and least-squares adjustment of the atomic parameters converged to R 6·2% over 1486 reflections.

MIKANOLIDE (1), the principal sesquiterpenoid dilactone isolated from *Mikania* species, and miscandenin (2), a minor component, can be regarded as being related *via* a hypothetical intermediate (3) which can undergo a divinyloxiran–dihydroxepin rearrangement.[2] We undertook *X*-ray crystallographic studies of dihydromikanolide and miscandenin in order to define the stereochemistry of the biological rearrangement and the implications of the results have been reported briefly.[3]

Dihydromikanolide is a sesquiterpenoid dilactone of the germacrane type and was extracted as one of five such dilactones from *Mikania scandens* (L.) Willd. (climbing hempvine).[2] The crystal structure was elucidated by non-centrosymmetric direct-method procedures and least-squares adjustment of the atomic parameters converged to R 6·2% over 1486 independent reflections. The stereochemistry deduced for the molecule is shown in (4), from which it follows that in (1) and (3) the 2,3-epoxide is *cis* and β. The arrangement of atoms in the molecule is shown in Figure 1 and the crystal structure illustrated in Figure 2. Atomic co-ordinates are listed in Table 1, thermal parameters in Table 2, and bond lengths, valency angles, torsion angles, and intermolecular separations in Tables 3—6.

The conformation of the ten-membered ring is closely

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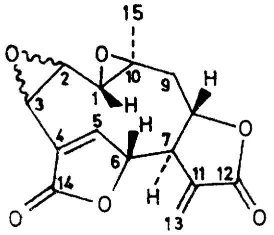
† No reprints available.

[1] Part XVI, A. T. McPhail and G. A. Sim, *Tetrahedron*, 1973, **29**, 1751.

[2] W. Herz, P. S. Subramanian, P. S. Santhanam, K. Aota, and A. L. Hall, *J. Org. Chem.*, 1970, **35**, 1453.

[3] P. J. Cox, G. A. Sim, J. S. Roberts, and W. Herz, *J.C.S. Chem. Comm.*, 1973, 428.

related to that in pregeijerene–silver nitrate,[4] the major difference being in the region of the bond C(2)–C(3) which in dihydromikanolide is part of an epoxide system. The conformation is also related to those of the germacranolides glaucolide-A (5),[5] and shiromodiol acetate *p*-bromobenzoate (6),[6] and to one of the less-favourable



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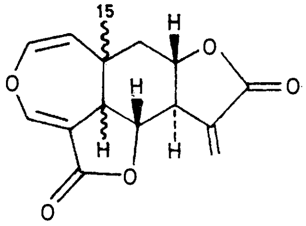

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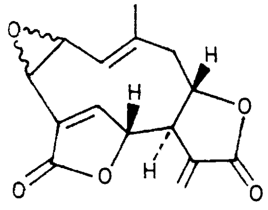

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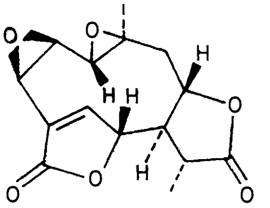

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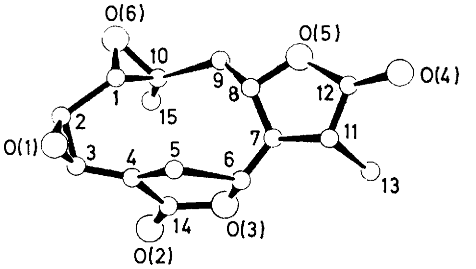

FIGURE 1 The atomic arrangement in the molecule

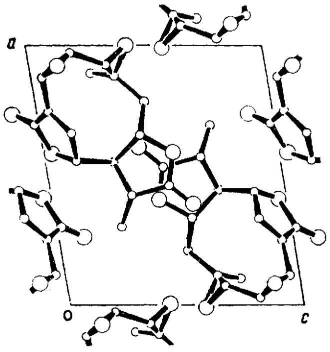

FIGURE 2 The crystal structure viewed in projection along the *b* axis

TABLE 1

Fractional atomic co-ordinates, with standard deviations

Atom	*x*	*y*	*z*
O(1)	0·9146(4)	0·7570	0·1139(4)
O(2)	0·7381(4)	0·2414(8)	−0·1061(4)
O(3)	0·5881(3)	0·2932(7)	0·0359(3)
O(4)	0·3918(3)	0·3820(7)	0·5958(3)
O(5)	0·5921(3)	0·3992(7)	0·5465(3)
O(6)	1·0095(3)	0·4180(9)	0·4259(3)
C(1)	0·9263(4)	0·5379(8)	0·3255(4)
C(2)	0·9723(4)	0·5876(9)	0·1844(5)
C(3)	0·8795(4)	0·5805(9)	0·0440(5)
C(4)	0·7475(4)	0·5164(8)	0·0504(4)
C(5)	0·6635(4)	0·5807(7)	0·1308(4)
C(6)	0·5592(4)	0·4402(8)	0·1348(4)
C(7)	0·5538(3)	0·3567(7)	0·2886(4)
C(8)	0·6578(4)	0·4215(7)	0·4182(4)
C(9)	0·7871(4)	0·3192(8)	0·4607(4)
C(10)	0·8842(3)	0·3474(8)	0·3565(4)
C(11)	0·4273(4)	0·4137(8)	0·3413(4)
C(12)	0·4631(4)	0·3944(7)	0·5063(4)
C(13)	0·3048(4)	0·3098(9)	0·2746(5)
C(14)	0·6975(4)	0·3363(9)	−0·0175(4)
C(15)	0·8957(5)	0·1856(8)	0·2557(5)
H(1)	0·891(5)	0·631(10)	0·367(6)
H(2)	1·064(5)	0·588(9)	0·182(6)
H(3)	0·913(7)	0·552(12)	−0·048(7)
H(5)	0·681(5)	0·711(8)	0·180(6)
H(6)	0·469(4)	0·479(7)	0·102(4)
H(7)	0·554(4)	0·227(6)	0·285(4)
H(8)	0·675(4)	0·561(7)	0·417(5)
H(9A)	0·772(5)	0·185(8)	0·474(6)
H(9B)	0·839(5)	0·354(9)	0·572(6)
H(11)	0·408(4)	0·560(6)	0·319(4)
H(13A)	0·239(4)	0·315(8)	0·323(5)
H(13B)	0·329(5)	0·180(9)	0·276(6)
H(13C)	0·271(7)	0·363(15)	0·152(9)
H(15A)	0·809(5)	0·153(9)	0·197(5)
H(15B)	0·947(5)	0·212(8)	0·191(5)
H(15C)	0·939(6)	0·088(12)	0·317(8)

TABLE 2

(*a*) Anistropic thermal parameters * for the oxygen and carbon atoms ($\times 10^4$)

Atom	b_{11}	b_{22}	b_{33}	b_{12}	b_{13}	b_{23}
O(1)	162(4)	190(8)	179(5)	−89(10)	101(8)	44(10)
O(2)	156(4)	323(10)	117(4)	5(11)	83(7)	−127(11)
O(3)	105(3)	245(8)	84(3)	−61(8)	25(5)	−75(8)
O(4)	129(3)	180(6)	124(3)	−13(8)	113(6)	−3(8)
O(5)	100(3)	207(6)	87(3)	−14(8)	50(4)	7(8)
O(6)	79(3)	326(10)	136(4)	−43(9)	−24(5)	6(11)
C(1)	81(4)	195(9)	118(5)	−60(9)	8(7)	−43(11)
C(2)	85(4)	206(9)	147(6)	−43(11)	65(7)	−5(13)
C(3)	109(4)	201(10)	126(5)	−26(11)	97(8)	34(12)
C(4)	90(4)	175(8)	86(4)	0(9)	40(6)	29(10)
C(5)	94(3)	141(7)	95(4)	34(9)	46(6)	42(9)
C(6)	73(3)	183(9)	84(4)	30(8)	9(5)	20(9)
C(7)	72(3)	122(6)	82(3)	20(7)	29(5)	12(7)
C(8)	80(3)	138(6)	79(3)	−10(8)	31(5)	17(9)
C(9)	81(3)	171(8)	105(4)	2(9)	2(6)	53(10)
C(10)	69(3)	169(8)	99(4)	23(8)	−14(6)	−11(9)
C(11)	82(3)	171(8)	98(4)	2(9)	57(6)	−10(10)
C(12)	106(4)	109(6)	100(4)	1(8)	66(7)	−19(9)
C(13)	77(3)	241(10)	130(5)	−20(10)	33(7)	7(14)
C(14)	94(4)	231(10)	82(4)	19(10)	18(6)	−30(11)
C(15)	147(6)	160(9)	135(6)	98(12)	35(10)	−20(12)

(*b*) Isotropic thermal parameters † (*B*) for the hydrogen atoms

H(1)	4·4	H(9B)	4·1
H(2)	2·2	H(11)	1·0
H(3)	5·6	H(13A)	2·6
H(5)	3·3	H(13B)	4·1
H(6)	1·3	H(13C)	4·9
H(7)	1·3	H(15A)	1·9
H(8)	1·3	H(15B)	2·2
H(9A)	2·0	H(15C)	7·4

* In the form: $T = \exp[-(b_{11}h^2 + b_{22}k^2 + b_{33}l^2 + b_{12}hk + b_{13}hl + b_{23}kl)]$. † Mean standard deviation of isotropic temperature factors 0·9 Å.

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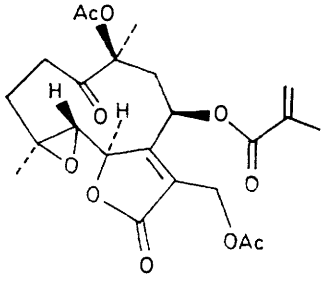
[4] P. Coggon, A. T. McPhail, and G. A. Sim, *J. Chem. Soc.* (*B*), 1970, 1024.

[5] W. G. Padolina, H. Yoshioka, N. Nakatani, T. J. Mabry, S. A. Monti, R. E. Davis, P. J. Cox, G. A. Sim, W. H. Watson, and I. B. Wu, *Tetrahedron*, 1974, **30**, 1161.

[6] R. J. McClure, G. A. Sim, P. Coggon, and A. T. McPhail, *Chem. Comm.*, 1970, 128.

conformations derived by strain-energy minimization calculations for cyclodecane.[7] The torsion angles describing the relationship among these ten-membered rings are listed in Table 7 and the results show that the conformations most closely related to the cyclodecane conformation are those of glaucolide-A and shiromodiol. Although these various sesquiterpenoid rings are related conformationally it is noteworthy that glaucolide-A differs from the others by having corresponding torsion angles associated with different bonds; accordingly C(7) plays the same conformational role in dihydromikanolide, shiromodiol, and pregeijerene (7) as does C(1) in glaucolide-A.



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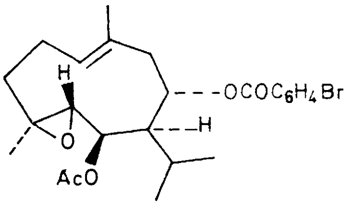

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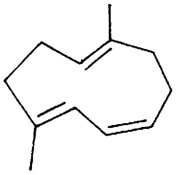

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Table 3

Intramolecular bonded distances (Å), with standard deviations

O(1)–C(2)	1·453(6)	C(9)–C(10)	1·525(6)
O(1)–C(3)	1·432(6)	C(10)–C(15)	1·499(7)
O(2)–C(14)	1·193(7)	C(11)–C(12)	1·512(5)
O(3)–C(6)	1·454(6)	C(11)–C(13)	1·516(7)
O(3)–C(14)	1·355(6)	C(1)–H(1)	0·88(9)
O(4)–C(12)	1·206(6)	C(2)–H(2)	0·96(5)
O(5)–C(8)	1·475(5)	C(3)–H(3)	0·99(7)
O(5)–C(12)	1·337(6)	C(5)–H(5)	1·00(6)
O(6)–C(1)	1·439(7)	C(6)–H(6)	0·97(5)
O(6)–C(10)	1·447(6)	C(7)–H(7)	0·92(3)
C(1)–C(2)	1·506(6)	C(8)–H(8)	0·99(4)
C(1)–C(10)	1·469(8)	C(9)–H(9A)	0·98(5)
C(2)–C(3)	1·483(7)	C(9)–H(9B)	1·11(6)
C(3)–C(4)	1·464(7)	C(11)–H(11)	1·07(4)
C(4)–C(5)	1·324(6)	C(13)–H(13A)	0·90(5)
C(4)–C(14)	1·483(8)	C(13)–H(13B)	0·97(7)
C(5)–C(6)	1·484(7)	C(13)–H(13C)	1·15(7)
C(6)–C(7)	1·550(5)	C(15)–H(15A)	1·00(5)
C(7)–C(8)	1·544(5)	C(15)–H(15B)	0·91(5)
C(7)–C(11)	1·539(6)	C(15)–H(15C)	0·98(8)
C(8)–C(9)	1·527(6)		

The C(14) and C(15) carbon atoms carried by C(4) and C(10) in these sesquiterpenoids are *cis* and on the α-face of the macrocycle, whereas in a number of other germacrane sesquiterpenes, *e.g.* germacratriene,[8] elephantol,[9] and costunolide,[10] the C(14) and C(15) carbon atoms are *cis* and β. The *anti*-arrangement of C(14) and C(15) is also known.[11]

Table 4

Valency angles (deg.), with standard deviations

C(3)–O(1)–C(2)	61·9(3)	C(9)–C(10)–O(6)	114·5(3)
C(1)–C(2)–O(1)	114·4(3)	C(15)–C(10)–O(6)	112·4(3)
C(3)–C(2)–O(1)	58·4(3)	C(10)–C(1)–C(2)	122·4(4)
C(2)–C(3)–O(1)	59·7(3)	C(3)–C(2)–C(1)	119·4(3)
C(4)–C(3)–O(1)	115·3(4)	C(9)–C(10)–C(1)	119·8(3)
O(3)–C(14)–O(2)	122·8(4)	C(15)–C(10)–C(1)	122·1(3)
C(4)–C(14)–O(2)	129·7(4)	C(4)–C(3)–C(2)	117·1(3)
C(14)–O(3)–C(6)	110·1(3)	C(5)–C(4)–C(3)	129·4(3)
C(5)–C(6)–O(3)	103·8(3)	C(14)–C(4)–C(3)	121·3(4)
C(7)–C(6)–O(3)	110·0(3)	C(14)–C(4)–C(5)	108·5(4)
C(4)–C(14)–O(3)	107·5(4)	C(6)–C(5)–C(4)	109·9(4)
O(5)–C(12)–O(4)	121·5(3)	C(7)–C(6)–C(5)	115·0(3)
C(11)–C(12)–O(4)	128·4(3)	C(8)–C(7)–C(6)	117·7(3)
C(12)–O(5)–C(8)	111·4(2)	C(11)–C(7)–C(6)	110·8(3)
C(7)–C(8)–O(5)	103·2(2)	C(11)–C(7)–C(8)	101·9(3)
C(9)–C(8)–O(5)	104·8(3)	C(9)–C(8)–C(7)	122·2(3)
C(11)–C(12)–O(5)	110·0(3)	C(12)–C(11)–C(7)	102·4(3)
C(10)–O(6)–C(1)	61·2(3)	C(13)–C(11)–C(7)	117·0(3)
C(2)–C(1)–O(6)	116·7(3)	C(10)–C(9)–C(8)	115·4(3)
C(10)–C(1)–O(6)	59·7(3)	C(15)–C(10)–C(9)	115·0(4)
C(1)–C(10)–O(6)	59·1(4)	C(13)–C(11)–C(12)	114·4(3)

Table 5

Torsion angles (deg.) *

C(3)–O(1)–C(2)–C(1)	−111	C(3)–C(4)–C(5)–C(6)	−163
C(2)–O(1)–C(3)–C(4)	108	C(14)–C(4)–C(5)–C(6)	6
C(14)–O(3)–C(6)–C(5)	2	C(3)–C(4)–C(14)–O(2)	−17
C(14)–O(3)–C(6)–C(7)	−122	C(3)–C(4)–C(14)–O(3)	165
C(6)–O(3)–C(14)–O(2)	−177	C(5)–C(4)–C(14)–O(2)	173
C(6)–O(3)–C(14)–C(4)	2	C(5)–C(4)–C(14)–O(3)	−5
C(12)–O(5)–C(8)–C(7)	−20	C(4)–C(5)–C(6)–O(3)	−5
C(12)–O(5)–C(8)–C(9)	−149	C(4)–C(5)–C(6)–C(7)	116
C(8)–O(5)–C(12)–O(4)	−178	O(3)–C(6)–C(7)–C(8)	115
C(8)–O(5)–C(12)–C(11)	0	O(3)–C(6)–C(7)–C(11)	−129
C(10)–O(6)–C(1)–C(2)	−114	C(5)–C(6)–C(7)–C(8)	−2
C(1)–O(6)–C(10)–C(9)	−111	C(5)–C(6)–C(7)–C(11)	115
C(1)–O(6)–C(10)–C(15)	115	C(6)–C(7)–C(8)–O(5)	153
O(6)–C(1)–C(2)–O(1)	−158	C(6)–C(7)–C(8)–C(9)	−90
O(6)–C(1)–C(2)–C(3)	136	C(11)–C(7)–C(8)–O(5)	31
C(10)–C(1)–C(2)–O(1)	132	C(11)–C(7)–C(8)–C(9)	148
C(10)–C(1)–C(2)–C(3)	66	C(6)–C(7)–C(11)–C(12)	−157
O(6)–C(1)–C(10)–C(9)	102	C(6)–C(7)–C(11)–C(13)	77
O(6)–C(1)–C(10)–C(15)	−99	C(8)–C(7)–C(11)–C(12)	−31
C(2)–C(1)–C(10)–O(6)	104	C(8)–C(7)–C(11)–C(13)	−157
C(2)–C(1)–C(10)–C(9)	−153	O(5)–C(8)–C(9)–C(10)	−171
C(2)–C(1)–C(10)–C(15)	6	C(7)–C(8)–C(9)–C(10)	73
O(1)–C(2)–C(3)–C(4)	−105	C(8)–C(9)–C(10)–O(6)	124
C(1)–C(2)–C(3)–O(1)	102	C(8)–C(9)–C(10)–C(1)	57
C(1)–C(2)–C(3)–C(4)	−3	C(8)–C(9)–C(10)–C(15)	−103
O(1)–C(3)–C(4)–C(5)	−12	C(7)–C(11)–C(12)–O(4)	−162
O(1)–C(3)–C(4)–C(14)	180	C(7)–C(11)–C(12)–O(5)	20
C(2)–C(3)–C(4)–C(5)	55	C(13)–C(11)–C(12)–O(4)	−34
C(2)–C(3)–C(4)–C(14)	−113	C(13)–C(11)–C(12)–O(5)	148

* Sign convention is such that the sign is negative if an anticlockwise rotation is required of atom (1) to eclipse atom (4) whilst looking down the (2)–(3) bond. Mean standard deviation of torsion angle 0·7°.

The C(4)∶C(5) double bond in dihydromikanolide is clearly subject to some strain, for the C(3)–C(4)–C(5)–C(6)

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[11] S. F. Watkins, N. H. Fischer, and I. Bernal, *Proc. Nat. Acad. Sci. U.S.A.*, 1973, **70**, 2434.

torsion angle of 163° is notably different from the ideal value of 180°. The *trans*-double bonds in other germacrane sesquiterpenes show similar distortions, *cf.* torsion angles of 163° in elephantol,[9] 165° in pregeijerene,[4] and 167° in shiromodiol.[6] The distortion in dihydromikanolide is characterized by an appreciable departure from coplanarity of bonds at C(4), the angle between the planes C(3)—(5) and C(14), C(4), C(5) being 11°; on the other hand, since the angle between the planes C(4)—(6) and C(4), C(5), H(5) is only 1°, out-of-plane bending at C(5) is unimportant. Valency-angle distortion, attributable to lactone fusion, is present in this region with C(3)–C(4)–C(5) 129·4(3)° and C(4)–C(5)–C(6) 109·9(4)°.

TABLE 6

Intermolecular contacts <3·85 Å

$O(2) \cdots O(5^{I})$	3·495	$O(5) \cdots O(4^{V})$	3·695
$O(1) \cdots C(15^{II})$	3·340	$O(5) \cdots C(11^{V})$	3·823
$O(6) \cdots C(13^{III})$	3·680	$O(5) \cdots C(12^{V})$	3·594
$C(3) \cdots C(13^{IV})$	3·620	$O(5) \cdots C(13^{V})$	3·440
$C(4) \cdots C(13^{IV})$	3·621	$C(5) \cdots O(4^{V})$	3·435
$C(5) \cdots O(3^{IV})$	3·194	$C(8) \cdots O(4^{V})$	3·319
$C(6) \cdots O(2^{IV})$	3·748	$C(8) \cdots C(12^{V})$	3·705
$C(6) \cdots O(3^{IV})$	3·217	$C(11) \cdots O(4^{V})$	3·829
$C(6) \cdots C(14^{IV})$	3·917	$C(11) \cdots O(5^{V})$	3·625
$C(11) \cdots O(2^{IV})$	3·446	$C(11) \cdots C(12^{V})$	3·803
$C(13) \cdots O(2^{IV})$	3·440	$C(12) \cdots O(5^{V})$	3·661
$O(4) \cdots C(7^{V})$	3·562	$C(12) \cdots C(7^{V})$	3·817
$O(4) \cdots C(9^{V})$	3·624	$C(12) \cdots C(12^{V})$	3·650

Roman numeral superscripts refer to the following transformations of the atomic co-ordinates:

I $x, y, z - 1$ IV $1 - x, \frac{1}{2} + y, -z$
II $x, 1 + y, z$ V $1 - x, \frac{1}{2} + y, 1 - z$
III $1 + x, y, z$

TABLE 7

Endocyclic torsion angles (deg.) for some ten-membered rings

Compound	(4)	(6)	(7) *		(5)	(8) †
ω(1–2)	66	112	107	ω(5–6)	102	101
ω(2–3)	−3	−49	−59	ω(6–7)	−57	−44
ω(3–4)	55	86	82	ω(7–8)	103	104
ω(4–5)	−163	−151	−150	ω(8–9)	−148	−154
ω(5–6)	116	79	129	ω(9–10)	61	50
ω(6–7)	−2	57	−2	ω(10–1)	68	63
ω(7–8)	−90	−129	−86	ω(1–2)	−143	−134
ω(8–9)	73	53	59	ω(2–3)	55	62
ω(9–10)	57	64	66	ω(3–4)	55	53
ω(10–1)	−153	−166	−165	ω(4–5)	−149	−159

* 1 : 1 adduct of pregeijerene (7) with silver nitrate. † Cyclodecane; less stable conformation (calc. values).

The $C(1) \cdots C(5)$ transannular separation in (4) is distinctly short (3·03 Å) and this is also the case in elephantol (2·98 Å),[9] shiromodiol (3·05 Å),[6] and pregeijerene (2·91 Å).[4] A number of unsaturated germacrane sesquiterpenes have u.v. spectra which have been interpreted in terms of transannular interactions between double bonds, consistent with short $C(1) \cdots C(5)$ and $C(10) \cdots C(5)$ separations.[12]

The C–C(sp^3)–C valency angles of the macrocycle in dihydromikanolide range from 115·4 to 122·4°, mean 118·5°, and the large deviations from the tetrahedral value indicate a considerable amount of angular strain. Medium-sized saturated carbocycles, including cyclodecane, are subject to appreciable angular strain and valency angles of 116—117° are common.[13] In the sesquiterpenoids eupacunoxin *m*-bromobenzoate and eupacunin *o*-bromobenzoate, the ten-membered rings contain four sp^2-hybridized carbon atoms and the mean C–C(sp^3)–C valency angles are 113·7 and 113·2°.[14] A further reduction of angular strain is obtained by the presence of five sp^2 carbon atoms and the mean C–C(sp^3)–C angle in germacratriene is 109·2°.[8]

The unsaturated α,γ-fused lactone of dihydromikanolide approximates to a planar conformation, the maximum displacement from the mean plane of the ring being 0·03 Å. The β,γ-*trans*-fused lactone, on the other hand, adopts an envelope conformation; here C(7) is displaced by 0·52 Å from the plane defined by O(5), C(8), C(11), and C(12).

The C–C–R valency angles of the epoxide group (R = substituent carbon atom) are in the range 117·1—122·4, mean 120·2°, and are somewhat larger than the O–C–R valency angles which are 112·4—116·7, mean 114·7°. This difference is apparent in the analogous angles in other epoxides (*e.g.* 121 and 114° in elephantol,[9] 121 and 115° in shiromodiol [6]) but the difference is less marked in tetracyanoethylene oxide [15] (118 and 116°). The C(2)–C(1)–C(10)–C(9) epoxide torsion angle in dihydromikanolide is 153°, close to values of 156 in elephantol and 151° in shiromodiol. The C–C bond lengths in the epoxide groups (1·469 and 1·483, mean 1·476 Å) are significantly shorter than the C(sp^3)–C(sp^3) distances (1·527—1·550 Å) in the ten-membered ring, and indicate that the radius which should be assigned to an epoxide carbon atom is identical with the single-bond value (0·74 Å) appropriate to an sp^2 carbon atom.

EXPERIMENTAL

Crystal Data.—$C_{15}H_{16}O_6$, $M = 292{\cdot}3$. Monoclinic, $a = 10{\cdot}451(6)$, $b = 7{\cdot}122(4)$, $c = 9{\cdot}233(5)$ Å, $\beta = 99{\cdot}77(3)°$, $U = 677{\cdot}3$ Å^3, $D_m = 1{\cdot}40$, $Z = 2$, $D_c = 1{\cdot}43$, $F(000) = 308$. Mo-K_α radiation, $\lambda = 0{\cdot}7107$ Å; μ(Mo-K_α) $= 1{\cdot}20$ cm^{-1}. Space group $P2_1$ (C_2^2).

Crystallographic Measurements.—Cell dimensions were adjusted by least-squares analysis of the angular settings of 12 reflections measured on a Hilger and Watts computer-controlled four-circle diffractometer at θ(Mo-K_α) *ca.* 16°. The octants *hkl* and $hk\bar{l}$ were measured in the range $\theta \leqslant 30°$ with θ—ω scans consisting of 60 steps of 0·02° s^{-1}, background counts of 15 s being taken at each end of the scan range. In all, the intensities of 2116 independent reflections were obtained, of which 1486 having $I > 3\sigma(I)$ were considered observed. No correction was applied for absorption.

Structure Analysis.—The structure was determined by direct methods involving tangent-formula refinement of phases, by use of the '*X*-ray '70' series of programs.[16]

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[13] See *e.g.* F. H. Allen and D. Rogers, *J. Chem. Soc.* (*B*), 1968, 1047, and references therein.

[14] S. M. Kupchan, M. Maruyama, R. J. Hemingway, J. C. Hemingway, S. Shibuya, T. Fujita, P. D. Cradwick, A. D. U. Hardy, and G. A. Sim, *J. Amer. Chem. Soc.*, 1971, **93**, 4914.

[15] D. A. Mathews, J. Swanson, M. H. Mueller, and G. D. Stucky, *J. Amer. Chem. Soc.*, 1971, **93**, 5945.

[16] '*X*-Ray '70' series of programs, July 1970 version, eds. J. M. Stewart, F. A. Kundell, and J. C. Baldwin, University of Maryland.

Based on an overall isotropic temperature parameter B 3·47 Å^2, $|E|$ values were derived and Σ_2 relationships generated for the 220 reflections with $|E| \geqslant 1\cdot50$. Three origin-fixing phases [17] (Table 8, see Supplementary Publication) were assigned phases of 0°, the enantiomorph-defining phase was initially set at 90°, and an additional three phases were assigned values of $\pm 90°$. This procedure yielded eight possible starting sets of seven phases for input to the 'Tangen' program which then generated phase sets characterized by R_K 0·17 and 0·24—0·29.[18] An E map calculated from the phases with the lowest value of R_K yielded positions for all 21 carbon and oxygen atoms.

The initial co-ordinates gave R 35·6%, and three cycles of full-matrix least-squares refinement with isotropic thermal parameters lowered R to 14·5%. All sixteen hydrogen atoms were located in a difference electron-density distribution and subsequent further refinement with anisotropic thermal parameters for the carbon and oxygen atoms and isotropic thermal parameters for the hydrogen atoms converged to R 6·2, R' 7·1%. The weighting scheme employed in the final stages of the analysis was of the type: $w = 1/[1 + (F_O - F_B)/F_A]^2$, final values of F_A and F_B being 6·00 and 4·48. The mean and maximum shift-to-error ratios in the last cycle of calculations were 0·17 and 0·51, respectively. No allowance was made for anomalous dispersion in any of the calculations and the absolute configuration adopted for (4) is based [2] on the correlation of deoxymikanolide with the germacranolides isabelin and cnicin. Observed and calculated structure amplitudes, Table 8, and a list of torsion angles involving hydrogen atoms are included in Supplementary Publication No. SUP 21056 (12 pp., 1 microfiche).*

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* See Notice to Authors No. 7 in *J.C.S. Perkin II*, 1973, Index issue.

[17] H. Hauptman and J. Karle, *Acta Cryst.*, 1956, **9**, 45.

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