for the tub conformation, is 3·085 Å. The observed geometry is in striking accordance with the results of earlier electron-diffraction work and force-field computations (Ermer, 1981). Addition of substituents results in differences of the ring geometry. Thus steric repulsion of the methyl groups causes significant flattening of the ring of octamethyl-COT (Bordener, Parker & Stanford, 1972).

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Structures of Two Bufadienolides: Bufotalin (3β,14-Dihydroxy-16β-acetoxy-5β,14β-bufa-20,22-dienolide) and Cinobufotalin (3β,5β-Dihydroxy-14,15β-epoxy-16β-acetoxy-5β,14β-bufa-20,22-dienolide)

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Abstract. Bufotalin (16-Acetoxybufalin) (1), $C_{26}H_{36}O_6$, $M_r = 444{\cdot}57$, orthorhombic, $P2_12_12_1$, $a = 11{\cdot}247\,(1)$, $b = 12{\cdot}334\,(1)$, $c = 17{\cdot}031\,(1)$ Å, $V = 2362{\cdot}6\,(5)$ Å^3, $Z = 4$, $D_x = 1{\cdot}25$ Mg m^{-3}, λ(Cu $K\bar{\alpha}$) = 1·54184 Å, $\mu = 0{\cdot}67$ mm^{-1}, $F(000) = 960$, $T = 296\,(1)$ K, $R = 0{\cdot}045$ for 2479 unique observed reflections. The presence of a 16β-acetoxy group does not change the E^{14} conformation of ring *D* observed in the parent compound bufalin, but the rotation of the δ-lactone ring about C(17)–C(20) is

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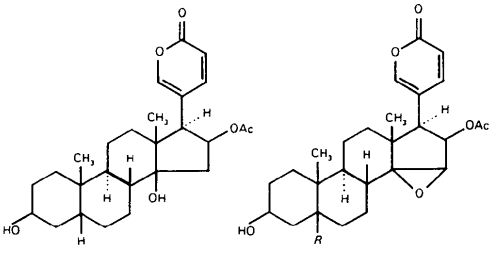
altered by 154°. Similarly, the hydrogen-bond network undergoes significant rearrangement in which 14-OH gains an additional acceptor role to its donor function observed in bufalin. Cinobufotalin (5-hydroxycinobufagin) (3), $C_{26}H_{34}O_7$, $M_r = 458{\cdot}29$, orthorhombic, $P2_12_12_1$, $a = 7{\cdot}631$ (1), $b = 15{\cdot}727$ (5), $c = 19{\cdot}557$ (2) Å, $V = 2347$ (1) Å^3, $Z = 4$, $D_x = 1{\cdot}30$ Mg m^{-3}, λ(Mo $K\alpha$) = 0·71069 Å, $\mu = 0{\cdot}055$ mm^{-1}, $F(000) = 984$, $T = 293$ (2) K, $R = 0{\cdot}046$ for 1785 unique observed reflections. Cinobufotalin is quasi-isostructural with cinobufagin (2) [Declercq, Germain & King (1977), *Abstr. 4th Eur. Crystallogr. Meet., Oxford,* pp. 279–280]. The additional OH group bonded to C(5) in the *A/B cis*-ring anellation does not affect the crystal packing, but forms only an intramolecular hydrogen bond with the other OH group in ring *A*.

Introduction. In a previous paper we reported the structures of gamabufotalin and arenobufagin (12-oxo-gamabufotalin) (Argay, Kálmán, Ribár, Vladimirov & Živanov-Stakić, 1987), both isolated from the dried venom of the Chinese toad Ch'an Su, a rich source of various cardenolides and bufadienolides (Höriger, Živanov, Linde & Meyer, 1970). This work deals with the structures of bufotalin (1) and cinobufotalin (3), isolated similarly by chromatography from the above mentioned Ch'an Su.



(1) Bufotalin (2) Cinobufagin R = H (3) Cinobufotalin R = OH

These two bufadienolides are related by an intermediate (2), cinobufagin. It is formed from bufotalin *via* 14,15β-epoxy ring closure. Its structure was published on a preliminary basis by Declercq, Germain & King (1977). The addition of a hydroxy group to C(5) in cinobufagin leads to cinobufotalin. This accounts for the similarity between the lattice parameters of (2) and (3), with the same space-group symmetry $P2_12_12_1$:

	a (Å)	b (Å)	c (Å)	V (Å^3)
(2)	7·663 (2)	15·900 (5)	19·291 (5)	2350 (4)
(3)	7·631 (1)	15·727 (5)	19·557 (2)	2347 (1).

Like digitoxigenin (Karle & Karle, 1969) and digirezigenin (Kálmán, Argay, Ribár, Vladimirov & Živanov-Stakić, 1984), and like gamabufotalin and arenobufagin (Argay *et al.*, 1987), they also form a quasi-isostructural pair.

Experimental. *Bufotalin* (1). A crystal 0·30 × 0·40 × 0·50 mm was mounted on a CAD-4 diffractometer (Budapest) using graphite-monochromated Cu $K\alpha$ radiation. Cell constants were refined by least-squares fit for 25 centred reflections with $27 \le \theta \le 35°$. Systematic absences $h00$: $h = 2n + 1$, $0k0$: $k = 2n + 1$, $00l$: $l = 2n + 1$. Data were collected by $\omega/2\theta$ scan in the range $0{\cdot}017 \le (\sin\theta)/\lambda \le 0{\cdot}626$ Å^{-1} with h: 0 to 15, k: 0 to 16 and l: 0 to 22. Of 2657 unique and not systematically absent reflections 2479 with $I > 3{\cdot}0\sigma(I)$ were taken as observed. Three standard reflections (0,0,10, 2,5,10, 800) were monitored every hour, but no intensity variations were recorded. The phase problems were solved by the *MULTAN*82 program (Main, Fiske, Hull, Lessinger, Germain, Declercq & Woolfson, 1982). Full-matrix least-squares refinement minimized $\sum w(\Delta F)^2$ for 290 parameters with $w = 4F_o^2/\sigma(F_o^2)^2$. At the end of the isotropic refinement an empirical absorption correction was performed with the program *DIFABS* (Walker & Stuart, 1983). Final $R = 0{\cdot}045$, $wR = 0{\cdot}077$, $R_{tot} = 0{\cdot}049$, $S = 1{\cdot}82$. Max. and min. peak heights in final $\Delta\rho = \pm 0{\cdot}32$ (4) e Å^{-3}. Data were not corrected for extinction. $(\Delta/\sigma)_{max} = 0{\cdot}32$. Positions of H atoms bound to C atoms were generated from assumed geometries, while those linked to O atoms were located in a difference Fourier map; their positions were taken into account without refinement in structure-factor calculations with isotropic temperature factors [$B_{iH} = (B_{iX} + 1)$ Å^2 where X = C or O]. Scattering factors were taken from the program system *SDP Plus* (Enraf–Nonius, 1983) adapted on a PDP 11/34 minicomputer (Budapest) with local modifications.

Cinobufotalin (3). A crystal 0·30 × 0·40 × 0·40 mm was mounted on a CAD-4 diffractometer (Ljubljana) using graphite-monochromated Mo $K\alpha$ radiation. Cell constants were refined by least-squares fit for 25 centred reflections with $7 \le \theta \le 11°$. Systematic absences $h00$: $h = 2n + 1$, $0k0$: $k = 2n + 1$, $00l$: $l = 2n + 1$. Data were collected by $\omega/2\theta$ scan in the range $0{\cdot}048 \le (\sin\theta)/\lambda \le 0{\cdot}660$ Å^{-1} with h: 0 to 10, k: 0 to 20 and l: 0 to 25. Of 3199 unique and not systematically absent reflections 1785 with $F_o > 3{\cdot}0\sigma(F_o)$ were taken as observed. Structure was solved by program *SHELX*76 (Sheldrick, 1976). Full-matrix least-squares refinement minimized $\sum w(\Delta F)^2$ for 299 parameters with $w = [\sigma^2(F_o) + 7{\cdot}5 \times 10^{-3}(F_o^2)]^{-1}$. Owing to the low μ value no absorption correction was applied. Final $R = 0{\cdot}046$, $wR = 0{\cdot}052$, $R_{tot} = 0{\cdot}067$, $S = 0{\cdot}27$. Max. and min. peak heights in final $\Delta\rho = \pm 0{\cdot}18$ e Å^{-3}. Data were not corrected for extinction. $(\Delta/\sigma)_{max} = 0{\cdot}57$. Positions of H atoms bound to C atoms were generated from assumed geometries while those linked to O atoms were located in difference Fourier map; their positions were refined isotropically along with the anisotropic treatment of non-H atoms. Scattering factors were taken from *SHELX*76 (Sheldrick, 1976). Calculations

were performed on an IBM 43/41 computer (Novi Sad).

Discussion. Atomic coordinates of non-H atoms are listed in Table 1.* The bond lengths and angles for non-H atoms are listed in Tables 2 and 3. The molecular geometry of bufotalin (1) depicted in Fig. 1(*a*) exhibits characteristic dissimilarities from the parent molecule bufalin (Rohrer, Fullerton, Kitatsuji, Nambara & Yoshii, 1982).† While the conformation of the 14-isoaethiocholane skeleton including the flexible *D* ring is basically similar to that observed in bufalin [ring *D* retains its E^{14} envelope shape with puckering parameters (Cremer & Pople, 1975) $Q = 0{\cdot}347\ (3)$ Å, $\varphi = 289{\cdot}6\ (5)°$] the δ-lactone ring assumes almost the opposite orientation about the C(17)–C(20) bond, *i.e.* the torsion angle C(13)–C(17)–C(20)–C(22) changes from −87·1 (5) (bufalin) to 67·0 (4)° (bufotalin). This motion is in accordance with the energy calculation of Höhne & Pfeiffer (1983) for the rotation of the γ-lactone ring about the C(17)–C(20) bond in cardenolides. It gave two valleys of energy minimum at about 70 to 80° and −80 to −90° of the torsion angle C(13)–C(17)–C(20)–C(22).

Though the 16β-acetoxy does not participate in the formation of hydrogen bonds it alters partly those which were found in bufalin (Rohrer *et al.*, 1982).

	Symmetry operation	*D*···*A* (Å)	H···*A* (Å)	*DH*···*A* (°)
O(1)–H···O(4)	[*x*, *y*, 1+*z*]	2·907 (3)	2·24 (4)	168 (3)
O(2)–H···O(1)	[−0·5−*x*, 2−*y*, 0·5+*z*]	3·004 (3)	2·15 (3)	167 (2)

in the following way:

O(1)–H···O(2)	[0·5−*x*, 2−*y*, 0·5+*z*]	2·882 (2)	1·95 (2)	158·8 (2)
O(2)–H···O(4)	[−0·5+*x*, 1·5−*y*, 1−*z*]	2·991 (2)	2·06 (2)	166·0 (2)

which means that in the O(1)···O(2) contact the role of the donor and acceptor are switched, thus preserving the infinite helix around the same *c* axis increased from 15·717 (1) to 17·031 (1) Å. However, the infinite chain formed by unique translations also along the *c* axis of bufalin is replaced by a second helix formed around the *a* axis which changes from 10·726 (1) to 11·247 (1) Å. In this helix O(2) acts as donor to the oxo group of the δ-lactone ring. Since the *b* axis is only altered from 12·381 (2) to 12·344 (1) Å the shape of the unit cell remains similar to that of bufalin. Of course, an increase of the volume, by *ca* 70 Å^3 per 16β-acetoxy group, has to be taken into account.

When the 14-OH group represented by O(2) is destroyed by a 14,15β-epoxy-ring-closure we obtain cinobufagin* depicted in Fig. 1(*b*) in the lattice of which the hydrogen bonding is altered basically since 14-OH no longer exists, either as donor or acceptor. Consequently, although the space-group symmetry

Table 1. *Final fractional coordinates for non-*H *atoms with e.s.d.'s in parentheses*

$B_{eq} = \frac{4}{3}$ trace (*BG*) where **G** is the metric tensor.

	x	*y*	*z*	B_{eq}(Å^2)
Bufotalin				
O(1)	0·0606 (2)	0·9426 (1)	1·1122 (1)	5·0 (1)
O(2)	0·2959 (1)	0·8793 (1)	0·6672 (1)	3·1 (1)
O(3)	0·4905 (2)	0·5068 (1)	0·5128 (1)	4·5 (1)
O(4)	0·5578 (2)	0·5585 (1)	0·3966 (1)	5·0 (1)
O(5)	0·5528 (1)	0·7822 (2)	0·6741 (1)	5·7 (1)
O(6)	0·6763 (2)	0·8532 (2)	0·7636 (1)	8·6 (1)
C(1)	0·0192 (2)	0·7843 (2)	0·9846 (1)	3·9 (1)
C(2)	0·1208 (2)	0·7828 (2)	1·0429 (1)	4·1 (1)
C(3)	0·1566 (2)	0·8970 (2)	1·0669 (1)	4·3 (1)
C(4)	0·1839 (2)	0·9647 (2)	0·9949 (1)	3·9 (1)
C(5)	0·0840 (2)	0·9645 (2)	0·9329 (1)	3·5 (1)
C(6)	0·1190 (2)	1·0340 (2)	0·8620 (1)	4·3 (1)
C(7)	0·2161 (2)	0·9825 (1)	0·8131 (1)	3·6 (1)
C(8)	0·1836 (2)	0·8660 (1)	0·7883 (1)	2·8 (1)
C(9)	0·1474 (1)	0·7956 (1)	0·8593 (1)	2·8 (1)
C(10)	0·0456 (2)	0·8491 (1)	0·9082 (1)	3·2 (1)
C(11)	0·1200 (2)	0·6802 (2)	0·8318 (1)	4·0 (1)
C(12)	0·2273 (2)	0·6315 (1)	0·7902 (1)	3·9 (1)
C(13)	0·2668 (2)	0·6945 (1)	0·7164 (1)	2·9 (1)
C(14)	0·2838 (1)	0·8160 (1)	0·7383 (1)	2·6 (1)
C(15)	0·4071 (2)	0·8181 (1)	0·7768 (1)	3·1 (1)
C(16)	0·4820 (2)	0·7338 (2)	0·7350 (1)	3·6 (1)
C(17)	0·3950 (2)	0·6532 (1)	0·6949 (1)	3·0 (1)
C(18)	0·1773 (2)	0·6772 (2)	0·6512 (1)	3·7 (1)
C(19)	−0·0711 (2)	0·8527 (2)	0·8608 (1)	4·8 (1)
C(20)	0·4240 (2)	0·6325 (1)	0·6094 (1)	3·0 (1)
C(21)	0·4504 (2)	0·5309 (2)	0·5867 (1)	3·6 (1)
C(22)	0·4314 (2)	0·7150 (1)	0·5510 (1)	3·3 (1)
C(23)	0·4716 (2)	0·6928 (2)	0·4787 (1)	3·7 (1)
C(24)	0·5113 (2)	0·5864 (2)	0·4574 (1)	3·6 (1)
C(25)	0·6520 (3)	0·8321 (3)	0·6955 (2)	6·9 (1)
C(26)	0·7160 (4)	0·8735 (4)	0·6234 (3)	11·6 (2)
Cinobufotalin				
O(1)	0·4941 (6)	0·6864 (3)	0·6009 (2)	6·6 (2)
O(2)	0·5804 (5)	0·2442 (2)	0·4150 (2)	4·6 (2)
O(3)	0·7224 (5)	0·1427 (2)	0·1512 (2)	4·8 (2)
O(4)	0·7243 (6)	0·0028 (2)	0·1465 (2)	6·4 (2)
O(5)	0·3337 (4)	0·2405 (2)	0·2956 (2)	3·8 (2)
O(6)	0·2777 (6)	0·3059 (2)	0·1962 (2)	5·6 (2)
O(7)	0·6907 (6)	0·5478 (3)	0·6420 (1)	6·1 (2)
C(1)	0·7689 (6)	0·6206 (3)	0·5059 (2)	4·3 (2)
C(2)	0·5898 (8)	0·6546 (3)	0·4864 (3)	5·1 (2)
C(3)	0·4546 (8)	0·6348 (4)	0·5412 (3)	5·6 (2)
C(4)	0·4566 (6)	0·5407 (4)	0·5602 (3)	4·9 (2)
C(5)	0·6378 (6)	0·5060 (3)	0·5791 (2)	4·4 (2)
C(6)	0·6321 (10)	0·4115 (3)	0·5956 (2)	5·8 (2)
C(7)	0·5832 (10)	0·3576 (3)	0·5331 (2)	5·6 (2)
C(8)	0·7056 (6)	0·3751 (3)	0·4726 (2)	3·8 (2)
C(9)	0·7215 (6)	0·4710 (2)	0·4567 (2)	3·2 (2)
C(10)	0·7728 (6)	0·5247 (3)	0·5214 (2)	3·7 (2)
C(11)	0·8463 (6)	0·4826 (3)	0·3965 (2)	3·7 (2)
C(12)	0·7724 (6)	0·4391 (3)	0·3334 (2)	3·5 (2)
C(13)	0·7503 (6)	0·3424 (3)	0·3423 (2)	3·0 (2)
C(14)	0·6467 (6)	0·3305 (3)	0·4082 (2)	3·5 (2)
C(15)	0·4633 (6)	0·3102 (3)	0·3918 (2)	4·0 (2)
C(16)	0·4404 (6)	0·3120 (3)	0·3160 (2)	3·4 (2)
C(17)	0·6272 (6)	0·3070 (3)	0·2846 (2)	3·2 (2)
C(18)	0·9293 (6)	0·2996 (3)	0·3434 (3)	4·7 (2)
C(19)	0·9606 (6)	0·5031 (4)	0·5449 (3)	5·6 (2)
C(20)	0·6675 (6)	0·2214 (3)	0·2532 (2)	3·2 (2)
C(21)	0·6970 (6)	0·2171 (3)	0·1855 (2)	4·0 (2)
C(22)	0·6629 (6)	0·1411 (3)	0·2889 (2)	4·3 (2)
C(23)	0·6857 (6)	0·0670 (3)	0·2558 (3)	5·0 (2)
C(24)	0·7121 (6)	0·0649 (3)	0·1825 (3)	4·5 (2)
C(25)	0·2642 (6)	0·2443 (3)	0·2328 (2)	4·0 (2)
C(26)	0·1700 (8)	0·1645 (3)	0·2143 (3)	5·6 (2)

* Lists of structure factors, anisotropic thermal parameters and H-atom parameters have been deposited with the British Library Document Supply Centre as Supplementary Publication No. SUP 51021 (28 pp.). Copies may be obtained through The Executive Secretary, International Union of Crystallography, 5 Abbey Square, Chester CH1 2HU, England.

† To gain the increasing $a < b < c$ sequence of the lattice parameters of bufalin the original choice given by Rohrer *et al.* (1982) has been changed.

* The still unpublished atomic coordinates of cinobufagin were kindly provided by Professor G. S. D. King (Catholic University of Leuven, Belgium) in 1982.

Table 2. *Bond lengths* (Å) *with their e.s.d.'s*

Bufotalin			
O(1)–C(3)	1·441 (4)	C(8)–C(14)	1·541 (3)
O(2)–C(14)	1·447 (3)	C(9)–C(10)	1·563 (3)
O(3)–C(21)	1·369 (3)	C(9)–C(11)	1·530 (3)
O(3)–C(24)	1·381 (3)	C(10)–C(19)	1·541 (4)
O(4)–C(24)	1·211 (3)	C(11)–C(12)	1·523 (4)
O(5)–C(16)	1·438 (3)	C(12)–C(13)	1·543 (3)
O(5)–C(25)	1·325 (4)	C(13)–C(14)	1·557 (3)
O(6)–C(25)	1·220 (5)	C(13)–C(17)	1·573 (3)
C(1)–C(2)	1·515 (4)	C(13)–C(18)	1·514 (3)
C(1)–C(10)	1·555 (4)	C(14)–C(15)	1·534 (3)
C(2)–C(3)	1·521 (4)	C(15)–C(16)	1·516 (3)
C(3)–C(4)	1·515 (4)	C(16)–C(17)	1·553 (3)
C(4)–C(5)	1·541 (4)	C(17)–C(20)	1·513 (3)
C(5)–C(6)	1·532 (4)	C(20)–C(21)	1·345 (3)
C(5)–C(10)	1·546 (3)	C(20)–C(22)	1·425 (3)
C(6)–C(7)	1·514 (4)	C(22)–C(23)	1·341 (3)
C(7)–C(8)	1·542 (3)	C(23)–C(24)	1·433 (4)
C(8)–C(9)	1·543 (3)	C(25)–C(26)	1·511 (7)
Cinobufotalin			
O(1)–C(3)	1·453 (7)	C(8)–C(9)	1·545 (6)
O(2)–C(14)	1·455 (6)	C(8)–C(14)	1·510 (6)
O(2)–C(15)	1·443 (6)	C(9)–C(10)	1·571 (6)
O(3)–C(21)	1·363 (6)	C(9)–C(11)	1·525 (6)
O(3)–C(24)	1·370 (6)	C(10)–C(19)	1·543 (7)
O(4)–C(24)	1·208 (6)	C(11)–C(12)	1·520 (6)
O(5)–C(16)	1·445 (6)	C(12)–C(13)	1·540 (7)
O(5)–C(25)	1·339 (6)	C(13)–C(14)	1·523 (6)
O(6)–C(25)	1·209 (6)	C(13)–C(17)	1·570 (6)
O(7)–C(5)	1·452 (5)	C(13)–C(18)	1·523 (7)
C(1)–C(2)	1·516 (8)	C(14)–C(15)	1·471 (7)
C(1)–C(10)	1·539 (7)	C(15)–C(16)	1·493 (6)
C(2)–C(3)	1·520 (8)	C(16)–C(17)	1·554 (6)
C(3)–C(4)	1·526 (9)	C(17)–C(20)	1·511 (6)
C(4)–C(5)	1·532 (8)	C(20)–C(21)	1·345 (6)
C(5)–C(6)	1·521 (7)	C(20)–C(22)	1·443 (6)
C(5)–C(10)	1·556 (6)	C(22)–C(23)	1·344 (7)
C(6)–C(7)	1·534 (6)	C(23)–C(24)	1·448 (8)
C(7)–C(8)	1·532 (7)	C(25)–C(26)	1·491 (7)

Table 3. *Bond angles* (°) *with their e.s.d.'s*

Bufotalin			
C(21)–O(3)–C(24)	122·0 (4)	C(12)–C(13)–C(18)	109·5 (3)
C(16)–O(5)–C(25)	117·5 (4)	C(14)–C(13)–C(17)	104·8 (3)
C(2)–C(1)–C(10)	114·2 (4)	C(14)–C(13)–C(18)	113·2 (3)
C(1)–C(2)–C(3)	111·4 (4)	C(17)–C(13)–C(18)	113·2 (3)
O(1)–C(3)–C(2)	107·9 (4)	O(2)–C(14)–C(8)	108·4 (3)
O(1)–C(3)–C(4)	111·7 (4)	O(2)–C(14)–C(13)	109·2 (3)
C(2)–C(3)–C(4)	110·3 (4)	O(2)–C(14)–C(15)	105·3 (3)
C(3)–C(4)–C(5)	113·9 (4)	C(8)–C(14)–C(13)	115·3 (3)
C(4)–C(5)–C(6)	110·6 (4)	C(8)–C(14)–C(15)	114·8 (3)
C(4)–C(5)–C(10)	113·1 (4)	C(13)–C(14)–C(15)	103·3 (3)
C(6)–C(5)–C(10)	111·9 (4)	C(14)–C(15)–C(16)	106·8 (3)
C(5)–C(6)–C(7)	112·6 (4)	O(5)–C(16)–C(15)	111·2 (4)
C(6)–C(7)–C(8)	111·8 (4)	O(5)–C(16)–C(17)	107·3 (3)
C(7)–C(8)–C(9)	111·9 (3)	C(15)–C(16)–C(17)	107·3 (3)
C(7)–C(8)–C(14)	110·5 (3)	C(13)–C(17)–C(16)	105·5 (3)
C(9)–C(8)–C(14)	113·6 (3)	C(13)–C(17)–C(20)	118·4 (3)
C(8)–C(9)–C(10)	112·0 (3)	C(16)–C(17)–C(20)	113·3 (3)
C(8)–C(9)–C(11)	109·7 (3)	C(17)–C(20)–C(21)	118·7 (4)
C(10)–C(9)–C(11)	114·2 (3)	C(17)–C(20)–C(22)	124·3 (4)
C(1)–C(10)–C(5)	107·4 (3)	C(21)–C(20)–C(22)	116·8 (4)
C(1)–C(10)–C(9)	111·7 (3)	O(3)–C(21)–C(20)	122·6 (4)
C(1)–C(10)–C(19)	106·9 (4)	C(20)–C(22)–C(23)	121·1 (4)
C(5)–C(10)–C(9)	109·2 (3)	C(22)–C(23)–C(24)	121·6 (4)
C(5)–C(10)–C(19)	110·8 (4)	O(3)–C(24)–O(4)	117·2 (4)
C(9)–C(10)–C(19)	110·9 (4)	O(3)–C(24)–C(23)	115·2 (4)
C(9)–C(11)–C(12)	110·5 (4)	O(4)–C(24)–C(23)	127·6 (4)
C(11)–C(12)–C(13)	114·1 (4)	O(5)–C(25)–O(6)	123·3 (6)
C(12)–C(13)–C(14)	108·9 (3)	O(5)–C(25)–C(26)	109·6 (6)
C(12)–C(13)–C(17)	106·9 (3)	O(6)–C(25)–C(26)	126·4 (7)
Cinobufotalin			
C(14)–O(2)–C(15)	61·0 (5)	C(12)–C(13)–C(17)	109·5 (6)
C(21)–O(3)–C(24)	122·6 (7)	C(12)–C(13)–C(18)	109·9 (7)
C(16)–O(5)–C(25)	116·2 (6)	C(14)–C(13)–C(17)	104·7 (6)
C(2)–C(1)–C(10)	114·4 (7)	C(14)–C(13)–C(18)	113·5 (7)
C(1)–C(2)–C(3)	111·2 (8)	C(17)–C(13)–C(18)	113·0 (6)
O(1)–C(3)–C(2)	108·1 (8)	O(2)–C(14)–C(8)	117·4 (6)
O(1)–C(3)–C(4)	110·1 (8)	O(2)–C(14)–C(13)	111·9 (6)
C(2)–C(3)–C(4)	111·3 (8)	O(2)–C(14)–C(15)	59·1 (5)
C(3)–C(4)–C(5)	114·4 (8)	C(8)–C(14)–C(13)	119·6 (7)
O(7)–C(5)–C(4)	107·1 (7)	C(8)–C(14)–C(15)	124·5 (7)
O(7)–C(5)–C(6)	105·7 (7)	C(13)–C(14)–C(15)	109·6 (6)
O(7)–C(5)–C(10)	110·2 (6)	O(2)–C(15)–C(14)	59·9 (5)
C(4)–C(5)–C(6)	111·9 (7)	O(2)–C(15)–C(16)	113·5 (7)
C(4)–C(5)–C(10)	110·8 (7)	C(14)–C(15)–C(16)	108·9 (7)
C(6)–C(5)–C(10)	110·9 (7)	O(5)–C(16)–C(15)	109·0 (6)
C(5)–C(6)–C(7)	112·2 (8)	O(5)–C(16)–C(17)	111·6 (6)
C(6)–C(7)–C(8)	111·6 (8)	C(15)–C(16)–C(17)	106·5 (6)
C(7)–C(8)–C(9)	112·3 (7)	C(13)–C(17)–C(16)	104·3 (6)
C(7)–C(8)–C(14)	112·3 (7)	C(13)–C(17)–C(20)	119·1 (6)
C(9)–C(8)–C(14)	108·0 (6)	C(16)–C(17)–C(20)	113·1 (6)
C(8)–C(9)–C(10)	112·5 (6)	C(17)–C(20)–C(21)	118·6 (7)
C(8)–C(9)–C(11)	108·7 (6)	C(17)–C(20)–C(22)	125·3 (7)
C(10)–C(9)–C(11)	113·7 (6)	C(21)–C(20)–C(22)	115·9 (7)
C(1)–C(10)–C(5)	108·4 (6)	O(3)–C(21)–C(20)	123·5 (7)
C(1)–C(10)–C(9)	111·3 (6)	C(20)–C(22)–C(23)	121·5 (8)
C(1)–C(10)–C(19)	107·0 (7)	C(22)–C(23)–C(24)	121·0 (8)
C(5)–C(10)–C(9)	108·5 (6)	O(3)–C(24)–O(4)	117·2 (8)
C(5)–C(10)–C(19)	110·9 (7)	O(3)–C(24)–C(23)	115·5 (8)
C(9)–C(10)–C(19)	110·7 (6)	O(4)–C(24)–C(23)	127·3 (9)
C(9)–C(11)–C(12)	110·0 (6)	O(5)–C(25)–O(6)	123·0 (7)
C(11)–C(12)–C(13)	113·2 (7)	O(5)–C(25)–C(26)	112·1 (7)
C(12)–C(13)–C(14)	105·9 (6)	O(6)–C(25)–C(26)	124·9 (8)

($P2_12_12_1$) is similar the lattice parameters of bufotalin (1) and cinobufagin (2) differ significantly (see above). The formation of the epoxy ring, of course, changes the conformation of ring *D* (see below). No such effect upon the molecular conformation and packing is observed when cinobufagin (2) gains an additional 5β-hydroxy group which leads to cinobufotalin (3), depicted in Fig. 1(*c*). The resemblance between the conformations of (2) and (3) can be demonstrated by the comparison of the Newman projections perpendicular to C(5)–C(10), C(14)–C(13), C(13)–C(17) and C(17)–C(20) bonds (Fig. 2). Similarly to the conformation of ring *D* revealed in digirezigenin (Kálmán *et al.*, 1984) in cinobufotalin it also assumes a rare E^{17} envelope shape [the corresponding puckering parameters (Cremer & Pople, 1975): $Q = 0{\cdot}244\ (5)$ Å, $\varphi = 319{\cdot}1\ (13)°$] instead of the usual E^{14}. This pseudorotation may be attributed to the influence of the oxirane ring fused at the C(14)–C(15) bond. This may also account for the decrease of the dihedral angle between rings *C* and *D* [56·9 (2)°] as compared with the corresponding one [64·1 (1)°] in bufotalin. The rotation of the quasi-planar ring *E* about the C(17)–C(20) bond is also quite close ($\Delta \simeq 2°$) to that found in bufotalin. As can be seen from Fig. 1(*c*) 5β-OH represented by O(7) is bent over ring *A* donating only an intramolecular hydrogen bond to O(1) with the parameters O···O = 2·766 (7), H···O = 1·70 (1) Å, OH···O = 151·8 (5)°. This is why the existing intermolecular hydrogen bonding of cinobufagin (2) is hardly altered in cinobufotalin (3), resulting in the observed isostructurality of this pair of cardenolides.

In both structures there is only one intermolecular hydrogen bond O(1)–H···O(6) forming an infinite chain along the screw axis 2_1 [$\frac{1}{4}$,0,*z*]. The parameters for cinobufotalin are O···O = 2·791 (7), H···O = 1·77 (7) Å, OH···O = 172·9 (5)°. The similarity in the molecular packing is underscored by the identical unit-cell volumes (see above) unaffected by the presence or absence of the 5β-OH group. The special *isomorphism* of cinobufagin and cinobufotalin together

with that of digitoxigenin/digirezigenin and gamabufotalin/arenobufagin pairs, termed for the time being as *quasi-isostructurality*, has recently been discussed by us (Kálmán, Argay, Fülöp, Ribár & Lazar, 1987) with some descriptors of the phenomena. Further, detailed study of the hydrogen-bond influence upon the packing of these related molecules (cardenolides and bufadienolides) is in progress. To summarize, the formation of a 14,15β-epoxy ring in cinobufagin (2) prevents the development of the hydrogen bonding built up *via* 14-OH in bufotalin (1). Consequently, their lattices differ significantly. In contrast with this, the position of 5β-OH of cinobufotalin (3) – apart from an intramolecular hydrogen bond – has hardly any influence upon the conformation of the steroid skeleton and its packing, and therefore (2) and (3) are quasi-isostructural.

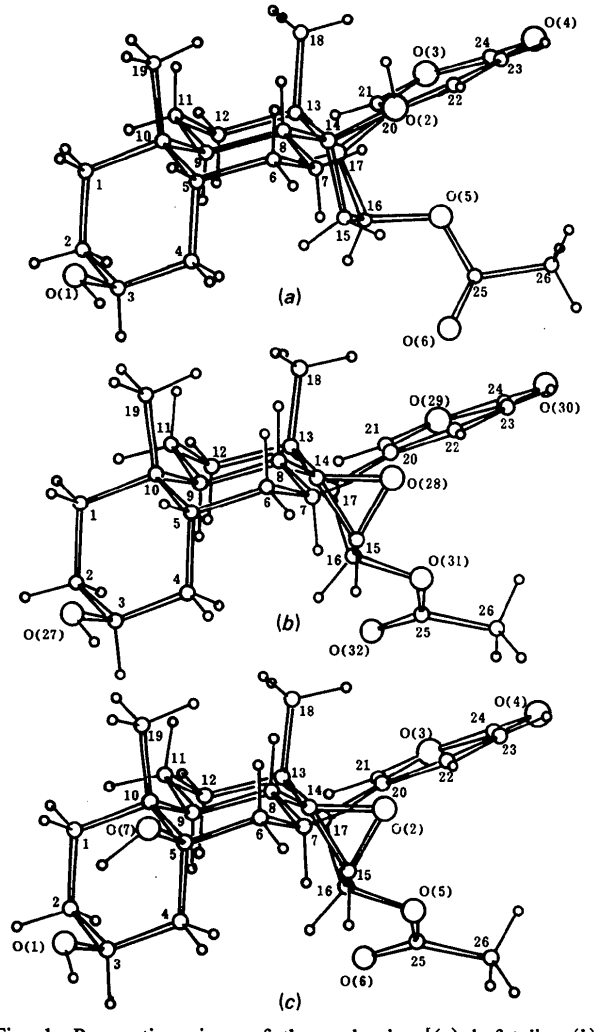


Fig. 1. Perspective views of the molecules [(*a*) bufotalin, (*b*) cinobufagin, (*c*) cinobufotalin] showing atomic numbering. The bare numbers are for carbon atoms unless indicated otherwise. The numbering of oxygen atoms for cinobufagin corresponds to that used by Professor G. S. D. King (Declercq, Germain & King, 1977). The H atoms are shown but not labelled.

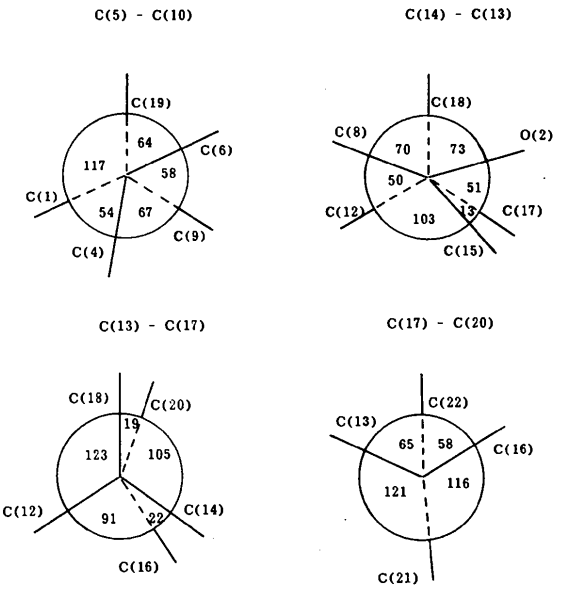


Fig. 2. Newman projections showing characteristic moieties of cinobufotalin. The corresponding Newman projections for cinobufagin, digitoxigenin and digirezigenin are depicted in Fig. 2 of Kálmán *et al.* (1984).

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