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HERCYNOLACTONE, A NEW CAROTANE SESQUITERPENOID FROM THE LIVERWORTS BARBILOPHOZIA LYCOPODIOIDES AND B. HATCHERI. CRYSTAL STRUCTURE ANALYSIS.

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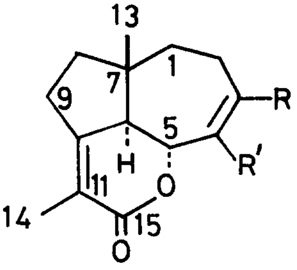
Summary. Hercynolactone, a new carotane sesquiterpenoid isolated from two *Barbilophozia* liverwort species, has been assigned the structure and relative configuration (1) on the basis of spectroscopic (especially ^{1}H and ^{13}C n.m.r.) and X-ray crystal structure analysis.

Extraction of the liverworts *Barbilophozia lycopodioides*, collected at the Hohne Cliffs in the Harz Mountains (DDR), and *B. hatcheri*, collected in Bulgaria, has afforded a new sesquiterpenoid hercynolactone.[1] Spectroscopic studies and an X-ray crystal structure analysis show that the new compound is a carotane derivative with the structure and relative configuration (1).



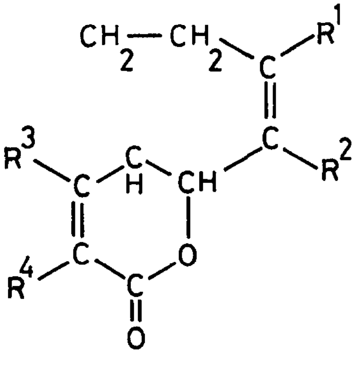
(1) R = H_3C-12; R^1 = H

(6) R = H; R^1 = H_3C-12

Hercynolactone, $C_{15}H_{20}O_2$(m/z 232.1441; calc. 232.1463), m.p. 97-98° (ex. hexane), $[\alpha]_D$ -84.2° (c 0.875 in $CHCl_3$), ORD (MeOH): $[\alpha]_{400}$ -300°, $[\alpha]_{300}$ -1650°, $[\alpha]_{266}$ -5300°, $[\alpha]_{250}$ 0°, has a carbonyl band at 1716 cm^{-1} (CCl_4) and a u.v. maximum at 232 nm (ε 10,000) suggesting the presence of an α,β-unsaturated δ-lactone. The ^{13}C n.m.r. spectrum in $CDCl_3$ solution (retrospective assignments in parentheses) shows resonances for a carbonyl [δ 166.8 (s, C-15)], two double bonds, one tetrasubstituted [δ 160.7 (s, C-10) and 119.6 (s, C-11)] and one trisubstituted [δ 126.3 (d, C-4) and 137.0 (s, C-3)], a secondary carbon bearing oxygen [δ 77.7 (d, C-5)], three methyl groups [δ 12.7 (q, C-14), 16.8 (q, C-13), and 28.6 (q, C-12)], four methylenes [δ 27.2 (t, C-9), 30.2

(t, C-2), 38.6 and 40.5 (both t, C-1 and C-8)], one methine [δ 53.4 (d, C-6)], and a fully substituted carbon [δ 43.1 (s, C-7)]. The molecule is therefore bicarbocyclic.

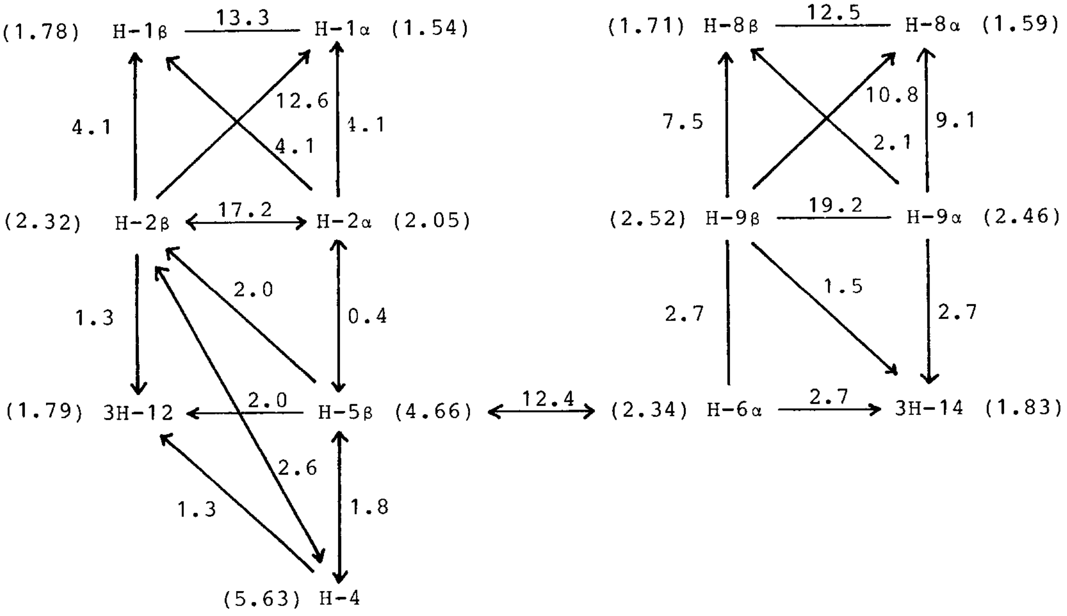
The 360 MHz ^1H n.m.r. spectrum of hercynolactone indicates that there are one tertiary (δ 0.85) and two olefinic (δ 1.83 and 1.79) methyl groups. The proton attached to the lactone terminus (H-5) appears as a broad doublet of sextets (J 12.4, 2.0 Hz) at δ 4.66 and the olefinic proton as a septet at δ 5.63. Irradiation of the olefinic proton caused the loss of small couplings from the lactone terminus H-5 (1.8 Hz), the olefinic methyl group at δ 1.79 (1.3 Hz), and a methylene proton at δ 2.32 (2.6 Hz). Irradiation of H-5 resulted in the loss of the major coupling from H-6 at δ 2.34 and small couplings from the olefinic proton, the olefinic methyl at δ 1.79, and the two C-2 methylene protons. The relationship between the olefinic methyl group at δ 1.83 and H-6 was established by irradiation at δ 2.49 to decouple the two allylic methylene protons at C-9. This resulted in collapse of the olefinic methyl signal to a sharp doublet (J 2.7 Hz) coupled to H-6 which became a doublet of quartets (J 12.4, 2.7 Hz). This and additional decoupling experiments showed that the C-2 and C-9 methylene groups each have methylene neighbours which are not further coupled. These results lead to alternative part structures (2)-(5) which account for thirteen of the fifteen carbon atoms of hercynolactone.



(2) $R^1 = R^4 = CH_3$; $R^2 = H$; $R^3 = CH_2CH_2$
(3) $R^1 = H$; $R^2 = R^4 = CH_3$; $R^3 = CH_2CH_2$
(4) $R^1 = R^3 = CH_3$; $R^2 = H$; $R^4 = CH_2CH_2$
(5) $R^1 = H$; $R^2 = R^3 = CH_3$; $R^4 = CH_2CH_2$

It only remains to insert a quaternary carbon bearing a methyl group in such a way that two carbocyclic rings are formed. It is readily apparent that this can be achieved with (2) or (3) only and, neglecting stereochemistry, leads to structures (1) or (6) for hercynolactone.

The coupling constant data are shown [with the numbering of (1)] in the Scheme (chemical shifts in parentheses). These show that the seven-membered ring adopts a chair conformation with a trans diaxial arrangement of H-5 and H-6, but cannot distinguish clearly between a cis and a trans ring junction with the five-membered ring. The coupling between the double bond proton and the C-2 methylene protons is more consistent with an allylic than a vicinal disposition



Scheme

and supports (1) rather than (6). In view of the ambiguities a crystal structure analysis was undertaken and showed that the structure and relative stereochemistry of hercynolactone is as in (1).

Intensity measurements were made on an Enraf-Nonius CAD4 diffractometer, using a small crystal[2] exposed to graphite-monochromated Mo radiation. The intensities ($I \geqslant 2.5\ \sigma_I$) of 1207 independent reflexions were recorded in the range 2 θ, 0 to 60°, using the ω, 2 θ scan technique. The structure was solved by direct phasing using the MULTAN suite of programs. Refinement of positional, thermal and scale parameters by least-squares calculations converged when R was 0.059. Positions for hydrogen atoms were calculated during the refinement, and these atoms were included (but not refined) in the refinement calculations. An ORTEP drawing of hercynolactone is shown in (7).

Carotanes are relatively rare in Nature, but have been found both in fungi and higher plants.[3] The isolation of hercynolactone from members of the Hepaticae extends further the range of skeletal types found in this family.[4]

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References

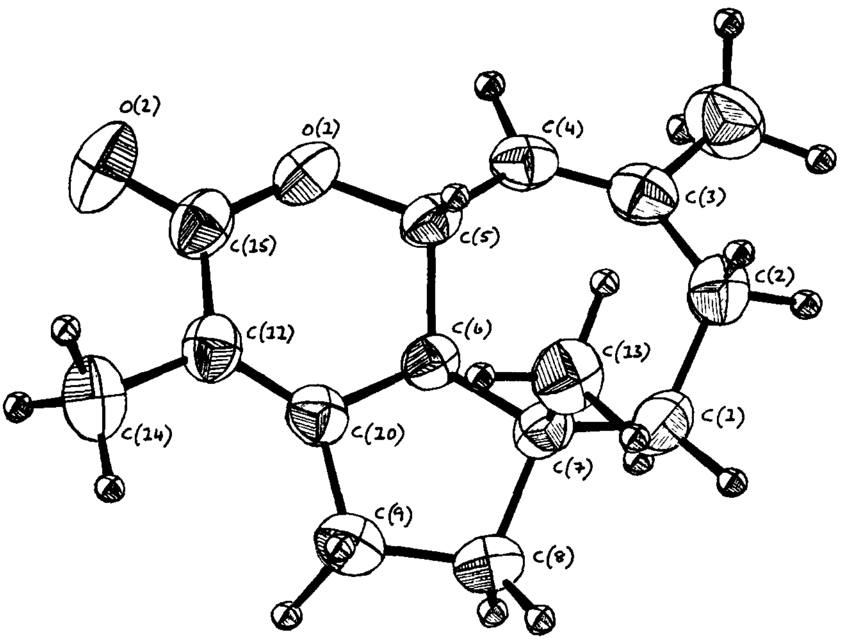
1. We originally called this compound hercynin. Since this name has already been assigned to an amino acid we have chosen the alternative name hercynolactone.

2. The crystal data are:

   Monoclinic, *a* = 9.235, *b* = 7.456, *c* = 9.934 Å, β = 72.10°, *Z* = 2, *U* = 650.9 Å^3. D_c = 1.184 g. cm^{-3} . F (000) = 252. Space group $P\,2_1$.
   Mo *K*α radiation, λ = 0.71069, μ (Mo *K*) = 0.43 cm^{-1}.

3. Y. Tsuda, M. Kaneda, A. Tada, K. Nitta, Y. Yamamoto, and Y. Iitaka, *J.C.S. Chem. Comm.*, 1978, 160.

4. K.R. Markham and L.J. Porter, *Progress in Phytochemistry*, 1978, *5*, 181.



(7)

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