Studies in Terpenoids. Part XLIV.[1] Structure of the Adduct from *p*-Mentha-1,5-diene and β-Naphthol, and its Isomer

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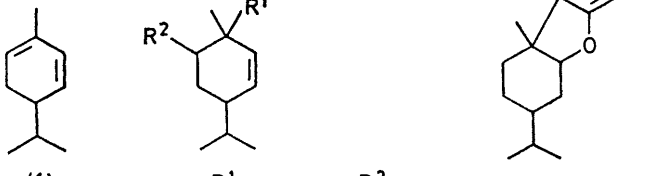
The adduct formed from (−)-*p*-mentha-1,5-diene(α-phellandrene) (1) and β-naphthol is identified as 1-[(3*R*,4*R*)-*p*-menth-1-en-3-yl]-2-naphthol (18). It undergoes isomerisation by methanolic hydrogen chloride to afford (1*S*,2*R*,5*S*)-2,3,4,5-tetrahydro-2-isopropyl-5-methyl-1,5-methano-1*H*-naphth[2,1-*b*]oxocin (19).

SALFELD reported [2] that the reaction of *p*-mentha-1,5-diene (α-phellandrene) (1) with β-naphthol gave the 1 : 1 adduct (2), which, under the influence of methanolic hydrogen chloride, suffered ring closure to yield the iso-adduct (3).[2,3] In principle the diene (1) might be expected to incorporate β-naphthol by involving the 1- or 3-position of the latter, to generate any of the isomeric adducts (2) and (4)—(12). In the present study the structure of the 1 : 1 adduct has been established as (4) [stereochemistry as in (18)] and that of the iso-adduct as (14) [stereochemistry as in (19)]; thus the assignments of Salfeld were in error.

For the adduct, $C_{20}H_{24}O$, the molecular ion at *m/e* 280 is in agreement with a 1 : 1 constitution. I.r. bands at 3 400 and 850 cm^{-1} are associated with a phenolic function and a trisubstituted olefinic linkage, respectively. The 100 MHz ^1H n.m.r. spectrum displays a double doublet centred at δ 0.8 (in the 60 MHz spectrum, this appears as a triplet [4]), assignable to the isopropyl substituent, in which the methyl groups are anisochronous by virtue of adjacent dissymetry. That the C-1′ methyl group is linked to a double bond is revealed by the singlet at δ 1.7 with small allylic couplings. The olefinic ring proton signal at δ 5.5 integrates for only one proton. For reasons of magnetic anisotropy of the



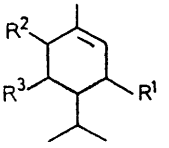
(1)

	R¹	R²
(2)	3-OH-2-Np	H
(5)	H	2-OH-1-Np
(8)	2-OH-1-Np	H
(10)	H	3-OH-2-Np

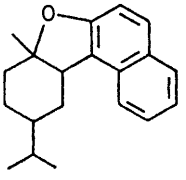
Np = naphthyl

(3)

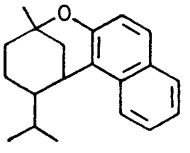
naphthalene ring system, the 2-, 3-, 6-, and 7-protons are more shielded than the 1-, 4-, 5-, and 8-protons. Introduction of an oxy-substituent into a benzenoid system is known to lead to a *ca.* 0.5 p.p.m. upfield shift in the



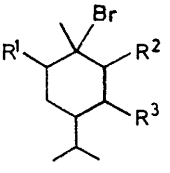
	R¹	R²	R³
(4)	2-OH-1-Np	H	H
(6)	H	H	2-OH-1-Np
(7)	H	2-OH-1-Np	H
(9)	3-OH-2-Np	H	H
(11)	H	H	3-OH-2-Np
(12)	H	3-OH-2-Np	H



(13)



(14)



	R¹	R²	R³
(15)	H	Br	2-OH-1-Np
(16)	Br	H	2-OH-1-Np

signal of an adjacent proton, and hence the 3-proton signal should be clearly discernible.[5] The doublet at δ 6.99 (*J* 8.7 Hz) is ascribed to this proton. The 4-proton, δ *ca.* 7.5, has the same coupling constant. Thus it is the 1-position of the β-naphthol which is linked to the *p*-menthenyl skeleton. The benzylic proton signal is visible as a doublet at δ 4.2 (*J* 11 Hz), broader than other signals, apparently as a result of long-range coupling.

These facts suggest that only three structures, (4),

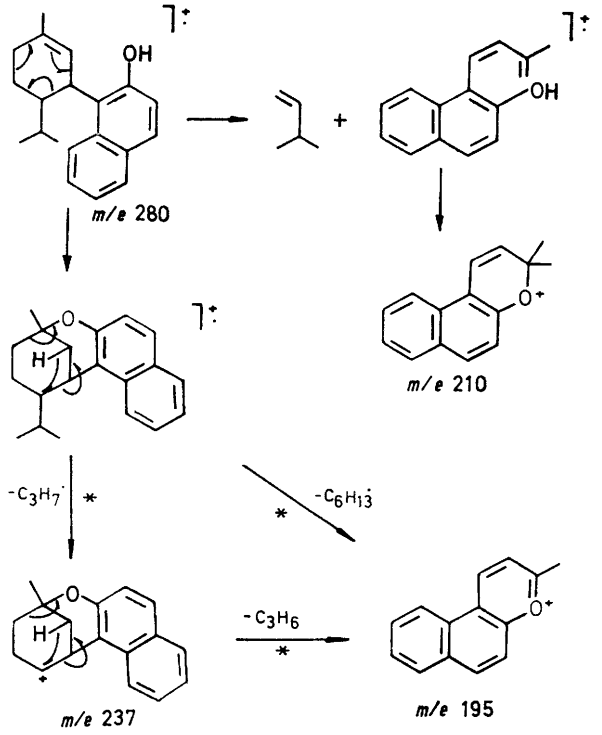
[1] Part XLIII, R. M. Carman, G. N. Saraswathi, and J. Verghese, submitted to *Austral. J. Chem.*

[2] J. C. Salfeld, *Chem. Ber.*, 1940, **73**, 376.

[3] G. G. Acheson and T. F. West, *J. Chem. Soc.*, 1949, 812.

[4] B. Singaram and J. Verghese, *Current Sci.*, 1975, **44**, 583.

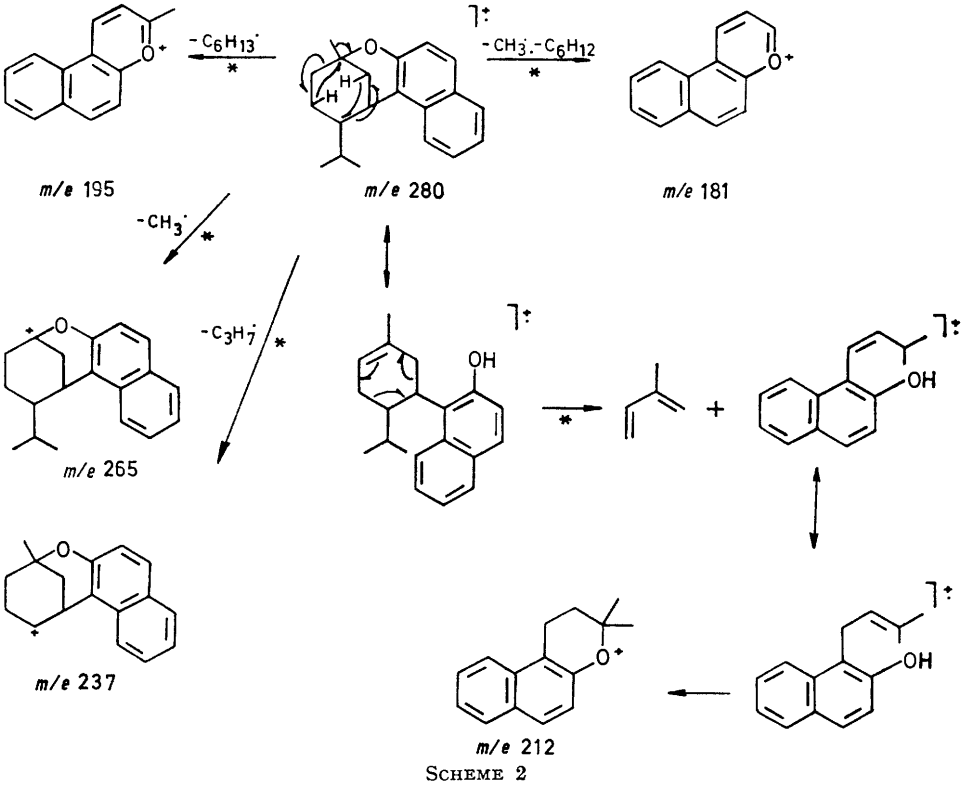
[5] F. W. Wehrli, personal communication.



SCHEME 1

site of the double bond through chemical shift study of the olefinic proton [6,7] is precluded owing to the free rotation of the β-naphthol ring.[6] Neither the i.r. nor the ^{1}H n.m.r. data of the *p*-nitrobenzoate of the adduct throw any light on this problem (see Experimental section). With regard to the mass spectrum, if a retro-Diels–Alder reaction were operative, one might expect the ion $M - C_5H_8$ from structure (6) and the ion $M - C_5H_{10}$ from (4) and (7). However, in addition to the peak due to molecular ion, the only other of appreciable abundance occurs at *m/e* 195, presumably $M - C_3H_7 - C_3H_6$ (Scheme 1). The free phenolic OH perhaps interferes with the retro-Diels–Alder fragmentation.[8,9]

In the formation of the iso-adduct, ring closure of structures (4) and (6) would lead to the dihydropyran (14), whereas structure (7) would give the dihydrofuran (13). The actual product, $C_{20}H_{24}O$ (M^+ 280), showed an i.r. band at 1 241 cm^{-1}, characteristic of an aryl ether linkage. In the ^{1}H n.m.r. spectrum, the coupling (*J* 8.7 Hz) of the aromatic protons adjacent to the ethereal oxygen atom again reveals an *ortho*-arrangement. Close proximity to the ring system may be responsible for the large magnetic non-equivalence of the isopropyl protons. The remaining methyl group resonates as a singlet at δ 1.36. Assignment of the signal at δ 3.7 to an ether type proton is ruled out because the ^{13}C n.m.r.



SCHEME 2

(6), and (7) (without stereochemical implications), need be considered for the adduct. Location of the spectrum exhibits a singlet at δ 74.1 which can only be assigned to a quaternary carbon atom next to oxygen.[10]

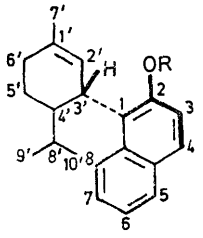
[6] R. Mechoulam and Y. Gaoni, *Tetrahedron*, 1965, **21**, 1226.
[7] R. Mechoulam and Y. Gaoni, *Tetrahedron*, 1966, **22**, 1482.
[8] L. Vollner, D. Bieniek, and F. Korte, *Tetrahedron Letters*, 1969, 146.
[9] U. Claussen, H. W. Fehlhaber, and F. Korte, *Tetrahedron*, 1966, **22**, 2536.
[10] N. S. Bhacca, F. W. Wehrli, and N. H. Fischer, *J. Org. Chem.*, 1973, **38**, 3618.

The broad singlet at δ 3.7 must be attributed to a benzylic proton.

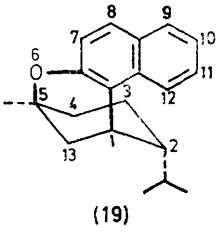
One cannot differentiate the isomers (13) and (14) by ^{1}H n.m.r.[11] An unambiguous discrimination is, however, feasible through mass spectrometry.[12] The mass spectrum shows a molecular ion at *m/e* 280, and peaks at $M - CH_3$, $M - C_3H_7$, 212, 195, and 181 (Scheme 2), which are typical of a dihydropyran system,[12-14] and consistent with structure (14).

To determine the position of the double bond in the original adduct, the dibromo-derivative, $C_{20}H_{24}Br_2O$, was prepared. Structures (4) and (6) would be expected to yield compounds (15) and (16), respectively. Structure (16) is ruled out because the bromomethine proton resonates at δ 4.7 as a doublet (J 4.5 Hz); this evidence also supports the exclusion of structure (7) for the adduct. Since the benzylic proton signal appears as a quartet at δ 4.3 ($J_{3',4'}$ 16, $J_{2',3'}$ 4.5 Hz), the C-2′ bromine atom is assigned an axial orientation. The structure of the adduct is thus established as (4) (without stereochemical implications).

The stereostructures (18) and (19) for the adduct and iso-adduct, respectively, are deduced from the following evidence. In the adduct, the benzylic proton is



(17) R = OC·C$_6$H$_4$·NO$_2$-*p*
(18) R = H



(19)

more deshielded than that in the iso-adduct (δ 4.1 and 3.7, respectively). A Dreiding model of structure (4) shows that the most stable conformer has the naphthalene ring in the same plane as the benzylic proton, which is therefore deshielded.[7] On the other hand, in the iso-adduct (19) the benzylic proton experiences a shielding effect, because the ring generated by the cyclisation step tilts the aromatic system. In the iso-adduct, the benzylic proton signal has $W_{\frac{1}{2}}$ 10 Hz, establishing its equatorial nature.[15] The cyclisation is thus preceded by a conformational change of the *p*-menthenyl system from diequatorial to diaxial.

In the ^{1}H n.m.r. spectra of substituted rigid cyclohexane derivatives, an α-benzylic proton appears at δ 2.8 or 3.5 depending upon whether a γ-methyl group is axial or equatorial.[7] Since in the iso-adduct the benzylic proton signal occurs at lower field, the equatorial orientation of the C-5 methyl group and, consequently, the *cis*-fusion of the ether ring are revealed.

EXPERIMENTAL

General procedures are as given previously.[16] ^{1}H N.m.r. spectra were recorded at 60 or 100 MHz for solutions in $CDCl_3$, with tetramethylsilane as internal reference. Mass spectra were run at 70 eV with samples being introduced at 150 °C.

1-[(3R,4R)-p-*Menth*-1-*en*-3-*yl*]-2-*naphthol* (4).—This compound, prepared by Salfeld's procedure,[2] had m.p. 139—140° (lit.,[2] 139—140°), $[\alpha]_D^{30}$ +109.6° (*c* 0.5 in $CHCl_3$) (Found: C, 85.9; H, 8.7%; M^+, 280. $C_{20}H_{24}O$ requires C, 85.7; H, 8.6%; *M*, 280), $\nu_{max.}$ 3 400 (OH), 1 620 (C=C), 1 600, 1 510 (aromatic), 1 380, 1 375, 1 160 (isopropyl), 880, 860 (trisubstituted C=C), and 810 (aromatic) cm^{-1}, δ(100 MHz) 7.88 (1 H, m, $J_{5,6}$ 7.5, $J_{5,7}$ 1.5, $J_{5,4}$ 0.6 Hz, 5-H), 7.67 (1 H, q, $J_{7,8}$ 7.5, $J_{6,8}$ 1.5 Hz, 8-H), 7.57 (1 H, q, $J_{3,4}$ 8.7, $J_{4,5}$ 0.6 Hz, 4-H), 7.35 (1 H, dt, J 7.5 and 1.5 Hz, 6- or 7-H), 7.20 (1 H dt, J 7.5 and 1.5 Hz, 6- or 7-H), 6.99 (1 H, d, $J_{3,4}$ 8.7 Hz, 3-H), 6.34 (1 H, s, CH), 5.52br (1 H, s, $W_{\frac{1}{2}}$ 10 Hz, 2′-H), 4.12br (1 H, d, $J_{3',4'}$ 11 Hz, 3′-H), 1.79 (3 H, s, 1′-Me), and 0.86 and 0.76 (6 H, d, J 7 Hz, CMe_2), *m/e* 280 (M^+, 55%), 265 (6), 237 (9), 210 (11), 195 (100), 181 (11), 165 (10), and 157 (6), *m** (280 → 231) 200.5, *m** (237 → 195) 160—161, *m** (280 → 195) 135.0.

(1S,2R,5S)-2,3,4,5-*Tetrahydro*-2-*isopropyl*-5-*methyl*-1,5-*methano*-1H-*naphth*[2,1-b]*oxocin* (14).—Compound (4) was isomerised to the *naphthoxocin* (14) with methanolic hydrogen chloride by following the directions previously described;[1] m.p. 105—106° (lit.,[2,3] 105—106°), $[\alpha]_D^{30}$ −85.6° (*c* 0.5 in $CHCl_3$) (Found: C, 85.5; H, 8.8%; M^+, 280. $C_{20}H_{24}O$ requires C, 85.7; H, 8.6%; *M*, 280), $\nu_{max.}$ 3 050, 1 620, 1 595, 1 510 (aromatic), 1 380, 1 375 (isopropyl), 1 250, 1 230 (aryl ether), 1 100, 1 075 (C–O str.), and 810 cm^{-1} (aromatic), δ(100 MHz) 7.73 (1 H, m, $J_{9,10}$ 7.5, $J_{9,11}$ 1.5, $J_{9,8}$ 0.6 Hz, 9-H), 7.65 (1 H, q, $J_{11,12}$ 7.5, $J_{10,12}$ 1.5 Hz, 12-H), 7.52 (1 H, q, $J_{7,8}$ 8.7, $J_{8,9}$ 0.6 Hz, 8-H), 7.36 (1 H, dt, 7.5 and 1.5 Hz, 10- or 11-H), 7.18 (1 H, dt, J 7.5 and 1.5 Hz, 10- or 11-H), 6.97 (1 H, d, $J_{7,8}$ 8.7 Hz, 7-H), 3.7br (1 H, s, $W_{\frac{1}{2}}$ 10 Hz, 1-H), 2.04 (1 H, q, $J_{13ax,13eq}$ 14, $J_{13eq,1}$ 2.5 Hz, 13_{eq}-H), 1.36 (3 H, s, 5-Me), and 1.22 and 0.93 (6 H, d, J 7 Hz, 6 H, CMe_2), *m/e* 280 (M^+, 86%), 265 (6), 237 (8), 212 (10), 210 (8), 195 (100), 181 (12), 165 (6), and 157 (17), *m** (280 → 265) 251.5, *m** (280 → 237) 200.6, *m** (280 → 212), 160.5, *m** (280 → 195) 136.0, *m** (280 → 181) 117.0.

1-[(3R,4R)-p-*Menth*-1-*en*-3-*yl*]-2-*naphthyl* p-*Nitrobenzoate* (17).—The procedure of Salfeld was used.[2] The *product* had m.p. 164—165° (lit.,[2,3] 164°), $[\alpha]_D^{30}$ +88.1° (*c* 2.6 in $CHCl_3$) (Found: C, 74.9; H, 6.6; N, 3.1. $C_{27}H_{24}NO_4$ requires C, 75.5; H, 6.3; N, 3.3%), $\nu_{max.}$ (KBr) 3 100, 3 070, 3 050 (aromatic), 1 730 (aryl ester C=O), 1 600, 1 590 (aromatic), 1 570 (NO_2), 1 380, 1 375, 1 170 (isopropyl), 850 (trisubstituted C=C), 730, and 698 cm^{-1} (monosubstituted benzene), δ(60 MHz) 8.2 (4 H, s, *p*-NO_2·C_6H_4), 7.8—7.2 (4 H, m, naphthyl protons), 7.60, 7.47, 7.07, and 6.94

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[13] R. K. Razdan and V. Kane, *J. Amer. Chem. Soc.*, 1969, **91**, 5190.
[14] H. Budzikiewicz, R. T. Alpin, D. A. Lightner, C. Djerassi, R. Mechoulam, and Y. Gaoni, *Tetrahedron*, 1965, **21**, 1881.
[15] E. C. Taylor, K. Lenard, and Y. Shvo, *J. Amer. Chem. Soc.*, 1966, **88**, 368.
[16] G. N. Saraswathi, N. V. Muraleedharan, and J. Verghese, *Indian J. Chem.*, 1974, **6**, 561.

(2 H, ABq, $J_{3,4}$ 8.5 Hz, 3- and 4-H), 5.35br (1 H, s, $W_{\frac{1}{2}}$ 12 Hz, 2′-H), 4.0br (1 H, d, $J_{3',4'}$ 11 Hz, 3′-H), 1.6 (3 H, s, 1′-Me), and 0.83 and 0.76 (6 H, d, J 7 Hz, CMe_2).

1-(1,6-*Dibromo*-p-*menthan*-3-*yl*)-2-*naphthol* (15).—To the adduct (4) (0.5 g) in ether (4 ml), cooled to 0 °C, was added dropwise with stirring a solution of bromine (0.3 g) in glacial acetic acid (2 ml), and the mixture was set aside for 1 h. It was then poured on ice and extracted with ether; the extract was washed successively with aqueous 10% sodium hydrogen carbonate and water. The usual work-up afforded the *dibromide* (0.25 g), m.p. 75° (from 80% ethanol) (Found: C, 54.7; H, 5.7; Br, 36.8. $C_{20}H_{24}Br_2O$ requires C, 54.5; H, 5.5; Br, 37.1%), $\nu_{max.}$ 3 400br (OH), 1 620, 1 590 (aromatic), 1 380, 1 375, 1 170 (isopropyl), 730, and 670 (C–Br) cm^{-1}, δ(60 MHz) 7.9 (4 H, m, naphthyl protons), 7.80, 7.66, 7.21, and 7.08 (2 H, ABq, J 8.5 Hz, 3- and 4-H), 4.71 (1 H, d, $J_{2',3'}$ 4.5 Hz, 2′-H), 4.3 (1 H, q, $J_{3',4'}$ 16, $J_{2',3'}$ 4.5 Hz, 3′-H), 2.0 (3 H, s, 1′-Me), and 0.92 and 0.75 (6 H, d, J 7 Hz, CMe_2).

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