4(1H)-Thiono-5,6-dihydro-4H-3,1-cyclopentathiazine-2-spirocyclopentane (IIa).—A solution of Ib (5 g) and cyclopentanone (6 g) in 200 ml of ethanol was refluxed for 4 hr. The resulting colorless material was collected and recrystallized from methanol to give *ca.* 0.2 g of morpholinium morpholine-N-dithiocarboxylate, mp 233–234° (in sealed tube).[2,3] The filtrate was concentrated and water was added. The yellow material which separated from the solution was recrystallized from ethanol to give *ca.* 3 g of yellow plates (IIa): mp 189–190°; uv max (99% EtOH) 336, 407 mμ (log ϵ 3.89, 4.36); ir ($CHCl_3$) 3398 (s, ν_{NH}), 1555 (vs, $\nu_{conjd\ C=C}$), 1518 cm^{-1} (vs, ν_{ring}); nmr (CF_3COOH) δ 9.50 (br, 1, **NH**), 2.97 (t, 4, C-5,7 $\mathbf{H}_2$), 2.30 (m, 6, C-6,2′,6′ $\mathbf{H}_2$), 2.05 (m, 4, C-3′,4′ $\mathbf{H}_2$). *Anal.* Calcd for $C_{11}H_{15}NS_2$: C, 58.65; H, 6.71; N, 6.22; S, 28.41. Found: C, 58.77; H, 6.68; N, 6.50; S, 28.18.

2,2-Dimethyl-4(1H)-thiono-5,6-dihydro-4H-3,1-cyclopentathiazine (IIb).—A mixture of Ib (5 g), acetone (5 g), and 200 ml of ethanol was refluxed for 4 hr and worked up as above to yield *ca.* 3.2 g of yellow plates (IIb): yield 80%, mp 172–173°; uv max (99% EtOH) 336, 406 mμ (log ϵ 3.67, 4.26); ir ($CHCl_3$) 3397 (s, ν_{NH}), 1548 (vs), 1520 (s), 1453 cm^{-1} (m); nmr (CF_3COOH) δ 9.50 (br, 1, **NH**), 2.95 (t, 4, C-5,7 $\mathbf{H}_2$), 2.27 (m, 2, C-6 $\mathbf{H}_2$), 1.87 (s, 6, 2C$\mathbf{H}_3$). *Anal.* Calcd for $C_9H_{13}NS_2$: C, 54.26; H, 6.58; N, 7.03; S, 32.13. Found: C, 54.53; H, 6.73; N, 7.11; S, 31.87.

4(1H)-Thiono-5,6-dihydro-4H-3,1-cyclopentathiazine-2-spirocyclohexane (IIc).—A mixture of Ib (5 g), cyclohexanone (6 g), and 200 ml of ethanol was refluxed for 4 hr and worked up as above to yield *ca.* 4 g of yellow plates (IIc): yield 85%; mp 186–187°; uv max (99% EtOH) 334, 406 mμ (log ϵ 3.91, 4.41); ir ($CHCl_3$) 3385 (s), 1550 (vs), 1520 (s), 1450 cm^{-1} (m); nmr (CF_3COOH) δ 9.40 (br, 1, **NH**), 2.93 (t, 4, C-5,7 $\mathbf{H}_2$), 2.25 (m, 6, C-6,2′,6′ $\mathbf{H}_2$), 1.80 (m, 6, C-3′,4′,5′ $\mathbf{H}_2$). *Anal.* Calcd for $C_{12}H_{17}NS_2$: C, 60.24; H, 7.16; N, 5.85; S, 26.75. Found: C, 60.20; H, 7.09; N, 5.99; S, 26.79.

4(1H)-Thiono-5,6-dihydro-4H-3,1-cyclopentathiazine-2-spirocycloheptane (IId).—A mixture of Ib (5 g), cycloheptanone (4,3 g), and 200 ml of ethanol was refluxed for 4 hr and worked up as above to yield *ca.* 4.0 g of yellow plates (IId): yield 80%; mp 204–205°; uv max (99% EtOH) 338, 408 mμ (log ϵ 3.80, 4.32); nmr (CF_3COOH) δ 9.10 (br, 1, **NH**), 2.95 (t, 4, C-5,7 $\mathbf{H}_2$), 2.33 (m, 6, C-6,2′,7′ $\mathbf{H}_2$), 1.73 (s, 8, C-3′,4′,5′,6′ $\mathbf{H}_2$). *Anal.* Calcd for $C_{13}H_{19}NS_2$: C, 61.64; H, 7.56; N, 5.53; S, 25.27. Found: C, 61.42; H, 7.40; N, 5.50; S, 25.45.

2,2-Diethyl-4(1H)-thiono-5,6-dihydro-4H-3,1-cyclopentathiazine (IIe).—A mixture of Ib (5 g), diethyl ketone (10 g), and 200 ml of ethanol was refluxed for 4 hr and worked up as above to yield *ca.* 2.3 g of yellow plates (IIe): yield 50%; mp 183–184°; uv max (99% EtOH) 338, 411 mμ (log ϵ 3.76, 4.19); nmr (CF_3COOH) δ 9.56 (br, 1, **NH**), 2.95 (t, 4, C-5,7 $\mathbf{H}_2$), 2.35 (m, 6, C-6 $\mathbf{H}_2$, $-C\mathbf{H}_2-CH_3$), 2.03 (t, 6, 2-C$\mathbf{H}_3$). *Anal.* Calcd for $C_{11}H_{17}NS_2$: C, 58.13; H, 7.54; N, 6.16; S, 28.16. Found: C, 58.36; H, 7.45; N, 6.19; S, 27.90.

2-Isopropyl-2-methyl-4(1H)-thiono-5,6-dihydro-4H-3,1-cyclopentathiazine (IIf).—A mixture of Ib (5 g), methyl isopropyl ketone (10 g), and 200 ml of ethanol was refluxed for 4 hr and worked up as above to yield *ca.* 2.8 g of yellow plates (IIf): yield 60%; mp 184–185°; uv max (99% EtOH) 338, 409 mμ (log ϵ 3.79, 4.31); nmr (CF_3COOH) δ 9.56 (br, 1, **NH**), 2.95 (t, 4, C-5,7 $\mathbf{H}_2$), 2.45 [m, 1, $-C\mathbf{H}(CH_3)_2$], 2.33 (s, 3, C$\mathbf{H}_3$), 2.15 [d, 6, $-CH(C\mathbf{H}_3)_2$], 2.00 (m, 2, C-6 $\mathbf{H}_2$). *Anal.* Calcd for $C_{11}H_{17}NS_2$: C, 58.13; H, 7.54; N, 6.16; S, 28.16. Found: C, 58.34; H, 7.35; N, 6.33; S, 28.09.

Compounds IIa–IIf were easily soluble in methanol, pyridine, and hydrochloric acid and hardly soluble in water; in methanol solution they readily decolorized bromine water.

Di(2-iminocyclopentylidenemercaptomethyl) Disulfide (III).—Compound I (5 g) and an equivalent amount of sodium hydroxide were dissolved in a requisite amount of water and oxidized with iodine solution in the usual way. The yellow material obtained was recrystallized from pyridine–water to yield 4.5 g of yellow plates (III): yield *ca.* 90%; mp 152–153°; uv max (99% EtOH) 308, 398 mμ (log ϵ 4.01, 4.64); ir ($CHCl_3$) 3450 (s, ν_{NH}), 1650 (sh, δ_{NH}), 1630 (sh, $\nu_{C=N}$), 1600 cm^{-1} (vs, $\nu_{conjd\ C=C}$); nmr (CD_3SOCD_3) δ 10.80 (m, 2, 2NH), 9.30 (s, 2, 2S**H**), 2.95 (t, 4, C-5,5′ $\mathbf{H}_2$, J = 6 cps), 2.70 (t, 4, C-3,3′ $\mathbf{H}_2$, J = 6 cps), 1.90 (m, 4, C-4,4′ $\mathbf{H}_2$, J = 8 cps); mass spectrum (75 eV) m/e (rel intensity) 318 (0.04), 316 (0.2), 158 (20), 157 (100), 126 (65), 125 (20), 124 (71), 76 (98). *Anal.* Calcd for $C_{12}H_{16}N_2S_4$: C, 45.50; H, 5.10; N, 8.80; S, 40.50. Found: C, 45.75; H, 4.95; N, 8.90; S, 40.53.

Compound III was also obtained by refluxing I with tetrahydrofuran for 0.5 hr; the yield was 40%.

4(1H)-Thiono-5,6,7,8-tetrahydro-4H-3,1-cycloheptathiazine-2-spirocycloheptane (IV).—A mixture of cycloheptanone (25 g, 0.26 mol), carbon disulfide (30 g, 0.39 mol), and 290 ml of aqueous ammonia (28%) was stirred below 0° for 8 hr. The reaction mixture was kept overnight in an icebox. The yellow solid product was collected, washed with water, and dried: yield *ca.* 20 g. The crude product was recrystallized from methanol to give *ca.* 18 g of yellow plates (IV): yield *ca.* 50%; mp 199–200°; color reaction toward cupric ion, deep red; uv max (99% EtOH) 335, 409 mμ (log ϵ 3.67, 4.32); ir ($CHCl_3$) 3392, (s, ν_{NH}), 1520 (vs, $\nu_{conjd\ C=C}$), 1460 (m, ν_{ring}), 1450 cm^{-1} (m, ν_{ring}). *Anal.* Calcd for $C_{15}H_{23}NS_2$: C, 64.03; H, 8.24; N, 4.98; S, 22.75. Found: C, 63.90; H, 7.95; N, 5.09; S, 22.45.

4,5,6,7-Tetrahydro-1,2-cycloheptadithiole-3-thione (V).—The preceding mother liquor from which IV was removed was concentrated under diminished pressure at 40° and allowed to stand at 0° for 3 hr. The yellow solid material was collected and recrystallized from carbon tetrachloride to give *ca.* 3.5 g of yellow needles: yield *ca.* 7%; mp 98–99° (lit.[5] mp 99°); uv max (99% EtOH) 229 244, 279, 312, 413 mμ (log ϵ 4.04, 3.81, 3.86, 3.73, 4.00); ir ($CHCl_3$) 2980 (s, ν_{CH}), 2930 (vs, ν_{CH}), 2855 (s, ν_{CH}), 1520 (m, $\nu_{conjd\ C=C}$), 1300 (vs, $\nu_{heteroring}$), 1150 (vs, $\nu_{C=S}$), 530 cm^{-1} (s, ν_{S-S}); nmr ($CDCl_3$) δ 2.98 (t, 4, C-1′,5′ $\mathbf{H}_2$), 1.75 (m, 6, C-2′,3′,4′ $\mathbf{H}_2$). *Anal.* Calcd for $C_8H_{10}S_3$: C, 47.53; H, 4.99; S, 47.49. Found: C, 47.47; H, 4.96; S, 47.25.

Registry No.—Ammonia, 7664-41-7; cyclopentanone, 120-92-3; cycloheptanone, 502-42-1; I, 18521-91-0; Ia, 18521-92-1; Ib, 18521-93-2; IIa, 18521-94-3; IIb, 18521-95-4; IIc, 18521-96-5; IId, 18521-97-6; IIe, 18521-98-7; IIf, 18521-99-8; III, 18522-00-4; IV, 18522-01-5; V, 6125-89-9.

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Synthesis of (−)-1,2β,3,4,4a,5,6,7,8,8aβ-Decahydro-4aα,8β-dimethyl-7-oxo-2-naphthoic Acid Methyl Ester

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In connection with studies directed toward the total synthesis of *cis*- and *trans*-fused bicyclic sesquiterpenes of the eudalene group having carbon skeleton I,[1,2] the

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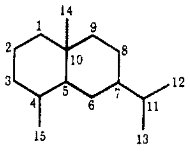
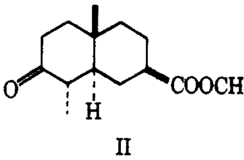
[1] We thank the donors of the Petroleum Research Fund administered by the American Chemical Society for their initial support (Grant No. 283-G) of this program, and the National Institutes of Health for continued support (Grant No. 5-R01-GM-13441-01 to -03). Portions of this Note were abstracted from Y. Wang, M.S. Thesis, Washington University, 1966.

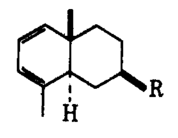
[2] The numbering system and nomenclature used are essentially those of W. Cocker and T. B. H. McMurry, *J. Chem. Soc.*, 4549 (1956).



I

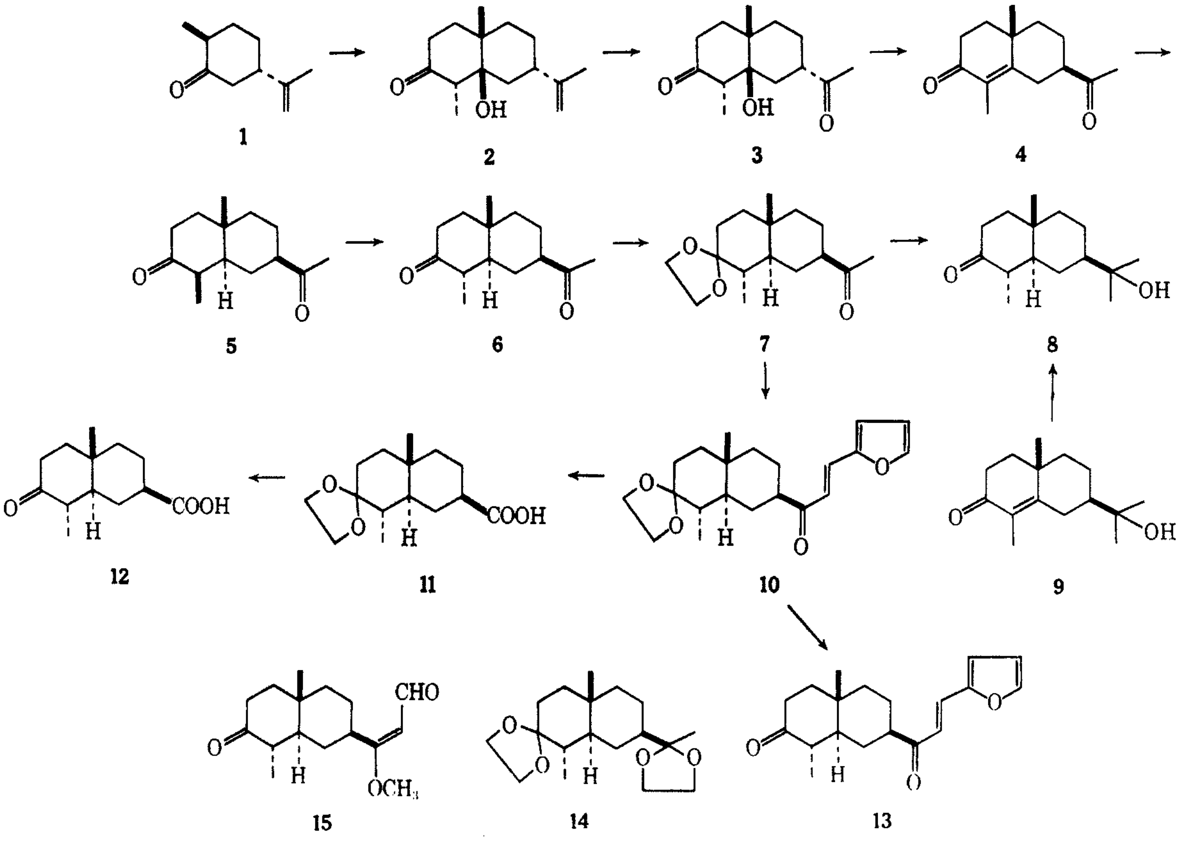


II



III

SCHEME I



need arose for a *trans*-4,10-dimethyl-3-decalone having a functional group at C-7 which would be relatively inert toward a variety of reaction conditions necessary to effect further modifications of ring A, would allow for the determination (by studies of base-catalyzed epimerization at C-7) of the relative stabilities of the 5αH,10α-CH_3 and 5βH,10β-CH_3 *cis*-fused dienes derivable by photolysis–recyclization of a corresponding 5α,10β-*trans*-fused diene III,[3] and, finally, would be readily convertible into the 7-$C(CH_3)_2OH$, 7-$C(CH_3){=}CH_2$, and 7-$CH(CH_3)_2$ groups commonly found in naturally occurring eudesmanes. The title compound [(−)-II] was ideally suited to our purposes, and its synthesis and correlation with (−)-*trans*-dihydrocarissone are the subject of this Note.[4–6]

Ketol **2** was prepared (Scheme I) by condensation of (−)-dihydrocarvone (**1**) with 1-chloro-3-pentanone, a reported procedure[7,8] which we have found can be improved by using an excess of chloro ketone and operating at lower temperature.[9] Ozonolysis of **2** gave diketo alcohol **3** (92%) which was cleanly dehydrated (and epimerized at C-7) under acidic conditions yielding diketone **4** (82%). Diketone **4**, on hydrogenation over palladium on strontium carbonate, yielded predominantly **5**. Refluxing the crude reduction product with hydrochloric acid in ethanol gave a mixture of **6** and a *cis*-fused isomer in an *ca.* 4:1 ratio (glpc analysis)[10] from which it was possible to isolate pure, crystalline diketone **6** in 67% yield. Diketone **6** exhibited an optical rotation value similar to that reported[7] for a *liquid* ketone of the same structure and gave biscarbonyl derivatives having melting points in agreement with those reported;[7] however, more convincing proof for the assigned *trans* ring fusion came from conversion of **6** into the monoketal **7** which, on treatment with

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(3) A. G. Hortmann, M. Tio, and J. E. Martinelli, unpublished results; *cf.* E. J. Corey and A. G. Hortmann, *J. Amer. Chem. Soc.*, **87**, 5736 (1965).

(4) Racemic compounds related to II have been synthesized in very low yield *via* the annelation of esters of 2-methylcyclohexane 5-carboxylate,[3,5] and by other unrelated, but novel, routes.[6]

(5) A. R. Pinder and R. A. Williams, *J. Chem. Soc.*, 2773 (1963).

(6) A. C. Kryger, Ph.D. Thesis, Iowa State University, 1963; N. J. Johnston, Ph.D. Thesis, University of Virginia, 1963.

(7) T. G. Halsall, D. W. Theobald, and K. B. Walshaw, *J. Chem. Soc.*, 1029 (1964), and references cited. Although the yield of **2** obtained by these authors, is comparable with those obtained previously[8] in similar annelations of **1**, their preparation of this valuable, and often-used, intermediate represents a marked improvement in terms of convenience. Our own experience with all of these preparations indicates that considerable care and manipulation are required to isolate **2** in yields approaching those reported; the low-temperature preparation reported here results in higher yields and allows for crystallization of most of the ketol **2** directly from the crude, undistilled reaction product.[9]

(8) F. J. McQuillin, *J. Chem. Soc.*, 528 (1955); R. Howe and R. J. McQuillin, *ibid.*, 2423 (1955).

(9) A similar preparation which utilized ethyl vinyl ketone and was conducted at −10° gave a moderate yield of **2** mixed with its 5α,10α diastereomer in a 7:3 ratio: J. A. Marshall and W. I. Fanta, *J. Org. Chem.*, **29**, 2501 (1964).

(10) *Cf.* R. L. Augustine, *ibid.*, **28**, 152 (1963).

methyllithium followed by hydrolysis of the ketal function, gave (−)-*trans*-dihydrocarissone (**8**) identical in all respects with a sample of **8** prepared as described previously[11] by reduction of (+)-carissone (**9**) with lithium in liquid ammonia.

The conversion of **6** into title compound II was accomplished most efficiently by the route **6** → **7** → **10** → **11** → **12** → II which was effected in 41% over-all yield without isolation or purification of any intermediates. Diketone **6**, on extended treatment with 1.2 mol equiv of ethylene glycol in the presence of acid, gave an equilibrium mixture of **7**, **14**, and **6** in a ratio of 5:2:1 along with minor amounts of other substances (nmr analysis). The crude product, on treatment with furfural and sodium hydroxide,[12] gave a mixture **10**, **14** and (presumably) the difurfurylidene derivative of **6**. Exposure of this mixture to excess ozone, followed by reduction of the resulting ozonides with hydrogen peroxide in aqueous base, yielded the neutral diketal **14** (20% recovery), and a mixture of acidic products (including **11**) which was treated with aqueous acid to remove any ethylenedioxy groups present. Esterification of the resulting crude keto acid **12** with diazomethane, followed by rapid filtration through alumina, afforded essentially pure keto ester II. The recovered diketal **14** could be recycled through the above procedure *via* initial equilibration[13] with 0.85 mol equiv of diketone **6**.

An alternate preparation of II involving oxidation of **7** to **11** with potassium hypoiodite could be effected in 26% yield, but was found to be impractical for large-scale work.

A third approach to II, based on observations made with steroidal methyl ketones,[14] involved the conversion of **6**, in the presence of trimethyl orthoformate and perchloric acid, to an air-sensitive mixture of products believed to contain **15**; ozonolysis of **15** afforded II in 15% yield.

Experimental Section[15,16]

(−)-5β-Hydroxy-4,7βH-eudesm-11-en-3-one[7] (2).—To 86.5 g (3.60 mol) of sodium hydride in 3 l. of freshly distilled anhydrous tetrahydrofuran containing 10 ml of absolute ethanol was added 534 g (3.51 mol) of (−)-dihydrocarvone (**1**), bp 60–61° (2.5 mm). After refluxing under nitrogen for 6 hr the mixture was cooled (ice–salt bath) to −7° and 1-chloropentan-3-one[17] [454 g (3.77 mol); bp 46.0–48.5° (4.8–5.1 mm)] was added dropwise with stirring during 2.75 hr. The temperature was maintained at 0–5° during the addition and for 1.5 hr afterward. Excess sodium hydride and base were decomposed at 0° by adding 35 ml of 20% aqueous acetic acid followed by 500 ml of water. The tetrahydrofuran layer was separated from the resulting aqueous layer which was then extracted with ether. The tetrahydrofuran layer and ether extracts were combined; washing with saturated sodium chloride solution containing ~1% sodium bicarbonate followed by removal of solvent and small amounts of ethyl vinyl ketone gave a slurry of crystals which yielded, upon addition of petroleum ether and cooling, 395 g (two crops) of **2** as white prisms, mp 102.0–105.5°. Recrystallization from methylene chloride–petroleum ether afforded 288 g, mp 106.5–107.5°. A *rapid* simple distillation of the combined mother liquors yielded four main fractions: fraction 1, 104 g, bp 70–75° (0.6 mm), which was mainly (−)-dihydrocarvone (**1**) (nmr analysis); fraction 2, 11 g, bp 75–133° (0.3 mm); fraction 3, 243 g, bp 133–146° (0.3 mm); fraction 4, 85 g, bp 158–208° (0.7 mm). On seeding with **2**, fraction 3 yielded 78 g of **2** in two crops (no melting point taken); combination of this material with the 288 g of crop and recrystallization gave 340 g of **2** as heavy prisms from methylene chloride–petroleum ether: mp 105.5–107.5° (lit.[7] mp 108°); yield[18] 51% (based on unrecovered **1**).

(−)-5β-Hydroxy-4,7βH-noreudesmane-3,11-dione (3).—A solution of **2** (93.6 g, 0.395 mol) in 150 ml of methanol and 320 ml of methylene chloride was treated with ozone at −70° until the solution became blue. Excess ozone was expelled and the ozonide was decomposed by addition of the cold solution to a stirred slurry of sodium iodide (150 g) in 275 ml of methanol and 200 ml of glacial acetic acid initially at 0–5°. After 15 min the ice bath was removed and stirring was continued at ambient temperature for 1.5 hr. The resulting slurry of iodine and dissolved product was poured into 3 l. of water containing 100 g of sodium bisulfite and the product was exhaustively extracted into six 150-ml portions of methylene chloride. The usual work-up procedure was followed by successive replacement of boiling methylene chloride with ethyl acetate, and boiling ethyl acetate with petroleum ether and concurrent crystallization of the product from *ca.* 400 ml of boiling solution. Filtration of the cooled solution gave 84.2 g of hydroxy diketone **3** as minute prisms: mp 179.0–180.2°; ir ($CHCl_3$) 3500, 1715 cm^{-1}; nmr ($CDCl_3$) τ 7.88 (s, 3, H-13), 8.75 (s, 3, H-14), 8.94 (d, 3, $J = 7$ Hz, H-15) and 7.13 (q, 1, $J = 6.7$ Hz, H-4). An additional 2.6 g of **3**, mp 176.8–178.8°, was obtained from the mother liquors; total yield 86.8 g (92%). The analytical sample, mp 178.5–179.5°, was obtained by recrystallization of the first crop material from ethyl acetate.

Anal. Calcd for $C_{14}H_{22}O_3$: C, 70.56; H, 9.30. Found: C, 70.68; H, 9.20.

In several experiments **3** was obtained as a polymorph: flat plates, mp 138–140°; ir and nmr spectra were identical with those of the higher melting form.

7αH-12-Noreudesm-4-ene-3,11-dione (4).—A solution of hydroxy diketone **3** (141.7 g, 0.596 mol) in 700 ml of glacial acetic acid and 1000 ml of methylene chloride was treated with 80 g of dry hydrogen chloride gas at 10°. After refrigeration at 3–5° for 17.5 hr, the reaction mixture was poured into water and extracted with methylene chloride. The usual work-up procedure[16] yielded 83.3 g of **4**, mp 75.5–79°, in several crops from petroleum ether. Simple distillation of the mother liquors yielded a large fraction, bp ~153–156° (0.3 mm), which afforded an additional 24.9 g of **4**, mp 77.6–79.0°. Recrystallization of low-melting materials afforded a total of 107.4 g (82%) of diketone **4** as pale yellow prisms: mp 77.6–79.3°; ir 1720, 1680, and 1620 cm^{-1}; nmr τ 7.89 (s, 3, H-13), 8.31 (s, 3, H-15) and 8.76 (s, 3, H-14). An analytical sample, mp 77.5–78.1°, uv max (MeOH) 247 mμ (ϵ 16,500), was obtained after three additional recrystallizations from petroleum ether.

Anal. Calcd for $C_{14}H_{20}O_2$: C, 76.33; H, 9.15. Found: C, 76.28; H, 8.95.

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[11] D. C. Humber, A. R. Pinder, and R. A. Williams, *J. Org. Chem.*, **32**, 2335 (1967). We wish to thank Professor Pinder for kindly supplying us with a sample of (+)-carissone (**9**).

[12] W. S. Johnson, J. C. Collins, Jr., R. Pappo, M. B. Rubin, P. J. Kropp, W. F. Johns, J. E. Pike, and W. Bartmann, *J. Amer. Chem. Soc.*, **85**, 1409 (1963), and references cited.

[13] W. S. Johnson, D. S. Allen, Jr., R. R. Hindersinn, G. N. Sausen, and R. Pappo, *ibid.*, **84**, 2181 (1962).

[14] J. P. Dusza, private communication, 1967.

[15] All boiling points are uncorrected; all melting points were taken on a Hoover capillary melting point apparatus and are corrected. Infrared spectra were obtained on 10% solutions (w/v) in carbon tetrachloride as solvent (unless indicated otherwise) using a Perkin-Elmer Model 21 spectrophotometer. Nmr spectra were obtained on *ca.* 20% solutions (CCl_4) using a Varian A-60A instrument; peak positions are reported in τ (parts per million) using tetramethylsilane at τ 10.00 as an internal standard. Ultraviolet spectra were run on a Cary 14 recording spectrophotometer. Microanalyses were performed by the Microanalytical Laboratory at the Institute for Physical Chemistry, Vienna, Austria, and by Galbraith Laboratories, Inc., Knoxville, Tenn. 37921.

[16] Unless described otherwise, all products were isolated by extracting into an organic solvent and successively washing the combined extracts with water, saturated sodium bicarbonate solution and saturated sodium chloride solutions (the wash solutions were back-extracted), drying over anhydrous sodium or magnesium sulfate, and removing the solvent *in vacuo* at *ca.* 40–60°. The petroleum ether used was the fraction boiling at 63–69°.

[17] R. B. Woodward, F. Sondheimer, D. Taub, K. Heusler, and W. M. McLamore, *J. Amer. Chem. Soc.*, **74**, 4223 (1952).

[18] We anticipate that further improvements in yield might be achieved by operating at slightly lower temperatures, and by chromatographing[8] the material in the mother liquors on alumina.

Comparable yields of **4** can be obtained by refluxing a benzene solution of **3** containing 1% *p*-toluenesulfonic acid for an extended period, removing the water formed with a Dean–Stark trap. The C-7 epimer of **4** which is found in the mother liquors after removal of most of **4** can be recycled under similar conditions to yield additional **4**.

4,5,7αH-12-Noreudesmane-3,11-dione (5).—A solution of **4** (1.00 g, 0.0045 mol) in 50 ml of ethanol containing a trace of water was hydrogenated using 0.05 g of 2% Pd–$SrCO_3$[17] as catalyst. After absorption of 1.07 mol equiv of hydrogen the catalyst was removed and the filtrate evaporated to dryness yielding 1.01 g of crystalline solid, mp 80–81°. Two recrystallizations afforded 0.31 g of diketone **5**: mp 84.4–85°; ir 1720 cm^{-1}; nmr ($CDCl_3$) τ 8.91 (d 3, J = 7 Hz, H-15), 8.88 (s, 3, H-14) and 7.85 (s, 3, H-13); nmr (CCl_4) τ 9.04 (s, 1.5, H-15), 8.89 [s, 4.5, H-14 (3) and H-15 (1.5)] and 7.94 (s 3, H-13). The structural assignment for diketone **5** rests on the differences in its infrared (1300–840 cm^{-1}) and nmr spectra when compared with those of **6**, and on the conversion of **5** to **6** upon refluxing in ethanolic hydrochloric acid solution.

5,7αH,4βH-12-Noreudesmane-3,11-dione (6).—A solution of **4** (99.2 g, 0.454 mol) in 1390 ml of ethanol containing 25 ml of water was hydrogenated at 27° (755 mm) using 2.62 g of 2% Pd–$SrCO_3$[17] as catalyst. After absorption of 0.99 mol equiv, further uptake of hydrogen ceased. The catalyst was removed and 160 ml of 12 *N* HCl was added to the filtrate which was then refluxed for 3.2 hr, cooled, reduced in volume *in vacuo*, and worked up in the usual way[16] to yield 71.9 g of nearly pure **6** in several crops from cold petroleum ether. Recrystallization afforded 66.7 g of diketone **6** as colorless prismatic bars: mp (two crops) 51–52.5° (uncor); ir 1706 cm^{-1}; nmr (CCl_4) τ 9.06 (d, 3, J = 6.5 Hz, H-15), 8.88 (s, 3, H-14) and 7.91 (s, 3, H-13); nmr ($CDCl_3$) τ 8.93 (d, 3, J = 6.5 Hz, H-15), 8.82 (s, 3, H-14) and 7.75 (s, 3, H-13). An analytically pure sample of **6** exhibited mp 53–54° (cor); $[\alpha]^{26.5}\text{D}$ −36.8° (*c* 1.8, $CHCl_3$) [lit.[7] $[\alpha]\text{D}$ −31° (*c* 1.8, $CHCl_3$)].

Anal. Calcd for $C_{14}H_{22}O_2$: C, 75.63; H, 9.97. Found: C, 75.75; H, 10.06.

The bis-2,4-DNP derivative of **6** exhibited mp 278° (turned black), 282–284° dec (lit.[7] mp 275–277°); the bissemicarbazone of **6** had mp 241–242° dec (lit.[7] mp 252°).

The combined mother liquors from crystallization of **6** appear, from nmr and glpc analysis, to contain additional **6** mixed with a *cis*-fused isomer of **6** in a ratio of about 1:2 and were not further investigated.

3-Ethylenedioxy-5,7αH,4βH-12-noreudesman-11-one (7).—A solution of diketone **6** (8.89 g, 0.040 mol), diketal **14** (9.35 g, 0.030 mol), ethylene glycol (0.744 g, 0.012 mol) and *p*-toluenesulfonic acid monohydrate (0.51 g) in 150 ml of benzene was equilibrated[13] at reflux temperature for 22.5 hr, using a water separator to remove any small amounts of water initially present. The usual work-up procedure yielded 17.1 g of orange oil which contained **7**, **14** and **6** in a 5:2:1 ratio (estimated by nmr analysis). Chromatography on basic alumina (Alcoa F-20, grade 2; 785 g packed to yield a 75 × 4.2 (diameter) cm column). Fifty-seven fractions (750 ml) were collected starting with petroleum ether–benzene (3:1) as eluent: fractions 1–8 (25% benzene) and 9–12 (33% benzene), 2.60 g of yellow oil which yielded 1.24 of diketal **14**, mp 86.0–88.5°; fractions 13–45 (33–100% benzene), 9.60 g of oil which contained *ca.* 70% monoketal **7** (nmr) and yielded 1.51 g, mp 54–55° (uncor) from fractions 25–35; fractions 46–57 (pure benzene to pure diethyl ether), 5.05 g of yellow oil, *ca.* 80% **6** (nmr). Two recrystallizations of the 1.51-g crop of **7** from petroleum ether afforded essentially pure monoketal **7** as heavy prisms: mp 54.3–55.0° (uncor); ir ($CHCl_3$) 1710 cm^{-1}; nmr τ 9.23 (d, 3, J = 6 Hz, H-15), 9.12 (s, 3, H-14), 7.95 (s, 3, H-13) and 6.13 (s, 4, $-OCH_2CH_2O-$). The structure of **7** rests on spectral data and on its conversion to **8** (see B below).

(−)-12-Hydroxy-5,7αH,4βH-eudesman-3-one (8) [(−)-*trans*-Dihydrocarissone]. A.—An authentic sample of (−)-*trans*-dihydrocarissone (**8**), mp 110.5–111.5°, was prepared by reduction of (+)-carissone (**9**) with lithium in ammonia as previously described.[11]

B.—To a solution of 0.500 g (0.00188 mol) of monoketal **7** in anhydrous ether at 0° was added 2.4 ml of a solution (~0.8 *M*) of methyllithium in ether. The mixture was stirred for 2 hr, diluted with water and extracted with ether. The usual work-up procedure yielded a colorless oil which appeared to contain at least 80% of the 3-ethylenedioxy derivative of **8** by nmr analysis. The crude product was dissolved in 10 ml of ethanol and 2 ml of 10% HCl and the resulting solution was kept at 0–5° for 2 hr. Extraction with ether followed by the usual work-up procedure gave 0.242 g (46%) of **8** as prisms from petroleum ether, mp 90–106°; several recrystallizations from the same solvent yielded 0.093 g of (−)-*trans*-dihydrocarissone (**8**) as colorless plates: mp 111.3–112.5° [lit.[11] mp 109–110° (uncor)]; $[\alpha]^{27}\text{D}$ −7.9° (*c* 2.0, $CHCl_3$) [lit.[11] $[\alpha]^{25}\text{D}$ −11.7° (*c* 2.0, $CHCl_3$)]; ir 3450, 1708 cm^{-1} [lit.[11] (CCl_4) 3615, 1715 cm^{-1}]; nmr[19] τ 9.04 (d, 3, J = 6.5 Hz, H-15), 8.92 (s, 3, H-14) and 8.84 (s, 6, H-12 and H-13). This material exhibited no melting point depression when admixed with a sample of **8** prepared as described above in A.

13-Furfurylidene-5,7αH,4βH-12-noreudesmane-3,11-dione (13).—To a solution of monoketal **7** (1.33 g, 0.005 mol) in 7 ml of absolute ethanol containing 2.5 ml of aqueous 15% NaOH was added 0.70 g (0.0073 mol) of freshly distilled furfural at 0° under nitrogen. After stirring for 2 hr at ambient temperature, the mixture was stored at −5° for 12 hr. The usual work-up procedure[16] gave 1.85 g of viscous yellow oil which could not be induced to crystallize. Two-thirds of the crude product was treated with 10% HCl (10 ml) in dioxane (25 ml) for 3 hr at room temperature. The usual work-up procedure (during which some accidental losses were incurred) gave 0.81 g of red-brown crystals which were dissolved in methylene chloride and adsorbed on a column of alumina (8 g). Elution with 75 ml of methylene chloride gave **13** as an oil which crystallized as pale yellow prisms, mp 114.5–116.5° from diethyl ether–methylene chloride–petroleum ether. Several recrystallizations afforded a sample of **13** which exhibited mp 117–118°; ir ($CHCl_3$) 1695, 1675, 1605 and 1548 cm^{-1}; nmr τ 8.86 (s, 3, H-14), 9.05 (d, 3, J = 6.5 Hz, H-15) and an AB pattern (J = 15.6 Hz) centered at 2.71 and 3.39 (partially obscured by signals due to three other protons located on the furan ring).

Methyl 3-Oxo-5,7αH,4βH-12,13-bisnoreudesman-11-oate (11). A. *Via* **Ozonolysis of 3-Ethylenedioxy-13-furfurylidene-5,7αH,4βH-12-noreudesman-11-one (10).**—A solution of diketone **6** (52.2 g, 0.235 mol), ethylene glycol (19.44 g, 0.298 mol), and *p*-toluenesulfonic acid monohydrate (1.7 g) in 300 ml of benzene was heated at reflux temperature for 18.5 hr, removing the water formed with a Dean–Stark water separator. The usual work-up[16] yielded an orange oil which contained a mixture of **7**, **15** and **6** in a ratio of 5:2:1 (estimated by nmr analysis) along with minor amounts of other substances. The oil was dissolved in 340 ml of absolute ethanol. The resulting solution was placed under a nitrogen atmosphere, cooled to 0° and treated successively, while being stirred rapidly, with 15% aqueous NaOH (120 ml) and freshly distilled furfural (34.0 g, 0.354 mol; added all at once). The cooling bath was removed and stirring was continued at ambient temperature for 2.25 hr during which the solution turned deep red in color and an oily layer separated. The reaction mixture was stored at 5° for 12 hr and then worked up as usual after adding 1.5 l. of water. The resulting gum was dissolved in 750 ml of methanol–methylene chloride (2:1) and treated with a stream of ozone in oxygen (0.2 mol/hr) at −70° for 4.8 hr. The cold reaction mixture was carefully poured into a rapidly stirred mixture of water (500 ml), 30% aqueous hydrogen peroxide (350 ml) and potassium bicarbonate (160 g) while maintaining the temperature at 5–15°. After 18 hr at *ca.* 35° the resulting basic solution was diluted with 2800 ml of water and extracted with three 250-ml portions of chloroform; the extracts were washed and dried as usual; and the solvent was removed yielding 32.8 g of yellow oil which afforded 17.48 g of pale yellow crystalline solid from petroleum ether. One additional recrystallization yielded 14.5 g (0.047 mol) of nearly pure diketal **14**, mp 85.5–89.0°, which represents a 20% recovery of **6**. The remaining basic peroxide solution was slowly poured into 250 ml of 12 *N* HCl while stirring rapidly to allow the evolved carbon dioxide to escape. Extraction with seven 160-ml portions of chloroform and washing the combined extracts with brine gave a colorless oil which was dissolved in a 10% solution of hydrochloric acid in tetrahydrofuran–water (8:2) and kept at room temperature for 1.7 hr to facilitate hydrolysis of any ketal groups. Dilution with water and thorough extraction with chloroform gave 34.4 g of semicrystalline product which was dissolved in diethyl ether and treated with excess diazomethane (in ether) for 5 min at 0°. The resulting mixture of methyl esters, after removal of the solvent, was adsorbed on a column of alumina

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[19] The nmr peak positions cited here are identical with those reported.[11] The original assignments[11] have been revised: D. C. Humber, A. R. Pinder, and R. A. Williams, *J. Org. Chem.*, **33**, 4314 (1968).

(290 g; Alcoa F-20; activity grade ~2) packed in benzene–petroleum ether (3:2); elution with the same solvent mixture (1400 ml) followed by pure benzene (2000 ml) yielded 19.36 g of nearly pure keto methyl ester II, mp 92.5–96.5° after crystallization from petroleum ether. One recrystallization gave 18.52 g (41.4%; based on amount of **6** unrecovered as **14**) of II as slender bars: mp 95.6–97.3°; $[\alpha]^{30}\mathrm{D}$ −38.4° (*c* 3.4, $CHCl_3$); ir ($CHCl_3$) 1725, 1705, 1230, 1170 and 1158 cm^{-1}; nmr τ 9.05 (d, 3, J = 6.5 Hz, H-15), 8.87 (s, 3, H-14) and 6.38 (s, 3, $-OCH_3$).

Anal. Calcd for $C_{14}H_{22}O_3$: C, 70.56; H, 9.30. Found: C, 70.56; H, 9.14.

An analytical sample of the corresponding acid, **3-oxo-5,7αH,-4βH-12,13-bisnoreudesman-11-oic acid (12)**, obtained after several recrystallizations from methylene chloride–diethyl ether, exhibited mp 138–140°; ir ($CHCl_3$) 3490–2500 (broad band) and 1718 cm^{-1} (three peaks); nmr ($CDCl_3$) τ 8.99 (d, 3, J = 6.5 Hz, H-15), 8.87 (s, 3, H-14) and 0.39 (s, 1, −COOH).

Anal. Calcd for $C_{13}H_{20}O_3$: C, 69.61; H, 8.99. Found: C, 69.40; H, 8.76.

B. *Via* Potassium Hypoiodite Oxidation of 3-Ethylenedioxy-5,7αH,4βH-12-noreudesman-11-one (7).—A mixture (1.93 g) of **7**, **14** and **6**, obtained from 0.0071 mol of **6** plus **14** and ethylene glycol in a manner similar to that described for the preparation of pure **7**, was dissolved in dioxane (48 ml) and water (23 ml) containing 5.8 g of 85% KOH pellets. A solution of 18 g (0.07 mol) of iodine and 36 g of potassium iodide in 72 ml of water was then added dropwise at room temperature. After stirring for 11 hr, 10 g of 85% KOH pellets were added to destroy the purple color. Suspended solids (unreacted **14** and iodoform) were removed by filtration. The filtrate was extracted with methylene chloride to remove additional neutral materials, cooled, acidified (HCl), treated with saturated sodium bisulfite solution to destroy the remaining iodine, stirred at room temperature for 20 hr and extracted with methylene chloride. The extracts were washed with brine and dried (Na_2SO_4). Removal of the solvent gave 1.35 g of brown liquid which was treated with excess diazomethane in ether–ethyl acetate at 0° and chromatographed on 20 g of alumina (Woelm, grade I; 28 × 1.4 mm column) using benzene as eluent to give 0.43 g (26%) of keto ester II as needles, mp 89–93°. A second ester (ir, nmr) which was not investigated further was obtained in comparable yield as a yellow oil upon further elution with benzene. Studies using a wide range of similar conditions indicate that the 26% yield cited is optimum. Large-scale preparations using *ca.* 10 g of **6** and 1.2 mol equiv of ethylene glycol gave somewhat poorer yields of II.

C. *Via* Treatment of 6 with Trimethyl Orthoformate–Perchloric Acid.—Aqueous 70% perchloric acid (10 ml, 0.113 mol) was added slowly to 30 ml of trimethyl orthoformate initially at 2°; the temperature during the addition was maintained below 20° and safety precautions against possible detonation were taken. The reaction mixture was cooled to 1° and a solution of diketone **6** (2.50 g, 0.0113 mol) in 8 ml of cold trimethyl orthoformate was added dropwise with stirring over a 5.5-min period; the temperature of the reaction mixture was maintained below 2° during the addition. After stirring for 1.6 hr at 0.5–1° the crude reaction mixture was poured into 300 ml of ice–water containing 4.5 g (0.112 mol) of NaOH and 13.6 g (0.10 mol) of sodium acetate trihydrate. The cold aqueous suspension was extracted rapidly with methylene chloride and worked up as usual, taking care not to heat or expose the oily unstable product to air for prolonged periods. Nmr analysis of the product indicated the presence of $\leq 25\%$ of **6** and $\leq 30\%$ of a product exhibiting signals of equal area at τ 4.77 (d, 1, J = 7.2 Hz) and 0.29 (d, 1, J = 7.2 Hz) and a peak at 6.27 (s, ~3.2). The crude product was dissolved in methylene chloride and treated with an excess of ozone over a period of 18 min; the resulting solution was reduced to an *ca.* 10-ml volume *in vacuo* and treated with 6.1 g of potassium iodide in acetic acid (6 ml) and methanol (8 ml) at 0°. The cooling bath was removed and stirring continued at ambient temperature for 2.5 hr. The final reaction mixture was treated with aqueous sodium bisulfite and extracted with methylene chloride. Washing the extracts with 5% sodium bicarbonate followed by acidification of the wash solutions and extraction of the organic acids gave 0.118 g of an acidic white solid which was not **12** (nmr analysis) and was not investigated further. The neutral product (2.43 g of orange oil) which was obtained in the usual manner from the methylene chloride extracts was found to contain about 20% of the starting diketone **6** and *ca.* 15–25% of keto ester II. The total crude product was hydrolyzed using potassium hydroxide in 80% methanol. The acidic portion (1.38 g) of the product was isolated in the usual manner after removal of any neutral material in the diluted reaction mixture by extraction with methylene chloride. Esterification of the acidic product with ethereal diazomethane, followed by chromatography on 20 g of alumina as described in B, yielded 0.412 g (15.4%) of **18**, mp 93.8–95.8°. Using nmr as a monitoring technique, studies under a range of conditions similar to those described above indicate that the yield of II cited is probably optimum.

3,11-Bisethylenedioxy-5,7αH,4βH-noreudesmane (14).—A mixture of diketone **6** (2.28 g, 0.0102 mol), ethylene glycol (3.80 g, 0.061 mol) and 0.034 g of *p*-toluenesulfonic acid in 17 ml of benzene was heated at reflux temperature for 10 hr using a Dean–Stark water separator. The usual work-up procedure afforded 3.10 g (97%) of diketal **14** as prisms, mp 86.5–88.5°. Four additional recrystallizations from petroleum ether–methylene chloride gave an analytical sample, mp 89.5–90.0°; the ir spectrum indicates the absence of a characteristic absorption band for a ketonic carbonyl group; nmr τ 9.25 (d, 3, J = 7 Hz, H-15), 9.16 (s, 3, H-14), 8.83 (s, 3, H-13) and 6.16 (m, 8, $-OCH_2CH_2O-$).

Anal. Calcd for $C_{18}H_{30}O_4$: C, 69.64; H, 9.74. Found: C, 69.70; H, 9.77.

Registry No.—II, 18508-76-4; **2**, 18540-91-5; **3**, 18508-83-3; **4**, 18508-84-4; **5**, 18508-85-5; **6**, 18540-92-6; **7**, 18508-86-6; **12**, 18508-87-7; **13**, 18508-88-8; **14**, 18508-89-9.

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The Structure of (+)-Occidentalol. A Revision[1]

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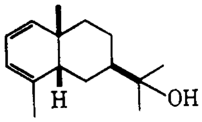
(+)-Occidentalol, a eudalene-type sesquiterpene alcohol obtained from *Thuja occidentalis* L., possesses a *cis* fusion and a 1,3-diene system,[2] two structural features rarely encountered in this series of natural products.[3] The recent isolation of the related *cis*-fused 1,3-dienes, dehydrochamaecynenol and -al, and several *cis*-fused Δ¹-3 ketones, from *Chamaecyparis formosensis* Matsum.,[4] has led to the suggestion[5] that these compounds arise by a unique biosynthetic pathway involving valence tautomerism of 1,3,5-*trans*,-



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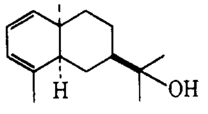

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[2] E. von Rudloff and H. Erdtman, *Tetrahedron*, **18**, 1315 (1962), and references cited.

[3] G. Ourisson, S. Munavelli, and C. Ehret, "International Tables of Selected Constants," Vol. 15 (Data Relative to Sesquiterpenoids), Pergamon Press, Oxford, 1966, pp 13, 14, 22, 25, 26. [Note that the *cis*-fused structure for juniper camphor has recently been revised to *trans*: G. L. Chetty, V. B. Zalkow, and L. H. Zalkow, *Tetrahedron Lett.*, 3223 (1968).]

[4] T. Asao, S. Ibe, K. Takase, Y. S. Cheng, and T. Nozoe, *ibid.*, 3639 (1968), and references cited.

[5] A. G. Hortmann, *ibid.*, 5785 (1968).