Synthetic Studies on Terpenoids. Part 19.† Synthesis of 3β,10α,14β-Trimethyl-1βH,11βH-tricyclo[9.3.0.0^{3,7}]tetradec-6-en-5-one, a Tricyclic Ketone related to the Ophiobolins [1]

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The tricarbocyclic ketone (36) with well defined stereochemistry at each of the four contiguous asymmetric centres has been synthesised, and the stereochemistry of these centres has been deduced mechanistically and confirmed by *X*-ray crystallographic analysis of the bicyclic acidic precursor (22). The orientation of the tertiary methyl group in structure (36) has been deduced from force-field calculations and confirmed by model studies. The configuration of the two ring junction hydrogen atoms and of the two methyl groups in structure (36) are the same as found in the ophiobolins. The conformations of substituted *cis*-perhydroindanones, bicyclo[3.3.1]nonanes, cyclo-octenes and cyclo-octanones, are described.

DICYCLOPENTA[*a*,*d*]CYCLO-OCTANE is the basic skeleton of many diterpenoids, *e.g.* fusicoccin [2] and aglycones of the cotylenins,[3] and two groups of sesterterpenes, the ophiobolins [4] and the ceroplastols.[5] Fusicoccin exhibits its highly phytotoxic activity by bringing about the wilting of almond leaves. Cotylenols affects leaf growth. Ophiobolins [*e.g.* (1)] are metabolites of phytopatho-

† Part 18, A. S. Sarma, A. K. Banerjee, and P. C. Dutta, *J.C.S. Perkin I*, 1976, 722.

[1] Preliminary report, T. K. Das and P. C. Dutta, *Synth. Comm.*, 1976, **6**, 253.

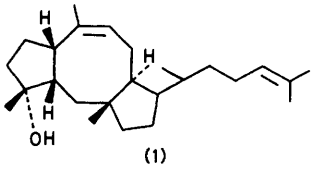
[2] A. Ballio, E. B. Chain, P. De Leo, B. F. Erlanger, M. Mauri, and A. Tonolo, *Nature*, 1964, **203**, 297.

[3] S. Takeshi, T. Akhishiro, and S. Tamutsu, *Agric. and Biol. Chem. (Japan)*, 1975, **39**, 1929.

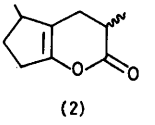
[4] (*a*) K. Ishibashi and R. Nakamura, *J. Agric. Chem. Soc. Japan*, 1958, **32**, 739; (*b*) M. Morisaki, S. Nozoe, and Y. Iitaka, *Acta Cryst.*, 1968, **B24**, 1293.

[5] (*a*) T. Rios and F. Colunga, *Chem. and Ind.*, 1965, 1184; (*b*) Y. Iitaka, I. Watanabe, I. T. Harrison, and S. Harrison, *J. Amer. Chem. Soc.*, 1968, **90**, 1092.

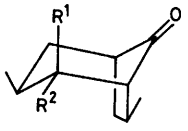
genic fungi, responsible for the leaf-spot disease of maize. Ceroplastols have been isolated from insect wax; the difference between their structures and those of the ophiobolins lies primarily in the stereochemistry at the AB ring junction. We describe here a general method for the construction of the tricarbocyclic skeleton of these compounds with an AB-*cis*-ring junction,



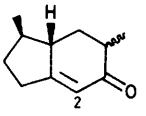
(1)



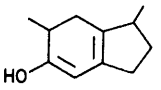
(2)



(3) a; R^1=OH, R^2=Me
b; R^1=Me, R^2=OH



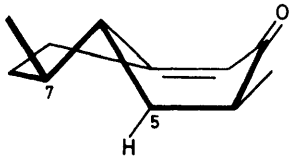
(4)



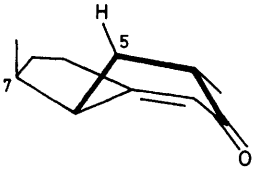
(5)

characteristic of the ophiobolins, and with well defined stereochemistry at each of the five asymmetric centres.

The reaction of the enol lactone (2) [1] with methylmagnesium iodide at 0 °C afforded exclusively a mixture of alcohols (3a and b), in the ratio *ca.* 5 : 3 (n.m.r.), identified from analytical and spectral data (M^+ 182). The same reaction carried out at −18 °C gave a mixture of products (3a and b) and (4), after treatment with alkali. At −78 °C, only the enone (4) was obtained in satisfactory yield. Evidently the Grignard reaction is temperature-dependent.[6] From molecular models of structure (4) and from arguments put forward earlier [7] the unsaturated ketone (4) should be represented by conformation (4a) rather than (4b). Conformer (4a), with the C-7 methyl group *cis* to H-6, was that desired for the present study since the AB-*cis*-ring junction [8] could be developed through catalytic reduction.



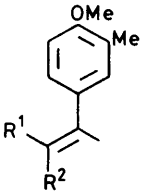
(4a)



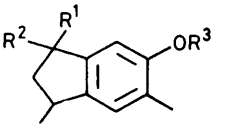
(4b)

Catalytic hydrogenation of the enone (4) at room temperature under atmospheric pressure afforded a phenolic product (10) (*ca.* 33%) along with the desired saturated ketone (6). Elemental analysis and n.m.r. data indicated that the structure of the phenolic product, which on methylation afforded the ether (12), identical with material synthesised by an independent route. Catalytic hydrogenation of the enone (4) under pressure, however, resulted in the ketone (6) with a negligible amount of phenol (10). If the unsaturated ketone (4) was allowed to remain in contact with the catalyst for a day or two under hydrogenating conditions, appreciable dehydrogenation occurred. Aromatisation appears to proceed through the intermediate (5), which is likely to be formed through migration [9] of the double bond to the more substituted position in the ring resulting in a less stable unconjugated ketone intermediate; this might occur because of the low rate of hydrogenation.

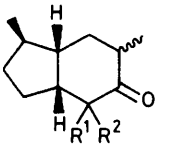
Subsequently, an alternative route to (6) was developed



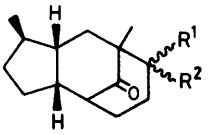
(7) R^1=CN, R^2=CO_2Et
(8) dihydro-(7)
(9) (8; R^1=H, R^2=CO_2H)



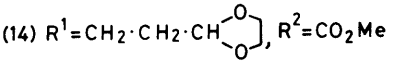
(10) R^1=R^2=R^3=H
(11) R^1 R^2=O, R^3=Me
(12) R^1=R^2=H, R^3=Me



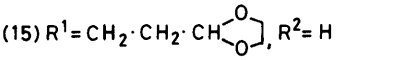
(6) R^1=R^2=H
(13) R^1=H, R^2=CO_2Me



(16) R^1=H, R^2=OH
(17) R^1=H, R^2=OTs
(18) R^1 R^2=O



(14) R^1=CH_2·CH_2·CH(O,O), R^2=CO_2Me



(15) R^1=CH_2·CH_2·CH(O,O), R^2=H

with a better overall yield. *o*-Cresol methyl ether was subjected to a Friedel–Crafts reaction with acetic anhydride and the product, 4′-methoxy-3′-methylacetophenone, was condensed with ethyl cyanoacetate to afford the unsaturated ester (7). This was reduced with aluminium amalgam to afford the saturated cyano-ester (8), which on acidic and alkaline hydrolysis followed by thermal decarboxylation furnished the saturated acid (9). Cyclisation of (9) with polyphosphoric acid afforded in high yield the crystalline indanone (11), the n.m.r. spectra of which showed no *ortho*-coupling. Huang-Minlon reduction of the indanone (11) afforded the indane (12); during reduction demethylation occurred to a small extent, and the resulting phenolic compound could be converted back into (12). Birch reduction of the methyl ether (12) and acidic hydrolysis of the resulting enol ether afforded the unsaturated ketone (4), which was reduced catalytically as before. The identity of the saturated ketone and that previously described was established from i.r. and g.l.c. com-

[6] E. Piers, R. W. Britton, and W. De Waal, *Canad. J. Chem.*, 1969, 4307.

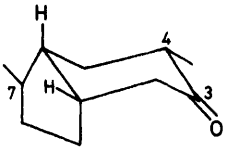
[7] T. K. Das, A. Dasgupta, P. K. Ghosal, and P. C. Dutta, *Indian J. Chem.*, 1976, **14B**, 238.

[8] R. L. Augustine, *J. Org. Chem.*, 1963, **28**, 152.

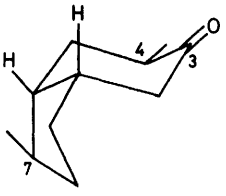
[9] R. A. Barness and M. Sedlak, *J. Org. Chem.*, 1962, **27**, 4562.

parisons. As the ketone (4) does not carry any substituent at C-2, catalytic hydrogenation afforded mainly the thermodynamically favoured *cis*-fused [8] bicyclic ketone (6) (92% by g.l.c.). The preference for the *exo*-orientation of the secondary methyl group in the cyclopentane ring and its *cis*-relationship to the adjacent ring hydrogen atom is clear from a molecular model, and is supported [10] by the established greater stability of *cis*-fused perhydroindanones having a side chain with an *exo*-orientation.

The *cis*-perhydroindanone (6) can be represented by two epimeric structures [11] (6a and b). Conversion of (6a) into (6b) places the C-4 methyl group in the axial



(6a)



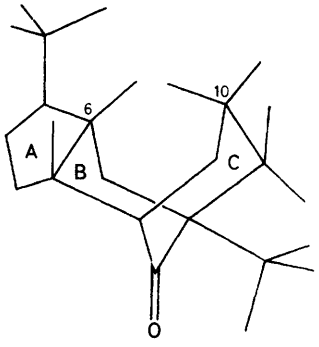
(6b)

position, and conformational inversion would probably then occur to give an equatorially disposed methyl group. However in (6b) there will be appreciable interaction between H-4 and H-7, as is evident from molecular models. Consequently the epimer (6a) should be preferred. This epimer has two *exo*-axial bonds suitably positioned for development of the desired bicyclo[3.3.1]nonane system with a chair–chair conformation of the two cyclohexane rings.

The ketone (6) was methoxycarbonylated in an excellent yield with dimethyl carbonate in the presence of sodium hydride, and the product (13) was alkylated with 1-bromo-3,3-ethylenedioxypropane to afford (14) in moderate yield. This was decarboxylated [12] to afford (15), which on deacetalisation and internal aldol condensation [13] gave the cyclisation product (16) as a mixture of epimeric alcohols in moderate yield. The product was purified by careful distillation and shows no aldehydic proton n.m.r. signal. The conformational mobility of the cyclohexane ring in (16) is probably restricted and the yield of cyclisation product was only moderate (*ca.* 40%). The oxo-alcohols (16) were oxidised with Jones reagent to the crystalline diketone (18).

The two cyclohexane rings in bicyclo[3.3.1]nonanes generally prefer to retain the chair–chair conformation [14] in the absence of overpowering substitutional factors and/or an *endo*-3-substituent.[15] The equatorial alcoholic function in (16) can be best represented as in structure (16a), where the two cyclohexane rings are in the chair conformation with an *exo*-situated cyclopentane ring in spite of H-6,H-10 interactions, which are relieved through splaying. Compound (16) is an ideal system for a Grob fragmentation reaction [16] leading to an eight-membered ring.

The mixture of epimeric alcohols (16) was converted into the solid tosylates (17). Under mild basic conditions [17] these afforded an oil, and a substantial amount of axial tosylate was recovered. G.l.c. of the oil showed the presence of two components (9 : 1). The oil was hydrolysed at room temperature to afford the crystalline acid (22). Very mild alkaline conditions were used during fragmentation and hydrolysis to avoid epimerisation of the ester function, as this phenomenon is conspicuous in the corresponding cycloheptane series.[18] The neutral fraction obtained after hydrolysis was characterised as the ketone (21) from elemental analysis and spectral data. As there is no ester function at the bridgehead position in structure (17) or (21), the possibility of a retro-Claisen process [19] may be ruled out. From the yields of the cyclo-octene ester (20) and the unsaturated ketone (21) and the amount of recovered axial tosylate, it can be concluded that the parent epimeric alcohols (16) are rich in equatorial isomer (*ca.* 5 : 1). Three contiguous asymmetric centres are not disturbed during the reaction, and the α-orientation of the secondary acid function in the eight-membered

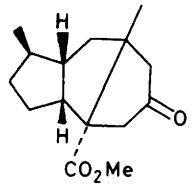


(16a)

ring is assigned from mechanistic considerations; thus the stereochemistry at each of the four asymmetric centres is defined. The structure (22) was confirmed by an *X*-ray crystallographic investigation. The crystals are monoclinic, in space group $P2_1/n$ with cell parameters $a = 7.71$, $b = 28.77$, $c = 5.78$ Å and monoclinic angle $\beta = 94.5°$. The diffraction intensity data (to

[10] D. Taub, R. D. Hoffsommer, C. H. Kuo, H. L. Slates, Z. S. Zelawski, and N. L. Wendler, *Tetrahedron*, 1973, **29**, 1447.
[11] R. E. Lack and J. D. Roberts, *J. Amer. Chem. Soc.*, 1968, **90**, 6997.
[12] von F. Elsinger, J. Schreiber, and A. Eschenmoser, *Helv. Chim. Acta*, 1960, **43**, 113.
[13] R. D. H. Murray, W. Parker, R. A. Raphael, and D. B. Jhaveri, *Tetrahedron*, 1962, **18**, 55.
[14] (*a*) G. Eglington, J. Martin, and W. Parker, *J. Chem. Soc.*, 1965, 1243; (*b*) W. A. C. Brown, J. Martin, and G. A. Sim, *ibid.*, p. 1844.
[15] (*a*) R. A. Appleton, C. Egan, J. M. Evans, S. H. Graham, and J. R. Dixon, *J. Chem. Soc.* (*C*), 1968, 1110; (*b*) W. D. K. Macrossan, J. Martin, and W. Parker, *Tetrahedron Letters*, 1965, 2589.
[16] C. A. Grob, 'I.U.P.A.C. Kekulé Symposium,' 1959, p. 114.
[17] G. L. Buchanan, A. McKillop, and R. A. Raphael, *J. Chem. Soc.*, 1965, 833.
[18] J. A. Marshall and R. A. Ruden, *J. Org. Chem.*, 1971, **36**, 2569.
[19] G. L. Buchanan and G. W. McLay, *Tetrahedron*, 1966, **22**, 1521.

Bragg angle 75°) were collected manually on a General Electric X.R.D. 3 diffractometer by the stationary crystal–stationary counter[20] method. A total of 2 803 unique reflections were measured, of which 2 223 had intensities greater than 2σ. The structure was solved by direct methods by using the program MULTAN,[21] and refined by the block diagonal least-squares method



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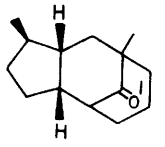

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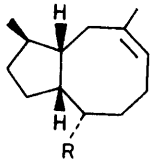
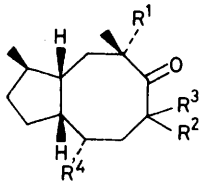
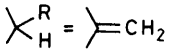
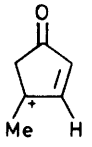
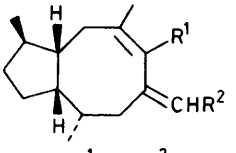




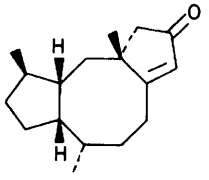
(20) R = CO_2Et
(22) R = CO_2H
(23) R = CO_2Me
(24) R = $CH_2 \cdot OH$
(25) R = $CH_2 \cdot OTs$
(26) R = Me
(27) 
(28) $R^1 = R^2 = R^3 = H$, $R^4 = Me$
(29) $R^1 = R^2 = R^3 = H$, R^4 = 
(30) $R^1 = H$, R^2R^3 = :CHOH, $R^4 = Me$
(31) $R^1 = H$, R^2R^3 = :CH·SBu^n, $R^4 = Me$
(32) $R^1 = H$, R^2R^3 = :CHNMePh, $R^4 = Me$
(34) $R^1 = CH_2$:CMe·CH_2, $R^2 = R^3 = H$, $R^4 = Me$
(35) $R^1 = CH_2 \cdot CO \cdot CH_3$, $R^2 = R^3 = H$, $R^4 = Me$



(37)



(33) $R^1 = O^-$, R^2 = NMePh
(38) $R^1 = R^2 = H$



(36)

to an R factor of 7.8%. All the 22 hydrogen atoms were seen in the electron density maps. The unit cell contains two pairs of enantiomeric molecules, one of which is shown in Figure 1.

The crystalline unsaturated acid (22) was esterified with diazomethane to afford the methyl ester (23), which is homogeneous on g.l.c. Introduction of a carbonyl function into a suitable position in the eight-membered ring is necessary for construction of the remaining five-membered ring. Initially it was planned to introduce the carbonyl function through allylic oxidation and then to perform a 1,4-addition reaction with a suitable Grignard reagent containing a C_3 chain. Attempts were made to bring about allylic oxidation with sodium dichromate in acetic acid–acetic anhydride and also with t-butyl chromate in carbon tetrachloride. In each case the product (M^+ 250), isolated in poor yield, exhibits a strong carbonyl absorption at 1 735 cm^{-1}, and there is no vinylic proton or vinylic methyl signal in the n.m.r. spectrum. The ester methyl signal appears as a sharp singlet at δ 3.55. All these data suggest structure (19), the product most likely of an

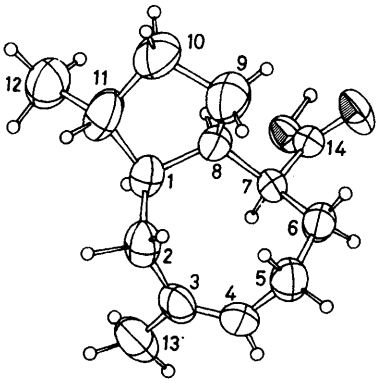


FIGURE 1 View of the molecule of the acid (22) in the crystal. Thermal ellipsoids for C and O are drawn to the 50% probability level, and hydrogen atoms are represented by spheres of arbitrary radius

intramolecular Michael-type addition involving the α-hydrogen atom of the ester function and the αβ-unsaturated carbonyl compound formed during oxidation. To avoid the effect of the ester function, the methyl ester (23) was reduced with lithium aluminium hydride to afford the unsaturated primary alcohol (24), which was converted into the tosylate (25). The crude tosylate (25) was reduced with lithium aluminium hydride; the product showed three peaks on g.l.c. (8 : 1 : 1), and the components were fully characterised as compounds (26), (24), and (27), respectively. More convincing proof of structure (27) was later obtained and this product was removed completely during a subsequent stage of the synthesis.

Attempted allylic oxidation of the unsaturated hydrocarbon mixture with chromium trioxide–pyridine in methylene chloride was unsuccessful. During hydroboration of the unsaturated hydrocarbon mixture and subsequent oxidation with Jones reagent, the diene (27) was oxidised to the acid (from the corresponding primary alcohol), which was isolated as the methyl ester (29). The ketone (28) was thus obtained chemically pure. G.l.c. showed the presence of two peaks (*ca.* 9 : 1), probably arising from the epimerisation α to the carbonyl function.

Formylation of the ketone (28) with ethyl formate and sodium methoxide afforded the hydroxymethylene

[20] T. C. Furnall and D. Harker, *Rev. Sci. Instr.*, 1955, **26**, 449.

[21] G. Germain, P. Main, and M. M. Woolfson, *Acta Cryst.*, 1971, **A27**, 368.

derivative (30), characterised by its colour reaction with iron(III) chloride. This was converted into the n-butylthiomethylene derivative (31), $\nu_{max.}$ 1 705 (C:O) and 1 665 cm^{-1} (:CH·SBu^n), $\lambda_{max.}$ 309 nm (log ε 3.75). From the u.v. data, it is evident that the product is about 50% pure. The impurity might have arisen from a transannular reaction in the eight-membered ring, particularly in the presence of the acidic reagent (toluene-*p*-sulphonic acid) used for the preparation of the thiomethylene derivative. Alkylation studies with the crude thiomethylene derivative were unsuccessful. Blocking of the α′-position of the ketone (28) was next achieved [22] by formation of the *N*-methylanilino-derivative (32) under basic conditions; the product (32) was alkylated with methallyl chloride in the presence of dry potassium t-butoxide in dimethoxyethane. The blocking group was removed under alkaline condition to afford (34) in high yield, as a mixture of stereoisomers in which the desired isomer (34) was predominant (as revealed from ozonisation results). Oxidation of the allylic methylene system with osmium tetraoxide having failed, the desired diketone (35) was obtained in satisfactory yield through ozonolysis at −55 °C as a crystalline compound (M^+ 264). In the mass spectrum, the base peak is at *m/e* 43 [$(COCH_3)^+$] and other prominent peaks appear at *m/e* 206, 207, 138, 121, 95, and 81. Cyclisation of the diketone (35) with methanolic potassium hydroxide solution afforded a mixture, and the enone (36) was isolated as a pure component * through extensive column chromatography and its identity confirmed through mass spectral data. The u.v. spectrum showed enone absorption at 235 nm (ε 12 000), and the i.r. spectrum exhibited peaks [23] at 1 695 and 1 720 cm^{-1} arising from Fermi resonance. In the mass spectrum (M^+ 246), the base peak is at *m/e* 95 [fragment (37)]. Other intense peaks appear at *m/e* 81, 123, 137, 109, and 231. In absence of well defined analogy the orientation of the tertiary 3-methyl group could not be determined chemically, and *X*-ray crystallographic analysis also failed because of the extremely fibrous nature of the diketone (35). The double bond in ring C of compound (36) may be utilisable to introduce the remaining C_3 or C_8 chain to complete the C_{20} or C_{25} framework of diterpenoids or ophiobolins.

Returning to the geometry of the newly created asymmetric centre in (34) arising through alkylation of the enolate (33), we have carried out a series of force-field calculations [24,25] on related compounds. It has been found that the alkylating agent approaches the reaction site mainly from the side opposite to the two axial hydrogen atoms at C-7 and C-1; the reasons for this are detailed in the following section. It follows that the condensation product is represented by structure (34). This concept gains further support from the fact that the alkylation process is stereospecific to the extent of *ca.* 70%, as revealed from the yield of the crystalline diketone (35). The final tricyclic ketone should thus be represented by structure (36). Of the five asymmetric centres in the molecule four are identical with those in the ophiobolins. The double bond in the eight-membered ring, which is always present in the ophiobolins, may be generated from the intermediate alcohol (24) through the corresponding aldehyde.

Conformational Studies on Eight-membered Ring Compounds.—The eight-membered ring in the crystalline acid (22) is very much distorted (Figure 1). Its overall conformation seems to be a boat–chair. The five-membered ring is in the envelope conformation with C-9 at the apex, and is itself puckered into a twist one as revealed from ring torsion angles (Figure 2). There

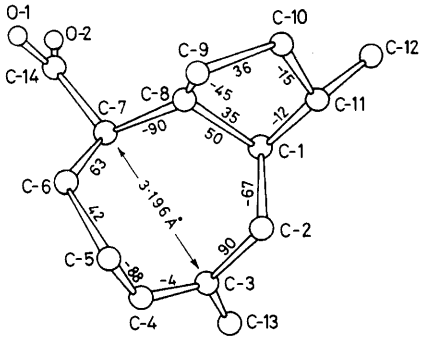


FIGURE 2 Selected torsion angles (°) in the molecule of the acid (22)

is a 3,4-double bond, in the *cis*-configuration. The hydrogen atoms on the asymmetric carbon atoms C-1, -7, and -8 are all oriented in the opposite direction to that on C-11, as shown in Figure 1. This is in agreement with the stereochemical deductions made earlier. The plane of the carboxy-group at C-14 is almost at right angles to the average plane of the eight-membered ring. The torsion angle about the double bond is −4°. The ring section C-1,C-2,C-3,C-4,C-5,C-6 has approximate mirror symmetry as seen in Figure 2. The C-3,C-7 distance is less than 3.2 Å. This may have significant biogenetic implications for this class of terpenoids, which always contain a similarly situated double bond. An examination of molecular models supported by force-field calculations † shows that the hydrocarbon (26) can adopt two types of conformations,‡·§ a chair–boat

* We thank Dr. A. Mitra, Department of Organic Chemistry, Columbia University, New York, for separating compound (36) as a pure component.

† The computer used in the force-field calculations was an IBM 370/168 instrument located at Orsay, France. It took 1—2 min of computing time to obtain the results. The program was that of Professor Allinger.

‡ The conformational diagram (Figure 3) is based upon a computer-produced perspective drawing of the energy-minimised conformation.

§ In all force-field calculations a few conformations were tried and the results were compared. The other minima found were *ca.* 3—5 kcal mol^{-1} higher than that of the most stable conformation.

[22] R. B. Woodward, F. Sondheimer, D. Taub, K. Hensler, and W. M. McLamore, *J. Amer. Chem. Soc.*, 1952, **74**, 4223.
[23] P. Yates and L. L. Williams, *J. Amer. Chem. Soc.*, 1958, **80**, 5896.
[24] N. L. Allinger, M. T. Tribble, M. A. Miller, and D. H. Wertz, *J. Amer. Chem. Soc.*, 1971, **93**, 1637.
[25] D. H. Wertz and N. L. Allinger, *Tetrahedron*, 1974, **30**, 1579.

(twisted) or chair–twist chair and a twist chair–twist chair. The energies calculated for the two conformations are 37.45 and 35.65 kcal mol^{-1}, respectively. The chair–twist chair conformation of the hydrocarbon (26) obtained from force-field calculations is similar to that found in the acid (22) from *X*-ray analysis.

Regarding the conformation of the ketone (28), it is now established [26] from low-temperature n.m.r. studies that cyclo-octanone exists predominantly in an unsymmetrical boat–chair conformation. Conformational deviations to chair–chair or twist chair–chair are also possible in substituted cyclo-octanones. An examination of molecular models supported by force-field calculations shows that again two conformations can be drawn for the ketone (28), and these may be called twist chair–chair. In both conformations non-bonded interactions are transannular in nature and likely to be similar in magnitude (*ca.* 0.5 kcal mol^{-1}).

To determine the conformational energy of the enolate (33), a force-field calculation has been carried out with structure (38), *i.e.* replacing the =C–O$^-$ grouping by =CH and =CH·NMePh by =CH$_2$ to avoid complexities in calculations; this does not affect the conformation of the eight-membered ring. Because of the presence of two conjugated double bonds, a considerable amount of rigidity has been introduced into the eight-membered ring, and the conformation shown in Figure 3

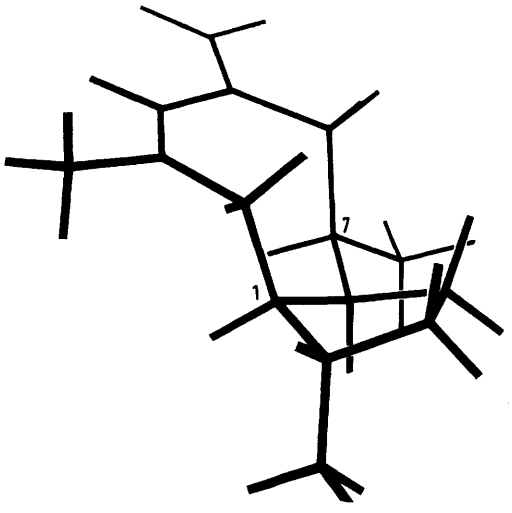


FIGURE 3 Minimum energy conformation of the molecule (38)

has been found to be the most stable from energy considerations and also from examination of molecular models. The two pseudoaxial hydrogen atoms at C-1 and C-7 will seriously affect the approach of any bulky alkylating agent at C-3 from the same side. Consequently in the alkylated product (34), the tertiary methyl group will be *cis* to the ring-junction hydrogen atoms thereby determining the stereochemistry of the tertiary methyl group in the tricyclic ketone (36). The energy of the tricyclic ketone with the tertiary methyl group of opposite stereochemistry is *ca.* 5 kcal mol^{-1} less, as revealed from force-field calculations. This value, however, is not very significant, as the alkylation process is a kinetically controlled step.

[26] F. A. L. Anet, M. St. Jacques, P. M. Henrichs, A. K. Cheng, J. Krane, and L. Wong, *Tetrahedron*, 1974, **30**, 1629.

EXPERIMENTAL

M.p.s were taken for samples in open capillary tubes in a sulphuric acid bath. U.v. spectra were recorded with a Beckman DU spectrophotometer for solutions in 95% ethanol. I.r. spectra were taken with a Perkin-Elmer 21 instrument. N.m.r. spectra were measured for solutions in carbon tetrachloride with a Varian T-60 spectrometer, with tetramethylsilane as internal standard. T.l.c. plates were coated (0.2 mm thickness) with silica gel G (200 mesh). Mass spectra were measured with Hitachi RM-60 spectrometer. G.l.c. was carried out with a Varian Aerograph 1868–4 instrument with (columns of SE 30 on Varaport and Carbowax 20M on Chromosorb W). Light petroleum refers to the fraction of b.p. 60—80 °C.

2-Hydroxy-2,3,7-trimethylbicyclo[3.2.1]*octan-8-one* (3a *and* b).—An ethereal solution of methylmagnesium iodide (40% excess) was added under nitrogen with stirring during 2 h to a solution of the enol lactone (2) (2.8 g) in dry ether (50 ml) maintained at 0 °C. The mixture was decomposed with 2N-hydrochloric acid. The crude product obtained after work-up was dissolved in methanol (150 ml). Potassium hydroxide (3 g) in water (15 ml) was added and the solution heated under reflux under nitrogen for 4 h. It was cooled and diluted with water. Work-up and distillation afforded the *alcohols* (3a and b) (1.3 g), b.p. 110—115° at 2 mmHg, $\nu_{max.}$ 1 440, 1 730, and 3 400 cm^{-1}, δ 5.8 (1 H, s, exchangeable), 1.35 and 1.31 (3 H, s, tert. Me), 1.18 and 1.15 (3 H, d, *J* 7 Hz, sec. Me), and 1.02 and 0.96 (3 H, d, *J* 6 Hz, sec. Me), M^+ 182 (Found: C, 72.1; H, 9.8. $C_{11}H_{18}O_2$ requires C, 72.4; H, 9.9%).

4,7β-Dimethyl-6βH-bicyclo[4.3.0]*non-1-en-3-one* (4).—(*a*) The above Grignard reaction with the enol lactone (2) (2.8 g) was carried out at −18 °C (freezing mixture) by the same procedure. The product on distillation afforded a mixture of alcohols (3a and b) and the ketone (4), b.p. 90—110° at 1 mmHg, $\nu_{max.}$ 1 675, 1 735, and 3 400 cm^{-1}, $\lambda_{max.}$ 236 nm.

(*b*) The same Grignard reaction with the enol lactone (2) (2.8 g) was performed at −78 °C (alcohol–liquid nitrogen mixture) and the product on distillation afforded the *ketone* (4) (1.4 g), b.p. 85—90° at 1 mmHg, $\nu_{max.}$ 1 675 cm^{-1}, $\lambda_{max.}$ 238 nm (log ε 4.18), δ 5.7 (1 H, m, vinylic H), 1.0 (3 H, d, *J* 6 Hz, 7-Me), and 1.1 (3 H, d, *J* 5.5 Hz, 4-Me) (Found: C, 80.1; H, 9.7. $C_{11}H_{16}O$ requires C, 80.4; H, 9.8%).

Ethyl 2-Cyano-3-(3-methyl-4-methoxyphenyl)crotonate (7).—A mixture of 4′-methoxy-3′-methylacetophenone (30 g), ethyl cyanoacetate (31.3 g), glacial acetic acid (11.3 ml), ammonium acetate (3.8 g), and benzene (70 ml) was heated under reflux (Dean–Stark water separator). Two more portions of ammonium acetate (2 g each) were added at intervals of 4 h and refluxing was carried out for a total of 20 h. The mixture was cooled, washed repeatedly with water, and evaporated. Distillation of the residual oil afforded the *cyano-ester* (7) (42 g), b.p. 165—170° at 0.8 mmHg (Found: C, 69.3; H, 6.6. $C_{15}H_{17}NO_3$ requires C, 69.4; H, 6.6%).

Ethyl 2-Cyano-3-(3-methyl-4-methoxyphenyl)butyrate (8).—The cyano-ester (7) (104 g) in ether (500 ml) was added to aluminium amalgam [from aluminium foil (35 g)] followed by water (50 ml). Water (100 ml) and ether (200 ml) were

added in three portions at intervals of 12 h. The mixture was acidified with dilute hydrochloric acid (600 ml). After the usual work-up, the residual oil afforded the *butyrate* (8) (75 g), b.p. 155—156° at 0.8 mmHg (Found: C, 68.7; H, 7.2. $C_{15}H_{19}NO_3$ requires C, 68.9; H, 7.3%).

3-(3-*Methyl*-4-*methoxyphenyl*)*butyric Acid* (9).—The ester (8) (90 g) was heated under reflux for 10 h with concentrated hydrochloric acid (450 ml). After distilling off a part of the hydrochloric acid (225 ml), a fresh batch of concentrated hydrochloric acid (225 ml) was added, and heating was continued for 10 h more. The solution was saturated with sodium chloride and extracted with ether. The extract was washed with saturated sodium carbonate solution, and the carbonate extract was acidified and extracted with ether. Removal of the solvent afforded the acid (9) (40 g). The neutral product (30 g) was heated under reflux for 3 h under nitrogen with potassium hydroxide (27 g) dissolved in water (54 ml) and ethylene glycol (216 ml). The cooled mixture was diluted with water (300 ml) and acidified with 6N-hydrochloric acid. The product was taken up in ether and the acid extracted with cold potassium hydroxide solution (2%). The extract was acidified with 6N-hydrochloric acid. After the usual work-up the resulting diacid was heated at 180—190 °C to afford the solid *acid* (9) (18 g), m.p. 64° (from light petroleum–benzene) (Found: C, 69.3; H, 7.7. $C_{12}H_{16}O_3$ requires C, 69.2; H, 7.7%).

6-*Methoxy*-3,5-*dimethylindan*-1-*one* (11).—To polyphosphoric acid [from phosphorus pentaoxide (240 g) and orthophosphoric acid (160 g; 89%)] was added at 80 °C the acid (19) (20 g) in one portion. The viscous mass was mixed well and kept at 80 °C for 1 h. The resultant mixture was poured onto ice (1 kg). The acidic solution was extracted with benzene; the extract was washed with cold water, saturated sodium hydrogen carbonate solution, and water. Removal of the solvent followed by distillation afforded the *indanone* (11) (13 g), b.p. 138° at 1.3 mmHg, m.p. 82—83° (from light petroleum), single peak on g.l.c., δ 7.1 and 7.3 (3 H, ArH), 3.85 (3 H, s, OMe), 2.3 (3 H, s, ArMe), and 1.35 (3 H, d, *J* 6 Hz, CH*Me*) (Found: C, 75.8; H, 7.6. $C_{12}H_{14}O_2$ requires C, 75.7; H, 7.4%).

5-*Methoxy*-1,6-*dimethylindane* (12).—To the indanone (11) (50 g) were added diethylene glycol (375 ml) and hydrazine hydrate (62 ml; 80%) and the mixture was heated under nitrogen. The temperature was gradually raised to 130 °C and kept between 130 and 140 °C for 1 h. The mixture was then cooled to 80 °C, potassium hydroxide (50 g) was added, and the temperature was raised to 200 °C and kept between 200—210 °C for 2 h. The mixture was diluted with water, acidified with 6N-hydrochloric acid, and extracted with ether. The extract was washed successively with water and sodium hydroxide solution (10%) and finally the *product* (12) was obtained as an oil (35 g), b.p. 125° at 7 mmHg (Found: C, 81.6; H, 9.1. $C_{12}H_{16}O$ requires C, 81.7; H, 9.1%).

5-*Hydroxy*-1,6-*dimethylindane* (10).—The sodium hydroxide extract from the previous experiment was acidified with 6N-hydrochloric acid. After the usual work-up, distillation of the residual oil afforded the *indanol* (10) (3 g), b.p. 110—115° at 3 mmHg, giving a colouration with iron(III) chloride. It was crystallised from light petroleum; m.p. 95—96° (Found: C, 79.6; H, 9.3. $C_{11}H_{14}O$ requires C, 79.9; H, 9.3%). The phenolic compound (10) (30 g) was dissolved in sodium hydroxide solution (130 ml; 8.5%). The solution was stirred for 10 min. Dimethyl sulphate (15 ml) was added dropwise at 40—45 °C. The solution was stirred for a further 10 min, and more sodium hydroxide solution (42 ml; 8.5%) and dimethyl sulphate (9 ml) were added. The mixture was stirred for 0.5 h. Work-up followed by distillation afforded the indanol (12) (28 g).

4,7β-*Dimethyl*-6β*H*-*bicyclo*[4.3.0]*non*-1-*en*-3-*one* (4) *and/or its* $\Delta^{1(6)}$-*Isomer*.—A solution of the indanol (12) (27 g) in dry ether (300 ml) was added to a stirred solution of lithium (22 g) in liquid ammonia (2 050 ml). The mixture was stirred for 10 min, then absolute ethanol (325 ml) was added dropwise, whereupon the blue colour was discharged. Ammonia was allowed to evaporate off and water (1 000 ml) added. The residue left after work-up was mixed with methanol (400 ml), water (200 ml), and concentrated hydrochloric acid (120 ml) and kept under nitrogen at 60 °C. After 2 h, the pink coloured solution was worked up; distillations afforded the unsaturated ketone (4) (22 g), b.p. 105° at 3 mmHg, $\nu_{max.}$ 1 670 cm^{-1}, $\lambda_{max.}$ 238 nm (log ε 4.2) (Found: C, 80.2; H, 9.7. Calc. for $C_{11}H_{16}O$: C, 80.4; H, 9.8%).

4,7β-*Dimethyl*-1β*H*,6β*H*-*bicyclo*[4.3.0]*nonan*-3-*one* (6).—The unsaturated ketone (4) (20 g) was hydrogenated in alcohol (75 ml) at room temperature and atmospheric pressure over palladium–charcoal (10%; 2 g). Uptake was complete in 36 h. After filtration and evaporation the residual oil was diluted with ether (200 ml); the solution was washed with sodium hydroxide solution (10%) and water, dried, and evaporated. Distillation afforded the *ketone* (6) (12 g), b.p. 88—90° at 2.5 mmHg, $\nu_{max.}$ 1 710 cm^{-1}, 92% by g.l.c. (Found: C, 79.1; H, 10.7. $C_{11}H_{18}O$ requires C, 79.4; H, 10.9%). The 2,4-*dinitrophenylhydrazone* had m.p. 142—143° (from benzene–methanol) (Found: C, 58.8; H, 6.4. $C_{17}H_{22}N_4O_4$ requires C, 58.9; H, 6.4%). The sodium hydroxide extract after work-up afforded the indanol (10), m.p. and mixed m.p. 95—96° (from light petroleum), δ 6.7 and 6.95 (2 H, ArH), 2.2 (3 H, s, ArMe), 1.25 (3 H, d, *J* 6 Hz, CHMe), and 4.65br (1 H, s, OH) (Found: C, 79.6; H, 9.3. Calc. for $C_{11}H_{14}O$: C, 79.9; H, 9.3%).

Methyl 4,7β-*Dimethyl*-3-*oxo*-1β*H*,6β*H*-*bicyclo*[4.3.0]*nonane*-2-*carboxylate* (13).—Freshly distilled dimethyl carbonate (450 ml) was added to oil-free sodium hydride (60 g as 50% dispersion). The mixture was stirred and heated under reflux under nitrogen and the saturated ketone (6) (100 g) in dimethyl carbonate (450 ml) was added dropwise. Stirring and refluxing were continued for 2 h. The cooled mixture was acidified, diluted with ether, washed successively with sodium hydrogen carbonate solution (5%) and water, and dried. Concentration and distillation afforded the *oxo-ester* (13) (115 g), b.p. 125—130° at 2 mmHg, δ 3.55 (3 H, s, OMe) (Found: C, 69.4; H, 8.9. $C_{13}H_{20}O_3$ requires C, 69.6; H, 8.9%).

Methyl 2-(3,3-*Ethylenedioxypropyl*)-4,7β-*dimethyl*-3-*oxo*-1β*H*,6β*H*-*bicyclo*[4.3.0]*nonane*-2-*carboxylate* (14).—To sodium dust (10.8 g) suspended in benzene (300 ml), the ester (13) (115 g) in benzene (225 ml) was added, and the mixture was left for 12 h. 1-Bromo-3,3-ethylenedioxypropane (115 g) in dimethylformamide (175 ml) was added dropwise to the ice-cooled mixture. Dry sodium iodide (10 g) was added and the mixture was refluxed for 10 h, cooled, and poured into sodium hydrogen carbonate solution (5%). Usual work-up and distillation afforded the *acetal* (14) (80 g), b.p. 170—172° at 0.25 mmHg, δ 4.7 (1 H, t, *J* 4.5 Hz, CHO_2), 3.9 (4 H, t, *J* 1 Hz, $O[CH_2]_2O$), 3.55 (3 H, s, OMe), 1.0 (3 H, d, *J* 6 Hz, 7-Me), and 1.1 (3 H, d, *J* 5.5 Hz,

4-Me) (Found: C, 66.3; H, 8.5. $C_{18}H_{28}O_5$ requires C, 66.6; H, 8.7%).

2-(3,3-*Ethylenedioxypropyl*)-4,7β-*dimethyl*-1β*H*,6β*H*-*bicyclo*[4.3.0]*nonan*-3-*one* (15).—The ester (14) (79 g) in dimethylformamide (700 ml) was heated under reflux under nitrogen with dry lithium iodide (200 g) for 2 h. After the usual work-up, distillation afforded the *ketone* (15) (42 g), b.p. 142—145° at 0.25 mmHg, $\nu_{max.}$ 1 710 cm^{-1} (Found: C, 72.1; H, 9.8. $C_{16}H_{26}O_3$ requires C, 71.9; H, 9.7%).

9-*Hydroxy*-5β,8α-*dimethyl*-2β*H*,6β*H*-*tricyclo*[6.3.1.$0^{2,6}$]-*dodecan*-12-*one* (16).—The ketone (15) (5 g) was mixed with glacial acetic acid (30 ml) and water (10 ml). The mixture was kept at room temperature for 24 h under nitrogen and then warmed to 50—60 °C for 0.5 h. It was cooled, diluted with water, neutralised with solid sodium carbonate, and then extracted with ether. Concentration and distillation afforded the corresponding *oxoaldehyde* (2.5 g), b.p. 114—115° at 0.15 mmHg (Found: C, 75.5; H, 9.9. $C_{14}H_{22}O_2$ requires C, 75.6; H, 9.9%). A mixture of the oxoaldehyde (28 g), acetic acid (210 ml), concentrated hydrochloric acid (52.5 ml), and water (105 ml) was heated on a steam-bath for 15 min and then kept at room temperature for 18 h. After the usual work-up the crude hydroxy-compound was dissolved in methanol (150 ml) and the solution was treated with methanolic potassium hydroxide (50 ml; 5%) and stirred under nitrogen at room temperature for 2 h. The solution was neutralised with acetic acid. Methanol was removed at reduced pressure and the usual work-up afforded the *ketols* (16) (19 g), b.p. 135° at 0.4 mmHg (Found: C, 75.5; H, 9.9. $C_{14}H_{22}O_2$ requires C, 75.6; H, 9.9%).

5β,8α-*Dimethyl*-2β*H*,6β*H*-*tricyclo*[6.3.1.$0^{2,6}$]*dodecane*-9,12-*dione* (18).—A solution of the ketols (16) (200 mg) in acetone (5 ml) was treated at −5 °C with a slight excess of Jones reagent. After stirring for a further 10 min the solution was poured into saturated brine (25 ml) and extracted with light petroleum. The product was chromatographed over neutral activated alumina (8 g). Elution with benzene–light petroleum (1 : 1) afforded the crystalline *diketone* (18) (100 mg), m.p. 60—61° (from light petroleum), single spot on t.l.c. (benzene–chloroform, 1 : 1), $\nu_{max.}$ 1 695 and 1 725 cm^{-1}, δ 1.1 (3 H, s, CMe) and 0.95 (3 H, d, *J* 6 Hz, CH*Me*) (Found: C, 76.5; H, 9.1. $C_{14}H_{20}O_2$ requires C, 76.3; H, 9.1%).

5β,8α-*Dimethyl*-9-*tosyloxy*-2β*H*,6β*H*-*tricyclo*[6.3.1.$0^{2,6}$]-*dodecan*-12-*one* (17).—The ketols (16) (8.5 g) were dissolved in dry pyridine (45 ml) and treated with toluene-*p*-sulphonyl chloride (9.5 g) (m.p. 66—67°). The mixture was heated on a water-bath at 60 °C for 1 h and kept at room temperature for 15 h. It was diluted with water and extracted with ether. The organic layer was washed with 2N-hydrochloric acid, saturated sodium carbonate solution, and water, and dried. Removal of the solvent *in vacuo* at room temperature gave a solid which was washed with light petroleum at 0 °C; the *tosylates* were obtained as a crystalline mixture of axial and equatorial isomers (17) (5 g), m.p. 115—119° (from ether–light petroleum), $\nu_{max.}$ 1 710, 1 162, and 1 092 cm^{-1} (Found: C, 66.9; H, 7.4. $C_{21}H_{28}O_4S$ requires C, 67.0; H, 7.5%).

Methyl 3,11β-*Dimethyl*-1β*H*,8β*H*-*bicyclo*[6.3.0]*undec*-3-*ene*-7α-*carboxylate* (23).—A solution of sodium ethoxide [from sodium (0.43 g)] in dry ethanol (10 ml) was added to a solution of the mixture of toluene-*p*-sulphonates (17) (4.87 g) in dry ethanol (15 ml) at 60 °C. Immediate precipitation of sodium toluene-*p*-sulphonate occurred. The mixture was heated under reflux for 5 min, cooled, diluted with saturated brine, and extracted with ether. During evaporation of the solvent *in vacuo* at room temperature, the axial tosylate separated as a crystalline solid from the oil. The oil was taken out from the mixture by washing with light petroleum at 0 °C. The axial *tosylate* was crystallised from ether–light petroleum; yield 300 mg, m.p. 147—148° (Found: C, 67.0; H, 7.4. $C_{21}H_{28}O_4S$ requires C, 67.0; H, 7.5%). The oil after sublimation ($\nu_{max.}$ 1 715 and 1 725 cm^{-1}) showed two peaks on g.l.c. A mixture of the oil (11 g), potassium hydroxide (8.25 g), and methanol (165 ml) was kept for 12 h at room temperature under nitrogen, then cooled, acidified with 6N-hydrochloric acid, saturated with sodium chloride, and extracted with ether. The extract was washed with saturated sodium carbonate solution. The neutral part was isolated. The sodium carbonate extract was acidified with 6N-hydrochloric acid. The resulting *acid* (22) (7.5 g) had m.p. 94—95° (from light petroleum), δ 10.36 (1 H, s, CO_2H), 5.35 (1 H, t, vinylic H), 1.8 (3 H, d, *J* 1 Hz, vinylic Me), and 1.0 (3 H, d, *J* 6 Hz, CHMe) (Found: C, 75.5; H, 9.9. $C_{14}H_{22}O_2$ requires C, 75.6; H, 9.9%). The neutral part after sublimation at 110° at 0.5 mmHg afforded the *enone* (21) (1 g), $\nu_{max.}$ 1 715 cm^{-1}, δ 5.22 (2 H, m, vinylic H), 1.3 (3 H, s, CMe), and 0.93 (3 H, d, *J* 6 Hz, CHMe) (Found: C, 82.1; H, 9.8. $C_{14}H_{20}O$ requires C, 82.3; H, 9.8%). The unsaturated acid (22) (2.9 g) was treated with diazomethane to furnish the *methyl ester* (23) (2.9 g), b.p. 110° at 0.5 mmHg, single peak on g.l.c., $\nu_{max.}$ 1 725 cm^{-1}, δ 5.3 (1 H, t, vinylic H), 3.55 (3 H, s, OMe), 1.75 (3 H, d, *J* 1 Hz, vinylic Me), and 1.0 (3 H, d, *J* 6 Hz, CH*Me*) (Found: C, 76.2; H, 10.2. $C_{15}H_{24}O_2$ requires C, 76.2; H, 10.2%).

3,11β-*Dimethyl*-1β*H*,8β*H*-*bicyclo*[6.3.0]*undec*-3-*en*-7α-*ylmethanol* (24).—A solution of the unsaturated ester (23) (2.9 g) in ether (100 ml) was added dropwise to a stirred slurry of lithium aluminium hydride (600 mg) in ether (200 ml). Stirring was continued under gentle reflux for 3 h. The excess of hydride was decomposed with ethyl acetate. The organic layer was washed with cold 2N-hydrochloric acid and brine, and dried. Concentration and distillation afforded the unsaturated *alcohol* (24) (2.53 g), b.p. 118° at 0.4 mmHg, δ 5.3 (1 H, t, vinylic H), 1.75 (3 H, d, *J* 1 Hz, vinylic Me), 1.0 (3 H, d, *J* 6 Hz), and 3.3 (2 H, d, *J* 6 Hz) (Found: C, 80.6; H, 11.5. $C_{14}H_{24}O$ requires C, 80.7; H, 11.6%).

3,7α,11β-*Trimethyl*-1β*H*,8β*H*-*bicyclo*[6.3.0]*undecan*-4-*one* (28).—A solution of the alcohol (24) (2.53 g) and toluene-*p*-sulphonyl chloride (3 g) in dry pyridine (25 ml) was kept at 0 °C for 48 h. The usual work-up afforded the tosylate (25) (4.2 g). A solution of the tosylate (25) (4.2 g) in ether (50 ml) was added dropwise to a stirred slurry of lithium aluminium hydride (1.22 g) in ether (350 ml). Stirring was continued under gentle reflux for 24 h. The mixture was cooled and the excess of hydride destroyed with saturated sodium sulphate solution. The precipitate was filtered off and washed with ether. The product (1.6 g) had b.p. 110—115° at 3 mmHg, δ 5.3 (1 H, t, vinylic H), 1.75 (3 H, d, *J* 1 Hz, vinylic Me), 1.0 (6 H, d, *J* 6 Hz), 4.5 and 4.65 (each s, vinylic impurity), and 3.3 (d, hydroxymethyl impurity). It showed three peaks on g.l.c. The two secondary methyl groups in the unsaturated hydrocarbon (26) showed only one doublet, centred at δ 1.0. The mixture was chromatographed over neutral activated alumina (30 g). Elution with light petroleum furnished an oily mixture (1.3 g) of (26) and (27), M^+ 192 ($C_{14}H_{24}$)

and 190 ($C_{14}H_{22}$). Elution with benzene afforded the alcohol (24) (100 mg), δ 3.3 (2 H, d, *J* 6 Hz, $-CH_2{\cdot}OH$). Diborane, generated by adding sodium borohydride (12 g) in small portions to a stirred mixture of bis-(2-methoxyethyl) ether (240 ml) and boron trifluoride–ether (60 g) at 45 °C (water-bath) was directly passed into a solution of the mixture of hydrocarbons (26) and (27) (1.56 g) in tetrahydrofuran (15 ml) at 10—15 °C. The reaction was continued for 3 h. The mixture was cooled. Sodium hydroxide solution (50 ml; 10%) was added, followed immediately by hydrogen peroxide (50 ml; 30%), and the suspension so obtained was heated under reflux for 1 h, whereupon two layers separated. After the usual work-up, the crude alcohol (1.5 g) in dry acetone (40 ml) was treated at −5 °C with a slight excess of Jones reagent. The solution was poured into saturated brine (125 ml) and extracted with ether. The extract was washed with brine, saturated sodium hydrogen carbonate solution, and water, and dried. The resulting product on distillation afforded the *ketone* (28) (1.2 g), b.p. 100° at 0.5 mmHg, $\nu_{max.}$ 1 710 cm^{-1}, δ 0.9 (3 H, d, *J* 6 Hz, 11-Me), 0.96 (3 H, d, *J* 6 Hz, 7-Me), and 1.1 (3 H, d, *J* 5.5 Hz, 3-Me) (Found: C, 80.6; H, 11.5. $C_{14}H_{24}O$ requires C, 80.7; H, 11.6%).

Methyl 3,11β-*Dimethyl*-4-*oxo*-1β*H*,8β*H*-*bicyclo*[6.3.0]*undecane*-7-*carboxylate* (29).—The foregoing sodium hydrogen carbonate extract was acidified with 6N-hydrochloric acid. The resulting acid (100 mg) was treated with diazomethane to afford the *oxo-ester* (29) (100 mg), b.p. 130° at 0.5 mmHg, single peak on g.l.c., δ 3.55 (3 H, s, OMe), 0.9 (3 H, d, *J* 6 Hz, 11-Me), and 1.1 (3 H, d, *J* 5.5 Hz, 3-Me) (Found: C, 71.0; H, 9.3. $C_{15}H_{24}O_3$ requires C, 71.3; H, 9.5%).

3β,7α,11β-*Trimethyl*-3α-*methallyl*-1β*H*,8β*H*-*bicyclo*[6.3.0]-*undecan*-4-*one* (34).—To an ice-cooled suspension of dry sodium methoxide [from sodium (575 mg)] in benzene (10 ml) under nitrogen, the ketone (28) (1.04 g) and purified ethyl formate (1.11 g) were added dropwise with stirring. After 12 h at room temperature, water (20 ml) was added. The mixture was thoroughly shaken. The separated organic layer was extracted with two portions of 2% sodium hydroxide. The combined basic and aqueous washings were chilled and acidified with 6N-hydrochloric acid. The usual work-up afforded the hydroxymethylene derivative (30) (1 g), which gave a purple colouration with iron(III) chloride. The amount of unchanged ketone (28) was 75 mg. Benzene was gradually distilled from a mixture of the hydroxymethylene ketone (30) (810 mg), *N*-methylaniline (365 mg), and benzene (50 ml) during 3 h. The last traces of benzene and finally the excess of methylaniline were removed *in vacuo*. The product was dried to afford the enamine (32) (1.04 g), $\nu_{max.}$ 1 700, 1 640, and 1 600 cm^{-1}. To dry potassium t-butoxide prepared [from potassium (210 mg)] in dimethoxyethane (4 ml) was added the crude methylaniline derivative (32) (450 mg) at room temperature. After 0.5 h, the mixture was cooled and methallyl chloride (610 mg) was added dropwise. After 12 h, sodium iodide (100 mg) was added and the mixture refluxed for 6 h. The mixture was cooled and acidified with 6N-hydrochloric acid. The product (500 mg) was heated under reflux with potassium hydroxide (1 g) in water (6 ml) under nitrogen for 14 h. The whole mixture was acidified with ice-cold 2N-hydrochloric acid. Work-up and distillation afforded the *ketone* (34) (310 mg), b.p. 110° at 0.01 mmHg, δ 4.6 and 4.75 (2 H, m, $C{:}CH_2$), 1.75 (3 H, d, *J* 1 Hz, $CH_2{:}CMe$), 1.2 (3 H, s, CMe), 0.9 (3 H, d, *J* 6 Hz, 11-Me), and 0.96 (3 H, *J* 6 Hz, 7-Me) (Found: C, 82.1; H, 11.4. $C_{18}H_{30}O$ requires C, 82.3; H, 11.5%).

3β,7α,11β-*Trimethyl*-3-(2-*oxopropyl*)-1β*H*,8β*H*-*bicyclo*-[6.3.0]*undecan*-4-*one* (35).—An excess of ozone was passed through a solution of the ketone (34) (400 mg) in methanol (4 ml) at −55 °C (ethyl acetate–liquid nitrogen). The solution was then added to a cooled mixture of potassium iodide (3 g) in methanol (6 ml) and acetic acid (2 ml). After 20 min at room temperature, iodine was reduced with sodium thiosulphate (2.5 g) in water (10 ml) and the solvent removed at 30 °C *in vacuo*. The usual work-up and distillation afforded an oil (350 mg), b.p. 135° at 0.02 mmHg. The product was chromatographed over neutral activated alumina (5 g). Elution with light petroleum furnished an oil (55 mg) which was mainly unoxidised material (from n.m.r. studies). Elution with benzene–light petroleum (1 : 9) afforded the *diketone* (35) (210 mg) as long fibrous crystals, m.p. 94—95° (from light petroleum), single spot on t.l.c. (benzene–chloroform, 1 : 1), δ 2.05 (3 H, s, COMe), 2.6 (2 H, s, $CH_2{\cdot}CO$), 1.3 (3 H, s, CMe), 0.93 (3 H, d, *J* 6 Hz, 11-Me), and 0.96 (3 H, d, *J* 6 Hz, 7-Me), *m/e* 264 (M^+) and 246 ($M^+ - H_2O$) (Found: C, 82.0; H, 11.3. $C_{17}H_{28}O_2$ requires C, 82.2; H, 11.3%). From the mother liquor an oil (*ca.* 50 mg) was isolated showing characteristic diketone signals in the n.m.r.

3β,10α,14β-*Trimethyl*-1β*H*,11β*H*-*tricyclo*[9.3.0.$0^{3,7}$]*tetradec*-6-*en*-5-*one* (36).—A mixture of the diketone (35) (70 mg) and potassium hydroxide (100 mg) in water (0.03 ml) and methanol (3 ml) was refluxed for 4 h under nitrogen. The product was sublimed at 120 °C and 0.03 mmHg to afford a mixture of compounds (35) and (36), $\lambda_{max.}$ 235 nm (ε 7 000), M^+ 264 and 246. The mixture was chromatographed over neutral activated alumina (3 g). Repeated elution with light petroleum afforded the unsaturated *ketone* (36) (25 mg) as an oil, single spot on t.l.c. (benzene–chloroform, 3 : 1), δ 5.88 (1 H, s, =CH), 1.28 (3 H, s, CMe), 0.95 (3 H, d, *J* 6 Hz, 14-Me), 0.98 (3 H, d, *J* 6 Hz, 10-Me), and 2.32 (2 H, s, $CH_2{-}C{=}O$) (Found: C, 82.6; H, 10.5. $C_{17}H_{26}O$ requires C, 82.8; H, 10.6%). Elution with benzene–light petroleum furnished the diketone (35) (15 mg).

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