Synthesis of (±)-Thaps-7(15)-ene and (±)-Thaps-6-enes

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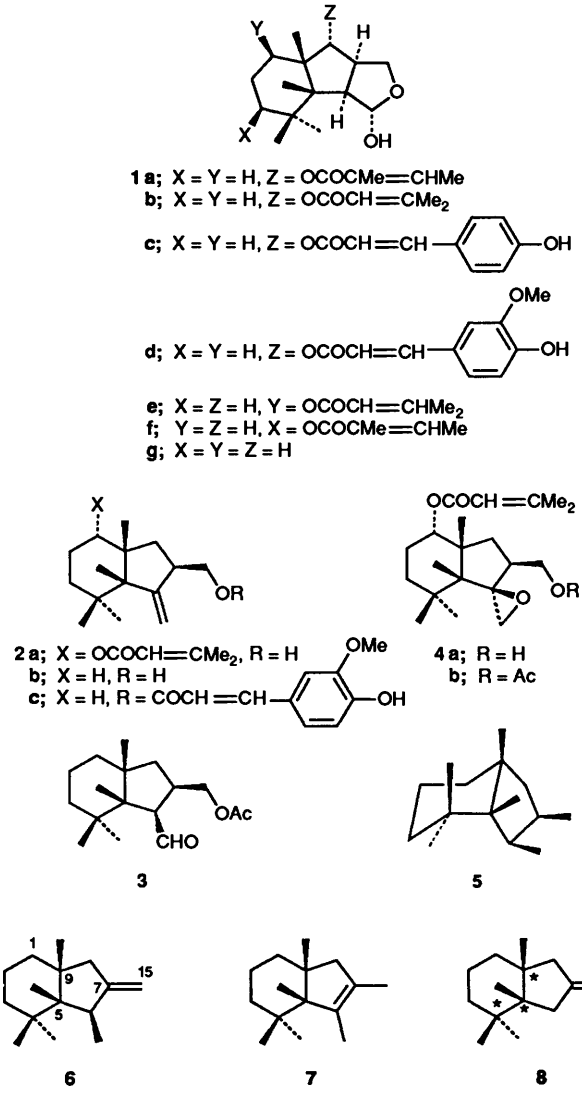
The synthesis of (±)-3a,4,4,7a-tetramethylhydrindan-2-one **8**, containing three contiguous quaternary carbons as present in thapsanes, and the total synthesis of thaps-7(15)-ene **6** and thaps-6-ene **7**, probable biogenetic precursors of thapsanes, have been achieved. Thus, orthoester Claisen rearrangement of cyclogeraniol **14**, followed by hydrolysis of the resultant ester **16** furnished the eneacid **13**. Copper sulfate-catalysed intramolecular cyclopropanation of the diazo ketone **18**, derived from the acid **13**, generated the cyclopropyl ketone **12**. Regiospecific reductive cleavage of cyclopropyl ketone **12** furnished the hydrindanone **8**, whereas the diazo ketone **26** furnished the hydrindanone **28a** *via* the cyclopropyl ketone **27**. Wittig methylenation of the hydrindanone **28a** furnished thaps-7(15)-ene **6**, which on isomerisation gave thaps-6-ene **7**. Allylic oxidation of thaps-6-ene furnished the thapsenone **31**, a degradation product of the natural thapsane **1b**.

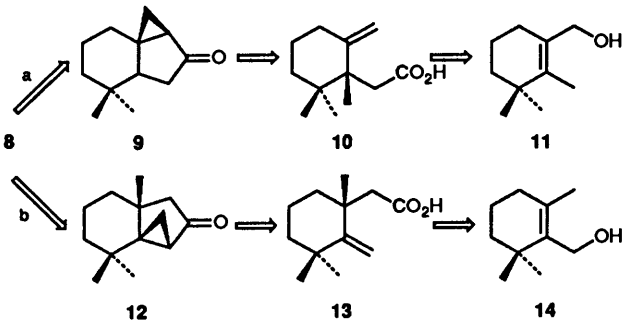
In 1984, Rasmussen and co-workers [1] reported the isolation of a new sesquiterpene, containing a new carbon skeleton, from the ethanolic extract of the roots of a Mediterranean umbelliferous plant, *Thapsia villosa* L. The structure, as well as the absolute configuration, of this new sesquiterpene was established as **1a**, by spectral and single-crystal X-ray analysis. Simultaneously, Grande and co-workers isolated the corresponding senecioate ester **1b** from the benzene extract of the roots of *Thapsia villosa* var *minor*, along with four other hemiacetalic, **1c–f**, four non-acetalic, **2a**, **3**, **4a** and **4b**, and a dimeric thapsane, all minor components, having the same carbon skeletal framework.[2,3] The trivial name thapsane was suggested for the bicyclic carbon skeleton, 1,2,3a,7,7,7a-hexamethylhydrindane with stereostructure **5**, present in these compounds. Recently, Christensen and co-workers have reported the isolation of three more new thapsanes,[4] two non-acetalic, **2b** and **2c**, and one hemiacetalic, **1g** from *Thapsia villosa* var *minor* collected near Capo Espichel (Portugal).

The presence of a unique *cis,anti,cis*-3b,4,4,7a-tetramethylperhydroindeno[1,2-*c*]furan framework,[1-4] containing three contiguous quaternary carbon atoms and five to six chiral centres, makes thapsanes attractive and challenging synthetic targets. Generation of the three contiguous quaternary carbons in the hydrindane framework in order to build the thapsane skeleton poses a considerable synthetic challenge. Herein, we report the details of our investigations[5] on the synthesis of thaps-7(15)-ene **6** and thaps-6-ene **7**, probable biogenetic precursors to thapsanes, based on Claisen rearrangement[6] and intramolecular diazo ketone cyclopropanation.[7] First our attention was focussed on the construction of the crucial 3a,4,4,7a-tetramethylhydrindane system, *e.g.* **8**, containing three contiguous quaternary carbon atoms.

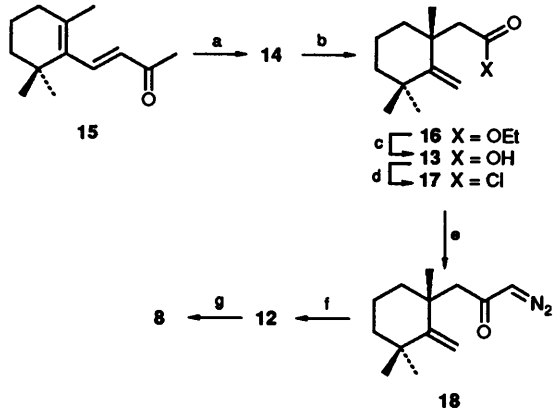


Results and Discussion

Synthesis of 3a,4,4,7a-*Tetramethylhydrindan*-2-*one* **8**.—The retrosynthetic analysis (Scheme 1) of the hydrindanone **8**, based on a combination of orthoester Claisen rearrangement and an intramolecular diazo ketone cyclopropanation, identified either (i) the cyclopropyl ketone **9** and eneacid **10** as key intermediates with the allylic alcohol **11** as probable starting material (*via* path a), or (ii) cyclopropyl ketone **12** and the eneacid **13** as the key intermediates with cyclogeraniol **14** as the starting material (path b). The second path was chosen for the obvious reason of ready access[8] to cyclocitral containing the first quaternary carbon atom, as depicted in Scheme 2. The starting material cyclogeraniol **14** was prepared from the readily available β-ionone **15**. Thus, controlled ozonation[8b] of the β-ionone **15** in methanol and direct reduction of the ozonide with an excess of sodium borohydride furnished the cyclogeraniol **14** in 61% yield. The second quaternary carbon was introduced *via* a



Scheme 1

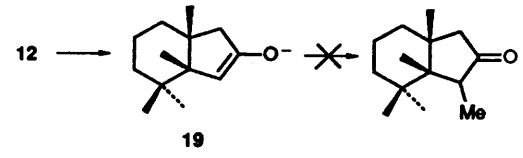


Scheme 2 *Reagents and conditions:* (a) (i) O_3, MeOH, −70 °C; (ii) $NaBH_4$, −70 °C ⟶ room temp, 12 h; (b) $MeC(OEt)_3$, $EtCO_2H$, 180 °C, 7 days; (c) 10% aq. NaOH, MeOH, reflux, 8 h; (d) $(COCl)_2$, benzene, room temp, 6 h; (e) CH_2N_2, Et_2O, room temp., 4 h; (f) $CuSO_4$, c-C_6H_{12}, *hν* (tungsten lamp), reflux, 4 h; (g) Li, liq. NH_3, 30 min.

Claisen rearrangement. Thus, orthoester Claisen rearrangement[9] of cyclogeraniol **14** with triethyl orthoacetate in the presence of a catalytic amount of propionic acid (Carius tube, 180 °C) furnished the ene-ester **16** whose IR spectrum exhibited characteristic bands for the ester (ν_{max} 1730 and 1200 cm^{-1}) and the *exo*-methylene (910 cm^{-1}) moieties, and whose ^1H NMR spectrum showed resonances due to the *exo*-methylene [δ 4.93 (1 H, s) and 4.88 (1 H, s)], methylene α to carbonyl [2.4 (s)], ethoxy group [4.0 (2 H, q, *J* 7.2 Hz) and 1.2 (3 H, t, *J* 7.2 Hz)] and three tertiary methyls [1.23 (3 H, s) and 1.16 (6 H, s)], thereby establishing its structure.

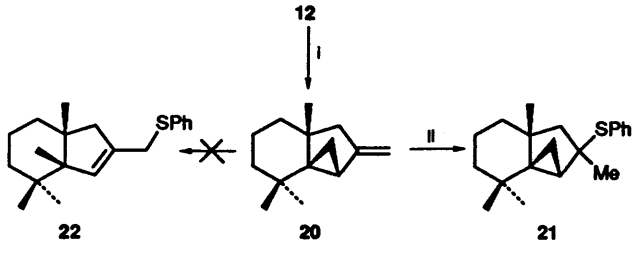
Base-catalysed hydrolysis of ester **16** furnished the first key intermediate of the sequence, the eneacid[10] **13** (60% yield from **14**). The third quaternary carbon was introduced in a stereospecific manner by use of an intramolecular diazo ketone cyclopropanation.[7] Treatment of the acid chloride **17**, obtained from the acid **13** and oxalyl dichloride, with an excess of ethereal diazomethane furnished the diazo ketone **18** (ν_{max} 2100 and 1630 cm^{-1}). Anhydrous copper sulfate-catalysed decomposition of the diazo ketone **18** in refluxing cyclohexane (using a 100 W tungsten lamp) and intramolecular addition of the resultant keto carbenoid into the *exo*-methylene stereospecifically gave the second key intermediate of the sequence, cyclopropyl ketone **12**, m.p. 118–121 °C (lit.,[11] 122 °C), a known degradation product of the sesquiterpene thujopsene.[11] Regiospecific reductive cleavage of the cyclopropane ring in compound **12** with lithium in liquid ammonia furnished the hydrindanone **8**, m.p. 124–127 °C (lit.,[12a] 171–175 °C);* 2,4-DNP, m.p., 171–173 °C (lit.,[12a] 125–127 °C). The regiospecificity in the cyclopropane cleavage can be explained by the cleavage of the cyclopropane bond which has maximum overlap with the p-orbital of the carbonyl system.[12]

Synthesis of Thaps-7(15)-ene **6** *and Thaps-6-ene* **7**.—Having achieved the synthesis of the hydrindanone **8**, demonstrating the feasibility of the sequence, we extended the methodology to the construction of the thapsane skeleton **5**. This requires introduction of two more carbons, one at C-2 and the other at C-3 of the hydrindanone **8**. Introduction of a carbon at C-2 will be straightforward, *e.g. via* Wittig olefination; however, introduction of a carbon substituent at C-3 posed regiochemical problems as the two methylenes α to carbonyl (C-1 and C-3) are not easily distinguishable. One way to circumvent this problem is to quench the regiospecific enolate **19**, formed in the lithium–



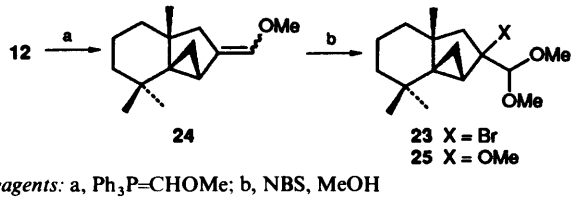
liq. ammonia reduction of the cyclopropyl ketone **12**, with carbon electrophiles.[13] However, all our attempts to quench the enolate **19** with methyl iodide were unsuccessful.

In other directions attempts were made to open the cyclopropane after the introduction of the C-2 methylene. Wittig methylenation [methyltriphenylphosphonium bromide and potassium *tert*-amylate in *tert*-amyl alcohol (1,1-dimethylpropan-1-ol)[14] in benzene] of the cyclopropyl ketone **12** furnished the vinyl cyclopropane **20**. Addition of thiophenol to the vinyl cyclopropane **20**, however, led to the formation of sulfide **21** *via* an ionic addition rather than to the expected allyl sulfide **22** *via* a radical addition.[15]



Reagents: i, $Ph_3P{=}CH_2$; ii, PhSH

To carry out the radical-mediated cyclopropane ring cleavage,[16] preparation of the bromo acetal **23** by a methoxymethylenation of the cyclopropyl ketone **12**, followed by bromoacetalisation of the enol ether **24** was attempted.[17] Wittig reaction of the cyclopropyl ketone **12** with methoxymethylenetriphenylphosphorane furnished the enol ether **24**. Reaction of the enol ether **24** with *N*-bromosuccinimide (NBS) and methanol furnished the α-methoxy acetal **25** instead of the expected bromo acetal **23** perhaps due to steric crowding, the intramolecular migration of the methoxy group followed by acetalisation occurring. The structure of the acetal **25** was delineated from its ^1H NMR spectrum, which exhibited three

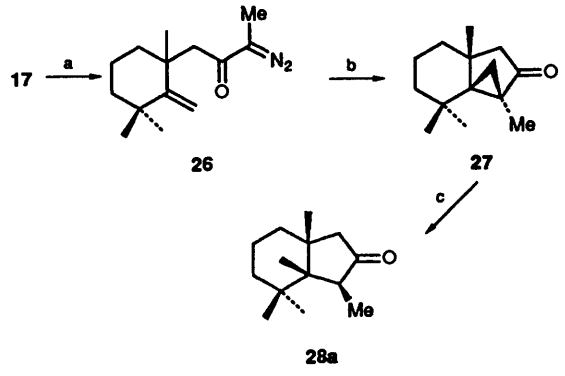


Reagents: a, $Ph_3P{=}CHOMe$; b, NBS, MeOH

* We believe that the m.p.s reported for the ketone **8** and its 2,4-DNP derivative were interchanged in ref. 12*a*.

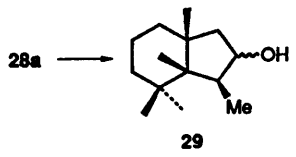
methoxy singlets [δ 3.59, 3.55 and 3.41], three methyl singlets [δ 1.07, 0.99 and 0.59] and the cyclopropane protons [δ 0.5–0.6 (3 H)].

Finally, it was decided to introduce the required carbon at C-1 of the indanone early in the sequence. To this end, diazoethane[18] was employed instead of diazomethane, to generate the diazo ketone **26**. Thus, treatment of the acid chloride **17** with an excess of diazoethane in diethyl ether furnished the diazo ketone **26** (ν_{max} 2060 and 1630 cm^{-1}) (Scheme 3). Copper sulfate-catalysed decomposition of the



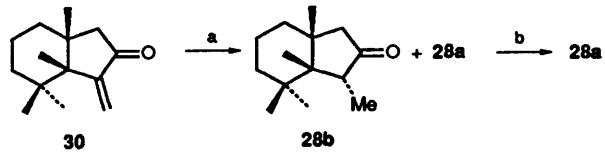
Scheme 3 *Reagents and conditions:* (a) $MeCHN_2$, Et_2O, room temp., 4 h; (b) $CuSO_4$, c-C_6H_{12}, *hv* (tungsten lamp), reflux, 4 h; (c) Li, liq. NH_3, 30 min

diazo ketone **26** in refluxing cyclohexane (using a 100 W tungsten lamp) furnished, stereospecifically, the cyclopropyl ketone **27** m.p. 116–120 °C (31% from the acid **13**), whose structure was delineated from the spectral data. The IR spectrum showed a carbonyl band at ν_{max} 1720 cm^{-1}. The ^1H NMR spectrum showed an AB quartet at δ 2.08 and 1.58 (*J* 18 Hz) for the methylene α to carbonyl, and four methyl singlets at δ 1.42, 1.24, 1.20 and 0.88, thus establishing the structure of compound **27**. The ^{13}C NMR spectrum (see Experimental section) confirmed the structure. Regiospecific reductive cleavage of the cyclopropyl ketone **27** by using lithium in liquid ammonia conditions furnished the ketone **28a**, m.p. 121–123 °C, whose IR spectrum showed a carbonyl band at ν_{max} 1740 cm^{-1} typical for the cyclopentanone system. In the ^1H NMR spectrum, a quartet at δ 2.61 for C*H*Me, an AB quartet at δ 2.26 and 1.90 for the methylene α to carbonyl, a methyl doublet at δ 1.08 and four methyl singlets at δ 1.21, 1.04 and 0.88 (2 × Me), and in the ^{13}C NMR spectrum resonances due to a cyclopentanone carbonyl at δ_C 221.4 (s), a methylene α to carbonyl at δ_C 54.0 (t), a methine α to carbonyl at δ_C 48.8 (d), and three quaternary carbon singlets at δ_C 48.1, 39.8 and 36.3 in addition to the other resonances confirmed the structure. The stereochemistry of the C-1 methyl group was assigned as *exo* based on thermodynamic considerations. The molecular mechanics (MMX) calculations predicted that the *exo* isomer **28a** is more stable than the *endo* isomer **28b** by 6 kcal mol^{-1}.* The inertness of the ketone **28** to various equilibration conditions (K_2CO_3/MeOH, NaOMe/MeOH, DBU, *etc*) suggested that it was the most stable isomer. Further evidence came from shift-reagent studies on the corresponding alcohols **29**. Reduction (sodium borohydride) of ketone **28** furnished a 1:1.5 mixture of inseparable epimeric alcohols **29**.† It was assumed that the major alcohol would have the *endo* orientation for the hydroxy group as a result of the preferred *exo* hydride attack. The ^1H NMR spectrum of the alcohol mixture with 0.75



Reagents: $NaBH_4$, MeOH

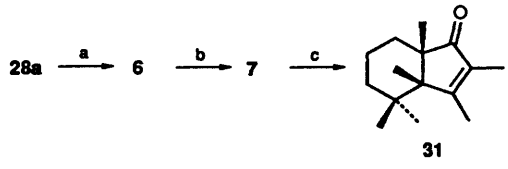
molar equivalents of Eu(fod)$_3$ showed two sets of signals for the two isomers (1.5:1). The resonance due to the methyl doublet for the minor isomer at δ 8.5, when compared with that for the major isomer at δ 4.82, established the *cis* nature of the hydroxy and methyl groups in the minor isomer, and hence the *exo* orientation for the methyl group in the ketone. This was finally confirmed by chemical studies. Hydrogenation of the enone **30**, obtained by a different method,[19] gave an inseparable mixture of epimers **28a** and **28b** (Scheme 4). The epimeric mixture **28**, on



Scheme 4 *Reagents:* a, H_2, Pd–C; b, K_2CO_3, MeOH

equilibration with potassium carbonate in methanol at room temperature, resulted in the thermodynamic isomer, whose ^1H NMR spectrum was identical with that of the ketone obtained in the lithium–liquid ammonia reduction of the cyclopropyl ketone **27**, thereby confirming the structure of the ketone **28a**.

The fifteenth carbon required to complete the construction of the carbon skeleton present in thapsanes was introduced using a Wittig olefination. Thus, reaction of the ketone **28a** with



Scheme 5 *Reagents:* a, $Ph_3P{=}CH_2$; b, PTSA; c, Bu^{t}OOH, CrO_3

methylenetriphenylphosphorane in benzene at room temperature gave thaps-7(15)-ene **6**, in 66% yield, whose structure was delineated from its spectral data. In the IR spectrum the absence of the carbonyl band and the presence of bands at ν_{max} 1650 and 880 cm^{-1} due to the *exo* methylene moiety indicated the structure. In the ^1H NMR spectrum resonances due to *exo* methylene at δ 4.83 (2 H, m), allylic protons [δ 2.8 (1 H, m), an AB quartet at δ 2.43 and 1.82], a methyl doublet at δ 1.12 and four methyl singlets at δ 1.1, 1.0, 0.9 and 0.8 and, in the ^{13}C NMR spectrum, resonances due to *exo* methylene [δ_C 157.5 (s) and 105.7 (t)], three quaternary carbon singlets (δ_C 49.4, 42.7 and 36.3) and five methyl quartets (δ_C 30.0, 25.4, 23.1, 18.4 and 13.1) confirmed the structure. Isomerisation of the olefin **6** by using toluene-*p*-sulfonic acid (PTSA) in methylene dichloride at room temperature furnished thaps-6-ene **7** in 80% yield. The absence of olefinic protons and the presence of the two olefinic methyls at δ 1.58 (6 H, br s) in the ^1H NMR spectrum and the presence of two quaternary olefinic carbon singlets at δ_C 136.2 and 130.0 in the ^{13}C NMR spectrum clearly established the structure of the olefin. Further confirmation of the structure of the olefin **7** came through its oxidation. Oxidation of the olefin **7** with *tert*-butyl hydroperoxide and a catalytic amount of chromium trioxide in methylene dichloride[20] at room temperature furnished the enone **31**, the degradation product[3] of the natural thapsane **1b**. The IR and ^1H NMR spectrum of the synthetic **31** product were found to be identical with those of

* 1 cal = 4.184 J.

† Formation of the mixture of epimeric alcohols **29** itself suggests that the structure of the starting ketone is **28a**, since the ketone **28b** is expected to give only one alcohol due to steric reasons.

the authentic compound derived from natural thapsane **1b**, kindly provided by Professor Grande.

In conclusion, synthesis of the hydrindanone **8** containing three contiguous quaternary carbons, starting from cyclogeraniol **14**, was achieved by use of an orthoester Claisen rearrangement and an intramolecular diazo ketone cyclopropanation to construct the two vicinal quaternary carbons, in addition to the one already present. The methodology has been extended to the total synthesis of thapsenes **6** and **7**, the probable biogenetic precursors of thapsanes. Even though these thapsenes **6** and **7** have not so far been isolated from Nature, one can anticipate, from the literature precedence (isolation of hydrocarbons much later than the oxygenated species), that either thapsenes (**6** or **7**), or both, may be isolated as natural products in the near future.

Experimental

M.p.s were measured on a Reichert-Kofler microheating stage fitted with a polarising microscope and are uncorrected. UV spectra were recorded on a Shimadzu UV-190 spectrometer. IR spectra (thin films) were recorded on a Perkin-Elmer 781 spectrophotometer. ^1H (60, 90, 270 MHz) and ^{13}C NMR (22.5 MHz) spectra were recorded on Varian T-60, JEOL FX-90Q and Bruker WH-270 spectrometers. The chemical shifts (δ) and the coupling constants (Hz) are reported in the standard fashion with reference to either internal tetramethylsilane (for ^1H) or the central line (δ_C 77.1) of $CDCl_3$ (for ^{13}C). In the ^{13}C NMR spectra off-resonance multiplicities, when recorded, are given in parentheses. Low- and high-resolution mass measurements were carried out with a JEOL JMS-DX 303 GC-MS instrument using a direct inlet mode. Relative intensities of the ions are given in parentheses. Ozonolysis was carried out by using a Penwalt Wallace and Tierman ozonator. Evaporations of solvent were carried out with either a steam-bath or a Buchi rotary evaporator. Acme's silica gel (100–200 mesh) was used for column chromatography. All the moisture-sensitive reactions were carried out using standard syringe-septum techniques under nitrogen. Dry benzene was obtained by washing with H_2SO_4 followed by distillation over sodium, and was stored over pressed sodium wire. Dry diethyl ether was obtained by distillation over sodium, and was stored over sodium wire. Tetrahydrofuran (THF) was dried by distillation over sodium benzophenone ketyl. Methylene dichloride was distilled over P_2O_5. Dry Am^{t}OH was obtained by distillation over sodium. Butyllithium and lithium (rods) were obtained from E-Merck. Methoxymethyltriphenylphosphonium chloride and methyltriphenylphosphonium bromide were prepared from the corresponding halides and triphenylphosphine according to the literature procedure.[21] Liquid ammonia was distilled over sodium. Anhydrous copper sulfate was made by heating copper sulfate in a furnace at 250 °C for 12 h. *N*-Ethyl-*N*-nitrosourea[18] was prepared from ethylamine hydrochloride and urea. β-Ionone was obtained as a gift from M/S Kelkar and Co. Light petroleum refers to the fraction boiling in the range 60–80 °C.

2,6,6-*Trimethylcyclohex*-1-*enemethanol* (*Cyclogeraniol*) **14**.—A stream of ozone in oxygen was passed through a cold (−78 °C, alcohol–liquid N_2-bath), magnetically stirred solution of β-ionone **15** (9.6 g, 50 mmol) in methanol (90 cm^3) for 3.5–4 h (until disappearance of starting material on TLC). The excess of ozone was flushed out with oxygen, and sodium borohydride (5.7 g, 150 mmol) was added while the temperature was kept between −20 and −50 °C. The reaction mixture was allowed to warm up to room temperature and was stirred for 12 h. Evaporation of methanol afforded a solid residue, which was acidified with 10% HCl and extracted with methylene dichloride (150 cm^3 × 3). The extract was washed with saturated aq. $NaHCO_3$ and dried over anhydrous Na_2SO_4. Evaporation of the solvent, and purification of the residue on a silica gel (100 g) column with 1:10 ethyl acetate–hexane as eluent, furnished cyclogeraniol **14** (4.7 g, 61%) as an oil, ν_{max}/cm^{-1} 3395, 1385, 1365, 1015 and 990; δ_H(90 MHz; $CDCl_3$) 4.12 (2 H, s, CH_2O), 1.92 (2 H, m, allylic), 1.74 (3 H, s, olefinic Me), 1.2–1.7 (4 H, m, 2 × CH_2) and 1.04 (6 H, s, *gem*-dimethyl); δ_C($CDCl_3$), 137.1 (s) and 133.1 (s) (C=C), 58.2 (t, CH_2OH), 39.4 (t, C-5), 33.8 (s, C-6), 32.6 (t, C-3), 28.3 (2 C, q, CMe_2), 19.5 (q, olefinic methyl) and 19.2 (t, C-4).

1,3,3-*Trimethyl*-2-*methylenecyclohexaneacetic acid* **13**.—A solution of cyclogeraniol **14** (1.078 g, 7 mmol), triethyl orthoacetate (2.57 cm^3, 14 mmol) and propionic acid (cat) in toluene (2 cm^3) was placed in a Carius tube under nitrogen and was heated to 180 °C for 7 days. The reaction mixture was cooled, poured into water (25 cm^3), and extracted with benzene (20 cm^3 × 3). The extract was washed successively with 10% aq. HCl (15 cm^3) and saturated aq. $NaHCO_3$ (15 cm^3) and dried over anhydrous Na_2SO_4. Evaporation of the solvent under reduced pressure afforded the ester **16**, ν_{max}/cm^{-1} 1730, 1625, 1470, 1385, 1370, 1325, 1200, 1125, 1050 and 910; δ_H(60 MHz; CCl_4) 4.93 (1 H, s) and 4.88 (1 H, s) (*exo* methylene), 4.0 (2 H, q, *J* 7.2, OCH_2Me), 2.4 (2 H, s, CH_2CO_2), 1.2–1.3 (6 H, m, 3 × CH_2), 1.23 (3 H, s), 1.20 (3 H, s), 1.16 (6 H, s) (3 × Me) and 1.20 (3 H, t, *J* 7.2, OCH_2Me).

A solution of the ester **16** in 1:1 methanol–10% aq. NaOH (30 cm^3) was refluxed for 8 h. The methanol was evaporated under reduced pressure, the residue was poured into water (15 cm^3), and the mixture was washed with methylene dichloride (15 cm^3 × 2). The aqueous phase was acidified with 10% HCl and extracted with methylene dichloride (30 cm^3 × 3). The organic extract was washed successively with water (15 cm^3) and brine, and dried over anhydrous Na_2SO_4. Evaporation of the solvent furnished the acid **13** (823 mg, 60% from **14**) as a yellow, viscous oil,[10] ν_{max}/cm^{-1} 3500–2400 (CO_2H), 1710, 1630 and 900; δ_H(60 MHz; CCl_4) 11.6 (1 H, br s, CO_2H), 4.96 (1 H, s) and 4.88 (1 H, s) (*exo* methylene), 2.48 (2 H, s, CH_2CO_2H), 1.3–1.8 (6 H, m, 3 × CH_2), 1.28 (3 H, s) and 1.17 (6 H, s) (3 × Me).

6,10,10-*Trimethyltricyclo*[4.4.0.0^{1,3}]*decan*-4-*one* **12**.—To a magnetically stirred solution of the acid **13** (784 mg, 4 mmol) in dry benzene (3 cm^3) was added oxalyl dichloride (0.7 cm^3, 8 mmol). The reaction mixture was stirred for 5 h at room temperature and was then concentrated under reduced pressure to afford the acid chloride **17**.

To an ice-cold, magnetically stirred solution of ethereal diazomethane [prepared from *N*-methyl-*N*-nitrosourea (3 g, 29 mmol)] was added, dropwise, a solution of the acid chloride **17** in anhydrous diethyl ether (20 cm^3), and the resulting solution was stirred for 3 h at room temperature. The excesses of diazomethane and diethyl ether were removed by careful evaporation on a water-bath and the residue was rapidly filtered through a silica gel (10 g) column by using 1:6 ethyl acetate–hexane as eluent to furnish the diazo ketone **18** as a yellow oil, ν_{max}/cm^{-1} 3080, 2100, 1630, 1360, 1170 and 900.

To a magnetically stirred, refluxing (by use of two 100 W tungsten lamps placed at a distance of 2.5 cm from the flask on either side) suspension of anhydrous copper sulfate (1 g) in cyclohexane (60 cm^3) was added, dropwise, a solution of the diazo ketone **18** in cyclohexane (6 cm^3), and the reaction mixture was stirred at reflux for 5 h. After cooling, the copper sulfate was filtered off. Evaporation of the solvent under reduced pressure and purification of the residue on a silica gel (12 g) column with 1:20 ethyl acetate–hexane as eluent furnished the cyclopropyl ketone **12** (307 mg, 40% from the acid **13**) as a solid, which was recrystallised from light petroleum,

m.p. 118–121 °C (lit.,[11] 122 °C); ν_{max}/cm^{-1} 1725, 1278, 1170 and 810; δ_H (270 MHz; $CDCl_3$) 2.08 (1 H, $\frac{1}{2}$ AB q, J 17.3, C*H*HCO), 1.88 (1 H, d, J 8.6, CHCO), 1.2–1.8 (9 H, m, 4 × CH_2, 3- and CH*H*CO), 1.23 (3 H, s, 6-Me), 1.13 (3 H, s, 10ax-Me) and 0.60 (3 H, s, 10eq-Me); δ_C($CDCl_3$) 212.9 (s, carbonyl), 49.8 (t, *C*H_2CO), 46.1 (s, C-1), 39.8 (t) and 39.5 (t) (C-7 and -9), 38.1 (s, C-6), 35.0 (d, C-3), 31.4 (s, C-10), 27.5 (q), 27.1 (q) and 23.3 (q) (3 × Me), 18.5 (t, C-8) and 15.4 (t, C-2); m/z 192 (M^+, 23%), 135 (44), 123 (40), 122 (70), 109 (35), 107 (48), 95 (40), 93 (46), 91 (40) and 41 (100).

1,2,2,6-*Tetramethylbicyclo*[4.3.0]*nonan*-8-*one* **8**.—To magnetically stirred, freshly distilled liquid ammonia (40 cm^3) in a three-necked flask, equipped with a Dewar condenser at −33 °C (evaporative cooling), was added a solution of the cyclopropyl ketone **12** (298 mg, 1.55 mmol) in dry THF (1 cm^3), followed by freshly cut lithium (54 mg, 7.75 mmol) in small pieces and the resulting blue solution was stirred at −33 °C for 15 min. The reaction mixture was quenched with solid NH_4Cl, and the ammonia was allowed to evaporate off over a period of 2 h. The residue was then taken up in water (10 cm^3) and extracted with diethyl ether (25 cm^3 × 3). The extract was washed with brine and dried over anhydrous Na_2SO_4. Evaporation of the solvent, and purification of the residue on a silica gel (8 g) column with 1 : 20 ethyl acetate–hexane as eluent, furnished the ketone **8** (195 mg, 65%) as a solid, m.p. 124–127 °C (lit.,[12a] 171–175 °C); 2,4-DNP m.p. 171–173 °C (lit.,[12a] 125–127 °C); ν_{max}/cm^{-1} (Nujol) 1740, 1400, 1395, 1380, 1265, 1210, 1188, 1165, 1135 and 978; δ_H (270 MHz; $CDCl_3$) 2.65 and 1.88 (2 H, AB q, J 18.5, CH_2CO), 2.35 and 1.93 (2 H, AB q, J 18.8, CH_2CO), 1.2–1.7 (6 H, m, 3 × CH_2), and 1.19 (3 H, s), 1.06 (3 H, s), 1.01 (3 H, s) and 0.83 (3 H, s) (4 × Me); δ_C($CDCl_3$) 218.1 (s, carbonyl), 54.3 (t) and 49.3 (t) (C-7 and -9), 45.8 (s, C-1), 40.6 (s, C-6), 37.3 (2 C, t, C-3 and -5), 34.8 (s, C-2), 28.1 (q), 24.7 (q), 22.2 (q) and 18.1 (q) (4 × Me) and 18.4 (t, C-4) (Found: M^+, 194.1681. Calc. for $C_{13}H_{22}O$; M, 194.1671).

6,10,10-*Trimethyl*-4-*methylenetricyclo*[4.4.0.0^{1,3}]*decane* **20**.—To a magnetically stirred suspension of methyltriphenylphosphonium bromide (357 mg, 1 mmol) in dry benzene (3 cm^3) was added a solution of potassium *tert*-amylate in *tert*-amyl alcohol (1 mol dm^{-3}, 1 cm^3, 1 mmol), and the resulting yellow solution was stirred at room temperature for 10 min. To this solution was added a benzene (0.5 cm^3) solution of cyclopropyl ketone **12** (38 mg, 0.2 mmol), and the mixture was stirred at room temperature for 10 h. The reaction was quenched with saturated aq. NH_4Cl (4 cm^3) and the mixture was extracted with diethyl ether (7 cm^3 × 3). The extract was washed with brine and dried over anhydrous Na_2SO_4. Evaporation of the solvent, and purification of the residue on a silica gel (3 g) column with hexane as eluent, furnished the olefin **20** (24 mg, 64%) as an oil, ν_{max}/cm^{-1} 1641, 1599, 1461, 1380, 1365, 882 and 669; δ_H(60 MHz; CCl_4) 4.63 (1 H, br s) and 4.4 (1 H, br s) (*exo* methylene), 0.55–2.1 (11 H, m), and 1.02 (3 H, s), 0.97 (3 H, s) and 0.53 (3 H, s) (3 × Me); m/z 190 (M^+, 84%), 175 (26), 147 (26), 123 (43), 119 (37), 107 (74) and 91 (100) (Found: M^+, 190.1716. $C_{14}H_{22}$ requires M, 190.1721).

4,6,10,10-*Tetramethyl*-4-*phenylthiotricyclo*[4.4.0.0^{1,3}]*decane* **21**.—A solution of the olefin **20** (23 mg, 0.12 mmol) and thiophenol (0.02 cm^3, 0.2 mmol) in benzene (1 cm^3) was placed in a Carius tube and heated to 80 °C for 12 h. The reaction mixture was cooled, poured into water (5 cm^3), and extracted with diethyl ether (5 cm^3 × 3). The extract was washed successively with 5% aq. NaOH (5 cm^3) and brine, and dried over anhydrous Na_2SO_4. Evaporation of the solvent, and purification of the residue on a silica gel (2 g) column with 1 : 40 ethyl acetate–hexane as eluent, furnished the sulfide **21** (29 mg, 80%) as a solid, m.p. 100–102 °C; ν_{max}/cm^{-1} 1479, 1464, 1440 1110, 753, 723 and 693; δ_H(270 MHz; $CDCl_3$) 7.55 (2 H, br s) and 7.3 (3 H, br s) (aromatic), 0.55–1.8 (11 H, m), and 1.49 (3 H, s), 1.1 (3 H, s), 1.01 (3 H, s) and 0.58 (3 H, s) (4 × Me); m/z 300 (M^+, < 1%), 191 (M^+ − SPh, 100), 123 (14), 109 (17) and 95 (27) (Found: M^+, 191.1799. $C_{14}H_{23}$ (M^+ − SPh) requires 191.1800).

4-*Dimethoxymethyl*-4-*methoxy*-6,10,10-*trimethyltricyclo*-[4.4.0.0^{1,3}]*decane* **25**.—To a magnetically stirred suspension of (methoxymethyl)triphenylphosphonium chloride (343 mg, 1 mmol) in dry benzene (4 cm^3) was added butyllithium (1.6 mol dm^{-3} in hexane; 0.65 cm^3, 1 mmol), and the resulting orange solution was stirred at room temperature for 10 min. To this solution was added a benzene (1 cm^3) solution of the cyclopropyl ketone **12** (38 mg, 0.2 mmol) and the mixture was refluxed for 3 h. The reaction mixture was cooled, poured into water (10 cm^3), and extracted with benzene (10 cm^3 × 2). The extract was washed with brine and dried over anhydrous Na_2SO_4. Evaporation of the solvent, and purification of the residue on a silica gel (3 g) column with hexane as eluent, furnished the enol ether **24** (20 mg, 45%), contaminated with traces of triphenylphosphine, as an oil, ν_{max}/cm^{-1} 1698, 1374, 1239, 1212, 1191 and 1122.

To a magnetically stirred, cold (−50 °C, ethanol–liq. N_2-bath) solution of the enol ether **24** (20 mg, 0.09 mmol) in dry methylene dichloride were added sequentially methanol (0.3 cm^3) and NBS (18 mg, 0.1 mmol). The resulting mixture was stirred for 10 min, poured into water (10 cm^3), and extracted with methylene dichloride (5 cm^3 × 2). The combined extract was washed successively with 3% aq. NaOH and brine, and dried over anhydrous Na_2SO_4. Evaporation of the solvent, and purification of the residue on a silica gel (2 g) column with ethyl acetate–hexane (1 : 10) as eluent, furnished the acetal **25** (20 mg, 78%) as an oil, δ_H(270 MHz; $CDCl_3$) 4.33 (1 H, s, OCHO), 3.59 (3 H, s), 3.55 (3 H, s) and 3.41 (3 H, s) (3 × OMe), 1.82 and 1.26 (2 H, AB q, J 14.4, 5-H_2), 1.2–1.6 (6 H, m, $[CH_2]_3$), 1.07 (3 H, s), 0.99 (3 H, s) and 0.59 (3 H, s) (3 × Me) and 0.5–0.6 (3 H, m, cyclopropane CH).

3,6,10,10-*Tetramethyltricyclo*[4.4.0.0^{1,3}]*decan*-4-*one* **27**.—To a magnetically stirred solution of the acid **13** (1.57 g, 8 mmol) in benzene (3 cm^3) was added oxalyl dichloride (1.4 cm^3, 16 mmol). The reaction mixture was stirred for 5 h at room temperature and concentrated under reduced pressure to afford the acid chloride **17**.

To an ice-cold, magnetically stirred solution of ethereal diazoethane [prepared from *N*-ethyl-*N*-nitrosourea[18] (3.5 g, 30 mmol)] was added a solution of the acid chloride **17** in anhydrous diethyl ether (20 cm^3) and the reaction mixture was stirred for 3 h at room temperature. The excesses of diazoethane and diethyl ether were carefully evaporated off on a hot water-bath and the residue was rapidly filtered through a silica gel (15 g) column with 1 : 6 ethyl acetate–hexane as eluent to furnish the diazo ketone **26**, ν_{max}/cm^{-1} 2060, 1630, 1380, 1340, 1260, 1040 and 895.

To a magnetically stirred, refluxing (by use of two 100 W tungsten lamps as described earlier) suspension of anhydrous copper sulfate (2 g) in cyclohexane (120 cm^3) was added, dropwise, a solution of the diazo ketone **26** in cyclohexane (12 cm^3), and the reaction mixture was stirred at reflux for 5 h. After cooling, the copper sulfate was filtered off. Evaporation of the solvent, and purification of the residue on a silica gel (20 g) column with 1 : 20 ethyl acetate–hexane as eluent, furnished the cyclopropyl ketone **27** (511 mg, 31%) as a pale yellow solid, which was recrystallised from hexane, m.p. 116–120 °C; ν_{max}/cm^{-1} 1720, 1385, 1335, 1285, 1180, 1160, 1130, 1070, 853 and 825; δ_H(90 MHz; $CDCl_3$) 2.08 and 1.58 (2 H, AB q, J 18,

CH_2CO), 1–1.9 (8 H, m, 4 × CH_2), 1.42 (3 H, s, 3-Me), 1.24 (3 H, s, Me), 1.2 (3 H, s, Me) and 0.88 (3 H, s, 10eq-Me); $\delta_C(CDCl_3)$ 214.1 (s, carbonyl), 49.4 (t, CH_2CO), 41.9 (s, C-1), 40.3 (t) and 39.6 (t) (C-7 and -9), 37.9 (s) and 34.0 (s) (C-6 and -10), 28.9 (2 C, q) and 23.5 (q) (3 × Me), 22.1 (t, C-2), 18.7 (t, C-8) and 14.2 (q, 3-Me) (signal due to C-3 merged with other signals); *m/z* 206 (M^+, 39%), 136 (35), 135 (38), 123 (100), 122 (85), 107 (73), 95 (70), 93 (64) and 91 (65) (Found: M^+, 206.166. $C_{14}H_{22}O$ requires *M*, 206.1671).

9-exo-1,2,2,6,9-*Pentamethylbicyclo*[4.3.0]*nonan*-8-*one* **28a**.—Reduction of the cyclopropyl ketone **27** (495 mg, 2.4 mmol) in liquid ammonia (50 cm^3)–dry THF (2 cm^3) with freshly cut lithium (84 mg, 12 mmol) for 15 min as described for the cyclopropyl ketone **12**, followed by purification of the product on a silica gel (10 g) column with 1:20 ethyl acetate–hexane as eluent, furnished the ketone **28a** (365 mg, 73%) as a solid, which was recrystallised from light petroleum, m.p. 121–123 °C; ν_{max}/cm^{-1} 1740, 1455, 1420, 1400, 1385, 1270, 1190, 1025 and 985; δ_H(270 MHz; $CDCl_3$) 2.61 (1 H, q, *J* 7.2, CHCO), 2.26 and 1.9 (2 H, AB q, *J* 18.2, CH_2CO), 1.2–1.7 (6 H, m, 3-, 4- and 5-H_2), 1.21 (3 H, s, Me), 1.08 (3 H, d, *J* 7.2, 9-Me) and 1.04 (3 H, s) and 0.88 (6 H, s) (3 × Me); $\delta_C(CDCl_3)$ 221.4 (s, carbonyl), 54.0 (t, CH_2CO), 48.8 (d, CHCO), 48.1 (s, C-1), 39.8 (s, C-6), 37.9 (t) and 37.4 (t) (C-3 and -5), 36.3 (s, C-2), 29.7 (q), 25.5 (q), 22.9 (q), 18.5 (t, C-4) and 13.4 (2 C, q); *m/z* 208 (M^+, 15%), 193 (10), 137 (24), 125 (40), 124 (77), 123 (25), 109 (30), 97 (64), 96 (40), 95 (42) and 55 (100) (Found: M^+ 208.1825. $C_{14}H_{24}O$ requires *M*, 208.1827).

1β,6β,9β- *and* 1β,6β,9α-1,2,2,6,9-*Pentamethylbicyclo*[4.3.0]*nonan*-8-*one* **28a** *and* **28b**.—The enone [19] **30** (21 mg, 0.1 mmol) in ethanol (5 cm^3) and 10% Pd–C (10 mg) were placed in a 250 cm^3 pressure bottle and hydrogenated at 50 psi for 2 h in a hydrogenation apparatus (Parr type). The reaction mixture was filtered through a silica gel (2 g) column with 1:20 ethyl acetate–hexane as eluent. Evaporation of the solvent furnished the epimeric mixture of ketones **28** (20 mg, 95%), ν_{max}/cm^{-1} 1737, 1455, 1385, 1270 and 985; δ_H(90 MHz; $CDCl_3$; 1:1 epimers) 2.54 and 1.9 (AB q, *J* 18), 2.26 and 1.9 (AB q, *J* 18) ($COCH_2$), 1–1.7 (m, 3 × CH_2) and 1.24 (s), 1.21 (s), 1.84 (s), 1.04 (s), 0.94 (s), 0.90 (s) and 0.88 (s) (4 × Me), (secondary methyl signals were merged with those of tertiary methyl signals).

Epimerisation of the Ketones **28**.—To a magnetically stirred solution of the epimeric mixture of ketones **28** (11 mg, 0.05 mmol) in methanol (2 cm^3) was added potassium carbonate (5 mg) and the mixture was stirred at room temperature for 24 h. The reaction mixture was poured into water (5 cm^3) and extracted with methylene dichloride (5 cm^3 × 2). The extract was washed successively with 5% aq. HCl (5 cm^3) and brine and dried over anhydrous Na_2SO_4. Evaporation of the solvent, and purification of the residue on a silica gel (2 g) column with 1:20 ethyl acetate–hexane as eluent, furnished the ketone **28a** (10 mg, 90%), which was identified by comparison (^1H NMR) with the ketone **28a** obtained earlier.

9-exo-8-*Methylene*-1,2,2,6,9-*pentamethylbicyclo*[4.3.0]*nonane*, [*Thaps*-7(15)-*ene*] **6**.—To a magnetically stirred suspension of methyltriphenylphosphonium bromide (1.822 g, 5.1 mmol) in dry benzene (6 cm^3) was added a 1 mol dm^{-3} solution of potassium *tert*-amylate in *tert*-amyl alcohol (5 cm^3, 5 mmol) and the resulting yellow solution was stirred for 20 min at room temperature. To this solution was added a benzene (3 cm^3) solution of the ketone **28a** (354 mg, 1.7 mmol), and the reaction mixture was stirred at room temperature for 10 h. The reaction was quenched with saturated aq. NH_4Cl (10 cm^3) and the mixture was extracted with diethyl ether (30 cm^3 × 3). The extract was washed with brine and dried over anhydrous Na_2SO_4. Evaporation of the solvent, and filtration through a short silica gel (5 g) column with hexane as eluent, furnished the thapsene **6** (231 mg, 66%) as an oil, ν_{max}/cm^{-1} 3060, 1650, 1395, 1375, 1090, 1070 and 880; δ_H(90 MHz; $CDCl_3$) 4.83 (2 H, m, *exo* methylene), 2.8 (1 H, m, 9-H), 2.43 (1 H, q of ½ AB q, *J* 17 and 3) and 1.82 (1 H, ½ AB q, *J* 17) (7-H_2), 1–1.9 (6 H, m, $[CH_2]_3$), 1.12 (3 H, d, *J* 7, 9-Me), and 1.1 (3 H, s), 1.0 (3 H, s), 0.9 (3 H, s) and 0.8 (3 H, s) (4 × Me); $\delta_C(CDCl_3)$ 157.5 (s, C=CH_2), 105.7 (t, C=CH_2), 49.7 (t, C-7), 49.4 (s, C-1), 42.7 (s, C-6), 42.5 (d, CHC=CH_2), 38.4 (t) and 36.5 (t) (C-3 and -5), 36.3 (s, C-2), 30.0 (q), 25.4 (q), 23.1 (q), 19.0 (t, C-4), 18.4 (q) and 13.1 (q, 9-Me); *m/z* 206 (M^+, 19%), 191 (18), 177 (13), 137 (100), 124 (20), 123 (25), 121 (67), 109 (20), 107 (37) and 95 (45) (Found: M^+, 206.2008. $C_{15}H_{26}$ requires *M*, 206.2034).

1,5,5,6,7,8-*Hexamethylbicyclo*[4.3.0]*non*-7-*ene* (*Thaps*-6-*ene*) **7**.—To a magnetically stirred solution of thaps-7(15)-ene **6** (206 mg, 1 mmol) in methylene dichloride (5 cm^3) was added PTSA (cat) and the mixture was stirred for 5 h before being diluted with methylene dichloride (10 cm^3), washed with saturated aq. $NaHCO_3$ (10 cm^3) and dried over anhydrous Na_2SO_4. Evaporation of the solvent, and filtration through a silica gel (5 g) column with hexane as eluent, furnished thaps-6-ene **7** (165 mg, 80%) as an oil, ν_{max}/cm^{-1} 2950, 1460, 1400, 1385 and 1370; δ_H(90 MHz; $CDCl_3$) 2.38 (1 H, br d, *J* 17, ½ AB q, allylic CH), 1.58 (6 H, br s, 2 × olefinic Me), 1.05–1.8 (7 H, m, 3 × CH_2 and allylic CH) and 0.92 (6 H, s), 0.84 (3 H, s) and 0.76 (3 H, s) (4 × Me); $\delta_C(CDCl_3)$ 136.2 and 130.0 (olefinic), 55.0 (C-6), 50.7, 43.8, 38.4, 37.6, 35.1, 30.9, 30.5, 27.1, 18.7, 15.0, 14.1 and 13.0; *m/z* 206 (M^+, 58%), 191 (10), 136 (20), 135 (100), 123 (30), 122 (85), 121 (25), 107 (38) and 91 (25) (Found: M^+, 206.2058. $C_{15}H_{26}$ requires *M*, 206.2034).

1,2,2,6,8,9-*Hexamethylbicyclo*[4.3.0]*non*-8-*en*-7-*one* (*Thaps*-6-*en*-8-*one*) **31**.—To a magnetically stirred solution of CrO_3 (20 mg, 0.2 mmol) in methylene dichloride (2 cm^3) was added 70% *tert*-butyl hydroperoxide (0.5 cm^3, 3.5 mmol), followed by a solution of thaps-6-ene **7** (103 mg, 0.5 mmol) in methylene dichloride (1 cm^3), and the mixture was stirred at room temperature for 6 h, then was filtered through a pad of alumina. Evaporation of the solvent, and purification of the residue on a silica gel (4 g) column with 1:20 ethyl acetate–hexane as eluent, furnished the enone **31** (21 mg, 20%); λ_{max}(hexane)/nm 236; ν_{max}/cm^{-1} 3100, 1700, 1650, 1390 and 1335; δ_H(90 MHz; $CDCl_3$) 1.98 (3 H, s, 9-Me), 1.72 (3 H, s, 8-Me), 1–2.2 (6 H, m, 3 × CH_2) and 1.16 (3 H, s), 1.07 (3 H, s), 0.9 (3 H, s) and 0.57 (3 H, s) (4 × Me).

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References

1 E. Lemmich, B. Jensen and U. Rasmussen, *Phytochemistry*, 1984, **23**, 809.
2 J. D. Pascual Teresa, J. R. Moran and M. Grande, *Chem. Lett.*, 1985, 865.
3 J. D. Pascual Teresa, J. R. Moran, A. Fernandez and M. Grande, *Phytochemistry*, 1986, **25**, 703 and 1171.
4 U. M. Smitt, C. Cornett, E. Norup and S. B. Christensen, *Phytochemistry*, 1990, **29**, 873.
5 Preliminary communication: A. Srikrishna and K. Krishnan, *Tetrahedron Lett.*, 1989, **30**, 6577.

6 L. Claisen, *Ber. Dtsch. chem. Ges.*, 1912, **45**, 3157; S. J. Rhoads and R. N. Raulins, *Org. React.*, 1975, **22**, 1; F. E. Ziegler, *Acc. Chem. Res.*, 1977, **10**, 227; G. B. Bennett, *Synthesis*, 1977, 589; R. P. Lutz, *Chem. Rev.*, 1984, **84**, 205; F. E. Ziegler, *Chem. Rev.*, 1988, **88**, 1423.
7 G. Stork and J. Ficini, *J. Am. Chem. Soc.*, 1961, **83**, 4678; S. D. Burke and P. A. Grieco, *Org. React.*, 1979, **26**, 361; L. N. Mander, *Synlett.*, 1991, 134; A. Padwa and K. E. Krumpe, *Tetrahedron*, 1992, **48**, 5385.
8 (*a*) R. N. Gedye, P. C. Arora and K. Deck, *Can. J. Chem.*, 1971, **49**, 1764; (*b*) M. Jalali-Naini, D. Guillerm and J.-Y. Lallemand, *Tetrahedron*, 1983, **39**, 749.
9 W. S. Johnson, L. Werthemann, W. R. Bartlett, T. J. Brocksom, T. Li, D. J. Faulkner and M. R. Petersen, *J. Am. Chem. Soc.*, 1970, **92**, 741; A. Srikrishna and S. Nagaraju, *J. Chem. Soc., Perkin Trans. 1*, 1992, 311.
10 S. J. Branca, R. L. Lock and A. B. Smith, III, *J. Org. Chem.*, 1977, **42**, 3165; J. E. McMurry and L. C. Blaszczak, *J. Org. Chem.*, 1974, **39**, 2217.
11 S. Forsen and T. Norin, *Acta Chem. Scand.*, 1961, **15**, 592; H. Sekizaki, M. Ito and S. Inoue, *Bull. Chem. Soc. Jpn.*, 1978, **51**, 2439.
12 (*a*) T. Norin, *Acta Chem. Scand.*, 1963, **17**, 738; (*b*) W. G. Dauben and E. J. Deviny, *J. Org. Chem.*, 1966, **31**, 3794; (*c*) W. G. Dauben and R. E. Wolf, *J. Org. Chem.*, 1970, **35**, 374 and 2361; (*d*) T. Norin, *Acta Chem. Scand.*, 1965, **19**, 1289.
13 G. Stork, S. Uyeo, T. Wakamatsu, P. Grieco and J. Labovitz, *J. Am. Chem. Soc.*, 1971, **93**, 4945.
14 T. Hudlicky, G. Sinai-Zingde, M. G. Natchus, B. C. Ranu and P. Papadopolous, *Tetrahedron*, 1987, **43**, 5685.
15 P. A. Wender and J. J. Howbert, *Tetrahedron Lett.*, 1983, **24**, 5325.
16 D. L. J. Clive and S. Daigneault, *J. Chem. Soc., Chem. Commun.*, 1989, 332; *J. Org. Chem.*, 1991, **56**, 3801.
17 A. Srikrishna and K. C. Pullaiah, *Tetrahedron Lett.*, 1987, **28**, 5203; A. Srikrishna and G. Sundarababu, *Tetrahedron*, 1990, **46**, 7901; A. Srikrishna, S. Nagaraju and G. V. R. Sharma, *J. Chem. Soc., Chem. Commun.*, 1993, 285.
18 A. Marshall and J. J. Partridge, *J. Org. Chem.*, 1968, **33**, 4090; F. Arndt, *Org. Synth.*, 1943, Coll. Vol. 2, p. 461.
19 A. Srikrishna, K. Krishnan and C. V. Yelamaggad, *Tetrahedron*, 1992, **48**, 9725.
20 J. Muzart, *Tetrahedron Lett.*, 1987, **28**, 4665.
21 (*a*) G. Wittig and M. Schlosser, *Chem. Ber.*, 1961, **94**, 1373; (*b*) Vogel, *Text Book of Practical Organic Chemistry*, B. S. Furniss, A. J. Hannaford, V. Rogers, P. W. G. Smith and A. R. Tatchell, Longman, London, 4th edn., p. 338.

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