74. A Stereoselective Total Synthesis of (±)-Maritimol, (±)-2-Deoxystemodinone, (±)-Stemodinone, and (±)-Stemodin

by **Rinaldo Marini Bettolo**[1]) and **Pietro Tagliatesta**

Centro di Studio del C.N.R. per la Chimica delle Sostanze Organiche Naturali, Istituto di Chimica Organica, Facoltà di Scienze Mathematiche Fisiche e Naturali, Università degli Studi «La Sapienza», Piazzale Aldo Moro 2, I-00185 Roma

and by **Alessandro Lupi**[1]) and **Doriano Bravetti**

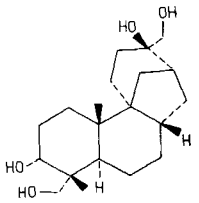
Centro di Studio del C.N.R. per la Chimica dei Recettori e delle Molecole Biologicamente Attive, Istituto di Chimica, Facoltà di Medicina e Chirurgia, Università Cattolica del Sacro Cuore, Largo Francesco Vito 1, I-00168 Roma

(28.XII.82)

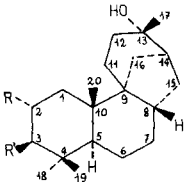
Summary

A simple and stereoselective total synthesis of (±)-maritimol (**2d**) and its conversion into the other title compounds ((±)-**2a**), ((±)-**2b**), and ((±)-**2c**) is described. The unique bicyclo[3.2.1]octane moiety, constituting their C/D-ring system, is stereospecifically obtained by solvolytic rearrangement of the methanesulfonate **23**.

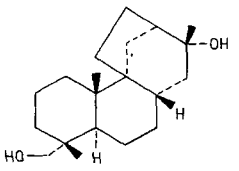
There has been much interest in the recent past in the synthesis of the diterpenes aphidicolin (=aphidicolane-3α,16,17,18-tetrol; **1**) [1], stemodin (=stemodane-2α,16α-diol; **2a**) [2], stemodinone (=13α-hydroxy-stemodan-2-one; **2b**) [2], 2-deoxystemodinone (=stemodan-13α-ol; **2c**) [2] [3], maritimol (=stemodane-3β,16α-diol; **2d**) [4], and stemarin (=stemarane-13α,18-diol: **3**) [3], owing to their



1



2a R=OH, R′=H
2b R=O=, R′=H
2c R=H, R′=H
2d R=H, R′=OH
29 R=H, R′=O=
31 R=H, R′=TsNH–N=



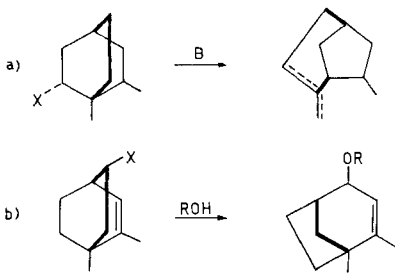
3

[1]) Authors to whom correspondence should be addressed.

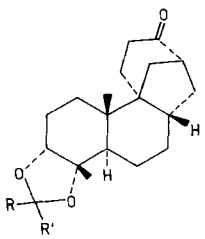
intersting biological properties [4] [5] and to their challenging C/D-ring system constituted by a unique bicyclo[3.2.1]octane moiety.

The same system is also present in the more complex delphinine- and napelline-type diterpene alkaloids for which *Wiesner et al.* developed synthetic routes based on the solvolytic rearrangement of suitably substituted bicyclo[2.2.2]-octane systems [6]. Considering only solvolytic conditions, this rearrangement can be performed either on substrates which can undergo elimination and in the presence of a suitable base (→ delphinine-type)[2]) [8], or on substrates which may or may not be deprotonated, but in the absence of a suitable base and in the presence of a nucleophile (→ napelline-type) [9]. In the first case, elimination follows the rearrangement (a) in *Scheme 1*), and obviously these conditions are synthetically useful for compounds alkylated at the bridgehead C-atom next to the leaving group. In the second case the nucleophile will capture the carbenium ion which developes at the original bridgehead C-atom (b) in *Scheme 1*). Whether or not the rearrangement will proceed quantitatively depends on the presence [9–11] of a double bond *syn* to the leaving group.

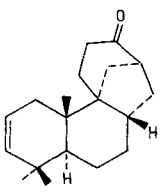
Scheme 1



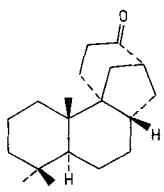
When the first syntheses of compounds **1** [12a–c], and **2a** [13] *via* the ketones **4** and **5**, respectively, were published, it appeared very attractive to us to synthesize these key intermediates by a napelline-type rearrangement. We have therefore prepared, from podocarpic acid, the ketones **6** and **7** [10], models for the ketones **4** and **5**, showing that the two systems can be easily synthesized by this approach.



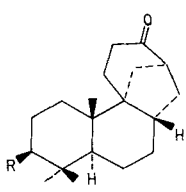
4a R = R′ = CH_3
4b R = *t*-Bu, R′ = H



5



6



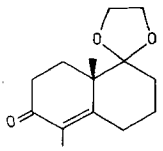
7 R = H
26 R = OH

[2]) Pyrolytic conditions are also possible and were used first for this type of rearrangement [7].

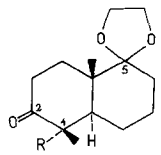
A delphinine-type rearrangement was on the contrary used for the syntheses of **2b** [14], **3** [15], and **2d** [16].

While we will dedicate a forthcoming paper to the total synthesis of aphidicolin (**1**), we wish to describe herein a new stereoselective and direct total synthesis of maritimol (**2d**) by solvolytic rearrangement of the methanesulfonate **23**, and its conversion into 2-deoxystemodinone (**2c**) [13] [14] [17] and into the unsaturated alcohol **32**, which had already been transformed into stemodin (**2a**) and stemodinone (**2b**) [13].

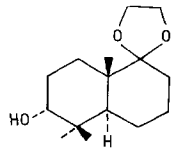
Our starting material was the easily available enone **8** [12a] [12b]; methylation in liquid NH_3 of the enolate intermediate formed during the metal/NH_3 reduction [18] of **8** gave regiospecifically the geminal-dimethylated ketone **9a**, which was subsequently reduced with $LiAlH_4$ in ethyl ether (Et_2O) to the alcohol **10a**[3]). The 2β-configuration, assigned to the alcohol **10a** on the basis of many precedents [20], was confirmed (s. below) by chemical correlation.



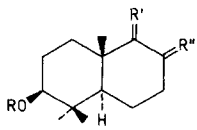
8



9a R = CH_3
9b R = H



10b



10a R = H, R′ = OCH_2CH_2O, R″ = H,H
11 R = CH_2Ph, R′ = O, R″ = H,H
12 R = H, R′ = O, R″ = H,H
13 R = CH_2Ph, R′ = O, R″ = CHOH

Alcohol **10a** was then protected as benzyl ether by refluxing it in THF with benzyl bromide in the presence of NaH; after standard workup, treatment with dilute HCl-solution unblocked the keto group giving directly compound **11**[4]).

The following C-ring construction was realized by a *Robinson* annellation; to this purpose, the ketone **11** was transformed into the more reactive hydroxymethylidene derivative **13**, by condensing it with ethyl formate in C_6H_6 in the presence of CH_3ONa [22]. Compound **13** was then reacted, in the presence of triethylamine, with 3-buten-2-one, and subsequent treatment of the intermediate

---

[3]) The small amount (11%) of alcohol **10b** formed in the course of this reaction was reoxidized to **9a** with pyridinium dichromate [19] in CH_2Cl_2 and then recycled.

[4]) Hydrogenolysis of **11** gave the known **12** [21] confirming the 2β-configuration assigned to the hydroxy group of **10a** and establishing that epimerization had not occurred to any extent during NaH treatment.

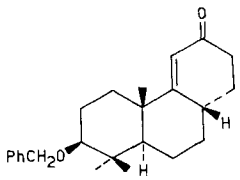
Michael adducts with CH_3ONa in CH_3OH gave finally the enone **14** [23]. Since the new chiral center at C(8) was set-up under equilibrating conditions, it was assigned the more stable (on stereochemical grounds) β-configuration, in agreement with precedent results [24]; this assignment was confirmed by the correct configuration of the final compounds.

The stage was then set for the construction of the bicyclo[2.2.2]octane system which was realized by the *Wiesner*-two-carbon-annellation sequence [25]; thus photoaddition of allene to **14** gave regio- and stereospecifically the adduct **15**, whose configuration, anticipated on the basis of the *Wiesner* rule [26] and precedent results [10] [15], was later confirmed by the correct structure of the final compounds.

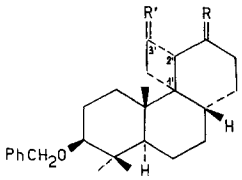
The photoadduct **15** was quantitatively converted into the ethylene acetal **16** under standard conditions in C_6H_6 in the presence of *p*-toluenesulfonic acid. The acetal **16** was then ozonized in a 1:1 mixture of abs. C_2H_5OH/CH_2Cl_2 at $-78°$, and the ozonide was reduced in the same solution with $NaBH_4$ yielding the cyclobutanol **17**.

Treatment of crude **17** with dilute HCl-solution in THF caused the unblocking of the keto group; subsequently, the resulting aldol system underwent, in dilute NaOH-solution, a *retro*-aldol reaction followed by a new aldol condensation to give the aldols **18a** and **18b**[5]) in a 4.5:1 ratio.

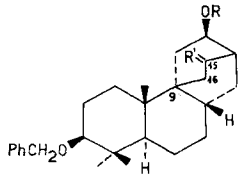
As indicated by many precedents [6] [11], the hydroxy group of the major epimer **18a** was assigned the β-configuration stabilized by H-bonding. This assignment was confirmed also by the success of the subsequent rearrangement to the



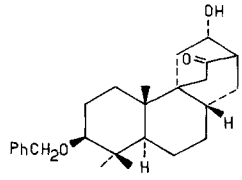
14



15 R = O, R′ = CH_2
16 R = OCH_2CH_2O, R′ = CH_2
17 R = OCH_2CH_2O, R′ = OH, H



18a R = H, R′ = O
19 R = THP, R′ = O
20 R = THP, R′ = H, OH
21 R = THP, R′ = H, $OCSSCH_3$



18b

[5]) The minor epimer **18b** underwent further equilibration in dilute NaOH-solution resulting in additional **18a**.

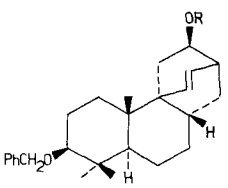
stemodin system. It should also be noticed that, as a result of the choice of the proper synthetic strategy, the hydroxy group emerges from the aldol condensation *'in the correct configuration for the rearrangement simultaneously with the construction of the skeleton'* [8b].

The next step was the introduction of the Δ^{15}-double bond which is necessary for a quantitative rearrangement [9] [10] [11b]. The aldol **18a** was therefore transformed by standard procedure into the tetrahydropyranyl ether **19** which, upon $NaBH_4$ reduction in CH_3OH/Et_2O 1:1, gave the secondary alcohol **20**. The sodium salt of the latter was then converted into the dithiocarbonate **21** by treatment with CS_2 followed by that with CH_3I. Compound **21**, on heating at reflux in *o*-xylene, underwent a *Chugaev* reaction to form the Δ^{15}-double bond; during this operation a partial loss of the pyranyl group also occurred, and the complete removal of the latter was achieved by acidic workup to give the unsaturated alcohol **22**.

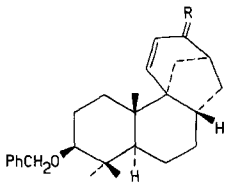
At this point it was only necessary to elaborate the hydroxy into a good leaving group, to set the stage for the rearrangement of the bicyclo[2.2.2]octane to the bicyclo[3.2.1]octane system. The alcohol **22**, dissolved in CH_2Cl_2, was therefore treated with methanesulfonyl chloride in the presence of Et_3N to give quantitatively the corresponding methanesulfonate **23**.

The conditions for the rearrangement were slightly modified in comparison with those adopted in the model series [10]: in fact we found that the methanesulfonate **23** rearranges also in acetone/water 2:1 giving directly and stereospecifically the allylic alcohol **24**[6]).

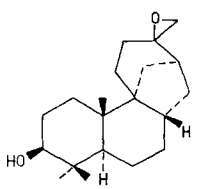
Oxidation of the latter with pyridinium chlorochromate on alumina [27] in CH_2Cl_2 afforded the α,β-unsaturated ketone **25**, proving beyond any doubt the rearrangement had proceeded successfully. Hydrogenation of **25** in the presence of 10% Pd/C gave then the hydroxy ketone **26** which was reacted with dimethyl-



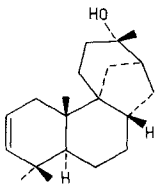
22 R = H
23 R = Ms



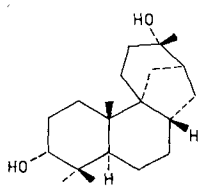
24 R = OH,H
25 R = O



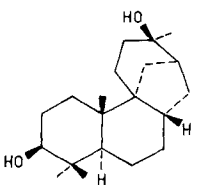
27



32



30



28

[6]) The stereospecific outcome of this reaction could be explained by the attack of the nucleophile either to a classical carbonium ion from the less hindered *exo*-side or to a non classical bridged one.

sulfoxonium methylide in dimethylsulfoxide (DMSO) [1] [13] to give an epimeric mixture of spiro-epoxides **27**. Finally, $LiB(C_2H_5)_3H$ ('Super-Hydride') reduction [13] of the mixture **27** afforded in a 5:1 ratio a mixture of racemic maritimol (**2d**; identical with an authentic sample by TLC. in several solvent systems, IR., ^{1}H-NMR., and MS. [4]) and its C(13) epimer **28**.

We turned then to the synthesis of the other *Stemodia maritima* component 2-deoxystemodinone (**2c**)[7]). Oxidation of **2d** with pyridinium chlorochromate in CH_2Cl_2 afforded the hydroxy ketone **29**[8]), already prepared from natural **2d** [4]. Treatment of **29** with *p*-toluenesulfonohydrazide in CH_3OH at reflux gave then quantitatively the *p*-toluenesulfonylhydrazone **31** which, on reduction with $NaBH_3CN$ [28] in THF yielded 2-deoxystemodinone (**2c**; identical with an authentic sample by TLC. in several solvent systems, IR., ^{1}H-NMR.[9]) and MS.).

Finally **31**, treated in THF with CH_3Li [29], gave the known **32** [13] formally completing therefore a new total synthesis of stemodin (**2a**)[10]) and stemodinone (**2b**).

We wish to thank Mrs. *Anna Brugnoli* and Mr. *Romano Amore* for technical assistance. Mass spectra are due to the courtesy of Prof. *P. L. Giacomello* and Mr. *Fausto Angelelli* (Istituto di Chimica Farmaceutica, Facoltà di Farmacia, Università «La Sapienza», Roma). We are also indebted to Prof. *N. Doorembos* (University of Southern Illinois) and *C. D. Hufford* (University of Mississippi) for kindly providing a sample of **2d** and to Dr. *P. S. Manchand (Hoffmann-La Roche Inc.)* for generously donating us samples of **2a**, **2b** and **2c**.

Experimental Part

General remarks. Thin layer chromatography (TLC.): silica gel *60 F_{254}, Merck*. Column chromatography: silica gel *60*, 70–230 mesh ASTM. All solvents were analytical grade. All solutions were evaporated to dryness under vacuum. RT. = room temperature; physical constants and spectra were determined using the following instrumentation. Melting points (m.p.): *Kofler* or *Mettler-FP-61* apparatus (uncorrected). UV. spectra ($\lambda_{max}(\varepsilon)$): *Varian-DMS-90*. IR. spectra (absorptions in cm^{-1}): *Perkin-Elmer-298*-infrared spectrophotometer. ^{1}H-NMR. spectra (chemical shifts in ppm relative to internal tetramethylsilane (= 0 ppm), coupling constants *J* in Hz; *s* = singlet, *d* = doublet, *m* = multiplet, br. = broad): *Varian-EM-360*-NMR. spectrometer. Mass spectra (MS.) [*m/z*]: *Hewlett-Packard-5980* spectrometer with a model *5934* data collection system (70 eV), electron ionization.

Synthesis of 5,5-ethylenedioxy-1,1,4a,β-trimethyl-trans-*3,4,4a,5,6,7,8,8a-octahydronaphthalen-2(1H)-one* (**9a**). A solution of the enone **8** (5.0 g, 21.2 mmol) in anh. THF (50 ml) was added dropwise under N_2 to a solution of Li (0.5 g, 72.0 mmol) in distilled NH_3 (300 ml) at –78°. After stirring for 1 h at –78°, CH_3I (7.0 ml, 112.4 mmol) was added dropwise, and the medium soon turned white. The dry-ice/acetone bath was then removed and stirring was continued overnight. Then water (50 ml) was added and the mixture thoroughly extracted with Et_2O. The combined org. exctracts were washed with water and sat. NaCl-solution, dried (Na_2SO_4) and evaporated. The residue was purified by SiO_2-column chromatography (petroleum ether (40–70°)/Et_2O 7:3) giving pure **9a** (3.3 g, 62%) and **9b** (0.55 g, 11%). Crystallization of **9a** (CH_3OH) gave an analytical sample, m.p. 50–51.5°. – IR. ($CHCl_3$): 1693. – ^{1}H-NMR. (CCl_4): 0.97 (*s*, 3 H, CH_3); 1.00 (*s*, 3 H, CH_3); 1.16 (*s*, 3 H, CH_3); 3.84 (*s*, 4 H, OCH_2CH_2O). – MS.: 252 (M^+, 2.1), 209 (51.3), 112 (34.7), 99 (100.0), 86 (29.6).

$C_{15}H_{24}O_3$ (252.34) Calc. C 71.39 H 9.59% Found C 71.35 H 9.61%

---

7) We had already prepared this compound in the course of our model work [10].

8) $LiB[CH(CH_3)C_2H_5]_3H$ *(L-Selectride)* reduction of **29** gave (±)-3-epimaritimol (**30**).

9) Our ^{1}H-NMR. data match those reported in [13] rather than in [17].

10) For another synthetic approach to the stemodane skeleton s. [30].

Synthesis of 5,5-ethylenedioxy-1,1,4aβ-trimethyl-trans-*perhydro-2β-naphthol* (**10a**). A solution of **9a** (9.0 g, 35.7 mmol) in anh. Et_2O (30 ml) was added dropwise at r.t. to a stirred $LiAlH_4$ (1.5 g, 39.5 mmol) suspension in anh. Et_2O (30 ml). After 15 min, the mixture was cooled with an ice-bath, the excess $LiAlH_4$ cautiously quenched with CH_3OH (10 ml) and the mixture poured into water and thoroughly extracted with Et_2O. The combined extracts were washed with water and sat. NaCl-solution, dried (Na_2SO_4) and evaporated to dryness. The residue was crystallized (hexane) affording **10a** (6.0 g). The mother liquors were evaporated and the residue was chromatographed on a SiO_2-column (petroleum ether (40–70°)/Et_2O 6:4) yielding, besides **10b** (1.0 g, 11%), additional **10a** (0.7 g) which was crystallized to give an analytical sample, m.p. 103–104°. Total yield of **10a** 73%. – IR. ($CHCl_3$): 3610, 3465. – ^{1}H-NMR. (CCl_4): 0.72 (*s*, 3 H, CH_3); 0.96 (*s*, 3 H, CH_3); 1.00 (*s*, 3 H, CH_3); 3.84 (*s*, 4 H, OCH_2CH_2O). – MS.: 254 (10.0, M^+), 99 (100.0), 86 (19.2).

$C_{15}H_{26}O_3$ (254.36) Calc. C 70.83 H 10.30% Found C 70.90 H 10.40%

Synthesis of 6β-benzyloxy-5,5,8aβ-trimethyl-trans-*3,4,4a,5,6,7,8,8a-octahydronaphthalen-1(2H)-one* (**11**). To a stirred solution of **10a** (10.0 g, 39.3 mmol) in anh. THF (150 ml), NaH (80% in white oil, 4.6 g, 153.3 mmol) was added portionwise under N_2. After refluxing for 1 h, benzyl bromide (6.0 ml, 50.5 mmol) was added and boiling at reflux continued for 3 h. Then the mixture was cooled with an ice-bath, excess NaH quenched with CH_3OH (40 ml), HCl (6N, 40 ml) added, the mixture refluxed for 30 min, cooled to r.t. and thoroughly extracted with Et_2O. The combined extracts were washed with $NaHCO_3$-solution, water and sat. NaCl-solution, and dried (Na_2SO_4). Evaporation of the solvent gave a residue which was crystallized (CH_3OH) giving **11** (8.9 g). The mother liquors were evaporated, and the residue was chromatographed on a SiO_2-column (petroleum ether (40–70°)/Et_2O 9:1) affording additional **11** (2.0 g) which was crystallized to obtain an analytical sample, m.p. 93–94°. Total yield of **11** 92%. – IR. ($CHCl_3$): 1695. – ^{1}H-NMR. (CCl_4): 0.90 (*s*, 3 H, CH_3); 0.97 (*s*, 3 H, CH_3); 1.10 (*s*, 3 H, CH_3); 4.43 (*AB*, J_{AB} = 12, 2 H, $C_6H_5CH_2$); 7.20 (*s*, 5 H, $C_6H_5CH_2$). – MS.: 300 (12.9, M^+), 209 (29.3), 201 (9.9), 149 (12.3), 91 (100).

$C_{20}H_{28}O_2$ (300.42) Calc. C 79.95 H 9.39% Found C 79.88 H 9.45%

Synthesis of 6β-benzyloxy-2-hydroxymethylidene-5,5,8aβ-trimethyl-trans-*3,4,4a,5,6,7,8,8a-octahydronaphthalen-1(2H)-one* (**13**). Dry HCO_2Et (12.0 ml, 149.0 mmol) was added to a stirred suspension of CH_3ONa (4.5 g, 83.3 mmol) in anh. C_6H_6 (45 ml). After 30 min, the mixture was cooled with an ice-bath, and a solution of **11** (3.0 g, 10.0 mmol) in anh. C_6H_6 (45 ml) was added dropwise under N_2 with stirring. The mixture was allowed to warm up to r.t. overnight, then it was diluted with Et_2O, acidified with 2N H_2SO_4, the org. layer was separated, washed with water and sat. NaCl-solution, and dried (Na_2SO_4). Evaporation of the solvent gave **13** (3.2 g, 97%) which was pure enough to be used in the next reaction without purification. An analytical sample was obtained by SiO_2-column chromatography (petroleum ether (40–70°)/Et_2O 9:1) and subsequent crystallization (hexane), m.p. 72–73°. – IR. ($CHCl_3$): 1705. – ^{1}H-NMR. (CCl_4): 0.73 (*s*, 3 H, CH_3); 0.86 (*s*, 3 H, CH_3); 1.06 (*s*, 3 H, CH_3); 4.46 (*AB*, J_{AB} = 12, 2 H, $C_6H_5CH_2$); 7.23 (*s*, 5 H, $C_6H_5CH_2$); 8.40 (*s*, 1 H, C=C*H*OH). – MS.: 328 (3.6, M^+), 177 (4.3), 91 (100.0).

$C_{21}H_{28}O_3$ (328.44) Calc. C 76.79 H 8.59% Found C 76.70 H 8.67%

Synthesis of 3β-benzyloxy-9(11)-podocarpen-12-one (**14**). To a cooled (ice-bath) mixture of **13** (12.0 g, 36.5 mmol) and 3-buten-2-one (8.0 ml, 97.6 mmol), Et_3N (8.0 ml, 57.4 mmol) was added under N_2. After 2 h, the ice-bath was removed and stirring continued overnight at r.t.. Then the solution, diluted with Et_2O, was repeatedly washed with water and sat. NaCl-solution, dried (Na_2SO_4) and evaporated. The residue was taken up with CH_3OH (400 ml) and cooled in an ice-bath. CH_3ONa (10.2 g, 188.8 mmol) was subsequently added while stirring under N_2, and the mixture was allowed to warm up to r.t. overnight. Then the solution was refluxed for 3 h, cooled to r.t., diluted with water, neutralized with 5% HCl-solution and CH_3OH was evaporated. The residue was thoroughly extracted with CH_2Cl_2, and the combined org. extracts were washed with water and sat. NaCl-solution, dried (Na_2SO_4) and evaporated. The crude product was crystallized (hexane) giving **14** (5.8 g). The mother liquors were evaporated and the residue purified by SiO_2-column chromatography (petroleum ether (40–70°)/Et_2O 6:4) to afford additional **14** (4.0 g) which was crystallized to give an analytical sample, m.p. 98–99°. Total yield of **14** 76%. – UV. (EtOH): 239 (26000). – IR. ($CHCl_3$): 1658, 1600. – ^{1}H-NMR. (CCl_4): 0.90 (*s*, 3 H, CH_3); 0.99 (*s*, 3 H, CH_3); 1.13 (*s*, 3 H, CH_3); 4.47 (*AB*, J_{AB} = 12, 2 H, $C_6H_5CH_2$); 5.66

(*d*, J = 1, 1H, H–C(11)); 7.22 (*s*, 5 H, $C_6H_5CH_2$). – MS.: 352 (12.6, M^+), 261 (98.4), 253 (46.0), 244 (22.4), 214 (11.4), 91 (100.0).

$C_{24}H_{32}O_2$ (352.50) Calc. C 81.77 H 9.15% Found C 81.74 H 9.10%

Synthesis of 3β-benzyloxy-3'-methylidene-9,11β,3',4'-tetrahydrocyclobuta[1',2':9a,11]podocarpan-12-one (**15**). The enone **14** (3.0 g, 8.5 mmol) was dissolved in freshly distilled THF (50 ml) and poured into a gas-washing bottle (pyrex). After cooling to –78°, allene was added in a large excess (about 40-fold). The stirred mixture was then irradiated for 6 h under N_2 by an *Italquartz UV 13F* 200 W Hg-lamp placed side by side in a *Dewar* containing a dry-ice/acetone bath. The reaction well was then removed from the cooling bath and left overnight at r.t. to allow excess allene to evolve. Then the solution was evaporated and the residue crystallized (hexane) yielding **15** (2.6 g). The mother liquors were purified by SiO_2-column chromatography (petroleum ether (40–70°)/Et_2O 6:4) giving further **15** (0.3 g) which was crystallized to give an analytical sample, m.p. 100.5–101.5°. Total yield of **15** 87%. – IR. ($CHCl_3$): 1685. – ^{1}H-NMR. (CCl_4): 0.83 (*s*, 3 H, CH_3); 0.87 (*s*, 3 H, CH_3); 0.97 (*s*, 3 H, CH_3); 4.46 (*AB*, J_{AB} = 12, 2 H, $C_6H_5CH_2$); 4.82 (br. *s*, 2 H, C=CH_2); 7.26 (*s*, 5 H, $C_6H_5CH_2$). – MS.: 392 (1.0, M^+), 301 (5.3), 283 (10.6), 269 (8.5), 266 (9.0), 186 (49.8), 173 (14.9), 91 (100.0).

$C_{27}H_{36}O_2$ (392.56) Calc. C 82.60 H 9.24% Found C 82.46 H 9.31%

Synthesis of 3β-benzyloxy-3'-methylidene-9,11β,3',4'-tetrahydrocyclobuta[1',2':9a,11]podocarpan-12-one ethylene acetal (**16**). To **15** (2.0 g, 5.1 mmol), dissolved in anh. C_6H_6 (25 ml), ethylene glycol (1.0 ml, 17.9 mmol) and *p*-TsOH (75 mg, 0.39 mmol) were added. The mixture was refluxed under N_2 for 3 h with a *Dean-Stark* apparatus. After cooling to r.t., the mixture was diluted with Et_2O and washed with $NaHCO_3$-solution, water and sat. NaCl-solution. Evaporation gave a residue which was crystallized (hexane) yielding **16** (2.0 g). The mother liquors were evaporated, and the residue was chromatographed on a SiO_2-column (petroleum ether (40–70°)/Et_2O 8:2) affording additional **16** (130 mg) which was crystallized to yield an analytical sample, m.p. 112–113°. Total yield of **16** 96%. – IR. ($CHCl_3$): 1464. – ^{1}H-NMR. (CCl_4): 0.85 (*s*, 3 H, CH_3); 0.93 (*s*, 6 H, 2 CH_3); 3.85 (*s*, 4 H, OCH_2CH_2O); 4.43 (*AB*, J_{AB} = 12, 2 H, $C_6H_5CH_2$); 4.70 and 4.83 (2 *m*, 2 H, C=CH_2); 7.20 (*s*, 5 H, $C_6H_5CH_2$). – MS.: 436 (100.0, M^+), 191 (23.1), 177 (28.4), 99 (70.2), 91 (57.5).

$C_{29}H_{40}O_3$ (436.61) Calc. C 79.77 H 9.23% Found C 79.45 H 9.29%

Synthesis of 3β-benzyloxy-12β-hydroxy-9β,13β-ethano-9β-podocarpan-15-one (**18a**). Compound **16** (1.5 g, 3.4 mmol) was dissolved in abs. C_2H_5OH/CH_2Cl_2 1:1 (150 ml) and cooled to –78°; a stream of ozone was then slowly passed through the solution until a faint blue color persisted. $NaBH_4$ (3.0 g, 79.3 mmol) was then added portionwise, and the mixture was stirred for an additional 4 h at –78°. After evaporation of the solvent, the residue was taken up with water, neutralized with 5% HCl-solution and thoroughly extracted with CH_2Cl_2. The combined extracts were washed with water and sat. NaCl-solution, dried (Na_2SO_4) and evaporated. To the residue, dissolved in THF (30 ml), 1N HCl (15 ml) was added, and the solution was stirred under N_2 overnight at r.t. Then 1N NaOH (30 ml) was added dropwise, followed by CH_3OH (30 ml) and THF (50 ml); stirring at r.t. under N_2 was continued for 24 h. After neutralization with 5% HCl-solution and evaporation of the org. solvents, the residue was diluted with water and thoroughly extracted with $CHCl_3$. The combined org. extracts were washed with water and sat. NaCl-solution, dried (Na_2SO_4) and evaporated. The residue was purified by SiO_2-column chromatography ($CHCl_3/Et_2O$ 8:2) affording first **18b** (0.2 g, 15%) and then its epimer **18a** (0.9 g, 67%). The aldol **18a** was then crystallized ($CHCl_3/CH_3OH$) to give an analytical sample, m.p. 211–212°. – IR. ($CHCl_3$): 3600, 3415, 1710. – ^{1}H-NMR. ($CDCl_3$): 0.86 (*s*, 3 H, CH_3); 0.96 (*s*, 3 H, CH_3); 1.00 (*s*, 3 H, CH_3); 2.10 (*s*, 2 H, 2 H–C(16)); 4.50 (*AB*, J_{AB} = 12, 2 H, $C_6H_5CH_2$); 7.32 (*s*, 5 H, $C_6H_5CH_2$). – MS.: 378 (0.3, $M^+ - 18$), 368 (6.6), 324 (11.1), 231 (14.8), 147 (23.4), 91 (100.0).

$C_{26}H_{36}O_3$ (396.55) Calc. C 78.74 H 9.15% Found C 78.51 H 9.19%

Synthesis of 3β-benzyloxy-12β-(3,4,5,6-tetrahydro-2H-pyran-2-yl)oxy-9β,13β-ethano-9β-podocarpan-15-one (**19**). To a stirred solution of **18a** (1.8 g, 4.5 mmol) and *p*-TsOH (40 mg, 0.2 mmol) in $CHCl_3$ (70 ml), 3,4-dihydro-2*H*-pyran (3.2 ml, 35.3 mmol) was added dropwise at r.t. After 2 h, the mixture was washed with $NaHCO_3$-solution, water and sat. NaCl-solution, dried (Na_2SO_4) and evaporated. The residue was chromatographed on a SiO_2-column (petroleum ether (40–70°)/Et_2O 6:4)

yielding **19** (2.0 g, 4.2 mmol, 93%) which was crystallized (hexane/CH_2Cl_2) to give an analytical sample, m.p. 168–169°. – IR. ($CHCl_3$): 1715. – ^{1}H-NMR. ($CDCl_3$): 0.86 (*s*, 3 H, CH_3); 0.96 (*s*, 3 H, CH_3); 1.00 (*s*, 3 H, CH_3); 4.50 (*AB*, J_{AB} = 12, 2 H, $C_6H_5CH_2$); 7.30 (*s*, 5 H, $C_6H_5CH_2$). – MS.: 480 (5.9, M^+), 271 (30.4), 229 (17.6), 91 (100.0), 85 (74.3).

$C_{31}H_{44}O_4$ (480.66) Calc. C 77.46 H 9.23% Found C 77.15 H 9.31%

*Synthesis of 3β-benzyloxy-12β-(3,4,5,6-tetrahydro-2*H*-pyran-2-yl)oxy-9β,13β-ethano-9β-podocarpan-15-ol* (**20**). To a stirred solution of **19** (1.5 g, 3.1 mmol) in CH_3OH/Et_2O 1:1 (300 ml), $NaBH_4$ (1.5 g, 39.6 mmol) was added portionwise. After 30 min, the mixture was evaporated, taken up with water and thoroughly extracted with $CHCl_3$. The combined extracts were washed with NH_4Cl-solution, water and sat. NaCl-solution, dried (Na_2SO_4) and evaporated. Purification of the residue by SiO_2-column chromatography (petroleum ether (40–70°)/Et_2O 6:4) afforded **21** (1.3 g, 87%) which was crystallized (hexane) to give an analytical sample, m.p. 95–97°. – IR. ($CHCl_3$): 3510. – ^{1}H-NMR. (CCl_4): 0.87 (*s*, 3 H, CH_3); 0.97 (*s*, 3 H, CH_3); 1.00 (*s*, 3 H, CH_3); 4.43 (*AB*, J_{AB} = 12, 2 H, $C_6H_5CH_2$); 7.20 (*s*, 5 H, $C_6H_5CH_2$). – MS.: 381 (1.4, $M^+ - 101$), 273 (45.2), 255 (13.8), 91 (100.0), 85 (91.0).

$C_{31}H_{46}O_4$ (482.68) Calc. C 77.13 H 9.61% Found C 76.91 H 9.70%

Synthesis of O-*[3β-benzyloxy-12β-(3,4,5,6-tetrahydro-2*H*-pyran-2-yl)oxy-9β,13β-ethano-9β-podocarpan-15-yl]* S-*methyl dithiocarbonate* (**21**). To a solution of **20** (900 mg, 1.86 mmol) in anh. Et_2O (9 ml), NaH (80% in white oil, 180 mg, 6.0 mmol) was added while stirring under N_2. After refluxing overnight, CS_2 (1.8 ml, 29.8 mmol) was added, boiling continued for 6 h additional, the mixture cooled to r.t. and CH_3I (0.6 ml, 9.60 mmol) added. After refluxing for 2 h, the mixture was cooled to r.t., excess NaH quenched with CH_3OH, water added and the resulting solution thoroughly extracted with Et_2O. The combined extracts were washed with water and sat. NaCl-solution, dried (Na_2SO_4) and evaporated. Purification of the residue by SiO_2-column chromatography (petroleum ether (40–70°)/Et_2O 9:1) afforded **21** (795 mg, 74%) which was crystallized (Et_2O/CH_3OH) to m.p. 153–154°. – IR. ($CHCl_3$): 1235. – ^{1}H-NMR. (CCl_4): 0.87 (*s*, 3 H, CH_3); 1.00 (*s*, 6 H, 2 CH_3); 2.49 (*s*, 3 H, SCH_3); 4.46 (*AB*, J_{AB} = 12, 2 H, $C_6H_5CH_2$); 5.50 (br. *s*, 1 H, H–C(15)); 7.23 (*s*, 5 H, $C_6H_5CH_2$). – MS.: 380 (0.1, $M^+ - 180 - 84$), 336 (5.6), 228 (7.6), 91 (44.1), 85 (100.0).

$C_{33}H_{48}S_2O_4$ (572.71) Calc. C 69.20 H 8.45 S 11.17% Found C 69.40 H 8.52 S 11.19%

Synthesis of 3β-benzyloxy-9β,13β-vinylene-9β-podocarpan-12β-ol (**22**). A solution of **21** (900 mg, 1.57 mmol) in *o*-xylene (5 ml) was heated at reflux under N_2 for 5 h. After evaporation of the solvent, the residue was dissolved in 10 ml of THF/5% HCl-solution 4:1 (10 ml) and stirred under N_2 for 2 h at r.t. The mixture was then diluted with water, neutralized with $NaHCO_3$-solution and thoroughly extracted with $CHCl_3$. The combined org. extracts were washed with water and sat. NaCl-solution, dried (Na_2SO_4) and evaporated. The residue was chromatographed on a SiO_2-column (petroleum ether (40–70°)/Et_2O 1:1) yielding **22** (450 mg) which was crystallized (pentane/Et_2O) to give an analytical sample, m.p. 108–109°. – IR. ($CHCl_3$): 3590, 3445. – ^{1}H-NMR. ($CDCl_3$): 0.84 (*s*, 3 H, CH_3); 0.96 (*s*, 3 H, CH_3); 1.06 (*s*, 3 H, CH_3); 4.43 (*AB*, J_{AB} = 12, 2 H, $C_6H_5CH_2$); 5.93 (*B* of *ABX*, J_{AB} = 9, J_{BX} = 6, 1 H, H–C(15)); 6.26 (*A* of *ABX*, J_{AB} = 9, J_{AX} = 1, 1 H, H–C(16)); 7.16 (*s*, 5 H, $C_6H_5CH_2$). – MS.: 336 (19.3, $M^+ - 26 - 18$), 105 (24.6), 91 (100.0).

$C_{26}H_{36}O_2$ (380.55) Calc. C 82.06 H 9.54% Found C 81.82 H 9.49%

Synthesis of 3β-benzyloxy-9β,13β-vinylene-9β-podocarpan-12β-yl methanesulfonate (**23**). A solution of **22** (400 mg, 1.05 mmol) and Et_3N (0.4 ml, 2.87 mmol) in anh. CH_2Cl_2 (10 ml) was cooled to 0° and treated with MsCl (0.2 ml, 2.57 mmol). After 30 min, the solution was diluted with CH_2Cl_2, washed with 3% HCl-solution, water until neutrality and sat. NaCl-solution, dried (Na_2SO_4) and evaporated. Crystallization (CH_2Cl_2/hexane) afforded **23** (435 mg, 90%), m.p. 99–100° (dec.). – IR. ($CHCl_3$): 1360, 1330, 1170. – ^{1}H-NMR. ($CDCl_3$): 0.87 (*s*, 3 H, CH_3); 0.97 (*s*, 3 H, CH_3); 1.06 (*s*, 3 H, CH_3); 2.93 (*s*, 3 H, OSO_2CH_3); 4.60 (*AB*, J_{AB} = 12, 2 H, $C_6H_5CH_2$); 6.03 (*B* of *ABX*, J_{AB} = 9, J_{BX} = 6, 1 H, H–C(15)); 6.40 (*A* of *ABX*, J_{AB} = 9, J_{AX} = 1, 1 H, H–C(16)); 7.30 (*s*, 5 H, $C_6H_5CH_2$).

Synthesis of 3β-benzyloxy-17-nor-stemod-11-en-13-ol (**24**). A solution of **23** (250 mg, 0.55 mmol) in acetone/water 2:1 (24 ml) was heated at 70° for 5 h under N_2. After evaporation of the acetone, the aq. layer was thoroughly extracted with CH_2Cl_2. The combined org. extracts were washed with water and sat. NaCl-solution, dried (Na_2SO_4) and evaporated. The residue was chromatographed on a

SiO_2-column (petroleum ether (40–70°)/Et_2O 1:1) affording **24** (173 mg, 82%), which was crystallized (hexane) to give an analytical sample, m.p. 111–112°. – IR. ($CHCl_3$): 3600, 3430. – ^{1}H-NMR. (CCl_4): 0.87 (*s*, 3 H, CH_3); 0.97 (*s*, 3 H, CH_3); 1.10 (*s*, 3 H, CH_3); 4.40 (*AB*, J_{AB} = 12, 2 H, $C_6H_5CH_2$); 5.38 (*B* of *ABX*, J_{AB} = 9, J_{BX} = 2, 1 H, H–C(11)); 5.98 (*A* of *ABX*, J_{AB} = 9, 1 H, H–C(12)); 7.16 (*s*, $C_6H_5CH_2$). – MS.: 380 (1.2, M^+), 272 (10.8), 233 (21.8), 159 (13.8), 91 (100.0).

$C_{26}H_{36}O_2$ (380.55) Calc. C 82.06 H 9.54% Found C 81.91 H 9.59%

Synthesis of 3β-benzyloxy-17-nor-stemod-11-en-13-one (**25**). A stirred solution of **24** (250 mg, 0.66 mmol) in anh. CH_2Cl_2 was treated portionwise with pyridinium chlorochromate/Al_2O_3 until TLC. monitoring (petroleum ether (40–70°)/Et_2O 1:1) indicated the disappearance of the starting material. The mixture was then diluted with Et_2O and filtered through a *Celite* pad. The resulting solution was then evaporated and the residue chromatographed on a SiO_2-column (petroleum ether (40–70°)/Et_2O 6:4) affording **25** (220 mg, 88%). An analytical sample was crystallized (Et_2O/CH_3OH) to a m.p. of 176.5–177.5°. – UV. (EtOH): 237 (12954). – IR. ($CHCl_3$): 1670. – ^{1}H-NMR. ($CDCl_3$): 0.95 (*s*, 3 H, CH_3); 1.02 (*s*, 3 H, CH_3); 1.20 (*s*, 6 H, 2 CH_3); 4.52 (*AB*, J_{AB} = 12, 2 H, $C_6H_5CH_2$); 5.72 and 5.89 (2 *d*, *J* = 2, H–C(11), H–C(12)); 7.32 (*s*, 5 H, $C_6H_5CH_2$). – MS.: 378 (0.4, M^+), 350 (14.0), 287 (14.0), 259 (24.3), 217 (15.4), 203 (14.2), 91 (100.0).

$C_{26}H_{34}O_2$ (378.53) Calc. C 82.49 H 9.05% Found C 82.25 H 9.11%

Synthesis of 3β-hydroxy-17-nor-stemodan-13-one (**26**). A solution of **25** (85 mg, 0.22 mmol) in anh. dioxane (4 ml) was hydrogenated at atmospheric pressure in the presence of 10% Pd/C (40 mg). After 4 h, the H_2 was pumped off, the mixture diluted with Et_2O and filtered through a Na_2SO_4-pad to remove the catalyst; evaporation of the solvent afforded **26** (60 mg, 95%). Crystallization (Et_2O/hexane) to a m.p. 135.5–136.5° gave an analytical sample. – IR. ($CHCl_3$): 3610, 3470, 1705. – ^{1}H-NMR. ($CDCl_3$): 0.84 (*s*, 3 H, CH_3); 1.00 (*s*, 6 H, 2 CH_3). – MS.: 290 (43.5, M^+), 257 (36.6), 215 (100.0), 93 (37.7), 79 (35.7).

$C_{19}H_{30}O_2$ (290.43) Calc. C 78.57 H 10.41% Found C 78.33 H 10.32%

Synthesis of (±)-maritimol (**2d**). To a stirred solution of **26** (75 mg, 0.26 mmol) in anh. DMSO (1.5 ml) at 20° under N_2, a DMSO solution of dimethylsulfoxonium methylide (0.6 ml), prepared from NaH (80% in white oil, 45 mg, 1.5 mmol) and $[(CH_3)_3SO]^+I^-$ (330 mg, 1.5 mmol) in anh. DMSO (1.5 ml) [13], was added and stirred overnight. Then water was added and the mixture thoroughly extracted with Et_2O; the combined extracts were washed with water and sat. NaCl-solution, dried (Na_2SO_4) and evaporated. To the residue (**27**), dissolved in anh. THF (1.5 ml), $Li(C_2H_5)_3BH$ (1M in THF, 0.6 ml, 0.60 mmol) was added with a syringe while stirring under N_2 at r.t. After 1 h, THF (2 ml) was added, followed by CH_3OH (0.1 ml), 10% NaOH-solution (0.35 ml) and 30% H_2O_2-solution (0.8 ml) and the mixture stirred overnight. After dilution with water, the solution was thoroughly extracted with CH_2Cl_2. The combined org. extracts were then washed with water and sat. NaCl-solution, dried (Na_2SO_4) and evaporated. The residue was chromatographed on a SiO_2-column (Et_2O/petroleum ether (40–70°) 8:2) giving *(±)-13-epimaritimol* (**28**; 10 mg, 11%) and **2d** (54 mg, 69%), m.p. (hexane/Et_2O) 211.5–212.5° ([16]: 212.5–214°).

Synthesis of (±)-2-deoxystemodinone (**2c**). To a stirred solution of **2d** (70 mg, 0.23 mmol) in anh. CH_2Cl_2 (2 ml) pyridinium chlorochromate (345 mg, 0.92 mmol) was added. After 24 h, the mixture was diluted with Et_2O and filtered through a *Celite* pad. The solution was evaporated and the residue chromatographed on a SiO_2-column (Et_2O/petroleum ether (40–70°) 7:3) to yield *13α-hydroxy-stemodan-3-one* (**29**) [4] (64 mg, 91%), m.p. (hexane) 90–91°. To **29** (20 mg, 0.066 mmol) dissolved in CH_3OH (1.5 ml), *p*-toluenesulfonohydrazide (37 mg, 0.20 mmol) was added, and the stirred solution was gently refluxed under N_2 for 12 h. After dilution with Et_2O, the mixture was washed with 0.1N HCl, and washings were reextracted with Et_2O; the combined org. layers were washed with $NaHCO_3$- and sat. NaCl-solution, dried (Na_2SO_4) and evaporated. The residue, constituted by the *3-(p-toluenesulfonyl-hydrazono)stemodan-13α-ol* (**31**), was dissolved in anh. THF (3 ml) and $NaBH_3CN$ (12 mg, 0.19 mmol) was added; the solution was then refluxed for 4 h under N_2. After dilution with water, the mixture was thoroughly extracted with Et_2O; the org. layers were washed with water and sat. NaCl-solution, dried (Na_2SO_4) and evaporated. The residue was chromatographed on a SiO_2-column (petroleum ether (40–70°)/Et_2O 7:3) to yield **2c** (12 mg, 63%), m.p. (hexane) 146–147° ([17]: 144°).

Synthesis of stemod-2-en-13a-ol (**32**). To the crude **31** (30 mg, 0.063 mmol), obtained as described for the synthesis of **2c**, in THF (3 ml), CH_3Li (1.6M in Et_2O, 0.6 ml, 0.96 mmol) was slowly added under N_2 while stirring at r.t. After 1 h, the solution was diluted with Et_2O and washed with water and 0.1N HCl; washings were then reextracted with Et_2O; the org. layers were washed with $NaHCO_3$- and sat. NaCl-solution, dried (Na_2SO_4) and evaporated yielding **32** (16 mg, 87%), m.p. (pentane) 128–129° ([13]: 119–122°). – IR. (CCl_4): 3615, 3430, 1665. – ^{1}H-NMR. ($CDCl_3$): 0.90 (*s*, 3 H, CH_3); 0.95 (*s*, 6 H, 2 CH_3); 1.11 (*s*, 3 H, CH_3); 5.10–5.70 (*m*, 2 H, H–C(2), H–C(3)). – MS.: 288 (12.8, M^+), 273 (38.5), 134 (69.5), 105 (45.5), 43 (100.0).

$C_{20}H_{32}O$ (288.46) Calc. C 83.27 H 11.18% Found C 83.45 H 11.29%

REFERENCES

[1] *W. Dalziel, B. Hesp, K.M. Stevenson & J.A. Jarvis,* J. Chem. Soc., Perkin Trans. I *1973*, 2841.
[2] *P.S. Manchand, J.D. White, H. Wright & J. Clardy,* J. Am. Chem. Soc. *95*, 2705 (1973).
[3] *P.S. Manchand & J.F. Blount,* J. Chem. Soc., Chem. Commun. *1975*, 894.
[4] *C.D. Hufford, R.O. Guerrero & N.J. Doorembos,* J. Pharm. Sci. *65*, 778 (1976).
[5] *R.A. Bucknall, H. Moores, R. Simms & B. Hesp,* Antimicrob. Agents Chemother. *4*, 294 (1973).
[6] *K. Wiesner,* Pure Appl. Chem. *41*, 93 (1975); *idem,* Chem. Soc. Rev. *6*, 413 (1977).
[7] *J.P. Johnston & K.H. Overton,* J. Chem. Soc., Perkin Trans I *1972*, 1490.
[8] a) *K. Wiesner, T.Y.R. Tsai, K. Huber, S.E. Bolton & R. Vlahov,* J. Am. Chem. Soc. *96*, 4990 (1974); b) *T.Y.R. Tsai, S.J. Tsai, W.W. Sy, M.N. Shanbag, W.C. Liu, S.F. Lee & K. Wiesner,* Heterocycles *7*, 217 (1977); c) *K. Wiesner, T.Y.R. Tsai & K.P. Nambiar,* Can. J. Chem. *56*, 1451 (1978); d) *T.Y.R. Tsai, K.P. Nambiar, D. Krikorian, M. Botta, R. Marini Bettolo & K. Wiesner,* ibid. *57*, 2124 (1979).
[9] a) *K.S. Atwal, R. Marini Bettolo, I.H. Sanchez, T.Y.R. Tsai & K. Wiesner,* Can. J. Chem. *56*, 1102 (1978); b) *S.P. Sethi, K.S. Atwal, R. Marini Bettolo, T.Y.R. Tsai & K. Wiesner,* ibid. *58*, 1889 (1980).
[10] *D. Bravetti, R. Marini Bettolo & A. Lupi,* Helv. Chim. Acta *65*, 371 (1982).
[11] a) *H.M. Walborsky, M.E. Baum & A.A. Youssef,* J. Am. Chem. Soc. *83*, 988 (1961); b) *H.L. Goering & M.F. Sloan,* ibid. *83*, 1992 (1961).
[12] a) *B.M. Trost, Y. Nishimura, K. Yamamoto & S.S. McElvain,* J. Am. Chem. Soc. *101*, 1328 (1979); b) *J.E. McMurry, A. Andrus, G.M. Ksander, J.H. Musser & M.A. Johnson,* ibid. *101*, 1330 (1979); *J.E. McMurry, A. Andrus, G.M. Ksander, J.H. Musser & M.A. Johnson,* Tetrahedron *37*, 319 (1981); c) *E.J. Corey, M.A. Tius & J. Das,* J. Am. Chem. Soc. *102*, 1742 (1980).
[13] *E.J. Corey, M.A. Tius & J. Das,* J. Am. Chem. Soc. *102*, 7612 (1980).
[14] *R.B. Kelly, M.L. Harley, S.J. Alward & P.S. Manchand,* Can. J. Chem. *60*, 675 (1982).
[15] *R.B. Kelly, M.L. Harley & S.J. Alward,* Can. J. Chem. *58*, 755 (1980).
[16] *E.E. van Tamelen, J.G. Carlson, R.K. Russel & S.R. Zawacky,* J. Am. Chem. Soc. *103*, 4615 (1981).
[17] *S. Chatterjee,* J. Chem. Soc., Chem. Commun. *1979*, 622.
[18] *G. Stork, P. Rosen, N. Goldman, R.V. Coombs & J. Tsuji,* J. Am. Chem. Soc. *87*, 275 (1965).
[19] *E.J. Corey & G. Schmidt,* Tetrahedron Lett. *25*, 399 (1979).
[20] *R.B. Turner, O. Buchardt, E. Herzog, R.B. Morin, R. Richel & G.M. Sanders,* J. Am. Chem. Soc. *88*, 1766 (1966).
[21] *F. Sondheimer & D. Elad,* J. Am. Chem. Soc. *80*, 1967 (1958).
[22] *C.H. Shunk & A.L. Wilds,* J. Am. Chem. Soc. *71*, 3946 (1949).
[23] *R.B. Turner, D.E. Nettleton, jr. & R. Ferrebee,* J. Am. Chem. Soc. *78*, 5923 (1956).
[24] a) *E. Wenkert, V.I. Stenberg & P. Beak,* J. Am. Chem. Soc. *83*, 2320 (1961); b) *T.A. Spencer, R.A.J. Smith, D.L. Storm & R.M. Villarica,* ibid. *93*, 4856 (1971).
[25] *R.W. Guthrie, A. Philipp, Z. Valenta & K. Wiesner,* Tetrahedron Lett. *34*, 2945 (1965).
[26] a) *K. Wiesner,* Tetrahedron *31*, 1655 (1975); b) *G. Marini Bettolo, S.P. Sahoo, G.A. Poulton, T.Y.R. Tsai & K. Wiesner,* ibid. *36*, 719 (1980); c) *J.F. Blount, G.D. Gray, K.S. Atwal, T.Y.R. Tsai & K. Wiesner,* Tetrahedron Lett. *26*, 4413 (1980).
[27] *Y. Cheng, W. Liu & S. Chen,* Synthesis *1980*, 223.
[28] a) *L. Caglioti,* Org. Synth. *52*, 122 (1972); b) *R.O. Hutchins,* Synthesis *1975*, 135.
[29] *R.H. Shapiro & M.J. Heath,* J. Am. Chem. Soc. *89*, 5734 (1967).
[30] *E. Piers, B.F. Abeysekere, D.J. Herbert & I.D. Suckling,* J. Chem. Soc., Chem. Commun. *1982*, 404.