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# SYNTHESIS OF BACTERIAL $C_{50}$ CAROTENOID SARCINAXANTHIN.

J.P. Férézou and M. Julia*

École Normale Supérieure, Laboratoire de Chimie,
24, rue Lhomond, 75231 PARIS CEDEX 05, FRANCE.
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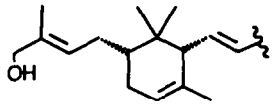
*Abstract: Alkylation of the distal double bond of geranyl acetate 8 with isoprene epoxide 5 has been carried out under anhydrous $ZnCl_2$/nitromethane conditions to give a mixture of $C_{15}$ hydroxyprenylated compounds. The major diol acetate isomer 12 was dehydrated to the expected γ-cis synthon 17 which was converted into racemic sarcinaxanthin 3 in few steps through the corresponding sulfone 21.*

Application of biogenetic processes to synthetic chemistry has always been a fascinating challenge for the organic chemist. During the past few decades we have devoted much interest to the transfer of prenyl residues to olefins, a crucial operation in the carbon chain elongation during terpenoid biosynthesis.

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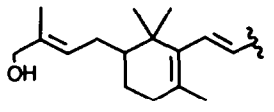


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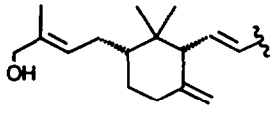


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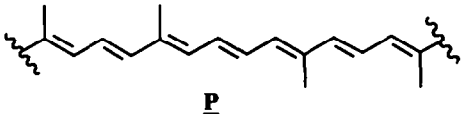


P

1: A - P - A
2: B - P - B
3: C - P - C

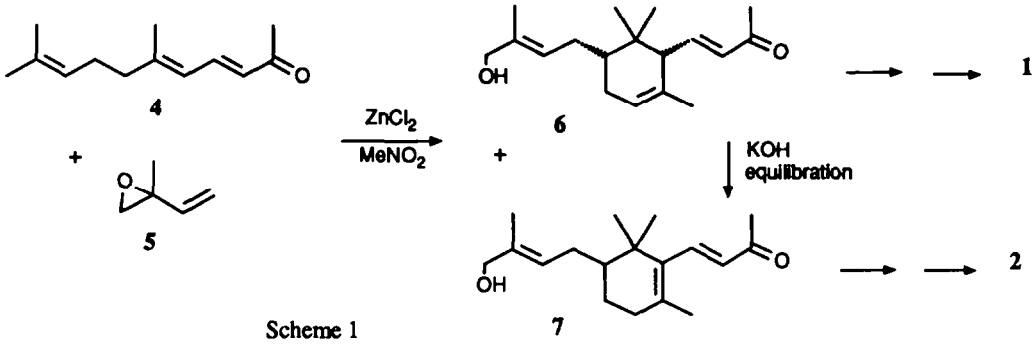
Recent progress in the development of biomimetic, acid-promoted prenylation reactions [1] led us to apply these results to the synthesis of $C_{50}$ bicyclic carotenoids* where the cyclisation reaction is believed to be biogenetically initiated by an electrophilic attack of an extra $C_5$ unit at the C-2, C-2' positions of lycopene [2].

Three bicyclic $C_{50}$ carotenoids are known: decaprenoxanthin **1** from *Flavobacterium dehydrogenans* with two substituted ε-end groups A [3], C.p.450 **2** from *Corynebacterium poinsettiae* with two substituted β-end groups B [4] and sarcinaxanthin **3** from *Sarcina lutea* with two substituted γ-end groups C [5].

In a previous paper [6] the synthesis of the two former carotenoids has been reported using as key step

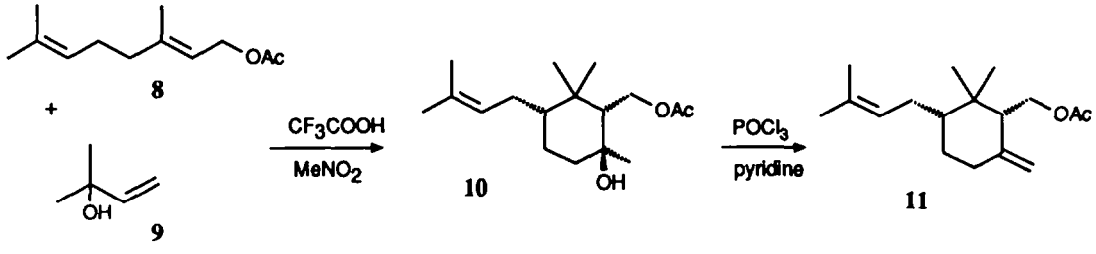
* Carbon atom numbering of carotenoids is used throughout this paper.

an original hydroxyprenylation-cyclisation reaction that was initiated by alkylation of the distal double bond of *E*-pseudoionone **4** with isoprene epoxide **5** under $ZnCl_2$ treatment in nitromethane (Scheme 1). The corresponding α-*cis* and β-hydroxyprenylionone isomers **6** and **7** have been converted in few steps into racemic decaprenoxanthin **1** and C.p.450 **2** respectively. Unfortunately this route did not give any γ-isomer required for the synthesis of sarcinaxanthin **3** and we had to look for other access to exocyclic olefinic building blocks.




Scheme 1

More recent results from our laboratory have shown that geranyl acetate **8** reacted with 2-methyl 3-buten 2-ol **9** under trifluoroacetic acid catalysis in nitromethane to give $C_{20}$ hydroxylated-cyclised products containing more than 50% of the isomer **10** [7]. Controlled dehydration of **10** led mainly to the sesquicyclogeranyl acetate **11** possessing the γ-*cis* structure required for sarcinaxanthin synthesis (Scheme 2).




Scheme 2

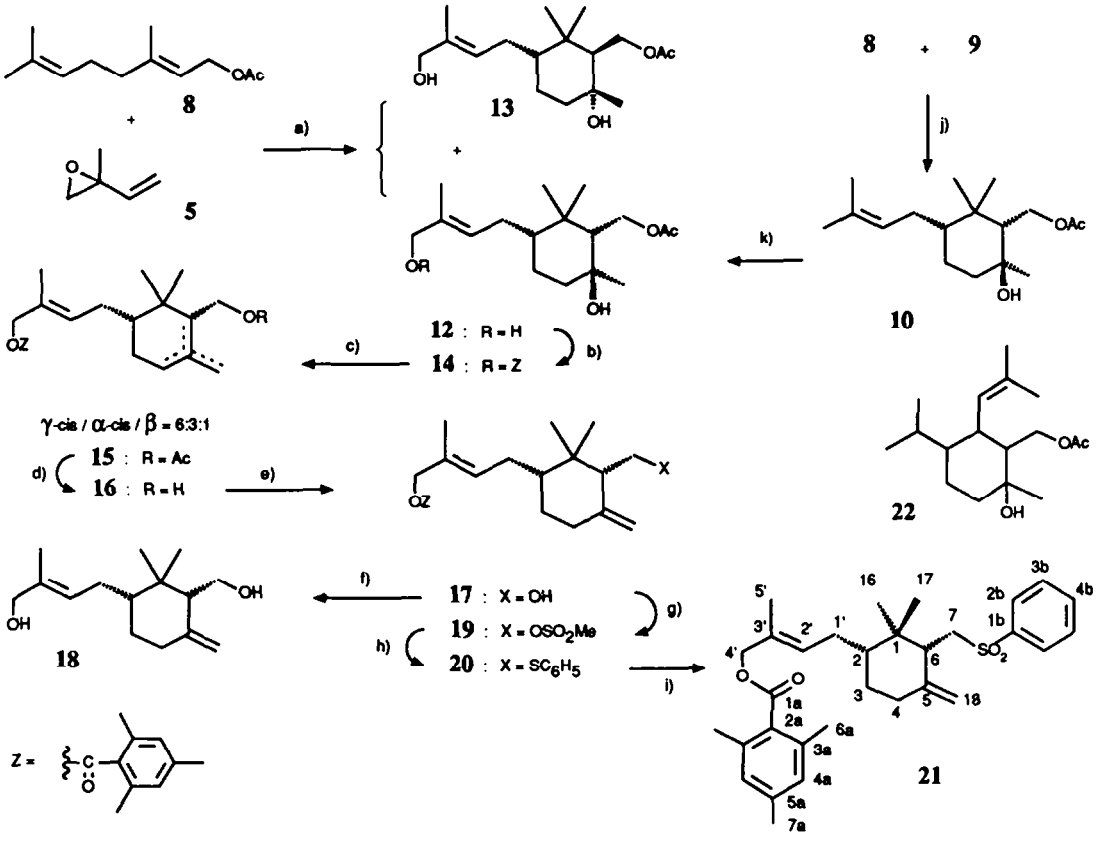
Allylic oxidation of the distal double bond of **11** would easily provide the terminal *E*-allylic alcohol functions of **3** [8]. A more direct route to the key building block **12** could also be explored using a $ZnCl_2$ mediated alkylation of isoprene epoxide **5** with geranyl acetate **8** instead of pseudoionone **4** previously used in the decaprenoxanthin **1** case [6] (Scheme 3).

A stereoselective synthesis of racemic sarcinaxanthin **3** is reported here : the key step is the alkylation-cyclisation of geranyl acetate **8** with either isoprene epoxide **5** or 2-methyl 3-buten 2-ol **9** to give the $C_{15}$ intermediate **12**. Synthesis of sarcinaxanthin from **12** is then carried out using the homologated $C_{20}$ intermediate phosphonium salt **34** through a $C_{20}+C_{10}+C_{20}$ approach corresponding to the classical $C_{15}+C_{10}+C_{15}$ route for $C_{40}$ carotenoids synthesis [2a].

## I - Synthesis of the γ-*cis* $C_{15}$ building block 21.

- From isoprene epoxide **5** (scheme 3).

Reaction of isoprene epoxide **5** with geranyl acetate **8** under the previous $ZnCl_2$/nitromethane conditions gave a complex mixture of $C_{15}$ hydroxyprenylated products containing some unreacted **8**. Silica gel flash chromatography gave a polar fraction from which the two major acetoxy-diol isomers **12** and **13** were easily separated (8.4 and 6.3% respective yields calculated on isoprene epoxide, 24 and 18% on consumed geranyl acetate). Both isomers exhibited an *E*-stereochemistry of the allylic hydroxyl function [9]. The relative stereochemistry of the cyclohexane substituents was tentatively deduced from comparison of their $^1H$ and $^{13}C$ NMR data with those of the previously reported 4'-deoxy analogs [7]. The major acetoxy-diol **12** has the 2,6-*cis* stereochemistry required for sarcinaxanthin synthesis.




Scheme 3: a) $ZnCl_2$, $MeNO_2$; b) $Me_3(C_6H_2)COCl$, pyridine; c) $POCl_3$, pyridine; d) NaOH, EtOH; e) $SiO_2$ chromatography; f) $LiAlH_4$, $Et_2O$; g) $MeSO_2Cl$, $Et_3N$; h) $C_6H_5SH$, KH, EtOH; i) $H_2O_2$, ammonium molybdate, EtOH; j) $CF_3COOH$, $MeNO_2$; k) $SeO_2$, t-BuOOH.

This isomer was protected as its mesitoyl ester [10] **14** (86%) and then dehydrated under the previously described $POCl_3$/pyridine conditions to give, from $^1H$ NMR analysis [7], a 6:3:1 mixture of γ-cis, α-cis and β isomers **15** (95%). This mixture was directly hydrolysed to **16** (quantitative yield) and the γ-*cis* alcohol **17** isolated

by silica gel chromatography. Its structure was confirmed by comparison of $^1H$ NMR data of the corresponding deprotected diol **18** with those of sarcinaxanthin **3** [5]. Particularly, $^1H$ NMR singlets at 0.63 and 1.09 for the C-16 and C-17 gem-dimethyl groups of **18** fit well with the already reported values of 0.62 and 1.09ppm for the corresponding 4'-deoxy analog obtained after saponification of **11** [7].

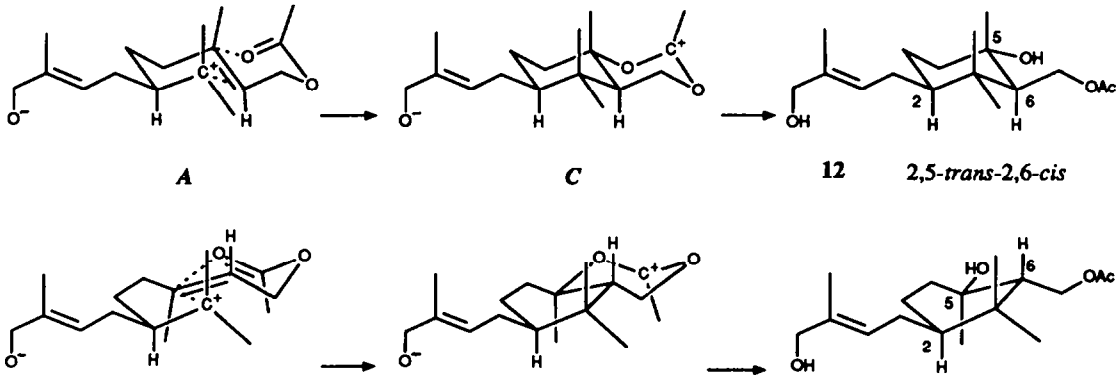
Conversion of **17** into the sulfone **21** was straightforward: the corresponding mesylate **19** afforded the sulfide **20** using potassium thiophenate as nucleophile (75% yield). As already observed in a similar case this reaction proved difficult to bring to completion probably due to severe hindrance around the C-6 hydroxymethyl group [11]. Subsequent oxidation with $H_2O_2$/ammonium molybdate [12] gave the sulfone **21** in 76% yield (mp:101-102 °C).

- From 2-methyl 3-buten 2-ol **9** (Scheme 3).

As previously described [7] direct alkylation of geranyl acetate **8** with 2-methyl 3-buten 2-ol **9** under trifluoroacetic acid catalysis gave a complex mixture from which the most polar cyclised isomer **10** was easily purified in 14% yield (30% from consumed **8**). This yield was improved to 21% after further prenylation of recovered geranyl acetate with **9**. After silica gel chromatography, isomer **10** was found to be contamined with *ca.*10% of structural isomer **22** and no further attempt to separate the mixture was made at this stage. However, allylic oxidation of this fraction with $SeO_2$/*t*-BuOOH [8] gave 41% of the 4'-*E*-hydroxyderivative **12** together with unchanged **22** which was separated at this stage [13]. Spectroscopic data for **12** obtained through this route was identical with that depicted for the same product elaborated before from isoprene epoxide.

- Mechanistic aspect of prenylation reactions.

The stereochemical course of acid-catalysed cyclisation of *Z*- and *E*-monoterpenes is well documented and was shown to be much more selective for the *Z*-isomers [6, 7, 16, 20]. The 53/47 ratio of 2,6-*cis* **6**/2,6-*trans* isomers already obtained during alkylation of *E*-pseudoionone with isoprene epoxide was believed to reflect a kinetic control during cyclisation involving chair and boat transition states respectively [6].




Scheme 4

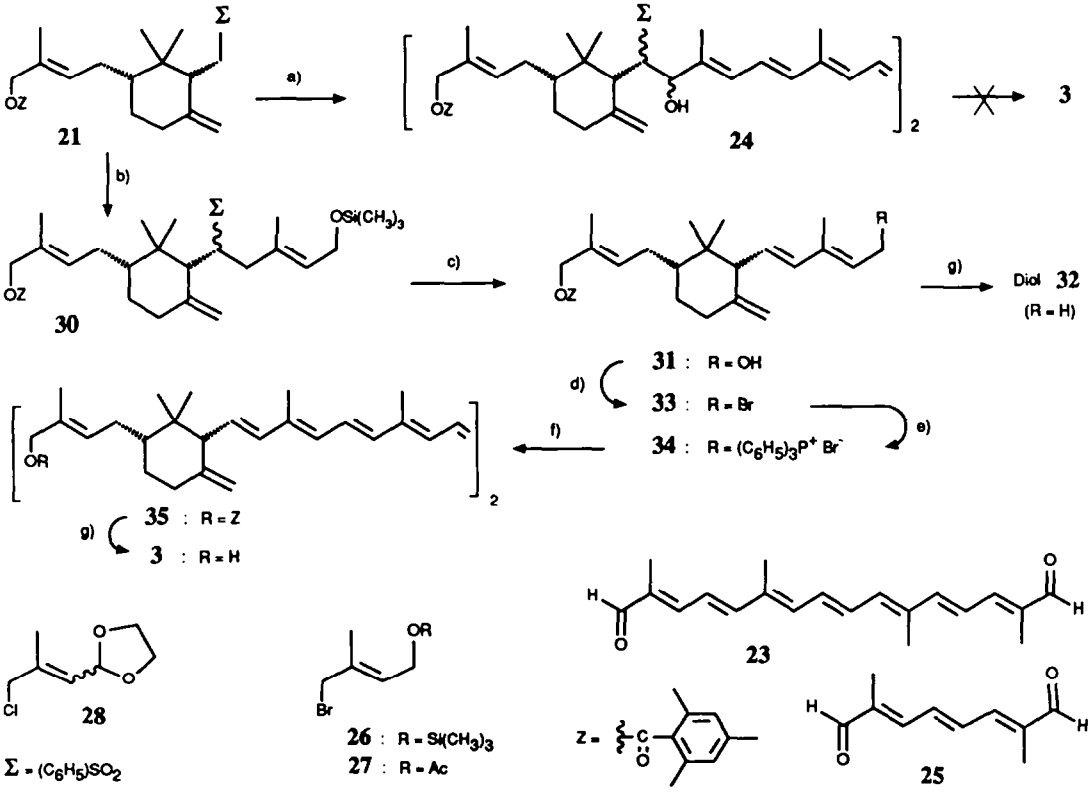
Similar results were obtained on reaction of geranyl acetate with 2-methyl 3-buten 2-ol **9** which led to a *ca.* 60/30 ratio of 2,6-*cis* acetoxy-alcohol **10** and its corresponding 2,6-*trans* isomer respectively [7]. Moreover

the tertiary hydroxyl group was shown to enter mainly *anti* to the $C_5$ "extra" nucleophile.

The reaction of geranyl acetate with isoprene epoxide gave the 2,6-*cis* **12** and 2,6-*trans* **13** major isomers in a 57/43 ratio, resulting from a probable cyclisation through ***A*** and ***B*** transition states respectively (scheme 4). However, in the anhydrous $ZnCl_2$/nitromethane medium it seems reasonable to claim a probable formation of the dioxolanium stabilized intermediates ***C*** and ***D*** respectively, due to the neighbouring group participation of the acetoxy residue [17]. In both cases an *anti* attack of the acetoxy carbonyl group would lead to the most favourable equatorial new C-5–O bond in ***C*** and ***D***. As further hydrolysis of such species is assumed to occur with retention of configuration at the carbon atom, this mechanism is in agreement with the observed relative stereochemistry in **12** and **13**. A point of interest is the isolation of the abnormally cyclised products **22** at the outset of the reaction of geranyl acetate with 2-methyl 3-buten 2-ol. Their structure and their mode of formation will be discussed in the following paper [13].

## II- Synthesis of sarcinaxanthin 3 (Scheme 5).

Having secured by two different routes the preparation of the γ-*cis* sulfone **21** we next turned to the elaboration of sarcinaxanthin $C_{50}$ skeleton.




Scheme 5 : a) LDA, THF then **23**; b) LDA, THF then **26**; c) t-BuOK, THF, then citric acid, MeOH; d) $CBr_4$, $P(C_6H_5)_3$, THF; e) $P(C_6H_5)_3$, THF; f) **25**, 40% aqueous KOH/$CH_2Cl_2$; g) $LiAlH_4$, $Et_2O$.

We first envisaged a direct $C_{15}$ + $C_{20}$ + $C_{15}$ strategy using as central unit precursor the known $C_{20}$ dialdehyde **23** [2a,18]. Condensation of the sulfone **21** with **23** gave a mixture of the expected $C_{50}$ diastereomers **24**. Unfortunately all attempts to convert these bis-(α-hydroxysulfonyl) derivatives into sarcinaxanthin failed. Particularly Na/Hg treatment of the α-hydroxy, α-acetoxy or α-benzoyloxysulfones only resulted in intractable mixtures of discoloured products.

A second approach was then studied using a $C_{20}$ + $C_{10}$ + $C_{20}$ route already followed for the synthesis of decaprenoxanthin **1** and C.p.450 **2** [6] with final condensation of the corresponding $C_{20}$ phosphonium salt end groups with the central $C_{10}$ diol **25** [18]. The $C_{15}$ protected sulfone **21** was first converted into the $C_{20}$ alcohol **30** through condensation with the $C_5$ trimethylsilyloxy-bromobutene **26** which was readily obtained by silylation of the corresponding known bromoalcohol [19]. At this point it is worth noting that all attempts to alkylate the anion of sulfone **21** with other known ω-difunctionalised $C_5$ unit as **27**, **28** or isoprene epoxide **5** failed or only proceeded in very low yields. However, alkylation with **26** took place smoothly to give a mixture of the diastereomers **30** which were directly submitted to sulfonyl group elimination using potassium *tert*-butoxide [20]. Subsequent aqueous acidic work-up afforded, after purification, the pure all-*E* $C_{20}$ alcohol **31** in 45% yield from **21**. Conversion of **31** into the bromide **33** followed by triphenylphosphine treatment gave the required $C_{20}$ phosphonium salt **34** in 85% yield.

Final Wittig condensation of **34** with the $C_{10}$ dialdehyde **25** under heterogenous conditions [21] (40% aqueous KOH/$CH_2Cl_2$) gave dimesitoyl sarcinaxanthin **35** which was then deprotected to the (±)-meso-threo-diol **3** by $LiAlH_4$ treatment, 95% yield for these two steps. Repeated crystallisations to constant melting point gave a pure compound whose spectroscopic data were in full agreement with those reported for the natural product [5].

## EXPERIMENTAL PART

Microanalysis were carried out by the "Service de Microanalyses de l'Université Pierre et Marie Curie, 4, Place Jussieu, 75005 PARIS.

Melting points are determined on a Büchi apparatus and are not corrected.

Unless otherwise stated, all $^1H$ NMR spectra were recorded at 250MHz on a Cameca 250 apparatus and $^{13}C$ spectra on a Bruker WP 90 (22.63MHz), in $CDCl_3$ using tetramethylsilane as internal standard. Protons and $^{13}C$ assigments are made using carbon numbering of carotenoids.

Mass spectra were obtained by direct introduction on a Nermag R10-10 spectrometer using either electron impact (EI) or chemical ionisation (CI) modes.

Geranyl acetate was prepared by acetylation (acetic anhydride-pyridine) of geraniol FLUKA and used after distillation.

For all other general indications, see preceding paper [6].

**Alkylation of geranyl acetate by isoprene epoxide to give 12 and 13.**

A solution of geranyl acetate **8** (98 g, 0.5 mol) and isoprene epoxide (93% purity, 21 g, 0.25 mol) in nitromethane (125 mL) was slowly added over 30 min at -20 °C to a suspension of anhydrous zinc chloride (137g, 1 mol) in 375 mL nitromethane with vigorous mechanical stirring under a dry atmosphere of nitrogen. After a further 3 h at -20 °C the reaction mixture was quenched with cold saturated aqueous sodium bicarbonate. The zinc salts were eliminated by filtration through a celite pad and washed with diethyl ether.The organic phase was separated, the aqueous layer was reextracted twice with ether and the combined organic phases were washed with brine and dried over $MgSO_4$. After taking off an aliquot for GLC analysis, the solvent was removed under vacuum and the oily residue flash chromatographed on silica gel using an ethyl acetate/petroleum ether gradient as eluent. Unchanged geranyl acetate (81 g), an intermediate fraction which was not further analysed (11.4 g) and a more polar fraction (12.6 g) containing isomers **12** and **13** were successively collected. Chromatography of this latter fraction by HPLC (ethyl acetate/petroleum ether, from 1:1 to 4:1) gave in order of elution pure **13** (4.7 g, 6.3% from epoxide) and **12** (6.3 g, 8.4%) as colourless oily compounds (respectively 18 and 24% calculated on consumed geranyl acetate).

**2-*r*-Acetoxymethyl-1,3,3-trimethyl-4-*c*-(4-hydroxy-3-methyl-2-*E*-buten-1- yl)-1-*t*-cyclohexanol 12**

$\nu_{max}$: 3650 (w), 3580 (m), 3430(m), 2980 (s), 2920 (s), 2860 (m), 1720 (s), 1445 (m), 1370 (s),

1205-1250 (s), 1150 (m), 1030 (m) and 915 (m) $cm^{-1}$. $^1H$ NMR, δ: 0.76 and 1.05 (6H, 2s, 16,17-$CH_3$), 1.17 (3H, s, 18-$CH_3$), 1.65 (3H, s, 5'-$CH_3$), 2.07 (3H, s, $CH_3CO$), 3.98 (2H, s, 4'$H_2$), 4.33 (2H, AB part of ABX system, $J_{AB}$=11, $J_{AX}$=$J_{BX}$=5 Hz, 7-$H_2$) and 5.36 (1H, t, J=7 Hz, 2'H). $^{13}C$ NMR : see table. MS (CI) ,m/z: 299 (3%, $M^+$+1), 281 (100%, $M^+$+1-$H_2O$), 221 (9%, $M^+$-$H_2O$-AcOH) and 203 (42%, $M^+$+1-2$H_2O$-AcOH). Anal. calc. for $C_{17}H_{30}O_4$, % : C, 68.42 ; H, 10.13. Found : C, 68.23 ; H, 9.97.

**2-*r*-Acetoxymethyl-1,3,3-trimethyl-4-*t*-(4-hydroxy-3-methyl-2-*E*-buten-1 -yl)-1-*t*-cyclohexanol 13**

$\nu_{max}$: 3660 (w), 3600 (m), 3470 (m), 2990 (m), 2960 (s), 2920 (s), 2860 (m), 1725 (s), 1450 (m), 1380 (m), 1370 (m), 1240 (s), 1030 (m) and 920 (w) $cm^{-1}$. $^1H$ NMR, δ : 1.02 and 1.06 (6H, 2s, 16,17-$CH_3$), 1.23 (3H, s, 18-$CH_3$), 1.67 (3H, s, 5'-$CH_3$), 2.08 (3H, s, $CH_3CO$), 3.98 (2H, s, 4'-$H_2$), 4.28 (2H, d, J=5 Hz, 7-$H_2$) and 5.35 (1H, br. t, J=7 Hz, 2'-H). $^{13}C$ NMR : see table. MS (CI) , m/z: 316 (17%, $M^+$+1+$NH_3$), 299 (10%, $M^+$+1), 281 (93%, $M^+$+$H_2O$), 256 (21%), 221 (58%, $M^+$+1-$H_2O$-AcOH) and 203 (100%, $M^+$+1-2$H_2O$-AcOH).

**Alkylation of geranyl acetate by 2-methyl-3-buten-2-ol (DMVC).**

This reaction was carried out using a procedure modified from C. Schmitz [7]. A solution of trifluoroacetic acid (100 mL, 1.3 mol) in nitromethane (300 mL) was added over 45 min at 0 °C to a stirred solution of geranyl acetate (196 g, 1 mol) and 2-methyl 3-buten 2-ol (86 g, 1 mol) in nitromethane (2.5 L). After stirring 3 h at 0 °C the reaction mixture was treated as described. The unreacted geranyl acetate was distilled from the oily residue (105 g, 0.54 mol) and submitted to a second alkylation reaction in the above conditions (trifluoroacetic acid: 55 ml, 0.7 mol; DMVC: 47 g, 0.55 mol). After reaction work-up and elimination of unconsumed geranyl acetate (53 g) by distillation, the oily residue was combined with the first one and chromatographed on silica gel 60 (4 Kg). Elution performed with an increasing gradient of diethyl ether in petroleum ether afforded 59.3 g (21%) of **10** which was shown to be 85% pure by GLC analysis. This product was contaminated with c.a. 10% of the abnormally cyclised acetate **22** [13]. $^1H$ NMR, MS and IR spectra of a purified sample of **10** (HPLC: ethyl acetate/petroleum ether, 15:85) were fully consistent with those previously reported [7].

**2-*r*-Acetoxymethyl-1,3,3-trimethyl-4-*c*-(4-hydroxy-3-methyl-2-*E*-buten-1-yl)-1-*t*-cyclohexanol 12 from 10.**

To a stirred suspension of freshly sublimed $SeO_2$ (8.3 g, 75 mmol) in $CH_2Cl_2$ (20 mL) at 25 °C containing 10 mol% of salicylic acid (2 g) were successively added a 3 N solution of *tert*-butylhydroperoxide in $CH_2Cl_2$ (150 mL, 0.45 mol) and, after stirring 15 min, a solution of hydroxyacetate **10** (43 g, 0.152 mol) in 20 mL $CH_2Cl_2$ dropwise. The reaction mixture was stirred at room temperature for 30 h and washed with saturated $NaHCO_3$ and brine, then dried over $MgSO_4$. Solvent and excess *t*-BuOOH were carefully removed under vacuum at 25 °C to give 49 g of crude product. This fraction was dissolved in dry MeOH (70 mL) at 0 °C and treated with $NaBH_4$ (4 g) added portionwise. The reaction mixture was stirred for 30 min and then acidified with a solution of 10% acetic acid. Subsequent extraction with ethyl acetate afforded after usual work up 29g of an oil which was subjected to $SiO_2$ column chromatography. Elution with an ethyl acetate/petroleum ether gradient gave 5.6 g (13%) of abnormally cyclised products containing **22** as a mixture of isomers and 18.6 g (41%) of the pure hydroxylated synthon **12** (colourless oil) which was shown to be identical to the same product obtained by direct hydroxyprenylation of geranyl acetate with isoprene epoxide (*vide supra*).

**2-*r*-Acetoxymethyl-1,3,3-trimethyl-4-*c*-[4-(2,4,6-trimethylbenzoyloxy)-3-methyl-2-*E*-buten-1-yl]-1-*t*-cyclohexanol 14.**

To a stirred solution diol acetate **12** (22.3 g, 75 mmol) in dry $CH_2Cl_2$ (100 mL) were successively added at 0 °C pyridine (13 mL) and 2,4,6-trimethylbenzoyl chloride (17.1 g, 94 mmol). The reaction mixture was allowed to stirr at 0 °C for 24 h (under a dry atmosphere of $N_2$) and then poured into ice cold N HCl solution (200 mL). The aqueous phase was decanted and reextracted twice with $CH_2Cl_2$. The combined organic phases were washed with water, diluted $NaHCO_3$ solution, brine and dried over $MgSO_4$. After evaporation of the solvent, the resulting oil was purified by flash chromatography using an ethyl acetate/petroleum ether gradient as eluant, to obtain pure mesitoate **14** (30 g, 90%) as an oil.

$\nu_{max}$: 3630 (w), 3600 (m), 3480 (m), 3040 (m), 3010 (m), 2980 (s), 2920 (s), 2860 (m), 1715 (s), 1615 (m), 1460 (m), 1370 (m), 1275 (s), 1250-1220 (s), 1165 (s), 1090 (s), 980 (w), 930 (w) and 855 (m) $cm^{-1}$. $^1H$ NMR, δ: 0.76 and 1.05 (6H, 2s, 16,17-$CH_3$), 1.18 (3H, s, 18-$CH_3$), 1.71 (3H, s, 5'-$CH_3$), 2.07 (3H, s, $CH_3CO$), 2.27 and 2.29 (3H+6H, 2s, 3 mesitoyl-$CH_3$), centr. 4.35 (2H, AB part of ABX syst., $J_{AB}$=11, $J_{AX}$=$J_{BX}$=5 Hz, 7-$H_2$), 4.71 (2H, s, 4'-$H_2$), 5.52 (1H, t, J=7 Hz, 2'-H) and 6.86 (2H, s, mesitoyl-$H_2$). MS (EI), m/z : 444 (7%, $M^+$), 426 (32%, $M^+$-$H_2O$), 366 (5%, $M^+$-$H_2O$-AcOH), 280 (15%, $M^+$-mesitoic acid), 262 (12%, $M^+$-$H_2O$-mesitoic acid), 231 (13%), 220 (15%), 205 (17%), 203 (30%), 187 (35%) and 147 (100%).

**Dehydration of 14.**

To a solution of mesitoate ester **14** (29 g, 65 mmol) in dry pyridine (100 mL) was slowly added at 0 °C freshly distilled $POCl_3$ (59.1 mL, 1.5 eq). After stirring overnight at room temperature the reaction mixture was poured into ice cold dilute HCl solution and extracted with $CH_2Cl_2$ (3 portions). The combined organic phases were washed with water, $NaHCO_3$ solution, brine, dried over $MgSO_4$ and concentrated to give the dehydrated products **15** (26.5 g, 96%). GLC and $^1H$ NMR analysis of the mixture showed 60% γ-*cis*, 30% α-*cis* and 10% β isomers to be present.

$^1$H NMR signals for the gem-dimethyl groups were of diagnostic value : 0.66 and 1.12 for the γ-*cis* isomer, 0.75 and 1.06 for α-*cis* isomer, and 0.88 and 1.05 ppm for β isomer. These values are in agreement with those reported for the 4'-deoxy analogues [7]. These isomers were not separated at this stage and the crude mixture **15** was directly submitted to hydrolysis.

***cis*-1-Hydroxymethyl-2,2-dimethyl-6-methylene-3-[4-(2,4,6-trimethylbenzoyloxy) -3-methyl-2-*E*-buten-1-yl]--cyclohexane 17.**

The crude reaction product **15** (25 g, 59 mmol) was dissolved at 0 °C in a N ethanolic NaOH solution (100 mL). After 4 h the reaction mixture was diluted with water and extracted twice with $CH_2Cl_2$. The combined organic phases were washed with brine, dried over $MgSO_4$ and concentrated to give a mixture of alcohols **16** (22 g, 98%) which was submitted to chromatography. Two repeated silica gel column purifications (ethyl acetate/petroleum ether, 3:7) afforded pure γ-*cis* **17** (12.3 g, 55%) as a pale yellow oil.

$\nu_{max}$: 3580 (m), 3450 (w), 3070 (w), 3030 (w), 3005 (m), 2970 (s), 2940 (s), 2860 (m), 1715 (s), 1645 (w), 1615 (m), 1575 (w), 1455-1440 (m), 1380 (w), 1370 (w), 1275 (s), 1175 (s), 1090 (s), 1030 (w), 1010 (w), 960 (w), 900 (m) and 860 (m) cm$^{-1}$. $^1$H NMR, δ: 0.63 and 1.09 (6H, 2s, 16,17-$CH_3$), 1.70 (3H, s, 5'-$CH_3$), 2.28 and 2.29 (3H+6H, 2s, 3 mesitoyl-$CH_3$) centr. 3.85 (2H, AB part of ABX system, $J_{AB}$=11, $J_{AX}$=9.5 and $J_{BX}$=4 Hz, 7-$H_2$), 4.68 and 4.97 (2H, d, J=1 Hz, 18-$H_2$), 4.70 (2H, s, 4'-$H_2$), 5.57( 1H, t, J=7 Hz, 2'-H) and 6.86 (2H, s, mesitoyl-$H_2$). $^{13}$C NMR : see table. MS (CI), m/z: 402 (20%, $M^+$+1+$NH_3$), 385 (3%, $M^+$+1), 367 (14%, $M^+$+1-$H_2O$) and 221 (100%, $M^+$+1-mesitoic acid). Anal. calc. for $C_{25}H_{36}O_3$, % ; C, 78.08 ; H, 9.44. Found : C, 78.10 ; H, 12.47.

The corresponding α-*cis* isomer was also isolated at the outset of the purification step (6.2 g, 28%) but the minor β isomer was lost.

**α-*cis* Isomer 17**; $\nu_{max}$: 3600 (m), 3480 (m), 3020 (w), 3000 (m), 2960 (s), 2920 (s), 2890 (m), 1715 (s), 1610 (m), 1575 (w), 144 (m), 1380 (m), 1370 (m), 1270 (s), 1210 (m), 1170 (s), 1085 (s), 1035 (w) and 850 (m) cm$^{-1}$. $^1$H NMR, δ: 0.80 and 1.06 (6H, 2s, 16,17-$CH_3$), 1.71 (3H ,s, 5'-$CH_3$), 1.78 (3H, s, 18-$CH_3$), 2.27 and 2.29 (3H+6H, 2s, 3 mesitoyl-$CH_3$) centr. 3.86 (2H, AB part of an ABX system, $J_{AB}$=11, $J_{AX}$= $J_{BX}$= 4 Hz, 7-$H_2$), 4.70 (2H, s, 4'-$H_2$), 5.52 (1H, m, 4-H), 5.58 (1H, t, J=7 Hz, 2'-H) and 6.86 (2H, s, mesitoyl-$H_2$). $^{13}$ CMR : see table. MS (CI), m/z: 402 (38%, $M^+$+1+$NH_3$) and 221 (100%, $M^+$+1-mesitoic acid). Anal. found : C, 77.92 ; H, 9.47.

Better analytical samples of the γ-*cis* isomer were obtained after deprotection of the allylic alcohol function ($LiAlH_4$, diethyl ether; 2 h, 0 °C) to give the **γ-*cis* diol 18**: white crystals ($CH_2Cl_2$) mp: 94-95 °C.

$\nu_{max}$: 3600 (s), 3430 (s), 3070 (w), 3025 (w), 3005 (m), 2970 (s), 2940 (s), 2860 (m), 1705-1675 (w), 1640 (m), 1440 (m), 1385 (m), 1370 (m), 1190 (m), 1025 (w), 1005 (s), 950 (w), 900 (w), 870 (w) and 860 (w) cm$^{-1}$. $^1$H NMR, δ: 0.63 and 1.09 (6H, 2s, 16,17-$CH_3$), 1.65 (3H, s, 5'-$CH_3$), centr. 3.86 (2H, AB part of ABX system, $J_{AB}$=11, $J_{AX}$=9.5, $J_{BX}$=4 Hz, 7-$H_2$), 4.01 (2H, s, 4'-$H_2$) 4.68 and 4.97 (2H, 2d, J=1 Hz, 18-$H_2$) and 5.40 (2H, t, J=7 Hz, 2'H). $^{13}$C NMR : see table. MS (CI), m/z: 256 (30%, $M^+$+1+$NH_3$), 238 (23%, $M^+$+1+$NH_3$-$H_2O$), 221 (100%, $M^+$+1-$H_2O$) and 203 (83%, $M^+$+1-2$H_2O$), 221 (100%, $M^+$+1-$H_2O$) and 203 (83%, $M^+$+1-2$H_2O$). Anal. Calc. for $C_{15}H_{26}O_2$, % : C, 75.58 ; H, 10.99. Found : C, 75.54 ; H,10.98.

***cis*-1-Methanesulfonyloxymethyl-2,2-dimethyl-6-methylene-3-[4-(2,4,6-trimethylbenzoyloxy)-3-methyl--2-*E*-buten-1-yl]-cyclohexane 19.**

To a solution of γ-*cis* isomer **17** (3.9 g, 10 mmol) in $CH_2Cl_2$ (15 mL) at -10 °C under a dry atmosphere of $N_2$ were added triethylamine (2.5 mL) and methanesulfonyl chloride (0.95 mL, 12.3 mmol). The reaction mixture was stirred overnight at -10 °C, then quenched with iced water and diluted with ether. The organic layer was washed twice with 1 N HCl, once with saturated $NaHCO_3$, once with brine, dried over $MgSO_4$ and concentrated to give the mesylate **19** (4.58 g, quantitative) as a pale yellow oil. This crude product was used without further purification.

$\nu_{max}$: 3070 (w), 3020 (m), 2960 (m), 2930 (s), 2860 (m), 1715 (s), 1645 (w), 1610 (m), 1480 (m), 1440 (m), 1360 (s), 1335 (s), 1270 (s), 1210 (m), 1175 (s), 1085 (s), 975 (m), 950 (s), 900 (w), 860 (w) and 820 (w) cm$^{-1}$. $^1$H NMR, δ: 0.65 and 1.14 (6H, 2s, 16,17-$CH_3$), 1.71 (3H, s, 5'-$CH_3$), 2.28 and 2.29 (3H+6H, 2s, 3 mesitoyl-$CH_3$), 3.00 (3H, s, $CH_3SO_2$), centr. 4.47 (2H, AB part of ABX system, $J_{AB}$=10, $J_{AX}$=9, $J_{BX}$=4 Hz, 7-$H_2$), 4.66 and 4.94 (2H, 2 br. s, 18-$H_2$), 4.70 (2H, s, 4'-$H_2$), 5.57 (1H, t, J=7 Hz, 2'-H) and 6.85 (2H, s, mesitoyl-$H_2$). MS (CI), m/z: 480 (100%, $M^+$+1+$NH_3$), 426 (17%), 203 (33%, $M^+$+1-mesitoic acid-methanesulfonic acid).

***cis*-1-Phenylthiomethyl-2,2-dimethyl-6-methylene-3-[4-(2,4,6-trimethylbenzoyloxy)-3-methyl-2-E-buten--1-yl]-cyclohexane 20.**

To a stirred slurry of KH (35% in oil, 2.3 g, 20 mmol) in dry ethanol (20 mL) was added at room temperature under $N_2$ thiophenol (2.05 mL, 20 mmol) and, after 15 min, 10 mL of an ethanolic solution of the methanesulfonate **19** (4.62 g, 10 mmol). The reaction mixture was stirred for 4 days, then poured into an ice cold 0.1 N NaOH solution and diluted with ether. The organic phase was washed with brine, dilute HCl, brine, dried over $MgSO_4$ and concentrated. Chromatography of the oily residue using ethyl acetate/petroleum ether, 1:10 then 2:10, as eluent afforded starting material **19** (1 g, 22%) and the pure thioether **20** (3.5 g, 75%) as an oil. Attempts to force reaction conditions only resulted in the formation of non negligible amounts of a di-phenylthioether by substitution of the mesitoate function.

$\nu_{max}$: 3070 (w), 3020 (w), 3000 (m), 2960 (s), 2930 (s), 2860 (m), 1715 (s), 1645 (w), 1610 (m), 1580 (m), 1480 (m), 1440 (m), 1270 (s), 1210 (w), 1170 (s), 1090 (s), 1030 (w), 895 (m), 855 (w) and 695 (m) $cm^{-1}$. $^1H$ NMR, δ: 0.66 and 1.08 (6H, 2s, 16,17-$CH_3$), 1.69 (3H, s, 5'-$CH_3$), 2.28 and 2.30 (3H+6H, 2s, 3 mesitoyl-$CH_3$), centr. 3.14 (2H, AB part of ABX system, $J_{AB}$=15, $J_{AX}$=11, $J_{BX}$=3 Hz, 7-$H_2$), 4.35 and 4.99 (2H, 2s, 18-$H_2$), 4.70 (2H, s, 4'-$H_2$), 5.56 (1H, t, J=7 Hz, 2'-H), 6.87 (2H, s, mesitoyl-$H_2$) and 7.25-7.35 (5H, m, $C_6H_5S$). MS (CI), m/z: 494 (30%, $M^+$+1+$NH_3$), 477 (11%, $M^+$+1), 440 (6%), 423 (73%) and 313 (100%, $M^+$+1-mesitoic acid). Anal. calc. for $C_{31}H_{40}O_2S$, % : C, 78.10 ; H, 8.46 ; S, 6.73. Found : C,77.94 ; H, 8.66 ; S, 6.52.

**_cis_-1-Benzenesulfonylmethyl-2,2-dimethyl-6-methylene-3-[4-(2,4,6-trimethylbenzoyloxy)-3-methyl-2-_E_-buten-1-yl]-cyclohexane 21.**

A mixture of ammonium molybdate (1.28 g, 1.1 mmol, 0.15 eq) and aqueous hydrogen peroxide (33%, 2 mL, 3 eq) was slowly added dropwise at -10 °C to a stirred solution of the sulfide **20** (3.45 g, 7.25 mmol) in ethanol (75 mL). The reaction was allowed to warm to room temperature and stirred for 15 h. After addition of water the mixture was extracted three times with ether. The combined organic phases were washed with saturated ferrous sulfate twice, brine twice, dried over $MgSO_4$ and concentrated to afford an oily residue which was flash chromatographed using an ethyl acetate/petroleum ether gradient as eluent (from 1:9 to 3:7). The collected pure sulfone **21** (2.8 g, 76%) was recrystallised from petroleum ether/isopropyl ether, white crystals, mp: 101-102 °C.

$\nu_{max}$: 3070 (w), 3020 (w), 2930 (s), 2860 (m), 1715 (s), 1645 (w), 1610 (m), 1445 (s), 1390 (w), 1370 (w), 1315 (m), 1305 (m), 1270 (s), 1210 (m), 1170 (s), 1140 (m), 1090 (s), 890 (m), 855 (m) and 690 (m) $cm^{-1}$. $^1H$ NMR, δ: 0.53 and 0.95 (6H, 2s, 16,17-$CH_3$), 1.67 (3H, s, 5'-Me), 2.28 and 2.29 (3H+6H, 2s, 3 mesitoyl-$CH_3$), 2.43 (1H, d, J=9 Hz, 6-H), 3.36 (2H, AB part of an ABX system, $J_{AB}$=15, $J_{AX}$=1.5, $J_{BX}$= 9 Hz, 7-$H_2$), 4.50 and 4.78 (2H, 2 br. s, 18-$H_2$), 4.69 (2H, s, 4'-$H_2$), 5.53 (1H, t, J=7 Hz, 2'-H), 6.86 (2H, s, mesitoyl-$H_2$) and 7.50-7.92 (5H, m, $C_6H_5SO_2$-). $^{13}C$ NMR : see table. MS (CI), m/z: 526 (100%, $M^+$+1+$NH_3$), 201 (13%) and 190( 24%). Anal. Calc. for $C_{31}H_{40}O_4S$, % : C, 73.20 ; H, 7.92 ; S, 6.30. Found : C, 73.18 ; H, 8.05 ; S, 6.15.

**1-Trimethylsilyloxy-3-methyl-4-bromo-2-butene 26.**

To a solution of 3-methyl-4-bromo-2-butene-1-ol [20] (1.65 g, 10 mmol) in pentane (2 mL) were successively added at 0 °C under $N_2$ hexamethyldisilazan (0.83 mL, 4 mmol) and trimethylchlorosilane (0.44 mL, 3.5mmol). After stirring 30 min. at 0 °C and a further 1 h at room temperature, the reaction mixture was diluted with pentane and directly poured on a short silica gel column. Elution with pentane and pentane/ether fractions from 9:1 to 7:3 yielded the pure silyloxy derivative **17** as a colourless oil after evaporation of the solvent.

$^1H$ NMR: the product was shown to be 87% _E_, δ: 0.14 (9H, s, $SiMe_3$), 1.79 (2, 6H, s, 3-_E_-$CH_3$), 1.87 (0.44, s, 3-_Z_-$CH_3$), 3.94 (2H, s, 4-$H_2$), 4.18 (2H, d, J=6.5 Hz, 2-$H_2$), 5.55 (0.13H, t, J=6 Hz, 2-_Z_-H) and 5.73 (0.87H, t, J=6 Hz, 2-_E_-H). MS (EI) m/z: 237 (100%). Anal. Calc. for $C_8H_{17}BrOSi$ : C, 40.51 ; H, 7.22 . Found : C, 40.47 ; H, 7.20.

**_cis_-5-[2,2-Dimethyl-6-methylene-3-[4-(2,4,6-trimethylbenzoyloxy)-3-methyl-2-_E_-buten-1-yl]-cyclohexan--1-yl]-3-methyl-2-_E_,4-_E_-pentadien-1-ol 31.**

To a stirred solution of sulfone **21** (1.52 g, 3 mmol) in THF (15 mL) at -78 °C under $N_2$ was added dropwise a solution of LDA prepared from diisopropylamine (0.5 mL, 3.6 mmol) and n-butylithium (1.45 N, 2.50 mL) in THF (10 mL). After 15 min at -78 °C bromide **26**, (1.6 g, 6.6 mmol) was added in one portion and the reaction mixture was stirred overnight while allowing it to warm up slowly to room temperature. It was then quenched with ice cold saturated $NH_4Cl$ and diluted with ether. The organic layer was separated and the aqueous phase reextracted twice with ether. The combined organic phases were washed with brine, dried over $MgSO_4$ and concentrated to give 2.58 g of an oily residue containing the protected sulfone **30** as a mixture of diastereomers (TLC and $^1H$ NMR analysis).

To the crude $C_{20}$ sulfone **30** (2.58 g) dissolved in THF (15 mL) was added at -30 °C freshly sublimed potassium _tert_-butoxide (625 mg) in one portion. The reaction mixture was allowed to warm up to room temperature and stirred for 2 h. After cooling to 0 °C a solution of citric acid (1 g, 5 mmol) in methanol (15 mL) was added to the reaction mixture that was stirred for a further 1 h at 0 °C before dilution with ether and water. After decantation, the aqueous layer was reextracted twice with ether and the combined organic fractions washed with saturated $NaHCO_3$, brine, dried over $MgSO_4$ and the solvent evaporated. The crude product was purified by silica gel column chromatography using ether/pentane gradient from 1:4 to 4:1 as eluent to give the pure all-_E_ $C_{20}$ synthon **31** (605 mg, 45% from **21**) as a colourless oil.

$\nu_{max}$: 3600 (w), 3530 (w), 3070 (w), 3020 (w), 2960 (m), 2920 (s), 2860 (m), 1715 (s), 1645 (w), 1610 (m), 1455 (m), 1390 (w), 1380 (w), 1370 (w), 1270 (s), 1175 (s), 1090 (s), 895 (m), 860 (w) and 825 (m) $cm^{-1}$. $^1H$ NMR, δ: 0.71 and 0.94 (6H, 2s, 16,17-$CH_3$), 1.71 (3H, s, 5'-$CH_3$), 1.84 (3H, s, 19-$CH_3$), 2.28 and 2.30 (3H+6H, 2s, 3 mesitoyl-$CH_3$), 2.46 (1H, d, J =10 Hz, 6-H), 4.26 (2H, d, J=7 Hz, 11-$H_2$), 4.52 and 4.77 (2H, 2 br. s, 18-$H_2$), 4.71 (2H, s, 4'-$H_2$), 5.59 (2H, 2 surimposed t, J=7 Hz, 10-H, 2'-H), 5.81 (1H, q, J=16 and 10 Hz, 7-H), 6.07 (1H, d, J=16 Hz, 8-H) and 6.86 (2H, s, mesitoyl-$H_2$). $^{13}C$ NMR: see Table. MS (CI) : 468 (12%, $M^+$+1+$NH_3$), 433 (100%, $M^+$+1-$H_2O$), 269 (42%, $M^+$+1+$H_2O$-mesitoic acid) and 182 (23%).

An analytical sample of the corresponding diol **32** was obtained after treatment of **31** with $LiAlH_4$, 2 h at 0 °C in diethyl ether followed by usual work-up and flash chromatography (colourless oil).

$\nu_{max}$: 3600 (s), 3460 (s), 3080 (w), 3020( w), 3000 (m), 2960 (m), 2930 (s), 1710 (m), 1645 (m), 1620 (w), 1610 (w), 1440 (m), 1390 (m), 1360 (w), 1145 (w), 1000 (s), 980 (s), 895 (m), 880-855 (w) and 825 (w) $cm^{-1}$. $\lambda_{max}$ (95% ethanol): 236 nm ($\epsilon$= 16600). $^1H$ NMR, $\delta$: 0.72 and 0.95 (6H, 2s, 16,17-$CH_3$), 1.65 (3H, s, 5'-$CH_3$), 1.85 (3H, s, 19-$CH_3$), 2.46 (1H, d, J=10 Hz, 6-H), 4.02 (2H, s, 4'-$H_2$), 4.28 (2H, d, J=7 Hz, 11-$H_2$), 4.52 and 4.74 (2H, 2 br. s, 18-$H_2$), 5.43 (1H, br. t, J=7 Hz, 2'-H), 5.60 (1H, br. t, J=7 Hz, 10-H), 5.82 (1H, q, J=16 and 10 Hz, 7-H) and 6.09 (1H, d, J=16 Hz, 8-H). $^{13}C$ NMR : see table. MS (EI), m/z: 304 (7%,$M^+$), 286 (35%, $M^+$-$H_2O$) and 268 (17%, $M^+$-$2H_2O$). Anal. Calc. for $C_{26}H_{32}O_2$ : C, 78.90 ; H, 10.59 . Found : C, 78.84 ; H, 10.69.

**_cis_-[-5-[[2,2-Dimethyl-6-methylene-3-[4-(2,4,6-trimethylbenzoyloxy)-3-methyl-2-_E_-buten-1-yl]-cyclohexan--1-yl]]-3-methyl-2,4-pentadien-1-yl]-triphenylphosphonium bromide 34.**

To a solution of the $C_{20}$ alcohol **31** (470 mg, 1.05 mmol) in 6 mL THF at 0 °C were added carbon tetrabromide (700 mg, 2.10 mmol) and triphenylphosphine (550 mg, 2.1 mmol) [22]. The reaction mixture was allowed to warm up to room temperature, stirred for 30 min and directly flash chromatographed on a silica gel pad after dilution with ether. Elution with ether gave 1.07 g of crude labile bromide **33** after evaporation of solvent at 25 °C.

This bromide was directly dissolved in THF (8 mL) containing triphenylphosphine (526 mg, 2 mmol). The reaction mixture was stirred overnight at room temperature, then directly loaded on a silica gel column. Elution with methanol/dichloromethane mixtures (from 1 to 8%) afforded the phosphonium bromide **34** (680 mg, 84% from **32**) as an amorphous white solid.

$\nu_{max}$: 3070 (w), 3020 (w), 2930 (s), 2860 (m), 2450 (w), 1715 (s), 1640 (w), 1610 (m), 1585 (w), 1480 (w), 1440 (s), 1390 (w), 1370 (w), 1270 (s), 1245 (m), 1210 (m), 1170 (s), 1115 (s), 1085 (s), 1000 (w), 970 (w), 895 (w), 880 (w), 855 (w), 695 (s) and 665 (s) $cm^{-1}$. $^1H$ NMR, $\delta$: 0.67 and 0.90 (6H, 2s, 16,17-$CH_3$), 1.38 (3H, d, J=4 Hz, 19-$CH_3$), 1.71 (3H, s, 5'-$CH_3$), 2.28 and 2.30 (3H+6H, 2s, 3 mesitoyl-$CH_3$), 2.39 (1H, d, J=10 Hz, 6-H), 4.40 and 4.75 (2H, 2s, 18-$H_2$), 4.64 (1H, ddd, J=17.5, 16.0 and 8.5 Hz, 11-$H_A$), 4.71 (2H, s, 4'-$H_2$), 4.91 (1H, ddd, J=17.5, 16.0 and 7 Hz, 11-$H_B$), 5.36 (1H, m, 10-H), 5.58 (1H,br. t, J=7 Hz, 2'-H), 5.69 (1H, ddd, J=16, 10 and 2 Hz, 7-H), 6.00 (1H, d, J=16 Hz, 8-H), 6.86 (2H, s, mesitoyl-$H_2$) and 7.60-7.85 (15H, m, $(C_6H_5)_3P$). MS (FAB), m/z: 695 (100%, $M^+$-Br).

**(±)All-_E,cis_-sarcinaxanthin di-(2,4,6-trimethylbenzoyl)-ester 35.**

To a stirred mixture containing 40% aqueous KOH solution (3 mL) and the $C_{10}$ dial **25** (33 mg, 0.2 mmol) in $CH_2Cl_2$ (1 mL) was added dropwise at -10 °C under $N_2$ a solution of the phosphonium bromide **34** (465 mg, 0.6 mmol) in $CH_2Cl_2$ (5 mL). The reaction mixture was stirred 1 h at -10 °C, then 30 min at room temperature. After dilution with water and ether the decanted aqueous phase was extracted twice with ether and the combined organic phases washed with brine, dried over $MgSO_4$ and concentrated to give an deep red oily residue. Flash chromatography eluted with ether/pentane 1:5 gave the protected carotenoid **35** (198 mg, quantitative yield from the dial) as a red oil. This racemic carotenoid is probably a mixture of meso-threo-isomers.

$\nu_{max}$: 3070 (w), 3020 (w), 2915 (s), 2860 (m), 1715 (s), 1640 (w), 1610 (m), 1565 (w), 1435 (m), 1385 (m), 1365 (m), 1265 (s), 1165 (s), 1090 (s), 970 (s), 890 (m), 880 (w) and 855 (m) $cm^{-1}$. $^1H$ NMR (400MHz), $\delta$: 0.71 and 0.94 (2x6H, 2s, 16,17-$CH_3$), 1.71 (2x3H, s, 5'-$CH_3$), 1.97 (2x6H, s, 19,20-$CH_3$), 2.29 and 2.31 (18H, 2s, 3 mesitoyl-$CH_3$), 2.49 (2x1H, d, J=10 Hz, 6-H), 4.55 and 4.77 (2x2H, 2 br. s, 18-$H_2$), 4.72 (2x2H, s, 4'-$H_2$), 5.60 (2x1H, t, J=7 Hz, 2'-H), 5.84 (2x1H, q, J=16 and 10 Hz, 7-H), 6.14 (2x1H, d, J=16 Hz, 8-H), 6.10 to 6.70 (2x5H, m, 10,11,12,14 and 15-H) and 6.87 (2x2H, s, 2 mesitoyl-$H_2$).

**(±)All _E,cis_-sarcinaxanthin 3.**

To a solution of **35** (198 mg, 0.2 mmol) in dry THF (20 mL) at 0 °C under $N_2$ was added a decanted M solution of $LiAlH_4$ in dry ether (2 mL). The reaction mixture was warmed to room temperature, stirred for 2 h, quenched with $H_2O$ and extracted with ether (3 portions). The combined organic fractions were washed with brine, dried over $MgSO_4$ and concentrated. The red oily residue was purified by silica gel chromatography eluted with ether/pentane 3:7 to give pure sarcinaxanthin **3** (127 mg, 90%) which was recrystallised from acetone untill constant melting point, mp: 208-210 °C.

$\nu_{max}$: 3600 (m), 3450 (s), 3070 (w), 3020 (w), 2990 (m), 2960 (s), 2920 (s), 2860 (m), 1660 (w), 1640 (m), 1565 (w), 1440 (m), 1385 (m), 1365 (m), 1005 (m), 970 (s), 895 (m), 860 (w) and 820 (w) $cm^{-1}$. $\lambda_{max}$ (acetone): 397 (shoulder), 416, 442 and 470 nm ($\epsilon$: $5.10^4$; $9.710^4$; $1.47\ 10^5$ and $1.46\ 10^5$). $^1H$ NMR, $\delta$: 0.73 and 0.95 (2x6, 2s, 16,17-$CH_3$), 1.66 (2x3H, s, 5'-$CH_3$), 1.97 and 1.98 (2x6H, 2s, 19,20-$CH_3$), 2.48 (2x1H, d, J=10 Hz, 6-H), 4.03 (2x2H, s, 4'-$H_2$), 4.54 and 4.77 (2x2H, 2s, 18-$H_2$), 5.44 (2x1H, t, J=7 Hz, 2'-H), 5.84 (2x1H, q, J=16 and 10 Hz, 7-H), 6.13 (2x1H, d, J=16 Hz, 8-H), 6.14 (2x1H, m, 10-H), 6.26 (2x1H, m, 14-H), 6.34 (2x1H, d, J=15 Hz, 12H) and 6.63 (2x2H, m, 11,15-H). MS (EI), m/z: 704 (20%, $M^+$), 687 (3%), 669 (2%), 612 (3%), 598 (2%), 119 (30%), 105 (43%) and 91 (100%).

These data are in agreement with those reported for the natural product [5].

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| Carbon Number | 12 | 13 | 17 | 16α-*cis* | 18 | 21 | 31 | 32 |
|---|---|---|---|---|---|---|---|---|
| 1 | 37.6 | 36.5 | 38.2 | 35.1 | 38.4 | 39.6 | 39.0 | 39.2 |
| 2 | 48.5 | 44.4 | 47.9 | 44.2 | 48.2 | 47.8 | 48.2 | 48.5 |
| 3 | 25.4* | 22.4* | 28.3* | 28.3* | 29.7* | 29.4* | 28.7* | 28.6* |
| 4 | 42.4 | 36.4 | 36.6 | 122.6 | 36.7 | 36.6 | 36.3 | 36.4 |
| 5 | 70.3 | 72.4 | 147.0 | 133.3 | 147.3 | 144.9 | 149.6 | 149.9 |
| 6 | 56.4 | 51.9 | 55.9 | 52.9 | 56.2 | 47.8 | 58.1 | 58.2 |
| 7 | 63.1 | 63.4 | 59.1 | 60.8 | 59.3 | 53.1 | 128.4** | 128.4** |
| 8 | | | | | | | 136.4 | 136.4 |
| 9 | | | | | | | 135.6 | 136.1 |
| 10 | | | | | | | 127.9** | 128.2** |
| 11 | | | | | | | 59.1 | 59.3 |
| 16 | 16.6 | 26.7 | 15.6 | 16.3 | 15.8 | 15.2 | 15.1 | 15.4 |
| 17 | 23.5 | 26.2* | 26.3 | 26.8 | 26.5 | 26.0 | 27.6* | 27.7* |
| 18 | 28.0* | 27.6* | 106.5 | 22.1 | 105.6 | 107.6 | 107.9 | 107.9 |
| 19 | | | | | | | 12.9 | 13.0 |
| 1' | 28.0* | 25.9* | 29.6* | 27.8* | 28.2* | 29.1* | 28.9* | 29.0* |
| 2' | 124.9 | 124.9 | 130.0 | 130.1 | 125.2 | 129.5 | 130.3 | 125.8 |
| 3' | 135.3 | 134.7 | 138.5 | 138.5 | 135.0 | 138.6 | 138.8 | 135.0 |
| 4' | 68.3 | 68.1 | 70.4 | 70.6 | 68.4 | 70.3 | 70.8 | 68.9 |
| 5' | 13.6 | 13.7 | 14.4 | 14.3 | 13.8 | 14.4 | 14.6 | 14.0 |
| $CH_3CO$ | 21.3 | 21.0 | | | | | | |
| $CH_3CO$ | 170.7 | 170.4 | | | | | | |
| 1a | | | 169.3 | 169.4 | | 169.2 | 169.6 | |
| 2a | | | 129.9** | 129.7** | | 130.2** | 130.0*** | |
| 3a | | | 134.4 | 134.4 | | 134.5 | 134.7 | |
| 4a | | | 127.8 | 127.8 | | 127.6 | 128.0 | |
| 5a | | | 130.7** | 130.7** | | 130.7** | 130.8*** | |
| 6a | | | 19.6 | 19.6 | | 19.6 | 19.8 | |
| 7a | | | 20.9 | 20.9 | | 21.0 | 21.1 | |
| 1b | | | | | | 139.3*** | | |
| 2b | | | | | | 127.9 | | |
| 3b | | | | | | 128.6 | | |
| 4b | | | | | | 133.0*** | | |

Table: $^{13}C$ NMR chemical shifts Any values with *, ** or *** in one given column may be reversed.

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