Synthesis of BC Ring-Systems of Taxol by Ring-Closing Metathesis

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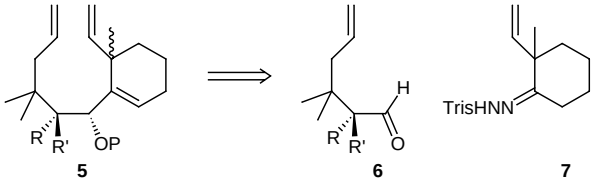
Abstract: Highly functionalized BC ring-systems of Taxol® having the required chemistry for the C1, C2 and C8 centers have been synthesized using a ring-closing metathesis (RCM) reaction as the key step. Silylene **26** and acetonide **27** were obtained in excellent yields with Schrock's and our recently reported catalyst. In the case of carbonate **23**, a *trans* cyclooctene was formed when using Grubbs' catalyst, indicating that RCM does not always proceed to completion of thermodynamic equilibrium.

Key words: cyclooctenes, cyclization, metathesis, olefin, Taxol, ruthenium, molybdenum

In spite of numerous synthetic approaches towards Taxol® (**1**)[1] and Taxotere® (**2**),[2] including six total syntheses,[3] these two antitumor agents still constitute a remarkable challenge for organic chemists (Scheme 1). In the course of our studies towards the total synthesis of Taxol,[4] a convergent approach with a key coupling reaction between the A- and C-rings, where all the taxol functionalities were potentially present was envisaged. A metathesis reaction was planned for the final B-ring closure. This route proved to be too ambitious and we designed the synthesis plan outlined below, where the metathesis reaction would form the BC ring-system of the target molecule by creating the C9-C10 bond (Scheme 1).

When we began this work, only a few cyclooctenes had been formed by ring-closing metathesis (RCM).[5] We therefore decided to check the feasibility of this route with model compounds.[6] Metathesis precursors **5** could be synthesized by Shapiro coupling between aldehydes **6** and trisylhydrazone **7**, which was prepared in one step from the known 2-methyl-2-vinylcyclohexanone[7] (Scheme 2).

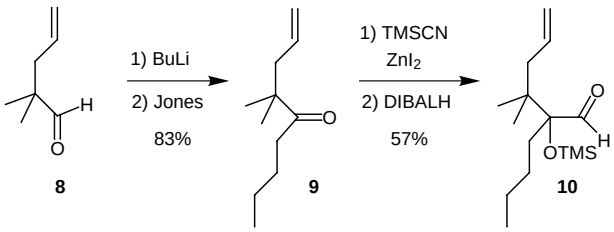


5 **6** **7**

Scheme 2

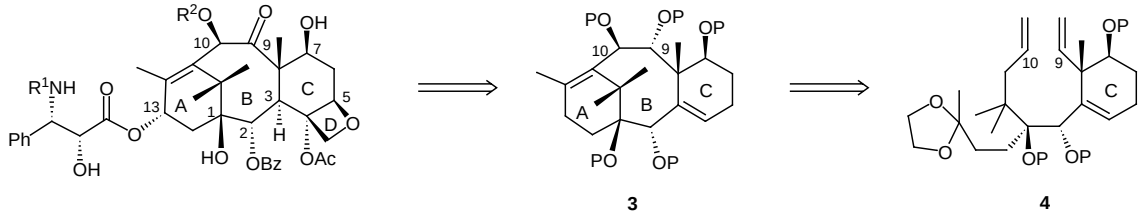
Two substituted hex-4-enals were selected. Aldehyde **10** was synthesized in four steps from commercially available 2,2-dimethylpent-4-enal (**8**) by conversion to ketone **9** (Scheme 3). Cyanohydrin homologation and DIBALH reduction of the nitrile gave **10** in 57% yield for the two steps, along with 15−20% of the corresponding α-hydroxy aldehyde. Compound **12** (Scheme 4) has been reported by Pattenden.[8]

Shapiro coupling was first tested with pentenal **8**. The desired alcohol was obtained in 77% yield when the intermediate vinyllithium was formed with *t*-BuLi (Scheme



8 **9** **10**

Scheme 3



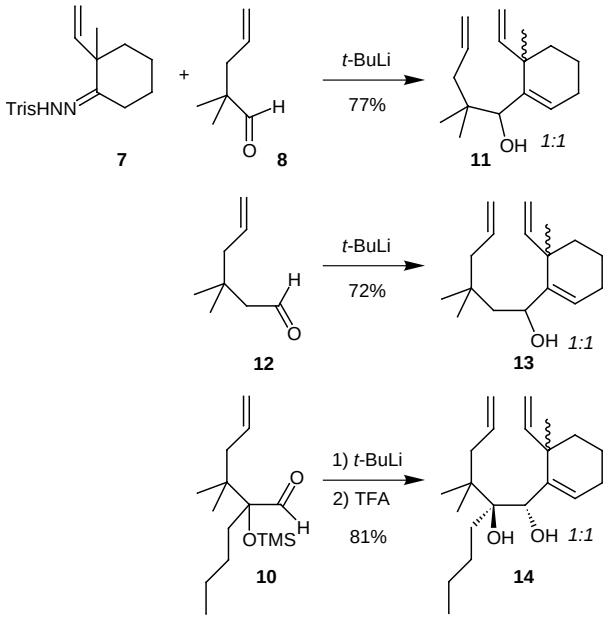
1 Taxol® (paclitaxel) $R^1 = C_6H_5CO$, R^2 = Ac

2 Taxotere® (docetaxel) $R^1 = t$BuOCO, R^2 = H

3 **4**

Scheme 1

4).[4e] Similarly, reaction of hydrazone **7** with aldehydes **12** and **10** furnished compounds **13** and **14** in 72 and 85% yield, respectively. Since the two coupling partners are racemic, the adducts are produced as 1:1 mixture of diastereomers, even in the case of **14** where the addition is totally stereoselective at the diol level, producing only the *trans* diastereomer.[9]



Scheme 4

The RCM catalysts used in this work are presented in Figure 1: Grubbs' ruthenium complex [Ru],[10] Schrock's molybdenum compound [Mo],[11] and our recently reported catalyst [RuIm].[12] Schrock's catalyst was not employed with substrates with free OH groups, as it is known to be incompatible with this functional group.

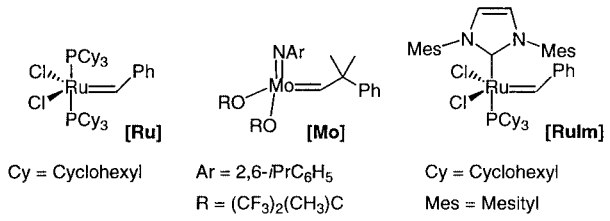
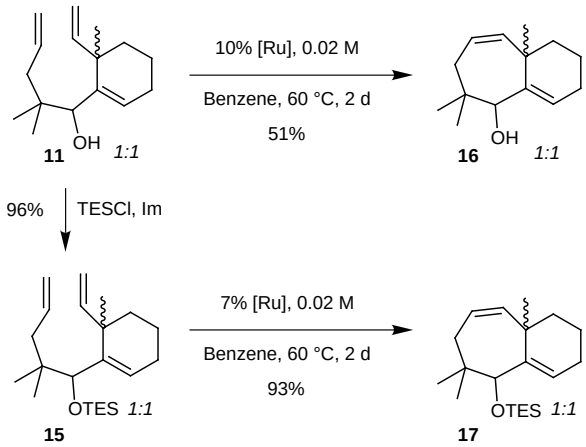


Figure Catalysts used for RCM reactions

The closure of the B-ring of Taxol between C9 and C10 by RCM presents two separate difficulties: the unfavorable formation of an eight-membered ring has to be overcome and the neopentylic position at C8 adjacent to one of the olefinic partners might prevent the formation of the intermediate metallacyclobutane, which is already fused to a highly substituted eight-membered ring. In order to assess rapidly the influence of the steric hindrance at C8 on the RCM reaction, we first focused our study on the RCM of alcohol **11**, which would lead to a seven-memberd ring.

Compound **11**, when submitted to Grubbs' catalyst, furnished the seven-membered ring **16** in 51% isolated yield (Scheme 5). The remaining material was a complex mixture of **11** and oligomers. When the alcohol function of **11** was protected as a triethylsilyl ether (TES), the yield of the RCM increased to 93%. Both reactions were slow and required two days to proceed to completion. In each case (**11** → **16** and **15** → **17**), the two diastereomeric dienes cyclized at a comparable rate, and the products were formed as a 1:1 mixture of diastereomers.[13] The Thorpe−Ingold effect of an alcohol protecting group (OTES vs OH) is noteworthy and a similar example has been recently reported for a RCM reaction leading to a hydroxyoxocene.[14]

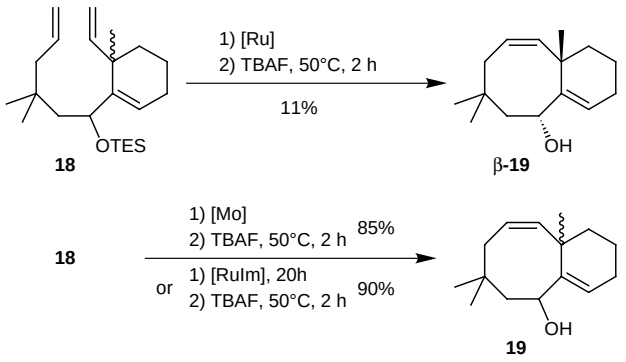


Scheme 5

Having established that the neopentylic position was not deleterious to the RCM, we turned our attention to the formation of cyclooctenes. No reaction occurred at 60 °C, which is the temperature generally recommended for substrates which are not very reactive towards olefin metathesis. The following general conditions were used: RCM with [Ru] or [Mo] were performed in benzene (0.02 M) at 80 °C for several days (8 days for [Ru], 3 days for [Mo]) and fresh catalyst was added every 24 hours.[15] In the case of [RuIm], which is a more active catalyst and which is also thermally stable, RCM reactions were complete in 12 hours at 80 °C in 1,2-dichloroethane without any further catalyst addition.

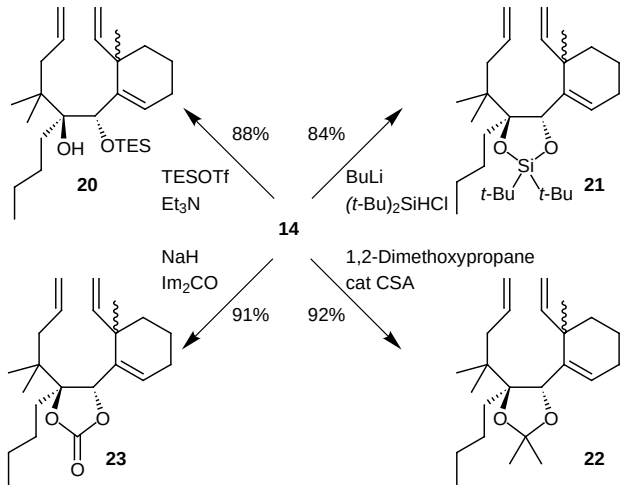
Alcohol **13**, when submitted to Grubbs' catalyst [Ru], only led to polymers. With [RuIm], traces of a cyclized product were found in the ^{1}H NMR spectrum of the unpurified reaction mixture. Metathesis of triethylsilyl ether **18** with Grubbs' catalyst furnished, after deprotection of the TES ether,[16] 11% of cyclooctene **19**[17] as a single diastereomer with the β-configuration at C8.[18] The mass balance consisted of starting diene **18**. On the other hand, excellent yields were obtained for the RCM reactions with catalysts [Mo] and [RuIm], which gave both the diastereomers of

19 (Scheme 6). Here also, a Thorpe−Ingold effect could explain the difference in yields between the RCM with the free alcohol and the TES ether.



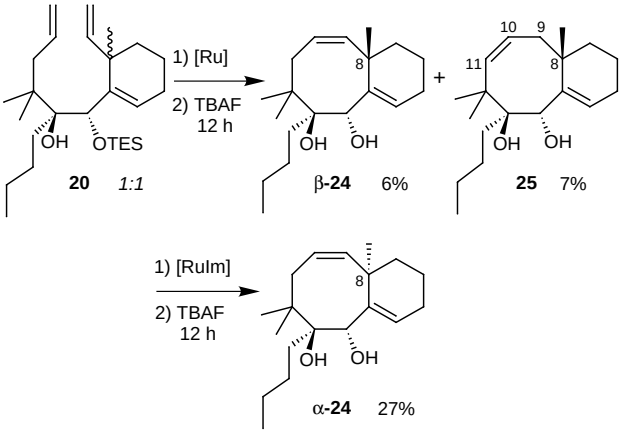
Scheme 6

The following metathesis precursors contain most of the substituents found in compound **4**. Only the acetal on the side-chain and the protected alcohol at C7 are missing. The secondary alcohol present in **14** was protected as its TES ether to give **20** in excellent yield. Cyclic protecting groups were also installed to lead to silylene **21**,[19] acetonide **22** and carbonate **23** in 84, 92 and 91% yields, respectively (Scheme 7).



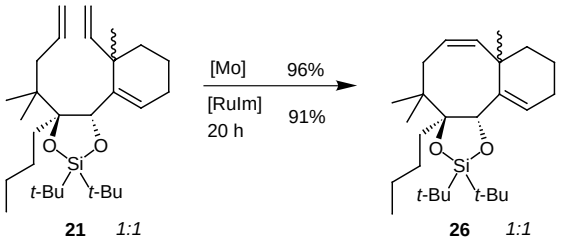
Scheme 7

We were disappointed by the outcome of RCM reaction of compound **20** with catalyst [Ru]: the desired product **24** was obtained in only 6% yield, along with 7% of cyclooctene **25** where the double bond had migrated to the C10-C11 position (Scheme 8). A similar isomerization has been reported by Taylor.[14] The authors invoke an acid catalysis due to the use of dichloromethane as solvent, since the presence of triethylamine inhibits the formation of the isomerized product. Here, the isomerization might result from prolonged exposure of the product to ruthenium derivatives at high temperature: Grubbs observed isomerization of RCM products during distillation when residual amounts of the catalyst were present.[20] Both products **24** and **25** have the β-configuration at C8.[21] In the case of [RuIm], the yield was slightly better but the intriguing feature was the stereochemical outcome of the cyclization: α-**24** was the only observed cyclooctene. We are unable at this time to explain why only one diastereomer undergoes RCM in each case.



Scheme 8

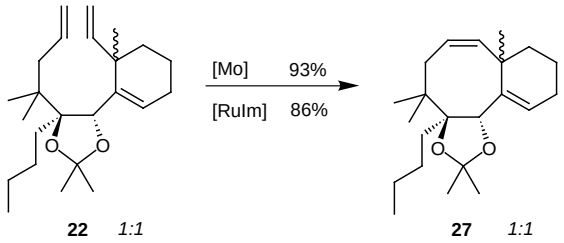
Cyclic protecting groups for the diol moiety were the next logical step. A poor conversion of silylene **21** to cyclooctene β-**26**[22] was obtained with Grubbs' catalyst. However, we were gratified to discover that catalysts [Mo] and [RuIm] led to excellent yields of **26** (Scheme 9). Contrary to the case of **20**, both diastereomers of **21** underwent cyclization.



Scheme 9

Similar results were obtained with acetonide **22**: no noticeable reaction occurred with catalyst [Ru], whereas RCM with [Mo] and [RuIm] furnished the bicyclo compound **27** in 93 and 86% yield, respectively (Scheme 10).

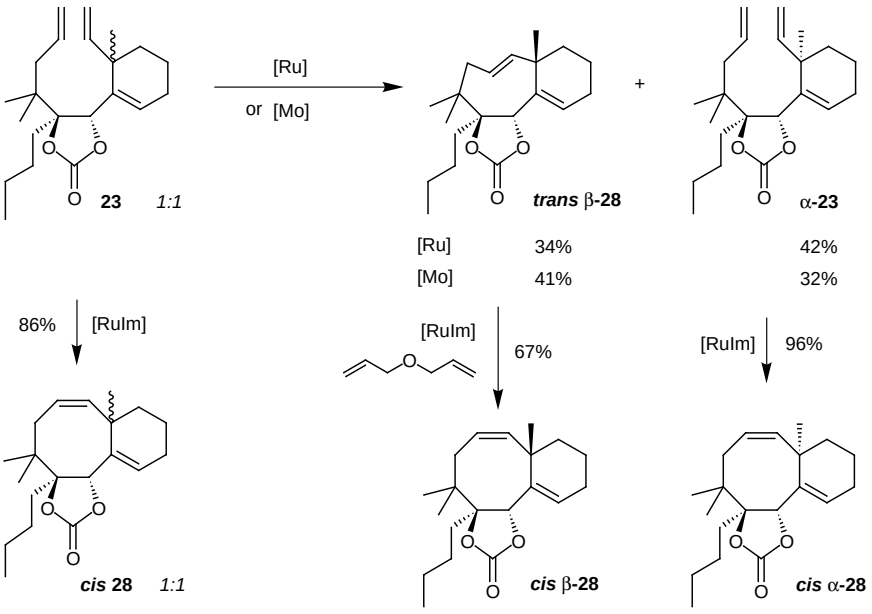
We next examined the olefin metathesis of carbonate **23**. Choice of this derivative was prompted by Nicolaou's finding that it makes a convenient protecting group for the C1-C2 diol of Taxol. When phenyllithium was added to a carbonate derivative of an ABC ring-system of this mole-



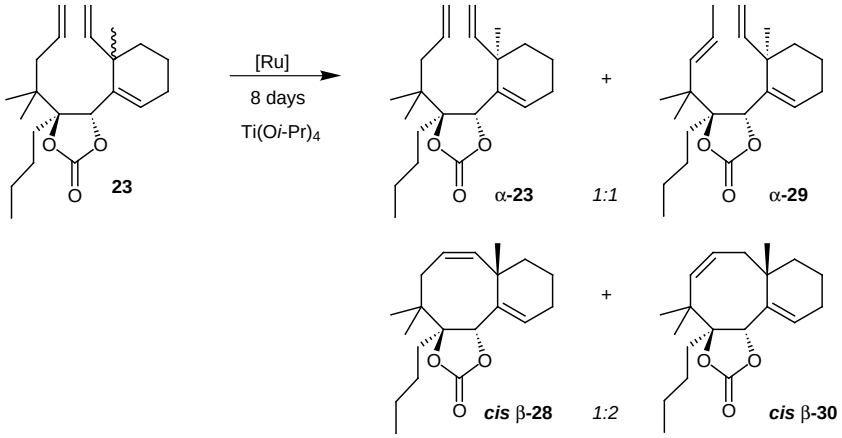
Scheme 10

cule, the C2 benzoate was directly formed.[23] Moreover, it has also been shown that the corresponding acetonide was not easily hydrolyzed.[24] Treatment of a diastereomeric mixture of carbonate **23** with Grubbs' or Schrock's catalyst led to a surprising result: only the C8 β-diastereomer of **23** cyclized, and the α-diastereomer was recovered almost quantitatively (Scheme 11). For the first time with [Ru], the conversion was complete (for one diastereomer), and no polymeric side products were formed. The totally unexpected feature of this reaction was the *trans* geometry of the C9-C10 olefin in *trans* β-**28**.[25] No trace of *cis* β-**28** was observed, even when the reaction was performed with 1 equivalent[26] of [Ru] in C_6D_6 and monitored by ^1H NMR. On the contrary, both epimers at C8 underwent cyclization with [RuIm], giving a 86% yield of *cis*-**28** as a 1:1 mixture of diastereomers. This result was confirmed by independent RCM of α-**23** with [RuIm] which led to *cis* α-**28** in 96% yield. It appears that olefin metathesis of **23** does not proceed to complete thermodynamic equilibrium with catalysts [Ru] and [Mo]. To check the stability of the *trans* cyclooctene, we attempted to convert *trans* β-**28** to *cis* β-**28** with classical reagents (cat. $I_2/CDCl_3$, cat. CSA/$CDCl_3$, CSA/benzene/reflux/15 h), to no avail. On the other hand, catalyst [RuIm] is capable of isomerizing *trans* β-**28** to *cis* β-**28** in the presence of (bis)allyl ether (an easily measurable source of ethylene)[27] presumably through a ring-closing/ring-opening process, effectively proving that RCM with this catalyst proceeds under thermodynamic control.

A complexation of the catalyst by the carbonyl moiety might be invoked to explain the formation of a *trans* cyclooctene, although the involved chelate would be an eight-membered ring.[28] To clarify this point, a metathesis reaction was performed in the presence of 1 equivalent of titanium isopropoxide, according to the work of Fürstner and Langemann.[29] In this instance, only the β-epimer cyclized, as above, but this time *cis* β-**28** was produced, along with *cis* β-**30** where the olefin has migrated to the C10-C11 position (Scheme 12). The α-diastereomer did not undergo metathesis, but a similar isomerization of the double bond led to α-**29**. Two aspects of this reaction deserve comments. First, no *trans* cyclooctene is produced. This may be explained by complexation of the titanium by the carbonyl moiety, which prevents complexation of the ruthenium catalyst. The transition state would not adopt the rigid conformation leading to the *trans* double bond any longer. The second matter is the double bond migration to the C10-C11 position, that occurs both in the cyclized product (formation of *cis* β-**30**)[30] and in the starting material (formation of α-**29**).[31] This migration was also observed with the more active [RuIm] catalyst: during the isomerization of *trans* β-**28** with [RuIm] in 1,2-dichloroethane, *cis* β-**28** was contaminated with 20% of the Δ-10,11 isomer *cis* β-**30**. In the case of [RuIm], when the metatheses were conducted in benzene, isomerization of the starting diene was also observed and the results were not reproducible. For example, RCM of carbonate **23** in benzene only produced 50% of cyclooctene *cis* -**28**, along with 50% of isomerized starting material **29**. Performing



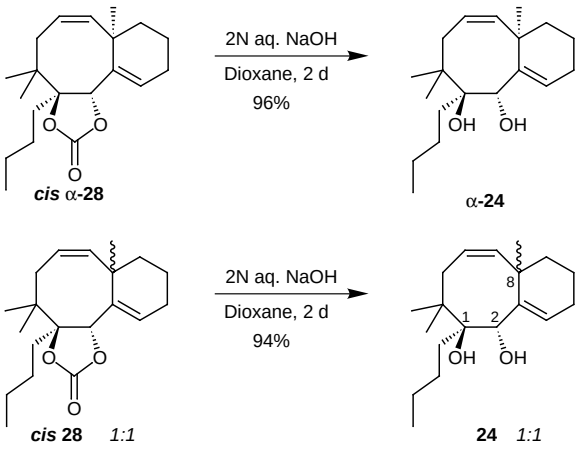
Scheme 11



Scheme 12

the catalysis using 1,2-dichloroethane solved the problem for all substrates except carbonate **23**, where 10% of **29** was detected in the ^{1}H NMR of the unpurified reaction mixture. It seems that isomerization becomes a non-negligible side reaction with active catalysts (according to Fürstner and Langemann, titanium isopropoxide activates [Ru]) in the case of unreactive metathesis precursors like carbonate **23**.

Determination of the stereochemistry of the metathesis products was based on the X-ray structure of *trans* β-**28**. First, the *trans* configuration of the C1-C2 diol was established. The C8 configuration of *cis* α-**28** was then established, since this compound is derived from the unreacted epimer recovered from metathesis of **23** with [Ru] or [Mo] (Scheme 11). Compound *cis* α-**28** was deprotected to furnish diol α-**24** (Scheme 13), which is identical to the compound resulting from RCM of **20** with [RuIm] followed by fluoride treatment (cf. Scheme 8).



Scheme 13

The two epimers of *cis* -**28**, resulting from cyclization of **23** with [RuIm], were unseparable but the carbonate moiety could be hydrolyzed to furnish both epimers of **24** that were separated by flash chromatography. Compound β-**24** was identical to the RCM product of **20** with [Ru] followed by TBAF deprotection (cf. Scheme 8). Finally, the unpurified mixture containing β-**26** was treated with TBAF for 2 days and only β-**24** was found in the ^{1}H NMR of the resulting mixture of products, with no trace of α-**24**. Diastereomers of silylene **26** and acetonide **27** were separated by flash chromatography and their stereochemistry was assigned by extensive NMR studies (COSY, NOESY, HMBC, HMQC).

In conclusion, we have synthesized elaborate BC ring-systems of Taxol in very good yields using RCM to form the eight-membered ring. These model compounds possess the required configuration for the C1, C2 and C8 stereogenic centers of the target molecule. We have tested three different catalysts, [Ru], [Mo], and [RuIm], on several substrates and we have shown that catalyst [RuIm] was the most active in all cases. During this study, we have uncovered a specific case where a *trans* cyclooctene was formed, proving that olefin metathesis does not always proceed to completion of thermodynamic equilibrium with [Ru] and [Mo], contrary to RCM [RuIm] which gave the expected *cis* product.

All air and/or water sensitive reactions were carried out under argon with, freshly distilled anhydrous solvents using standard syringe-cannula/septa techniques. THF and Et_2O were distilled from sodium-benzophenone, MeOH from $Mg(OMe)_2$. Petroleum used had bp 40-65 °C. All corresponding glassware was oven dried (110 °C) and/or carefully dried in line with a flameless heat gun, unless otherwise stated.

^{1}H NMR spectra were recorded in $CDCl_3$ on a Bruker WP 200 (200 MHz) or on a Bruker AM 400 (400 MHz) instrument. The chemical shifts are expressed in parts per million (ppm) referenced to residual $CHCl_3$ (7.27 ppm). Data are reported as follows: δ, chemical shift; multiplicity (recorded as s, singlet; d, doublet; t, triplet; q, quadruplet and m, multiplet), coupling constants (*J* in Hertz), integration and assignment. H,H-COSY and H,H-NOESY experiments were routinely carried out to ascertain H-H connections and configuration assignments, respectively. ^{13}C NMR spectra were recorded on the same instruments at 50.3 MHz and 100.6 MHz respectively. ^{13}C NMR chemical shifts are expressed in parts per million (ppm), re-

ported from the central peak of $CDCl_3$ (77.14 ppm). J-modulated spin-echo technique (J-mod) experiments were used for evaluating CH multiplicities.

Mass spectra (MS) were obtained on a Hewlett-Packard HP 5989B spectrometer via either direct introduction (CI, NH_3) or GC/MS coupling with a Hewlett-Packard HP 5890 chromatograph. IR spectra were obtained on a Perkin-Elmer FT 1600 instrument using NaCl salt plates (thin film) and are reported in terms of frequency of absorption (ν, cm^{-1}). Microanalyses were performed by the Service de Microanalyse, Institut de Chimie des Substances Naturelles, C.N.R.S., F-91198, Gif sur Yvette. Flash chromatography was performed on E. Merck silica gel Si 60 (40−63 mm, Ref. 9385).

Taxol numbering was used for assignment on all compounds encompassing the BC skeleton of Taxol.

(6*R/*S**)-*N*-2,4,6-Triisopropylbenzenesulfonyl,*N*'-(6-methyl-6-vinylcyclohex-1-en-1-yl)hydrazine (7)**

To a suspension of (±)-2-methyl-2-vinylcyclohexan-1-one[7] (3.2 g, 2.3 mmol) and *N*-2,4,6-triisopropylbenzenesulfonylhydrazine (6.6 g, 2.2 mmol, 0.96 equiv) in Et_2O (15 mL) was added dropwise concd HCl (10 drops) at 25 °C until complete dilution of the solid. The reacting mixture was stirred for 10 min until the appearance of a white precipitate, and then allowed to stay for a further 15 min. The suspension was filtered and the solid washed with Et_2O/petroleum ether (10:90) (2 × 10 mL) to yield 6.1 g (63%) of hydrazone **7** as a white solid. The mother liquors were concentrated, and another 1.15 g (12%) of **7** was recovered after recrystallization from Et_2O/petroleum ether (1:1); mp 145−146 °C.

^{1}H NMR ($CDCl_3$, 200 MHz): δ = 7.53 (br s, 1 H, NH), 7.16 (s, 2 H, H-Ar), 5.75 (dd, 1 H, *J* = 17.6, 10.7 Hz, H-1'), 4.88 [dd, 1 H, *J* = 10.7, 1.0 Hz, H-2' (*cis*)], 4.58 [dd, 1 H, *J* = 17.6, 1.0 Hz, H-2' (*trans*)], 4.20 (sept, 2 H, *J* = 6.7 Hz, C*H*-Ar), 2.90 (sept, 1 H, *J* = 6.7 Hz, C*H*-Ar), 2.51-2.28 (m, 1 H), 2.05-1.90 (m, 1 H), 1.84-1.72 (m, 2 H, CH_2), 1.62-1.40 (m, 4 H, 2 CH_2), 1.28 [d, 6 H, *J* = 6.4 Hz, $(CH_3)_2$CH-Ar], 1.26 [d, 12 H, *J* = 6.9 Hz, 2 $(CH_3)_2$CH-Ar], 1.02 (s, 3 H, CH_3-6).

^{13}C NMR ($CDCl_3$, 50.3 MHz): δ = 161.5 (1), 153.0, 151.2 (Ar), 145.0 (1'), 131.5, 123.4 (Ar), 113.5 (8'), 45.6 (6), 39.4 (3), 34.1, 29.7, 26.1, 25.7, 24.8, 24.7, 23.5, 21.6.

IR (film): ν = 3262, 3054, 2960, 2864, 1601, 1460, 1382, 1330, 1165, 1105, 990, 934, 657 cm^{-1}.

MS (CI, NH_3): *m*/*z* = 436 (MNH_4^+), 419 (MH^+), 375, 355, 301, 280, 251, 153, 140.

4,4-Dimethylnon-1-en-5-one (9)

To a solution of 90% 2,2-dimethylpent-4-enal (**8**; 4.0 g, 3.2 mmol) in anhyd THF (80 mL) was added a crystal of 2,2'-bisquinoline. The solution was cooled to −78 °C, and then a solution of BuLi (1.5 M in hexanes) was added over a 15 min period until persistency of a purple colour (19.4 mL, 29 mmol, 0.9 equiv). The reaction mixture was then quenched with sat. aq NH_4Cl solution (40 mL), diluted with Et_2O (100 mL) and allowed to warm to r.t. The layers were separated, the aqueous layer was extracted with Et_2O, and the combined organic layers were washed with H_2O and brine, dried ($MgSO_4$) and concentrated in vacuo. The crude product was diluted with acetone (60 mL), and Jones reagent (CrO_3/H_2SO_4) was added dropwise over a 10 min period at 0 °C until persistency of an orange colour. The mixture was stirred for 1 h at 0 °C and then quenched with MeOH (5 mL). After 10 min, the mixture was poured into H_2O (50 mL) at 0 °C and diluted with Et_2O (100 mL). The layers were separated, the aqueous layer was extracted with Et_2O, and the combined organic layers were washed with H_2O and brine, dried ($MgSO_4$) and concentrated in vacuo. Distillation of the crude product afforded 4.5 g (83%) of ketone **9** as a colorless oil; bp 47 °C/0.1 Torr.

^{1}H NMR ($CDCl_3$, 400 MHz): δ = 5.71-5.61 (m, 1 H, H-2), 5.04-4.99 (m, 2 H, H_2-1), 2.45 (t, 2 H, *J* = 7.3 Hz, H_2-6), 2.25 (d, 2 H, *J* = 7.3 Hz, H_2-3), 1.55-1.48 (m, 2 H), 1.32-1.22 (m, 2 H), 1.11 (s, 6 H, $2CH_3$-4), 0.89 (t, 3 H, *J* = 7.3 Hz, H_3-9).

^{13}C NMR ($CDCl_3$, 100.6 MHz): δ = 215.4 (5), 134.1 (2), 117.7 (1), 47.4 (4), 43.9 (3), 36.7 (6), 25.8, 22.3 (7, 8), 24.0 (CH_3-4), 13.9 (9).

IR (film): ν = 3077, 2960, 2873, 1705, 1640, 1467, 1365, 1120, 1039, 995, 916 cm^{-1}.

MS (CI, NH_3): *m*/*z* = 186 (MNH_4^+), 169 (MH^+), 153, 139, 126.

(2*R/*S**)-2-Butyl-3,3-dimethyl-2-trimethylsilyloxyhex-5-enal (10) and (2*R**/*S**)-2-Butyl-3,3-dimethyl-2-hydroxyhex-5-enal (10a)**

To a solution of ketone **9** (1.2 g, 7.1 mmol) in anhyd CH_2Cl_2 (20 mL) at 25 °C was added a pinch of ZnI_2 and then trimethylsilylcyanide (1.4 mL, 10.5 mmol, 1.5 equiv). The resulting mixture was heated at reflux for 2 h, then cooled to r.t. and concentrated in vacuo (with a NaOCl/NaOH trap). The crude product was filtered on a pad of silica gel, and the silica gel was washed three times with Et_2O/petroleum ether (1:1, 50 mL). The cyanohydrin thus obtained was concentrated in vacuo and used as such for the following step. It was diluted with Et_2O (25 mL), and the resulting solution was cooled to −78 °C. A solution of DIBALH (1 M in hexanes, 15.0 mL, 1.5 mmol, 2.2 equiv) was added, and the reaction mixture was stirred at −78 °C for 2 h, then 30 min at 0 °C, and finally quenched with EtOAc (2 mL). The mixture was then diluted with Et_2O (100 ml), warmed to r.t. and silica gel (20 g) was added. The resulting suspension was vigorously stirred for 6 h, and then filtered and concentrated in vacuo. Purification by flash chromatography on silica gel (Et_2O/petroleum ether, 2:98) yielded 1.1 g (57%) of aldehyde **10** along with 200 mg (14%) of deprotected aldehyde **10a** as colorless oils.

10

^{1}H NMR ($CDCl_3$, 400 MHz): δ = 9.68 (s, 1 H, H-1), 5.78 (ddt, 1 H, *J* = 17.5, 10.0, 7.4 Hz, H-5), 5.05 [br d, 1 H, *J* = 10.0 Hz, H-6 (*cis*)], 5.01 [br d, 1 H, *J* = 17.5 Hz, H-6 (*trans*)], 2.14 (dd, 1 H, *J* = 13.4, 7.4 Hz, H-4), 2.07 (dd, 1 H, *J* = 13.4, 7.4 Hz, H-4), 1.88-1.81 (m, 1 H), 1.68-1.61 (m, 1 H), 1.43-1.23 (m, 3 H), 0.98-0.96 (m, 1 H), 0.93, 0.92 (2 s, 6 H, 2 CH_3-3), 0.89 (t, 3 H, *J* = 7.1 Hz, CH_2CH_3), 0.16 (s, 9 H, CH_3Si).

^{13}C NMR ($CDCl_3$, 100.6 MHz): δ = 205.2 (1), 134.9 (5), 117.7 (6), 88.7 (2), 41.7 (4), 41.5 (3), 31.2, 26.4, 23.2 (CH_2), 22.2 (CH_3-3), 13.9 (CH_2CH_3), 2.9 (CH_3Si).

IR (film): ν = 3072, 2959, 2874, 1734, 1639, 1468, 1248, 1145, 1082, 840, 754 cm^{-1}.

MS (CI, NH_3): *m*/*z* = 305, 288, 271, 253, 181, 90.

10a

^{1}H NMR ($CDCl_3$, 400 MHz): δ = 9.76 (d, 1 H, *J* = 1.0 Hz, H-1), 5.79 (ddt, 1 H, *J* = 17.4, 10.4, 7.4 Hz, H-5), 5.06 [br d, 1 H, *J* = 10.4 Hz, H-6 (*cis*)], 5.02 [br d, 1 H, *J* = 17.4 Hz, H-6 (*trans*)], 3.38 (s, 1 H, OH), 2.18 (dd, 1 H, *J* = 13.4, 7.4 Hz, H-4), 2.06 (dd, 1 H, *J* = 13.4, 7.4 Hz, H-4), 1.94-1.87 (m, 1 H), 1.77-1.70 (m, 1 H), 1.33-1.23 (m, 3 H), 0.97, 0.95 (2 s, 6 H, 2 CH_3-3), 0.86 (t, 3 H, *J* = 7.1 Hz, CH_2CH_3), 0.82-0.76 (m, 1 H).

^{13}C NMR ($CDCl_3$, 100.6 MHz): δ = 206.0 (1), 134.4 (5), 118.0 (6), 84.0 (2), 41.6 (4), 40.5 (3), 29.7, 25.1, 23.1 (CH_2), 21.9, 21.8 (CH_3-3), 13.9 (CH_2CH_3).

IR (film): ν = 3505, 3075, 2959, 2873, 1719, 1639, 1468, 1338, 1248, 914, 641 cm^{-1}.

MS (CI, NH_3): *m*/*z* = 220, 216, 199.

[1*R(6*R**/*S**)]-2,2-Dimethyl-1-(6-methyl-6-vinylcyclohex-1-en-1-yl)pent-4-en-1-ol (11)**

To a solution of **7** (300 mg, 720 μmol) in THF (3 mL) at -78 °C was added dropwise a 1.7 M of *t*-BuLi in hexanes (930 μL, 1.6 mmol, 2.2 equiv) over 5 min. The resulting red solution was stirred at -78 °C for 30 min, during which time it turned dark red. Temperature was then quickly raised to 0 °C for 1 min causing intense bubbling and decoloration to light yellow, then set back down to -78 °C. A solution of 2,2-dimethylpent-4-enal (**8**; 150 μL, 980 μmol, 1.5 equiv) in THF (1 mL) was then added via cannula to the vinyl anion solution prepared above, and the resulting mixture was stirred at -78 °C for 30 min. The reaction mixture was then quenched at -78 °C by sat. aq NH_4Cl solution (5 mL) and allowed to warm to r.t. The layers were separated, the aqueous layer was extracted with Et_2O, and the combined organic layers were washed with H_2O and brine, dried ($MgSO_4$) and concentrated in vacuo. The resulting crude product was purified by flash chromatography on silica gel (Et_2O/petroleum ether, 10:90) to give 130 mg (77%) of a 1:1 mixture of the two diastereomers of **11** as a colorless oil.

^{1}H NMR ($CDCl_3$, 400 MHz): δ = 6.08 (t, 0.5 H, *J* = 4.0 Hz, 0.5 H-2'), 6.03 (t, 0.5 H, *J* = 4.0 Hz, 0.5 H-2'), 5.89 (dd, 0.5 H, *J* = 17.4, 10.7 Hz, 0.5 H-7'), 5.93-5.82 (m, 1 H, H-4), 5.76 (dd, 0.5 H, *J* = 17.45, 10.7 Hz, 0.5 H-6'), 5.10-5.00 (m, 4 H, H_2-5 + H_2-8'), 3.72 (s, 0.5 H, 0.5 H-1), 3.71 (s, 0.5 H, 0.5 H-1), 2.22-1.98 (m, 4 H, H_2-3 + H_2-3'), 1.64-1.45 (m, 4 H, H_2-4' + H_2-5'), 1.24, 1.12, 0.98, 0.96, 0.88, 0.85 (6 s, 9 H, 2 CH_3-2 + CH_3-6').

^{13}C NMR ($CDCl_3$, 100.6 MHz): δ = 147.1, 146.9 (7'), 145.8, 144.9 (1'), 135.9, 135.7 (4), 128.9, 128.5 (2'), 117.0, 116.8 (5), 112.6, 111.9 (8'), 75.3, 75.2 (1), 44.9 (3), 41.2 (6'), 39.1, 38.9 (2), 38.1, 37.7 (5'), 24.0, 23.9 (3'), 23.9, 23.2, 23.2, 22.5 (CH_3-6', CH_3-2), 18.3, 18.2 (4').

IR (film): ν = 3481, 3075, 2965, 2931, 2872, 2825, 1701, 1635, 1469, 966, 911 cm^{-1}.

MS (CI, NH_3): *m*/*z* = 252 (MNH_4^+), 234 (M^+), 217 (MH^+ - H_2O), 175, 151, 109.

Anal. calcd for $C_{16}H_{26}O$ (234.4): C, 82.00; H, 11.18. Found C, 81.91; H, 11.13.

[1*R(6*R**/*S**)]-3,3-Dimethyl-1-(6-methyl-6-vinylcyclohex-1-en-1-yl)hex-5-en-1-ol (13)**

To a solution of **7** (1.8 g, 4.3 mmol) in THF (15 mL) at -78 °C was added dropwise over 12 min a 1.7 M solution of *t*-BuLi in hexanes (5.6 mL, 9.5 mmol, 2.2 equiv). The resulting red solution was stirred at -78 °C for 30 min, during which time it turned dark red. Temperature was then quickly raised to 0 °C for 1 min causing intense bubbling and decoloration to light yellow, then set back down to -78 °C. A solution of 3,3-dimethylhex-5-enal (**12**; 600 mg, 4.75 mmol, 1.1 equiv) in THF (5 mL) was then added via cannula to the vinyl anion solution prepared above, and the resulting mixture was stirred at -78 °C for 30 min. The reaction mixture was then quenched at -78 °C by sat. aq NH_4Cl solution (5 mL) and allowed to warm to r.t. The layers were separated, the aqueous layer was extracted with Et_2O, and the combined organic layers were washed with H_2O and brine, dried ($MgSO_4$) and concentrated in vacuo. The resulting crude product was purified by flash chromatography on silica gel (Et_2O/petroleum ether, 10:90) yielding 770 mg (72%) of a 1:1 mixture of the two diastereomers of **13** as a colorless oil.

^{1}H NMR ($CDCl_3$, 400 MHz, *taxol numbering*): δ = 5.93 (t, 0.5 H, *J* = 3.8 Hz, 0.5 H-4), 5.89 (t, 0.5 H, *J* = 3.8 Hz, 0.5 H-4), 5.90-5.80 (m, 1.5 H, H-10 + 0.5 H-9), 5.71 (dd, 0.5 H, *J* = 17.6, 10.6 Hz, 0.5 H-9), 5.10-4.94 (m, 4 H, H_2-10' + H_2-9'), 4.20-4.14 (m, 1 H, H-2), 2.11-1.96 (m, 4 H), 1.58-1.25 (m, 6 H), 1.26, 1.11 (2 s, 3 H, CH_3-8), 0.97, 0.94, 0.90 (3 s, 6 H, 2 CH_3-15).

^{13}C NMR ($CDCl_3$, 100.6 MHz, *taxol numbering*): δ = 148.1 (3), 146.5 (9), 135.9 (10), 123.7, 123.6 (4), 116.7, 116.7 (10'), 112.9, 112.8 (9'), 68.1, 67.7 (2), 49.9, 49.4, 47.4, 47.3 (1, 11), 40.8 (8), 37.7, 37.6 (7), 33.5, 33.4 (15), 27.5 (CH_3-8), 25.4 (5), 24.9, 24.2 (CH_3-15), 18.3 (6).

IR (film): ν = 3478, 3075, 2930, 1636, 1466, 1365, 1049, 997, 911 cm^{-1}.

MS (CI, NH_3): *m*/*z* = 248, 231, 175, 149.

[1*R,2*R**(6*R**/*S**)]-2-Butyl-3,3-dimethyl-1-(6-methyl-6-vinylcyclohex-1-en-1-yl)hex-5-ene-1,2-diol (14)**

To a solution of **7** (1.1 g, 2.6 mmol) in THF (10 mL) at -78 °C was added dropwise over 10 min a 1.7 M solution of *t*-BuLi in hexanes (3.4 mL, 5.8 mmol, 2.2 equiv). The resulting red solution was stirred at -78 °C for 30 min, during which time it turned dark red. Temperature was then quickly raised to 0 °C for 1 min causing intense bubbling and decoloration to light yellow, then set back down to -78 °C. A solution of aldehyde **10** (780 mg, 2.9 mmol, 1.1 equiv) in THF (4 mL) was then added via cannula to the vinyl anion solution prepared above, and the resulting mixture was stirred at -78 °C for 30 min. The reaction mixture was then quenched at -78 °C by sat. aq $NaHCO_3$ solution (5 mL) and allowed to warm to r.t. The layers were separated, the aqueous layer was extracted with Et_2O, and the combined organic layers were washed with H_2O and brine, dried ($MgSO_4$) and concentrated in vacuo. The resulting crude product was diluted with CH_2Cl_2 (20 mL) and treated with trifluoroacetic acid (20 drops). The solution turned yellow and was stirred at r.t. for 5 min, after which time it was concentrated in vacuo. The resulting crude product was purified by flash chromatography on silica gel (Et_2O/petroleum Ether, 10:90) to give 680 mg (81%) of a 1:1 mixture of the two diastereomers of **14** as a colorless oil.

^{1}H NMR ($CDCl_3$, 400 MHz, *taxol numbering*): δ = 6.33 (t, 0.5 H, *J* = 3.8 Hz, 0.5 H-4), 6.29 (t, 0.5 H, *J* = 3.6 Hz, 0.5 H-4), 5.92-5.84 (m, 1.5 H, H-10 + 0.5 H-9), 5.80 (dd, 0.5 H, *J* = 17.6, 10.5 Hz, 0.5 H-9), 5.14-5.00 (m, 4 H, H_2-9' + H_2-10'), 4.09 (d, 0.5 H, *J* = 10.5 Hz, 0.5 H-2), 4.08 (d, 0.5 H, *J* = 10.0 Hz, 0.5 H-2), 3.07 (s, 0.5 H, 0.5 OH), 2.98 (s, 0.5 H, 0.5 OH), 2.18-2.14 (m, 2 H), 2.09-2.05 (m, 2 H), 1.70-1.49 (m, 6 H), 1.43-1.25 (m, 4 H), 1.27, 1.16 (2 s, 3 H, CH_3-8), 0.92, 0.91, 0.90, 0.89 (4 s, 6 H, 2 CH_3-15), 0.87-0.85 (m, 3 H, CH_2CH_3).

^{13}C NMR ($CDCl_3$, 100.6 MHz, *taxol numbering*): δ = 146.6, 146.3 (9), 145.6 (3), 136.9, 136.7 (10), 128.1, 127.3 (4), 116.6, 116.5 (10'), 112.8 (9'), 78.7, 78.4 (1), 70.5, 70.4 (2), 43.8, 43.7, 41.3, 41.0 (8, 15), 42.2, 42.1, 37.8, 37.3 (7, 11), 33.4, 33.1 (CH_2), 27.1, 27.0, 25.6, 25.4, 23.7 (3C, CH_2), 24.4, 24.1, 22.9, 22.6, 22.5 (4C, CH_3), 18.3, 18.2 (6), 14.1 (CH_2CH_3).

IR (film): ν = 3510, 3075, 2961, 1636, 1456, 1375, 1004, 911, 726 cm^{-1}.

MS (CI, NH_3): *m*/*z* 338 (MNH_4^+), 321 (MH^+), 303, 285, 221, 203.

[1*R(6*R**/*S**)]-[2,2-Dimethyl-1-(6-methyl-6-vinylcyclohex-1-en-1-yl)pent-4-en-1-oxy]triethylsilane (15)**

To a solution of alcohol **11** (100 mg, 430 μmol) in CH_2Cl_2 (2 mL) was added imidazole (87 mg, 1.28 mmol, 3 equiv), chlorotriethylsilane (110 μL, 640 μmol, 1.5 eq) and a catalytic pinch of 4-dimethylaminopyridine. After stirring at 25 °C for 3 h, additional imidazole (29 mg, 430 μmol, 1.0 equiv) and chlorotriethylsilane (37 μL, 210 μmol, 0.5 equiv) were added, and the reaction mixture was stirred 6 h at 25 °C, and then MeOH (1 mL) was added. After 10 min, the mixture was quenched with sat. aq NH_4Cl solution (5 mL) and diluted with 50 ml of Et_2O. The layers were separated, and the organic layer was washed with H_2O (2 × 5 mL) and brine (5 mL), dried ($MgSO_4$) and concentrated in vacuo. The resulting crude product was purified by flash chromatography on silica gel

(Et_2O/petroleum ether, 1:99) to give 146 mg (96%) of a 1:1 mixture of the two diastereomers of **15** as a colorless oil.

^{1}H NMR ($CDCl_3$, 400 MHz): δ = 6.02-5.76 (m, 3 H, H-4 + H-2' + H-7'), 5.08-4.93 (m, 4 H, H_2-5 + H_2-8'), 3.86 (s, 0.5 H, 0.5 H-1), 3.80 (s, 0.5 H, 0.5 H-1), 2.19-1.97 (m, 4 H), 1.73-1.43 (m, 4 H), 1.25, 1.14 (2 s, 3 H, CH_3-6'), 0.96-0.92 (m, 9 H, 3 C*H*$_3$CH$_2$Si), 0.85, 0.82, 0.80, 0.77 (4 s, 6 H, 2 CH_3-2), 0.60-0.50 (m, 6 H, 3 CH_2Si).

^{13}C NMR ($CDCl_3$, 100.6 MHz): δ = 148.4, 147.8 (7'), 143.3, 143.1 (1'), 136.4, 136.3 (4), 128.5, 127.6 (2'), 116.5, 116.3 (5), 111.8, 110.8 (8'), 76.1 (1), 43.9, 43.8 (3), 40.4, 40.1, 39.8, 39.3 (2, 6'), 39.0 (5'), 25.7, 25.1 (3'), 25.0, 24.7, 24.3, 24.1, 23.2 (CH_3), 18.4, 18.1 (4'), 7.1, 6.8 (*C*H$_3$CH$_2$Si), 6.3, 5.6 (CH_2Si).

IR (film): ν = 3076, 2955, 2876, 1637, 1458, 1237, 1069, 1007, 910, 839, 739 cm^{-1}.

MS (CI, NH_3): *m*/*z* = 265, 234 (MNH_4^+ − TESOH), 217 (MH^+ − TESOH), 175.

[1*R(6*R**/*S**)]-[3,3-Dimethyl-1-(6-methyl-6-vinylcyclohex-1-en-1-yl)hex-5-en-1-oxy]triethylsilane (18)**

To a solution of **13** (770 mg, 3.1 mmol) in anhyd CH_2Cl_2 (10 mL) was added imidazole (880 mg, 12.9 mmol, 4.1 equiv) and chlorotriethylsilane (1.0 mL, 6.0 mmol, 1.9 equiv). The resulting mixture was stirred at r.t. for 4 h, and quenched with MeOH (1 mL). The organic layer was diluted with Et_2O (50 mL) and treated with sat. NH_4Cl solution (5 mL). The layers were separated, and the organic layer was washed successively with H_2O (5 mL) and brine (5 mL), dried ($MgSO_4$) and concentrated in vacuo. Purification by flash chromatography on silica gel (Et_2O/petroleum ether, 2:98) yielded 1.1 g (98%) of a 1:1 mixture of the two diastereomers of **18** as a colorless oil.

^{1}H NMR ($CDCl_3$, 400 MHz, *taxol numbering*): δ = 5.98 (dd, 1 H, *J* = 17.6, 10.6 Hz, H-9), 5.86-5.78 (m, 2 H, H-4 + H-10), 5.79 (dd, 1 H, *J* = 17.6, 10.6 Hz, H-9), 5.08-4.94 (m, 4 H, H_2-9' + H_2-10'), 4.23 (br d, 1 H, *J* = 9.4 Hz, H-2), 2.05-1.88 (m, 4 H), 1.65-1.20 (m, 6 H), 1.24 (s, 1.5 H, 0.5 CH_3-8), 1.11 (s, 1.5 H, 0.5 CH_3-8), 0.97-0.90 (m, 12 H, 3 C*H*$_3$CH$_2$Si + CH_3-15), 0.84 (s, 3 H, CH_3-15), 0.62-0.56 (m, 6 H, 3 CH_2-Si).

^{13}C NMR ($CDCl_3$, 100.6 MHz, *taxol numbering*): δ = 147.3, 146.8 (9), 146.5 (3), 136.4, 136.2 (10), 123.6, 123.0 (4), 116.3, 116.2 (10'), 111.6, 111.5 (9'), 68.7, 68.6 (2), 52.6, 51.5, 47.6, 47.5 (1, 11), 39.8, 39.6 (8), 38.6, 38.2 (7), 33.6, 33.6 (15), 27.5, 27.3 (CH_3), 25.3, 25.1 (CH_2), 25.1, 23.8 (CH_3), 18.6, 18.4 (6), 7.1 (*C*H$_3$CH$_2$Si), 5.4, 5.1 (CH_2Si).

IR (film): ν = 3065, 2951, 2922, 2876, 1633, 1457, 1411, 1110, 1082, 987, 868, 734 cm^{-1}.

MS (CI, NH_3): *m*/*z* = 333, 321, 291, 265, 231, 149.

[1*R,2*R**(6*R**/*S**)]-[2-Butyl-3,3-dimethyl-1-(6-methyl-6-vinylcyclohex-1-en-1-yl)hex-5-en-2-ol-1-oxy]triethylsilane (20)**

To a solution of **14** (135 mg, 0.42 mmol) in anhyd CH_2Cl_2 (3 mL) at -78 °C was added 2,6-lutidine (75 μL, 0.63 mmol, 1.5 equiv) and triethylsilyl trifluoromethanesulfonate (115 μL, 0.50 mmol, 1.2 equiv). The resulting mixture was stirred at -78 °C for 2 h, quenched with MeOH (1 mL) and allowed to warm up to r.t. The organic layer was diluted with Et_2O (50 mL) and treated with sat. aq NH_4Cl solution (5 mL). The layers were separated, and the organic layer was washed successively with H_2O (5 mL) and brine (5 mL), dried ($MgSO_4$) and concentrated in vacuo. Purification by flash chromatography on silica gel (Et_2O/petroleum ether, 2:98) yielded 160 mg (88%) of a 1:1 mixture of the two diastereomers of **20** as a colorless oil.

^{1}H NMR ($CDCl_3$, 400 MHz, *taxol numbering*): δ = 6.04-5.93 (m, 2 H, H-4 + H-9), 5.87-5.79 (m, 1 H, H-10), 5.14-4.96 (m, 4 H, H_2-9' + H_2-10'), 4.34 (s, 0.5 H, 0.5 H-2), 4.26 (s, 0.5 H, 0.5 H-2), 3.98 (br s, 0.5 H, 0.5 OH), 3.70 (br s, 0.5 H, 0.5 OH), 2.17-2.02 (m, 4 H), 1.70-1.18 (m, 10 H), 1.29, 1.16 (2 s, 3 H, CH_3-8), 0.97-0.85 (m, 9 H, 3 C*H*$_3$CH$_2$Si), 0.83 (s, 6 H, 2 CH_3-15), 0.68-0.60 (m, 9 H, 3 CH_2Si + CH_2CH_3).

^{13}C NMR ($CDCl_3$, 100.6 MHz, *taxol numbering*): δ = 147.2, 146.8 (9), 142.2, 141.6 (3), 136.7, 136.6 (10), 129.3, 128.4 (4), 116.5, 116.4 (10'), 112.6, 112.2 (9'), 78.7, 78.2 (1), 71.3, 71.1 (2), 43.7, 43.5 (15), 41.6, 41.3 (11), 40.7, 40.1 (8), 38.5, 37.6 (7), 33.0, 32.5 (CH_2), 30.2, 25.0, 24.2, 22.5, 22.4, 22.1, 22.0 (CH_3), 27.4, 27.3, 25.5, 25.0, 23.8 (CH_2), 18.4, 18.1 (6), 14.3 (CH_2*C*H$_3$), 7.1 (*C*H$_3$CH$_2$Si), 5.8, 5.8 (CH_2Si).

IR (film): ν = 3498, 3074, 2956, 2875, 1634, 1455, 1372, 1239, 1059, 1005, 911, 740 cm^{-1}.

MS (CI, NH_3): *m*/*z* = 435 (MH^+), 417, 392, 321, 303, 285, 221, 203.

Anal. calcd for $C_{27}H_{50}O_2Si$ (434.8): C, 74.59; H, 11.59. Found C, 74.59; H, 11.71.

[1*R,2*R**(6*R**/*S**)]-[2-Butyl-3,3-dimethyl-1-(6-methyl-6-vinylcyclohex-1-en-1-yl)hex-5-en-1,2-dioxy]di-*tert*-butylsilylene (21)**

To a solution of **14** (45 mg, 125 μmol) in THF (1 mL) was added at 0 °C a 1.5 M BuLi solution in hexanes (95 μL, 125 μmol, 1.0 equiv) and the solution was stirred for 15 min. Then di-*tert*-butylchlorosilane (31 μL, 150 μmol, 1.1 equiv) was added, and the reaction mixture was stirred at r.t. for 5 h. It was then diluted with Et_2O (50 mL) and treated with sat. aq NH_4Cl solution (5 mL). The layers were separated, and the organic layer was washed successively with H_2O (5 mL) and brine (5 mL), dried ($MgSO_4$) and concentrated in vacuo. Purification by flash chromatography on silica gel (Et_2O/petroleum ether, 3:97) yielded 51 mg (84%) of a 1:1 mixture of the two diastereomers of **21** as a colorless oil.

^{1}H NMR ($CDCl_3$, 400 MHz, *taxol numbering*): δ = 6.19 (t, 0.5 H, *J* = 3.9 Hz, 0.5 H-4), 6.16 (t, 0.5 H, *J* = 3.8 Hz, 0.5 H-4), 6.05 (dd, 0.5 H, *J* = 17.6, 10.5 Hz, 0.5 H-9), 6.02 (dd, 0.5 H, *J* = 17.6, 10.6 Hz, 0.5 H-9), 5.89-5.80 (m, 1 H, H-10), 5.08-4.97 (m, 4 H, H_2-9' + H_2-10'), 4.54 (s, 0.5 H, 0.5 H-2), 4.51 (s, 0.5 H, 0.5 H-2), 2.37-2.12 (m, 3 H), 1.96-1.71 (m, 2 H), 1.66-1.49 (m, 6 H), 1.46-1.10 (m, 3 H), 1.33, 1.30 (2 s, 3 H, CH_3-8), 1.06, 1.01, 0.99, 0.97 (4 s, 6 H, 2 CH_3-15), 1.10, 1.10, 1.08 [3 s, 18 H, 2 $(CH_3)_3$CSi], 0.92 (t, 3 H, *J* = 6.8 Hz, CH_2C*H*$_3$).

^{13}C NMR ($CDCl_3$, 100.6 MHz, *taxol numbering*): δ = 148.2, 148.0 (9), 142.2, 142.1 (3), 136.5, 136.3 (10), 130.0, 128.9 (4), 116.7, 116.6 (10'), 111.9, 111.3 (9'), 88.7, 88.3 (1), 78.9, 77.7 (2), 43.1, 43.0 (11), 41.9, 41.7, 41.5 (8, 15), 39.7, 39.5 (7), 35.4 (CH_2), 28.9, 28.3 ((*C*H$_3$)$_3$CSi), 28.7, 28.7, 26.4, 26.2, 23.9 (CH_2), 25.2, 25.1, 24.7 (CH_3), 22.0, 21.9, 20.5 (C-Si), 18.1, 18.0 (6), 14.4 (CH_2*C*H$_3$).

IR (film): ν = 3076, 2934, 2860, 1824, 1635, 1478, 1387, 1364, 1110, 969, 911, 862, 735, 640 cm^{-1}.

MS (CI, NH_3): *m*/*z* = 461, 418, 403, 379, 309, 285, 203.

[1*R,2*R**(6*R**/*S**)]-2-Butyl-3,3-dimethyl-1,2-*O*-isopropylidene-1-(6-methyl-6-vinylcyclohex-1-en-1-yl)hex-5-ene (22)**

To a solution of **14** (200 mg, 0.58 mmol) in 2,2-dimethoxypropane (2 mL) was added a pinch of CSA, and the resulting mixture was stirred at 25 °C for 48 h. It was then diluted with Et_2O (50 mL) and treated with sat. aq $NaHCO_3$ solution (5 mL). The layers were separated, and the organic layer was washed successively with H_2O (5 mL) and brine (5 mL), dried ($MgSO_4$) and concentrated in vacuo. Purification by flash chromatography on silica gel (Et_2O/petroleum ether, 1:99) yielded 207 mg (92%) of a 1:1 mixture of the two diastereomers of **22** as a colorless oil.

^{1}H NMR ($CDCl_3$, 200 MHz, *taxol numbering*): δ = 6.20 (q, 1 H, *J* = 4.1 Hz, H-4), 5.97 (dd, 1 H, *J* = 17.3, 10.6 Hz, H-9), 5.86-5.76 (m, 1 H, H-10), 5.14-4.94 (m, 4 H, H_2-9' + H_2-10'), 4.35 (s, 0.5 H, 0.5 H-2), 4.33 (s, 0.5 H, 0.5 H-2), 2.23-2.12 (m, 4 H), 1.91-1.78 (m,

2 H), 1.72-1.54 (m, 4 H), 1.50-1.25 (m, 4 H), 1.45, 1.44, 1.34, 1.29, 1.27, 1.25, 0.96, 0.96 [8 s, 15 H, CH_3-8 + 2 CH_3-15 + $(CH_3)_2C$], 0.93-0.88 (m, 3 H, CH_2CH_3).

^{13}C NMR ($CDCl_3$, 50.3 MHz, *taxol numbering*): δ = 147.7, 147.5 (9), 138.2 (3), 136.2, 136.1 (10), 129.8, 129.6 (4), 116.7, 116.6 (10'), 112.2, 111.0 (9'), 104.4, 104.3 [$OC(CH_3)_2O$], 89.4, 89.3 (1), 77.4, 77.2 (2), 43.0, 43.0 (11), 42.0, 41.9 (15), 40.3, 40.1 (8), 39.0, 28.7 (7), 33.5, 33.4, 28.3, 26.2, 26.1, 23.9 (CH_2), 29.4, 28.1, 26.5, 26.3, 24.2, 24.0, 23.9, 23.8 (CH_3), 18.1, 18.0 (6), 14.0, 13.9 (CH_2CH_3).

IR (film): ν = 3077, 2960, 1636, 1455, 1367, 1247, 1215, 1173, 1016, 910 cm^{-1}.

MS (CI, NH_3): *m*/*z* = 303, 285, 245, 221, 177.

[1*R,2*R**(6*R**/*S**)]-2-Butyl-1,2-carbonyldioxy-3,3-dimethyl-1-(6-methyl-6-vinylcyclohex-1-en-1-yl)hex-5-ene (23)**

To a solution of **14** (250 mg, 780 μmol) in anhyd DMF (2 mL) was added portionwise NaH (80% in oil, 49 mg, 1.6 mmol, 2.1 equiv). The resulting suspension was vigorously stirred at r.t. for 15 min, and then carbonyldiimidazole (630 mg, 3.9 mmol, 5.0 equiv) was added. The resulting mixture was stirred at r.t. for 3 h, then diluted with Et_2O (50 mL) and quenched with sat. aq NH_4Cl solution (5 mL). The layers were separated, and the organic layer was washed successively with water (3 × 10 mL) and brine (10 mL), dried ($MgSO_4$) and then concentrated in vacuo. The resulting crude product was purified by flash chromatography on silica gel (Et_2O/petroleum ether, 10:90) to yield 245 mg (91%) of a 1:1 mixture of the two diastereomers of **23** as a pale yellow solid.

^{1}H NMR ($CDCl_3$, 400 MHz, *taxol numbering*): δ = 5.95 (t, 0.5 H, *J* = 3.9 Hz, 0.5 H-4), 5.87 (t, 0.5 H, *J* = 3.9 Hz, 0.5 H-4), 5.81-5.67 (m, 2 H, H-9 + H-10), 5.19-5.04 (m, 4 H, H_2-9' + H_2-10'), 4.88 (s, 0.5 H, 0.5 H-2), 4.83 (s, 0.5 H, 0.5 H-2), 2.37-2.05 (m, 4 H), 1.86-1.11 (m, 10 H), 1.26, 1.13 (2 s, 3 H, CH_3-8), 0.93, 0.93, 0.91 (3 s, 6 H, 2 CH_3-15), 0.88 (t, 3 H, *J* = 6.5 Hz, CH_2CH_3).

^{13}C NMR ($CDCl_3$, 100.6 MHz, *taxol numbering*): δ = 155.6 (C=O), 145.5, 145.0 (9), 138.7, 137.4 (3), 133.8, 133.6 (10), 131.6, 131.2 (4), 118.6, 118.4 (10'), 114.7, 114.3 (9'), 92.0, 91.9 (1), 80.1, 79.3 (2), 43.7, 43.6, 41.1, 40.5 (8, 15), 40.0, 39.8, 37.8, 37.1 (7, 11), 30.7, 30.3, 27.2, 27.0, 25.5, 25.2, 23.1 (4C, CH_2), 24.6, 23.3, 20.9, 20.8, 20.6 (3C, CH_3), 17.9, 17.8 (6), 13.8 (CH_2CH_3).

IR (film): ν = 3078, 2960, 2872, 1799, 1637, 1466, 1323, 1197, 1044, 916, 770 cm^{-1}.

MS (CI, NH_3): *m*/*z* = 364 (MNH_4^+), 347 (MH^+), 303, 285, 219, 203.

Anal. calcd for $C_{22}H_{34}O_3$: C, 76.26; H, 9.89. Found C, 76.42; H, 9.91.

Metathesis Reactions with Grubbs' Catalyst; General Procedure

To a refluxing solution of the diene in dry degassed benzene or 1,2-dichloroethane (0.02M) was added 2 mol% of Grubbs' catalyst, and the resulting mixture was refluxed under argon for 8 d, during which time 1 mol% of catalyst was added every 24 h to the refluxing mixture. The reaction mixture was cooled to r.t., concentrated in vacuo and purified by flash chromatography on silica gel.

Metathesis Reactions with Schrock's Catalyst; General Procedure

To a refluxing solution of the diene (dried azeotropically with 3 mL of anhyd benzene) in anhyd degassed benzene (0.02 M solution) was added 5 mol% of Schrock's catalyst (weighed as quickly as possible under argon), and the resulting mixture was refluxed under argon for 3 d, during which time 5 mol% of catalyst was added every 24 h to the refluxing mixture. The reaction mixture was cooled to r.t., concentrated in vacuo and purified by flash chromatography on silica gel.

Metathesis Reactions with Nolan's Catalyst

To a refluxing solution of the diene in dry degassed benzene or 1,2-dichloroethane (0.02 M solution) was added 5 mol% of Nolan's catalyst, and the resulting mixture was refluxed under argon for 12 h. The reaction mixture was cooled to r.t., concentrated in vacuo and purified by flash chromatography on silica gel.

(5*R,9a*S**,8*Z*)-6,6,9a-Trimethyl-1,2,3,5,6,7,9a-octahydro-1*H*-benzocyclohepten-5-ol (β-16) and (5*R**,9a*R**,8*Z*)-6,6,9a-Trimethyl-1,2,3,5,6,7,9a-octaahydro-1*H*-benzocyclohepten-5-ol (α-16)**

A solution of **11** (35 mg, 150 μmol) and Grubbs' catalyst (6.1 mg, 5 mol%) in anhyd benzene (5 mL) was stirred at 60 °C for 24 h under argon. More catalyst (3 mg, 2.5 mol%) was added more and the reaction mixture was further stirred at 60 °C for 24 h. The resulting mixture was cooled to r.t. and concentrated in vacuo. Purification by flash chromatography (Et_2O/petroleum ether, 5:95) yielded 6 mg (19%) and then 10 mg (32%) of the two separated diastereomers of **16** as colorless oils.

First Isomer

^{1}H NMR ($CDCl_3$, 400 MHz): δ = 5.54 (ddd, 1 H, *J* = 11.4, 7.3, 5.8 Hz, H-8), 5.47-5.43 (m, 2 H, H-5 + H-9), 3.83 (d, 1 H, *J* = 6.3 Hz, H-5), 2.13-2.04 (m, 2 H), 1.93 (dd, 1 H, *J* = 14.8, 7.3 Hz, H-7), 1.84 (d, 1 H, *J* = 6.8 Hz), 1.73-1.57 (m, 4 H), 1.48-1.43 (m, 1 H), 1.32 (s, 3 H, CH_3-9a), 1.06, 0.84 (2 s, 6 H, 2 CH_3-6).

^{13}C NMR ($CDCl_3$, 100.6 MHz): δ = 141.9 (4a), 140.9 (9), 125.6, 125.2 (4, 8), 87.8 (5), 39.0 (6), 38.7, 35.5 (1, 7), 29.8, 27.7, 26.9 (CH_3), 29.6 (9a), 24.9, 18.1 (2, 3).

IR (film): ν = 3474, 2925, 1457, 1364, 1042, 994, 794 cm^{-1}.

MS (CI, NH_3): *m*/*z* = 206 (MH^+), 189, 173, 147.

Anal. calcd for $C_{14}H_{22}O$: C, 81.50; H, 10.75. Found C, 81.31; H, 10.77.

Second Isomer

^{1}H NMR ($CDCl_3$, 400 MHz): δ = 5.67 (t, 1 H, *J* = 3.6 Hz, H-4), 5.42 (ddd, 1 H, *J* = 10.6, 7.9, 6.3 Hz, H-8), 5.28 (dd, 1 H, *J* = 10.6, 1.8 Hz, H-9), 4.10 (s, 1 H, H-5), 2.14-2.07 (m, 3 H), 1.75-1.50 (m, 5 H), 1.32-1.29 (m, 1 H), 1.17, 1.08, 0.84 (3 s, 9 H, 3 CH_3).

^{13}C NMR ($CDCl_3$, 100.6 MHz): δ = 145.5 (4a), 140.1 (9), 122.3, 118.4, (4, 8), 76.3 (5), 39.9 (6), 38.0, 35.8 (1, 7), 29.6 (9a), 27.7, 26.8, 20.7 (CH_3), 24.5 (3), 18.3 (4).

IR (film): ν = 3454, 2926, 1455, 1362, 1037, 737, 662 cm^{-1}.

MS (CI, NH_3): *m*/*z* = 207 (MH^+), 206, 189, 173, 147, 121.

Anal. calcd for $C_{14}H_{22}O$: C, 81.50; H, 10.75. Found C, 81.91; H, 10.91.

(5*R,9a*R**/*S**,8*Z*)-[6,6,9a-Trimethyl-1,2,3,5,6,7,9a-octahydro-1*H*-benzocyclohepten-5-oxy]triethylsilane (17)**

A solution of **15** (100 mg, 285 μmol) in anhyd benzene (10 mL) with Grubbs' catalyst (11.7 mg, 5 mol%) was stirred at 60 °C for 24 h under argon. More catalyst (5.8 mg, 2.5 mol%) was added and the reaction mixture was further stirred at 60 °C for 24 h. The resulting mixture was cooled to r.t. and concentrated in vacuo. Purification by flash chromatography (petroleum ether) yielded 85 mg (93%) the two diastereomers of **17** as a colorless oil.

^{1}H NMR ($CDCl_3$, 400 MHz): δ = 5.65 (t, 0.5 H, *J* = 3.8 Hz, 0.5 H-4), 5.45-5.34 (m, 2 H, 0.5 H-4 + H-8 + 0.5 H-9), 5.26 (dd, 0.5 H, *J* = 10.7, 1.9 Hz, 0.5 H-9), 4.01 (d, 0.5 H, *J* = 1.1 Hz, 0.5 H-5), 3.80

(s, 0.5 H, 0.5 H-5), 2.66 (dt, 0.5 H, *J* = 15.5, 2.6 Hz, 0.5 H-7), 2.11-1.96 (m, 2.5 H), 1.74-1.47 (m, 5 H), 1.29 (s, 1.5 H, 0.5 CH_3), 1.16 (s, 1.5 H, 0.5 CH_3), 0.99-0.93 (m, 9 H, CH_3 + 3 C*H*$_3$$CH_2$Si), 0.78, 0.75 (2 s, 3 H, CH_3), 0.62-0.49 (m, 6 H, 3 CH_2Si).

^{13}C NMR ($CDCl_3$, 100.6 MHz): δ = 143.7, 140.3 (4a), 140.6, 140.1 (9), 126.7, 125.4, 122.7, 119.4 (4, 8), 90.0, 76.3 (5), 41.7, 37.6, 36.0, 34.9 (1, 7), 41.0, 39.3, 39.2, 37.0 (6, 9a), 29.7, 28.5, 28.0, 25.4, 21.4 (CH_3-6 + CH_3-9a), 25.9, 24.4 (3), 19.0, 18.4 (8), 7.1, 7.0 (*C*$H_3$$CH_2$Si), 6.3, 5.0 ($CH_2$Si).

IR (film): ν = 2954, 1654, 1457, 1238, 1066, 1004, 841, 740 cm^{-1}.

MS (CI, NH_3): *m*/*z* = 320 (M^+), 291, 264, 189.

(5*R,10a*S**,9*Z*)-7,7,10a-Trimethyl-1,2,3,5,6,7,8,10a-octahydro-1*H*-benzocycloocten-5-ol (β-19)**

After the usual procedure with Grubbs' catalyst was applied to **18** (75 mg, 0.21 mmol, 11 mL of benzene, 3.4 + 6 × - 1.7 mg of catalyst), the resulting crude product was dissolved in THF (1.5 mL), and TBAF (100 mg, 0.32 mmol, 1.5 equiv) was added. The reaction mixture was stirred for 3 h at 50 °C, cooled to r.t., diluted with Et_2O (50 mL) and treated with sat. aq NH_4Cl solution (5 mL). The layers were separated, and the organic layer was washed successively with H_2O (5 mL) and brine (5 mL), dried ($MgSO_4$) and concentrated in vacuo. The resulting crude mixture was purified by flash chromatography on silica gel (Et_2O/petroleum ether, 10:90) yielding 5 mg (11%) of β-**19** as a colorless oil.

^{1}H NMR ($CDCl_3$, 400 MHz, *taxol numbering*): δ = 5.89 (t, 1 H, *J* = 3.7 Hz, H-4), 5.35 (dt, 1 H, *J* = 11.7, 8.7 Hz, H-10), 5.29 (d, 1 H, *J* = 11.7 Hz, H-9), 4.40 (br d, 1 H, *J* = 7.1 Hz, H-2), 2.69 (dd, 1 H, *J* = 13.5, 8.7 Hz, H-11), 2.12−2.04 (m, 2 H), 1.80 (dd, 1 H, *J* = 13.3, 2.7 Hz), 1.76−1.56 (m, 5 H), 1.48−1.40 (m, 1 H), 1.17 (s, 3 H, CH_3-8), 0.98, 0.92 (2 s, 6 H, 2 CH_3-15).

^{13}C NMR ($CDCl_3$, 100.6 MHz, *taxol numbering*): δ = 150.4 (3), 140.2 (9), 125.7 (10), 121.8 (4), 69.0 (2), 50.9 (1), 39.8 (8), 38.2, 35.7 (7,11), 33.4 (15), 32.9, 28.4, 27.3 (CH_3), 25.6 (5), 18.8 (6).

IR (film): ν = 3419, 2925, 1456, 1363, 1261, 1176, 1031, 972, 813, 717 cm^{-1}.

(5*R,10a*R**/*S**,9*Z*)-7,7,10a-Trimethyl-1,2,3,5,6,7,8,10a-octahydro-1*H*-benzocycloocten-5-ol (19)**

1. After the usual procedure with Nolan's catalyst was applied to **18** (50 mg, 0.14 mmol, 7 mL of 1,2-dichloroethane, 5.8 mg of catalyst), the resulting crude product was dissolved in THF (1 mL), and TBAF (55 mg, 0.20 mmol, 1.5 equiv) was added. The reaction mixture was stirred for 3 h at 50 °C, cooled to r.t., diluted with Et_2O (50 mL) and treated with sat. aq NH_4Cl solution (5 mL). The layers were separated, and the organic layer was washed successively with H_2O (5 mL) and brine (5 mL), dried ($MgSO_4$) and concentrated in vacuo. The resulting crude mixture was purified by flash chromatography on silica gel (Et_2O/petroleum ether, 10:90) yielding 30 mg (90%) of a 1:1 mixture of the two diastereomers of **19** as a colorless oil.

2. After the usual procedure with Schrock's catalyst was applied to **18** (60 mg, 0.16 mmol, 8 mL of benzene, 3 × 4 mg of catalyst), the resulting crude product was dissolved in THF (1 mL), and TBAF (67 mg, 0.25 mmol, 1.5 equiv) was added. The reaction mixture was stirred for 3 h at 50 °C, cooled to r.t., diluted with Et_2O (50 mL) and treated with sat. aq NH_4Cl solution (5 mL). The layers were separated, and the organic layer was washed successively with H_2O (5 mL) and brine (5 mL), dried ($MgSO_4$) and concentrated in vacuo. The resulting crude mixture was purified by flash chromatography on silica gel (Et_2O/petroleum ether, 10:90) yielding 31 mg (85%) of a 1:1 mixture of the two diastereomers of **19** as a colorless oil.

^{1}H NMR ($CDCl_3$, 400 MHz, *taxol numbering, italicized values correspond to the* β-**19** *isomer*): δ = *5.88* (t, 0.5 H, *J* = 3.9 Hz, 0.5 H-4), 5.81 (t, 0.5 H, *J* = 3.8 Hz, 0.5 H-4), 5.45 (dt, 0.5 H, *J* = 11.8, 8.8 Hz, 0.5 H-10), *5.34* (ddd, 0.5 H, *J* = 11.7, 8.6, 8.0 Hz, 0.5 H-10), *5.27* (d, 0.5 H, *J* = 11.7 Hz, 0.5 H-9), 5.21 (dd, 0.5 H, *J* = 11.8, 0.5 Hz, 0.5 H-9), *4.39-4.36* (m, 0.5 H, 0.5 H-2), 4.35 (dd, 0.5 H, *J* = 12.3, 3.5 Hz, 0.5 H-2), *2.76* (dd, 0.5 H, *J* = 13.0, 8.6 Hz, 0.5 H-11), 2.66 (dd, 0.5 H, *J* = 13.5, 8.8 Hz, 0.5 H-11), *2.12-2.02* (m, 2 H), *1.72* (dd, 0.5 H, *J* = 13.5, 2.9 Hz), *1.69-1.18* (m, 7.5 H), 1.32 (s, 1.5 H, 0.5 CH_3-8), *1.16* (s, 1.5 H, 0.5 CH_3-8), *0.96* (s, 3 H, CH_3), *0.90*, 0.84 (2 s, 3 H, CH_3).

^{13}C NMR ($CDCl_3$, 100.6 MHz, *taxol numbering, italicized values correspond to the* β-**19** *isomer*): δ = *150.3*, 145.2 (3), 141.5, *140.2* (9), 131.2, *125.6*, 124.2, *121.8* (4, 10), 78.5, *68.9* (2), *50.8*, 43.3 (1), *40.6*, *38.1*, *35.6*, 35.2 (7, 11), *39.9* (8), 33.4, *33.1* (15), *32.9*, 30.0, 29.8, *28.3*, 28.0, *27.3* (CH_3), 27.3, *25.6* (5), 19.0, *18.8* (6).

IR (film): ν = 3383, 2928, 1647, 1456, 1363, 1173, 1033, 975, 719 cm^{-1}.

MS (CI, NH_3): *m*/*z* = 221 (MH^+), 220 (M^+), 203, 187.

(5*R,6*R**,10a*R**,9*Z*)-6-Butyl-7,7,10a-trimethyl1,2,3,5,6,7,8,10a-octahydro-1*H*-benzocyclooctene-5,6-diol (β-24) and (5*R**, 6*R**, 10a*R**,8*Z*)-6-Butyl-7,7,10a-trimethyl-1,2,3,5,6,7,10,10a-octahydro-2*H*-benzocyclooctene-5,6-diol (25)**

After the usual procedure with Grubbs' catalyst was applied to **20** (87 mg, 0.20 mmol, 10 mL of benzene, 16.3 mg of catalyst), the resulting crude product was dissolved in THF (2 mL), and TBAF (95 mg, 0.30 mmol, 1.5 equiv) was added. The reaction mixture was stirred for 5 h at 25 °C, diluted with Et_2O (50 mL) and treated with sat. aq NH_4Cl solution (5 mL). The layers were separated, and the organic layer was washed successively with H_2O (5 mL) and brine (5 mL), dried ($MgSO_4$) and concentrated in vacuo. The resulting crude mixture was purified by flash chromatography on silica gel (Et_2O/petroleum ether, 10:90 to 20:80) yielding 3.5 mg (6%) of β-**24** and then 4 mg (7%) of **25** as a white solid.

β-24

^{1}H NMR ($CDCl_3$, 400 MHz, *taxol numbering*): δ = 6.07 (t, 1 H, *J* = 4.1 Hz, H-4), 5.57 (br q, 1 H, *J* = 11.0 Hz, H-10), 5.26 (d, 1 H, *J* = 11.0 Hz, H-9), 4.43 (s, 1 H, H-2), 3.08-2.94 (m, 2 H, H-11 + OH), 2.16-2.12 (m, 2 H), 1.99-1.87 (m, 2 H), 1.57-1.50 (m, 6 H), 1.45-1.29 (m, 3 H), 1.23 (s, 3 H, CH_3-8), 1.02, 0.99 (2 s, 6 H, 2 CH_3-15), 0.94 (t, 3 H, *J* = 7.1 Hz, CH_2C*H*$_3$).

^{13}C NMR ($CDCl_3$, 100.6 MHz, *taxol numbering*): δ = 145.5 (3), 140.2 (9), 126.4, 124.3 (4, 10), 80.4 (1), 73.8 (2), 44.0 (15), 41.0 (8), 38.8 (11), 34.5, 31.8, 27.0, 26.0, 23.9 (CH_2), 29.0, 28.2, 23.6 (CH_3), 18.4 (6), 14.2 (CH_2*C*H_3).

IR (film): ν = 3481, 2929, 1654, 1636, 1457, 1379, 1262, 1001, 748 cm^{-1}.

MS (CI, NH_3): *m*/*z* = 308, 291 (MH^+ - 2), 275 (MH^+ - H_2O), 257, 205, 189.

25

Mp 84−86 °C.

^{1}H NMR ($CDCl_3$, 400 MHz, *taxol numbering*): δ = 5.96 (dd, 1 H, *J* = 4.7, 2.9 Hz, H-4), 5.59 (br q, 1 H, *J* = 12.2 Hz, H-10), 5.35 (br d, 1 H, *J* = 12.2 Hz, H-11), 4.51 (s, 1 H, H-2), 2.64-2.52 (m, 2 H, H-1 + OH), 2.18-1.97 (m, 3 H), 1.82-1.57 (m, 5 H), 1.52-1.38 (m, 2 H), 1.34 (br s, 3 H, CH_3), 1.29-1.20 (m, 3 H), 1.19, 1.15 (2 s, 6 H, 2 CH_3), 0.91 (t, 3 H, *J* = 7.3 Hz, CH_2C*H*$_3$).

^{13}C NMR ($CDCl_3$, 100.6 MHz, *taxol numbering*): δ = 145.7 (3), 140.0 (11), 128.7, 126.4 (4, 10), 81.2 (1), 72.9 (2), 42.2 (15), 38.2 (9), 31.3 (8), 29.5, 28.0, 25.4, 23.8 (CH_2), 27.6 (CH_3), 18.5 (6), 14.0 (CH_2*C*H_3).

IR (film): ν = 3394, 2955, 1458, 1377, 1261, 999 cm^{-1}.

MS (CI, NH_3): *m*/*z* = 310 (MH^+), 293, 275.

(5*R,6*R**,10a*S**,9*Z*)-6-Butyl-7,7,10a-trimethyl-1,2,3,5,6,7,8,10a-octahydro-1*H*-benzocyclooctene-5,6-diol (α-24)**

After the usual procedure with Nolan's catalyst was applied to **20** (100 mg, 0.23 mmol, 12 mL of 1,2-dichloroethane, 9.8 mg of catalyst), the resulting crude product was dissolved in THF (2 mL), and TBAF (110 mg, 0.35 mmol, 1.5 equiv) was added. The reacting mixture was stirred for 15 h at 25 °C, cooled to r.t., diluted with Et_2O (50 mL) and treated with sat. aq NH_4Cl solution (5 mL). The layers were separated, and the organic layer was washed successively with H_2O (5 mL) and brine (5 mL), dried ($MgSO_4$) and concentrated in vacuo. The resulting crude mixture was purified by flash chromatography on silica gel (Et_2O/petroleum ether, 10:90) yielding 19 mg (27%) of α-**24** as a white solid; mp 63−65 °C.

^{1}H NMR ($CDCl_3$, 400 MHz, *taxol numbering*): δ = 5.74 (d, 1 H, *J* = 10.6 Hz, H-9), 5.61-5.53 (m, 2 H, H-4 + H-10), 4.44 (d, 1 H, *J* = 12.3 Hz, H-2), 2.48 (dd, 1 H, *J* = 14.1, 10.5 Hz, H-11), 2.45 (d, 1 H, *J* = 12.3 Hz, OH), 2.19-2.15 (m, 2 H), 1.91-1.81 (m, 2 H), 1.71-1.52 (m, 5 H), 1.49-1.31 (m, 4 H), 1.34 (s, 3 H, CH_3-8), 1.04, 0.97 (2 s, 6 H, 2 CH_3-15), 0.92 (t, 3 H, *J* = 7.1 Hz, CH_2CH_3).

^{13}C NMR ($CDCl_3$, 100.6 MHz, *taxol numbering*): δ = 144.5 (3), 140.6 (9), 128.6, 123.3 (4, 10), 80.5 (2), 76.4 (1), 42.7 (15), 37.8 (11), 37.5 (8), 33.9, 32.4 (CH_2), 31.9, 29.3, 24.0 (CH_3), 25.8, 23.9, 23.4 (CH_2), 17.6 (6), 14.2 (CH_2CH_3).

IR (film): ν = 3544, 2931, 2869, 1731, 1651, 1455, 1370, 1242, 1193, 1114, 1055, 999, 875, 758 cm^{-1}.

MS (CI, NH_3): *m*/*z* = 308, 291 (MH^+−2), 275 ($MH^+ - H_2O$), 257, 205, 189.

(5*R,6*R**,10a*R**,9*Z*)-[6-Butyl-7,7,10a-trimethyl-1,2,3,5,6,7,8,10a-octahydro-1*H*-benzocyclooctene-5,6-dioxy]di-*tert*-butylsilylene (β-26) and (5*R**,6*R**,10a*S**,9*Z*)-6-[Butyl-7,7,10a-trimethyl-1,2,3,5,6,7,8,10a-octahydro-1*H*-benzocyclooctene-5,6-dioxy]di-*tert*-butylsilylene (α-26)**

1. The usual procedure with Schrock's catalyst, applied to **21** (53 mg, 0.11 mmol, 6 mL of benzene, 3 × 4 mg of catalyst), yielded 25 mg (50%) of α-**26** as a white solid and 23 mg (46%) of β-**26** as a white solid after flash chromatography on silica gel (Et_2O/petroleum ether, 2:98).

2. The usual procedure with Nolan's catalyst, applied to **21** (62 mg, 0.14 mmol, 8.5 mL of 1,2-dichloroethane, 7.2 mg of catalyst), yielded 58 mg (91%) of a 1:1 mixture of the two diastereomers α-**26**and β-**26** after flash chromatography on silica gel (Et_2O/petroleum ether, 2:98).

α-26

Mp 82-84 °C

^{1}H NMR ($CDCl_3$, 400 MHz, *taxol numbering*): δ = 6.06 (ddd, 1 H, *J* = 5.9, 3.0, 2.5 Hz, H-4), 5.67 (dt, 1 H, *J* = 11.8, 8.8 Hz, H-10), 5.43 (d, 1 H, *J* = 11.8 Hz, H-9), 5.00 (d, 1 H, *J* = 1.5 Hz, H-2), 2.76 (dd, 1 H, *J* = 14.1, 8.8 Hz, H-11), 2.34-2.18 (m, 2 H), 1.97-1.83 (m, 1 H), 1.67-1.47 (m, 6 H), 1.40 (s, 3 H, CH_3-8), 1.45-1.41 (m, 2 H), 1.20-1.15 (m, 2 H), 1.21 (s, 3 H, CH_3-15), 1.11 (s, 3 H, CH_3-15), 1.10 [s, 18 H, 2 $(CH_3)_3CSi$], 0.87 (t, 3 H, *J* = 7.0 Hz, CH_2CH_3).

^{13}C NMR ($CDCl_3$, 100.6 MHz, *taxol numbering*): δ = 145.1 (3), 140.0 (9), 129.6, 124.1 (4, 10), 87.0 (1), 80.2 (2), 42.9 (15), 40.9, 37.3, 34.7 (CH_2), 37.7 (8), 30.2 (CH_3), 28.6, 27.9 ($(CH_3)_3CSi$), 28.2 (CH_2), 26.2, 23.6 (CH_3-8, CH_3-15), 21.5 (CH_2), 20.9 (CSi), 15.7 (6), 14.2 (CH_2CH_3).

IR (film): ν = 2937, 1478, 1382, 1039, 991, 912, 861, 823 cm^{-1}.

MS (CI, NH_3): *m*/*z* = 434 (MH^+), 404, 377, 275, 257, 201.

Anal. calcd for $C_{27}H_{48}O_2Si$ (432.8): C, 74.94; H, 11.18. Found C, 75.16; H, 11.29.

β-26

Mp 129−131 °C.

^{1}H NMR ($CDCl_3$, 400 MHz, *taxol numbering*): δ = 6.06 (dd, 1 H, *J* = 4.7, 2.9 Hz, H-4), 5.33 (ddd, 1 H, *J* = 11.8, 9.4, 8.7 Hz, H-10), 5.23 (d, 1 H, *J* = 11.8 Hz, H-9), 4.57 (s, 1 H, H-2), 2.51 (dd, 1 H, *J* = 14.1, 9.4 Hz, H-11), 2.21 (dt, 1 H, *J* = 8.8, 5.3 Hz), 2.11-1.95 (m, 2 H), 1.83-1.76 (m, 1 H), 1.66-1.51 (m, 6 H), 1.42 (dd, 1 H, *J* = 14.1, 8.7 Hz, H-11), 1.26-1.21 (m, 2 H), 1.22 (s, 3 H, CH_3), 1.14 [s, 12 H, $(CH_3)_3CSi$, CH_3], 1.11 (s, 3 H, CH_3), 1.08 [s, 9 H, $(CH_3)_3CSi$], 0.89 (t, 3 H, *J* = 7.3 Hz, CH_2CH_3).

^{13}C NMR ($CDCl_3$, 100.6 MHz, *taxol numbering*): δ = 142.0 (3), 139.5 (9), 125.3, 124.1 (4, 10), 86.9 (1), 76.4 (2), 40.2, 39.5 (8, 15), 36.7, 35.7, 33.4, 29.6 (CH_2), 29.7 (CH_3), 28.9, 28.5 [$(CH_3)_3CSi$], 24.9, 24.1 (CH_2), 24.5 (CH_3), 22.1, 20.7 (CSi), 18.2 (6), 14.1 (CH_2CH_3).

IR (film): ν = 2936, 1645, 1458, 1363, 973 cm^{-1}.

MS (CI, NH_3): *m*/*z* = 434 (MH^+), 417, 375, 257.

Anal. calcd for $C_{27}H_{48}O_2Si$: C, 74.94; H, 11.18. Found C, 74.51; H, 11.09.

(5*R,6*R**,10a*R**,9*Z*)-6-Butyl-5,6-*O*-isopropylidene-7,7,10a-trimethyl-1,2,3,5,6,7,8,10a-octahydro-1*H*-benzocyclooctene (β-27) and (5*R**,6*R**,10a*S**,9*Z*)-6-Butyl-5,6-*O*-isopropylidene-7,7,10a-trimethyl-1,2,3,5,6,7,8,10a-octahydro-1*H*-benzocyclooctene (α-27)**

1. The usual procedure with Nolan's catalyst, applied to **22** (63 mg, 175 μmol, 7 mL of 1,2-dichloroethane, 7.4 mg of catalyst), yielded 25 mg (43%) of α-**27** and 25 mg (43%) of β-**27** as colorless oils after flash chromatography on silica gel (Et_2O/petroleum ether, 1:99 to 2:98).

2. The usual procedure with Schrock's catalyst, applied to **22** (46 mg, 130 μmol, 7 mL of benzene, 3 × 5 mg of catalyst), yielded 19 mg (45%) of α-**27** and 20 mg (48%) of β-**27** after flash chromatography on silica gel (Et_2O/petroleum ether 1:99 to 2:98).

α-27

^{1}H NMR ($CDCl_3$, 400 MHz, *taxol numbering*): δ = 6.01-5.99 (dd, 1 H, *J* = 5.0, 0.7 Hz, H-4), 5.71 (ddd, 1 H, *J* = 11.6, 9.5, 8.9 Hz, H-10), 5.44 (d, 1 H, *J* = 11.6 Hz, H-9), 4.97 (q, 1 H, *J* = 1.7 Hz, H-2), 2.76 (br dd, 1 H, *J* = 14.0, 9.5 Hz, H-11), 2.28-2.22 (m, 2 H), 1.98-1.86 (m, 1 H), 1.67-1.50 (m, 8 H), 1.46, 1.40, 1.35 [3 s, 9 H, CH_3-8, $(CH_3)_2C$], 1.31-1.23 (m, 2 H), 1.16, 1.03 (2 s, 6 H, 2 CH_3-15), 0.90 (t, 3 H, *J* = 7.3 Hz, CH_2CH_3).

^{13}C NMR ($CDCl_3$, 100.6 MHz, *taxol numbering*): δ = 141.2 (3), 140.2 (9), 129.5 (10), 124.9 (4), 105.2 [$OC(CH_3)_2O$], 87.8 (1), 79.7 (2), 40.9 (15), 40.5 (11), 36.8 (7), 32.3 (CH_2), 29.9 (8), 29.2, 28.1, 27.1, 24.4, 23.6 (CH_3), 27.8, 23.9, 22.0 (CH_2), 16.0 (6), 14.2 (CH_2CH_3).

IR (film): ν = 2958, 1653, 1456, 1367, 1246, 1215, 1180, 1012, 912, 739 cm^{-1}.

MS (CI, NH_3): *m*/*z* = 332, 317, 292, 275, 257, 201.

β-27

^{1}H NMR ($CDCl_3$, 400 MHz, *taxol numbering*): δ = 6.13 (dd, 1 H, *J* = 4.2, 3.6 Hz, H-4), 5.36 (dt, 1 H, *J* = 11.7, 9.2 Hz, H-10), 5.25 (d, 1 H, *J* = 11.7 Hz, H-9), 4.58 (s, 1 H, H-2), 2.44 (br dd, 1 H, *J* = 14.2, 10.0 Hz, H-11), 2.21-2.11 (m, 2 H), 1.87-1.73 (m, 2 H), 1.70-1.64 (m, 6 H), 1.49, 1.34, 1.20 [3 s, 9 H, CH_3-8 + $(CH_3)_2C$], 1.42 (dd, 1 H, *J* = 14.2, 8.2 Hz, H-11), 1.82-1.27 (m, 2 H), 1.04, 1.03 (2 s, 6 H, 2 CH_3-15), 0.93 (t, 3 H, *J* = 7.3 Hz, CH_2CH_3).

^{13}C NMR ($CDCl_3$, 100.6 MHz, *taxol numbering*): δ = 139.7 (9), 138.3 (3), 126.5, 124.2 (4, 10), 105.6 [O*C*$(CH_3)_2$O], 87.6 (1), 76.1 (2), 40.4, 37.8 (8, 15), 36.7, 34.3, 31.5 (CH_2), 30.2, 29.5, 28.2, 26.3, 22.0 (CH_3), 28.2, 25.0, 24.4 (CH_2), 18.1 (6), 14.2 (C*H*$_2$CH$_3$).

IR (film): ν = 2930, 1654, 1456, 1366, 1244, 1215, 1173, 1023 cm^{-1}.

MS (CI, NH_3): *m*/*z* = 332, 317, 292, 275, 257.

(5*R,6*R**,10a*R**/*S**,9*Z*)-6-Butyl-5,6-carbonyldioxy-7,7,10a-trimethyl-1,2,3,5,6,7,8,10a-octahydro-1*H*-benzocyclooctene (*cis*-28)**

The usual procedure with Nolan's catalyst, applied to **23** (70 mg, 0.2 mmol, 10 mL of 1,2-dichloroethane, 8.5 mg of catalyst), yielded 55 mg (86%) of a 1:1 mixture of the two diastereomeric derivatives *cis*-**28** as a colorless oil after flash chromatography on silica gel (Et_2O/petroleum ether, 8:92).

^{1}H NMR ($CDCl_3$, 400 MHz, *taxol numbering*): δ = 6.10 (t, 0.5 H, *J* = 3.6 Hz, 0.5 H-4), 6.02-5.97 (br s, 0.5 H, 0.5 H-4), 5.73 (dt, 0.5 H, *J* = 11.8, 9.2 Hz, 0.5 H-10), 5.56 (s, 0.5 H, 0.5 H-2), 5.48-5.39 (m, 1 H, 0.5 H-9 + 0.5 H-10), 5.34 (d, 0.5 H, *J* = 11.8 Hz, 0.5 H-9), 5.25 (s, 0.5 H, 0.5 H-2), 2.66 (dd, 0.5 H, *J* = 14.1, 9.2 Hz, 0.5 H-11), 2.23-2.04 (m, 3 H), 2.00-1.75 (m, 5 H), 1.72-1.58 (m, 3 H), 1.57-1.45 (m, 1.5 H), 1.43 (s, 1.5 H, CH_3), 1.25 (s, 1.5 H, 0.5 CH_3), 1.30-1.20 (m, 1 H), 1.16 (s, 1.5 H, 0.5 CH_3), 1.11 (s, 1.5 H, 0.5 CH_3), 1.09 (s, 3 H, CH_3), 0.88 (t, 1.5 H, *J* = 7.0 Hz, 0.5 CH_2C*H*$_3$), 0.86 (t, 1.5 H, *J* = 7.1 Hz, 0.5 CH_2C*H*$_3$).

^{13}C NMR ($CDCl_3$, 100.6 MHz, *taxol numbering*): δ = 154.8, 154.0 (C = O), 140.6, 140.5 (9), 135.8, 134.7 (3), 128.8, 128.5, 126.1, 124.7 (4, 10), 92.1, 91.5 (1), 82.0, 79.8 (2), 40.9, 38.2, 35.5, 34.9 (7, 11), 39.9, 39.2, 39.1, 36.7 (8, 15), 31.7, 30.5 (CH_2), 28.2, 27.1, 26.8, 25.0, 23.3, 21.7, 21.6 (CH_3), 26.6, 24.8, 24.5, 23.3, 23.0, 22.3 (CH_2), 17.7, 15.9 (6), 13.8 (CH_2CH_3).

IR (film): ν (cm^{-1}) 2957, 1797, 1469, 1454, 1323, 1249, 1192, 1051, 1011.

MS (CI, NH_3): (*m*/*z*) 336 (MNH_4^+), 319 (MH^+), 275, 257, 217, 201.

(5*R,6*R**,10a*R**,9*E*)-6-Butyl-5,6-carbonyldioxy-7,7,10a-trimethyl-1,2,3,5,6,7,8,10a-octahydro-1*H*-benzocyclooctene (*trans* β-28) and [1*R**,2*R**(6*S**)]-2-Butyl-1,2-carbonyldioxy-3,3-dimethyl-1-(6-methyl-6-vinylcyclohex-1-en-1-yl)hex-5-ene (α-23)**

1. The usual procedure with Grubbs' catalyst, applied to **23** (80 mg, 0.23 mmol, 11 mL of benzene, 3.8 + 6 × 1.9 mg of catalyst), yielded 25 mg (34%) of *trans* β-**28** as a white solid and 34 mg (42%) of unreacted α-**23** as a pale yellow solid after flash chromatography on silica gel (Et_2O/petroleum ether, 5:95).

2. The usual procedure with Schrock's catalyst, applied to **23** (80 mg, 0.23 mmol, 11 mL of benzene, 3 × 10 mg of catalyst), yielded 33 mg (41%) of *trans* β-**28** and 24 mg (32%) of unreacted α-**23** after flash chromatography on silica gel (Et_2O/petroleum ether, 5:95).

***trans* β-28**

Mp 73−75 °C.

^{1}H NMR ($CDCl_3$, 400 MHz, *taxol numbering*): δ = 6.01 (ddd, 1 H, *J* = 5.0, 2.5, 1.5 Hz, H-4), 5.80 (ddd, 1 H, *J* = 16.7, 12.0, 3.5 Hz, H-10), 5.39 (d, 1 H, *J* = 16.7 Hz, H-9), 5.09 (d, 1 H, *J* = 2.5 Hz, H-2), 2.27 (t, 1 H, *J* = 12.0 Hz, H-11), 2.25-2.18 (m, 1 H), 2.10 (dd, 1 H, *J* = 12.0, 3.5 Hz, H-11), 2.11-2.01 (m, 1 H), 1.88-1.81 (m, 3 H), 1.76-1.68 (m, 2 H), 1.65-1.56 (m, 2 H), 1.28 (d, 3 H, *J* = 0.4 Hz, CH_3-8), 1.22, 1.17 (2 s, 6 H, 2 CH_3-15), 0.89 (t, 3 H, *J* = 7.1 Hz, CH_2C*H*$_3$).

^{13}C NMR ($CDCl_3$, 100.6 MHz, *taxol numbering*): δ = 154.2 (C=O), 142.3 (9), 137.5 (3), 126.7, 125.4 (4, 10), 93.2 (1), 82.7 (2), 48.2 (8), 43.6 (11), 41.8 (15), 36.2 (6), 31.7, 26.0, 24.8, 23.0 (CH_2), 26.2, 22.0, 20.4 (CH_3), 17.6 (6), 13.8 (CH_2*C*H$_3$).

IR (film): ν = 2931, 2871, 1798, 1455, 1376, 1321, 1242, 1048, 1027, 772 cm^{-1}.

MS (CI, NH_3): (m/z) 336 (MNH_4^+), 319 (MH^+), 303, 285, 221, 169, 151.

α-23:

mp 85−87 °C.

^{1}H NMR ($CDCl_3$, 400 MHz, *taxol numbering*): δ = 5.95 (t, 1 H, *J* = 3.8 Hz, H-4), 5.78 (ddt, 1 H, *J* = 17.0, 10.0, 7.1 Hz, H-10), 5.70 (dd, 1 H, *J* = 17.5, 10.5 Hz, H-9), 5.18 (dd, 1 H, *J* = 10.5, 1.0 Hz, H-9'(*cis*)), 5.10 (br d, 1 H, *J* = 10.0 Hz, H-10'(*cis*)), 5.07 (br d, 1 H, *J* = 17.0 Hz, H-10'(*trans*)), 5.06 (dd, 1 H, *J* = 17.5, 1.0 Hz, H-9'(*trans*)), 4.88 (s, 1 H, H-2), 2.20-2.02 (m, 3 H), 1.80-1.69 (m, 1 H), 1.62-1.15 (m, 8 H), 1.13 (s, 3 H, CH_3-8), 0.93 (s, 6 H, 2 CH_3-15), 0.88 (t, 3 H, *J* = 7.0 Hz, CH_2C*H*$_3$).

^{13}C NMR ($CDCl_3$, 100.6 MHz, *taxol numbering*): δ = 155.6 (C=O), 145.4 (9), 137.4 (3), 133.6 (10), 131.5 (4), 118.6, 118.5 (10'), 114.6 (9'), 91.8 (1), 80.0 (2), 43.6 (15), 41.0 (8), 39.8, 37.7 (7, 11), 30.3, 27.0, 25.4, 23.0 (CH_2), 24.5, 20.6, 20.5 (CH_3-8, CH_3-15), 17.8 (6), 13.8 (CH_2CH_3).

IR (film): ν = 3078, 2961, 2934, 2872, 1799, 1637, 1466, 1332, 1198, 1045, 916, 770 cm^{-1}.

(5*R,6*R**,10a*R**,9*Z*)-6-Butyl-5,6-carbonyldioxy-7,7,10a-trimethyl-1,2,3,5,6,7,8,10a-octahydro-1*H*-benzocyclooctene (*cis* β-28)**

To a refluxing solution of *trans* β-**28** (34 mg, 100 μmol) in anhyd degassed 1,2-dichloroethane (5.5 mL) was added a 0.1 M solution of diallyl ether in 1,2-dichloroethane (100 μL, 10 mol%), then Nolan's catalyst (4.5 mg, 5 mol%), and the resulting mixture was refluxed under argon for 12 h. The reaction mixture was cooled to r.t., concentrated in vacuo and purified by flash chromatography on silica gel (Et_2O/petroleum ether, 8:92) to yield 23 mg (67%) of a 4:1 mixture of what was assigned to be after deprotection with 2 N aq NaOH in dioxane *cis* β-**28** and *cis* β-**30**.

(5*R,6*R**,10a*S**,9*Z*)-6-Butyl-5,6-carbonyldioxy-7,7,10a-trimethyl-1,2,3,5,6,7,8,10a-octahydro-1*H*-benzocyclooctene (*cis* α-28)**

The usual procedure with Nolan's catalyst catalyst, applied to α-**23** (35 mg, 95 μmol, 5 mL of 1,2-dichloroethane, 4.0 mg of catalyst), yielded 29 mg (96%) of *cis* α-**28** as a white solid after flash chromatography on silica gel (Et_2O/petroleum ether, 8:92); mp 78−80 °C.

^{1}H NMR ($CDCl_3$, 400 MHz, *taxol numbering*): δ = 6.03 (td, 1 H, *J* = 4.5, 2.0 Hz, H-4), 5.73 (dt, 1 H, *J* = 11.5, 9.0 Hz, H-10), 5.56 (q, 1 H, *J* = 2.3 Hz, H-2), 5.47 (dd, 1 H, *J* = 11.8, 1.5 Hz, H-9), 2.68 (br dd, 1 H, *J* = 14.3, 9.0 Hz, H-11), 2.26-2.21 (m, 2 H), 1.92-1.88 (m, 3 H), 1.82 (dd, 1 H, *J* = 14.3, 9.0 Hz, H-11), 1.78-1.68 (m, 2 H), 1.57-1.50 (m, 2 H), 1.46 (d, 3 H, *J* = 0.5 Hz, CH_3-8), 1.44-1.24 (m, 3 H), 1.19, 1.12 (2 s, 6 H, 2 CH_3-15), 0.89 (t, 3 H, *J* = 7.2 Hz, CH_2C*H*$_3$).

^{13}C NMR ($CDCl_3$, 100.6 MHz, *taxol numbering*): δ = 154.0 (C=O), 140.6 (9), 136.0 (3), 128.9, 126.3 (4, 10), 91.6 (1), 82.2 (2), 41.0 (7), 40.0 (15), 36.8 (8), 35.6 (11), 31.8 (CH_2), 27.1, 25.1, 21.8 (CH_3), 24.6, 23.1, 22.4 (CH_2), 16.0 (6), 13.8 (CH_2*C*H$_3$).

IR (film): ν = 2957, 1797, 1469, 1454, 1323, 1249, 1192, 1051, 1011, 774 cm^{-1}.

MS (CI, NH_3): *m*/*z* = 336 (MNH_4^+), 319 (MH^+), 275, 257, 217, 201.

[1*R,2*R**(6*S**)]-2-Butyl-1,2-carbonyldioxy-3,3-dimethyl-1-(6-methyl-6-vinylcyclohex-1-en-1-yl)hex-4-ene (α-29) and (5*R**,6*R**,10a*R**,8*Z*)-6-Butyl-5,6-carbonyldioxy-7,7,10a-trimethyl-1,2,3,5,6,7,8,10a-octahydro-1*H*-benzocyclooctene (*cis* β-30)**

To a refluxing solution of the diene **23** (40 mg, 115 μmol) in anhyd degassed benzene (6 mL) was added titanium tetraisopropoxide (34 μL, 115 μmol, 1.0 equiv) and then Grubbs' catalyst (4.7 mg, 5 mol%), and the resulting mixture was refluxed under argon for 8 d, during which time 0.9 mg (1 mol%) of catalyst was added every 24 h to the refluxing mixture. The reaction mixture was cooled to r.t., concentrated in vacuo and purified by flash chromatography on silica gel (Et_2O/petroleum ether, 8:92) to yield 18 mg (45%) of a 1:1 mixture of α-**23** and α-**29** and 10 mg (28%) of a 1:2 mixture of what was assigned to be after deprotection with 2 N aq NaOH in dioxane *cis* β-**28** and *cis* β-**30**.

Hydrolysis of *cis* α-28; (5*R,6*R**,10a*S**,9*Z*)-6-Butyl-7,7,10a-trimethyl-1,2,3,5,6,7,8,10a-octahydro-1*H*-benzocyclooctene-5,6-diol (α-24)**

To a solution of *cis* α-**28** (25 mg, 80 μmol) in dioxane (1 mL) was added at 0 °C 2 N aq NaOH solution (0.2 mL). The resulting mixture was stirred at r.t. for 2 d, diluted with Et_2O (50 mL) and quenched with sat. aq NH_4Cl solution (5 mL). The layers were separated, and the organic layer was washed successively with H_2O (2 × 5 mL) and brine (5 mL), dried ($MgSO_4$) and concentrated in vacuo. The resulting crude product was purified by flash chromatography on silica gel (Et_2O/petroleum ether, 10:90) and yielded 22 mg (96%) of α-**24** as a white solid.

Hydrolysis of *cis* 28; (5*R,6*R**,10a*S**,9*Z*)-6-Butyl-7,7,10a-trimethyl-1,2,3,5,6,7,8,10a-octahydro-1*H*-benzocyclooctene-5,6-diol (α-24) and (5*R**,6*R**,10a*R**,9*Z*)-6-Butyl-7,7,10a-trimethyl-1,2,3,5,6,7,8,10a-octahydro-1*H*-benzocyclooctene-5,6-diol (β-24)**

To a solution of *cis*-**28** (30 mg, 95 μmol) in dioxane (1 mL) was added at 0 °C 2 N aq NaOH solution (0.5 mL). The resulting mixture was stirred at r.t. for 2 d, diluted with Et_2O (50 mL) and quenched with sat. aq NH_4Cl solution (5 mL). The layers were separated, and the organic layer was washed successively with H_2O (2 × 5 mL) and brine (5 mL), dried ($MgSO_4$) and concentrated in vacuo. The resulting crude product was purified by flash chromatography on silica gel (Et_2O/petroleum ether, 10:90) and yielded 13 mg (47%) of α-**24** as a white solid and 13 mg (47%) of β-**24** as a colorless oil.

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