Selected Paper

Stereoselective Synthesis of 19-Hydroxytaxoid by Utilizing Samarium(II) Iodide-Mediated Double Aldol Cyclization

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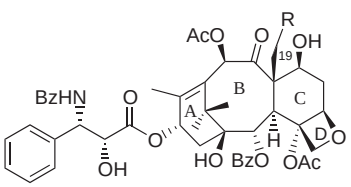
The stereoselective synthesis of new 19-hydroxytaxoid **36**, possessing a double-aldol skeleton was achieved by way of B to BC to ABC ring construction. Optically active 8-membered ring **6** corresponding to the B-ring of 19-hydroxytaxol has been synthesized in high yield from epoxyketo aldehyde **8** by intramolecular samarium(II) iodide-mediated double aldol cyclization. The bicyclic compound **5** corresponding to the BC ring system was prepared from the 8-membered ring **6** by successive trimethylaluminium-assisted stereoselective conjugated addition and intramolecular samarium(II) iodide-mediated double aldol cyclization. The ABC-ring system **4** was constructed by stereoselective homoallylation and pinacol coupling cyclization with low-valent titanium. The synthesis of new 19-hydroxytaxoid **36** was accomplished from ABC ring system **4** by olefination of vicinal diol unit.

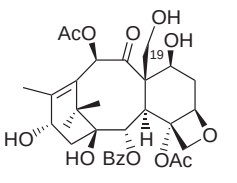
Taxol® (**1**, paclitaxel)[1] is currently considered as one of the most important drugs used in chemotherapy, and is actually the agent of choice for the treatment of ovarian, breast, and lung cancer. However, lack of sufficient solubility in water (0.25 μg/mL)[2] was one of taxol's most-concerned problems associated with its formulation for clinical applications. During our preparing of a new anticancer agent by chemical modification of taxol, 19-hydroxytaxol (**2**) was chosen so as to improve its pharmacological profile, especially its water-solubility, by the introducing a hydrophilic molecule such as sugar onto the newly-introduced C-19 hydroxy group[3] of **2** (Fig. 1).

Although 19-hydroxybaccatin III (**3**) can be isolated from natural resources,[4] the quantities of the isolated **3** are not sufficient to prepare its derivatives **2** to develop new biological activities. Therefore, it was planned to synthesize **2** based on our strategy for the total synthesis of **1**.

Retrosynthetic analysis of **2** is shown in Scheme 1. The synthesis of taxane's basic skeleton according to our strategy for the total synthesis of **1**[5] was tried by starting from the B ring prepared from an optical active polyoxy unit **7** followed by construction of the A and C ring systems on this framework. The major difference between 19-hydroytaxol and taxol in chemical behavior is that the 19-hydroxytaxol has an unstable double-aldol (β,β'-dihydroxy ketone) skeleton. Taking this into consideration, the synthesis of 19-hydroxytaxoid was studied by utilizing the newly-developed samarium(II) iodide (SmI_2)-mediated double aldol reaction[6] as a key step.

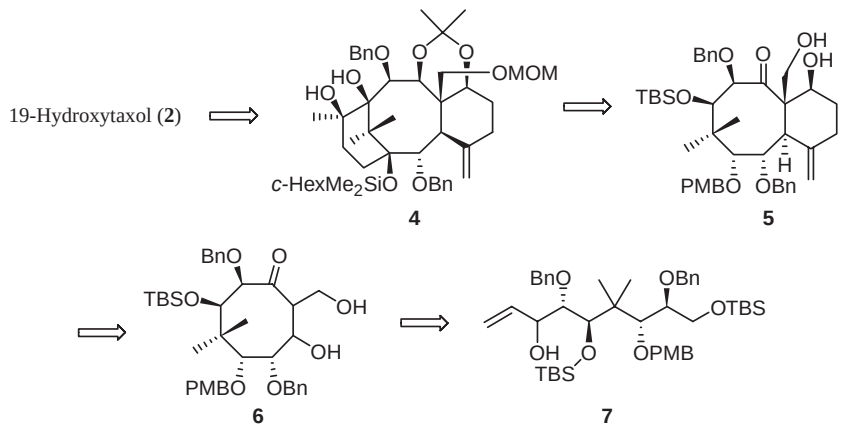


Taxol®(**1**, paclitaxel): R = H
19-Hydroxytaxol (**2**): R = OH



19-Hydroxybaccatin III (**3**)

Fig. 1.



Scheme 1. Retrosynthetic analysis.

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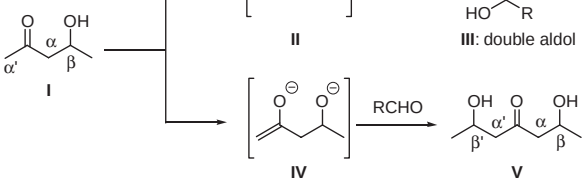
Results and Discussion

Synthesis of the B Ring of 19-Hydroxytaxol.[7] In the first place, construction of a polyoxy eight-membered ring intermediate **6** that contained a double-aldol skeleton was examined. However, very few examples are known that involve the synthesis of double aldols, in spite of remarkable recent developments of aldol chemistry.[8] The undesired enolate **IV** is generally known to be liberated from β-hydroxy ketone **I** by deprotonation at α'-carbon with strong bases such as lithium diisopropylamide (LDA). The thus formed **IV** reacts with aldehyde to afford dihydroxy ketone **V** (Scheme 2).[9]

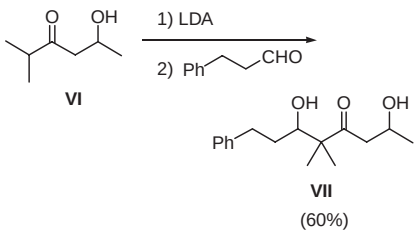
For example, a dihydroxy ketone **VII** was obtained in 60% yield by deprotonation of β-hydroxy ketone **VI** with LDA, followed by aldol reaction with 3-phenylpropionaldehyde (Scheme 3).

In order to overcome these synthetic difficulties, it was tried to find a new and useful method for the synthesis of unsymmetrical double-aldols. Eventually, the desired SmI_2-mediated aldol reaction of aldehydes with aryl or alkyl oxiranyl ketones was established recently in our laboratory (Scheme 4).[6]

Then, it was considered that the intermediate **6** would be prepared from α,β-epoxyketo aldehyde **8** by the above-mentioned double-aldol reaction (Scheme 5).



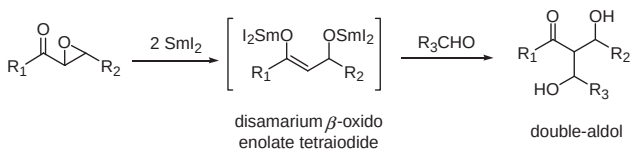
Scheme 2.



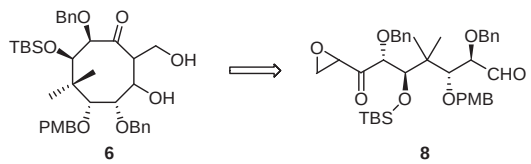
Scheme 3.

In previous papers, the SmI_2-mediated intramolecular aldol reaction of α,β-epoxyketo aldehyde had already been reported (Scheme 6).[6,7] It was shown there that a mixture of *cis-syn* and *cis-anti* diasteromers of the eight-membered double-aldol products was obtained in 78% yield when 3 equiv of water were used as additives.

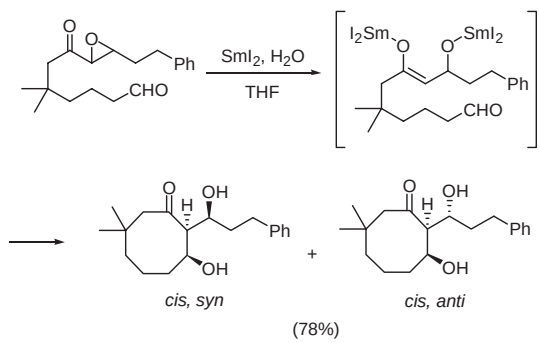
The above method was further applied to the synthesis of a key intermediate **6**, a polyoxy eight-membered ring compound corresponding to the B ring of 19-hydroxytaxol. As shown in Scheme 7, α,β-epoxyketo aldehyde **8** was obtained from aldehyde **9** that was prepared from D-pantolactone according to our original procedure.[10] Vinylation of aldehyde **9** with vinylmagnesium bromide gave allylic alcohol **10** in 98% yield as a mixture of two diastereomers. In order to remove the *t*-butyldimethylsilyl (TBS) group at the primary hydroxy group selectively, a diastereomeric mixture of allylic alcohol **10** was treat-



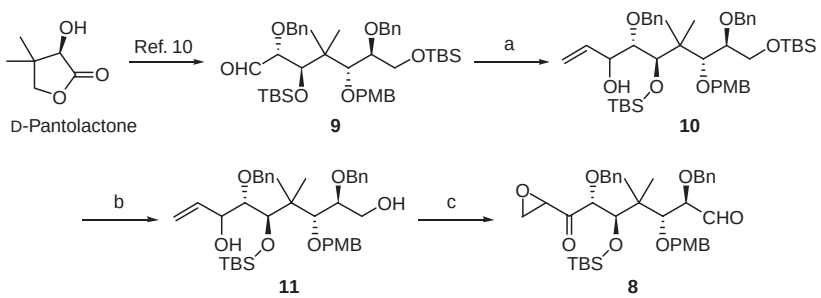
Scheme 4.



Scheme 5.

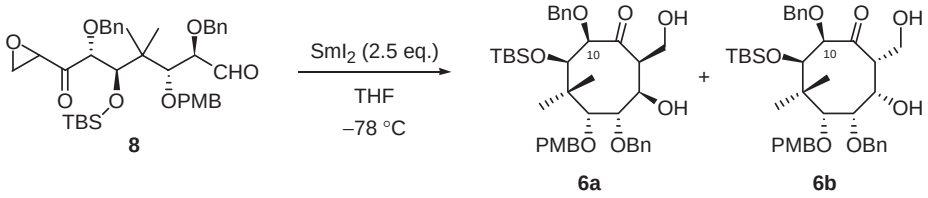


Scheme 6. The eight-membered ring formation by the SmI_2-mediated aldol reaction.

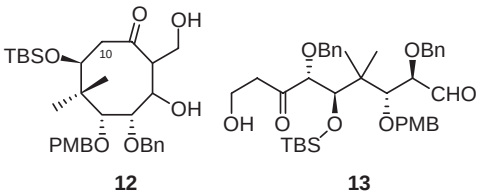


Scheme 7. Reagents and conditions: a) vinyl-MgBr, THF, 0 °C (98%). b) 1 M HCl, THF, rt (88%). c) *m*-CPBA, CH_2Cl_2, 50 °C (96%); $(COCl)_2$, DMSO, Et_3N, CH_2Cl_2, −78 °C to 0 °C (96%).

Table 1. Formation of the Eight-Membered Ring (**6**) by the SmI_2-Mediated Aldol Reaction



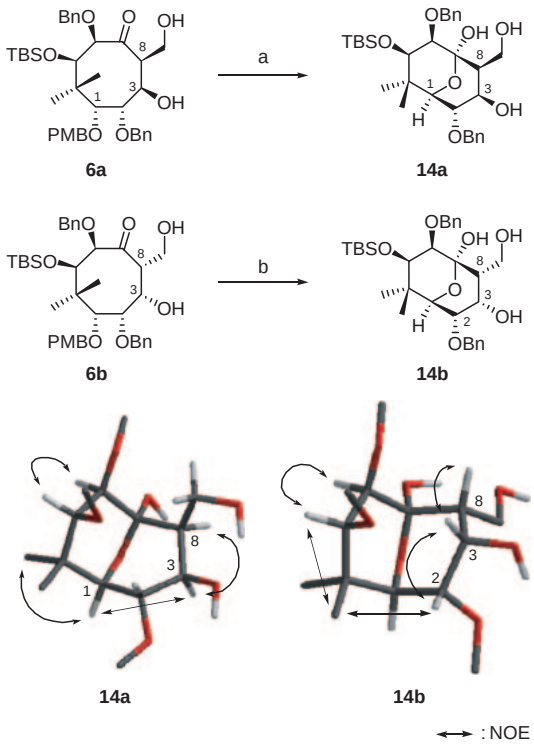
Entry	Additive/equiv	Yield/%		
		6 (**a**/**b**)	**12**	**13**
1	—	83 (50/50)	10	—
2	H_2O/3.0	76 (39/61)	—	12
3	*i*-PrOH/2.0	91 (49/51)	—	trace



ed with 1 M HCl under high-diluted reaction conditions to give diol **11** in 88% yield. After epoxydation of terminal olefin with *m*-chloroperoxybenzoic acid (*m*-CPBA), Swern oxidation afforded the desired α,β-epoxyketo aldehyde **8** as a mixture of two diastereomers in 92% yield in two steps.

Since the precursor for the eight-membered double-aldol **6** was prepared, the following SmI_2-mediated intramolecular aldol reaction of α,β-epoxyketo aldehyde **8** was investigated in detail. In the first place, **8** was treated with 2.5 equiv of SmI_2 in THF at -78 °C, and the cyclized products **6a** and **6b** were obtained in 83% yields (Table 1, Entry 1). Under the conditions of Entry 1, the by-products **12** which were formed by cleavage of benzyloxy group at 10-position of **6a** and **6b** were obtained at the same time. It was considered that the debenzyloxygenation might take place by further reduction of **6** with SmI_2. In order to inhibit the reductive elimination of benzyloxy group with SmI_2, the reactivity of SmI_2 was controlled by the use of additives. When 3 equiv of water were used as additives, the aldol reaction of **8** proceeded smoothly to give the cyclized products **6a** and **6b** in 76% yield, along with a small amount of **13**, which was formed by ring opening of epoxide **8** (Entry 2). There, hydrolysis of disamarium β-oxido enolate tetraiodide with water was thought to take place competitively with the desired cyclization. It was further found that the yield of the cyclized product increased up to 91% when *i*-PrOH was used as additives (Entry 3). In this case, debenzyloxygenation and ring opening of the epoxide were not observed. The diastereomer ratio (**6a**/**6b**) was not influenced by the stereochemistry of epoxide **8**: that is, SmI_2-mediated aldol reaction of each of diastereomers of **8** gave the same diastereomer ratio (**6a**/**6b**). In order to clarify the structure of these eight-membered ring compounds, **6a** and **6b** were transformed into bicyclic derivatives **14a** and **14b** on treatment with 2,3-dichloro-5,6-dicyano-1,4-benzoquinone (DDQ) and the structures of the formed rigid bicyclic skeletons were determined by NOE analysis (Scheme 8). The NOEs between C-3 proton and C-8 proton, and C-3 proton and C-1 proton of **14a** indicated that both C-8 hydroxymethyl group and C-3 hydroxy group had β-configurations. On the other hand, the NOEs between C-3 proton and C-8 proton, and C-3 proton and C-2 proton of **14b** indicated that both C-8 hydroxymethyl group and C-3 hydroxy group had α-configurations.

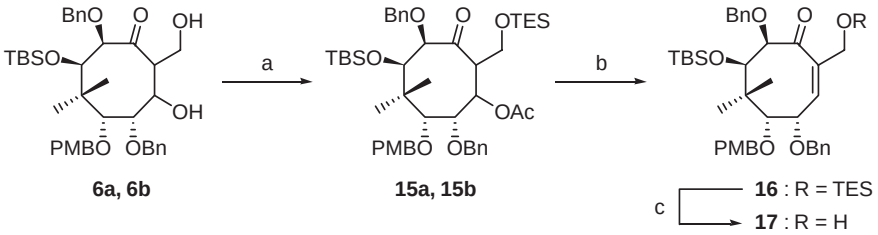
For installation of C-ring segment, eight-membered ring



Scheme 8. Reagents and conditions: a) DDQ, H_2O, CH_2Cl_2, rt (51%). b) DDQ, H_2O, CH_2Cl_2, rt (64%).

compounds **6a** and **6b** were converted into the corresponding cyclooctenone derivative **17** (Scheme 9). Selective protection of the primary hydroxy group of **6a** and **6b** with triethylsilyl (TES) group followed by acetylation of the remaining secondary hydroxy group gave **15a** and **15b**. At this point, the crystalline **15a** was subjected to X-ray crystallographic analysis to confirm the assigned stereochemistry (Fig. 2).[11] Then, successive treatment with 1,8-diazabicyclo[5.4.0]undec-7-ene (DBU)–benzene (4/1) gave enone **16** in 59% yield along with **17** in 26% yield. Conversion of **16** to **17** was carried out by deprotection of TES group of **16** under acidic conditions.

Synthesis of the BC Ring System of 19-Hydroxytaxol.[12,13] In the strategy of total synthesis of **2**, the construction of the C-ring is most important because a double aldol unit is stereose-



Scheme 9. Reagents and conditions: a) TESCl, pyridine, 0 °C (95%); Ac_2O, DMAP, pyridine, rt (96%). b) DBU, benzene, rt (**16**: 59%, **17**: 26%). c) 0.1 M HCl, THF, 0 °C (95%).

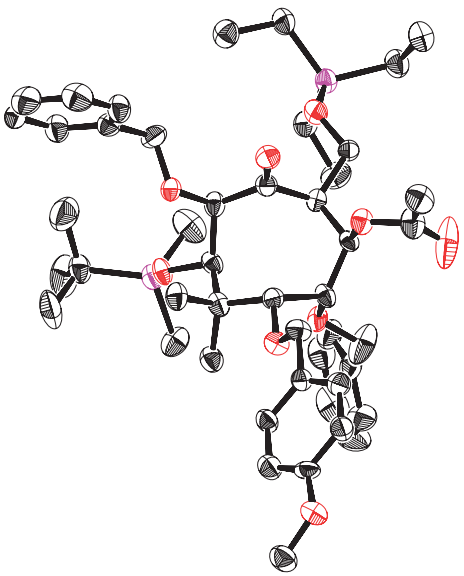


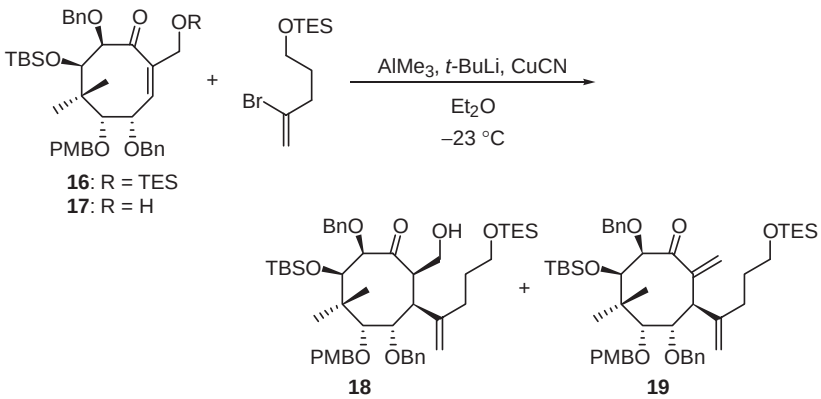
Fig. 2. ORTEP drawing of compound **15a**.

lectively prepared during this stage. The synthetic plan for the construction of the C-ring is similar to that of B-ring; that is, its preparation is attained by SmI_2-mediated double aldol cyclization of epoxyketo aldehyde.

In order to construct the C-ring on the eight-membered ring compound, the conjugated addition to enone **16** using a higher order cuprate reagent, generated in situ from 10 equiv of 2-bromo-5-(triethylsilyloxy)pentene with 20 equiv of *t*-BuLi and 5 equiv of CuCN, was attempted first (Table 2, Entry 1).[12] However, the desired 1,4-adduct was not obtained at all. Then, nonprotected hydroxymethyl enone **17** was employed since this conjugated addition was probably prevented by the protecting group because of its steric hindrance. The desired conjugated addition proceeded by using 5 equiv of cuprate reagent, yet the yield of 1,4-adduct still remained low (Entry 3). To improve the yield of the desired 1,4-adduct and to reduce the amount of cuprate reagent, use of a suitable activating agent was considered necessary for the promotion of the reaction. Trimethylaluminium was found to work effectively as an activating agent (Scheme 10). When 1.1 equiv of trimethylaluminium and only 2.5 equiv of the cuprate reagent were used, the reaction proceeded smoothly and the desired β-substituted eight-membered ring ketone **18** having the C-3,C-8-*cis* configuration (71% yield) and dehydrated compound **19** (22% yield) were obtained with perfect diastereoselectivity (Entry 4).

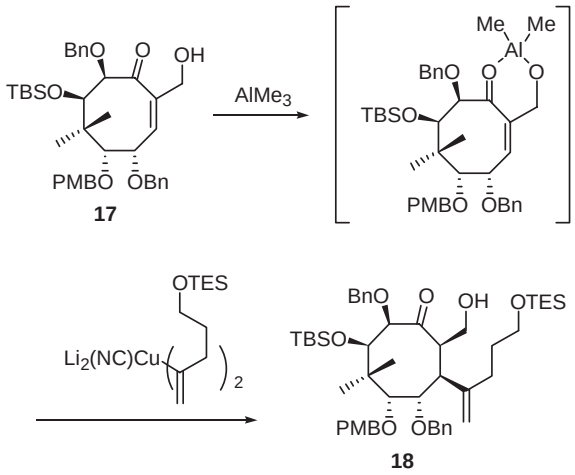
Next, preparation of the key intermediate, epoxyketo aldehyde **21**, is illustrated in Scheme 11:[13] namely, hydroxymethyl ketone **18**, prepared by the above-mentioned 1,4-addition of

Table 2. Trimethylaluminium-Assisted Conjugated Addition to Enone

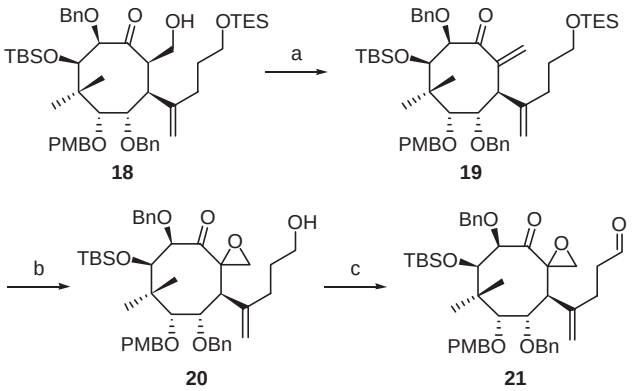


Entry	R	Cuprate reagent/equiv	$AlMe_3$/equiv	**18**	**19**
1[a)]	TES	5.0	—	ND[c)]	ND
2[b)]	H	2.0	—	ND	ND
3	H	5.0	—	55	26
4	H	2.5	1.1	71	22
5	H	3.5	1.1	67	21

a) **16** was 85% recovered. b) **17** was 83% recovered. c) Not detected.

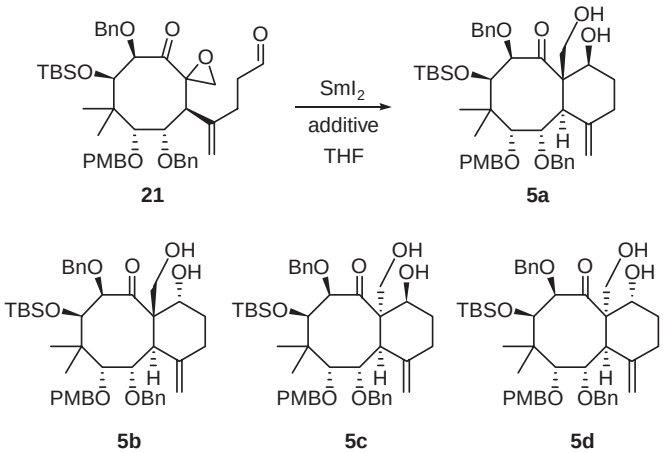


Scheme 10. Trimethylaluminium-assisted conjugate addition.



Scheme 11. Reagents and conditions: a) Ac_2O, DMAP, pyridine, rt (89%); DBU, CH_2Cl_2, rt (85%); b) 0.5 M HCl, THF, −20 °C (91%); H_2O_2, NaOH, MeOH, 0 °C (82%); c) PhSNH*t*-Bu, NCS, K_2CO_3, MS4A, CH_2Cl_2, rt (95%).

Table 3. SmI_2-Mediated Intramolecular Cyclization of Epoxyketo Aldehyde (**21**)



Entry	SmI_2 /equiv	Additive equiv	Temp. /°C	Yield/% 5a	5b	5c	5d
1	3.0	—	−100	71	ND[a)]	10	15
2	3.0	—	−78	59	ND	9	16
3	3.0	—	−45	42	ND	3	20
4	5.0	—	−23	24	ND	2	16
5	4.0	H_2O/3.0	−78	45	ND	44	6
6	4.0	MeOH/3.0	−78	27	ND	38	7
7	3.0	^{i}PrOH/3.0	−78	41	ND	35	9
8	3.0	HMPA/3.0	−78	45	ND	24	17

a) The product was not detected.

higher order cyanocuprate, was acetylated first. This was followed by the formation of α,β-unsaturated ketone **19** by regioselective elimination of the formed α-acetoxymethyl ketone with DBU. After deprotection of TES group, epoxidation of enone using H_2O_2 and NaOH gave α-epoxy ketone **20** as a 1:1 mixture of diastereomers. Swern oxidation and tetrapropylammonium perruthenate (TPAP)-catalyzed oxidation of the primary hydroxy group of a diastereomixture of **20** did not give the desired aldehyde **21**, whereas sulfenamide-catalyzed oxidation[14] of **20** with *N*-chlorosuccinimide (NCS) proceeded smoothly to give **21** in 95% yield.

Then, SmI_2-mediated cyclization of **21** was tried for stereoselective construction of C-ring (Table 3). In the first place, the reaction was carried out at temperatures ranging from −100 °C to −23 °C in the absence of additives (Entries 1–4). The desired isomer **5a** was obtained in 71% yield along with diastereomers **5c** (10%) and **5d** (15%) at −100 °C. On the other hand, the yields of diastereomers **5a** and **5c** decreased at the elevated reaction temperatures. In these experiments, a 1:1 diastereomixture of **21** was employed, since the results were the same whether a mixture of two isomers or the single isomer was employed. Therefore, it is assumed that the desired facial selectivity of the formed samarium enolate and an aldehyde moiety could be controlled if the reaction temperature was lowered.

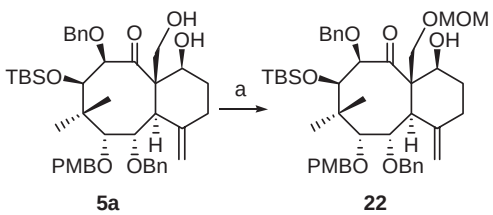
Next, our investigation on the effects of additives revealed that, contrary to our expectations, the addition of additives such as H_2O, MeOH, *i*-PrOH, or hexamethylphosphoric triamide (HMPA) did not improve the yield of the desired product **5a**, while that of diastereomer **5c** increased. No formation of diastereomer **5b** was detected throughout the above-mentioned trials. The stereochemistry of compound **5a** was clearly identified by X-ray crystal structure analysis of a methoxymethyl (MOM) ether **22**, which was obtained by protecting the primary hydroxy group of **5a** with MOM group (Scheme 12, Fig. 3).[15]

The stereochemistry of **5d** was determined in the following way: the primary alcohol of **5d** was protected with TBS group first and then the *p*-methoxybenzyl (PMB) group was deprotected with DDQ to form a bridged tricyclic compound **23**. The stereochemistry of **23** was determined by NOE analysis. The NOE between C-5β proton and C-7 proton of **23** indicated that the C-7 hydroxy group had α-configuration. As for C-8 (*t*-butyldimethylsilyloxy)methyl group, the NOEs between C-19 proton and C-3 proton as well as C-6α proton revealed that C-8 (*t*-butyldimethylsilyloxy)methyl group had α-configuration. Thus, the stereochemistry of **5d** was determined as shown in Scheme 13. Furthermore, in order to determine the structure of **5c**, structurally-defined **5d** was oxidized by Dess–Martin periodinane to give ketone **24**, which was also formed by oxidation of **5c**. Thus, it was noted that **5c** had the opposite stereochemistry concerning a hydroxy group at 7-position.

Next, isomerization of undesired diastereomers **5c** and **5d** to the desired isomer **5a** was examined. However, after protection of primary hydroxy group of **5c** and **5d** with TBS group, an isomerization experiment using NaOMe in MeOH–THF did not give any isomerized product which had the desired stereochemistry for synthesis of **2**.

Synthesis of the ABC Ring System of 19-Hydroxytaxol.[16] The conversion of **22**, prepared by the SmI_2-mediated double aldol reaction, to a tricyclic compound **4** is shown in Scheme 14.

In the first place, MOM-protected double aldol **22** was diastereoselectively reduced with AlH_3 to afford the corresponding C-7,C-9-*cis*-diol; protection of thus formed *cis*-diol with isopropylidene acetal provided tricyclic compound **25**. Then, **25** was converted to 8-membered ring ketone **26** by oxidative deprotection of PMB group, followed by successive oxidation of C-1 hydroxy group with Dess–Martin periodinane. Alkylation of **26** at C-1 position with homoallyllithium[5] in benzene afforded the desired β-alcohol in high yield with perfect diastereoselectivity. Deprotection of TBS group resulted in the formation of *cis*-diol **27** and successive treatment of **27** with



Scheme 12. Reagents and conditions: a) MOMCl, *n*-Bu_4NI, *i*-Pr_2NEt, CH_2Cl_2, rt (76%).

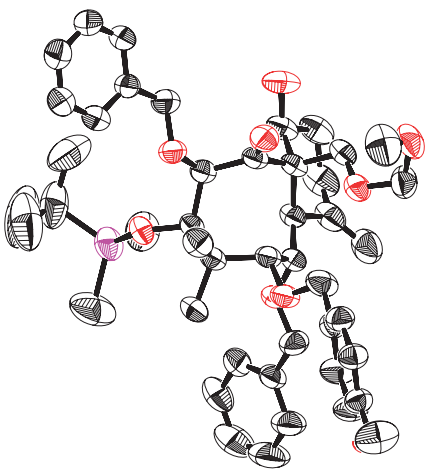
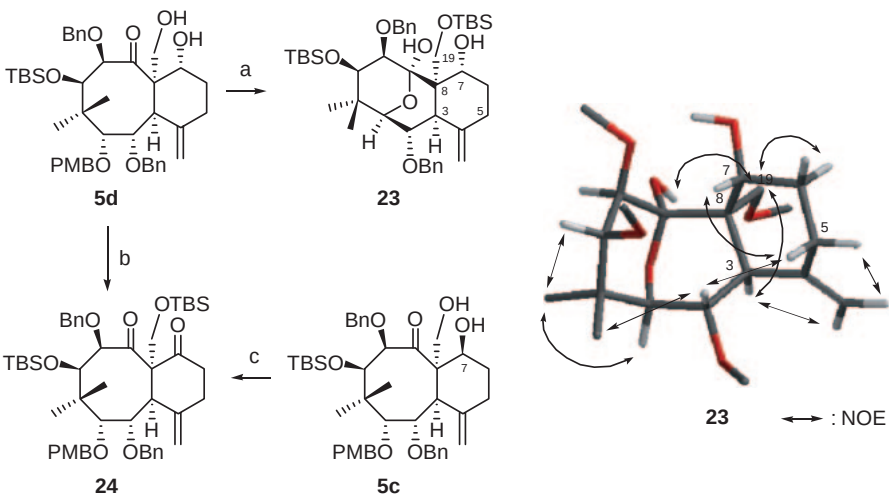
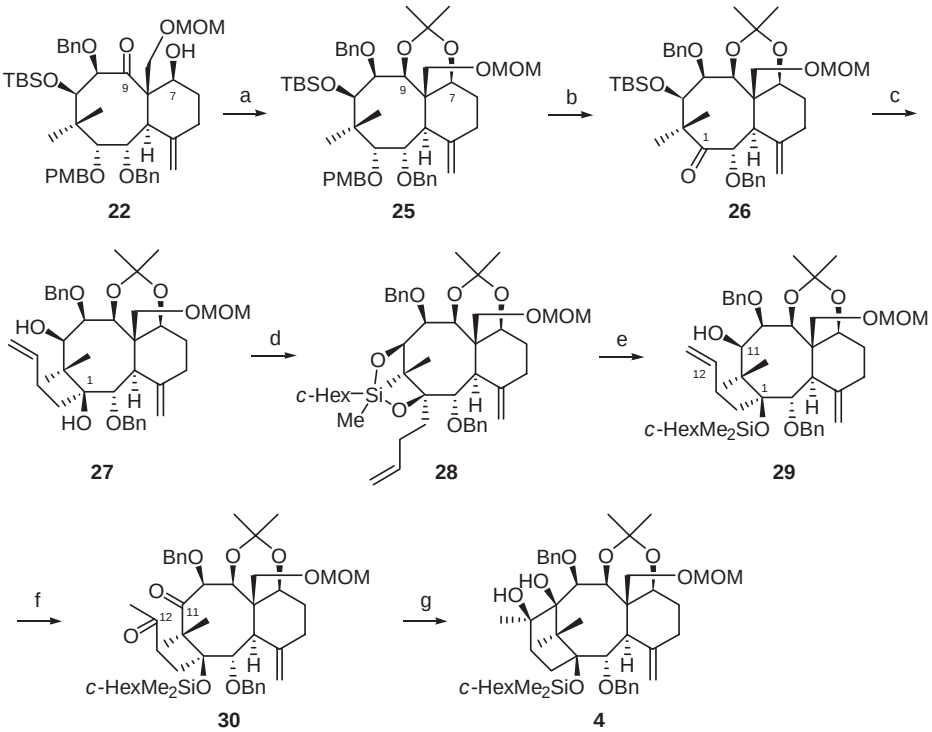


Fig. 3. ORTEP drawing of compound **22**.



Scheme 13. Reagents and conditions: a) TBSOTf, pyridine, rt (65%); DDQ, H_2O, CH_2Cl_2, 0 °C (96%). b) TBSOTf, pyridine, rt (65%); Dess–Martin periodinane, $NaHCO_3$, CH_2Cl_2 (91%). c) TBSOTf, pyridine, rt (82%); Dess–Martin periodinane, $NaHCO_3$, CH_2Cl_2, 0 °C (82%).



Scheme 14. Reagents and conditions: a) AlH_3, THF, −23 °C (81%); 2,2-dimethoxypropane, CSA, CH_2Cl_2, rt (92%). b) DDQ, phosphate buffer, CH_2Cl_2, 0 °C (quant); Dess–Martin periodinane, $NaHCO_3$, CH_2Cl_2, 0 °C (95%). c) homoallyllithium, benzene, −23 °C (97%); TBAF, THF, 50 °C (80%). d) dichloro(cyclohexyl)methylsilane, imidazole, DMF, rt (quant). e) MeLi, THF–HMPA, −78 °C (99%). f) Dess–Martin periodinane, $NaHCO_3$, CH_2Cl_2, 0 °C (97%); $PdCl_2$, DMF–H_2O, rt (83%). g) $TiCl_2$, $LiAlH_4$, THF, 40 °C (64%).

dichlorocyclohexylmethylsilane yielded silylenedioxy derivative **28** in high yield. Alkylation of **28** with methyllithium furnished **29**, which had the desired C-1 silyloxy group. Oxidation of the thus formed secondary hydroxy group at C-11 with Dess–Martin periodinane gave the corresponding ketone in good yield. The terminal olefin of **29** was then oxidized by using $PdCl_2$ in DMF–H_2O to afford the desired diketone **30** in good yield. By the above sequence of experiments, compound **30**, a precursor of ABC-ring system, was efficiently synthesized from BC-ring units. Intramolecular pinacol coupling of diketone **30** using low-valent titanium reagent,[17] prepared from $TiCl_2$ and $LiAlH_4$, gave ABC-ring system of **4** as a main product. Under the pinacol coupling conditions, the MOM group of C-19 hydroxy group was not cleaved. On the other hand, the same pinacol coupling reaction using SmI_2 did not give the desired coupling product. The stererochemistry of **4** was confirmed by NOE experiments (Fig. 4).

The conversion of **4** to 19-hydroxytaxoid **36** is shown in Scheme 15. After deprotections of benzyl groups of **4** with Na/NH_3 and of a cyclohexyldimethylsilyl group with tetrabutylammonium fluoride (TBAF), regioselective protection of the thus formed pentol with bis(trichloromethyl) carbonate afforded C-1,C-2 carbonate **31** in high yield. Deprotection of both MOM group and isopropylidene acetal under acidic conditions was tried at this point. Unexpectedly, acid hydrolysis with 6 M HCl followed by protection with diisopropylsilanediyl bis(trifloromethanesulfonate) (i-$Pr_2Si(OTf)_2$) gave cyclic ether **32** in moderate yield. Through careful observation, it was revealed that the deprotection of MOM group and the intramolecular ether formation took place rapidly while deprotection of isopropylidene acetal did not proceed completely. Since it was difficult to suppress the undesired formation of cyclic ether, C-19 hydroxy group, which was formed by selective deprotection of MOM group, was protected by the intramolecular bromo ether formation procedure[18] using *N*-bromosuccinimide (NBS). After the five-membered ether ring was formed, the deprotection of isopropylidene acetal moiety under acidic conditions proceeded smoothly, and regoiselective protection

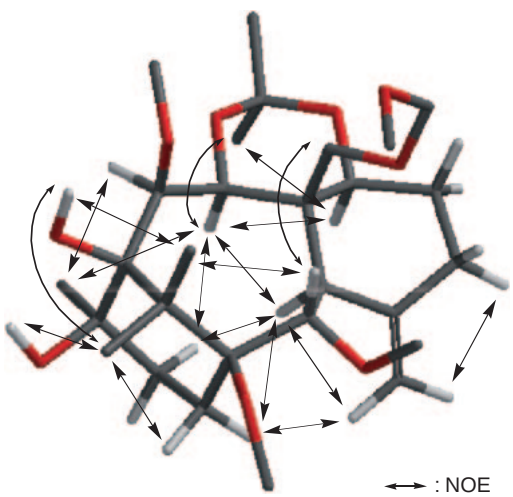
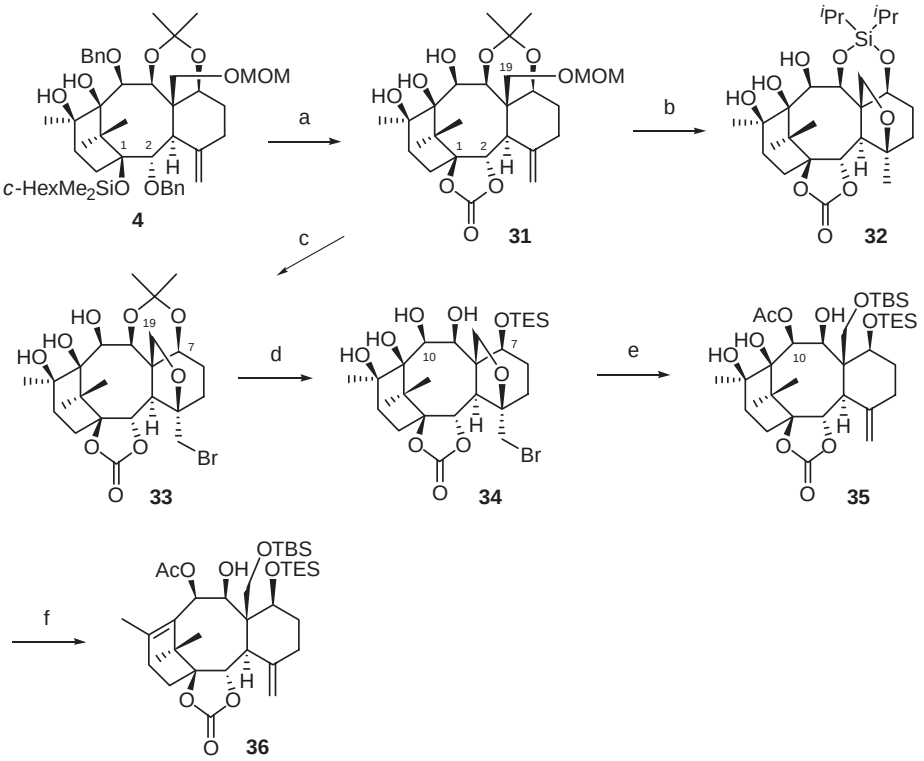


Fig. 4. Stable conformation of pinacol **4** generated by calculation. Some atoms have been omitted for clarity.



Scheme 15. Reagents and conditions: a) Na, liq. NH_3, THF, −78 °C to −45 °C; TBAF, THF, rt (94%); triphosgene, pyridine, CH_2Cl_2, −45 °C (quant). b) 6 M HCl, THF, 60 °C; *i*-$Pr_2Si(OTf)_2$, pyridine, CH_2Cl_2, −45 °C (37%). c) 6 M HCl, THF, rt (quant); NBS, CH_2Cl_2, rt (quant). d) 3 M HCl, THF; TESOTf, pyridine, −23 °C (91%). e) Zn–Ag, AcOH, EtOH, 90 °C (81%); TBSOTf, pyridine, −23 °C (83%); Ac_2O, DMAP, pyridine, rt (77%). f) thiophosgene, DMAP, $CHCl_3$, 80 °C; $P(OMe)_3$, 110 °C (43% based on 35% conversion).

of hydroxy group at C-7 with triethylsilyl trifluoromethanesulfonate (TESOTf) afforded tetrol **34**. Deprotection of cyclic bromo ether **34** with zinc–silver couple in EtOH,[19] protection of the formed primary hydroxy group with *t*-butyldimethylsilyl trifluoromethanesulfonate (TBSOTf), and the following selective acetylation of hydroxy group at C-10 gave acetate **35**. A novel 19-hydroxytaxoid **36** was synthesized from acetate **35** by a two-step procedure. Namely, conversion of the vicinal diol unit to the corresponding thiocarbonate using thiophosgene, followed by heating the thiocarbonate with trimethyl phosphite,[20] afforded 19-hydroxytaxoid **36**.

Conclusion

Stereoselective synthesis of 19-hydroxytaxoid was accomplished by starting from D-pantolactone. The synthesis of the eight-membered ring compound corresponding to the B ring of 19-hydroxytaxol was achieved by intramolecular SmI_2-mediated double aldol cyclization. The ABC ring system of 19-hydroxytaxol was constructed on the B ring by successive trimethylaluminium-assisted stereoselective conjugated addition, intramolecular SmI_2-mediated double aldol cyclization, stereoselective homoallylation, and pinacol coupling cyclization. Thus, the synthesis of 19-hydroxytaxoid from ABC ring system by olefination was performed. The advantage of our previously reported synthetic strategy for the synthesis of taxol was proved by the present experiment to synthesize taxol-analogs having additional functional groups. This is the first report on the synthesis of 19-hydroxytaxoid,[21] which is expected to be employed not only as a precursor of 19-hydroxytaxol but also as a starting material in developing new chemotherapeutic agents.

Experimental

General. All melting points were determined on a Yanagimoto micro melting point apparatus (Yanaco MP-S3) and are not corrected. Infrared (IR) spectra were recorded on a JASCO FT-IR-8900 spectrometer. ^{1}H NMR spectra were recorded on a JEOL JNM EX270L (270 MHz) spectrometer; chemical shifts (δ) are reported in parts per million relative to tetramethylsilane. Splitting patterns are designated as s, singlet; d, doublet; t, triplet; q, quartet; m, multiplet; br, broad. ^{13}C NMR spectra were recorded on an EX270L (68 MHz) spectrometer with complete proton decoupling. Chemical shifts are reported in parts per million relative to tetramethylsilane, with the solvent resonance as the internal standard ($CDCl_3$; $\delta = 77.0$ ppm, C_6D_6; $\delta = 128.0$ ppm). High resolution mass spectra (HRMS) were recorded on a JEOL JMS-AX-505HA or a JMS-700 mass spectrometer. Analytical TLC measurements were performed on Merck preparative TLC plates (silica gel 60 GF254, 0.25 mm). Column chromatography was carried out on Merck silica gel 60 (0.063–0.200 mm). Preparative thin-layer chromatography (pTLC) was carried out on silica gel Wakogel B-5F. All reactions were carried out under an argon atmosphere in dried glassware, unless otherwise noted. Dichloromethane was distilled from diphosphorus pentaoxide, then from calcium hydride, and finally dried over MS 4A; benzene and toluene were distilled from diphosphorus pentaoxide and dried over MS 4A; DMF, HMPA, and DMSO were distilled from calcium

hydride, and dried over MS 4A; and THF and diethyl ether were distilled from sodium/benzophenone immediately prior to use. All reagents were purchased from Tokyo Kasei Kogyo, Kanto Chemical, Kokusan Chemical, Wako Pure Chemical Industries, or Aldrich Chemical, and were used without further purification unless otherwise noted.

(4*S*,5*R*,7*R*,8*S*)-4,8-Bis(benzyloxy)-5,9-bis(*t*-butyldimethylsilyloxy)-7-(4-methoxybenzyloxy)-6,6-dimethylnon-1-en-3-ol (10). To a solution of aldehyde **9** (9.22 g, 12.3 mmol) in THF (100 mL) at −78 °C was added vinylmagnesium bromide (1.0 M in THF, 24.6 mL, 24.6 mmol); the reaction mixture was stirred for 1 h. The temperature was allowed to rise to 0 °C, and then the reaction was quenched with saturated aqueous NH_4Cl. The mixture was extracted with Et_2O and the combined organic layers were washed with H_2O and brine, dried over $MgSO_4$, and then filtered. The filtrate was concentrated under reduced pressure and the crude product was purified by column chromatography (silica gel, 5% EtOAc–hexane) to afford a 1:1 diastereomeric mixture of allylic alcohol **10** (9.61 g, 96%) as a colorless oil. A part of the diastereomeric mixture of **10** (157 mg) was separated by preparative TLC (15% EtOAc–hexane) to isolate **10a** (74.6 mg) and **10b** (78.3 mg). **10a** (less-polar isomer): $[\alpha]_D^{21} = -7.87$ (*c* 1.01, $CHCl_3$); IR (neat) 3056, 1612, 1510, 1260, 1061 cm^{-1}; ^1H NMR ($CDCl_3$) δ 7.35–7.21 (m, 12H), 6.87 (d, $J = 8.6$ Hz, 2H), 5.98 (ddd, $J = 17.0$, 10.3, 6.2 Hz, 1H), 5.31 (d, $J = 17.0$ Hz, 1H), 5.11 (d, $J = 10.3$ Hz, 1H), 4.72 (d, $J = 11.1$ Hz, 1H), 4.63 (d, $J = 10.5$ Hz, 1H), 4.58–4.52 (m, 1H), 4.52 (d, $J = 10.5$ Hz, 1H), 4.46 (d, $J = 11.1$ Hz, 1H), 4.32 (d, $J = 1.9$ Hz, 1H), 4.23 (s, 2H), 4.16–4.12 (brs, 1H), 4.11–4.03 (m, 1H), 3.87 (dd, $J = 11.7$, 3.8 Hz, 1H), 3.80 (s, 3H), 2.72 (d, $J = 5.9$ Hz, 1H), 3.62–3.52 (m, 2H), 1.22 (s, 3H), 1.09 (s, 3H), 0.95 (s, 9H), 0.90 (s, 9H), 0.02 (s, 3H), 0.02 (s, 3H), 0.01 (s, 3H), −0.01 (s, 3H); ^{13}C NMR ($CDCl_3$) δ 159.0, 139.3, 138.8, 138.1, 130.9, 129.1, 128.4, 128.2, 128.1, 127.7, 127.4, 127.2, 114.3, 113.7, 85.9, 82.6, 81.5, 78.1, 73.9, 73.2, 72.4, 72.2, 63.0, 55.2, 44.1, 26.3, 26.0, 22.3, 19.8, 18.5, 18.3, −3.2, −3.5, −4.8, −5.3; HRMS (EI) calcd for $C_{45}H_{70}O_7Si_2$ $[M]^+$ 778.4660, found 778.4612. **10b** (more-polar isomer): $[\alpha]_D^{21} = -22.7$ (*c* 1.10, $CHCl_3$); IR (neat) 3054, 1610, 1510, 1250, 1054 cm^{-1}; ^1H NMR ($CDCl_3$) δ 7.36–6.83 (m, 12H), 6.85 (d, $J = 8.6$ Hz, 2H), 6.10 (ddd, $J = 17.0$, 10.5, 4.9 Hz, 1H), 5.28 (d, $J = 17.0$ Hz, 1H), 5.09 (d, $J = 10.5$ Hz, 1H), 4.78 (d, $J = 11.1$ Hz, 1H), 4.62 (d, $J = 10.8$ Hz, 1H), 4.56 (d, $J = 12.2$ Hz, 1H), 4.47 (d, $J = 11.3$ Hz, 1H), 4.41–4.32 (m, 1H), 4.30 (d, $J = 11.3$ Hz, 1H), 4.26 (d, $J = 1.4$ Hz, 1H), 4.07 (d, $J = 11.6$, 1.9 Hz, 1H), 3.87 (d, $J = 11.6$, 4.6 Hz, 1H), 3.83 (d, $J = 6.2$ Hz, 1H), 3.79 (s, 3H), 3.70–3.62 (m, 1H), 3.56 (d, $J = 6.8$ Hz, 1H), 2.74 (d, $J = 5.4$ Hz, 1H), 1.16 (s, 3H), 1.02 (s, 3H), 0.94 (s, 9H), 0.92 (s, 9H), 0.09 (s, 3H), 0.08 (s, 3H), 0.03 (s, 3H), −0.02 (s, 3H); ^{13}C NMR ($CDCl_3$) δ 159.1, 138.6, 138.3, 138.0, 130.6, 129.1, 128.4, 127.9, 127.8, 127.7, 127.3, 127.2, 115.7, 113.7, 82.1, 81.1, 80.9, 79.7, 74.3, 73.9, 73.4, 72.2, 62.0, 55.2, 43.6, 26.2, 26.0, 22.1, 19.3, 18.7, 18.3, −3.4, −3.5, −5.0, −5.3; HRMS (EI) calcd for $C_{45}H_{70}O_7Si_2$ $[M]^+$ 778.4660, found 778.4683.

(2*S*,3*R*,5*R*,6*S*)-2,6-Bis(benzyloxy)-5-(*t*-butyldimethylsilyloxy)-3-(4-methoxybenzyloxy)-4,4-dimethylnon-8-ene-1,7-diol (11). To a solution of a diastereomeric mixture of allylic alcohol **10** (2.07 g, 2.67 mmol) in THF (100 mL) at 0 °C was added HCl (1 M, 160 mL, 160 mmol). The reaction mixture was stirred for 1 h at 0 °C and then the temperature was allowed to rise to room temperature. After the reaction mixture was stirred for 2 h, it was diluted with hexane at room temperature and neutralized with saturated aqueous $NaHCO_3$ at 0 °C. The mixture was extracted with Et_2O, and the organic layer was washed with H_2O and brine, dried over $MgSO_4$, and then filtered. The filtrate was concentrated under reduced pressure and the crude product was purified by column chromatography (silica gel, 20–30% EtOAc–hexane) to afford a diastereomeric mixture of diol **11** (1.55 g, 88%) as a colorless oil. A part of the diastereomeric mixture of **11** (145 mg) was separated by preparative TLC (30% EtOAc–hexane) to isolate **11a** (68.5 mg) and **11b** (74.4 mg). **11a** (less-polar isomer): $[\alpha]_D^{21} = -15.1$ (*c* 0.91, $CHCl_3$); IR (neat) 3355, 3116, 1620, 1519, 1095 cm^{-1}; ^1H NMR ($CDCl_3$) δ 7.35–7.25 (m, 12H), 6.91 (d, $J = 8.4$ Hz, 2H), 5.92 (ddd, $J = 16.7$, 10.8, 5.7 Hz, 1H), 5.30 (d, $J = 17.0$ Hz, 1H), 5.12 (d, $J = 10.3$ Hz, 1H), 4.78 (d, $J = 10.5$ Hz, 1H), 4.57 (s, 2H), 4.52 (d, $J = 6.5$ Hz, 1H), 4.48 (d, $J = 6.5$ Hz, 1H), 4.42 (d, $J = 11.1$ Hz, 1H), 4.24 (d, $J = 1.9$ Hz, 1H), 3.97–3.75 (m, 3H), 3.80 (s, 3H), 3.72–3.67 (m, 1H), 3.61–3.48 (m, 2H), 2.02 (brs, 1H), 1.14 (s, 3H), 1.12 (s, 3H), 0.93 (s, 9H), 0.10 (s, 3H), 0.08 (s, 3H); ^{13}C NMR ($CDCl_3$) δ 159.2, 138.9, 137.9, 137.8, 130.5, 129.1, 128.6, 128.2, 127.9, 127.9, 127.6, 127.2, 115.7, 113.8, 83.1, 82.7, 80.9, 78.1, 74.6, 73.9, 73.3, 71.7, 61.7, 55.3, 43.5, 26.3, 21.8, 19.5, 18.7, −3.3, −4.5; HRMS (EI) calcd for $C_{39}H_{56}O_7Si$ $[M]^+$ 664.3795, found 664.3822. **11b** (more-polar isomer): $[\alpha]_D^{17} = -32.3$ (*c* 0.90, $CHCl_3$); IR (neat) 3370, 3108, 1596, 1511, 1095 cm^{-1}; ^1H NMR ($CDCl_3$) δ 7.32–7.21 (m, 12H), 6.85 (d, $J = 8.5$ Hz, 2H), 6.09 (ddd, $J = 17.0$, 10.5, 5.1, 1H), 5.31 (d, $J = 17.0$ Hz, 1H), 5.14 (d, $J = 10.8$ Hz, 1H), 4.77 (d, $J = 10.8$ Hz, 1H), 4.60 (d, $J = 11.6$ Hz, 1H), 4.55 (s, 2H), 4.53 (d, $J = 11.3$ Hz, 1H), 4.45 (d, $J = 11.3$ Hz, 1H), 4.41–4.33 (m, 1H), 4.25 (d, $J = 1.9$ Hz, 1H), 3.98–3.80 (m, 3H), 3.79 (s, 3H), 3.75–3.68 (m, 1H), 3.58 (dd, $J = 6.5$, 1.9 Hz, 1H), 2.55 (brs, 1H), 2.20 (brs, 1H), 1.14 (s, 3H), 1.07 (s, 3H), 0.94 (s, 9H), 0.11 (s, 3H), 0.04 (s, 3H); ^{13}C NMR ($CDCl_3$) δ 159.1, 138.9, 138.5, 137.8, 130.5, 129.3, 128.5, 128.2, 127.8, 127.8, 127.4, 127.2, 115.0, 113.8, 84.9, 82.7, 81.1, 78.4, 74.7, 72.9, 72.5, 71.5, 61.4, 55.2, 43.9, 26.3, 22.2, 19.9, 18.5, −3.1, −4.5; HRMS (EI) calcd for $C_{39}H_{56}O_7Si$ $[M]^+$ 664.3795, found 664.3766.

(2*S*,3*R*,5*R*,6*S*)-2,6-Bis(benzyloxy)-3-(*t*-butyldimethylsilyloxy)-5-(4-methoxybenzyloxy)-4,4-dimethyl-1-oxiranylheptane-1,7-diol. To a stirred solution of **11** (2.28 g, 3.44 mmol) in CH_2Cl_2 (50 mL) at 0 °C was added *m*-CPBA (1.78 g, 10.32 mmol) and then the mixture was heated to reflux at 50 °C. After the reaction mixture was stirred for 8 h, it was cooled to 0 °C and then the reaction was quenched with saturated aqueous Na_2SO_3. The mixture was extracted with CH_2Cl_2 and the combined organic layers were washed with saturated aqueous $NaHCO_3$, H_2O, and brine, dried over $MgSO_4$, and then filtered. The filtrate was concentrated under reduced pressure and the residue was purified by column chromatography (silica gel, 25–35% EtOAc–hexane) to give (2*S*,3*R*,5*R*,6*S*)-2,6-bis(benzyloxy)-3-(*t*-butyldimethylsilyloxy)-5-(4-methoxybenzyloxy)-4,4-dimethyl-1-oxiranylheptane-1,7-diol (a mixture of 4 diastereomers, 2.24 g, 96%) as colorless oils. IR (neat) 3559, 3112, 1023, 1252, 1103 cm^{-1}; ^1H NMR ($CDCl_3$) δ 7.29–7.12 (m, 12H), 6.82–6.78 (m, 2H), 4.75–4.20 (m, 7H), 3.81–3.62 (m, 8H), 3.42–1.98 (m, 4H), 1.08–1.03 (m, 6H), 0.88–0.85 (m, 9H), 0.60–0.00 (m, 6H).

(2*R*,3*R*,5*R*,6*R*)-2,6-Bis(benzyloxy)-5-(*t*-butyldimethylsilyloxy)-3-(4-methoxybenzyloxy)-4,4-dimethyl-7-oxiranyl-7-oxoheptanal (8). To a solution of oxalyl chloride (0.94 mL, 10.8 mmol) in CH_2Cl_2 (40 mL) at −78 °C was added DMSO (1.28 mL, 18.0 mmol). After the reaction mixture was stirred for 15 min at −78 °C, a solution of a diastereomeric mixture of (2*S*,3*R*,5*R*,6*S*)-2,6-bis(benzyloxy)-3-(*t*-butyldimethylsilyloxy)-5-(4-methoxybenzyl-

oxy)-4,4-dimethyl-1-oxiranylheptane-1,7-diol (2.45 g, 3.60 mmol) in CH_2Cl_2 (30 mL) was added. The stirring was continued at −78 °C for 30 min and then triethylamine (3.52 mL, 25.2 mmol) was added. The reaction mixture was allowed to warm to room temperature and then the reaction was quenched with H_2O. The mixture was extracted with CH_2Cl_2, and the combined organic layers were washed with brine, and dried over $MgSO_4$. After filtration of the mixture and evaporation of the solvent, the crude product was purified by column chromatography (silica gel, 10–20% EtOAc–hexane) to afford a 1:1 diastereomeric mixture of α,β-epoxyketo aldehyde **8** (2.33 g, 96%) as a colorless oil. A part of the diastereomeric mixture of **8** (170 mg) was separated by preparative TLC (20% EtOAc–hexane) to isolate **8a** (91.1 mg) and **8b** (77.2 mg). **8a** (less-polar isomer): $[\alpha]_D^{22} = +20.0$ (*c* 1.06, $CHCl_3$); IR (neat) 3116, 1712, 1079 cm^{-1}; ^1H NMR ($CDCl_3$) δ 9.59 (d, $J = 2.2$ Hz, 1H), 7.26–7.12 (m, 12H), 6.80 (d, $J = 8.9$ Hz, 2H), 4.52 (d, $J = 11.6$ Hz, 1H), 4.51 (d, $J = 11.1$ Hz, 1H), 4.41 (s, 1H), 4.37 (s, 1H), 4.31 (d, $J = 9.5$ Hz, 1H), 4.27 (d, $J = 11.3$ Hz, 1H), 4.16 (s, 3H), 3.98–3.93 (m, 2H), 3.85 (d, $J = 4.3$ Hz, 1H), 3.72 (s, 3H), 2.84 (dd, $J = 7.0$, 4.3 Hz, 1H), 2.79 (dd, $J = 6.8$, 2.4 Hz, 1H), 0.89 (s, 3H), 0.87 (s, 3H), 0.84 (s, 9H), 0.02 (s, 3H), 0.00 (s, 3H); ^{13}C NMR ($CDCl_3$) δ 206.9, 201.3, 159.2, 136.9, 136.8, 129.9, 129.3, 128.6, 128.5, 128.4, 128.3, 128.2, 128.1, 128.1, 113.7, 86.1, 83.9, 83.4, 77.9, 73.7, 73.2, 72.5, 55.2, 51.7, 47.7, 44.3, 26.3, 21.4, 18.9, 18.6, −3.0, −4.7; HRMS (EI) calcd for $C_{39}H_{52}O_8Si$ $[M]^+$ 676.3431, found 676.3468. **8b** (more-polar isomer): $[\alpha]_D^{23} = -7.00$ (*c* 0.96, $CHCl_3$); IR (neat) 3124, 1704, 1050 cm^{-1}; ^1H NMR ($CDCl_3$) δ 9.61 (d, $J = 1.9$ Hz, 1H), 7.27–7.11 (m, 12H), 6.79 (d, $J = 8.9$ Hz, 2H), 4.54 (d, $J = 11.3$ Hz, 1H), 4.49 (d, $J = 10.8$ Hz, 1H), 4.39 (d, $J = 11.1$ Hz, 1H), 4.29 (d, $J = 11.3$ Hz, 1H), 4.26–4.14 (m, 2H), 4.09 (d, $J = 4.9$ Hz, 1H), 4.01–3.93 (m, 2H), 3.87 (d, $J = 4.6$ Hz, 1H), 3.72 (s, 3H), 3.70 (d, $J = 8.1$ Hz, 1H), 2.76 (dd, $J = 6.8$, 4.9Hz, 1H), 2.52 (dd, $J = 6.8$, 2.4 Hz, 1H), 1.00 (s, 3H), 0.92 (s, 3H), 0.86 (s, 9H), 0.03 (s, 3H), 0.00 (s, 3H); ^{13}C NMR ($CDCl_3$) δ 206.9, 201.3, 159.2, 136.9, 136.8, 130.0, 129.3, 128.6, 128.5, 128.4, 128.3, 128.3, 128.1, 128.1, 113.7, 86.2, 83.9, 83.5, 77.9, 73.8, 73.3, 72.5, 55.2, 51.7, 47.7, 44.3, 26.3, 21.5, 18.9, 18.6, −2.9, −4.8; HRMS (EI) calcd for $C_{39}H_{52}O_8Si$ $[M]^+$ 676.3431, found 676.3396.

(2*R*,3*R*,5*R*,6*S*,7*R*,8*S*)-2,6-Bis(benzyloxy)-3-(*t*-butyldimethylsilyloxy)-7-hydroxy-8-hydroxymethyl-5-(4-methoxybenzyloxy)-4,4-dimethylcyclooctanone (6a) and (2*R*,3*R*,5*R*,6*S*,7*S*,8*R*)-2,6-Bis(benzyloxy)-3-(*t*-butyldimethylsilyloxy)-7-hydroxy-8-hydroxymethyl-5-(4-methoxybenzyloxy)-4,4-dimethylcyclooctanone (6b). To a solution of a diastereomeric mixture of α,β-epoxyketo aldehyde **8** (1.54 g, 2.38 mmol) in THF (100 mL) were added a solution of SmI_2 in THF (0.1 M, 71.4 mL, 7.14 mmol) and *i*-PrOH (300 mg, 4.76 mmol) immediately in succession at −78 °C. The reaction mixture was stirred for 30 min at the same temperature and then saturated aqueous NH_4Cl was added. The mixture was filtered through a short pad of Celite and the filtrate was extracted with Et_2O. The combined organic layers were washed with H_2O and brine, and dried over $MgSO_4$. After filtration of the mixture and evaporation of the solvent, the crude product was purified by column chromatography (silica gel, 20–45% EtOAc–hexane) to afford a 1:1 diastereomeric mixture of the cyclized product **6** (1.47 g, 91%) as a colorless oil. A part of the diastereomeric mixture of **6** (45.5 mg) was separated by preparative TLC (40% EtOAc–hexane) to isolate **6a** (24.7 mg) and **6b** (20.3 mg). **6a**: $[\alpha]_D^{21} = -4.16$ (*c* 0.99, $CHCl_3$); IR (neat) 3480, 1699 cm^{-1}; ^1H NMR ($CDCl_3$) δ 7.40–7.15 (m, 12H), 6.88 (d, $J = 8.6$ Hz, 2H), 4.95–4.20 (m, 5H), 4.18–3.70 (m, 6H), 3.81 (s, 3H), 3.57 (brs, 1H), 3.15–3.05 (m, 1H), 1.90–1.81 (m, 1H), 1.13–0.76 (m, 9H), 0.74 (s, 6H), −0.02 (s, 6H); ^{13}C NMR ($CDCl_3$) very broadened spectra; HRMS (FAB) calcd for $C_{39}H_{54}NaO_8$ $[M + Na]^+$ 701.3486, found 701.3486. **6b**: $[\alpha]_D^{22} = +25.4$ (*c* 0.95, $CHCl_3$); IR (neat) 3454, 1708 cm^{-1}; ^1H NMR ($CDCl_3$) δ 7.38–7.18 (m, 12H), 6.84 (d, $J = 8.1$ Hz, 2H), 4.94 (d, $J = 3.4$ Hz, 1H), 4.78–4.45 (m, 5H), 4.16–3.79 (m, 5H), 3.77 (s, 3H), 3.70–3.31 (m, 2H), 2.96 (brs, 1H), 2.15–2.05 (m, 1H), 1.17 (s, 3H), 1.14 (s, 3H), 0.88 (s, 9H), 0.00 (s, 3H), −0.12 (s, 3H); ^{13}C NMR ($CDCl_3$) very broadened spectra; HRMS (FAB) calcd for $C_{39}H_{54}NaO_8$ $[M + Na]^+$ 701.3486, found 701.3482.

(1*R*,2*S*,3*R*,4*S*,5*R*,7*R*,8*R*)-4,8-Bis(benzyloxy)-7-(*t*-butyldimethylsilyloxy)-2-hydroxymethyl-6,6-dimethyl-9-oxabicyclo[3.3.1]-nonane-1,3-diol (14a). To a solution of bis-aldol **6a** (15 mg, 0.04 mmol) in CH_2Cl_2 (7 mL) at 0 °C were added H_2O (1.3 mL) and DDQ (13 mg, 0.057 mmol). The reaction mixture was stirred at room temperature for 1 h and then H_2O was added. The mixture was extracted with CH_2Cl_2 and the combined organic layers were washed with H_2O and brine, and dried over Na_2SO_4. After filtration of the mixture and evaporation of the solvent, the crude product was purified by preparative TLC (50% EtOAc–hexane) to afford hemiacetal **14a** (11.4 mg, 51%) as a colorless oil. $[\alpha]_D^{25} = +9.39$ (*c* 1.15, benzene); IR (neat) 3378, 3023, 1697, 1079 cm^{-1}; ^1H NMR ($CDCl_3$) δ 7.49–7.33 (m, 10H), 6.09 (t, $J = 3.5$ Hz, 1H), 6.02 (s, 1H), 5.12 (d, $J = 10.5$ Hz, 1H), 4.81 (d, $J = 11.1$ Hz, 1H), 4.74 (d, $J = 11.1$ Hz, 1H), 4.46 (d, $J = 11.1$ Hz, 1H), 4.36 (t, $J = 3.5$ Hz, 1H), 4.23 (d, $J = 4.3$ Hz, 1H), 4.15–4.07 (m, 1H), 3.85 (d, $J = 4.3$ Hz, 1H), 3.69–3.58 (m, 2H), 3.02 (dd, $J = 4.3$, 8.1 Hz, 1H), 1.98–1.90 (m, 1H), 1.07 (s, 3H), 1.05 (s, 3H), 0.90 (s, 9H), 0.07 (s, 3H), 0.01 (s, 3H); ^{13}C NMR ($CDCl_3$) δ 138.3, 137.7, 129.0, 128.4, 128.4, 128.2, 127.9, 127.7, 95.8, 82.4, 81.1, 77.9, 76.7, 76.0, 71.5, 67.8, 60.7, 49.9, 40.1, 31.4, 26.2, 23.5, 18.9, −4.3, −4.6; HRMS (FAB) calcd for $C_{31}H_{46}NaO_7Si$ $[M + Na]^+$ 581.2911, found 581.2910.

(1*R*,2*R*,3*S*,4*S*,5*R*,7*R*,8*R*)-4,8-Bis(benzyloxy)-7-(*t*-butyldimethylsilyloxy)-2-hydroxymethyl-6,6-dimethyl-9-oxabicyclo[3.3.1]-nonane-1,3-diol (14b). To a solution of bis-aldol **6b** (10 mg, 0.027 mmol) in CH_2Cl_2 (5 mL) at 0 °C were added H_2O (1 mL) and DDQ (8.7 mg, 0.057 mmol). The reaction mixture was stirred at room temperature for 1 h and then H_2O was added. The mixture was extracted with CH_2Cl_2 and the combined organic layers were washed with H_2O, brine and, dried over Na_2SO_4. After filtration of the mixture and evaporation of the solvent, the crude product was purified by preparative TLC (50% EtOAc–hexane) to afford hemiacetal **14b** (14.3 mg, 64%) as a colorless oil. $[\alpha]_D^{25} = -33.6$ (*c* 0.50, benzene); IR (neat) 3394, 3077, 1704, 1033 cm^{-1}; ^1H NMR ($CDCl_3$) δ 7.37–7.24 (m, 10H), 5.40 (t, $J = 9.7$ Hz, 1H), 4.84 (d, $J = 11.3$ Hz, 1H), 4.76 (d, $J = 4.6$ Hz, 1H), 4.73 (d, $J = 11.1$ Hz, 1H), 4.72 (d, $J = 11.1$ Hz, 1H), 4.68 (d, $J = 11.3$ Hz, 1H), 4.33 (dd, $J = 3.5$, 11.1 Hz, 1H), 3.85 (dd, $J = 8.8$, 11.1 Hz, 1H), 3.70–3.60 (m, 3H), 3.57 (d, $J = 4.6$ Hz, 1H), 3.10–3.04 (m, 1H), 2.83 (ddd, $J = 3.2$, 8.9, 12.2 Hz, 1H), 1.30 (s, 3H), 1.09 (s, 6H), 0.99 (s, 9H), 0.07 (s, 3H), 0.00 (s, 3H); ^{13}C NMR ($CDCl_3$) δ 138.8, 137.7, 129.0, 128.4, 128.4, 128.2, 127.9, 127.7, 95.8, 82.4, 81.1, 77.9, 76.7, 76.0, 71.5, 67.8, 60.7, 49.9, 40.1, 31.4, 26.2, 23.5, 18.9, −2.8, −5.1; HRMS (FAB) calcd for $C_{31}H_{46}NaO_7Si$ $[M + Na]^+$ 581.2911, found 581.2910.

(2*R*,3*R*,5*R*,6*S*,7*R*,8*S*)-2,6-Bis(benzyloxy)-3-(*t*-butyldimethylsilyloxy)-7-hydroxy-5-(4-methoxybenzyloxy)-4,4-dimethyl-8-(triethylsilyloxymethyl)cyclooctanone and (2*R*,3*R*,5*R*,6*S*,7*S*,8*R*)-2,6-Bis(benzyloxy)-3-(*t*-butyldimethylsilyloxy)-7-hydroxy-

5-(4-methoxybenzyloxy)-4,4-dimethyl-8-(triethylsilyloxymethyl)cyclooctanone. To a solution of a diastereomeric mixture of **6a** and **6b** (2.36 g, 3.48 mmol) in pyridine (20 mL) at 0 °C was added TESCl (0.64 mL, 3.82 mmol) dropwise. After the reaction mixture was stirred for 1 h, the reaction was quenched with phosphate buffer (pH = 7) and the mixture was extracted with EtOAc. The combined organic layers were washed with saturated aqueous $CuSO_4$, H_2O, and brine, and then dried over $MgSO_4$. After filtration, the filtrate was concentrated under reduced pressure and the obtained crude product was purified by column chromatography (silica gel, 10–15% EtOAc–hexane) to give a mixture of (2*R*,3*R*,5*R*,6*S*,7*R*,8*S*)-2,6-bis(benzyloxy)-3-(*t*-butyldimethylsilyloxy)-7-hydroxy-5-(4-methoxybenzyloxy)-4,4-dimethyl-8-(triethylsilyloxymethyl)cyclooctanone and (2*R*,3*R*,5*R*,6*S*,7*S*,8*R*)-2,6-bis(benzyloxy)-3-(*t*-butyldimethylsilyloxy)-7-hydroxy-5-(4-methoxybenzyloxy)-4,4-dimethyl-8-(triethylsilyloxymethyl)cyclooctanone (2.63 g, 95%) as a colorless oil. A part of the diastereomeric mixture of TES ethers (62.3 mg) was separated by preparative TLC (20% EtOAc–hexane) to isolate (2*R*,3*R*,5*R*,6*S*,7*R*,8*S*)-2,6-bis(benzyloxy)-3-(*t*-butyldimethylsilyloxy)-7-hydroxy-5-(4-methoxybenzyloxy)-4,4-dimethyl-8-(triethylsilyloxymethyl)cyclooctanone (29.2 mg) and (2*R*,3*R*,5*R*,6*S*,7*S*,8*R*)-2,6-bis(benzyloxy)-3-(*t*-butyldimethylsilyloxy)-7-hydroxy-5-(4-methoxybenzyloxy)-4,4-dimethyl-8-(triethylsilyloxymethyl)cyclooctanone (30.3 mg). (2*R*,3*R*,5*R*,6*S*,7*R*,8*S*)-2,6-bis(benzyloxy)-3-(*t*-butyldimethylsilyloxy)-7-hydroxy-5-(4-methoxybenzyloxy)-4,4-dimethyl-8-(triethylsilyloxymethyl)cyclooctanone: $[\alpha]_D^{21} = +0.75$ (*c* 0.50, benzene); IR (neat) 3332, 3023, 1712, 1042 cm^{-1}; ^1H NMR ($CDCl_3$) δ 7.38–7.08 (m, 12H), 6.83 (d, $J = 8.6$ Hz, 2H), 4.94–4.29 (m, 7H), 4.16–3.83 (m, 4H), 3.75 (s, 3H), 3.73–3.60 (m, 2H), 2.77 (d, $J = 11.1$ Hz, 1H), 0.98–0.75 (m, 18H), 0.66 (s, 6H), 0.55 (q, $J = 7.8$ Hz, 6H), 0.03 (s, 3H), −0.08 (s, 3H); ^{13}C NMR ($CDCl_3$) very broadened spectra; HRMS (EI) calcd for $C_{45}H_{68}O_8Si_2$ $[M]^+$ 792.4453, found 792.4412. (2*R*,3*R*,5*R*,6*S*,7*S*,8*R*)-2,6-bis(benzyloxy)-3-(*t*-butyldimethylsilyloxy)-7-hydroxy-5-(4-methoxybenzyloxy)-4,4-dimethyl-8-(triethylsilyloxymethyl)cyclooctanone: $[\alpha]_D^{22} = +17.4$ (*c* 0.83, benzene); IR (neat) 3185, 3085, 1720, 1095 cm^{-1}; ^1H NMR ($CDCl_3$) δ 7.40–7.08 (m, 12H), 6.80 (d, $J = 8.6$ Hz, 2H), 4.90 (d, $J = 3.2$ Hz, 1H), 4.68 (d, $J = 11.3$ Hz, 1H), 4.67 (d, $J = 11.1$ Hz, 1H), 4.63–4.39 (m, 3H), 4.33 (d, $J = 11.3$ Hz, 1H), 4.16–3.98 (m, 2H), 3.94–3.82 (m, 2H), 3.74 (s, 3H), 3.72–3.65 (brm, 1H), 3.54–3.40 (brm, 1H), 3.34 (d, $J = 8.10$ Hz, 1H), 2.91 (s, 1H), 1.20 (s, 3H), 1.13 (s, 3H), 0.91 (t, $J = 7.8$ Hz, 9H), 0.84 (s, 9H), 0.55 (q, $J = 7.8$ Hz, 6H), −0.03 (s, 3H), −0.14 (s, 3H); ^{13}C NMR ($CDCl_3$) very broadened spectra; HRMS (EI) calcd for $C_{45}H_{68}O_8Si_2$ $[M]^+$ 792.4453, found 792.4409.

(1*R*,2*S*,3*R*,5*R*,6*R*,8*S*)-2,6-Bis(benzyloxy)-5-(*t*-butyldimethylsilyloxy)-3-(4-methoxybenzyloxy)-4,4-dimethyl-7-oxo-8-(triethylsilyloxymethyl)cyclooctyl Acetate (15a) and (1*S*,2*S*,3*R*,5*R*,6*R*,8*R*)-2,6-Bis(benzyloxy)-5-(*t*-butyldimethylsilyloxy)-3-(4-methoxybenzyloxy)-4,4-dimethyl-7-oxo-8-(triethylsilyloxymethyl)cyclooctyl Acetate (15b). To a solution of a mixture of (2*R*,3*R*,5*R*,6*S*,7*R*,8*S*)-2,6-bis(benzyloxy)-3-(*t*-butyldimethylsilyloxy)-7-hydroxy-5-(4-methoxybenzyloxy)-4,4-dimethyl-8-(triethylsilyloxymethyl)cyclooctanone and (2*R*,3*R*,5*R*,6*S*,7*S*,8*R*)-2,6-bis(benzyloxy)-3-(*t*-butyldimethylsilyloxy)-7-hydroxy-5-(4-methoxybenzyloxy)-4,4-dimethyl-8-(triethylsilyloxymethyl)cyclooctanone (7.78 g, 9.81 mmol) in pyridine (50 mL) at 0 °C were added DMAP (119.8 mg, 0.98 mmol) and acetic anhydride (27.8 mL, 294.2 mmol). After the reaction mixture was stirred for 30 min at 0 °C and for 30 min at room temperature, the reaction was quenched with phosphate buffer (pH = 7). The mixture was extracted with EtOAc and the combined organic extracts were washed with saturated aqueous $CuSO_4$, H_2O, and brine, and then dried over $MgSO_4$. After filtration, the filtrate was concentrated under reduced pressure and the obtained crude product was purified by column chromatography (silica gel, 5–15% EtOAC–hexane) to give a mixture of **15a** and **15b** (7.76 g, 96%) as colorless oils. A part of the diastereomeric mixture of **15** (83.0 mg) was separated by preparative TLC (20% EtOAc–hexane) to isolate **15a** (38.7 mg) and **15b** (41.2 mg). **15a**: mp 140–142 °C; $[\alpha]_D^{20} = +44.4$ (*c* 0.50, benzene); IR (neat) 3162, 3076, 1718, 1049 cm^{-1}; ^1H NMR ($CDCl_3$) δ 7.37–7.23 (m, 10H), 7.19 (d, $J = 8.4$ Hz, 2H), 6.87 (d, $J = 8.4$ Hz, 2H), 6.05 (s, 1H), 4.83 (d, $J = 11.6$ Hz, 1H), 4.73 (d, $J = 12.2$ Hz, 1H), 4.66 (d, $J = 11.6$ Hz, 1H), 4.50 (d, $J = 11.3$ Hz, 1H), 4.45 (d, $J = 12.2$ Hz, 1H), 4.35 (d, $J = 3.3$ Hz, 1H), 4.18 (d, $J = 11.3$ Hz, 1H), 3.81 (s, 3H), 3.80–3.75 (m, 2H), 3.53 (s, 1H), 3.31 (s, 1H), 2.03 (s, 3H), 0.99 (t, $J = 7.8$ Hz, 9H), 0.97 (s, 3H), 0.85 (s, 3H), 0.80 (s, 9H), 0.63 (q, $J = 7.8$ Hz, 6H), 0.04 (s, 3H), 0.02 (s, 3H); ^{13}C NMR ($CDCl_3$) very broadened spectra; HRMS (EI) calcd for $C_{47}H_{70}O_9Si_2$ $[M]^+$ 834.4558, found 834.4537. **15b**: $[\alpha]_D^{20} = -5.81$ (*c* 0.50, benzene); IR (neat) 3154, 3077, 1718, 1033 cm^{-1}; ^1H NMR ($CDCl_3$) δ 7.13–6.87 (m, 10H), 6.82 (d, $J = 8.4$ Hz, 2H), 6.52 (d, $J = 8.4$ Hz, 2H), 4.66 (d, $J = 3.8$ Hz, 1H), 4.53 (d, $J = 11.3$ Hz, 1H), 4.38 (d, $J = 11.1$ Hz, 1H), 4.33 (d, $J = 11.1$ Hz, 1H), 4.23–4.15 (m, 1H), 4.05 (d, $J = 11.3$ Hz, 1H), 3.90 (d, $J = 10.5$ Hz, 1H), 3.80 (d, $J = 10.5$ Hz, 1H), 3.70–3.64 (m, 2H), 3.46 (s, 3H), 3.36 (d, $J = 9.5$ Hz, 1H), 2.80 (s, 1H), 1.80 (s, 3H), 0.84 (s, 3H), 0.82 (s, 3H), 0.64 (t, $J = 7.8$ Hz, 9H), 0.57 (s, 9H), 0.27 (q, $J = 7.8$ Hz, 6H), −0.34 (s, 3H), −0.46 (s, 3H); ^{13}C NMR ($CDCl_3$) very broadened spectra; HRMS (EI) calcd for $C_{47}H_{70}O_9Si_2$ $[M]^+$ 834.4558, found 834.4527.

(4*S*,5*R*,7*R*,8*R*)-4,8-Bis(benzyloxy)-7-(*t*-butyldimethylsilyloxy)-5-(4-methoxybenzyloxy)-6,6-dimethyl-2-(triethylsilyloxymethyl)cyclooct-2-enone (16). To a solution of a diastereomeric mixture of **15** (1.61 g, 2.08 mmol) in benzene (2 mL) at room temperature was added DBU (8 mL) dropwise. The reaction mixture was stirred for 30 min at room temperature. The mixture was diluted with EtOAc (10 mL) and the reaction was quenched with phosphate buffer (pH = 7) at 0 °C. The mixture was extracted with EtOAc and the combined organic layers were washed with saturated aqueous NH_4Cl, H_2O, and brine, and then dried over $MgSO_4$. After filtration, the filtrate was concentrated under reduced pressure and the crude product was purified by column chromatography (silica gel, 10–40% EtOAc–hexane) to afford **16** (0.86 g, 59%) as a colorless oil and **17** (0.33 g, 26%) as a colorless oil. $[\alpha]_D^{28} = +34.9$ (*c* 1.03, benzene); IR (neat) 3162, 3065, 1720, 917 cm^{-1}; ^1H NMR ($CDCl_3$) δ 7.34–7.12 (m, 12H), 6.84 (d, $J = 8.4$ Hz, 2H), 6.52 (s, 1H), 5.46 (s, 1H), 4.63 (d, $J = 11.3$ Hz, 1H), 4.60 (d, $J = 11.6$ Hz, 1H), 4.47–4.22 (m, 5H), 4.07 (s, 1H), 4.01 (d, $J = 12.2$ Hz, 1H), 3.90 (s, 1H), 3.81 (s, 3H), 3.41 (s, 1H), 1.10–0.86 (m, 24H), 0.65 (q, $J = 7.8$ Hz, 6H), 0.07 (s, 6H); ^{13}C NMR ($CDCl_3$) very broadened spectra; HRMS (EI) calcd for $C_{45}H_{66}O_7Si_2$ $[M]^+$ 774.4347, found 774.4348.

(4*S*,5*R*,7*R*,8*R*)-4,8-Bis(benzyloxy)-7-(*t*-butyldimethylsilyloxy)-2-hydroxymethyl-5-(4-methoxybenzyloxy)-6,6-dimethylcyclooct-2-enone (17). To a solution of TES-protected enone **16** (633 mg, 0.82 mmol) in THF (50 mL) at 0 °C was added HCl (0.1 M, 9.0 mL, 0.90 mmol) dropwise. After the reaction mixture was stirred for 40 min, hexane (20 mL) was added and then the reaction was quenched with saturated aqueous $NaHCO_3$. The mixture was extracted with Et_2O and the combined organic layers were washed with brine and dried over $MgSO_4$. After filtration, the solvent was

removed under reduced pressure and the crude product was purified by preparative TLC (30% EtOAc–hexane) to afford **17** (514 mg, 95%) as a colorless oil. $[\alpha]_D^{28} = +52.3$ (*c* 1.17, benzene); IR (liquid film) 3453, 1672 cm^{-1}; ^1H NMR ($CDCl_3$) δ 7.34–7.14 (m, 10H), 7.08 (d, $J = 8.7$ Hz, 2H), 6.76 (d, $J = 8.7$ Hz, 2H), 6.39 (brs, 1H), 5.37 (brs, 1H), 4.57 (d, $J = 11.7$ Hz, 1H), 4.50–4.06 (brm, 6H), 4.01 (d, $J = 11.7$ Hz, 1H), 3.90 (s, 1H), 3.79 (s, 3H), 3.43 (s, 1H), 2.40 (t, $J = 5.4$ Hz, 1H), 0.99 (s, 3H), 0.95 (s, 3H), 0.85 (s, 9H), 0.05 (s, 6H); ^{13}C NMR ($CDCl_3$) δ 201.7, 158.8, 139.8, 137.9, 137.5, 135.9, 129.5, 129.3, 128.5, 128.4, 128.3, 127.9, 127.8, 127.6, 113.4, 93.6, 90.7, 77.0, 75.5, 74.4, 71.6, 70.8, 65.1, 55.1, 43.9, 30.3, 25.8, 19.5, 18.0, −4.2, −5.1; HRMS (EI) calcd for $C_{39}H_{52}O_7Si$ $[M]^+$ 660.3482, found 660.3474.

(2*R*,3*R*,5*R*,6*S*,7*S*,8*R*)-2,6-Bis(benzyloxy)-3-(*t*-butyldimethylsilyloxy)-8-hydroxymethyl-5-(4-methoxybenzyloxy)-4,4-dimethyl-7-[1-methylene-4-(triethylsilyloxy)butyl]cyclooctanone (18). To a solution of 2-bromo-5-(triethylsilyloxy)pentene (212 mg, 0.76 mmol) in Et_2O (8 mL) was added *t*-butyllithium (1.51 M in pentane, 1.0 mL, 1.51 mmol) at −78 °C. The reaction mixture was stirred for 30 min and then it was added to a suspension of CuCN (33.9 mg, 0.38 mmol) in Et_2O (12 mL) at −78 °C. The reaction mixture was allowed to warm to −23 °C and stirred for 20 min to give a clear solution of cuprate. To a solution of cyclooctenone **17** (100 mg, 0.15 mmol) in Et_2O (3 mL) was added trimethylaluminium (1.08 M in hexane, 0.15 mL, 0.17 mmol) at 0 °C. After the reaction mixture was stirred for 30 min, it was cooled down to −23 °C and then the above cuprate was added through cannula. The reaction mixture was stirred for 1 h at −23 °C and then *i*-PrOH (0.5 mL) was added at −78 °C. The reaction was quenched with saturated aqueous NH_4Cl with vigorous stirring. The mixture was extracted with Et_2O and the combined organic layers were washed with H_2O and brine, and then dried over $MgSO_4$. After filtration, the solvent was removed under reduced pressure and the obtained residue was purified by preparative TLC (20% EtOAc–hexane) to give the **18** (102 mg, 71%) as a colorless oil and the dehydrogenated product **19** (37.1 mg, 22%) as a colorless oil. $[\alpha]_D^{22} = +8.05$ (*c* 1.13, $CHCl_3$); IR (neat) 3440, 3124, 1718, 1249, 1079 cm^{-1}; ^1H NMR ($CDCl_3$) δ 7.42–7.03 (m, 12H), 6.77 (d, $J = 8.7$ Hz, 2H), 5.01–3.75 (m, 11H), 3.72 (s, 3H), 3.70 (s, 1H), 3.52–3.45 (m, 4H), 2.74 (brs, 1H), 2.16 (brm, 1H), 1.92 (brm, 2H), 1.62–1.50 (m, 3H), 1.02 (s, 3H), 0.98 (s, 3H), 0.87 (t, $J = 7.8$ Hz, 9H), 0.79 (s, 9H), 0.48 (q, $J = 7.8$ Hz, 6H), 0.02 (s, 6H); ^{13}C NMR ($CDCl_3$) very broadened spectra; HRMS (FAB) calcd for $C_{50}H_{76}NaO_8Si_2$ $[M + Na]^+$ 883.4976, found 883.4953.

(1*R*,3*R*,4*R*,6*R*,7*S*,8*S*)-3,7-Bis(benzyloxy)-4-(*t*-butyldimethylsilyloxy)-6-(4-methoxybenzyloxy)-5,5-dimethyl-8-[1-methylene-4-(triethylsilyloxy)butyl]-2-oxocyclooctylmethyl Acetate. To a solution of ketone **18** (150 mg, 0.17 mmol) in pyridine (3 mL) were added DMAP (2.1 mg, 17.4 μmol) and Ac_2O (0.16 mL, 1.74 mmol) at 0 °C; the reaction mixture was stirred for 1 h. The reaction was quenched with phosphate buffer (pH = 7) and the mixture was extracted with EtOAc. The combined organic layers were washed with saturated aqueous $CuSO_4$, H_2O, and brine, and then dried over $MgSO_4$. After filtration, the filtrate was concentrated under reduced pressure and the crude product was purified by preparative TLC (20% EtOAc–hexane) to afford (1*R*,3*R*,4*R*,6*R*,7*S*,8*S*)-3,7-bis(benzyloxy)-4-(*t*-butyldimethylsilyloxy)-6-(4-methoxybenzyloxy)-5,5-dimethyl-8-[1-methylene-4-(triethylsilyloxy)butyl]-2-oxocyclooctylmethyl acetate (139 mg, 89%) as a colorless oil. $[\alpha]_D^{22} = +3.10$ (*c* 0.98, $CHCl_3$); IR (neat) 3100, 3085, 2949, 1705, 1245, 995 cm^{-1}; ^1H NMR ($CDCl_3$) δ 7.38–7.01 (m, 12H), 6.77 (d, $J = 8.7$ Hz, 2H), 5.12–3.90 (m, 14H), 3.74 (s, 3H), 3.53 (s, 1H), 3.50 (t, $J = 6.3$ Hz, 2H), 2.78 (brs, 1H), 2.24–1.73 (m, 2H), 1.82 (s, 3H), 1.71–1.58 (m, 2H), 1.07 (s, 3H), 1.04 (s, 3H), 0.96–0.82 (m, 18H), 0.61 (q, $J = 7.8$ Hz, 6H), 0.04 (s, 6H); ^{13}C NMR ($CDCl_3$) very broadened spectra; HRMS (FAB) calcd for $C_{52}H_{78}NaO_9Si_2$ $[M + Na]^+$ 925.5082, found 925.5112.

(2*R*,3*R*,5*R*,6*S*,7*R*)-2,6-Bis(benzyloxy)-3-(*t*-butyldimethylsilyloxy)-5-(4-methoxybenzyloxy)-4,4-dimethyl-8-methylene-7-[1-methylene-4-(triethylsilyloxy)butyl]cyclooctanone (19). To a solution of (1*R*,3*R*,4*R*,6*R*,7*S*,8*S*)-3,7-bis(benzyloxy)-4-(*t*-butyldimethylsilyloxy)-6-(4-methoxybenzyloxy)-5,5-dimethyl-8-[1-methylene-4-(triethylsilyloxy)butyl]-2-oxocyclooctylmethyl acetate (133 mg, 0.15 mmol) in CH_2Cl_2 (4 mL) was added DBU (0.44 mL, 2.94 mmol) dropwise. After the reaction mixture was stirred for 1.5 h, the reaction was quenched with phosphate buffer (pH = 7) and the mixture was extracted with CH_2Cl_2. The combined organic extracts were washed with H_2O and brine, and then dried over $MgSO_4$. After filtration, the solvent was removed under reduced pressure and the crude product was purified by preparative TLC (10% EtOAc–hexane) to afford **19** (105 mg, 85%) as a colorless oil. $[\alpha]_D^{23} = -6.24$ (*c* 1.00, $CHCl_3$); IR (neat) 3487, 3108, 2954, 1696, 1231, 1046 cm^{-1}; ^1H NMR ($CDCl_3$) δ 7.28–7.09 (m, 12H), 6.80 (d, $J = 8.4$ Hz, 2H), 6.13 (brs, 1H), 5.32 (s, 1H), 4.99–4.93 (m, 2H), 4.83 (brs, 1H), 4.81 (s, 1H), 4.67 (d, $J = 11.9$ Hz, 1H), 4.42 (d, $J = 12.7$ Hz, 1H), 4.38 (d, $J = 12.3$ Hz, 1H), 4.35 (d, $J = 11.1$ Hz, 1H), 4.24 (d, $J = 11.9$ Hz, 1H), 3.95 (d, $J = 10.5$ Hz, 1H), 3.74 (s, 3H), 3.62 (brs, 1H), 3.49 (brs, 1H), 3.42 (t, $J = 6.5$ Hz, 2H), 3.02 (d, $J = 10.5$ Hz, 1H), 1.98–1.60 (m, 2H), 1.58–1.33 (m, 2H), 1.11 (s, 6H), 0.93 (s, 9H), 0.88 (t, $J = 7.6$ Hz, 9H), 0.48 (q, $J = 7.6$ Hz, 6H), 0.16 (s, 3H), 0.01 (s, 3H); ^{13}C NMR ($CDCl_3$) very broadened spectra; HRMS (FAB) calcd for $C_{50}H_{74}NaO_7Si_2$ $[M + Na]^+$ 865.4871, found 865.4902.

(2*R*,3*R*,5*R*,6*S*,7*R*)-2,6-Bis(benzyloxy)-3-(*t*-butyldimethylsilyloxy)-7-(4-hydroxy-1-methylenebutyl)-5-(4-methoxybenzyloxy)-4,4-dimethyl-8-methylenecyclooctanone. To a solution of enone **19** (187 mg, 0.22 mmol) in THF (35 mL) at 0 °C was added HCl (0.5 M, 0.49 mL, 0.24 mmol) dropwise. After the reaction mixture was stirred for 15 min at 0 °C, the reaction was quenched with saturated aqueous $NaHCO_3$. The mixture was extracted with Et_2O and the combined organic layers were washed with H_2O and brine, dried over $MgSO_4$, and then filtered. The solvent was removed under reduced pressure and the crude product was purified by preparative TLC (30% EtOAc–hexane) to give (2*R*,3*R*,5*R*,6*S*,7*R*)-2,6-bis(benzyloxy)-3-(*t*-butyldimethylsilyloxy)-7-(4-hydroxy-1-methylenebutyl)-5-(4-methoxybenzyloxy)-4,4-dimethyl-8-methylenecyclooctanone (146.3 mg, 91%) as a colorless oil. $[\alpha]_D^{22} = -6.85$ (*c* 1.09, $CHCl_3$); IR (neat) 3509, 3065, 2981, 1687, 1373, 1044 cm^{-1}; ^1H NMR ($CDCl_3$) δ 7.34–7.17 (m, 12H), 6.87 (d, $J = 8.6$ Hz, 2H), 6.20 (brs, 1H), 5.38 (s, 1H), 5.05 (d, $J = 11.1$ Hz, 1H), 4.98 (s, 1H), 4.89 (s, 2H), 4.74 (d, $J = 12.4$ Hz, 1H), 4.49 (d, $J = 12.4$ Hz, 1H), 4.44 (d, $J = 12.4$ Hz, 1H), 4.40 (d, $J = 8.1$ Hz, 1H), 4.35 (d, $J = 9.2$ Hz, 1H), 4.00 (dd, $J = 2.2$, 8.5 Hz, 1H), 3.82 (s, 3H), 3.69 (brs, 1H), 3.60–3.51 (m, 1H), 3.46 (t, $J = 6.4$ Hz, 2H), 3.10 (d, $J = 10.7$ Hz, 1H), 2.17–1.38 (m, 4H), 1.18 (s, 6H), 0.91 (s, 9H), 0.23 (s, 3H), 0.07 (s, 3H); ^{13}C NMR ($CDCl_3$) δ 196.6, 159.9, 149.7, 146.3, 140.1, 138.4, 130.9, 130.1, 129.9, 128.6, 128.3, 128.0, 127.4, 125.4, 114.2, 113.9, 109.1, 85.2, 83.6, 80.3, 76.4, 73.7, 71.8, 62.3, 61.5, 54.8, 47.4, 45.0, 34.5, 31.2, 29.5, 26.7, 26.4, 26.1, 23.5, 18.8, −2.8,

−4.7; HRMS (FAB) calcd for $C_{44}H_{60}NaO_7Si$ $[M + Na]^+$ 751.4006, found 751.4035.

(5*R*,6*R*,8*R*,9*S*,10*S*)-5,9-Bis(benzyloxy)-6-(*t*-butyldimethylsilyloxy)-10-(4-hydroxy-1-methylenebutyl)-8-(4-methyoxybenzyloxy)-7,7-dimethyl-1-oxaspiro[2.7]decan-4-one (20). To a solution of (2*R*,3*R*,5*R*,6*S*,7*R*)-2,6-bis(benzyloxy)-3-(*t*-butyldimethylsilyloxy)-7-(4-hydroxy-1-methylenebutyl)-5-(4-methoxybenzyloxy)-4,4-dimethyl-8-methylenecyclooctanone (146 mg, 0.20 mmol) in MeOH were added H_2O_2 (30%, 0.12 mL, 1.00 mmol) and NaOH (6 M, 0.17 mL, 1.00 mmol) dropwise; the reaction mixture was stirred at 0 °C for 12 h. The reaction was quenched with saturated aqueous NH_4Cl and then MeOH was removed under reduced pressure. The aqueous layer was extracted with Et_2O and the combined organic extracts were washed with brine and dried over $MgSO_4$. After filtration, the filtrate was concentrated under reduced pressure and the obtained residue was purified by preparative TLC (30% EtOAc–hexane) to afford a diastereomeric mixture of **20** (123 mg, 82%) as a colorless oil. A part of the diastereomeric mixture of **20** (38.3 mg) was separated by preparative TLC (30% EtOAc–hexane) to obtained **20a** (20.0 mg) and **20b** (15.4 mg). **20a** (less-polar isomer): $[\alpha]_D^{15} = -24.0$ (*c* 0.5, EtOH); IR (neat) 3247, 3062, 1712, 1095 cm^{-1}; ^1H NMR (C_6D_6) δ 7.28–6.88 (m, 12H), 6.61 (d, $J = 8.8$ Hz, 2H), 5.16 (s, 1H), 4,83 (d, $J = 10.7$ Hz, 1H), 4.77 (s, 1H), 4.45 (d, $J = 11.2$ Hz, 1H), 4.32–4.20 (m, 5H), 4.04 (d, $J = 11.2$ Hz, 1H), 3.86 (d, $J = 10.7$ Hz, 1H), 3.36 (s, 1H), 3.21 (brs, 2H), 3.08 (s, 3H), 2.92 (d, $J = 11.2$ Hz, 1H), 2.53 (d, $J = 3.1$ Hz, 1H), 2.26–2.19 (m, 2H), 2.00–1.93 (m, 1H), 1.43–1.36 (m, 2H), 1.01 (s, 6H), 0.82 (s, 9H), 0.03 (s, 3H), 0.00 (s, 3H); ^{13}C NMR (C_6D_6) very broadened spectra; HRMS (FAB) calcd for $C_{44}H_{60}NaO_8Si$ $[M + Na]^+$ 767.3955, found 767.3986. **20b** (more-polar isomer): $[\alpha]_D^{16} = +19.9$ (*c* 1.00, EtOH); IR (neat) 3216, 3062, 2962, 1720, 1095 cm^{-1}; ^1H NMR (C_6D_6) δ 7.18–6.84 (m, 12H), 6.61 (d, $J = 8.6$ Hz, 2H), 4.98 (d, $J = 11.3$ Hz, 1H), 4.81 (brs, 1H), 4.79 (d, $J = 11.0$ Hz, 1H), 4.67 (s, 1H), 4.64–4.43 (m, 2H), 4.38 (d, $J = 11.0$ Hz, 1H), 4.24 (d, $J = 11.3$ Hz, 2H), 4.14 (d, $J = 11.0$ Hz, 1H), 4.08 (d, $J = 10.7$ Hz, 1H), 3.94 (d, $J = 11.6$ Hz, 1H), 3.49 (s, 1H), 3.28 (s, 1H), 3.10 (s, 3H), 2.54 (brs, 1H), 2.30 (d, $J = 7.3$ Hz, 2H), 2.23–1.81 (m, 2H), 1.51–1.40 (m, 2H), 1.20 (s, 3H), 0.94 (s, 3H), 0.86 (s, 9H), 0.01 (s, 3H), −0.02 (s, 3H); ^{13}C NMR (C_6D_6) very broadened spectra; HRMS (FAB) calcd for $C_{44}H_{60}NaO_8Si$ $[M + Na]^+$ 767.3955, found 767.4000.

4-[(4*S*,5*S*,6*R*,8*R*,9*R*)-5,9-Bis(benzyloxy)-8-(*t*-butyldimethylsilyloxy)-6-(4-methoxybenzyloxy)-7,7-dimethyl-10-oxo-1-oxaspiro[2.7]dec-4-yl]pent-4-enal (21). To a suspension of MS4A (281 mg), K_2CO_3 (388 mg, 2.81 mmol), and NCS (41.2 mg, 0.31 mmol) in CH_2Cl_2 (2.5 mL) were successively added a solution of alcohol **20** (209 mg, 0.28 mmol) in CH_2Cl_2 (3 mL) and a solution of *N*-*t*-butylbenzenesulfenamide (10.2 mg, 0.06 mmol) in CH_2Cl_2 (0.5 mL) at room temperature. After the reaction mixture was kept stirring for 2 h, it was filtered through a Celite pad, and the filtrate was extracted with 10% aqueous Na_2CO_3. The organic layers were washed with H_2O and brine, dried over $MgSO_4$, and then filtered. The solvent was removed under reduced pressure and the crude product was purified by preparative TLC (25% EtOAc–hexane) to afford a diastereomeric mixture of **21** (198 mg, 95%) as a colorless oil. A part of the diastereomeric mixture of **21** (58.3 mg) was separated by preparative TLC (20% EtOAc–hexane) to obtain **21a** (30.9 mg) and **21b** (25.4 mg). **21a** (less-polar isomer): $[\alpha]_D^{16} = -33.0$ (*c* 1.00, EtOH); IR (neat) 3424, 3070, 2954, 2892, 1720, 1087 cm^{-1}; ^1H NMR (C_6D_6) δ 9.04 (t, $J = 1.3$ Hz, 1H), 7.27–6.79 (m, 12H), 6.59 (d, $J = 8.7$ Hz, 2H), 5.07 (s, 1H), 4.84 (brs, 1H), 4.76 (d, $J = 11.4$ Hz, 1H), 4.50 (s, 1H), 4.41 (d, $J = 10.9$ Hz, 1H), 4.29–4.16 (m, 4H), 3.90 (d, $J = 11.2$ Hz, 1H), 3.79 (d, $J = 10.9$ Hz, 1H), 3.31 (s, 1H), 3.05 (s, 3H), 2.82 (d, $J = 11.1$ Hz, 1H), 2.47 (d, $J = 4.8$ Hz, 1H), 2.40–2.29 (m, 1H), 2.19–2.12 (m, 1H), 2.01–1.90 (m, 1H), 1.83–1.74 (m, 2H), 0.99 (s, 6H), 0.79 (s, 9H), 0.00 (s, 3H), −0.03 (s, 3H); ^{13}C NMR (C_6D_6) very broadened spectra; HRMS (FAB) calcd for $C_{44}H_{58}NaO_8Si$ $[M + Na]^+$ 765.3799, found 765.3834. **21b** (more-polar isomer): $[\alpha]_D^{16} = +10.5$ (*c* 1.00, EtOH); IR (neat) 3355, 3054, 2908, 2815, 1712, 1095 cm^{-1}; ^1H NMR (C_6D_6) δ 9.19 (t, $J = 1.3$ Hz, 1H), 7.36–6.82 (m, 12H), 6.64 (d, $J = 8.6$ Hz, 2H), 4.97 (d, $J = 11.3$ Hz, 1H), 4.78 (s, 1H), 4.74–3.93 (m, 8H), 3.68 (s, 1H), 3.50 (s, 1H), 3.12 (s, 3H), 3.11–2.88 (m, 1H), 2.54 (brs, 1H), 2.28 (s, 2H), 2.17–1.86 (m, 2H), 1.79 (brs, 1H), 0.97 (s, 3H), 0.93 (s, 3H), 0.89 (s, 9H), 0.05 (s, 3H), 0.00 (s, 3H); ^{13}C NMR (C_6D_6) very broadened spectra; HRMS (FAB) calcd for $C_{44}H_{58}NaO_8Si$ $[M + Na]^+$ 765.3799, found 765.3852.

(1*R*,3*R*,4*R*,6*R*,7*S*,8*R*,12*S*)-3,7-Bis(benzyloxy)-4-(*t*-butyldimethylsilyloxy)-12-hydroxy-1-hydroxymethyl-6-(4-methoxybenzyloxy)-5,5-dimethyl-9-methylenebicyclo[6.4.0]dodecan-2-one (5a) and (1*S*,3*R*,4*R*,6*R*,7*S*,8*R*,12*S*)-3,7-Bis(benzyloxy)-4-(*t*-butyldimethylsilyloxy)-12-hydroxy-1-hydroxymethyl-6-(4-methoxybenzyloxy)-5,5-dimethyl-9-methylenebicyclo[6.4.0]dodecan-2-one (5c) and (1*S*,3*R*,4*R*,6*R*,7*S*,8*R*,12*R*)-3,7-Bis(benzyloxy)-4-(*t*-butyldimethylsilyloxy)-12-hydroxy-1-hydroxymethyl-6-(4-methoxybenzyloxy)-5,5-dimethyl-9-methylenebicyclo[6.4.0]dodecan-2-one (5d). To a solution of a diastereomeric mixture of aldehyde **21** (20.0 mg, 26.9 μmol) in THF (2.7 mL) at −100 °C was added SmI_2 (0.1 M in THF, 81.0 μmol, 0.81 mL) dropwise; the reaction mixture was stirred for 1 h. The reaction was quenched with saturated aqueous NH_4Cl (0.5 mL) and then the resulting mixture was filtered through a short pad of silica gel. The filtrate was concentrated under reduced pressure and the residue was purified by preparative TLC (30% EtOAc–hexane) to give bicyclic diols **5a** (14.2 mg, 71%), **5c** (2.0 mg, 10%), and **5d** (3.1 mg, 15%) as colorless oils. **5a**: $[\alpha]_D^{22} = -2.15$ (*c* 0.81, $CHCl_3$); IR (KBr pellet) 3466, 1696 cm^{-1}; ^1H NMR ($CDCl_3$) δ 7.43 (d, $J = 7.0$ Hz, 2H), 7.35–7.10 (m, 10H), 6.90 (d, $J = 8.4$ Hz, 2H), 5.17 (d, $J = 11.6$ Hz, 1H), 5.04 (brs, 1H), 4.71–4.59 (m, 4H), 4.55 (d, $J = 11.1$ Hz, 1H), 4.47 (d, $J = 11.1$ Hz, 1H), 4.35 (d, $J = 11.6$ Hz, 1H), 4.28 (d, $J = 10.3$ Hz, 1H), 4.03–3.90 (m, 2H), 3.80 (s, 3H), 3.80–3.70 (m, 2H), 3.64 (d, $J = 11.3$ Hz, 1H), 3.34 (s, 1H), 3.27 (dd, $J = 10.5$, 3.2 Hz, 1H), 2.83 (d, $J = 10.0$ Hz, 1H), 2.59–2.43 (m, 1H), 2.30–2.07 (m, 2H), 1.95–1.77 (m, 1H), 1.19 (s, 3H), 1.15 (s, 3H), 0.85 (s, 9H), 0.01 (s, 3H), −0.01 (s, 3H); ^{13}C NMR ($CDCl_3$) δ 213.9, 159.1, 141.9, 138.6, 130.2, 129.3, 127.9, 127.9, 127.9, 127.5, 127.1, 126.9, 126.8, 113.7, 110.0, 84.6, 83.1, 79.1, 74.4, 73.6, 73.3, 72.5, 63.5, 58.1, 55.3, 50.0, 46.4, 35.4, 33.0, 29.8, 25.9, 21.7, 21.7, 18.2, −3.6, −4.5; HRMS (FAB) calcd for $C_{44}H_{60}NaO_8Si$ $[M + Na]^+$ 767.3955, found 767.3945. **5c**: $[\alpha]_D^{22} = +38.3$ (*c* 0.69, $CHCl_3$); IR (KBr pellet); 3448, 1695 cm^{-1}; ^1H NMR ($CDCl_3$) δ 7.44 (d, $J = 7.0$ Hz, 2H), 7.39–7.18 (m, 10H), 6.85 (d, $J = 8.6$ Hz, 2H), 4.93–4.87 (m, 2H), 4.83 (d, $J = 11.1$ Hz, 1H), 4.75 (d, $J = 4.9$ Hz, 1H), 4.73–4.61 (m, 2H), 4.57 (d, $J = 11.6$ Hz, 1H), 4.50 (d, $J = 10.8$ Hz, 1H), 4.47–4.31 (m, 4H), 4.28 (d, $J = 10.3$ Hz, 1H), 3.79 (s, 3H), 3.79–3.62 (m, 2H), 3.36 (d, $J = 3.0$ Hz, 1H), 3.33 (d, $J = 1.6$ Hz, 1H), 3.07 (d, $J = 9.7$ Hz, 1H), 2.63–2.47 (m, 1H), 2.14–1.89 (m, 2H), 1.85–1.68 (m, 1H), 1.21 (s, 3H), 1.18 (s, 3H), 0.92 (s, 9H), 0.12 (s, 3H), 0.10 (s, 3H); ^{13}C NMR ($CDCl_3$) δ 212.6, 158.6, 144.3, 139.3, 138.5, 131.2, 128.5,

127.9, 127.8, 127.7, 126.9, 126.8, 114.5, 113.5, 113.5, 88.4, 83.8, 79.3, 75.2, 74.3, 74.1, 72.3, 66.3, 59.6, 55.3, 51.8, 46.4, 32.0, 29.4, 26.1, 25.3, 22.6, 22.3, 18.3, −3.3, −4.6; HRMS (FAB) calcd for $C_{44}H_{60}NaO_8Si$ $[M + Na]^+$ 767.3955, found 767.3953. **5d**: $[\alpha]_D^{21} = -24.1$ (*c* 1.00, $CHCl_3$); IR (KBr pellet) 3466, 1693 cm^{-1}; ^1H NMR ($CDCl_3$) (1:1 conformer mixture) δ 7.50–7.21 (m, 11H), 7.18 (d, $J = 8.6$ Hz, 1H), 6.92 (d, $J = 8.6$ Hz, 1H), 6.82 (d, $J = 8.9$ Hz, 1H), 4.91–4.62 (m, 5H), 4.52–4.25 (m, 5H), 3.91 (brs, 0.5H), 3.82 (s, 1.5H), 3.79 (s, 1.5H), 3.78–3.48 (m, 2.5H), 3.32 (brs, 0.5H), 3.07–2.95 (m, 1.5H), 2.78–2.71 (m, 1H), 2.31–2.05 (m, 2H), 1.91–1.63 (m, 2H), 1.23 (s, 1.5H), 1.20 (s, 1.5H), 1.18 (s, 1.5H), 1.15 (s, 1.5H), 0.97 (s, 4.5H), 0.88 (s, 4.5H), 0.12 (s, 1.5H), 0.07 (s, 1.5H), 0.06 (s, 1.5H), 0.04 (s, 1.5H); ^{13}C NMR ($CDCl_3$) (1:1 conformer mixture) δ 214.9, 214.0, 159.3, 158.9, 142.2, 142.1, 138.7, 138.1, 132.0, 130.2, 130.2, 130.1, 129.9, 128.9, 128.8, 128.3, 128.1, 127.9, 127.9, 127.8, 127.7, 127.5, 127.1, 127.1, 126.8, 126.6, 115.3, 115.2, 113.7, 113.3, 86.3, 81.8, 80.0, 79.6, 75.2, 75.1, 74.1, 73.5, 72.8, 71.9, 71.6, 70.9, 70.8, 67.6, 65.6, 60.2, 57.5, 56.9, 55.4, 55.2, 53.8, 53.3, 46.6, 45.9, 31.8, 30.2, 29.3, 29.2, 28.1, 28.0, 26.4, 26.0, 25.8, 22.3, 22.1, 21.5, 18.6, 18.3, −3.3, −3.6, −4.5, −5.0; HRMS (FAB) calcd for $C_{44}H_{60}NaO_8Si$ $[M + Na]^+$ 767.3955, found 767.3954.

(1*R*,3*R*,4*R*,6*R*,7*S*,8*R*,12*S*)-3,7-Bis(benzyloxy)-4-(*t*-butyldimethylsilyloxy)-12-hydroxy-1-methoxymethoxymethyl-6-(4-methoxybenzyloxy)-5,5-dimethyl-9-methylenebicyclo[6.4.0]dodecan-2-one (22). To a solution of **5a** (7.7 mg, 0.01 mmol) in CH_2Cl_2 (1 mL) was added *N*,*N*-diisopropylethylamine (99 mg, 0.773 mmol), tetrabutylammonium iodide (190 mg, 0.515 mmol), and a solution of chloromethyl methyl ether (41 mg, 0.52 mmol) in CH_2Cl_2 (1 mL) at 0 °C. After the reaction mixture was stirred for 5 h at room temperature, the reaction was quenched with saturated aqueous sodium hydrogencarbonate and the mixture was extracted with CH_2Cl_2. The combined organic layers were washed with water and brine, dried over $MgSO_4$, and then filtered. The filtrate was concentrated under reduced pressure and the crude product was purified by preparative TLC (30% EtOAc–hexane) to afford **22** (6.2 mg, 76%) as a crystalline solid. mp 131–133 °C; $[\alpha]_D^{21} = +43.1$ (*c* 1.30, benzene); IR (KBr pellet) 3497, 1710 cm^{-1}; ^1H NMR ($CDCl_3$) δ 7.46 (d, $J = 6.9$ Hz, 2H), 7.38–7.17 (m, 10H), 6.90 (d, $J = 8.7$ Hz, 2H), 5.20 (d, $J = 11.4$ Hz, 1H), 5.09 (s, 1H), 4.80–4.53 (m, 7H), 4.40 (d, $J = 11.0$ Hz, 1H), 4.38 (d, $J = 11.4$ Hz, 1H), 4.27 (d, $J = 11.4$ Hz, 1H), 4.07 (d, $J = 10.1$ Hz, 1H), 3.99 (d, $J = 9.9$ Hz, 1H), 3.87 (d, $J = 10.1$ Hz, 1H), 3.82 (s, 3H), 3.46 (s, 3H), 3.37 (s, 1H), 3.24 (d, $J = 9.9$ Hz, 1H), 2.95 (d, $J = 10.4$ Hz, 1H), 2.60–2.46 (m, 1H), 2.38–2.19 (m, 1H), 2.15–2.02 (m, 1H), 1.80–1.71 (m, 1H), 1.20 (s, 3H), 1.14 (s, 3H), 0.87 (s, 9H), 0.33 (s, 3H), 0.02 (s, 3H); ^{13}C NMR ($CDCl_3$) δ 207.8, 159.1, 142.8, 138.9, 130.8, 129.1, 128.0, 127.9, 127.9, 127.6, 127.1, 127.0, 126.8, 113.7, 110.1, 97.1, 84.6, 83.8, 79.1, 78.3, 74.3, 73.5, 73.4, 72.5, 67.1, 58.7, 55.2, 50.7, 46.3, 35.4, 32.7, 29.8, 25.9, 21.6, 21.5, 18.1, −3.7, −4.7; HRMS (FAB) calcd for $C_{46}H_{64}NaO_9Si$ $[M + Na]^+$ 811.4217; found 811.4202.

(1*S*,3*R*,4*R*,6*R*,7*S*,8*R*,12*R*)-3,7-Bis(benzyloxy)-4-(*t*-butyldimethylsilyloxy)-1-(*t*-butyldimethylsilyloxymethyl)-12-hydroxy-6-(4-methoxybenzyloxy)-5,5-dimethyl-9-methylenebicyclo-[6.4.0]dodecan-2-one. To a solution of a diol **5d** (9.4 mg, 0.0126 mmol) in pyridine (1 mL) at 0 °C was added TBSOTf (0.03 mL, 0.131 mmol) dropwise. After the reaction mixture was stirred for 1.5 h, the reaction was quenched with phosphate buffer (pH = 7) and the mixture was extracted with EtOAc. The combined organic layers were washed with saturated aqueous $CuSO_4$, H_2O, and brine, dried over $MgSO_4$, and then filtered. The filtrate was concentrated under reduced pressure and the crude product was purified by preparative TLC (25% EtOAc–hexane) to afford (1*S*,3*R*,4*R*,6*R*,7*S*,8*R*,12*R*)-3,7-bis(benzyloxy)-4-(*t*-butyldimethylsilyloxy)-1-(*t*-butyldimethylsilyloxymethyl)-12-hydroxy-9-(4-methoxybenzyloxy)-5,5-dimethyl-9-methylenebicyclo[6.4.0]dodecan-2-one (7.0 mg, 65%) as colorless oil. $[\alpha]_D^{21} = +7.66$ (*c* 1.19, $CHCl_3$); IR (KBr pellet) 3537, 1694 cm^{-1}; ^1H NMR ($CDCl_3$) (1:1 conformer mixture) δ 7.34–7.05 (m, 12H), 6.82 (d, $J = 8.6$ Hz, 1H), 6.74 (d, $J = 8.6$ Hz, 1H), 5.03 (brs, 0.5H), 4.90–4.78 (m, 2H), 4.77 (s, 0.5H), 4.65–4.45 (m, 2H), 4.40–4.23 (m, 3H), 4.19–4.10 (m, 1H), 3.96–3.80 (m, 2H), 3.84 (s, 1.5H), 3.75 (s, 1.5H), 3.72–3.55 (m, 3H), 3.20 (s, 0.5H), 2.87 (d, $J = 10.1$ Hz, 0.5H), 2.15–1.60 (m, 4H), 1.47 (s, 1.5H), 1.21 (s, 1.5H), 1.10 (s, 1.5H), 1.05 (s, 1.5H), 0.85 (s, 4.5H), 0.82 (s, 4.5H), 0.81 (s, 4.5H), 0.78 (s, 4.5H), 0.04 (s, 1.5H), 0.02 (s, 1.5H), 0.02 (s, 1.5H), 0.00 (s, 1.5H), −0.01 (s, 1.5H), −0.02 (s, 1.5H), −0.03 (s, 1.5H), −0.04 (s, 1.5H); ^{13}C NMR ($CDCl_3$) (1:1 conformer mixture) δ 218.1, 215.7, 159.2, 158.5, 142.6, 142.4, 138.8, 138.1, 130.4, 130.3, 129.7, 129.5, 128.8, 128.3, 128.1, 128.0, 127.9, 127.8, 127.7, 127.4, 127.3, 127.2, 127.1, 127.0, 126.7, 126.3, 115.1, 114.8, 113.7, 113.3, 88.4, 82.4, 79.9, 79.2, 75.0, 74.9, 74.6, 74.0, 73.4, 72.7, 71.7, 71.3, 70.1, 69.7, 69.6, 65.2, 64.8, 58.9, 57.5, 55.4, 55.2, 52.7, 46.0, 45.5, 29.9, 27.7, 26.4, 26.3, 26.2, 26.0, 25.9, 25.8, 25.7, 22.1, 22.0, 21.5, 19.5, 18.9, 18.7, 18.6, 18.3, 18.1, −3.2, −3.3, −4.7, −4.9, −5.0, −5.2, −5.4, −6.0; HRMS (FAB) calcd for $C_{50}H_{74}NaO_8Si_2$ $[M + Na]^+$ 881.4820, found 881.4821.

(1*R*,2*S*,3*R*,7*R*,8*S*,9*R*,11*R*,12*R*)-8,12-Bis(benzyloxy)-11-(*t*-butyldimethylsilyloxy)-2-(*t*-butyldimethylsilyloxymethyl)-10,10-dimethyl-6-methylene-13-oxatricyclo[7.3.1.$0^{2,7}$]tridecane-1,3-diol (23). To a solution of alcohol (1*S*,3*R*,4*R*,6*R*,7*S*,8*R*,12*R*)-3,7-bis(benzyloxy)-4-(*t*-butyldimethylsilyloxy)-1-(*t*-butyldimethylsilyloxymethyl)-12-hydroxy-6-(4-methoxybenzyloxy)-5,5-dimethyl-9-methylenebicyclo[6.4.0]dodecan-2-one (6.0 mg, 0.00698 mmol) in CH_2Cl_2 (5 mL) at 0 °C were added H_2O (0.5 mL) and DDQ (5.0 mg, 0.0222 mmol). The reaction mixture was stirred at room temperature for 1 h and then H_2O was added. The mixture was extracted with CH_2Cl_2 and the combined organic layers were washed with H_2O and brine, and dried over Na_2SO_4. After filtration of the mixture and evaporation of the solvent, the crude product was purified by preparative TLC (20% EtOAc–hexane) to afford **23** (5.0 mg, 96%) as a colorless oil. $[\alpha]_D^{21} = +15.4$ (*c* 0.29, $CHCl_3$); IR (liquid film) 3441 cm^{-1}; ^1H NMR (C_6D_6) δ 7.38 (d, $J = 7.0$ Hz, 2H), 7.19–6.95 (m, 8H), 6.73 (s, 1H), 5.20 (brs, 1H), 5.10 (dt, $J = 11.0$, 5.0 Hz, 1H), 5.01 (d, $J = 10.0$ Hz, 1H), 4.95 (brs, 1H), 4.89 (d, $J = 9.5$ Hz, 1H), 4.83 (d, $J = 10.5$ Hz, 1H), 4.73 (d, $J = 3.5$ Hz, 1H), 4.69 (dd, $J = 12.5$, 5.5 Hz, 1H), 4.63 (d, $J = 10.0$ Hz, 1H), 4.57 (d, $J = 10.0$ Hz, 1H), 4.21 (d, $J = 5.0$ Hz, 1H), 4.09 (d, $J = 9.3$ Hz, 1H), 3.72 (d, $J = 4.5$ Hz, 1H), 3.66 (d, $J = 3.5$ Hz, 1H), 3.55 (d, $J = 11.5$ Hz, 1H), 2.58–2.48 (m, 1H), 2.29–2.21 (m, 1H), 2.10–2.01 (m, 1H), 1.76–1.64 (m, 1H), 1.11 (s, 3H), 1.06 (s, 3H), 1.00 (s, 9H), 0.96 (s, 9H), 0.11 (s, 3H), 0.07 (s, 3H), 0.03 (s, 3H), 0.01 (s, 3H); ^{13}C NMR (C_6D_6) δ 145.6, 139.6, 136.7, 130.1, 128.7, 128.4, 128.3, 127.9, 127.6, 115.5, 104.9, 84.5, 84.1, 78.6, 76.8, 74.2, 72.0, 67.3, 63.8, 53.4, 49.2, 38.6, 31.2, 30.5, 27.8, 26.7, 25.9, 22.6, 18.9, 18.2, −3.1, −5.0, −5.3, −5.7; HRMS (FAB) calcd for $C_{42}H_{67}O_7Si_2$ $[M + H]^+$ 739.4425, found 739.4421.

(1*S*,3*R*,4*R*,6*R*,7*S*,8*R*)-3,7-Bis(benzyloxy)-4-(*t*-butyldimethylsilyloxy)-1-(*t*-butyldimethylsilyloxymethyl)-6-(4-methoxybenzyloxy)-5,5-dimethyl-9-methylenebicyclo[6.4.0]dodecane-2,12-

dione (24). To a solution of (1*S*,3*R*,4*R*,6*R*,7*S*,8*R*,12*R*)-3,7-bis-(benzyloxy)-4-(*t*-butyldimethylsilyloxy)-1-(*t*-butyldimethylsilyloxymethyl)-12-hydroxy-9-(4-methoxybenzyloxy)-5,5-dimethyl-9-methylenebicyclo[6.4.0]dodecan-2-one (51.3 mg, 0.0597 mmol) in CH_2Cl_2 (5 mL) were added $NaHCO_3$ (50.2 mg, 0.597 mmol) and Dess–Martin periodinane (127 mg, 0.299 mmol) at room temperature. After the reaction mixture was stirred for 50 min, the reaction was quenched with 10% aqueous Na_2SO_3 (2 mL) and saturated aqueous $NaHCO_3$. The mixture was extracted with CH_2Cl_2 and the combined organic layers were washed with brine, dried over $MgSO_4$, and then filtered. The filtrate was concentrated under reduced pressure and the crude product was purified by preparative TLC (15% EtOAc–hexane) to afford ketone **24** (46.6 mg, 91%) as a colorless oil. $[\alpha]_D^{22} = -43.0$ (*c* 1.13, $CHCl_3$); IR (thin film) 1719, 1689 cm^{-1}; ^1H NMR ($CDCl_3$) δ 7.60–7.51 (m, 2H), 7.50–7.28 (m, 10H), 6.98 (d, $J = 8.4$ Hz, 2H), 5.12 (d, $J = 9.2$ Hz, 1H), 5.01 (s, 1H), 4.94 (d, $J = 1.9$ Hz, 1H), 4.88 (d, $J = 10.5$ Hz, 1H), 4.77 (d, $J = 9.2$ Hz, 1H), 4.59 (d, $J = 9.2$ Hz, 1H), 4.49 (d, $J = 9.2$ Hz, 1H), 4.36 (d, $J = 11.1$ Hz, 1H), 4.29 (s, 1H), 4.27 (d, $J = 11.1$ Hz, 1H), 4.11 (s, 1H), 3.95 (s, 1H), 3.91 (s, 3H), 3.69 (s, 1H), 3.65 (d, $J = 9.5$ Hz, 1H), 2.84 (d, $J = 10.5$ Hz, 1H), 2.29–2.21 (m, 2H), 2.16–1.95 (m, 2H), 1.44 (s, 3H), 1.11 (s, 3H), 1.07 (s, 9H), 0.88 (s, 9H), 0.35 (s, 3H), 0.26 (s, 3H), 0.01 (s, 3H), 0.00 (s, 3H); ^{13}C NMR ($CDCl_3$) δ 206.6, 204.8, 158.7, 143.5, 138.9, 136.9, 130.0, 129.6, 128.9, 128.2, 128.2, 128.0, 127.5, 127.2, 115.5, 113.4, 93.6, 90.4, 78.4, 78.2, 76.0, 75.8, 72.4, 69.4, 66.0, 55.2, 53.7, 43.8, 42.1, 30.0, 28.8, 26.1, 25.9, 20.3, 18.3, 18.2, −3.4, −5.1, −5.7, −5.7; HRMS (FAB) calcd for $C_{50}H_{72}NaO_8Si_2$ $[M + Na]^+$ 879.4663, found 879.4674.

(1*S*,3*R*,4*R*,6*R*,7*S*,8*R*,12*S*)-3,7-Bis(benzyloxy)-4-(*t*-butyldimethylsilyloxy)-1-(*t*-butyldimethylsilyloxymethyl)-12-hydroxy-6-(4-methoxybenzyloxy)-5,5-dimethyl-9-methylenebicyclo[6.4.0]-dodecan-2-one. To a solution of a diol **5c** (21.1 mg, 0.0283 mmol) in pyridine (2 mL) at 0 °C was added TBSOTf (22.4 mg, 0.0849 mmol) dropwise. After the reaction mixture was stirred for 1.5 h, the reaction was quenched with phosphate buffer (pH = 7) and the mixture was extracted with EtOAc. The combined organic layers were washed with saturated aqueous $CuSO_4$, H_2O, and brine, dried over $MgSO_4$, and then filtered. The filtrate was concentrated under reduced pressure and the crude product was purified by preparative TLC (25% EtOAc–hexane) to afford (1*S*,3*R*,4*R*,6*R*,7*S*,8*R*,12*S*)-3,7-bis(benzyloxy)-4-(*t*-butyldimethylsilyloxy)-1-(*t*-butyldimethylsilyloxymethyl)-12-hydroxy-6-(4-methoxybenzyloxy)-5,5-dimethyl-9-methylenebicyclo[6.4.0]dodecan-2-one (20.0 mg, 82%) as a colorless oil. $[\alpha]_D^{20} = +35.5$ (*c* 1.23, $CHCl_3$); IR (KBr pellet) 3548, 1698 cm^{-1}; ^1H NMR ($CDCl_3$) δ 7.35–7.10 (m, 12H), 6.75 (d, $J = 8.6$ Hz, 2H), 4.77 (d, $J = 9.2$ Hz, 1H), 4.74 (d, $J = 8.1$ Hz, 1H), 4.67 (d, $J = 6.8$ Hz, 1H), 4.60 (d, $J = 5.7$ Hz, 1H), 4.55 (d, $J = 10.8$ Hz, 1H), 4.52–4.46 (m, 1H), 4.31 (d, $J = 5.7$ Hz, 1H), 4.28 (d, $J = 10.8$ Hz, 1H), 4.25–4.10 (m, 2H), 3.81 (d, $J = 10.8$ Hz, 1H), 3.68 (s, 3H), 3.56 (d, $J = 10.8$ Hz, 1H), 3.42 (d, $J = 3.0$ Hz, 1H), 3.28 (s, 1H), 2.72 (d, $J = 10.3$ Hz, 1H), 2.60–2.42 (m, 1H), 2.05–1.83 (m, 2H), 1.75–1.55 (m, 1H), 1.09 (s, 3H), 1.07 (s, 3H), 0.81 (s, 9H), 0.77 (s, 9H), 0.03 (s, 3H), 0.01 (s, 3H), −0.05 (s, 3H), −0.07 (s, 3H); ^{13}C NMR ($CDCl_3$) δ 211.7, 158.6, 144.2, 139.2, 138.7, 131.1, 128.7, 128.0, 127.7, 127.7, 127.2, 126.8, 126.5, 114.4, 113.5, 87.2, 83.4, 79.1, 75.4, 74.3, 73.9, 72.3, 68.4, 66.1, 59.3, 53.2, 46.6, 28.9, 26.1, 26.0, 25.8, 25.7, 22.5, 22.5, 18.3, 18.2, −3.4, −4.5, −5.4, −5.5; HRMS (FAB) calcd for $C_{50}H_{74}NaO_8Si_2$ $[M + Na]^+$ 881.4820, found 881.4854.

(1*R*,2*S*,3*S*,4*R*,6*R*,7*S*,8*R*,12*S*)-3,7-Bis(benzyloxy)-4-(*t*-butyldimethylsilyloxy)-6-(4-methoxybenzyloxy)-1-(methoxymethoxymethyl)-5,5-dimethyl-9-methylenebicyclo[6.4.0]dodecane-2,12-diol. To a solution of lithium aluminium hydride in THF (1.0 M, 75 mL, 75 mmol) at 0 °C was added sulfuric acid (98%, 2.0 mL, 37.5 mmol). The reaction mixture was stirred for 1 h at room temperature and then it was allowed to stand. The clear solution of tetrahydridoaluminium in THF (1.0 M) was instantly used in the following reaction without further purification. To a solution of alcohol **22** (4.30 g, 5.45 mmol) in toluene (110 mL) at −23 °C was added tetrahydridoaluminium in THF (1.0 M, 54.5 mL, 54.5 mmol). The reaction mixture was stirred for 2 h at −23 °C and then saturated aqueous potassium sodium tartrate was added. The mixture was extracted with ethyl acetate, and the organic layer was washed with brine and dried over anhydrous sodium sulfate. After filtration of the mixture and evaporation of the solvent, the crude product was purified by column chromatography (silica gel, 10–20% EtOAc–hexane) to afford (1*R*,2*S*,3*S*,4*R*,6*R*,7*S*,8*R*,12*S*)-3,7-bis(benzyloxy)-4-(*t*-butyldimethylsilyloxy)-6-(4-methoxybenzyloxy)-1-(methoxymethoxymethyl)-5,5-dimethyl-9-methylenebicyclo[6.4.0]dodecane-2,12-diol (3.48 g, 81%) as a colorless oil. $[\alpha]_D^{23} = +29.3$ (*c* 0.45, benzene); IR (neat) 3492 cm^{-1}; ^1H NMR ($CDCl_3$) δ 7.36–7.11 (m, 12H), 6.80 (d, $J = 8.1$ Hz, 2H), 5.78 (s, 1H), 5.26 (s, 1H), 4.98–4.88 (m, 3H), 4.80–4.62 (m, 1H), 4.60–4.48 (m, 6H), 4.48–4.40 (m, 1H), 4.37 (s, 2H), 4.03–3.97 (m, 1H), 3.94–3.60 (m, 3H), 3.80 (s, 3H), 3.39 (s, 3H), 3.40–3.31 (m, 1H), 2.40–2.27 (m, 2H), 2.10–1.98 (m, 1H), 1.95–1.85 (m, 1H), 1.39 (s, 3H), 1.37 (s, 3H), 0.98 (s, 9H), 0.30 (s, 3H), 0.18 (s, 3H); ^{13}C NMR ($CDCl_3$) very broadened spectra; HRMS (FAB) calcd for $C_{46}H_{66}NaO_9Si$ $[M + Na]^+$ 813.4374; found 813.4348.

(1*R*,2*S*,3*S*,4*R*,6*R*,7*S*,8*R*,12*S*)-3,7-Bis(benzyloxy)-4-(*t*-butyldimethylsilyloxy)-2,12-(isopropylidenedioxy)-6-(4-methoxybenzyloxy)-1-(methoxymethoxymethyl)-5,5-dimethyl-9-methylenebicyclo[6.4.0]dodecane (25). To a solution of (1*R*,2*S*,3*S*,4*R*,6*R*,7*S*,8*R*,12*S*)-3,7-bis(benzyloxy)-4-(*t*-butyldimethylsilyloxy)-6-(4-methoxybenzyloxy)-1-(methoxymethoxymethyl)-5,5-dimethyl-9-methylenebicyclo[6.4.0]dodecane-2,12-diol (3.48 g, 4.4 mmol) in CH_2Cl_2 (220 mL) were added 2,2-dimethoxypropane (220 mL) and CSA (205 mg, 0.88 mmol) at 0 °C. The reaction mixture was allowed to warm to room temperature and stirred for 5 h. The reaction was quenched with Et_3N and the solvent was removed under reduced pressure. The obtained residue was purified by column chromatography (silica gel, 10–20% EtOAc–hexane) to afford **25** (3.35 g, 92%) as a colorless oil. $[\alpha]_D^{24} = +27.3$ (*c* 0.50, benzene); IR (thin film) 2952, 2858 cm^{-1}; ^1H NMR ($CDCl_3$) δ 7.46–7.18 (m, 12H), 6.84 (d, $J = 8.6$ Hz, 2H), 4.90–4.08 (m, 9H), 4.37–4.26 (m, 4H), 4.24 (d, $J = 2.2$ Hz, 1H), 4.02 (s, 1H), 3.97 (d, $J = 2.7$ Hz, 1H), 3.79 (s, 3H), 3.78–3.71 (m, 1H), 3.63 (d, $J = 2.7$ Hz, 1H), 3.35 (s, 3H), 3.04–2.85 (m, 1H), 2.43 (d, $J = 11.1$ Hz, 1H), 2.24–2.08 (m, 1H), 2.01–1.66 (m, 2H), 1.48 (s, 3H), 1.44 (s, 3H), 1.22 (s, 3H), 1.18 (s, 3H), 0.97 (s, 9H), 0.10 (s, 3H), 0.07 (s, 3H); ^{13}C NMR ($CDCl_3$) δ 158.6, 144.4, 139.7, 139.0, 131.7, 128.6, 128.0, 128.0, 127.9, 127.8, 127.3, 126.6, 115.4, 113.5, 98.9, 97.7, 92.6, 83.3, 81.9, 78.3, 77.2, 76.8, 75.8, 73.3, 72.1, 64.5, 56.5, 55.2, 50.3, 46.1, 43.0, 29.8, 27.7, 26.9, 25.9, 25.4, 21.3, 19.0, 18.0, −4.2, −4.7; HRMS (FAB) calcd for $C_{49}H_{70}NaO_9Si$ $[M + Na]^+$ 853.4687; found 853.4730.

(1*R*,2*S*,3*R*,5*R*,6*S*,7*S*,8*R*,9*S*)-2,6-Bis(benzyloxy)-5-(*t*-butyldimethylsilyloxy)-7,9-(isopropylidenedioxy)-8-(methoxymethoxymethyl)-4,4-dimethyl-12-methylenebicyclo[6.4.0]dodecan-3-ol. To a solution of **25** (3.35 g, 4.03 mmol) in CH_2Cl_2 (400 mL) at 0 °C were added phosphate buffer (pH = 7, 20 mL) and DDQ (1.37

g, 6.05 mmol). After the reaction mixture was stirred for 1 h, DDQ (0.46 g, 2.01 mmol) was added, and this mixture was stirred at 0 °C for 30 min. The reaction was quenched with a 1:1 mixture of 10% aqueous Na_2SO_3 and saturated aqueous $NaHCO_3$ and then the mixture was extracted with CH_2Cl_2. The combined organic layers were washed with H_2O and brine, dried over $MgSO_4$, and then filtered. The filtrate was concentrated under reduced pressure and the crude product was purified by column chromatography (silica gel, 10% EtOAc–hexane) to afford (1*R*,2*S*,3*R*,5*R*,6*S*,7*S*,8*R*,9*S*)-2,6-bis(benzyloxy)-5-(*t*-butyldimethylsilyloxy)-7,9-(isopropylidenedioxy)-8-(methoxymethoxymethyl)-4,4-dimethyl-12-methylenebicyclo[6.4.0]dodecan-3-ol (2.87 g, quant) as a colorless oil. $[\alpha]_D^{24} = +90.1$ (*c* 0.50, benzene); IR (thin film) 3568 cm^{-1}; ^1H NMR ($CDCl_3$) δ 7.36–7.20 (m, 10H), 4.86 (s, 2H), 4.75–4.52 (m, 6H), 4.47 (dd, $J = 3.0$, 10.8 Hz, 1H), 4.38–4.25 (m, 2H), 4.17 (d, $J = 11.6$ Hz, 1H), 4.02 (s, 1H), 3.90 (d, $J = 2.7$ Hz, 1H), 3.76 (t, $J = 7.8$ Hz, 1H), 3.62 (d, $J = 2.7$ Hz, 1H), 3.36 (s, 3H), 2.98–2.78 (m, 1H), 2.52 (d, $J = 11.6$ Hz, 1H), 2.20–2.12 (m, 1H), 1.95–1.72 (m, 2H), 1.44 (s, 3H), 1.41 (s, 3H), 1.17 (s, 3H), 1.04 (s, 3H), 0.93 (s, 9H), 0.08 (s, 3H), 0.03 (s, 3H); ^{13}C NMR ($CDCl_3$) δ 144.9, 138.8, 138.6, 128.3, 128.1, 128.0, 127.3, 127.3, 127.1, 115.4, 99.2, 97.2, 91.9, 82.0, 78.2, 77.1, 76.0, 74.1, 73.3, 72.1, 64.0, 55.8, 49.8, 45.6, 43.2, 29.7, 27.8, 27.4, 25.9, 24.1, 21.2, 19.0, 18.0, −4.1, −4.8; HRMS (FAB) calcd for $C_{41}H_{62}NaO_8Si$ $[M + Na]^+$ 733.4112; found 733.4122.

(1*R*,2*S*,5*R*,6*S*,7*S*,8*R*,9*S*)-2,6-Bis(benzyloxy)-5-(*t*-butyldimethylsilyloxy)-7,9-(isopropylidenedioxy)-8-(methoxymethoxymethyl)-4,4-dimethyl-12-methylenebicyclo[6.4.0]dodecan-3-one (26). To a solution of (1*R*,2*S*,3*R*,5*R*,6*S*,7*S*,8*R*,9*S*)-2,6-bis(benzyloxy)-5-(*t*-butyldimethylsilyloxy)-7,9-(isopropylidenedioxy)-8-(methoxymethoxymethyl)-4,4-dimethyl-12-methylenebicyclo[6.4.0]dodecan-3-ol (2.24 g, 3.15 mmol) in CH_2Cl_2 (315 mL) were added $NaHCO_3$ (2.65 g, 31.5 mmol) and Dess–Martin periodinane (6.68 g, 15.8 mmol) at room temperature. After the reaction mixture was stirred for 20 min, the reaction was quenched with 10% aqueous Na_2SO_3 and saturated aqueous $NaHCO_3$. The mixture was extracted with CH_2Cl_2 and the combined organic layers were washed with brine, dried over $MgSO_4$, and then filtered. The filtrate was concentrated under reduced pressure and the crude product was purified by column chromatography (silica gel, 5–10% EtOAc–hexane) to afford ketone **26** (2.13 g, 95%) as a colorless oil. $[\alpha]_D^{20} = -19.0$ (*c* 1.00, $CHCl_3$); IR (thin film) 1687 cm^{-1}; ^1H NMR ($CDCl_3$) δ 7.23–7.10 (m, 10H), 4.90 (s, 1H), 4.78 (s, 1H), 4.64 (d, $J = 11.3$ Hz, 1H), 4.56 (d, $J = 11.3$ Hz, 1H), 4.42–4.33 (m, 5H), 4.22 (d, $J = 11.6$ Hz 1H), 4.07 (d, $J = 11.3$ Hz, 1H), 3.98 (d, $J = 11.1$ Hz, 1H), 3.78–3.67 (m, 2H), 3.58 (d, $J = 2.2$ Hz, 1H), 3.30 (s, 3H), 2.72 (d, $J = 11.9$ Hz, 1H), 2.49–2.33 (m, 1H), 2.03–1.90 (m, 1H), 1.85–1.66 (m, 2H), 1.31 (s, 6H), 1.24 (s, 3H), 1.22 (s, 3H), 0.82 (s, 9H), 0.00 (s, 3H), −0.05 (s, 3H); ^{13}C NMR ($CDCl_3$) δ 210.4, 143.4, 138.9, 138.1, 128.8, 128.5, 128.5, 128.1, 127.9, 127.6, 115.9, 99.6, 97.3, 91.0, 82.8, 82.0, 76.5, 74.0, 71.7, 64.3, 55.9, 54.6, 48.1, 43.9, 30.2, 29.1, 29.0, 28.7, 26.2, 26.1, 20.3, 19.5, 18.4, −3.7, −4.4; HRMS (FAB) calcd for $C_{41}H_{60}NaO_8Si$ $[M + Na]^+$ 731.3955; found 731.3968.

(1*R*,2*S*,3*S*,5*R*,6*S*,7*S*,8*R*,9*S*)-2,6-Bis(benzyloxy)-3-(3-butenyl)-5-(*t*-butyldimethylsilyloxy)-7,9-(isopropylidenedioxy)-8-(methoxymethoxymethyl)-4,4-dimethyl-12-methylenebicyclo[6.4.0]dodecan-3-ol. To a solution of *s*-butyllithium in cyclohexane (0.97 M, 17.5 mL, 17.0 mmol) at 0 °C was added 4-iodobutene (3.09 g, 17 mmol). After the reaction had been stirred for 25 min at −23 °C, a solution of ketone **26** (600 mg, 0.846 mmol) in benzene (50 mL) was added. The reaction mixture was stirred for 1 h at 0 °C and then saturated aqueous ammonium chloride was added. The mixture was extracted with diethyl ether. The organic layer was washed with 10% aqueous sodium thiosulfate and brine, and dried over anhydrous sodium sulfate. After filtration of the mixture and evaporation of the solvent, the crude product was purified by column chromatography (silica gel, 1–2% Et_2O–benzene) to afford (1*R*,2*S*,3*S*,5*R*,6*S*,7*S*,8*R*,9*S*)-2,6-bis(benzyloxy)-3-(3-butenyl)-5-(*t*-butyldimethylsilyloxy)-7,9-(isopropylidenedioxy)-8-(methoxymethoxymethyl)-4,4-dimethyl-12-methylenebicyclo[6.4.0]dodecan-3-ol (630 mg, 97%) as a colorless oil. $[\alpha]_D^{19} = +32.0$ (*c* 1.10, $CHCl_3$); IR (liquid film) 3403 cm^{-1}; ^1H NMR ($CDCl_3$) δ 7.50–7.11 (m, 10H), 6.02–5.41 (brm, 2H), 5.11–3.98 (brm, 14H), 3.77–3.49 (brm, 2H), 3.45–3.11 (brm, 3H), 3.03–2.88 (brm, 1H), 2.87–1.70 (brm, 8H), 1.51–1.33 (brm, 6H), 1.31–1.15 (brm, 6H), 0.95 (s, 9H), 0.09 (s, 6H); ^{13}C NMR ($CDCl_3$) very broadened spectra; HRMS (FAB) calcd for $C_{45}H_{68}NaO_8Si$ $[M + Na]^+$ 787.4581; found 787.4564.

(1*R*,2*S*,3*S*,5*R*,6*R*,7*S*,8*R*,9*S*)-2,6-Bis(benzyloxy)-3-(3-butenyl)-7,9-(isopropylidenedioxy)-8-(methoxymethoxymethyl)-4,4-dimethyl-12-methylenebicyclo[6.4.0]dodecane-3,5-diol (27). To a solution of (1*R*,2*S*,3*S*,5*R*,6*S*,7*S*,8*R*,9*S*)-2,6-bis(benzyloxy)-3-(3-butenyl)-5-(*t*-butyldimethylsilyloxy)-7,9-(isopropylidenedioxy)-8-(methoxymethoxymethyl)-4,4-dimethyl-12-methylenebicyclo[6.4.0]dodecan-3-ol (301 mg, 0.393 mmol) in THF (53 mL) at room temperature was added TBAF in THF (1.0 M, 12 mL, 12 mmol). The reaction mixture was stirred for 1 h at 50 °C and then phosphate buffer (pH = 7) was added at 0 °C. The mixture was extracted with diethyl ether, and the organic layer was washed with brine and dried over anhydrous sodium sulfate. After filtration of the mixture and evaporation of the solvent, the crude product was purified by preparative TLC (25% EtOAc–hexane) to afford alcohol **27** (204 mg, 80%) as a colorless oil. $[\alpha]_D^{18} = +36.8$ (*c* 1.00, $CHCl_3$); IR (thin film) 3472 cm^{-1}; ^1H NMR ($CDCl_3$) δ 7.50–7.12 (m, 10H), 5.88–5.72 (brm, 1H), 5.41–5.30 (brm, 1H), 5.09–4.25 (brm, 12H), 4.21–4.03 (brm, 1H), 3.95–3.51 (brm, 3H), 3.34 (s, 3H), 3.30–2.92 (brm, 1H), 2.60–2.45 (brm, 1H), 2.38–2.01 (brm, 4H), 2.00–1.61 (brm, 3H), 1.52 (s, 3H), 1.46 (s, 3H), 1.26 (brs, 3H), 1.17 (brs, 3H); ^{13}C NMR ($CDCl_3$) very broadened spectra; HRMS (FAB) calcd for $C_{39}H_{54}NaO_8$ $[M + Na]^+$ 673.3716; found 673.3727.

(1*R*,2*S*,3*S*,4*R*,6*S*,7*S*,8*R*,12*S*)-3,7-Bis(benzyloxy)-6-(3-butenyl)-4,6-(cyclohexylmethylsilylenedioxy)-2,12-(isopropylidenedioxy)-1-(methoxymethoxymethyl)-5,5-dimethyl-9-methylenebicyclo[6.4.0]dodecane (28). To a solution of diol **27** (1.20 g, 1.84 mmol) and imidazole (12.6 g, 106 mmol) in DMF (102 mL) at 0 °C was added dichloro(cyclohexyl)methylsilane (7.3 g, 36.8 mmol). The reaction mixture was stirred for 10 min at room temperature and then saturated aqueous sodium hydrogencarbonate was added. The mixture was extracted with diethyl ether, and the organic layer was washed with brine and dried over anhydrous sodium sulfate. After filtration of the mixture and evaporation of the solvent, the crude product was purified by column chromatography (silica gel, 2–10% EtOAc–hexane) to afford alcohol **28** (1.49 g, quant) as a colorless oil. $[\alpha]_D^{18} = -3.72$ (*c* 1.07, $CHCl_3$); IR (thin film) 2922, 2849 cm^{-1}; ^1H NMR ($CDCl_3$) δ 7.46–7.35 (m, 2H), 7.33–7.10 (m, 8H), 5.88–5.71 (m, 1H), 5.65 (brs, 1H), 4.98 (d, $J = 11.3$ Hz, 1H), 4.90 (d, $J = 16.1$ Hz, 1H), 4.84 (s, 1H), 4.80 (s, 1H), 4.75–4.65 (m, 2H), 4.62 (d, $J = 5.9$ Hz, 1H), 4.57 (d, $J = 3.0$ Hz, 1H), 4.54 (d, $J = 3.0$ Hz, 1H), 4.50 (d, $J = 3.0$ Hz, 1H), 4.47 (d, $J = 3.0$ Hz, 1H), 4.44 (d, $J = 16.1$ Hz, 1H),

4.25 (s, 1H), 4.16 (d, $J = 8.9$ Hz, 1H), 4.07 (d, $J = 8.9$ Hz, 1H), 3.74 (dd, $J = 11.1$, 4.3 Hz, 1H), 3.37 (s, 3H), 2.65–2.12 (m, 6H), 1.92–1.52 (m, 4H), 1.44 (s, 3H), 1.44 (s, 3H), 1.42 (s, 3H), 1.38 (s, 3H), 1.25–0.95 (m, 9H), 0.70–0.55 (m, 1H), 0.10 (s, 3H); ^{13}C NMR ($CDCl_3$) δ 144.3, 140.9, 139.8, 138.1, 129.1, 127.9, 127.8, 127.5, 126.6, 126.5, 113.1, 114.1, 99.6, 96.5, 86.2, 83.8, 82.0, 79.6, 78.4, 76.9, 71.2, 66.5, 55.5, 49.5, 47.3, 42.0, 37.7, 31.5, 31.4, 30.0, 29.6, 29.2, 28.1, 27.9, 27.8, 27.5, 27.3, 27.0, 26.9, 19.9, −0.1, −1.4; HRMS (FAB) calcd for $C_{46}H_{66}NaO_8Si$ $[M + Na]^+$ 797.4425; found 797.4458.

(1*R*,2*S*,3*R*,4*R*,6*S*,7*S*,8*R*,12*S*)-3,7-Bis(benzyloxy)-6-(3-butenyl)-6-(cyclohexyldimethylsilyloxy)-2,12-(isopropylidenedioxy)-1-(methoxymethoxymethyl)-5,5-dimethyl-9-methylenebicyclo[6.4.0]dodecan-4-ol (29). To a solution of silylene **28** (1.49 g, 1.92 mmol) in THF (192 mL) and HMPA (19.2 mL) at −78 °C was added methyllithium in diethyl ether (1.02 M, 37.6 mL, 38.4 mmol). The reaction mixture was stirred for 30 min at −78 °C and then saturated aqueous ammonium chloride was added. The mixture was extracted with diethyl ether, and the organic layer was washed with brine and dried over anhydrous sodium sulfate. After filtration of the mixture and evaporation of the solvent, the crude product was purified by column chromatography (silica gel, 10–20% EtOAc–hexane) to afford alcohol **29** (1.51 g, 99%) as a colorless oil. $[\alpha]_D^{18} = +18.9$ (c 1.05, $CHCl_3$); IR (KBr pellet) 3469 cm^{-1}; ^{1}H NMR ($CDCl_3$) δ 7.45–6.98 (m, 10H), 5.88–5.61 (brm, 2H), 4.99–3.92 (brm, 14H), 3.73–3.52 (brm, 2H), 3.31–3.05 (brm, 3H), 2.80–2.60 (brm, 1H), 2.51–0.88 (brm, 18H), 1.57 (s, 3H), 1.38 (s, 3H), 1.15 (s, 3H), 1.04 (s, 3H), 0.58–0.51 (brm, 1H), 0.02 (s, 3H), −0.30 (s, 3H); ^{13}C NMR ($CDCl_3$) very broadened spectra; HRMS (FAB) calcd for $C_{47}H_{70}NaO_8Si$ $[M + Na]^+$ 813.4738; found 813.4729.

(1*R*,2*S*,3*S*,6*S*,7*S*,8*R*,12*S*)-3,7-Bis(benzyloxy)-6-(3-butenyl)-6-(cyclohexyldimethylsilyloxy)-2,12-(isopropylidenedioxy)-1-(methoxymethoxymethyl)-5,5-dimethyl-9-methylenebicyclo[6.4.0]dodecan-4-one. To a solution of alcohol **29** (225 mg, 0.284 mmol) in CH_2Cl_2 (14 mL) were added $NaHCO_3$ (477 mg, 5.68 mmol) and Dess–Martin periodinane (603 mg, 1.42 mmol) at room temperature. After the reaction mixture was stirred for 20 min, the reaction was quenched with 10% aqueous Na_2SO_3 (2 mL) and saturated aqueous $NaHCO_3$. The mixture was extracted with CH_2Cl_2 and the combined organic layers were washed with brine, dried over $MgSO_4$, and then filtered. The filtrate was concentrated under reduced pressure and the crude product was purified by preparative TLC (20% EtOAc–hexane) to afford (1*R*,2*S*,3*S*,6*S*,7*S*,8*R*,12*S*)-3,7-bis(benzyloxy)-6-(3-butenyl)-6-(cyclohexyldimethylsilyloxy)-2,12-(isopropylidenedioxy)-1-(methoxymethoxymethyl)-5,5-dimethyl-9-methylenebicyclo[6.4.0]dodecan-4-one (217 mg, 97%) as a colorless oil. $[\alpha]_D^{19} = +19.2$ (c 1.04, $CHCl_3$); IR (KBr pellet) 1673 cm^{-1}; ^{1}H NMR ($CDCl_3$) δ 7.41–7.05 (m, 10H), 5.78 (ddt, $J = 16.2$, 10.3, 5.9 Hz, 1H), 5.04–4.82 (m, 5H), 4.68 (s, 2H), 4.65–4.56 (m, 3H), 4.55 (d, $J = 1.6$ Hz, 1H), 4.42 (d, $J = 12.2$ Hz, 1H), 4.34 (d, $J = 1.6$ Hz, 1H), 4.22 (d, $J = 3.8$ Hz, 1H), 3.84 (d, $J = 3.8$ Hz, 1H), 3.78 (d, $J = 9.5$ Hz, 1H), 3.41 (s, 3H), 2.97–2.82 (m, 1H), 2.51–2.37 (m, 1H), 2.23–2.09 (m, 1H), 2.05–1.61 (m, 10H), 1.66 (s, 3H), 1.46 (s, 3H), 1.42 (s, 3H), 1.25 (s, 3H), 1.25–0.85 (m, 6H), 0.70–0.58 (m, 1H), 0.13 (s, 3H), −0.15 (s, 3H); ^{13}C NMR ($CDCl_3$) δ 215.6, 147.0, 140.4, 139.5, 137.6, 128.2, 127.7, 127.6, 127.5, 125.9, 125.0, 113.6, 113.1, 99.9, 97.3, 92.3, 89.5, 82.9, 80.6, 75.6, 74.3, 72.6, 64.4, 57.0, 56.0, 47.6, 44.9, 29.9, 29.8, 29.7, 29.1, 28.7, 28.1, 27.9, 27.3, 27.3, 27.0, 26.2, 21.5, 19.9, −0.0, −1.4; HRMS (FAB) calcd for $C_{47}H_{68}NaO_8Si$ $[M + Na]^+$ 811.4581; found 811.4598.

(1*R*,2*S*,3*S*,6*S*,7*S*,8*R*,12*S*)-3,7-Bis(benzyloxy)-6-(cyclohexyldimethylsilyloxy)-2,12-(isopropylidenedioxy)-1-(methoxymethoxymethyl)-5,5-dimethyl-9-methylene-6-(3-oxobutyl)bicyclo[6.4.0]dodecan-4-one (30). To a solution of (1*R*,2*S*,3*S*,6*S*,7*S*,8*R*,12*S*)-3,7-bis(benzyloxy)-6-(3-butenyl)-6-(cyclohexyldimethylsilyloxy)-2,12-(isopropylidenedioxy)-1-(methoxymethoxymethyl)-5,5-dimethyl-9-methylenebicyclo[6.4.0]dodecan-4-one (205 mg, 0.26 mmol) in DMF (71 mL) and water at 0 °C was added palladium(II) chloride (230 mg, 1.3 mmol). The reaction mixture was stirred for 3.5 h at room temperature and then phosphate buffer (pH = 7) was added at 0 °C. The mixture was extracted with ethyl acetate. Then the organic layers were washed with water and brine, and dried over anhydrous sodium sulfate. After filtration of the mixture and evaporation of the solvent, the crude product was purified by preparative TLC (20% EtOAc–hexane) to afford diketone **30** (174 mg, 83%) as a colorless oil. $[\alpha]_D^{18} = +33.4$ (c 1.04, $CHCl_3$); IR (KBr pellet) 1716, 1673 cm^{-1}; ^{1}H NMR ($CDCl_3$) δ 7.41–7.05 (m, 10H), 4.98 (d, $J = 12.4$ Hz, 1H), 4.89 (s, 1H), 4.86 (d, $J = 12.4$ Hz, 1H), 4.68 (s, 2H), 4.67 (d, $J = 11.6$ Hz, 1H), 4.63 (s, 1H), 4.59 (d, $J = 11.6$ Hz, 1H), 4.45–4.37 (m, 2H), 4.36 (d, $J = 1.9$ Hz, 1H), 4.24 (d, $J = 3.5$ Hz, 1H), 3.85 (d, $J = 3.5$ Hz, 1H), 3.78 (t, $J = 9.2$ Hz, 1H), 3.57–3.41 (m, 1H), 3.40 (s, 3H), 2.74–2.57 (m, 1H), 2.55–2.40 (m, 1H), 2.22–1.95 (m, 4H), 2.01 (s, 3H), 1.95–1.47 (m, 6H), 1.65 (s, 3H), 1.46 (s, 3H), 1.41 (s, 3H), 1.21 (s, 3H), 1.20–0.90 (m, 6H), 0.72–0.60 (m, 1H), 0.09 (s, 3H), −0.16 (s, 3H); ^{13}C NMR ($CDCl_3$) δ 214.8, 208.7, 147.8, 140.0, 137.3, 127.9, 127.5, 127.4, 127.2, 125.7, 124.6, 112.4, 99.7, 97.0, 91.9, 88.9, 82.6, 80.2, 75.4, 74.0, 72.2, 64.1, 56.6, 55.8, 47.3, 44.6, 40.6, 30.1, 29.6, 29.5, 28.3, 27.8, 27.6, 27.0, 26.6, 25.8, 23.7, 21.2, 19.5, 0.0, −1.5; HRMS (FAB) calcd for $C_{47}H_{68}NaO_9Si$ $[M + Na]^+$ 827.4530; found 827.4567.

(4*S*,4a*R*,5*S*,6*S*,7*R*,8*R*,11*S*,12*S*,12a*R*)-6,12-Bis(benzyloxy)-11-(cyclohexyldimethylsilyloxy)-4,5-(isopropylidenedioxy)-4a-(methoxymethoxymethyl)-8,13,13-trimethyl-1-methylenetetradecahydro-7,11-methanobenzocyclodecene-7,8-diol (4). Titanium(II) chloride was prepared from titanium(IV) chloride and hexamethyldisilane by the procedure of Paul et al.[17] To a solution of this titanium(II) chloride (1.23 g, 10.3 mmol) in THF (20 mL) at 0 °C was added lithium aluminium hydride in THF (1.0 M, 2.29 mL, 2.29 mmol). The reaction mixture was refluxed for 20 min and then THF (12 mL) was added at room temperature. The suspension of low-valent titanium in THF (0.2 M) thus prepared was immediately used in the following reaction. To a solution of diketone **30** (186 mg, 0.231 mmol) in THF (84 mL) at 35 °C was added the suspension of low-valent titanium in THF (0.2 M, 28.9 mL, 5.78 mmol). The reaction mixture was stirred for 20 min at 40 °C and then saturated aqueous sodium hydrogencarbonate was added at 0 °C. The mixture was stirred for 10 min at room temperature and then it was extracted with ethyl acetate. The organic layers were washed with water and brine, and dried over anhydrous sodium sulfate. After filtration of the mixture and evaporation of the solvent, the crude product was purified by preparative TLC (30% EtOAc–hexane) to afford diol **4** (119 mg, 64%) as a colorless oil. $[\alpha]_D^{21} = +28.4$ (c 1.00, $CHCl_3$); IR (KBr pellet) 3559 cm^{-1}; ^{1}H NMR (C_6D_6) δ 7.58 (d, $J = 7.5$ Hz, 2H), 7.38 (d, $J = 7.5$ Hz, 2H), 7.28 (t, $J = 7.5$ Hz, 2H), 7.24 (t, $J = 7.5$ Hz, 2H), 7.13 (t, $J = 7.5$ Hz, 1H), 7.10 (t, $J = 7.5$ Hz, 1H), 5.25 (d, $J = 10.5$ Hz, 1H), 5.19 (brs, 1H), 5.02 (d, $J = 13.0$ Hz, 1H), 4.98 (brs, 1H), 4.97 (d, $J = 13.0$ Hz, 1H), 4.94 (d, $J = 12.0$ Hz, 1H), 4.49 (d, $J = 12.0$ Hz, 1H), 4.39 (d, $J = 4.0$ Hz, 1H), 4.39 (d, $J =$

6.0 Hz, 1H), 4.38 (d, $J = 10.5$ Hz, 1H), 4.36 (d, $J = 6.0$ Hz, 1H), 3.95 (d, $J = 2.5$ Hz, 1H), 3.84 (t, $J = 9.0$ Hz, 1H), 3.82 (d, $J = 2.5$ Hz, 1H), 3.33 (d, $J = 4.5$ Hz, 1H), 3.20 (s, 1H), 3.11 (s, 3H), 3.02–2.94 (m, 2H), 2.56–2.47 (m, 1H), 2.38 (dd, $J = 14.0$, 5.5 Hz, 1H), 2.27–2.14 (m, 2H), 2.13–1.95 (m, 4H), 1.85–1.78 (m, 1H), 1.76–1.70 (m, 1H), 1.68–1.62 (m, 1H), 1.62 (s, 3H), 1.46 (s, 3H), 1.45–1.41 (m, 1H), 1.39 (s, 3H), 1.36–1.25 (m, 1H), 1.30 (s, 3H), 1.24–1.06 (m, 2H), 1.17 (s, 3H), 0.98–0.87 (m, 1H), 0.80–0.72 (m, 1H), 0.24 (s, 3H), 0.22 (s, 3H); ^{13}C NMR ($CDCl_3$) δ 147.6, 141.7, 139.5, 129.4, 128.8, 128.6, 128.2, 127.3, 127.0, 112.8, 99.6, 98.1, 93.5, 84.5, 83.1, 82.7, 80.6, 78.3, 75.4, 73.4, 73.4, 73.2, 64.2, 56.1, 51.1, 45.6, 45.4, 38.4, 31.4, 30.6, 29.7, 29.2, 29.1, 28.9, 28.5, 28.4, 28.3, 28.2, 28.0, 23.7, 19.4, 0.9, 0.4; HRMS (FAB) calcd for $C_{47}H_{70}NaO_9Si$ $[M + Na]^+$ 829.4687; found 829.4691.

(1*S*,4a*R*,5*S*,6*S*,9*R*,10*R*,11*S*,12*S*,12a*R*)-6-(Cyclohexyldimethylsilyloxy)-1,12-(isopropylidenedioxy)-12a-(methoxymethoxymethyl)-9,13,13-trimethyl-4-methylenetetradecahydro-6,10-methanobenzocyclodecene-5,9,10,11-tetrol. To a solution of diol **4** (133 mg, 0.164 mmol) in THF (12.6 mL) at −78 °C were added liquid ammonia (29.3 mL) and sodium (37.6 mg, 1.64 mmol). After the reaction mixture was stirred for 15 min at −78 °C, it was allowed to warm to −45 °C. The reaction mixture was stirred for 30 min at −45 °C and then solid ammonium chloride was added. After evaporation of liquid ammonia at room temperature, the residue was diluted with diethyl ether and dried over anhydrous sodium sulfate. After filtration of the mixture and evaporation of the solvent, the crude product was purified by preparative TLC (50% EtOAc–hexane) to afford (1*S*,4a*R*,5*S*,6*S*,9*R*,10*R*,11*S*,12*S*,12a*R*)-6-(cyclohexyldimethylsilyloxy)-1,12-(isopropylidenedioxy)-12a-(methoxymethoxymethyl)-9,13,13-trimethyl-4-methylenetetradecahydro-6,10-methanobenzocyclodecene-5,9,10,11-tetrol (98.7 mg, 96%) as a colorless oil. $[\alpha]_D^{18} = +18.9$ (*c* 1.01, $CHCl_3$); IR (KBr pellet) 3535 cm^{-1}; ^{1}H NMR ($CDCl_3$) δ 4.87 (s, 1H), 4.62 (s, 2H), 4.58 (s, 1H), 4.39 (d, $J = 5.9$ Hz, 1H), 4.37 (d, $J = 11.9$ Hz, 1H), 3.98 (d, $J = 11.9$ Hz, 1H), 3.89 (dd, $J = 5.4$, 2.7 Hz, 1H), 3.78 (s, 1H), 3.71 (d, $J = 2.7$ Hz, 1H), 3.64 (dd, $J = 10.8$, 7.0 Hz, 1H), 3.46 (d, $J = 5.4$ Hz, 1H), 3.36 (s, 3H), 2.92 (brs, 1H), 2.89 (d, $J = 7.0$ Hz, 1H), 2.67 (s, 1H), 2.61–2.47 (m, 1H), 2.11–1.68 (m, 7H), 1.67–1.50 (m, 4H), 1.41 (s, 3H), 1.36 (s, 3H), 1.34 (s, 3H), 1.25–0.88 (m, 6H), 1.27 (s, 3H), 1.11 (s, 3H), 0.63–0.51 (m, 1H), −0.01 (s, 3H), −0.02 (s, 3H); ^{13}C NMR ($CDCl_3$) δ 144.6, 113.5, 99.1, 97.1, 81.8, 79.8, 78.9, 78.1, 77.1, 73.9, 73.3, 64.0, 56.3, 47.6, 47.0, 45.1, 36.7, 31.1, 29.8, 28.0, 27.9, 27.8, 27.7, 27.7, 27.2, 27.1, 27.0, 26.9, 21.2, 19.3, 18.7, −2.8, −3.1; HRMS (FAB) calcd for $C_{33}H_{58}NaO_9Si$ $[M + Na]^+$ 649.3748; found 649.3773.

(1*S*,4a*R*,5*S*,6*S*,9*R*,10*R*,11*S*,12*S*,12a*R*)-1,12-(Isopropylidenedioxy)-12a-(methoxymethoxymethyl)-9,13,13-trimethyl-4-methylenetetradecahydro-6,10-methanobenzocyclodecene-5,6,9,10,11-pentol. To a solution of (1*S*,4a*R*,5*S*,6*S*,9*R*,10*R*,11*S*,12*S*,12a*R*)-6-(cyclohexyldimethylsilyloxy)-1,12-(isopropylidenedioxy)-12a-(methoxymethoxymethyl)-9,13,13-trimethyl-4-methylenetetradecahydro-6,10-methanobenzocyclodecene-5,9,10,11-tetrol (98.7 mg, 0.157 mmol) in THF (24.5 mL) at room temperature was added TBAF in THF (1.0 M, 0.98 mL, 0.98 mmol). The reaction mixture was stirred for 30 min at room temperature and then a small amount of methanol was added. After the solvent was evaporated, the crude product was purified by preparative TLC (75% EtOAc–hexane) to afford (1*S*,4a*R*,5*S*,6*S*,9*R*,10*R*,11*S*,12*S*,12a*R*)-1,12-(isopropylidenedioxy)-12a-(methoxymethoxymethyl)-9,13,13-trimethyl-4-methylenetetradecahydro-6,10-methanobenzocyclodecene-5,6,9,10,11-pentol (75.3 mg, 98%) as a colorless oil. $[\alpha]_D^{19} = +22.3$ (*c* 1.04, $CHCl_3$); IR (KBr pellet) 3483 cm^{-1}; ^{1}H NMR ($CDCl_3$) δ 5.27 (s, 1H), 4.97 (s, 1H), 4.66 (d, $J = 6.5$ Hz, 1H), 4.62 (d, $J = 6.5$ Hz, 1H), 4.44 (d, $J = 8.9$ Hz, 1H), 4.40 (d, $J = 10.5$ Hz, 1H), 4.22 (brs, 1H), 4.12 (d, $J = 1.6$ Hz, 1H), 4.03 (d, $J = 9.2$ Hz, 1H), 3.93 (dd, $J = 8.9$, 1.6 Hz, 1H), 3.76 (d, $J = 10.5$ Hz, 1H), 3.74 (t, $J = 5.7$ Hz, 1H), 3.60 (s, 1H), 3.41 (s, 3H), 3.30 (brs, 1H), 2.90 (brs, 1H), 2.65–2.55 (m, 1H), 2.53 (d, $J = 8.9$ Hz, 1H), 2.32–2.15 (m, 1H), 2.12–1.58 (m, 6H), 1.50 (s, 3H), 1.44 (s, 3H), 1.44 (s, 3H), 1.34 (s, 3H), 1.23 (s, 3H); ^{13}C NMR ($CDCl_3$) δ 148.8 110.9, 99.1, 97.2, 82.4, 79.4, 78.7, 77.2, 77.1, 73.4, 72.4, 64.0, 56.4, 50.4, 47.6, 47.3, 34.9, 34.7, 29.8, 29.7, 27.1, 27.0, 25.1, 20.5, 19.3; HRMS (FAB) calcd for $C_{25}H_{42}NaO_9$ $[M + Na]^+$ 509.2727; found 509.2729.

(4*S*,4a*R*,5*S*,6*S*,7*R*,8*R*,11*S*,12*S*,12a*R*)-11,12-(Carbonyldioxy)-4,5-(isopropylidenedioxy)-4a-(methoxymethoxymethyl)-8,13,13-trimethyl-1-methylenetetradecahydro-7,11-methanobenzocyclodecene-6,7,8-triol (31). To a solution of (1*S*,4a*R*,5*S*,6*S*,9*R*,10*R*,11*S*,12*S*,12a*R*)-1,12-(isopropylidenedioxy)-12a-(methoxymethoxymethyl)-9,13,13-trimethyl-4-methylenetetradecahydro-6,10-methanobenzocyclodecene-5,6,9,10,11-pentol (65.2 mg, 0.134 mmol) in dichloromethane (76 mL) and pyridine (530 mg, 6.70 mmol) at −45 °C was added bis(trichloromethyl) carbonate (199 mg, 0.67 mmol). The reaction mixture was stirred for 70 min at −45 °C and then saturated aqueous sodium hydrogencarbonate was added. The mixture was extracted with diethyl ether, and the organic layer was washed with saturated aqueous copper(II) sulfate, water, and brine and dried over anhydrous sodium sulfate. After filtration of the mixture and evaporation of the solvent, the crude product was purified by preparative TLC (75% EtOAc–hexane) to afford carbonate **31** (73.2 mg, quant) as a colorless oil. $[\alpha]_D^{17} = -5.99$ (*c* 1.03, $CHCl_3$); IR (KBr pellet) 3425, 1797 cm^{-1}; ^{1}H NMR ($CDCl_3$) δ 5.55 (d, $J = 11.1$ Hz, 1H), 5.32 (s, 1H), 4.87 (s, 1H), 4.70 (d, $J = 6.5$ Hz, 1H), 4.66 (d, $J = 6.5$ Hz, 1H), 4.65–4.52 (m, 1H), 4.29 (brs, 1H), 4.23 (d, $J = 10.3$ Hz, 1H), 3.92 (d, $J = 10.3$ Hz, 1H), 3.76 (dd, $J = 11.3$, 4.6 Hz, 1H), 3.48 (brs, 1H), 3.42 (s, 3H), 2.75 (brs, 1H), 2.52–2.25 (m, 3H), 2.23–1.97 (m, 3H), 1.94–1.70 (m, 2H), 1.69–1.50 (m, 1H), 1.51 (s, 3H), 1.45 (s, 3H), 1.45 (s, 3H), 1.34 (s, 3H), 1.26 (s, 3H); ^{13}C NMR ($CDCl_3$) δ 152.4, 141.2, 114.1, 99.2, 97.3, 93.0, 81.7, 80.5, 79.0, 78.0, 76.7, 73.2, 64.0, 56.9, 48.2, 45.8, 44.9, 36.0, 33.0, 31.2, 29.5, 27.5, 26.5, 22.5, 21.2, 19.3; HRMS (FAB) calcd for $C_{26}H_{41}O_9$ $[M + H]^+$ 513.2700; found 513.2681.

(1*S*,2*S*,3*R*,4*R*,7*S*,8*R*,9*S*,10*S*,11*R*,12*R*)-1,2-(Carbonyldioxy)-4,19-epoxy-7,9-(diisopropylsilylenedioxy)taxane-10,11,12-triol (32). 1) To a solution of carbonate **31** (5.0 mg, 0.00975 mmol) in THF (1 mL) at room temperature was added hydrochloric acid (6 M, 0.5 mL). The reaction mixture was stirred for 5 h at 60 °C and then solid sodium hydrogencarbonate was added at 0 °C. The mixture was diluted with ethyl acetate, and dried over anhydrous sodium sulfate. Filtration of the mixture through a short pad of silica gel and evaporation of the solvent afforded crude pentaol.

2) To a solution of the above crude pentaol in CH_2Cl_2 (2 mL) at −23 °C was added 2,6-lutidine (47 mg, 0.439 mmol) and diisopropylsilanediyl bistriflate (32.0 mg, 0.0975 mmol). The reaction mixture was stirred for 40 min at −23 °C and then saturated aqueous sodium hydrogencarbonate was added. The mixture was extracted with ethyl acetate, and the organic layer was washed with saturated aqueous copper(II) sulfate, water, and brine and dried over anhydrous sodium sulfate. After filtration of the mixture and evaporation of the solvent, the crude product was purified by preparative TLC (10% MeOH–CH_2Cl_2) to afford silylene **32**

(2.0 mg, 37%) as a colorless oil. $[\alpha]_D^{24} = +0.77$ (*c* 0.41, $CHCl_3$); IR (thin film) 3479, 1791 cm^{-1}; ^1H NMR ($CDCl_3$) δ 5.15 (d, $J =$ 10.0 Hz, 1H), 4.43 (d, $J = 9.5$ Hz, 1H), 4.34 (d, $J = 3.0$ Hz, 1H), 4.26 (d, $J = 9.5$ Hz, 1H), 4.15 (dd, $J = 3.0$, 2.5 Hz, 1H), 4.09 (dd, $J = 10.5$, 5.5 Hz, 1H), 3.27 (s, 1H), 2.99 (d, $J = 2.5$ Hz, 1H), 2.53 (s, 1H), 2.48–2.41 (m, 1H), 2.08–2.01 (m, 1H), 2.00–1.92 (m, 2H), 1.91–1.78 (m, 2H), 1.70–1.62 (m, 2H), 1.50 (s, 3H), 1.49 (s, 3H), 1.49–1.42 (m, 1H), 1.37 (s, 3H), 1.30 (s, 3H), 1.08–1.00 (m, 14H); ^{13}C NMR ($CDCl_3$) δ 152.7, 91.0, 86.9, 85.0, 81.9, 79.5, 79.1, 75.7, 73.2, 68.2, 58.1, 50.4, 46.5, 40.1, 31.3, 29.9, 26.9, 26.4, 26.2, 23.3, 22.0, 17.5, 17.2, 17.1, 16.9, 13.0, 12.5; HRMS (FAB) calcd for $C_{27}H_{44}KO_9$ $[M + K]^+$ 579.2391; found 579.2382.

(4*S*,4a*R*,5*S*,6*S*,7*R*,8*R*,11*S*,12*S*,12a*R*)-11,12-(Carbonyldioxy)-4a-hydroxymethyl-4,5-(isopropylidenedioxy)-8,13,13-trimethyl-1-methylenetetradecahydro-7,11-methanobenzocyclodecene-6,7,8-triol. To a solution of carbonate **31** (73.2 mg, 0.143 mmol) in THF (16 mL) at room temperature was added hydrochloric acid (6 M, 8 mL). The reaction mixture was stirred for 4 h at room temperature and then saturated aqueous sodium hydrogencarbonate was added. The mixture was extracted with ethyl acetate, and the organic layer was washed with water and brine and dried over anhydrous sodium sulfate. After filtration of the mixture and evaporation of the solvent, the crude product was purified by preparative TLC (35% acetone–$CHCl_3$) to afford (4*S*,4a*R*,5*S*,6*S*,7*R*,8*R*,11*S*,12*S*,12a*R*)-11,12-(carbonyldioxy)-4a-hydroxymethyl-4,5-(isopropylidenedioxy)-8,13,13-trimethyl-1-methylenetetradecahydro-7,11-methanobenzocyclodecene-6,7,8-triol (67.0 mg, quant) as a colorless oil. $[\alpha]_D^{24} = -28.6$ (*c* 1.00, $CHCl_3$); IR (KBr pellet) 3402, 1791 cm^{-1}; ^1H NMR ($CDCl_3$) δ 5.81 (d, $J = 10.8$ Hz, 1H), 5.34 (s, 1H), 5.00 (s, 1H), 4.25 (d, $J = 12.7$ Hz, 1H), 4.23 (s, 1H), 4.08 (d, $J = 12.7$ Hz, 1H), 3.75 (d, $J = 1.6$ Hz, 1H), 3.73 (dd, $J = 11.3$, 5.1 Hz, 1H), 2.49–2.28 (m, 3H), 2.25–2.01 (m, 3H), 1.95–1.78 (m, 2H), 1.72–1.64 (m, 1H), 1.51 (s, 3H), 1.45 (s, 3H), 1.43 (s, 3H), 1.36 (s, 3H), 1.29 (s, 3H); ^{13}C NMR ($CDCl_3$) δ 152.4, 140.7, 114.4, 99.1, 92.8, 82.1, 80.6, 79.0, 77.9, 77.1, 73.3, 58.0, 48.9, 45.9, 44.8, 36.0, 33.1, 31.2, 29.4, 27.4, 26.5, 22.4, 21.5, 19.3; HRMS (FAB) calcd for $C_{24}H_{37}O_9$ $[M + H]^+$ 469.2438; found 469.2462.

(1*S*,2*S*,3*R*,4*R*,7*S*,8*R*,9*S*,10*S*,11*R*,12*R*)-20-Bromo-1,2-(carbonyldioxy)-4,19-epoxy-7,9-(diisopropylidenedioxy)taxane-10,11,12-triol (33). To a solution of (4*S*,4a*R*,5*S*,6*S*,7*R*,8*R*,11*S*,12*S*,12a*R*)-11,12-(carbonyldioxy)-4a-hydroxymethyl-4,5-(isopropylidenedioxy)-8,13,13-trimethyl-1-methylenetetradecahydro-7,11-methanobenzocyclodecene-6,7,8-triol (53.0 mg, 0.106 mmol) in dichloromethane (20 mL) at room temperature was added *N*-bromosuccinimide (20.8 mg, 0.117 mmol). The reaction mixture was stirred for 1 h at room temperature and then water was added. The mixture was extracted with ethyl acetate, and the organic layer was washed with water and brine and dried over anhydrous sodium sulfate. After filtration of the mixture and evaporation of the solvent, the crude product was purified by preparative TLC (10% MeOH–$CHCl_3$) to afford bromo ether **33** (60.0 mg, quant) as a colorless oil. $[\alpha]_D^{25} = +5.64$ (*c* 1.00, $CHCl_3$); IR (KBr pellet) 3469, 1790 cm^{-1}; ^1H NMR ($CDCl_3$) δ 5.20 (d, $J = 9.5$ Hz, 1H), 4.57 (d, $J = 9.2$ Hz, 1H), 4.43 (d, $J = 9.2$ Hz, 1H), 4.23 (s, 1H), 4.08 (s, 1H), 4.06 (d, $J = 10.0$ Hz, 1H), 3.82 (dd, $J = 8.1$, 6.2 Hz, 1H), 3.54 (d, $J = 10.0$ Hz, 1H), 3.28 (brs, 1H), 2.65–2.57 (m, 2H), 2.56–2.38 (m, 1H), 2.20 (d, $J = 9.5$ Hz, 1H), 2.17–1.51 (m, 8H), 1.46 (s, 3H), 1.43 (s, 3H), 1.40 (s, 3H), 1.34 (s, 3H), 1.25 (s, 3H); ^{13}C NMR ($CDCl_3$) δ 152.4, 100.4, 90.9, 86.0, 84.5, 79.2, 79.1, 75.1, 73.3, 73.1, 68.9, 62.0, 53.9, 48.3, 47.1, 40.8, 35.8, 32.3, 29.6, 25.7, 23.4, 21.6, 20.0; HRMS (ESI) calcd for $C_{24}H_{35}BrNaO_9$ $[M + Na]^+$ 569.1362; found 569.1393.

(1*S*,2*S*,3*R*,4*R*,7*S*,8*S*,9*S*,10*S*,11*R*,12*R*)-20-Bromo-1,2-(carbonyldioxy)-4,19-epoxy-7-(triethylsilyloxy)taxane-9,10,11,12-tetrol (34). 1) To a solution of bromo ether **33** (60.0 mg, 0.106 mmol) in THF (10 mL) at room temperature was added hydrochloric acid (3 M, 5 mL). The reaction mixture was stirred for 5 h at 60 °C and then solid sodium hydrogencarbonate was added at 0 °C. The mixture was diluted with ethyl acetate, and dried over anhydrous sodium sulfate. Filtration of the mixture through a short pad of silica gel and evaporation of the solvent afforded crude pentol.

2) To a solution of the above crude pentol in pyridine (3 mL) at −23 °C was added triethylsilyl triflate (0.1 mL, 0.442 mmol). The reaction mixture was stirred for 30 min at −23 °C and then saturated aqueous sodium hydrogencarbonate was added. The mixture was extracted with ethyl acetate, and the organic layer was washed with saturated aqueous copper(II) sulfate, water, and brine and dried over anhydrous sodium sulfate. After filtration of the mixture and evaporation of the solvent, the crude product was purified by preparative TLC (30% acetone–$CHCl_3$) to afford triethylsilyl ether **34** (60.0 mg, 91%) as a colorless oil. $[\alpha]_D^{22} = +41.7$ (*c* 1.00, $CHCl_3$); IR (KBr pellet) 3454, 1795 cm^{-1}; ^1H NMR ($CDCl_3$) δ 5.39 (d, $J = 7.8$ Hz, 1H), 4.93 (s, 1H), 4.51 (d, $J =$ 10.0 Hz, 1H), 4.38 (d, $J = 10.0$ Hz, 1H), 4.37 (d, $J = 9.2$ Hz, 1H), 4.19 (s, 1H), 4.09 (s, 1H), 3.90–3.81 (m, 1H), 3.24 (d, $J =$ 9.2 Hz, 1H), 3.24–3.17 (brs, 1H), 3.15–3.05 (brs, 1H), 2.75–2.54 (m, 1H), 2.50–2.26 (m, 3H), 2.07–1.81 (m, 4H), 1.60–1.42 (m, 2H), 1.47 (s, 3H), 1.33 (s, 3H), 1.29 (s, 3H), 0.97 (t, $J =$ 8.7 Hz, 9H), 0.69 (q, $J = 8.7$ Hz, 6H); ^{13}C NMR ($CDCl_3$) δ 153.2, 88.3, 88.1, 85.3, 80.1, 79.3, 77.8, 74.8, 73.2, 71.4, 58.9, 49.3, 47.5, 38.8, 37.3, 31.2, 28.8, 26.3, 24.9, 24.8, 20.5, 6.9, 5.1; HRMS (ESI) calcd for $C_{27}H_{45}BrNaO_9Si$ $[M + Na]^+$ 643.1914; found 643.1905.

(4*S*,4a*S*,5*S*,6*S*,7*R*,8*R*,11*S*,12*S*,12a*R*)-11,12-(Carbonyldioxy)-4a-(hydroxymethyl)-8,13,13-trimethyl-1-methylene-4-(triethylsilyloxy)tetradecahydro-7,11-methanobenzocyclodecene-5,6,7,8-tetrol. To a solution of triethylsilyl ether **34** (27.1 mg, 0.0436 mmol) in EtOH (7.5 mL) and AcOH (0.1 mL) at room temperature was added zinc–silver (160 mg). The reaction mixture was stirred for 1 h at 90 °C. After filtration of the reaction mixture through a short pad of celite and evaporation of the solvent, the crude product was purified by preparative TLC (50% EtOAc–hexane) to afford (4*S*,4a*S*,5*S*,6*S*,7*R*,8*R*,11*S*,12*S*,12a*R*)-11,12-(carbonyldioxy)-4a-(hydroxymethyl)-8,13,13-trimethyl-1-methylene-4-(triethylsilyloxy)tetradecahydro-7,11-methanobenzocyclodecene-5,6,7,8-tetrol (19.2 mg, 81%) as a colorless oil. $[\alpha]_D^{22} = -4.57$ (*c* 1.00, $CHCl_3$); IR (KBr pellet) 3390, 1794 cm^{-1}; ^1H NMR ($CDCl_3$) δ 6.50 (brs, 1H), 5.82 (d, $J = 9.7$ Hz, 1H), 5.29 (s, 1H), 5.07 (s, 1H), 4.25–4.10 (m, 4H), 3.89 (dd, $J = 11.1$, 4.9 Hz, 1H), 3.40 (brs, 1H), 2.62 (brs, 1H), 2.50 (d, $J = 9.7$ Hz, 1H), 2.43–2.25 (m, 2H), 2.20–1.91 (m, 5H), 1.82–1.58 (m, 2H), 1.48 (s, 3H), 1.33 (s, 3H), 1.31 (s, 3H), 0.97 (t, $J = 7.8$ Hz, 9H), 0.69 (q, $J = 7.8$ Hz, 6H); ^{13}C NMR ($CDCl_3$) δ 152.6, 140.5, 115.3, 91.7, 83.3, 82.7, 79.7, 79.3, 77.2, 73.2, 57.6, 53.9, 46.1, 45.5, 35.4, 34.2, 32.8, 26.9, 26.6, 23.3, 21.8, 6.8, 5.1; HRMS (ESI) calcd for $C_{27}H_{46}NaO_9Si$ $[M + Na]^+$ 565.2809; found 565.2786.

(4*S*,4a*S*,5*S*,6*S*,7*R*,8*R*,11*S*,12*S*,12a*R*)-4a-(*t*-Butyldimethylsilyloxymethyl)-11,12-(carbonyldioxy)-8,13,13-trimethyl-1-methylene-4-(triethylsilyloxy)tetradecahydro-7,11-methanobenzocyclodecene-5,6,7,8-tetrol. To a solution of (4*S*,4a*S*,5*S*,6*S*,7*R*,8*R*,11*S*,12*S*,12a*R*)-11,12-(carbonyldioxy)-4a-(hydroxymethyl)-8,13,

13-trimethyl-1-methylene-4-(triethylsilyloxy)tetradecahydro-7,11-methanobenzocyclodecene-5,6,7,8-tetrol (32.9 mg, 0.0606 mmol) in pyridine (3 mL) at 0 °C was added *t*-butyldimethylsilyl triflate (0.1 mL, 0.434 mmol). The reaction mixture was stirred for 30 min at −23 °C and then saturated aqueous sodium hydrogencarbonate was added. The mixture was extracted with ethyl acetate, and the organic layer was washed with saturated aqueous copper(II) sulfate, water, and brine and dried over anhydrous sodium sulfate. After filtration of the mixture and evaporation of the solvent, the crude product was purified by preparative TLC (50% EtOAc–hexane) to afford (4*S*,4a*S*,5*S*,6*S*,7*R*,8*R*,11*S*,12*S*,12a*R*)-4a-(*t*-butyldimethylsilyloxymethyl)-11,12-(carbonyldioxy)-8,13,13-trimethyl-1-methylene-4-(triethylsilyloxy)tetradecahydro-7,11-methanobenzocyclodecene-5,6,7,8-tetrol (33.1 mg, 83%) as a colorless oil. $[\alpha]_D^{24} = +11.9$ (*c* 0.83, $CHCl_3$); IR (KBr pellet) 3392, 1795 cm^{-1}; ^1H NMR ($CDCl_3$) δ 6.14 (s, 1H), 5.46 (d, $J = 6.2$ Hz, 1H), 5.12 (s, 1H), 4.98 (s, 1H), 4.41 (d, $J = 11.3$ Hz, 1H), 4.22 (d, $J = 11.3$ Hz, 1H), 4.14 (s, 1H), 4.04 (s, 1H), 3.92 (s, 1H), 3.89 (dd, $J = 10.8$, 5.9 Hz, 1H), 3.70 (brs, 1H), 2.83 (d, $J = 6.2$ Hz, 1H), 2.68–2.54 (m, 1H), 2.45–2.33 (m, 2H), 2.19–2.03 (m, 2H), 2.00–1.94 (m, 2H), 1.89–1.65 (m, 2H), 1.48 (s, 3H), 1.35 (s, 3H), 1.28 (s, 3H), 1.02–0.93 (m, 18H), 0.68 (q, $J = 7.0$ Hz, 6H), 0.14 (s, 3H), 0.13 (s, 3H); ^{13}C NMR ($CDCl_3$) δ 153.1, 141.5, 115.1, 90.9, 83.1, 81.8, 80.6, 80.4, 77.8, 73.0, 58.7, 51.8, 46.6, 43.2, 34.1, 32.8, 32.4, 27.4, 26.1, 26.0, 24.4, 21.5, 18.6, 6.8, 5.2, −5.3, −5.7; HRMS (ESI) calcd for $C_{33}H_{61}O_9Si_2$ $[M + H]^+$ 657.3854; found 657.3826.

(4*S*,4a*S*,5*S*,6*S*,7*R*,8*R*,11*S*,12*S*,12a*R*)-4a-(*t*-Butyldimethylsilyloxymethyl)-11,12-(carbonyldioxy)-5,7,8-trihydroxy-8,13,13-trimethyl-1-methylene-4-(triethylsilyloxy)tetradecahydro-7,11-methanobenzocyclodecen-6-yl Acetate (35). To a solution of (4*S*,4a*S*,5*S*,6*S*,7*R*,8*R*,11*S*,12*S*,12a*R*)-4a-(*t*-butyldimethylsilyloxymethyl)-11,12-(carbonyldioxy)-8,13,13-trimethyl-1-methylene-4-(triethylsilyloxy)tetradecahydro-7,11-methanobenzocyclodecene-5,6,7,8-tetrol (29.3 mg, 0.0446 mmol) and DMAP (3.0 mg, 0.0245 mmol) in pyridine (3 mL) at 0 °C was added acetic anhydride (0.2 mL). The reaction mixture was stirred for 30 min at room temperature and then saturated aqueous sodium hydrogencarbonate was added. The mixture was extracted with ethyl acetate, and the organic layer was washed with saturated aqueous copper(II) sulfate, water, and brine and dried over anhydrous sodium sulfate. After filtration of the mixture and evaporation of the solvent, the crude product was purified by preparative TLC (50% EtOAc–hexane) to afford acetate **35** (24.1 mg, 77%) as a colorless oil. $[\alpha]_D^{20} = +4.07$ (*c* 0.35, $CHCl_3$); IR (KBr pellet) 3468, 3379, 1798 cm^{-1}; ^1H NMR ($CDCl_3$) δ 5.97 (s, 1H), 5.38 (d, $J = 4.9$ Hz, 1H), 5.31 (d, $J = 2.7$ Hz, 1H), 4.98 (s, 1H), 4.78 (s, 1H), 4.57 (d, $J = 12.2$ Hz, 1H), 4.24 (d, $J = 12.2$ Hz, 1H), 3.90 (dd, $J = 10.0$, 6.5 Hz, 1H), 3.84 (d, $J = 2.7$ Hz, 1H), 3.44 (s, 1H), 3.06 (s, 1H), 3.01 (d, $J = 4.9$ Hz, 1H), 2.82–2.68 (m, 1H), 2.50–1.83 (m, 7H), 2.19 (s, 3H), 1.44 (s, 3H), 1.33 (s, 3H), 1.25 (s, 3H), 1.02–0.81 (m, 18H), 0.68 (q, $J = 7.4$ Hz, 6H), 0.13 (s, 6H); ^{13}C NMR ($CDCl_3$) δ 173,4, 153.2, 141.6, 113.6, 90.0, 84.4, 83.3, 82.2, 79.1, 77.2, 73.1, 57.9, 51.2, 46.7, 41.5, 34.3, 31.6, 31.1, 27.1, 25.9, 24.8, 24.7, 21.2, 21.1, 18.4, 6.8, 5.3, −5.5, −5.6; HRMS (ESI) calcd for $C_{35}H_{62}O_{10}NaSi_2$ $[M + Na]^+$ 721.3779; found 721.3790.

(4*S*,4a*S*,5*S*,6*R*,11*S*,12*S*,12a*R*)-4a-(*t*-Butyldimethylsilyloxymethyl)-11,12-(carbonyldioxy)-5-hydroxy-8,13,13-trimethyl-1-methylene-4-(triethylsilyloxy)-1,2,3,4,4a,5,6,9,10,11,12,12a-dodecahydro-7,11-methanobenzocyclodecen-6-yl Acetate (36). 1) To a solution of acetate **35** (2.0 mg, 0.00295 mol) in $CHCl_3$ (1 mL) were added thiophosgene (17 mg, 0.148 mmol) and DMAP (72.3 mg, 0.592 mmol). The reaction mixture was stirred for 48 h at 80 °C and then it was diluted with ethyl acetate at room temperature. Filtration of the mixture through a short pad of silica gel and evaporation of the solvent afforded a crude thionocarbonate (2.0 mg).

2) To the above crude thionocarbonate was added trimethyl phosphite (1 mL) at room temperature. The reaction mixture was stirred for 5 h at 110 °C and then the crude product was purified by preparative TLC (40% EtOAc–hexane) to afford olefin **36** (0.4 mg, 43% based on 35% conversion) as a colorless oil and recovered acetate **35** (1.3 mg, 65%). $[\alpha]_D^{20} = -22.3$ (*c* 0.27, $CHCl_3$); IR (KBr pellet) 3451, 3370, 1797 cm^{-1}; ^1H NMR ($CDCl_3$) δ 6.11 (d, $J = 6.0$ Hz, 1H), 5.52 (s, 1H), 5.33 (d, $J = 2.0$ Hz, 1H), 5.24 (s, 1H), 4.89 (d, $J = 2.0$ Hz, 1H), 4.63 (s, 1H), 4.77 (d, $J = 11.0$ Hz, 1H), 4.54 (d, $J = 11.0$ Hz, 1H), 3.41 (dd, $J = 10.5$, 5.0 Hz, 1H), 2.75 (d, $J = 6.0$ Hz, 1H), 2.70–2.64 (m, 2H), 2.54–2.47 (m, 2H), 2.29 (dd, $J = 11.5$, 6.0 Hz, 1H), 2.16 (s, 3H), 2.15 (s, 3H), 2.01–1.87 (m, 2H), 1.71–1.63 (m, 1H), 1.40 (s, 3H), 1.34 (s, 3H), 0.95 (t, $J = 8.0$ Hz, 9H), 0.89 (s, 9H), 0.58 (q, $J = 8.0$ Hz, 6H), 0.11 (s, 3H), 0.10 (s, 3H); ^{13}C NMR ($CDCl_3$) δ 170.6, 152.9, 141.2, 140.1, 130.6, 116.2, 92.0, 78.4, 76.7, 75.4, 72.5, 64.0, 55.3, 49.7, 45.4, 37.2, 36.8, 33.6, 30.1, 27.1, 25.7, 24.8, 23.9, 20.4, 18.0, 6.9, 5.2, −5.9, −5.9; HRMS (ESI) calcd for $C_{35}H_{60}NaO_8Si_2$ $[M + Na]^+$ 687.3724; found 687.3739.

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