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Studies toward the total synthesis of gambieric acids, potent antifungal polycyclic ethers: convergent synthesis of a fully elaborated GHIJ-ring fragment

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This paper is dedicated to Professor Satoshi Ōmura on the occasion of his receiving the Tetrahedron Prize

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ABSTRACT

A stereocontrolled synthesis of a fully elaborated GHIJ-ring fragment of gambieric acids, which are potent antifungal polycyclic ether natural products, has been accomplished. The synthesis features convergent assembly of the tetracyclic polyether skeleton through aldol coupling/cyclodehydration/reductive etherification processes and stereoselective construction of the J-ring side chain by a $CeCl_3$-promoted Julia–Kocienski olefination.

1. Introduction

Gambieric acids A–D (**1**–**4**, Fig. 1) are marine polycyclic ether natural products isolated from the culture medium of the ciguatera causative dinoflagellate *Gambierdiscus toxicus* by Nagai and co-workers.[1] The gross structure, including the relative stereochemistry of the polycyclic ether domain, was determined by extensive 2D NMR studies,[1] and the complete stereostructure was subsequently proposed on the basis of degradation experiments, application of the modified Mosher method, and chiral HPLC analysis.[2] Structurally, gambieric acids are characterized by the nonacyclic polyether core arranged with complex side chains appended to the B- and J-rings, respectively. Recently, we synthesized the A/B-ring domain of gambieric acid B and their possible diastereomers, and a comparison

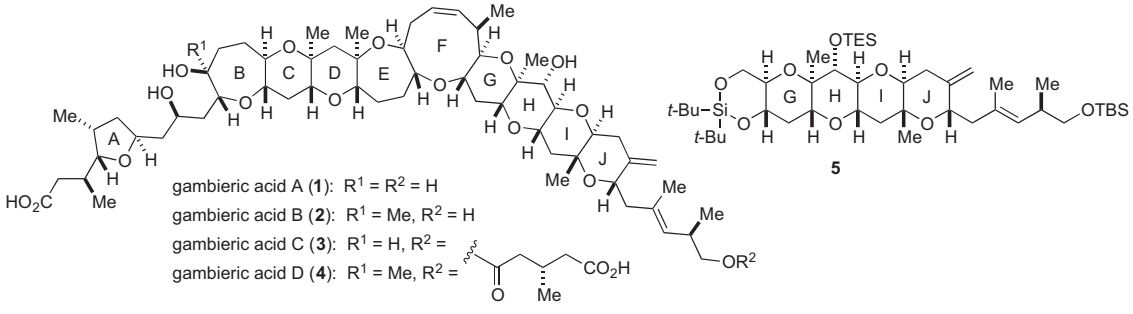

Fig. 1. Structures of gambieric acids A–D (**1**–**4**) and the GHIJ-ring fragment **5**.

of their NMR data with those of the natural product led to stereochemical reassignment of the absolute configuration of the nonacyclic polyether core as shown in Fig. 1.[3]

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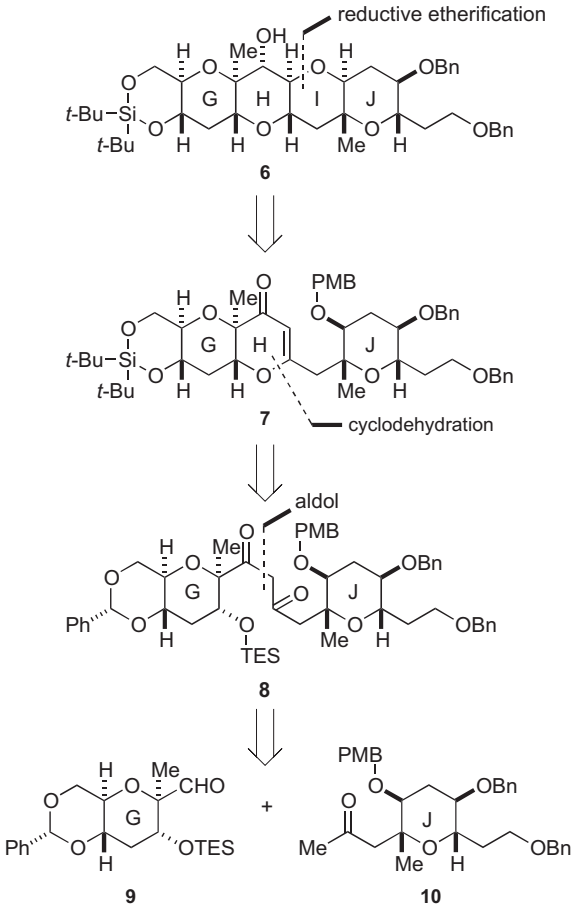
These polycyclic ethers exhibit extremely potent antifungal activity against filamentous fungi. Especially, the growth inhibitory activity against *Aspergillus niger* by the paper disk method was 2,000 times greater than that of amphotericin B, whereas they show only moderate toxicity against mice at a dose of 1 mg/kg given by intraperitoneal injection.[4] It has also been reported that gambieric acid A inhibits the binding of brevetoxin-B derivative (PbTx-3) to the voltage-gated sodium channels of excitable membranes, although its affinity is significantly lower than those of brevetoxins and ciguatoxins.[5] In addition to their remarkable range of biological activities, gambieric acid A was shown to possess a possible role as an endogenous growth regulator of *G. toxicus*.[6]

The complex molecular architecture of gambieric acids, coupled with their promising biological properties and lack of natural materials make these polycyclic ethers attractive candidates for total synthesis.[3,7–11] However, no total synthesis of these natural products has been reported to date. Herein, we describe the details of a convergent synthesis of a fully elaborated GHIJ-ring fragment **5** (Fig. 1) of gambieric acids.[12]

2. Results and discussion

2.1. Synthetic plan of the GHIJ-ring skeleton

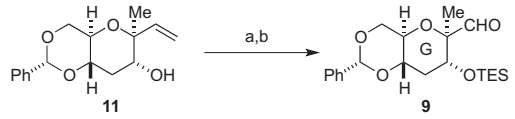
We have previously described a convergent synthesis of the GHIJ-ring fragment in its antipodal form based on acetylide-aldehyde coupling,[9b,c] which was originally developed by the Nakata group.[13] The present synthesis of the GHIJ-ring skeleton **6** relied on an alternative convergent strategy outlined in Scheme 1. The I-ring of **6** was to be constructed by reductive etherification.[9b,c,13] The precursor dihydropyrone **7** would be available from diketone **8** through cyclodehydration.[14] The diketone **8**, in turn, would be constructed by an aldol union of the G-ring aldehyde **9** and the J-ring methyl ketone **10**.



Scheme 1. Synthetic plan of the GHIJ-ring skeleton **6**.

2.2. Synthesis of the G- and J-rings

The synthesis of the G-ring aldehyde **9** is shown in Scheme 2. The known alcohol **11**[15] was protected as its triethylsilyl (TES) ether, and subsequent ozonolysis of the double bond afforded aldehyde **9** in 96% yield for the two steps.

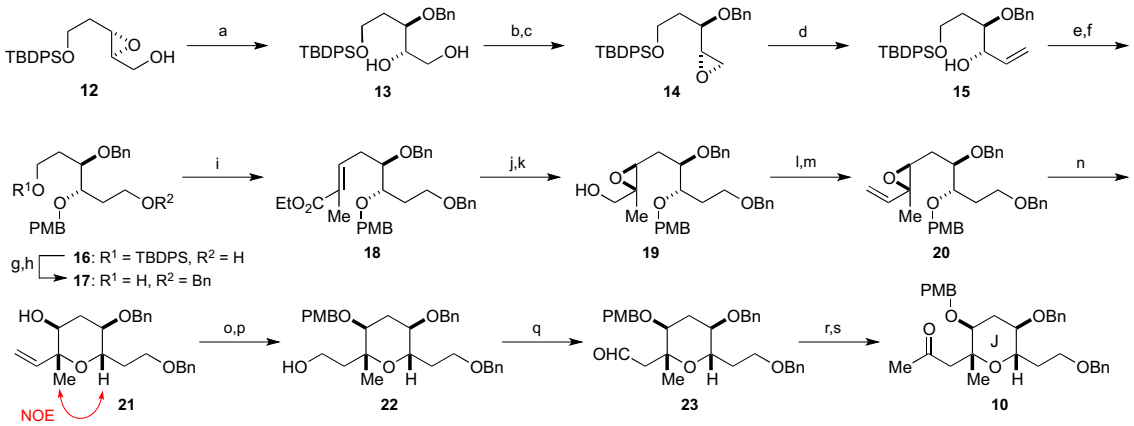


Scheme 2. Synthesis of the G-ring. Reagents and conditions: (a) TESCl, imidazole, CH_2Cl_2, rt; (b) O_3, CH_2Cl_2, −78 °C; then PPh_3, −78 °C to rt, 96% (two steps).

The synthesis of the J-ring methyl ketone **10** started with the known epoxy alcohol **12**.[16] Regioselective epoxide ring-opening with $Ti(OBn)_4$[17] afforded diol **13** in 79% yield (Scheme 3). Selective sulfonylation of the primary alcohol followed by base treatment gave epoxide **14** in 91% yield for the two steps. Exposure of **14** to dimethylsulfonium methylide (Me_3SI, *n*-BuLi)[18] afforded allylic alcohol **15** in 94% yield. Protection as its PMB ether using PMBOC(=NH)CCl_3 in the presence of $La(OTf)_3$[19] was followed by hydroboration with disiamylborane to afford alcohol **16** in 81% yield (two steps). Benzylation and removal of the *tert*-butyldiphenylsilyl (TBDPS) group provided primary alcohol **17** (77%, two steps), which was then converted into (*E*)-enoate **18** via a one-pot Swern oxidation[20]/Wittig reaction (95%). DIBALH reduction followed by Sharpless asymmetric epoxidation[21] gave epoxy alcohol **19** as a single stereoisomer (76%, two steps). This was oxidized with 2,2,6,6-tetramethylpiperidin-1-oxyl (TEMPO)/NaClO[22] and subsequently methylenated to afford vinyl epoxide **20** (93%, two steps). Upon treatment with DDQ, cleavage of the PMB group with concomitant 6-*endo* cyclization[23] took place to afford tetrahydropyran **21** in 72% yield.[24] The stereochemistry of **21** was confirmed by an NOE as shown. Protection of **21** as its PMB ether and hydroboration of the terminal olefin afforded primary alcohol **22** (98%, two steps). Oxidation of **22** under Parihk–Doering conditions[25] gave aldehyde **23**, which was reacted with MeMgBr and then oxidized with tetra-*n*-propylammonium perruthenate (TPAP)/NMO[26] to afford the desired methyl ketone **10** (83%, three steps).

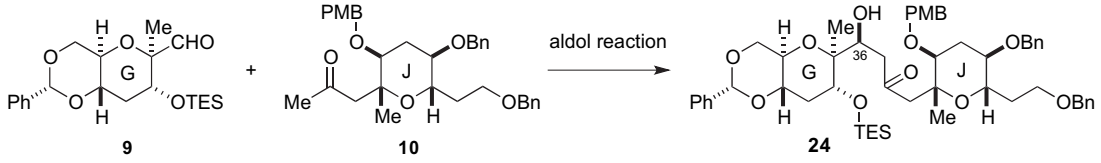
2.3. Aldol coupling of the G- and J-rings

With the two desired fragments in hand, their aldol union was next investigated (Table 1). We first examined Mukaiyama aldol reaction using silyl enol ether.[27,28] Thus, methyl ketone **10** was converted to the corresponding trimethylsilyl enol ether (TMSOTf, *i*-Pr_2NEt, CH_2Cl_2, 0 °C), which was reacted with aldehyde **9** in the presence of $MgBr_2\cdot OEt_2$.[29] Under these conditions, however, the starting ketone **10** was only recovered (Table 1, entry 1). While reaction of the lithium enolate derived from **10** (LDA, THF, −78 °C) with aldehyde **9** also led to no reaction (entry 2), the addition of the zinc enolate generated from **10** (LiHMDS, $ZnCl_2$, THF, −78 °C) to **9** gave the expected β-hydroxy ketone **24** albeit in moderate yield as an inconsequential 2.6:1 mixture of diastereomers at the C36 stereogenic center (entry 3).[30] Finally, it was found that the best result could be obtained by treatment of the dibutylboron enolate derived from **10** (*n*-Bu_2BOTf, *i*-Pr_2NEt, Et_2O, 0 °C)[28,31] with aldehyde **9** (1.5 equiv) at −78 to −20 °C. Under these conditions, the desired



Scheme 3. Synthesis of the J-ring. Reagents and conditions: (a) $Ti(OBn)_4$, toluene, 85 °C, 79%; (b) $MesSO_2Cl$, pyridine, rt; (c) K_2CO_3, MeOH, rt, 91% (two steps); (d) Me_3SI, *n*-BuLi, THF, −30 °C to rt, 94%; (e) PMBOC(=NH)CCl_3, $La(OTf)_3$, toluene, rt; (f) $(Sia)_2BH$, THF, 0 °C to rt; then 3 M aq NaOH, H_2O_2, 0 °C to rt, 81% (two steps); (g) KO*t*-Bu, BnBr, THF, rt; (h) 10% aq KOH, THF/MeOH, 70 °C, 77% (two steps); (i) $(COCl)_2$, DMSO, Et_3N, CH_2Cl_2, −78 °C to rt; then $Ph_3P{=}C(Me)CO_2Et$, rt, 95%; (j) DIBALH, CH_2Cl_2, −78 °C, 96%; (k) (+)-DET, Ti(O*i*-Pr)$_4$, TBHP, 4 Å molecular sieves, CH_2Cl_2, −40 °C, 79%; (l) TEMPO, aq NaClO, KBr, aq $NaHCO_3$, CH_2Cl_2, 0 °C; (m) Ph_3PCH_3Br, NaHMDS, THF, 0 °C, 93% (two steps); (n) DDQ, CH_2Cl_2/H_2O, rt, 72%; (o) KO*t*-Bu, PMBCl, TBAI, DMF, rt, 98%; (p) $(Sia)_2BH$, THF, 0 °C to rt; then 3 M aq NaOH, H_2O_2, rt, 100%; (q) SO_3·pyridine, Et_3N, DMSO/CH_2Cl_2, 0 °C; (r) MeMgBr, Et_2O, −78 °C; (s) TPAP, NMO, 4 Å molecular sieves, CH_2Cl_2, rt, 83% (three steps).

Table 1
Aldol coupling of the G- and J-rings



Entry	Reagents and conditions	Yield (%)	dr[a]
1	**10**, TMSOTf (5.0 equiv), *i*-Pr_2NEt (10 equiv), CH_2Cl_2, 0 °C; then **9** (1.5 equiv), $MgBr_2·OEt_2$ (5 equiv), CH_2Cl_2, 0 °C	0	—
2	**10** (1.2 equiv), LDA (1.2 equiv), THF, −78 °C; then **9**, −78 °C to rt	0	—
3	**10**, LiHMDS (3.0 equiv), $ZnCl_2$ (3.0 equiv), THF, −78 °C; then **9** (1.5 equiv), −78 °C to rt	62	2.6:1
4	**10**, *n*-Bu_2BOTf (1.5 equiv), *i*-Pr_2NEt (2.0 equiv), Et_2O, 0 °C; then **9** (1.5 equiv), −78 to −20 °C	74	4:1

[a] dr=diastereomer ratio at C36.

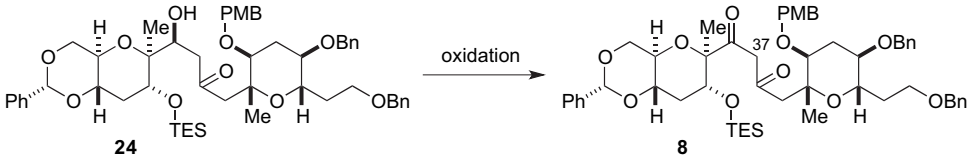
aldol adduct **24** was obtained in 74% yield (dr=4:1) after purification by preparative HPLC (entry 4).

2.4. Cyclodehydration to form the H-ring

Conversion of hydroxy ketone **24** to diketone **8** turned out to be unexpectedly nontrivial and required optimization experiments (Table 2). Swern oxidation of **24** resulted only in decomposition of the material (Table 2, entry 1). In contrast, oxidation of **24** by using 2-iodoxybenzoic acid (IBX)[32] in DMSO gave the desired diketone **8** in 62% yield, along with recovered starting **24** (13%) and decomposed products, probably due to overoxidation of the C37 position during extended reaction times (entry 2).[33] Treatment of **24** with Dess–Martin periodinane (DMP)[34] gave **8** only in low yield (entry 3). Under these conditions, the reaction stopped before the starting material was consumed completely, and only decomposition of **24** was observed after prolonged reaction times. In contrast, the use of *t*-BuOH as an additive[34] accelerated the Dess–Martin oxidation, thereby leading to the desired **8** in 91% yield (entry 4).

The synthesis of 1,3-diketone **8** could also be realized by an alternative aldol reaction between the G-ring methyl ketone **25** and

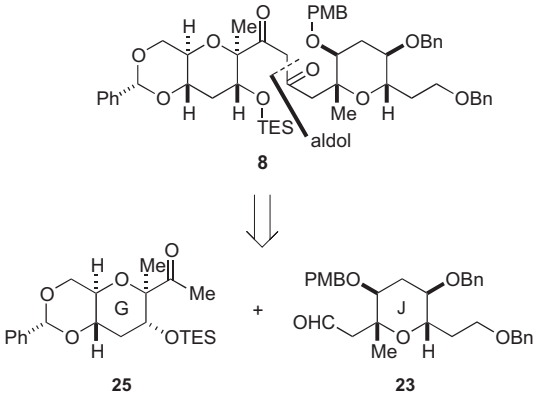
Table 2
Oxidation of hydroxy ketone **24**



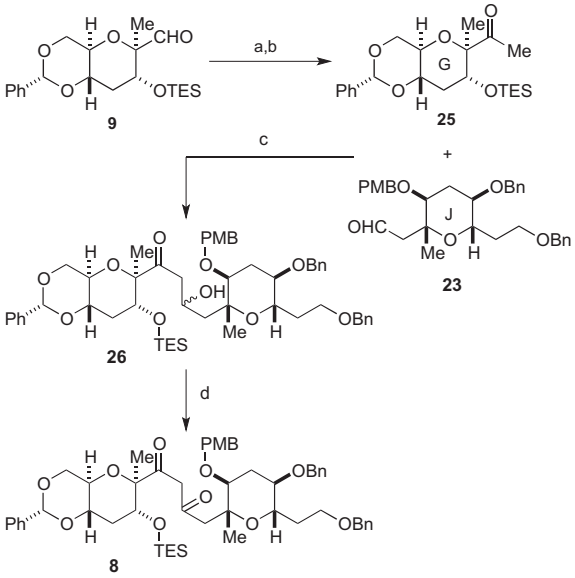
Entry	Reagents and conditions	Yield (%)
1	$(COCl)_2$, DMSO, Et_3N, CH_2Cl_2, −78 °C to rt	Decomposition
2	IBX,[a] DMSO, rt	62[b]
3	DMP,[c] CH_2Cl_2, rt	27
4	DMP,[c] CH_2Cl_2/*t*-BuOH, rt	91

[a] IBX=2-iodoxybenzoic acid.
[b] Hydroxy ketone **24** was recovered in 13% yield.
[c] DMP=Dess–Martin periodinane.

the J-ring aldehyde **23** (Scheme 4). Methyl ketone **25** was synthesized from aldehyde **9** in a two-step sequence involving methylation with MeMgBr (74%) and Swern oxidation (84%) (Scheme 5). Addition of the lithium enolate of methyl ketone **25** to aldehyde **23** led to the expected aldol adduct **26** in 67% yield as an inconsequential 1.7:1 mixture of diastereomers. Subsequent oxidation of β-hydroxy ketone **26** by using Dess–Martin periodinane (CH_2Cl_2/*t*-BuOH) provided diketone **8** in 92% yield. Importantly, this aldol sequence efficiently provided diketone **8** without complicated HPLC purification.



Scheme 4. Alternative aldol route to diketone **8**.

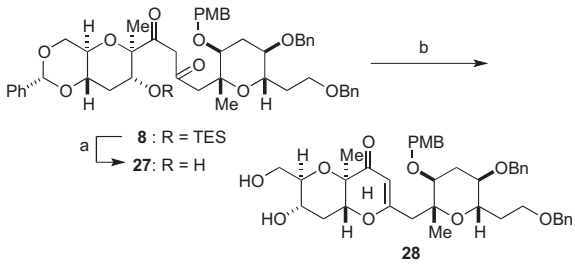


Scheme 5. Second synthesis of diketone **8**. Reagents and conditions: (a) MeMgBr, THF, −78 to 0 °C, 74%; (b) $(COCl)_2$, Et_3N, DMSO, CH_2Cl_2, −78 °C to rt, 84%; (c) **25** (1.3 equiv), LDA, THF, −78 °C; then **23**, −78 to −20 °C, 67%; (d) DMP, CH_2Cl_2/*t*-BuOH, rt, 92%.

Removal of the TES group within 1,3-diketone **8** thus prepared with TBAF/AcOH provided alcohol **27** (75%), which upon treatment with PPTS in MeOH at 80 °C underwent cyclodehydration[14] with concomitant removal of the benzylidene acetal group to afford dihydropyrone **28** in 88% yield (Scheme 6). More conveniently, direct treatment of TES ether **8** under the same conditions afforded the desired **28** in 95% yield.

2.5. Construction of the GHIJ-ring skeleton

Construction of the I-ring was carried out without incident following the previously described route.[9b,c,13] Diol **28** was



Scheme 6. Synthesis of dihydropyrone **28**. Reagents and conditions: (a) TBAF, AcOH, THF, rt, 75%; (b) PPTS, MeOH, 80 °C, 88% from **27**; 95% from **8**.

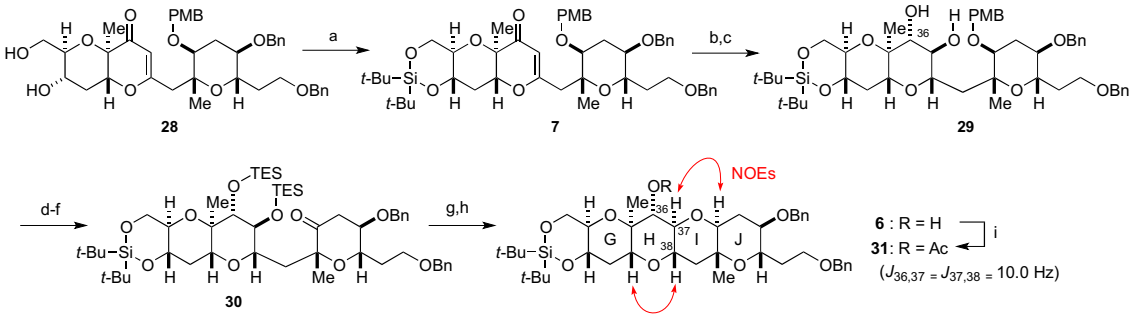
protected as its di-*tert*-butylsilylene to afford **7** in 93% yield (Scheme 7). Reduction of enone **7** under Luche conditions ($NaBH_4$, $CeCl_3 \cdot 7H_2O$)[35] gave the corresponding allylic alcohol with the desired stereochemistry at the C36 stereogenic center in 97% yield (dr >20:1), and ensuing hydroboration of the enol ether moiety gave diol **29** as a single stereoisomer in 80% yield. The observed high stereoselectivity of the hydroboration can be explained by considering the steric hindrance of the angular methyl group at the C35 stereogenic center.[36] Protection as the bis-TES ether and oxidative removal of the PMB group, followed by oxidation of the resultant alcohol, provided ketone **30** (80%, three steps). After cleavage of the TES ethers (93%), treatment of the resultant ketodiol with Et_3SiH/TMSOTf (EtCN, −78 °C) led to the desired GHIJ-ring skeleton **6** as a single stereoisomer in 74% yield.[37] The stereochemistry of **6** was unambiguously established based on NMR analysis after derivatization to the corresponding acetate **31** as shown.

2.6. Construction of the J-ring side chain

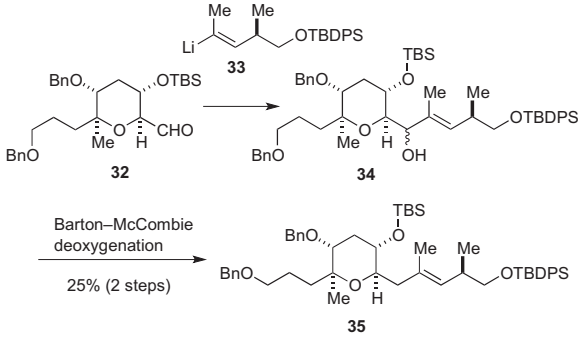
Having constructed the tetracyclic GHIJ-ring skeleton, we next turned our attention to introduction of the side chain to the J-ring. Stereocontrolled construction of the (*E*)-trisubstituted alkene in the J-ring side chain poses a significant synthetic challenge. The only synthesis of the J-ring side chain has been reported by the Kadota/Yamamoto group,[7b] which relied on the coupling of aldehyde **32** and alkenyl lithium **33** (Scheme 8). However, removal of the resultant hydroxy group within the coupling product **34** by means of Barton–McCombie deoxygenation[38] resulted only in a low yield of the desired trisubstituted alkene **35**. It was deemed that the development of a more efficient method for synthesis of the side chain would be indispensable for a successful total synthesis.

Initially, we planned to introduce the J-ring side chain by a Wittig or related olefination of methyl ketone **36** with a four-carbon unit **37** (Scheme 9). Exploratory experiments performed on ketone **38** as a model substrate by Wittig or Horner–Wadsworth–Emmons reaction[39] using phosphonium salt **37a** or phosphonate **37b** under a variety of conditions (*n*-BuLi, NaHMDS, or LiHMDS as a base, THF, DME, or THF/HMPA as a solvent) proved fruitless; the desired product **39** was not isolated at all and the starting material **38** remained unchanged.

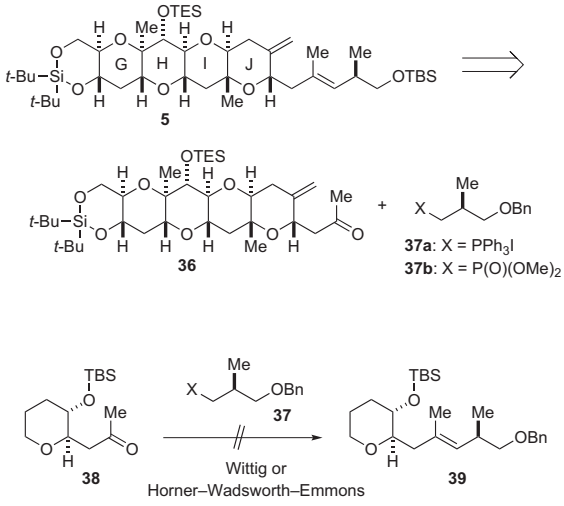
We next investigated Julia–Lythgoe olefination[40] of ketone **38** using phenyl sulfone **40** (Table 3). Reaction of ketone **38** with the lithium anion of sulfone **40a**,[41] followed by the addition of BzCl, afforded neither benzoate **41a** nor hydroxy sulfone **42a** at all (Table 3, entries 1 and 2). Under these conditions, only the undesired enol benzoate **43** was detected as a byproduct. Since the problem associated with the Julia–Lythgoe olefination reaction stemmed mainly from the enolizable nature of methyl ketone **38**, it was reasoned that the use of a cerium reagent might suppress the excessive basicity of the sulfone anion.[42] Gratifyingly, a far more promising result was obtained when the lithium anion of sulfone **40b**[43] (*n*-BuLi, THF, −78 °C) was added to ketone **38** in the presence of $CeCl_3$ in THF at −78 °C. This afforded the expected hydroxy



Scheme 7. Synthesis of the GHIJ-ring skeleton **6**. Reagents and conditions: (a) t-$Bu_2Si(OTf)_2$, 2,6-lutidine, DMF, rt, 93%; (b) $NaBH_4$, $CeCl_3 \cdot 7H_2O$, MeOH/CH_2Cl_2, 0 °C, 97%; (c) $BH_3 \cdot THF$, THF, rt; then 3 M aq NaOH, H_2O_2, 0 °C to rt, 80%; (d) TESOTf, 2,6-lutidine, CH_2Cl_2, rt, 94%; (e) DDQ, CH_2Cl_2/H_2O, 0 °C; (f) TPAP, NMO, 4 Å molecular sieves, CH_2Cl_2, 0 °C to rt, 85% (two steps); (g) $TsOH \cdot H_2O$, CH_2Cl_2/MeOH, rt, 93%; (h) Et_3SiH, TMSOTf, EtCN, −78 °C, 74%; (i) Ac_2O, pyridine, rt, 95%.



Scheme 8. Synthesis of the J-ring side chain by Kadota and co-workers[7b].



Scheme 9. Attempts at Wittig-type olefination.

sulfone **42b** in 95% yield as a mixture of four diastereomers (entry 3). Unfortunately, an attempted in situ trapping of the Julia–Lythgoe adduct by quenching the reaction with BzCl was unsuccessful (entry 4). Likewise, benzoylation of the isolated hydroxy sulfone **42b** was examined under several conditions but did not proceed at all.[44] The low reactivity of the sterically hindered tertiary alcohol within **42b** precluded the way to trisubstituted olefin **39**.

We next investigated $CeCl_3$-promoted Julia–Kocienski olefination[45] using phenyltetrazolyl sulfone **44**. The required sulfone **44** was synthesized from the known alcohol **45** (Scheme 10).[46] Thus, the primary alcohol of **45** was displaced with 1-phenyl-1*H*-tetrazole-5-thiol under Mitsunobu conditions[47] to generate a sulfide (88%), which was oxidized with *m*-CPBA to give sulfone **44** (89%). We were delighted to find that olefination of methyl ketone **38** with sulfone **44** (LDA, THF, −78 °C) proceeded in the presence of $CeCl_3$ to afford trisubstituted alkene **46** as an inseparable 1.6:1 mixture of *E*/*Z* isomers in 80% combined yield (Table 4, entry 1). In contrast, the absence of $CeCl_3$ resulted in lower yield of **46** (entry 2). The stereochemistry of the trisubstituted olefin within **46***E* and **46***Z* was assigned in each case by an NOE experiment as shown. To the best of our knowledge, this is the first use of an organocerium derivative for the Julia–Kocienski olefination.

2.7. Completion of the synthesis of a fully elaborated GHIJ-ring fragment

Having developed an efficient method for the introduction of the J-ring side chain, we proceeded to complete the synthesis of a fully elaborated GHIJ-ring fragment **5**. Protection of alcohol **6** as its TES ether, hydrogenolysis of the benzyl ethers, and selective protection of the primary alcohol as its pivaloate ester provided alcohol **47** in 80% yield for the three steps (Scheme 11). Dess–Martin oxidation followed by Wittig methylenation, and removal of the pivaloyl group with DIBALH afforded primary alcohol **48** in 64% yield for the three steps. Alcohol **48** was then converted into the requisite methyl ketone **36** by a three-step sequence involving oxidation to the aldehyde, methylation with MeMgBr, and a second oxidation (51%, three steps). Finally, introduction of the J-ring side chain was successfully performed under the optimized conditions described before. Thus, lithiation of phenyltetrazolyl sulfone **44** with LDA followed by addition to methyl ketone **36** in the presence of $CeCl_3$ (THF, −78 to 0 °C) furnished the desired trisubstituted (*E*)-alkene **5** in 58% yield, along with the corresponding (*Z*)-isomer **49** in 18% yield. The stereochemistry of **5** was unequivocally established by an NOE experiment as shown.

3. Conclusion

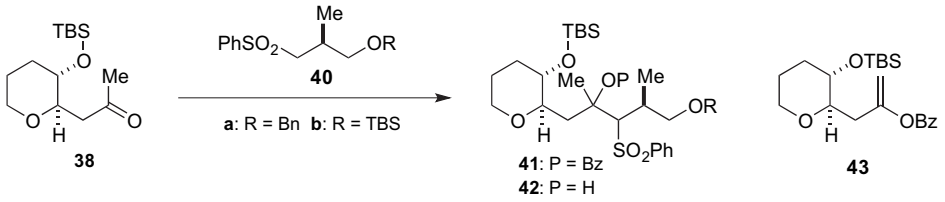
We have synthesized a fully elaborated GHIJ-ring fragment of gambieric acids through a convergent strategy. Key reactions of the synthesis include: (i) aldol reaction to couple the G- and J-rings; (ii) acid-catalyzed cyclodehydration to form the H-ring; and (iii) a $CeCl_3$-promoted Julia–Kocienski reaction for stereoselective introduction of the J-ring side chain. Further studies toward the total synthesis of gambieric acids are currently underway and will be reported in due course.

4. Experimental

4.1. General methods

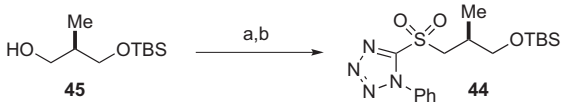
All reactions sensitive to moisture and/or air were carried out under an atmosphere of argon in dry, freshly distilled solvents under

Table 3
Model Julia–Lythgoe olefination



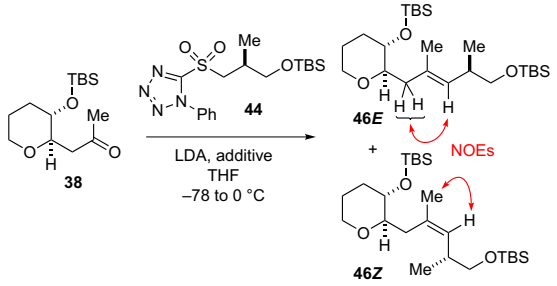
Entry	Sulfone	Regents and conditions	Yield (%)	
			41	**42**
1[a]	**40a**	*n*-BuLi, THF/HMPA, −78 °C to rt; then BzCl, rt	0	0
2[a]	**40a**	LiHMDS, THF, −78 °C; then BzCl, −78 °C to rt	0	0
3	**40b**	*n*-BuLi, $CeCl_3$, THF, −78 °C	—	95
4	**40b**	*n*-BuLi, $CeCl_3$, THF, −78 °C; then BzCl, −78 °C to rt	0	83

[a] Enol benzoate **43** was detected as an only isolable byproduct.

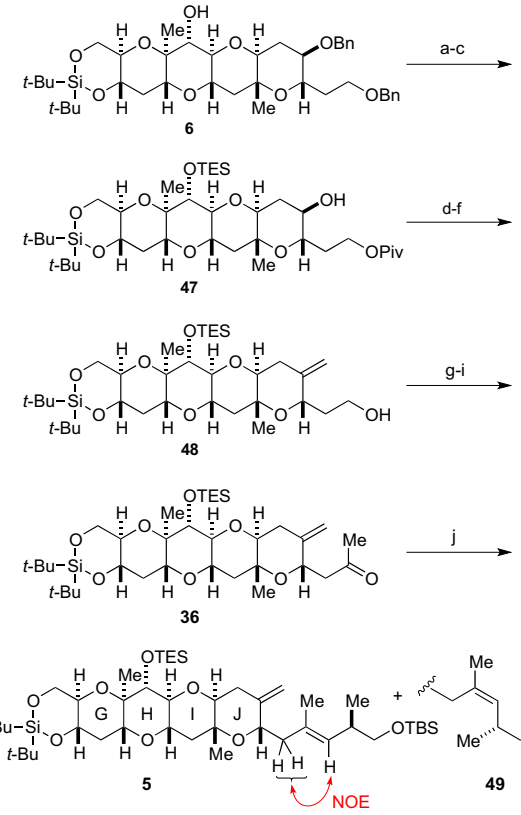


Scheme 10. Synthesis of phenyltetrazolyl sulfone **44**. Reagents and conditions: (a) 1-phenyl-1*H*-tetrazole-5-thiol, DIAD, Ph_3P, THF, rt, 88%; (b) *m*-CPBA, CH_2Cl_2, rt, 89%.

Table 4
Julia–Kocienski olefination of methyl ketone **38**



Entry	Additive	Yield (%)	*E*/*Z*
1	$CeCl_3$	80	1.6:1
2	None	38	1:1



Scheme 11. Completion of the synthesis of fully elaborated GHIJ-ring fragment **5**. Reagents and conditions: (a) TESOTf, 2,6-lutidine, CH_2Cl_2, rt, 97%; (b) H_2, $Pd(OH)_2$/C, EtOAc, rt, 97%; (c) PivCl, pyridine, 0 °C, 85%; (d) DMP, CH_2Cl_2, rt, 80%; (e) Ph_3PCH_3Br, NaHMDS, THF, 0 °C, 83%; (f) DIBALH, CH_2Cl_2, −78 °C, 96%; (g) DMP, CH_2Cl_2, rt; (h) MeMgBr, Et_2O, −78 °C; (i) DMP, CH_2Cl_2, rt, 51% (three steps); (j) **44**, LDA, $CeCl_3$, THF, −78 to 0 °C, **5**: 58%, **49**: 18%.

anhydrous conditions using oven-dried glassware unless otherwise noted. Anhydrous dichloromethane (CH_2Cl_2) was purchased from Kanto Chemical Co. Inc. and used directly without further drying. Anhydrous tetrahydrofuran (THF), diethyl ether (Et_2O), and toluene were purchased from Wako Pure Chemical Industries, Ltd. and further purified by a Glass Contour solvent purification system under an atmosphere of argon immediately prior to use. Diisopropylamine (*i*-Pr_2NH), triethylamine (Et_3N), 2,6-lutidine, 1,2-dichloroethane, and methanol (MeOH) were distilled from calcium hydride under an atmosphere of argon. Hexamethylphosphoramide (HMPA) was distilled from calcium hydride under reduced pressure. *N*,*N*-Dimethylformamide (DMF) and dimethyl sulfoxide (DMSO) were distilled from magnesium sulfate under reduced pressure. All other chemicals were purchased at the highest commercial grade and used directly. Analytical thin-layer chromatography (TLC) was performed using E. Merck silica gel 60 F_{254} plates (0.25-mm thickness). Flash column chromatography was carried out using Kanto Chemical silica gel 60N (40–100 mesh, spherical, neutral) or Fuji Silysia silica gel BW-300 (200–400 mesh). Preparative HPLC was carried out using a Japan Analytical Industry Co., Ltd. LC-9201 HPLC system. Optical rotations were recorded on a JASCO P-1020 digital polarimeter. IR spectra were recorded on a JASCO FT/IR-4100 spectrometer. ^1H and ^{13}C NMR spectra were recorded on a Varian Unity INOVA-500 or JEOL JNM-ECA-600 spectrometer, and chemical shift values are reported in parts per million (δ) downfield from tetramethylsilane with reference to internal residual solvent [^1H NMR, $CHCl_3$ (7.24), C_6HD_5 (7.15); ^{13}C NMR, $CDCl_3$ (77.0), C_6D_6 (128.0)] unless otherwise noted. Coupling constants (*J*) are reported in hertz (Hz). The following abbreviations were used to designate the multiplicities: s=singlet; d=doublet; t=triplet; m=multiplet; br=broad. ESI-TOF mass spectra were measured on a Bruker microTOFfocus spectrometer.

4.1.1. Aldehyde ***9***. To a solution of alcohol **11**[15] (1.35 g, 4.92 mmol) in CH_2Cl_2 (50 mL) were added imidazole (600 mg, 6.39 mmol) and TESCl (1.07 mL, 6.39 mmol). The resultant solution was stirred at room temperature for 5 h before it was diluted with EtOAc. The mixture was washed with saturated aqueous NH_4Cl solution and brine, dried over Na_2SO_4, filtered, and concentrated under reduced pressure. The residue was filtered through a short pad of silica gel to give a crude material, which was used in the next reaction without further purification.

Ozone was bubbled through a solution of the above TES ether in CH_2Cl_2 (50 mL) at −78 °C for 15 min. After oxygen was then bubbled through the solution to remove excess ozone, Ph_3P (3.87 g, 14.8 mmol) was added to the solution at −78 °C. The resultant solution was allowed to warm to room temperature overnight. The mixture was concentrated under reduced pressure, and the residue was purified by flash column chromatography (silica gel, 5–50% EtOAc/hexanes) to give aldehyde **9** (1.86 g, 96% for the two steps) as a colorless oil: $[\alpha]_D^{24}$ +2.1 (*c* 0.9, $CHCl_3$); IR (film) 2954, 2876, 1746, 1456, 1128, 1094, 1028, 828, 747 cm^{-1}; ^1H NMR (600 MHz, $CDCl_3$) δ 9.44 (s, 1H), 7.48–7.46 (m, 2H), 7.38–7.32 (m, 3H), 5.51 (s, 1H), 4.27 (dd, *J*=10.3, 4.5 Hz, 1H), 3.97 (dd, *J*=11.3, 4.8 Hz, 1H), 3.71 (dd, *J*=11.2, 10.0 Hz, 1H), 3.62 (ddd, *J*=10.3, 9.2, 4.8 Hz, 1H), 3.53 (m, 1H), 2.28 (ddd, *J*=11.7, 4.4, 4.4 Hz, 1H), 1.89 (ddd, *J*=11.6, 11.6, 11.6 Hz, 1H), 1.39 (s, 3H), 0.91 (t, *J*=7.8 Hz, 9H), 0.54 (q, *J*=7.8 Hz, 6H); ^{13}C NMR (150 MHz, $CDCl_3$) δ 199.3, 137.2, 129.2, 128.4, (2C), 126.1 (2C), 101.8, 82.0, 76.5, 69.6, 67.2, 66.3, 34.5, 11.1, 6.7 (3C), 4.9 (3C); HRMS (ESI) calcd for $C_{21}H_{32}O_5SiNa$ [$(M+Na)^+$] 415.1911, found 415.1897.

4.1.2. Diol ***13***. A mixture of benzyl alcohol (125 mL, 1.21 mol) and Ti(O*i*-Pr)$_4$ (42.6 mL, 182 mmol) was heated at 100 °C for 1 h. The mixture was cooled to room temperature and concentrated under reduced pressure. The residue was azeotropically dried with toluene twice. To the residual $Ti(OBn)_4$ was added a solution of epoxy alcohol **12**[16] (43.1 g, 121 mmol) in toluene (121 mL), and the resultant solution was stirred at 85 °C for 2 h. The mixture was cooled to room temperature, and the reaction was quenched with 5% aqueous H_2SO_4 solution. The mixture was diluted with EtOAc and stirred at room temperature for 3 h. The mixture was extracted with EtOAc, and the organic layer was washed with saturated aqueous $NaHCO_3$ solution and brine, dried over Na_2SO_4, filtered, and concentrated under reduced pressure. After removal of benzyl alcohol by vacuum distillation (5 Torr, 70 °C), the residue was purified by column chromatography (silica gel, 10–30% EtOAc/hexanes) to give diol **13** (44.3 g, 79%) as a colorless oil: $[\alpha]_D^{23}$ −8.2 (*c* 1.0, $CHCl_3$); IR (film) 3407, 3069, 2930, 2857, 1471, 1427, 1389, 1361, 1111, 1087, 737, 701 cm^{-1}; ^1H NMR (500 MHz, $CDCl_3$) δ 7.65–7.36 (m, 4H), 7.44 (m, 6H), 7.32–7.24 (m, 5H), 4.53 (d, *J*=12.0 Hz, 1H), 4.48 (d, *J*=12.0 Hz, 1H), 3.86–3.70 (m, 6H), 3.19 (m, 1H), 2.19 (m, 1H), 1.92–1.74 (m, 2H), 1.04 (s, 9H); ^{13}C NMR (125 MHz, $CDCl_3$) δ 135.6, 135.5 (2C), 129.8 (3C), 128.5 (3C), 127.80 (3C), 127.77 (6C), 78.4, 72.8, 72.4, 63.6, 60.2, 33.0, 26.8 (3C), 14.2; HRMS (ESI) calcd for $C_{28}H_{36}O_4SiNa$ [$(M+Na)^+$] 487.2275, found 487.2292.

4.1.3. Epoxide ***14***. To a solution of diol **13** (13.7 g, 29.3 mmol) in pyridine (100 mL) at 0 °C was added 2-mesitylenesulfonyl chloride (7.68 g, 35.1 mmol). The resultant solution was stirred at room temperature overnight before it was diluted with EtOAc. The mixture was washed successively with saturated aqueous $CuSO_4$ solution, saturated aqueous $NaHCO_3$ solution, and brine. The organic layer was dried over Na_2SO_4, filtered, and concentrated under reduced pressure. The residual crude sulfonate was used in the next reaction without further purification.

To a solution of the above material in MeOH (100 mL) at 0 °C was added K_2CO_3 (4.85 g, 35.1 mmol). The resultant solution was stirred at room temperature for 4 h before it was concentrated to approximately one-fifth of its volume under reduced pressure. The residue was diluted with H_2O and EtOAc. The organic layer was washed with saturated aqueous NH_4Cl solution and brine, dried over Na_2SO_4, filtered, and concentrated under reduced pressure. Purification of the residue by column chromatography (silica gel, 10% EtOAc/hexanes) gave epoxide **14** (11.9 g, 91% for the two steps) as a colorless oil: $[\alpha]_D^{25}$ +5.4 (*c* 1.0, $CHCl_3$); IR (film) 2929, 2856, 1472, 1427, 1360, 1190, 997 cm^{-1}; ^1H NMR (600 MHz, $CDCl_3$) δ 7.66–7.64 (m, 4H), 7.42–7.39 (m, 2H), 7.37–7.28 (m, 4H), 7.31–7.28 (m, 2H), 7.26–7.24 (m, 3H), 4.64 (d, *J*=11.3 Hz, 1H), 4.45 (d, *J*=11.3 Hz, 1H), 3.86 (ddd, *J*=10.0, 8.6, 4.8 Hz, 1H), 3.80 (ddd, *J*=10.3, 6.2, 4.4 Hz, 1H), 3.63 (ddd, *J*=9.3, 4.1, 3.8 Hz, 1H), 2.97 (m, 1H), 2.75 (dd, *J*=5.2, 3.8 Hz, 1H), 2.72 (dd, *J*=5.2, 2.8 Hz, 1H), 1.93 (m, 1H), 1.78 (dddd, *J*=8.9, 8.9, 5.2, 4.8 Hz, 1H), 1.04 (s, 9H); ^{13}C NMR (125 MHz, $CDCl_3$) δ 135.5 (3C), 129.6 (3C), 128.3 (3C), 127.62 (6C), 127.55 (3C), 74.7, 72.7, 59.8, 53.7, 45.3, 35.5, 26.8 (3C), 19.2; HRMS (ESI) calcd for $C_{28}H_{34}O_3SiNa$ [$(M+Na)^+$] 469.2169, found 469.2162.

4.1.4. Allylic alcohol ***15***. To a suspension of trimethylsulfonium iodide (22.1 g, 109 mmol) in THF (220 mL) at −30 °C was added *n*-BuLi (2.6 M solution in hexane, 52.2 mL, 136 mmol). After stirring at −30 °C for 30 min, a solution of epoxide **14** (24.2 g, 54.3 mmol) in THF (50 mL) was introduced to the mixture, producing a milky suspension. The resultant mixture was allowed to warm to room temperature over 1 h 45 min before it was treated with saturated aqueous NH_4Cl solution. The mixture was extracted with EtOAc, and the organic layer was washed with brine, dried over Na_2SO_4, filtered, and concentrated under reduced pressure. Purification of the residue by column chromatography (silica gel, 10% EtOAc/hexanes) gave allylic alcohol **15** (23.5 g, 94%) as a colorless oil: $[\alpha]_D^{24}$ −0.9 (*c* 1.0, $CHCl_3$); IR (film) 3454, 3070, 2957, 2930, 2857, 1471, 1427, 1111, 1088, 822, 738, 701 cm^{-1}; ^1H NMR (600 MHz, $CDCl_3$) δ 7.65–7.62 (m, 4H), 7.43–7.38 (m, 2H), 7.38–7.32 (m, 4H), 7.32–7.25 (m, 5H), 5.85 (ddd, *J*=17.2, 10.7, 5.5 Hz, 1H), 5.31 (ddd, *J*=17.2, 1.7, 1.4 Hz, 1H), 5.20 (ddd, *J*=13.8, 1.7, 1.4 Hz, 1H), 4.60 (d, *J*=11.5 Hz, 1H), 4.52 (d, *J*=11.5 Hz, 1H), 4.35 (m, 1H), 3.78 (apparent t, *J*=5.9 Hz, 2H), 3.73 (ddd, *J*=6.8, 5.5, 3.8 Hz, 1H), 1.79–1.74 (m, 2H), 1.03 (s, 9H), one proton missing due to H/D exchange of the hydroxyl group; ^{13}C NMR (125 MHz, $CDCl_3$) δ 138.3, 136.7, 135.5 (3C), 133.6, 133.5, 129.62, 129.60, 128.4 (3C), 127.7, 127.6 (6C), 116.3, 79.1, 73.3, 72.1, 60.2, 32.0, 26.8 (3C), 19.1; HRMS (ESI) calcd for $C_{29}H_{36}O_3SiNa$ [$(M+Na)^+$] 483.2326, found 483.2325.

4.1.5. Alcohol ***16***. To a solution of allylic alcohol **15** (34.6 g, 75.1 mmol) in toluene (200 mL) at room temperature were added $PMBOC(=NH)CCl_3$ (42.4 g, 150 mmol) and $La(OTf)_3$ (2.20 g, 3.76 mmol). The resultant mixture was stirred at 50 °C for 35 h before it was concentrated under reduced pressure. The residue was filtered through a short pad of silica gel, and the crude material was used in the next reaction without further purification.

To a solution of 2-methyl-2-butene (31.8 mL, 300 mmol) in THF (275 mL) at 0 °C was added $BH_3 \cdot SMe_2$ (1.9 M solution in THF, 79.0 mL, 150 mmol). The resultant solution was stirred at 0 °C for 1 h. To this solution was added a solution of the above crude material in THF (50 mL). After being stirred at room temperature for 90 min, the mixture was cooled to 0 °C and treated with 3 M aqueous NaOH solution (150 mL) and 30% aqueous H_2O_2 solution (150 mL). The resultant mixture was stirred at 0 °C for 30 min and then at room temperature for 3 h. The mixture was extracted with EtOAc, and the organic layer was washed with brine, dried over Na_2SO_4, filtered, and concentrated under reduced pressure. Purification of the residue by column chromatography (silica gel, 20–40% EtOAc/hexanes) gave alcohol **16** (36.2 g, 81% for the two steps) as a colorless oil: $[\alpha]_D^{25}$ −6.2 (*c* 1.0, $CHCl_3$); IR (film) 3069, 2930, 2857, 1612, 1587, 1513, 1471, 1248, 1111, 1086, 822 cm^{-1}; ^1H NMR (600 MHz, $CDCl_3$) δ 7.67–7.64 (m, 4H), 7.43–7.40 (m, 2H), 7.38–7.34 (m, 4H), 7.32–7.24 (m, 7H), 6.87–6.85 (m, 2H), 4.76 (d, *J*=11.3 Hz,

1H), 4.67 (d, *J*=11.3 Hz, 1H), 4.51 (d, *J*=11.3 Hz, 1H), 4.48 (d, *J*=11.3 Hz, 1H), 3.95 (ddd, *J*=10.0, 2.4, 2.0 Hz, 1H), 3.84 (m, 1H), 3.81–3.68 (m, 4H), 3.79 (s, 3H), 2.46 (br s, 1H), 1.88 (dddd, *J*=15.1, 12.0, 8.5, 4.1 Hz, 1H), 1.80 (dddd, *J*=14.1, 8.9, 4.8, 4.4 Hz, 1H), 1.75 (m, 1H), 1.70 (m, 1H), 1.07 (s, 9H); ^{13}C NMR (125 MHz, $CDCl_3$) δ 159.2, 138.6, 135.51, 135.49 (2C), 133.72, 133.71, 130.3, 129.6, 129.5 (2C), 129.0, 128.3 (2C), 128.2, 127.7 (2C), 127.6 (4C), 127.5 (2C), 113.8 (2C), 79.5, 72.8, 71.6, 60.44, 60.36, 55.2, 34.0, 32.6, 26.8 (3C), 19.2; HRMS (ESI) calcd for $C_{37}H_{46}O_5SiNa$ [$(M+Na)^+$] 621.3007, found 621.3034.

*4.1.6. Alcohol **17**.* To a solution of alcohol **16** (2.03g, 3.39 mmol) in THF (34 mL) at 0 °C was added KO*t*-Bu (571 mg, 5.09 mmol), and the resultant mixture was stirred at room temperature for 15 min. The mixture was cooled to 0 °C and treated with benzyl bromide (806 μL, 6.78 mmol). The resultant solution was stirred at room temperature overnight before it was quenched with saturated aqueous NH_4Cl solution. The mixture was extracted twice with EtOAc, and the organic layer was washed with brine, dried over Na_2SO_4, filtered, and concentrated under reduced pressure. The residual crude benzyl ether was used in the next reaction without further purification.

To a solution of the above benzyl ether in THF/MeOH (1:2, v/v, 45 mL) at room temperature was added 10% aqueous KOH solution (5.0 mL). After being stirred at 70 °C overnight, the mixture was cooled to room temperature and neutralized with 1 M aqueous HCl solution. The mixture was extracted with EtOAc and washed with brine. The aqueous layer was extracted with EtOAc. The combined organic layer was dried over Na_2SO_4, filtered, and concentrated under reduced pressure. Purification of the residue by column chromatography (silica gel, 20–60% EtOAc/hexanes) gave alcohol **17** (1.17 g, 77% for the two steps) as a colorless oil: $[\alpha]_D^{23}$ −7.1 (*c* 1.0, $CHCl_3$); IR (film) 3436, 2862, 1611, 1513, 1453, 1359, 1302, 1247, 1173, 1092, 737 cm^{-1}; ^{1}H NMR (500 MHz, $CDCl_3$) δ 7.34–7.25 (m, 10H), 7.21–7.17 (m, 2H), 6.84–6.80 (m, 2H), 4.70 (d, *J*=12.0 Hz, 1H), 4.66 (d, *J*=11.0 Hz, 1H), 4.52 (d, *J*=11.0 Hz, 1H), 4.46 (d, *J*=12.0 Hz, 1H), 4.43 (d, *J*=10.5 Hz, 1H), 4.41 (d, *J*=12.0 Hz, 1H), 3.83 (ddd, *J*=9.0, 3.5, 2.0 Hz, 1H), 3.77–3.67 (m, 3H), 3.76 (s, 3H), 3.59–3.49 (m, 2H), 2.08 (d, *J*=1.5 Hz, 1H), 1.91–1.70 (m, 4H); ^{13}C NMR (125 MHz, $CDCl_3$) δ 159.1, 138.33, 138.27, 130.5, 129.5 (2C), 128.4 (2C), 128.3 (2C), 127.8 (2C), 127.68, 127.66 (2C), 127.5, 113.7 (2C), 79.8, 76.8, 72.9, 72.5, 72.0, 66.7, 60.0, 55.2, 32.5, 31.3; HRMS (ESI) calcd for $C_{28}H_{34}O_5Na$ [$(M+Na)^+$] 473.2298, found 473.2295.

*4.1.7. (E)-Enoate **18**.* To a solution of DMSO (13.8 mL, 194 mmol) in CH_2Cl_2 (200 mL) at −78 °C was added oxalyl chloride (8.46 mL, 97.0 mmol), and the resultant solution was stirred at −78 °C for 15 min. To this solution was added a solution of alcohol **17** (21.8 g, 48.5 mmol) in CH_2Cl_2 (40 mL), and the resultant solution was stirred at −78 °C for 45 min before Et_3N (40.6 mL, 291 mmol) was introduced. The mixture was allowed to warm to room temperature over 1 h, and then treated with $Ph_3P{=}C(Me)CO_2Et$ (20.3 g, 58.2 mmol). After being stirred at room temperature for 3 h, the mixture was concentrated to approximately one-fifth of its volume. The mixture was diluted with EtOAc, washed successively with H_2O and brine, dried over Na_2SO_4, filtered, and concentrated under reduced pressure. Purification of the residue by column chromatography (silica gel, 0–20% EtOAc/hexanes) gave (*E*)-enoate **18** (24.6 g, 95%) as a pale yellow oil: $[\alpha]_D^{24}$ −1.6 (*c* 1.0, $CHCl_3$); IR (film) 2862, 1706, 1652, 1613, 1513, 1456, 1248, 1094, 1031, 821 cm^{-1}; ^{1}H NMR (500 MHz, $CDCl_3$) δ 7.34–7.25 (m, 10H), 7.18–7.16 (m, 2H), 6.85–6.80 (m, 3H), 4.62 (d, *J*=12.0 Hz, 1H), 4.56 (d, *J*=11.0 Hz, 1H), 4.53 (d, *J*=12.0 Hz, 1H), 4.45 (d, *J*=12.0 Hz, 1H), 4.40 (d, *J*=12.0 Hz, 1H), 4.40 (d, *J*=11.0 Hz, 1H), 4.18 (q, *J*=7.0 Hz, 2H), 3.76 (s, 3H), 3.71 (m, 1H), 3.60 (ddd, *J*=8.0, 4.5, 3.5 Hz, 1H), 3.55 (dd, *J*=5.5, 5.5 Hz, 1H), 3.55 (m, 1H), 2.50 (ddd, *J*=16.0, 8.0, 7.0 Hz, 1H), 2.36 (ddd, *J*=14.5, 6.5, 5.5 Hz, 1H), 1.86–1.82 (m, 2H), 1.78 (s, 3H), 1.28 (t, *J*=7.0 Hz, 3H); ^{13}C NMR (125 MHz, $CDCl_3$) δ 167.9, 159.1, 138.6, 138.4, 138.3, 130.5, 129.5 (2C), 129.1, 128.3 (2C), 128.2 (2C), 127.8 (2C), 127.6 (2C), 127.49, 127.46, 113.6 (2C), 79.3, 76.8, 72.9, 72.14, 72.13, 66.7, 60.3, 55.1, 31.1, 30.1, 14.2, 12.6; HRMS (ESI) calcd for $C_{33}H_{40}O_6Na$ [$(M+Na)^+$] 555.2717, found 555.2741.

*4.1.8. Epoxy alcohol **19**.* To a solution of (*E*)-enoate **18** (4.91 g, 9.23 mol) in CH_2Cl_2 (90 mL) at −78 °C was added DIBALH (0.97 M solution in hexane, 20.9 mL, 20.3 mmol). The resultant solution was stirred at −78 °C for 30 min before it was quenched with MeOH. The mixture was diluted with saturated aqueous potassium sodium tartrate solution and EtOAc, and stirred at room temperature overnight. The organic layer was separated, washed with brine, dried over Na_2SO_4, filtered, and concentrated under reduced pressure. Purification of the residue by column chromatography (silica gel, 10–30% EtOAc/hexanes) gave an allylic alcohol (4.36 g, 96%) as a pale yellow oil: $[\alpha]_D^{22}$ −7.6 (*c* 1.0, $CHCl_3$); IR (film) 3435, 2905, 2860, 1611, 1513, 1454, 1247, 1092, 1030, 820.6, 739, 698 cm^{-1}; ^{1}H NMR (500 MHz, $CDCl_3$) δ 7.33–7.25 (m, 10H), 7.19–7.17 (m, 2H), 6.83–6.81 (m, 3H), 5.40 (ddd, *J*=6.5, 6.5, 1.0 Hz, 1H), 4.64 (d, *J*=12.0 Hz, 1H), 4.55 (d, *J*=11.0 Hz, 1H), 4.53 (d, *J*=12.0 Hz, 1H), 4.46 (d, *J*=12.0 Hz, 1H), 4.40 (d, *J*=12.0 Hz, 1H), 4.38 (d, *J*=11.0 Hz, 1H), 3.93 (s, 2H), 3.76 (s, 3H), 3.68 (ddd, *J*=6.5, 4.0, 3.5 Hz, 1H), 3.58–3.53 (m, 3H), 2.35 (ddd, *J*=15.0, 7.5, 6.5 Hz, 1H), 2.24 (ddd, *J*=15.0, 7.0, 6.0 Hz, 1H), 1.88–1.84 (m, 2H), 1.61 (s, 3H); ^{13}C NMR (150 MHz, $CDCl_3$) δ 159.1, 138.8, 138.5, 136.5, 130.8, 129.6 (2C), 128.33 (2C), 128.26 (2C), 127.8 (2C), 127.7 (2C), 127.53, 127.49, 122.3, 113.7 (2C), 80.4, 76.9 72.9, 72.2, 72.0, 68.9, 66.9, 55.3, 30.9, 29.1, 13.9; HRMS (ESI) calcd for $C_{31}H_{38}O_5Na$ [$(M+Na)^+$] 513.2611, found 513.2587.

To a suspension of the above allylic alcohol (4.36 g, 8.90 mmol) and 4 Å molecular sieves (4.0 g) in CH_2Cl_2 (80 mL) at room temperature was added a solution of (+)-DET (2.74 g, 13.3 mmol) in CH_2Cl_2 (10 mL). The resultant mixture was cooled to −40 °C and treated with Ti(O*i*-Pr)$_4$ (3.13 mL, 10.7 mmol). After being stirred at −40 °C for 30 min, the reaction mixture was treated with TBHP (4.64 M solution in isooctane, 5.75 mL, 26.7 mmol). The reaction mixture was stirred at −40 °C for 1 h before it was diluted with 1 M aqueous NaOH solution and Et_2O. After being stirred at room temperature for 2 h, the mixture was filtered through a pad of Celite. The filtrate was diluted with EtOAc, washed with H_2O and brine, dried over Na_2SO_4, filtered, and concentrated under reduced pressure. Purification of the residue by column chromatography (silica gel, 20–40% EtOAc/hexanes) gave epoxy alcohol **19** (3.56 g, 79%) as a colorless oil: $[\alpha]_D^{23}$ −15.0 (*c* 1.0, $CHCl_3$); IR (film) 3449, 2927, 2861, 1611, 1513, 1454, 1247, 1092, 1034, 740, 698 cm^{-1}; ^{1}H NMR (500 MHz, $CDCl_3$) δ 7.34–7.24 (m, 10H), 7.20–7.18 (m, 2H), 6.83–6.81 (m, 2H), 4.65 (d, *J*=11.5 Hz, 1H), 4.59 (d, *J*=11.0 Hz, 1H), 4.55 (d, *J*=11.5 Hz, 1H), 4.45 (d, *J*=12.5 Hz, 1H), 4.40 (d, *J*=11.5 Hz, 1H), 4.40 (d, *J*=12.5 Hz, 1H), 3.77 (m, 1H), 3.76 (s, 3H), 3.62 (ddd, *J*=6.5, 4.5, 4.5 Hz, 1H), 3.59–3.53 (m, 3H), 3.45 (dd, *J*=12.0, 8.0 Hz, 1H), 3.11 (dd, *J*=6.5, 6.0 Hz, 1H), 1.95 (ddd, *J*=14.5, 7.0, 7.0 Hz, 1H), 1.85–1.82 (m, 2H), 1.74 (ddd, *J*=14.5, 5.0, 5.0 Hz, 1H), 1.58 (m, 1H), 1.20 (s, 3H); ^{13}C NMR (150 MHz, $CDCl_3$) δ 159.1, 138.4 (2C), 130.7, 129.6 (2C), 128.3 (4C), 127.9 (2C), 127.7 (2C), 127.61, 127.56, 113.7 (2C), 78.8, 76.8, 73.0, 72.2, 71.9, 66.7, 65.4, 60.5, 57.7, 55.2, 31.1, 29.5, 14.3; HRMS (ESI) calcd for $C_{31}H_{38}O_6Na$ [$(M+Na)^+$] 529.2561, found 529.2570.

*4.1.9. Vinyl epoxide **20**.* To a solution of epoxy alcohol **19** (822 mg, 1.62 mmol) in CH_2Cl_2 (16 mL) at 0 °C were added KBr (0.5 M solution in H_2O, 324 μL, 0.162 mmol) and TEMPO (12.7 mg, 81.0 μmol). To this mixture were added dropwise a freshly prepared mixture of NaOCl (1.80 M solution in H_2O, 900 μL, 1.62 mmol) and saturated aqueous $NaHCO_3$ solution (900 μL). The resultant mixture was vigorously stirred at 0 °C for 10 min before it was quenched with saturated aqueous $Na_2S_2O_3$ solution. The mixture was extracted with EtOAc, and the organic layer was washed with H_2O and brine.

The aqueous layers were combined and extracted with EtOAc. The combined organic layer was dried over Na_2SO_4, filtered, and concentrated under reduced pressure to give a crude aldehyde, which was used in the next reaction without further purification.

To a suspension of Ph_3PCH_3Br (1.74 g, 4.86 mmol) in THF (10 mL) at 0 °C was added NaHMDS (1.0 M solution in THF, 4.54 mL, 4.54 mmol), and the resultant mixture was stirred at 0 °C for 30 min. To this suspension was added a solution of the above crude aldehyde in THF (6.0 mL), and the resultant solution was stirred at 0 °C for 1 h before it was quenched with saturated aqueous NH_4Cl solution. The mixture was extracted twice with EtOAc. The organic layer was washed with brine, dried over Na_2SO_4, filtered, and concentrated under reduced pressure. Purification of the residue by column chromatography (silica gel, 10–20% EtOAc/hexanes) gave vinyl epoxide **20** (760 mg, 93% for the two steps) as a colorless oil: $[\alpha]_D^{23}$ −8.5 (*c* 1.0, $CHCl_3$); IR (film) 2927, 2858, 1509, 1456, 1247, 1092, 736, 697 cm^{-1}; ^1H NMR (500 MHz, C_6D_6) δ 7.35–7.34 (m, 2H), 7.28–7.24 (m, 4H), 7.18–7.15 (m, 4H), 7.10–7.07 (m, 2H), 6.80–6.79 (m, 2H), 5.61 (dd, *J*=17.5, 11.0 Hz, 1H), 5.24 (d, *J*=17.5 Hz, 1H), 4.99 (d, *J*=11.0 Hz, 1H), 4.64 (d, *J*=11.0 Hz, 1H), 4.56 (d, *J*=12.0 Hz, 1H), 4.50 (d, *J*=11.0 Hz, 1H), 4.47 (d, *J*=11.0 Hz, 1H), 4.30 (d, *J*=12.0 Hz, 1H), 4.26 (d, *J*=12.0 Hz, 1H), 3.88 (ddd, *J*=7.0, 4.5, 4.0 Hz, 1H), 3.66 (m, 1H), 3.58 (m, 1H), 3.48 (ddd, *J*=9.0, 5.5, 5.0 Hz, 1H), 3.28 (s, 3H), 3.01 (dd, *J*=6.0, 6.0 Hz, 1H), 2.06 (ddd, *J*=14.5, 7.0, 6.5 Hz, 1H), 1.98–1.91 (m, 2H), 1.78 (ddd, *J*=14.5, 5.0, 5.0 Hz, 1H), 1.22 (s, 3H); ^{13}C NMR (125 MHz, $CDCl_3$) δ 159.1, 140.8, 138.41, 138.39, 130.7, 129.6 (2C), 128.3 (4C), 127.8 (2C), 127.7 (2C), 127.5 (2C), 115.9, 113.7 (2C), 78.9, 76.8, 73.0, 72.2, 71.9, 66.7, 62.6, 59.1, 55.2, 31.1, 29.9, 15.0; HRMS (ESI) calcd for $C_{32}H_{38}O_5Na$ [(M+Na)$^+$] 525.2611, found 525.2601.

*4.1.10. Secondary alcohol **21**.* To a solution of vinyl epoxide **20** (711 mg, 1.41 mmol) in CH_2Cl_2/H_2O (20:1, v/v, 15 mL) at 0 °C was added DDQ (337 mg, 1.49 mmol), and the resultant mixture was stirred at room temperature overnight before it was quenched with saturated aqueous $NaHCO_3$ solution. The mixture was extracted with EtOAc, and the organic layer was washed with saturated aqueous $NaHCO_3$ solution and brine. The aqueous layers were combined and extracted with EtOAc. The combined organic layer was dried over Na_2SO_4, filtered, and concentrated under reduced pressure. Purification of the residue by column chromatography (silica gel, 10–30% EtOAc/hexanes) gave secondary alcohol **21** (390 mg, 72%) as a colorless oil: $[\alpha]_D^{24}$ −80.9 (*c* 1.0, $CHCl_3$); IR (film) 3438, 2868, 1496, 1454, 1362, 1454, 1362, 1096, 1028, 923, 736 cm^{-1}; ^1H NMR (500 MHz, $CDCl_3$) δ 7.34–7.24 (m, 10H), 5.90 (dd, *J*=17.5, 11.0 Hz, 1H), 5.26 (d, *J*=17.5 Hz, 1H), 5.13 (d, *J*=11.0 Hz, 1H), 4.61 (d, *J*=12.0 Hz, 1H), 4.50 (d, *J*=12.0 Hz, 1H), 4.48 (d, *J*=12.0 Hz, 1H), 4.45 (d, *J*=12.0 Hz, 1H), 3.62–3.54 (m, 3H), 3.44 (s, 1H), 3.18 (ddd, *J*=10.0, 10.0, 4.0 Hz, 1H), 2.34 (ddd, *J*=12.5, 4.5, 4.0 Hz, 1H), 2.23 (dddd, *J*=14.0, 8.0, 8.0, 5.0 Hz, 1H), 1.66 (m, 1H), 1.61 (ddd, *J*=11.5, 11.5, 11.5 Hz, 1H), 1.23 (s, 3H), one proton missing due to H/D exchange of the hydroxy group; ^{13}C NMR (125 MHz, $CDCl_3$) δ 143.0, 138.6, 138.1, 128.4 (2C), 128.3 (2C), 127.8 (2C), 127.7, 127.6 (2C), 127.4, 114.0, 76.8, 76.6, 72.9, 70.94, 70.92, 69.8, 66.9, 33.3, 32.4, 14.0; HRMS (ESI) calcd for $C_{24}H_{30}O_4Na$ [(M+Na)$^+$] 405.2036, found 405.2031.

*4.1.11. Primary alcohol **22**.* To a solution of alcohol **21** (1.13 g, 2.96 mmol) in DMF (10 mL) at 0 °C was added KO*t*-Bu (498 mg, 4.44 mmol), and the resultant mixture was stirred at room temperature for 15 min. To the mixture at 0 °C were added PMBCl (480 μL, 3.55 mmol) and TBAI (219 mg, 0.592 mmol), and the resultant solution was stirred at room temperature for 1 h. The reaction was quenched with saturated aqueous NH_4Cl solution at 0 °C. The mixture was extracted with EtOAc, and the organic layer was washed with brine, dried over Na_2SO_4, filtered, and concentrated under reduced pressure. Purification of the residue by column chromatography (silica gel, 5–20% EtOAc/hexanes) gave a PMB ether (1.45 g, 98%) as a colorless oil: $[\alpha]_D^{25}$ −40.7 (*c* 1.0, $CHCl_3$); IR (film) 2866, 1612, 1513, 1455, 1351, 1302, 1248, 1091, 1032, 922, 821, 736, 697 cm^{-1}; ^1H NMR (500 MHz, $CDCl_3$) δ 7.35–7.24 (m, 10H), 7.23–7.20 (m, 2H), 6.88–6.84 (m, 2H), 6.00 (dd, *J*=17.5, 11.0 Hz, 1H), 5.26 (d, *J*=17.5 Hz, 1H), 5.03 (d, *J*=11.0 Hz, 1H), 4.60 (d, *J*=11.5 Hz, 1H), 4.50 (d, *J*=12.0 Hz, 1H), 4.50 (d, *J*=11.5 Hz, 1H), 4.46 (d, *J*=12.0 Hz, 1H), 4.43 (d, *J*=11.5 Hz, 1H), 4.38 (d, *J*=11.0 Hz, 1H), 3.79 (s, 3H), 3.66–3.54 (m, 3H), 3.21 (dd, *J*=11.5, 4.5 Hz, 1H), 3.11 (ddd, *J*=10.5, 10.0, 4.5 Hz, 1H), 2.41 (ddd, *J*=11.5, 5.0, 4.5 Hz, 1H), 2.24 (m, 1H), 1.65 (m, 1H), 1.54 (ddd, *J*=11.5, 11.5, 11.5 Hz, 1H), 1.23 (s, 3H); ^{13}C NMR (125 MHz, $CDCl_3$) δ 159.1, 143.2, 138.7, 138.1, 130.5, 129.1 (2C), 128.4 (2C), 128.3 (2C), 127.8 (2C), 127.7, 127.6 (2C), 127.4, 113.7 (2C), 112.5, 78.5, 76.8, 75.6, 72.9, 71.3, 70.9, 69.8, 67.0, 55.3, 32.4, 31.0, 15.8; HRMS (ESI) calcd for $C_{32}H_{38}O_5Na$ [(M+Na)$^+$] 525.2611, found 525.2608.

To a solution of 2-methyl-2-butene (921 μL, 8.67 mmol) in THF (20 mL) at 0 °C was added $BH_3 \cdot SMe_2$ (1.9 M solution in THF, 4.34 mL, 2.28 mmol), and the resultant solution was stirred at 0 °C for 1 h. To this solution was added a solution of the above PMB ether (1.45 g, 2.89 mmol) in THF (9.0 mL). After being stirred at room temperature for 3 h, the mixture was cooled to 0 °C and treated with 3 M aqueous NaOH solution (15 mL) and 30% aqueous H_2O_2 solution (15 mL). The resultant mixture was stirred at 0 °C for 30 min and then at room temperature for 5 h. The mixture was extracted twice with EtOAc, and the organic layer was washed with brine, dried over Na_2SO_4, filtered, and concentrated under reduced pressure. Purification of the residue by column chromatography (silica gel, 20–40% EtOAc/hexanes) gave primary alcohol **22** (1.50 g, 100%) as a colorless oil: $[\alpha]_D^{25}$ −16.4 (*c* 1.0, $CHCl_3$); IR (film) 2867, 1611, 1513, 1454, 1248, 1173, 1088, 1030, 821, 737, 698 cm^{-1}; ^1H NMR (500 MHz, $CDCl_3$) δ 7.35–7.24 (m, 10H), 7.20–7.19 (m, 2H), 6.87–6.85 (m, 2H), 4.60 (d, *J*=11.5 Hz, 1H), 4.55 (d, *J*=11.0 Hz, 1H), 4.49 (d, *J*=12.5 Hz, 1H), 4.44 (d, *J*=11.5 Hz, 1H), 4.43 (d, *J*=11.5 Hz, 1H), 4.33 (d, *J*=11.5 Hz, 1H), 3.79 (s, 3H), 3.70 (ddd, *J*=11.5, 8.0, 3.5 Hz, 1H), 3.63 (ddd, *J*=11.0, 7.0, 3.5 Hz, 1H), 3.57 (ddd, *J*=9.5, 9.5, 2.0 Hz, 1H), 3.49 (apparent t, *J*=6.3 Hz, 2H), 3.32 (dd, *J*=11.5, 5.5 Hz, 1H), 3.09 (ddd, *J*=10.0, 9.5, 4.5 Hz, 1H), 2.47 (ddd, *J*=12.5, 5.0, 4.0 Hz, 1H), 2.20 (dddd, *J*=14.5, 7.5, 7.5, 2.5 Hz, 1H), 1.87 (ddd, *J*=15.5, 6.5, 3.5 Hz, 1H), 1.72 (ddd, *J*=15.0, 8.0, 3.5 Hz, 1H), 1.56 (m, 1H), 1.52 (ddd, *J*=12.0, 12.0, 11.5 Hz, 1H), 1.21 (s, 3H), one proton missing due to H/D exchange of the hydroxy group; ^{13}C NMR (125 MHz, $CDCl_3$) δ 159.2, 138.4, 138.0, 130.1, 129.2 (2C), 128.4 (2C), 128.3 (2C), 127.8 (2C), 127.8 (3C), 127.5, 113.8 (2C), 78.1, 77.1, 76.5, 72.9, 70.9, 70.7, 70.6, 66.9, 59.1, 55.2, 41.1, 32.3, 30.0, 15.9; HRMS (ESI) calcd for $C_{32}H_{40}O_6Na$ [(M+Na)$^+$] 543.2717, found 543.2695.

*4.1.12. Methyl ketone **10**.* To a solution of alcohol **22** (590 mg, 1.13 mmol) in CH_2Cl_2/DMSO (1:1, v/v, 12 mL) at 0 °C were added Et_3N (630 μL, 4.52 mmol) and $SO_3 \cdot$pyridine (542 mg, 3.40 mmol). The resultant mixture was stirred at 0 °C for 1 h before it was diluted with Et_2O. The mixture was washed successively with saturated aqueous NH_4Cl solution, H_2O, and brine, dried over Na_2SO_4, filtered, and concentrated under reduced pressure. The crude aldehyde **23** thus obtained was used in the next reaction without further purification.

To a solution of the above crude aldehyde **23** in Et_2O (11 mL) at −78 °C was added MeMgBr (3.0 M solution in Et_2O, 1.88 mL, 5.65 mmol), and the resultant solution was stirred at −78 °C for 20 min before it was quenched with saturated aqueous NH_4Cl solution. The mixture was extracted twice with EtOAc, and the organic layer was washed with brine, dried over Na_2SO_4, filtered, and concentrated under reduced pressure. The residue was filtered through a short pad of silica gel to give a crude material, which was used in the next reaction without further purification.

To a suspension of the above crude alcohol, 4 Å molecular sieves (500 mg), and NMO (265 mg, 2.26 mmol) in CH_2Cl_2 (11 mL) at room temperature was added TPAP (19.9 mg, 56.5 μmol). The resultant mixture was stirred at room temperature for 1 h before it was concentrated to approximately one-fifth of its volume under reduced pressure. Purification of the residue by column chromatography (silica gel, 0–10% EtOAc/hexanes) gave methyl ketone **10** (500 mg, 83% for the three steps) as a colorless oil: $[\alpha]_D^{22}$ −41.1 (*c* 4.3, $CHCl_3$); IR (film) 3031, 2937, 2867, 1704, 1612, 1514, 1455, 1354, 1249, 1173, 1098, 1030, 822, 739, 699 cm^{-1}; ^1H NMR (500 MHz, $CDCl_3$) δ 7.34–7.21 (m, 12H), 6.86–6.84 (m, 2H), 4.57 (d, *J*=11.5 Hz, 1H), 4.53 (d, *J*=11.0 Hz, 1H), 4.48 (d, *J*=12.0 Hz, 1H), 4.44 (d, *J*=12.0, Hz, 1H), 4.40 (d, *J*=11.5 Hz, 1H), 4.39 (d, *J*=11.0 Hz, 1H), 3.79 (s, 3H), 3.54–3.47 (m, 3H), 3.36 (dd, *J*=11.5, 5.0 Hz, 1H), 3.03 (ddd, *J*=11.5, 9.5, 5.0 Hz, 1H), 2.61 (d, *J*=12.0 Hz, 1H), 2.45 (d, *J*=12.0 Hz, 1H), 2.39 (ddd, *J*=12.5, 4.5, 4.0 Hz, 1H), 2.21 (m, 1H), 2.07 (s, 3H), 1.55 (m, 1H), 1.47 (ddd, *J*=12.0, 11.5, 11.5 Hz, 1H), 1.19 (s, 3H); ^{13}C NMR (150 MHz, $CDCl_3$) δ 208.7, 159.2, 138.5, 138.1, 130.5, 129.3 (2C), 128.4 (2C), 128.3 (2C), 127.8 (2C), 127.7 (2C), 127.6 (2C), 127.5, 113.7, 76.8, 76.7, 76.3, 72.9, 70.9 (2C), 70.0, 66.7, 55.3, 52.6, 33.2, 32.4, 30.4, 16.4; HRMS (ESI) calcd for $C_{33}H_{40}O_6Na$ $[(M+Na)^+]$ 555.2717, found 555.2686.

*4.1.13. β-Hydroxy ketone **24**.* To a solution of methyl ketone **10** (198 mg, 0.372 mmol) and *i*-Pr_2NEt (130 μL, 0.744 mmol) in Et_2O (3.0 mL) at 0 °C was added *n*-Bu_2BOTf (141 μL, 0.559 mmol, freshly prepared from *n*-Bu_3B and TfOH[31]). The resultant solution was stirred at 0 °C for 1 h and then cooled to −78 °C. To this solution was added a solution of aldehyde **9** (219 mg, 0.558 mmol) in Et_2O (0.7 mL), and the resultant solution was allowed to warm to −20 °C over 2 h before it was quenched with pH 7 buffer (0.5 mL) and MeOH (1 mL). The resultant mixture was treated with 30% aqueous H_2O_2 solution (0.5 mL) and MeOH (1 mL) at 0 °C and stirred at room temperature for 1 h. The mixture was extracted with EtOAc, and the organic layer was washed with brine, dried over Na_2SO_4, filtered, and concentrated under reduced pressure. Purification of the residue by flash column chromatography (silica gel, 10–30% EtOAc/hexanes) gave β-hydroxy ketone **24**, which was contaminated with a small amount of **9** and some impurities. Further purification by preparative HPLC gave pure hydroxy ketone **24** (254 mg, 74%, a 4:1 mixture of diastereomers) as a colorless oil: $[\alpha]_D^{23}$ −36.7 (*c* 0.98, $CHCl_3$); IR (film) 3503, 3031, 2953, 2874, 1708, 1611, 1513, 1455, 1364, 1248, 1092, 1028, 825 cm^{-1}; ^1H NMR (600 MHz, $CDCl_3$, major diastereomer) δ 7.49–7.25 (m, 17H), 6.87–6.85 (m, 2H), 5.44 (s, 1H), 4.57 (d, *J*=11.3 Hz, 1H), 4.55 (d, *J*=11.0 Hz, 1H), 4.50 (d, *J*=12.0 Hz, 1H), 4.45 (d, *J*=11.3 Hz, 1H), 4.45 (d, *J*=12.0 Hz, 1H), 4.39 (d, *J*=11.0 Hz, 1H), 4.14 (m, 1H), 4.09 (dd, *J*=8.9, 2.8 Hz, 1H), 3.95 (dd, *J*=11.3, 4.9 Hz, 1H), 3.79 (s, 3H), 3.58–3.52 (m, 5H), 3.45 (dd, *J*=11.7, 4.5 Hz, 1H), 3.38 (m, 1H), 3.23 (br s, 1H), 3.02 (ddd, *J*=10.3, 5.2, 4.8 Hz, 1H), 2.73 (dd, *J*=14.1, 2.8 Hz, 1H), 2.67 (m, 1H), 2.66 (d, *J*=12.4 Hz, 1H), 2.57 (d, *J*=12.4 Hz, 1H), 2.38 (ddd, *J*=12.1, 4.8, 4.4 Hz, 1H), 2.24–2.17 (m, 2H), 1.85 (ddd, *J*=11.7, 11.6, 11.3 Hz, 1H), 1.56–1.45 (m, 2H), 1.23 (s, 3H), 1.22 (s, 3H), 0.94 (t, *J*=7.9 Hz, 9H), 0.60 (q, *J*=7.9 Hz, 6H); ^{13}C NMR (150 MHz, $CDCl_3$, major diastereomer) δ 209.4, 159.1, 138.5, 138.0, 137.3, 130.6, 129.3 (2C), 129.1, 128.4 (2C), 128.3 (4C), 127.8 (2C), 127.7, 127.5 (2C), 127.4, 126.1 (2C), 113.7 (2C), 101.7, 78.8, 76.8, 76.6, 76.4, 76.3, 74.1, 72.9, 72.3, 71.0, 70.7, 70.0, 69.7, 66.9, 66.1, 55.2, 52.2, 47.2, 34.6, 32.5, 30.4, 16.8, 11.6, 6.8 (3C), 5.3 (3C); HRMS (ESI) calcd for $C_{54}H_{72}O_{11}SiNa$ $[(M+Na)^+]$ 947.4736, found 947.4738.

*4.1.14. Diketone **8**.* To a solution of hydroxy ketone **24** (132 mg, 0.142 mmol) in CH_2Cl_2/*t*-BuOH (10:1, v/v, 1.4 mL) at room temperature was added Dess–Martin periodinane (90.3 mg, 0.213 mmol). The resultant solution was stirred at room temperature for 90 min before it was quenched with a 1:1 mixture of saturated aqueous $NaHCO_3$ solution and saturated aqueous $Na_2S_2O_3$ solution (2 mL). The mixture was extracted with EtOAc, and the organic layer was washed with brine, dried over Na_2SO_4, filtered, and concentrated under reduced pressure. Purification of the residue by flash column chromatography (silica gel, 20% EtOAc/hexanes) gave diketone **8** (119 mg, 91%) as a colorless oil: $[\alpha]_D^{25}$ −12.0 (*c* 1.5, $CHCl_3$); IR (film) 2952, 2874, 1612, 1514, 1455, 1364, 1248, 1093, 1028, 830, 771 cm^{-1}; ^1H NMR (600 MHz, $CDCl_3$) δ 7.49–7.25 (m, 17H), 6.88 (d, *J*=8.5 Hz, 2H), 5.96 (br s, 1H), 5.43 (s, 1H), 4.62 (d, *J*=10.0 Hz, 1H), 4.55 (d, *J*=11.0 Hz, 1H), 4.50 (d, *J*=12.0 Hz, 1H), 4.46 (d, *J*=12.0 Hz, 1H), 4.42 (d, *J*=11.0 Hz, 1H), 4.42 (d, *J*=10.0 Hz, 1H), 4.21 (ddd, *J*=10.0, 10.0, 5.5 Hz, 1H), 3.92 (dd, *J*=11.0, 4.4 Hz, 1H), 3.80 (s, 3H), 3.65–3.54 (m, 5H), 3.49 (m, 1H), 3.36 (dd, *J*=11.7, 4.1 Hz, 1H), 3.06 (ddd, *J*=11.3, 9.3, 4.4 Hz, 1H), 2.55 (d, *J*=13.4 Hz, 1H), 2.49 (d, *J*=12.7 Hz, 1H), 2.45 (m, 1H), 2.27–2.19 (m, 2H), 1.87 (ddd, *J*=12.0, 12.0, 11.3 Hz, 1H), 1.58 (m, 1H), 1.51 (ddd, *J*=12.0, 12.0, 11.3 Hz, 1H), 1.43 (s, 3H), 1.23 (s, 3H), 0.89 (t, *J*=7.9 Hz, 9H), 0.51 (q, *J*=7.9 Hz, 6H), one proton missing due to H/D exchange of the enol form; ^{13}C NMR (150 MHz, $CDCl_3$) δ 196.1, 189.0, 159.2, 138.6, 138.1, 137.3, 130.5, 129.2 (2C), 129.1, 128.5 (2C), 128.3 (3C), 127.8 (4C), 127.5 (3C), 126.1 (2C), 113.7 (2C), 101.7, 99.0, 81.7, 77.1, 76.9, 76.0, 72.9, 70.9, 70.5, 69.9, 69.8, 66.9, 66.4, 55.3 (2C), 47.7. 35.0, 32.7, 30.4, 16.5, 14.1, 12.4, 6.8 (3C), 4.7 (3C); HRMS (ESI) calcd for $C_{54}H_{70}O_{11}SiNa$ $[(M+Na)^+]$ 945.4580, found 945.4600.

*4.1.15. Methyl ketone **25**.* To a solution of aldehyde **9** (594 mg, 1.51 mmol) in THF (7.5 mL) at −78 °C was added MeMgBr (3.0 M solution in Et_2O, 1.51 mL, 4.53 mmol), and the resultant solution was allowed to warm to 0 °C over 1.5 h before it was quenched with saturated aqueous NH_4Cl solution. The mixture was extracted with EtOAc, and the organic layer was washed with brine, dried over Na_2SO_4, filtered, and concentrated under reduced pressure. Purification of the residue by flash column chromatography (silica gel, 10–15% EtOAc/hexanes) gave a secondary alcohol (465 mg, 74%) as a colorless oil, which was used in the next reaction without further purification.

To a solution of DMSO (221 μL, 3.11 mmol) in CH_2Cl_2 (5 mL) at −78 °C was added oxalyl chloride (135 μL, 1.55 mmol), and the resultant solution was stirred at −78 °C for 15 min. To this solution was added a solution of the above alcohol (317 mg) in CH_2Cl_2 (3 mL), and the resultant solution was stirred at −78 °C for 45 min before Et_3N (650 μL, 4.66 mmol) was introduced. The mixture was allowed to warm to room temperature and stirred for 1 h before it was quenched with saturated aqueous $NaHCO_3$ solution. The mixture was extracted twice with EtOAc, and the organic layer was washed with brine, dried over Na_2SO_4, filtered, and concentrated under reduced pressure. Purification of the residue by flash column chromatography (silica gel, 10% EtOAc/hexanes) gave methyl ketone **25** (265 mg, 84%) as a colorless oil: $[\alpha]_D^{24}$ +11.2 (*c* 0.9, $CHCl_3$); IR (film) 2954, 2876, 1724, 1365, 1094, 1008, 825, 747 cm^{-1}; ^1H NMR (600 MHz, $CDCl_3$) δ 7.48–7.46 (m, 2H), 7.38–7.32 (m, 3H), 5.52 (s, 1H), 4.25 (dd, *J*=10.3, 4.5 Hz, 1H), 3.98 (dd, *J*=11.0, 4.8 Hz, 1H), 3.68 (dd, *J*=10.0, 10.0 Hz, 1H), 3.60 (ddd, *J*=9.3, 8.9, 4.4 Hz, 1H), 3.53 (m, 1H), 2.24 (ddd, *J*=12.0, 4.5, 4.5 Hz, 1H), 2.18 (s, 3H), 1.84 (ddd, *J*=11.7, 11.7, 11.3 Hz, 1H), 1.40 (s, 3H), 0.90 (t, *J*=7.9 Hz, 9H), 0.54 (q, *J*=7.9 Hz, 6H); ^{13}C NMR (150 MHz, $CDCl_3$) 206.9, 137.3, 129.2, 128.4 (2C), 126.1 (2C), 101.8, 84.2, 76.7, 69.9, 68.4, 66.4, 34.9, 24.5, 12.5, 6.7 (3C), 4.9 (3C); HRMS (ESI) calcd for $C_{22}H_{34}O_5SiNa$ $[(M+Na)^+]$ 429.2068, found 429.2066.

*4.1.16. Aldehyde **23**.* To a solution of alcohol **22** (766 mg, 1.47 mmol) in CH_2Cl_2 (8 mL) at 0 °C were added KBr (0.5 M solution in H_2O, 294 μL, 0.147 mmol) and TEMPO (11.5 mg, 73.5 μmol). To this mixture were added dropwise a freshly prepared mixture of NaOCl (1.73 M solution in H_2O, 850 μL, 1.47 mmol) and saturated aqueous $NaHCO_3$ solution (850 μL). The resultant mixture was vigorously stirred at 0 °C for 20 min before it was quenched with saturated aqueous $Na_2S_2O_3$ solution. The mixture was extracted

twice with EtOAc, and the organic layer was washed with H_2O and brine, dried over Na_2SO_4, filtered, and concentrated under reduced pressure. Purification of the residue by flash column chromatography (silica gel, 20% EtOAc/hexanes) gave aldehyde **23** (722 mg, 95%) as a colorless oil: $[\alpha]_D^{22}$ −28.7 (*c* 1.4, $CHCl_3$); IR (film) 2939, 2862, 1718, 1611, 1513, 1248, 1087, 1030, 821, 736, 697 cm^{-1}; ^1H NMR (600 MHz, $CDCl_3$) δ 9.68 (dd, *J*=3.4, 2.7 Hz, 1H), 7.35–7.24 (m, 10H), 7.19–7.18 (m, 2H), 6.87–6.84 (m, 2H), 4.60 (d, *J*=11.3 Hz, 1H), 4.50 (d, *J*=11.0 Hz, 1H), 4.50 (d, *J*=12.1 Hz, 1H), 4.44 (d, *J*=11.3 Hz, 1H), 4.42 (d, *J*=12.1 Hz, 1H), 4.30 (d, *J*=11.3 Hz, 1H), 3.79 (s, 3H), 3.59 (dd, *J*=9.3, 9.3 Hz, 1H), 3.54–3.51 (m, 2H), 3.24 (dd, *J*=12.0, 4.8 Hz, 1H), 3.08 (ddd, *J*=11.0, 9.6, 4.8 Hz, 1H), 2.52 (dd, *J*=14.4, 3.4 Hz, 1H), 2.44 (ddd, *J*=12.0, 4.8, 4.8 Hz, 1H), 2.37 (dd, *J*=14.5, 2.7 Hz, 1H), 2.22 (ddd, *J*=13.7, 7.9, 2.4 Hz, 1H), 1.56 (m, 1H), 1.49 (ddd, *J*=11.7, 11.7, 11.7 Hz, 1H), 1.27 (s, 3H); ^{13}C NMR (150 MHz, $CDCl_3$) δ 202.3, 159.3, 138.5, 138.0, 129.9, 129.4 (2C), 128.4 (2C), 128.3 (2C), 127.81 (2C), 127.78, 127.7 (2C), 127.5, 113.8 (2C), 77.8, 76.6, 75.6, 72.9, 71.0, 70.6, 69.9, 66.6, 55.3, 53.6, 32.3, 30.2, 16.4; HRMS (ESI) calcd for $C_{32}H_{38}O_6Na$ [(M+Na)$^+$] 541.2561, found 541.2575.

*4.1.17. β-Hydroxy ketone **26**.* To a solution of *i*-Pr_2NH (128 μL, 0.911 mmol) in THF (0.3 mL) at 0 °C was added *n*-BuLi (2.6 M solution in hexane, 303 μL, 0.788 mmol). After being stirred at 0 °C for 15 min, the resultant solution was cooled to −78 °C. To the solution was added a solution of methyl ketone **25** (308 mg, 0.789 mmol) in THF (0.7 mL), and the resultant solution was stirred at −78 °C for 1 h. To this cold solution was added a solution of aldehyde **23** (314 mg, 0.606 mmol) in THF (0.7 mL). The reaction mixture was gradually allowed to warm to −20 °C over 2 h before it was quenched with saturated aqueous NH_4Cl solution. The mixture was extracted twice with EtOAc, and the organic layer was washed with brine, dried over Na_2SO_4, filtered, and concentrated under reduced pressure. Purification of the residue by column chromatography (silica gel, 0–20% EtOAc/hexanes) gave β-hydroxy ketone **26** (365 mg, 67%) as a 1.7:1 mixture of diastereomers: $[\alpha]_D^{23}$ −15.4 (*c* 1.3, $CHCl_3$); IR (film) 3485, 2952, 2909, 2875, 1719, 1612, 1514, 1456, 1365, 1094, 1029, 824, 750 cm^{-1}; ^1H NMR (600 MHz, $CDCl_3$, major diastereomer) δ 7.48–7.45 (m, 2H), 7.37–7.24 (m, 13H), 7.22–7.20 (m, 2H), 6.87–6.85 (m, 2H), 5.47 (s, 1H), 4.58 (d, *J*=11.7 Hz, 1H), 4.52 (d, *J*=11.3 Hz, 1H), 4.48 (d, *J*=12.0 Hz, 1H), 4.44 (d, *J*=12.0 Hz, 1H), 4.41 (d, *J*=11.3 Hz, 1H), 4.37 (d, *J*=11.7 Hz, 1H), 4.23 (dd, *J*=13.7, 4.1 Hz, 1H), 3.99 (dd, *J*=11.0, 4.8 Hz, 1H), 3.79 (s, 3H), 3.65–3.55 (m, 3H), 3.51–3.46 (m, 3H), 3.24 (dd, *J*=11.7, 4.5 Hz, 1H), 3.06 (ddd, *J*=11.0, 9.7, 7.5 Hz, 1H), 2.94 (dd, *J*=17.5, 6.5 Hz, 1H), 2.54 (dd, *J*=17.5, 5.9 Hz, 1H), 2.40 (ddd, *J*=12.4, 4.5, 4.5 Hz, 1H), 2.23 (ddd, *J*=11.7, 4.4, 4.4 Hz, 1H), 2.19 (dddd, *J*=12.0, 6.9, 6.9, 4.9 Hz, 1H), 1.96 (dd, *J*=14.1, 1.7 Hz, 1H), 1.83 (ddd, *J*=11.7, 11.6, 11.6 Hz, 1H), 1.59–1.47 (m, 3H), 1.40 (s, 3H), 1.28 (s, 3H), 0.89 (t, *J*=7.9 Hz, 9H), 0.53 (q, *J*=7.9 Hz, 6H), one proton missing due to H/D exchange of the hydroxy group; ^{13}C NMR (150 MHz, $CDCl_3$, major diastereomer) δ 207.4, 159.2, 138.4, 138.0, 137.3, 130.5, 129.3, 129.1, 129.0 (2C), 128.4 (2C), 128.32 (2C), 128.27 (2C), 127.80, 127.76 (2C), 127.6, 127.4, 126.1 (2C), 113.7 (2C), 101.8, 83.6, 79.1, 77.6, 76.6, 76.4, 72.9, 70.9, 70.80, 70.77, 69.8, 68.3, 67.0, 66.3, 64.6, 55.2, 46.4, 44.2, 35.0, 32.2, 30.2, 15.2, 12.8, 6.8 (3C), 4.9 (3C); HRMS (ESI) calcd for $C_{54}H_{72}O_{11}SiNa$ [(M+Na)$^+$] 947.4736, found 947.4744.

*4.1.18. Diketone **8**.* To a solution of β-hydroxy ketone **26** (74.6 mg, 80.7 μmol) in CH_2Cl_2/*t*-BuOH (9:1, v/v, 1.0 mL) was added Dess–Martin periodinane (51.3 mg, 0.121 mmol), and the resultant solution was stirred at room temperature for 105 min before it was quenched with a 1:1 mixture of saturated aqueous $NaHCO_3$ solution and saturated aqueous $Na_2S_2O_3$ solution. The mixture was extracted with EtOAc, and the organic layer was washed with brine, dried over Na_2SO_4, filtered, and concentrated under reduced pressure. Purification of the residue by flash column chromatography (silica gel, 10–15% EtOAc/hexanes) gave diketone **8** (68.2 mg, 92%), which was identical in all aspects to that prepared by oxidation of **24**.

*4.1.19. Dihydropyrone **28**.* To a solution of diketone **8** (50.4 mg, 0.546 mmol) in MeOH (1 mL) at room temperature was added PPTS (4.2 mg, 16 μmol), and the resultant solution was stirred at 80 °C for 6 h. The mixture was cooled to room temperature, treated with Et_3N (4.6 μL, 33 μmol), and concentrated under reduced pressure. Purification of the residue by flash column chromatography (silica gel, 10% MeOH/EtOAc) gave dihydropyrone **28** (36.3 mg, 95%) as a colorless oil: $[\alpha]_D^{25}$ +79.8 (*c* 1.47, $CHCl_3$); IR (film) 3380, 2871, 1668, 1595, 1514, 1454, 1454, 1371, 1073, 1030, 772 cm^{-1}; ^1H NMR (600 MHz, $CDCl_3$) δ 7.34–7.23 (m, 10H), 7.18 (d, *J*=8.6 Hz, 2H), 6.86 (m, 2H), 5.21 (s, 1H), 4.60 (d, *J*=11.3 Hz, 1H), 4.54 (*J*=11.0 Hz, 1H), 4.48 (d, *J*=12.1 Hz, 1H), 4.44 (d, *J*=11.3 Hz, 1H), 4.40 (d, *J*=12.1 Hz, 1H), 4.25 (d, *J*=11.0 Hz, 1H), 3.87–3.84 (m, 2H), 3.79 (s, 3H), 3.74 (dd, *J*=12.7, 4.8 Hz, 1H), 3.58–3.44 (m, 5H), 3.20 (dd, *J*=11.7, 4.4 Hz, 1H), 3.06 (ddd, *J*=11.0, 9.6, 4.4 Hz, 1H), 2.49 (ddd, *J*=12.4, 4.4, 4.4 Hz, 1H), 2.42 (d, *J*=13.7 Hz, 1H), 2.33 (d, *J*=13.7 Hz, 1H), 2.25 (ddd, *J*=12.1, 4.8, 4.4 Hz, 1H), 2.20 (ddd, *J*=13.7, 7.9, 2.4 Hz, 1H), 1.93 (ddd, *J*=12.1, 12.0, 11.6 Hz, 1H), 1.52 (m, 1H), 1.48 (ddd, *J*=11.7, 11.6, 9.0 Hz, 1H), 1.27 (s, 3H), 1.19 (s, 3H), two protons missing due to H/D exchange of the hydroxy groups; ^{13}C NMR (150 MHz, $CDCl_3$) δ 173.6, 159.3, 138.6, 138.0, 130.1, 129.3 (2C), 128.4 (2C), 128.3 (2C), 127.8 (3C), 127.5 (3C), 127.4, 113.9 (2C), 105.2, 77.6, 77.5, 76.8, 75.8, 75.3, 73.4, 72.8, 71.1, 70.3, 69.9, 66.7, 66.0, 62.6, 55.3, 44.8, 32.4, 32.1, 30.1, 16.2, 12.8; HRMS (ESI) calcd for $C_{41}H_{50}O_{10}Na$ [(M+Na)$^+$] 725.3296, found 725.3294.

*4.1.20. Silylene **7**.* To a solution of diol **28** (151 mg, 0.215 mmol) and 2,6-lutidine (75.3 μL, 0.645 mmol) in DMF (2.2 mL) at 0 °C was added *t*-$Bu_2Si(OTf)_2$ (83.6 μL, 0.258 mmol), and the resultant solution was stirred at room temperature for 2 h before it was diluted with EtOAc. The mixture was washed successively with H_2O, saturated aqueous $NaHCO_3$ solution, and brine. The organic layer was dried over Na_2SO_4, filtered, and concentrated under reduced pressure. Purification of the residue by flash column chromatography (silica gel, 10–20% EtOAc/hexanes) gave silylene **7** (168 mg, 93%) as a white foam: $[\alpha]_D^{23}$+43.0 (*c* 1.05, $CHCl_3$); IR (film) 3535, 2933, 2855, 1685, 1604, 1514, 1472, 1364, 1249, 1075, 827 cm^{-1}; ^1H NMR (600 MHz, $CDCl_3$) δ 7.34–7.23 (m, 10H), 7.20–7.18 (m, 2H), 6.87–6.85 (m, 2H), 5.22 (s, 1H), 4.60 (d, *J*=11.3 Hz, 1H), 4.54 (d, *J*=11.0 Hz, 1H), 4.49 (d, *J*=12.4 Hz, 1H), 4.44 (d, *J*=11.3 Hz, 1H), 4.40 (d, *J*=12.4 Hz, 1H), 4.26 (d, *J*=11.0 Hz, 1H), 4.20 (dd, *J*=10.5, 5.2 Hz, 1H), 3.91 (dd, *J*=12.4, 4.1 Hz, 1H), 3.83 (dd, *J*=10.3, 10.0 Hz, 1H), 3.79 (s, 3H), 3.70 (ddd, *J*=11.0, 9.6, 4.8 Hz, 1H), 3.58–3.48 (m, 4H), 3.21 (dd, *J*=11.6, 2.8 Hz, 1H), 3.05 (ddd, *J*=11.3, 9.2, 4.8 Hz, 1H), 2.49 (ddd, *J*=12.1, 4.4, 4.4 Hz, 1H), 2.42 (d, *J*=13.7 Hz, 1H), 2.34 (d, *J*=13.7 Hz, 1H), 2.31 (ddd, *J*=12.4, 4.4, 4.4 Hz, 1H), 2.20 (dddd, *J*=13.7, 7.9, 7.9, 2.8 Hz, 1H), 1.92 (ddd, *J*=12.0, 11.7, 11.7 Hz, 1H), 1.53 (m, 1H), 1.48 (ddd, *J*=11.7, 11.7, 11.6 Hz, 1H), 1.31 (s, 3H), 1.20 (s, 3H), 1.01 (s, 9H), 0.98 (s, 9H); ^{13}C NMR (150 MHz, $CDCl_3$) δ 193.7, 173.0, 159.3, 138.6, 138.0, 130.0, 129.3 (2C), 128.4 (2C), 128.3 (2C), 127.8 (3C), 127.5 (2C), 127.4, 113.8 (2C), 105.4, 77.60, 77.56, 77.2, 75.8, 74.2, 72.9, 72.5, 71.12, 71.08, 70.3, 69.9, 67.2, 66.7, 55.3, 44.8, 32.8, 32.5, 30.1, 27.4 (3C), 27.0 (3C), 22.6, 19.9, 16.2, 12.9; HRMS (ESI) calcd for $C_{49}H_{66}O_{10}SiNa$ [(M+Na)$^+$] 865.4317, found 865.4295.

*4.1.21. Diol **29**.* To a solution of silylene **7** (289 mg, 0.343 mmol) in MeOH/CH_2Cl_2 (1:1, v/v, 4.0 mL) at 0 °C was added $CeCl_3 \cdot 7H_2O$ (141 mg, 0.378 mmol), and the resultant mixture was stirred at 0 °C for 15 min. $NaBH_4$ (14.3 mg, 0.378 mmol) was added to the mixture, and the resultant mixture was stirred at 0 °C for 2 h before it was quenched with pH 7 phosphate buffer. The mixture was extracted twice with EtOAc, and the organic layer was washed with brine, dried over Na_2SO_4, filtered, and concentrated under reduced

pressure. Purification of the residue by flash column chromatography (silica gel, 10% EtOAc/hexanes) gave an allylic alcohol (280 mg, 97%) as a white foam: $[\alpha]_D^{23}$ −1.0 (*c* 1.14, $CHCl_3$); IR (film) 3457, 2933, 2859, 1514, 1471, 1248, 1173, 1109, 1085, 1030, 826 cm^{-1}; ^1H NMR (600 MHz, C_6D_6) δ 7.39 (d, *J*=7.2 Hz, 2H), 7.30 (d, *J*=6.8 Hz, 2H), 7.21–7.09 (m, 8H), 6.79 (d, *J*=8.6 Hz, 2H), 4.67 (d, *J*=1.7 Hz, 1H), 4.54 (d, *J*=12.4 Hz, 1H), 4.50 (d, *J*=12.4 Hz, 1H), 4.46 (d, *J*=12.1 Hz, 1H), 4.41 (d, *J*=11.3 Hz, 1H), 4.27 (d, *J*=12.1 Hz, 1H), 4.27 (br s, 1H), 4.22 (dd, *J*=10.3, 4.8 Hz, 1H), 4.19 (d, *J*=11.3 Hz, 1H), 3.87 (dd, *J*=9.6, 9.6 Hz, 1H), 3.78–3.70 (m, 5H), 3.47 (dd, *J*=12.4, 4.5 Hz, 1H), 3.31 (s, 3H), 3.23 (dd, *J*=11.7, 4.8 Hz, 1H), 3.06 (ddd, *J*=11.0, 9.6, 4.4 Hz, 1H), 2.48 (d, *J*=13.7 Hz, 1H), 2.46 (m, 1H), 2.41 (ddd, *J*=12.0, 4.8, 4.4 Hz, 1H), 2.37 (ddd, *J*=12.0, 4.5, 4.4 Hz, 1H), 2.32 (d, *J*=13.7 Hz, 1H), 1.96 (ddd, *J*=12.0, 12.0, 11.0 Hz, 1H), 1.76 (m, 1H), 1.58 (ddd, *J*=11.7, 11.7, 11.7 Hz, 1H), 1.35 (s, 3H), 1.29 (s, 3H), 1.11 (s, 9H), 1.02 (s, 9H), one proton missing due to H/D exchange of the hydroxy group; ^{13}C NMR (150 MHz, C_6D_6) δ 159.7, 152.7, 139.7, 139.1, 131.0, 129.4, 128.6, 128.5, 128.3 (3C), 127.8 (4C), 127.7, 127.5, 114.1 (2C), 104.2, 78.3, 77.4, 75.8, 75.0, 74.4, 73.8, 73.5, 73.0, 71.2, 70.8, 70.5, 70.0, 68.0, 67.1, 54.8, 44.1, 33.9, 33.2, 30.7, 27.6 (3C), 27.5 (3C), 22.8, 20.1, 16.0, 9.8; HRMS (ESI) calcd for $C_{49}H_{68}O_{10}SiNa$ [$(M+Na)^+$] 867.4474, found 867.4484.

To a solution of the above allylic alcohol (140 mg, 0.166 mmol) in THF (1.7 mL) at 0 °C was added $BH_3\cdot THF$ (1.0 M solution in THF, 332 μL, 0.332 mmol), and the resultant solution was stirred at room temperature for 2 h. The mixture was cooled to 0 °C and treated with 3 M aqueous NaOH solution (1.7 mL) and 30% H_2O_2 solution (1.7 mL). The resultant mixture was stirred at 0 °C for 30 min and then at room temperature for 4 h. The mixture was extracted twice with EtOAc, and the organic layer was washed with brine, dried over Na_2SO_4, filtered, and concentrated under reduced pressure. Purification of the residue by column chromatography (silica gel, 30–40% EtOAc/hexanes) gave diol **29** (114 mg, 80%) as a white foam: $[\alpha]_D^{25}$ −13.9 (*c* 0.30, $CHCl_3$); IR (film) 3442, 2933, 2859, 1613, 1514, 1470, 1363, 1248, 1092, 1069, 826, 760 cm^{-1}; ^1H NMR (500 MHz, $CDCl_3$) δ 7.35–7.23 (m, 12H), 6.87 (d, *J*=8.5 Hz, 2H), 4.60 (d, *J*=11.0 Hz, 1H), 4.52 (d, *J*=11.5 Hz, 1H), 4.50 (d, *J*=12.0 Hz, 1H), 4.43 (d, *J*=12.0 Hz, 1H), 4.43 (d, *J*=11.0 Hz, 1H), 4.34 (d, *J*=11.5 Hz, 1H), 4.10 (dd, *J*=9.5, 6.5 Hz, 1H), 3.95 (br s, 1H), 3.79 (s, 3H), 3.79–3.73 (m, 2H), 3.66 (dd, *J*=9.5, 7.5 Hz, 1H), 3.55–3.47 (m, 4H), 3.30 (d, *J*=9.0 Hz, 1H), 3.21 (dd, *J*=9.0, 8.5 Hz, 1H), 3.10–3.01 (m, 2H), 2.86 (dd, *J*=12.5, 4.0 Hz, 1H), 2.49 (m, 1H), 2.48 (br s, 1H), 2.25 (ddd, *J*=12.5, 7.5, 7.5 Hz, 1H), 2.13 (ddd, *J*=12.0, 4.5, 4.0 Hz, 1H), 2.10 (dd, *J*=15.5, 4.0 Hz, 1H), 1.78 (dd, *J*=15.5, 6.0 Hz, 1H), 1.65 (ddd, *J*=11.5, 11.5, 11.5 Hz, 1H), 1.52 (m, 1H), 1.19 (s, 3H), 1.19 (s, 3H), 1.04 (s, 9H), 0.98 (s, 9H), one proton missing due to H/D exchange of the hydroxy group; ^{13}C NMR (125 MHz, $CDCl_3$) δ 159.3, 138.5, 138.0, 130.3, 130.0 (2C), 128.4 (2C), 128.3 (2C), 127.8 (3C), 127.7 (2C), 127.5, 113.7 (2C), 79.9, 76.7, 76.3, 76.1 (2C), 74.5, 74.4, 73.5, 72.9, 71.0, 70.6, 70.4, 69.8, 67.8, 66.4, 60.4, 55.3, 43.6, 33.2, 32.2, 30.2, 27.4 (3C), 27.1 (3C), 22.6, 19.9, 17.9, 10.1; HRMS (ESI) calcd for $C_{49}H_{70}O_{11}Si$ [$(M+Na)^+$] 885.4580, found 885.4571.

*4.1.22. Ketone **30**.* To a solution of diol **29** (110 mg, 0.128 mmol) and 2,6-lutidine (44.7 μL, 0.384 mmol) in CH_2Cl_2 (1.3 mL) at 0 °C was added TESOTf (72.3 μL, 0.319 mmol). The resultant solution was stirred at room temperature for 2 h before it was diluted with EtOAc. The mixture was washed with saturated aqueous NH_4Cl solution and brine, dried over Na_2SO_4, filtered, and concentrated under reduced pressure. Purification of the residue by column chromatography (silica gel, 10–20% EtOAc/hexanes) gave a bis-TES ether (132 mg, 94%) as a white foam: $[\alpha]_D^{24}$ −38.3 (*c* 0.6, $CHCl_3$); IR (film) 2952, 2360, 1093, 775 cm^{-1}; ^1H NMR (500 MHz, $CDCl_3$) δ 7.33–7.25 (m, 12H), 6.88–6.83 (m, 2H), 4.62 (d, *J*=11.5 Hz, 1H), 4.51 (d, *J*=12.0 Hz, 1H), 4.46 (d, *J*=10.5 Hz, 1H), 4.45 (d, *J*=11.5 Hz, 1H), 4.42 (d, *J*=12.0 Hz, 1H), 4.38 (d, *J*=10.5 Hz, 1H), 4.08 (dd, *J*=10.0, 5.0 Hz, 1H), 3.79 (s, 3H), 3.77–3.70 (m, 2H), 3.69 (dd, *J*=11.5, 4.5 Hz, 1H), 3.62–3.45 (m, 5H), 3.34 (d, *J*=8.5 Hz, 1H), 3.19 (dd, *J*=8.5, 8.5 Hz, 1H), 3.09 (ddd, *J*=10.5, 10.0, 4.0 Hz, 1H), 2.93 (dd, *J*=12.5, 7.5 Hz, 1H), 2.44 (ddd, *J*=12.0, 5.0, 4.0 Hz, 1H), 2.22 (ddd, *J*=12.0, 8.0, 8.0 Hz, 1H), 2.12 (ddd, *J*=12.0, 5.0, 4.0 Hz, 1H), 1.84 (d, *J*=14.0 Hz, 1H), 1.72 (dd, *J*=14.5, 9.5 Hz, 1H), 1.66–1.56 (m, 2H), 1.48 (ddd, *J*=12.0, 11.5, 11.0 Hz, 1H), 1.13 (s, 3H), 1.09 (s, 3H), 1.03 (s, 9H), 0.98 (s, 9H), 0.94 (t, *J*=8.0 Hz, 18H), 0.63 (q, *J*=8.0 Hz, 12H); ^{13}C NMR (125 MHz, $CDCl_3$) δ 159.0, 138.8, 138.3, 131.2, 129.3 (2C), 128.4 (2C), 128.3 (2C), 127.8 (2C), 127.6, 127.5 (2C), 127.4, 113.6 (2C), 82.1, 78.1, 77.14, 77.06, 76.3, 75.6, 74.9, 73.6, 72.9, 70.83, 70.78, 69.8, 69.5, 67.6, 67.3, 55.3 (2C), 41.2, 33.6, 32.5, 30.6, 27.5 (3C), 27.1 (3C), 22.6, 19.9, 17.6, 10.0, 7.1 (6C), 5.6 (3C), 5.1 (3C); HRMS (ESI) calcd for $C_{61}H_{98}O_{11}Si_3$ [$(M+Na^+)$] 1113.6309, found 1113.6284.

To a solution of the above bis-TES ether (182 mg, 0.167 mmol) in CH_2Cl_2/H_2O (9/1, v/v, 8.8 mL) at 0 °C was added DDQ (39.7 mg, 0.175 mmol) in five portions over 50 min. The resultant mixture was stirred at 0 °C for 2 h before it was quenched with saturated aqueous $NaHCO_3$ solution. The mixture was extracted with EtOAc, and the organic layer was washed with saturated aqueous $NaHCO_3$ solution and brine, dried over Na_2SO_4, filtered, and concentrated under reduced pressure. The residue was filtered through a short pad of silica gel to give a crude material, which was used in the next reaction without further purification.

To a solution of the above crude material, 4 Å molecular sieves (140 mg), and NMO (39.0 mg, 0.334 mmol) in CH_2Cl_2 (1.7 mL) at 0 °C was added TPAP (2.9 mg, 8.4 μmol). After being stirred at room temperature for 2 h, the mixture was filtered through a short pad of silica gel. The filtrate was concentrated and purified by column chromatography (silica gel, 0–10% EtOAc/hexanes) to give ketone **30** (137 mg, 85% for the two steps) as a colorless oil: $[\alpha]_D^{25}$ −24.9 (*c* 0.13, $CHCl_3$); IR (film) 2955, 1737, 1462, 1092, 1010, 827, 779, 736 cm^{-1}; ^1H NMR (600 MHz, $CDCl_3$) δ 7.33–7.24 (m, 10H), 4.55 (d, *J*=12.0 Hz, 1H), 4.50 (d, *J*=11.7 Hz, 1H), 4.45 (d, *J*=12.0 Hz, 1H), 4.40 (d, *J*=11.7 Hz, 1H), 4.04 (dd, *J*=10.0, 4.5 Hz, 1H), 3.90 (ddd, *J*=7.3, 5.5, 3.8 Hz, 1H), 3.74–3.67 (m, 3H), 3.62–3.56 (m, 2H), 3.52–3.45 (m, 2H), 3.30 (d, *J*=8.3 Hz, 1H), 3.18 (dd, *J*=8.9, 8.6 Hz, 1H), 2.92–2.88 (m, 2H), 2.44 (dd, *J*=15.5, 5.2 Hz, 1H), 2.08 (m, 1H), 1.96 (ddd, *J*=11.7, 4.4, 4.4 Hz, 1H), 1.93–1.92 (m, 2H), 1.80 (m, 1H), 1.26 (s, 3H), 1.02 (s, 3H), 1.02 (s, 9H), 0.98 (s, 9H), 0.93 (t, *J*=7.9 Hz, 9H), 0.91 (t, *J*=7.9 Hz, 9H), 0.65–0.55 (m, 12H); ^{13}C NMR (150 MHz, $CDCl_3$) δ 212.2, 138.4, 137.8, 128.5 (2C), 128.4 (2C), 127.8 (3C), 127.62 (2C), 127.57, 81.9, 80.1, 77.4, 76.19, 76.17, 73.6, 73.1, 71.1, 70.5, 69.5, 67.5, 66.6, 43.3, 41.4, 34.0, 33.2, 27.5 (3C), 27.1 (3C), 22.6, 22.5, 20.0, 10.0, 7.1 (3C), 7.0 (3C), 5.6 (3C), 5.1 (3C), two carbons missing presumably due to solvent overlapping; HRMS (ESI) calcd for $C_{53}H_{88}O_{10}Si_3$ [$(M+Na)^+$] 991.5577, found 991.5583.

*4.1.23. Alcohol **6**.* To a solution of ketone **30** (70.5 mg, 72.8 μmol) in CH_2Cl_2/MeOH (1:1, v/v, 2 mL) at 0 °C was added $TsOH\cdot H_2O$ (1.2 mg, 7.1 μmol). The resultant solution was stirred at room temperature for 3 h before it was quenched with Et_3N (2.0 μL, 14 μmol). The mixture was concentrated under reduced pressure. Purification of the residue by flash column chromatography (silica gel, 20–30% EtOAc/hexanes) gave a ketodiol (50.3 mg, 93%) as a colorless oil: $[\alpha]_D^{25}$ −37.0 (*c* 0.2, $CHCl_3$); IR (film) 2859, 1069, 826, 757 cm^{-1}; ^1H NMR (500 MHz, $CDCl_3$) δ 7.33–7.25 (m, 10H), 4.55 (d, *J*=11.5 Hz, 1H), 4.52 (d, *J*=11.5 Hz, 1H), 4.45 (d, *J*=12.5 Hz, 1H), 4.41 (d, *J*=12.5 Hz, 1H), 4.05 (dd, *J*=10.0, 5.0 Hz, 1H), 3.95 (ddd, *J*=8.5, 5.5, 4.5 Hz, 1H), 3.74–3.70 (m, 3H), 3.60–3.58 (m, 2H), 3.56–3.50 (m, 2H), 3.35 (d, *J*=9.0 Hz, 1H), 3.24 (dd, *J*=9.5, 8.5 Hz, 1H), 2.97 (dd, *J*=12.5, 4.0 Hz, 1H), 2.90 (dd, *J*=15.5, 5.0 Hz, 1H), 2.73 (br s, 1H), 2.51 (br s, 1H), 2.48 (dd, *J*=15.5, 6.0 Hz, 1H), 2.12–2.00 (m, 4H), 1.80 (m, 1H), 1.65 (ddd, *J*=12.0, 11.5, 11.5 Hz, 1H), 1.30 (s, 3H), 1.13 (s, 3H), 1.02 (s, 9H), 0.97 (s, 9H); ^{13}C NMR (125 MHz, $CDCl_3$) δ 211.9, 138.3, 137.7, 128.5 (2C), 128.4 (2C), 127.8, 127.7 (2C), 127.6 (2C), 127.6, 80.4, 80.3, 77.3, 76.6, 76.4, 76.3, 73.8, 73.5, 73.0, 71.4, 70.6, 69.8, 67.6, 66.5, 43.0, 41.3, 33.8,

33.0, 27.4 (3C), 27.0 (3C), 22.6, 22.2, 19.9, 10.1; HRMS (ESI) calcd for $C_{41}H_{60}O_{10}SiNa$ [$(M+Na)^+$] 763.3848, found 763.3838.

To a solution of the above ketodiol (43.6 mg, 45.0 μmol) in EtCN/Et_3SiH (4:1, v/v, 0.5 mL) at −78 °C was added TMSOTf (61 μL, 0.34 mmol). The resultant solution was stirred at −78 °C for 100 min before it was quenched with saturated aqueous $NaHCO_3$ solution. The mixture was extracted with EtOAc, and the organic layer was washed with brine, dried over Na_2SO_4, filtered, and concentrated under reduced pressure. Purification of the residue by flash column chromatography (silica gel, 10–30% EtOAc/hexanes) gave alcohol **6** (24.1 mg, 74%) as a solid: mp: 216–217 °C; $[\alpha]_D^{25}$ −41.1 (*c* 0.26, $CHCl_3$); IR (film) 2933, 2859, 1472, 1363, 1084, 827, 757 cm^{-1}; ^1H NMR (600 MHz, $CDCl_3$) δ 7.33–7.24 (m, 10H), 4.58 (d, *J*=11.7 Hz, 1H), 4.50 (d, *J*=12.0 Hz, 1H), 4.44 (d, *J*=12.0 Hz, 1H), 4.42 (d, *J*=12.0 Hz, 1H), 4.11 (dd, *J*=10.0, 4.8 Hz, 1H), 3.80–3.74 (m, 2H), 3.63 (ddd, *J*=9.3, 9.1, 2.7 Hz, 1H), 3.53 (dd, *J*=10.0, 4.9 Hz, 1H), 3.58–3.50 (m, 3H), 3.32 (ddd, *J*=11.7, 10.0, 4.5 Hz, 1H), 3.20–3.12 (m, 3H), 3.03 (dd, *J*=12.4, 3.8 Hz, 1H), 2.43 (br s, 1H), 2.36 (ddd, *J*=11.7, 4.4, 4.1 Hz, 1H), 2.21 (ddd, *J*=12.0, 4.4, 4.1 Hz, 1H), 2.18 (m, 1H), 2.08 (dd, *J*=11.7, 4.1 Hz, 1H), 1.71 (ddd, *J*=12.0, 11.7, 11.7 Hz, 1H), 1.64–1.59 (m, 1H), 1.57 (ddd, *J*=11.7, 11.7, 11.7 Hz, 1H), 1.49 (dd, *J*=11.7, 11.6 Hz, 1H), 1.27 (s, 3H), 1.21 (s, 3H), 1.02 (s, 9H), 0.98 (s, 9H); ^{13}C NMR (150 MHz, $CDCl_3$) δ 138.6, 137.8, 128.4 (2C), 128.3 (2C), 127.9 (2C), 127.8, 127.6 (2C), 127.4, 82.5, 79.7, 78.0, 77.25, 77.15, 77.12, 76.6, 73.5, 72.8, 72.4, 70.8, 70.0, 69.5, 67.7, 66.8, 43.0, 33.0, 32.5, 30.2, 27.4 (3C), 27.0 (3C), 22.6, 19.9, 16.1, 10.2; HRMS (ESI) calcd for $C_{41}H_{61}O_9Si$ [$(M+H)^+$] 725.4079, found 725.4108.

4.1.24. Acetate ***31***. To a solution of alcohol **6** (1.4 mg, 1.9 μmol) in pyridine (100 μL) was added Ac_2O (50 μL). The resultant solution was stirred at room temperature for 2 h before it was diluted with EtOAc. The mixture was washed successively with 1 M aqueous HCl solution, saturated aqueous $NaHCO_3$ solution, and brine. The organic layer was dried over Na_2SO_4, filtered, and concentrated under reduced pressure. Purification of the residue by flash column chromatography (silica gel, 20% EtOAc/hexanes) gave acetate **31** (1.4 mg, 95%) as a colorless oil: $[\alpha]_D^{22}$ −33.7 (*c* 0.5, $CHCl_3$); IR (film) 2939, 2858, 2360, 1750, 1457, 1221, 1084, 1056, 772, 669 cm^{-1}; ^1H NMR (600 MHz, $CDCl_3$) δ 7.34–7.24 (m, 10H), 4.98 (d, *J*=10.0 Hz, 1H), 4.59 (d, *J*=11.3 Hz, 1H), 4.50 (d, *J*=12.0 Hz, 1H), 4.43 (d, *J*=12.0 Hz, 1H), 4.39 (d, *J*=11.3 Hz, 1H), 3.97 (dd, *J*=10.0, 4.8 Hz, 1H), 3.76 (ddd, *J*=11.0, 11.0, 4.9 Hz, 1H), 3.73 (dd, *J*=10.0, 10.0 Hz, 1H), 3.63 (ddd, *J*=9.3, 9.3, 2.8 Hz, 1H), 3.57–3.49 (m, 3H), 3.38 (ddd, *J*=12.0, 9.7, 4.5 Hz, 1H), 3.23 (dd, *J*=12.4, 3.8 Hz, 1H), 3.19 (dd, *J*=10.0, 10.0 Hz, 1H), 3.17 (ddd, *J*=10.6, 10.6, 5.1 Hz, 1H), 2.96 (dd, *J*=12.7, 3.8 Hz, 1H), 2.26–2.15 (m, 3H), 2.10 (s, 3H), 2.08 (m, 1H) 1.69 (ddd, *J*=11.7, 11.6, 11.6 Hz, 1H), 1.64–1.46 (m, 4H), 1.27 (s, 3H), 1.19 (s, 3H), 1.00 (s, 9H), 0.96 (s, 9H); ^{13}C NMR (150 MHz, $CDCl_3$) δ 170.1, 138.7, 137.9, 128.4 (2C), 128.3 (2C), 127.9 (2C), 127.8, 127.6 (2C), 127.4, 81.0, 79.8, 78.3, 77.4, 77.2, 76.5,76.3, 73.4, 72.8, 72.4, 70.8, 69.9, 69.5, 67.6, 66.8, 43.2, 32.9, 32.6, 30.2, 27.4 (3C), 27.1 (3C), 22.6, 21.1, 19.9, 16.2, 11.0; HRMS (ESI) calcd for $C_{43}H_{63}O_{10}Si$ [$(M+H)^+$] 767.4185, found 767.4184.

4.1.25. Phenyltetrazolyl sulfone ***44***. To a solution of alcohol **45**[46] (340 mg, 1.68 mmol), 1-phenyl-1*H*-tetrazole-5-thiol (330 mg, 1.85 mmol), and PPh_3 (485 mg, 1.85 mmol) in THF (8.4 mL) at 0 °C was added DIAD (1.9 M solution in toluene, 0.97 mL, 1.8 mmol). The resultant solution was stirred at room temperature overnight and concentrated under reduced pressure. Purification by flash column chromatography (silica gel, 2–5% Et_2O/hexanes) gave a sulfide (540 mg, 88%), which was used in the next reaction without further purification.

To a solution of the above phenyltetrazolyl sulfide (540 mg, 1.48 mmol) in CH_2Cl_2 (8.0 mL) at 0 °C was added *m*-CPBA (639 mg, 3.70 mmol). The resultant solution was stirred at room temperature for 25 h before it was treated with 3 M aqueous NaOH solution (20 mL). The mixture was extracted with EtOAc, and the organic layer was washed with 3 M aqueous NaOH solution and brine, dried over Na_2SO_4, filtered, and concentrated under reduced pressure. Purification of the residue by column chromatography (silica gel, 0–20% EtOAc/hexanes) gave phenyltetrazolyl sulfone **44** (520 mg, 89%) as a colorless oil: $[\alpha]_D^{24}$ +4.2 (*c* 0.4, $CHCl_3$); IR (film) 3069, 2929, 2884, 2857, 1596, 1498, 1463, 1391, 1254, 1103, 1027, 841, 763, cm^{-1}; ^1H NMR (600 MHz, $CDCl_3$) δ 7.68–7.66 (m, 2H), 7.62–7.57 (m, 3H), 4.03 (dd, *J*=14.8, 4.8 Hz, 1H), 3.70 (dd, *J*=10.0, 4.8 Hz, 1H), 3.53 (dd, *J*=14.8, 7.9 Hz, 1H), 3.48 (dd, *J*=10.0, 5.5 Hz, 1H), 2.45 (m, 1H), 1.14 (d, *J*=6.9 Hz, 3H), 0.87 (s, 9H), 0.03 (s, 6H); ^{13}C NMR (150 MHz, $CDCl_3$) δ 154.0, 133.1, 131.4, 129.7 (2C), 125.1 (2C), 66.1, 58.6, 31.2, 25.8 (3C), 18.2, 16.8, −5.5, −5.6; HRMS (ESI) calcd for $C_{17}H_{28}N_4O_3SSiNa$ [$(M+Na)^+$] 419.1544, found 419.1524.

4.1.26. Trisubstituted olefin ***46***. To a solution of *i*-Pr_2NH (76 μL, 0.54 mmol) in THF (300 μL) at 0 °C was added *n*-BuLi (2.6 M solution in hexane, 188 μL, 0.490 mmol). After being stirred at 0 °C for 30 min, the solution was cooled to −78 °C. To the solution was added a solution of phenyltetrazolyl sulfone **44** (215 mg, 0.544 mmol) in THF (500 μL). The resultant solution was stirred at −78 °C for 30 min and then transferred to a suspension of methyl ketone **38** (14.8 mg, 54.4 μmol) and anhydrous $CeCl_3$ (134 mg, 0.545 mmol) in THF (800 μL) at −78 °C. The resultant mixture was gradually allowed to warm to 0 °C over 70 min before it was quenched with saturated aqueous NH_4Cl solution. The mixture was filtered through a pad of Celite, and the filtrate was extracted twice with EtOAc. The organic layer was washed with brine, dried over Na_2SO_4, filtered, and concentrated under reduced pressure. Purification of the residue by column chromatography (silica gel, 0–5% Et_2O/hexanes) gave olefin **45** (19.2 mg, 80%, an inseparable 1.6:1 mixture of (*E*)- and (*Z*)-isomers) as a colorless oil: IR (film) 2955, 2929, 2856, 1471, 1255, 1126, 1255, 836, 774, cm^{-1}; $[\alpha]_D^{22}$ +16.9 (*c* 1.4 $CHCl_3$); ^1H NMR (600 MHz, $CDCl_3$, (*E*)-isomer) δ 4.91 (d, *J*=8.6 Hz, 1H), 3.83 (m, 1H), 3.45 (dd, *J*=9.6, 3.8 Hz, 1H), 3.31–3.22 (m, 3H), 3.11 (dd, *J*=9.6, 9.6 Hz, 1H), 2.61–2.51 (m, 2H), 1.97 (m, 1H), 1.86 (dd, *J*=14.4, 9.6 Hz, 1H), 1.64 (s, 3H), 1.64–1.56 (m, 2H), 1.41 (m, 1H), 0.92 (d, *J*=6.5 Hz, 3H), 0.87 (s, 9H), 0.87 (s, 9H), 0.04 (s, 6H), 0.01 (s, 6H); ^1H NMR (600 MHz, $CDCl_3$, (*Z*)-isomer) δ 5.00 (d, *J*=9.7 Hz, 1H), 3.83 (m, 1H), 3.43 (dd, *J*=9.6, 5.8 Hz, 1H), 3.30 (dd, *J*=9.6, 7.6 Hz, 1H), 3.27–3.23 (m, 2H), 3.10 (ddd, *J*=11.0, 8.9, 2.0 Hz, 1H), 2.59 (m, 1H), 2.49 (d, *J*=13.7 Hz, 1H), 2.07 (dd, *J*=13.7, 10.3 Hz, 1H) 1.98 (m, 1H), 1.73 (s, 3H), 1.69–1.58 (m, 2H), 1.42 (m, 1H), 0.91 (d, *J*=6.8 Hz, 3H), 0.88 (s, 9H), 0.88 (s, 9H), 0.06 (s, 6H), 0.02 (s, 3H), 0.02 (s, 3H); ^{13}C NMR (150 MHz, $CDCl_3$, (*E*)-isomer) δ 133.3, 129.0, 81.6, 71.3, 68.1, 67.7, 42.4, 35.5, 33.7, 26.0 (3C), 25.8 (3C), 25.7, 18.4, 18.0, 17.5, 16.7, −3.9, −4.7, −5.3, −5.4; HRMS (ESI) calcd for $C_{24}H_{50}O_3Si_2Na$ [$(M+Na)^+$] 465.3191, found 465.3217.

4.1.27. Pivaloate ester ***47***. To a solution of alcohol **6** (10.8 mg, 14.9 μmol) and 2,6-lutidine (12 μL, 0.10 mmol) in CH_2Cl_2 (0.5 mL) at 0 °C was added TESOTf (17 μL, 75 μmol). The resultant solution was stirred at room temperature for 2 h before it was diluted with EtOAc. The mixture was washed with saturated aqueous NH_4Cl solution and brine. The organic layer was dried over Na_2SO_4, filtered, and concentrated under reduced pressure. Purification of the residue by column chromatography (silica gel, 0–10% EtOAc/hexanes) gave a TES ether (12.1 mg, 97%) as a white foam: $[\alpha]_D^{24}$ −36.7 (*c* 1.5, $CHCl_3$); IR (film) 2952, 2875, 1472, 1385, 1363, 1107, 1082, 1027, 827, 739 cm^{-1}; ^1H NMR (600 MHz, $CDCl_3$) δ 7.33–7.25 (m, 10H), 4.59 (d, *J*=11.3 Hz, 1H), 4.50 (d, *J*=12.0 Hz, 1H), 4.44 (d, *J*=12.0 Hz, 1H), 4.43 (d, *J*=11.3 Hz, 1H), 4.03 (dd, *J*=10.3, 4.8 Hz, 1H), 3.75–3.70 (m, 2H), 3.64 (ddd, *J*=9.3, 8.7, 2.8 Hz, 1H), 3.58 (m, 3H), 3.42 (d, *J*=9.3 Hz, 1H), 3.25 (ddd, *J*=9.6, 7.9, 5.9 Hz, 1H), 3.16 (ddd, *J*=12.2, 10.6, 5.2 Hz, 1H), 3.07 (dd, *J*=12.4, 3.8 Hz, 1H), 3.02 (dd, *J*=9.7,

9.6 Hz, 1H), 2.97 (dd, *J*=12.4, 3.5 Hz, 1H), 2.23–2.13 (m, 3H), 2.04 (dd, *J*=11.3, 4.4 Hz, 1H), 1.70 (ddd, *J*=12.0, 11.7, 11.7 Hz, 1H), 1.62 (m, 1H), 1.50 (ddd, *J*=12.0, 11.7, 11.6 Hz, 1H), 1.46 (dd, *J*=11.7, 11.6 Hz, 1H), 1.20 (s, 3H), 1.18 (s, 3H), 1.02 (s, 9H), 0.98 (s, 9H), 0.91 (t, *J*=7.9 Hz, 9H), 0.56 (q, *J*=7.9 Hz, 6H); ^{13}C NMR (150 MHz, $CDCl_3$) δ 138.7, 138.0, 128.4 (2C), 128.3 (2C), 127.9 (2C), 127.7, 127.6 (2C), 127.4, 83.4, 79.5, 78.3, 77.9, 77.43, 77.37, 73.8, 72.8, 72.5, 71.0, 69.7, 69.5, 67.7, 66.8, 60.4, 43.3, 33.2, 32.6, 30.1, 27.5 (3C), 27.1 (3C), 22.6, 19.9, 16.2, 10.3, 6.8 (3C), 5.1 (3C); HRMS (ESI) calcd for $C_{47}H_{74}O_9Si_2Na$ [(M+Na$^+$)] 861.4764, found 861.4781.

To a solution of the above TES ether (16.3 mg, 19.4 μmol) in EtOAc (0.5 mL) was added 20 wt% $Pd(OH)_2/C$ (1.6 mg). The resultant mixture was stirred at room temperature under an atmosphere of H_2 (balloon) for 27 h before it was filtered through a pad of Celite. The filtrate was concentrated under reduced pressure, and the residue was purified by flash column chromatography (silica gel, 30–100% EtOAc/hexanes) to give a diol (12.4 mg, 97%) as a colorless oil: $[\alpha]_D^{22}$ −14.8 (*c* 0.74, $CHCl_3$); IR (film) 3363, 2952, 2876, 1472, 1386, 1106, 1080, 1058, 1010, 826, 759 cm^{-1}; ^{1}H NMR (600 MHz, $CDCl_3$) δ 4.02 (dd, *J*=10.0, 4.8 Hz, 1H), 3.82–3.69 (m, 4H), 3.57 (m, 1H), 3.53 (ddd, *J*=9.6, 9.6, 4.9 Hz, 1H), 3.44 (m, 1H), 3.42 (d, *J*=9.7 Hz, 1H), 3.26 (ddd, *J*=12.0, 9.6, 4.1 Hz, 1H), 3.07 (ddd, *J*=11.7, 3.4, 2.4 Hz, 1H), 3.07 (d, *J*=11.7 Hz, 1H), 3.04 (d, *J*=9.6 Hz, 1H), 2.68 (br s, 1H), 2.18 (ddd, *J*=12.0, 4.4, 4.4 Hz, 1H), 2.15 (ddd, *J*=12.0, 4.1, 4.1 Hz, 1H), 2.09 (dd, *J*=11.3, 4.4 Hz, 1H), 1.95 (m, 1H), 1.76 (dddd, *J*=14.8, 7.2, 6.9, 3.4 Hz, 1H), 1.69 (ddd, *J*=11.7, 11.7, 11.6 Hz, 1H), 1.58 (ddd, *J*=12.0, 12.0, 11.3 Hz, 1H), 1.52 (dd, *J*=11.6, 11.3 Hz, 1H), 1.24 (s, 3H), 1.19 (s, 3H), 1.01 (s, 9H), 0.97 (s, 9H), 0.90 (t, *J*=7.9 Hz, 9H), 0.54 (q, *J*=7.9 Hz, 6H); ^{13}C NMR (150 MHz, $CDCl_3$) δ 83.5, 79.3, 78.4, 77.8, 77.4, 76.8, 74.8, 73.8, 73.1, 70.6, 69.7, 67.7, 61.1, 43.2, 35.4, 33.2 (2C), 27.5 (3C), 27.1 (3C), 22.6, 20.0, 16.2, 10.3, 6.8 (3C), 4.9 (3C); HMRS (ESI) calcd for $C_{33}H_{63}O_9Si_2$ [(M+H)$^+$] 659.4005, found 659.3996.

To a solution of the above diol (22.7 mg, 34.5 μmol) in pyridine (0.5 mL) at 0 °C was added PivCl (4.5 μL, 36 μmol). The resultant solution was stirred at 0 °C for 1 h before it was treated with H_2O and EtOAc. The mixture was stirred at room temperature for 1 h and then extracted with EtOAc. The organic layer was washed with brine, dried over Na_2SO_4, filtered, and concentrated under reduced pressure. Purification of the residue by column chromatography (silica gel, 10–20% EtOAc/hexanes) gave pivaloate ester **47** (21.8 mg, 85%) as a colorless oil: $[\alpha]_D^{24}$ −28.2 (*c* 0.16, $CHCl_3$); IR (film) 2955, 2876, 1729, 1463, 1385, 1287, 1080, 826 cm^{-1}; ^{1}H NMR (600 MHz, $CDCl_3$) δ 4.19 (ddd, *J*=10.6, 6.9, 5.2 Hz, 1H), 4.13 (dd, *J*=7.9, 6.2 Hz, 1H), 4.02 (dd, *J*=10.0, 4.8 Hz, 1H), 3.72 (m, 1H), 3.71 (dd, *J*=10.3, 10.0 Hz, 1H), 3.54 (ddd, *J*=10.0, 9.6, 4.9 Hz, 1H), 3.45 (ddd, *J*=9.0, 9.0, 3.1 Hz, 1H), 3.42 (d, *J*=9.3 Hz, 1H), 3.39 (ddd, *J*=11.0, 10.7, 5.2 Hz, 1H), 3.26 (ddd, *J*=12.0, 11.7, 4.4 Hz, 1H), 3.07 (dd, *J*=12.4, 3.4 Hz, 1H), 3.06 (m, 2H), 2.18 (ddd, *J*=12.0, 4.5, 4.1 Hz, 1H), 2.14 (ddd, *J*=12.0, 5.0, 4.4 Hz, 1H), 2.13–2.06 (m, 2H), 1.73–1.65 (m, 2H), 1.56 (ddd, *J*=11.7, 11.7, 11.6 Hz, 1H), 1.49 (dd, *J*=11.7, 11.7 Hz, 1H), 1.22 (br s, 1H), 1.19 (s, 3H), 1.19 (s, 3H), 1.17 (s, 9H), 1.00 (s, 9H), 0.97 (s, 9H), 0.89 (t, *J*=7.9 Hz, 9H), 0.54 (q, *J*=7.9 Hz, 6H); ^{13}C NMR (150 MHz, $CDCl_3$) δ 178.6, 83.4, 79.4, 78.4, 77.9, 77.4, 77.0, 73.8, 72.8, 71.0, 70.8, 69.7, 67.7, 61.3, 43.1, 38.7, 33.6, 33.2, 31.6, 27.5 (3C), 27.2 (3C), 27.1 (3C), 22.6, 19.9, 16.0, 10.3, 6.8 (3C), 4.9 (3C); HRMS (ESI) calcd for $C_{38}H_{70}O_{10}Si_2$ [(M+Na)$^+$] 765.4400, found 765.4394.

*4.1.28. Primary alcohol **48**.* To a solution of alcohol **47** (39.8 mg, 53.6 μmol) in CH_2Cl_2 (0.5 mL) was added Dess–Martin periodinane (68.0 mg, 0.161 mmol), and the resultant solution was stirred at room temperature for 50 min before it was quenched with a 1:1 mixture of saturated aqueous $NaHCO_3$ solution and saturated aqueous $Na_2S_2O_3$ solution (2 mL). The mixture was extracted with EtOAc, and the organic layer was washed with brine, dried over Na_2SO_4, filtered, and concentrated under reduced pressure. Purification of the residue by flash column chromatography (silica gel, 30% EtOAc/hexanes) gave a ketone (31.6 mg, 80%) as a colorless oil: $[\alpha]_D^{24}$ −2.9 (*c* 0.27, $CHCl_3$); IR (film) 3444, 2957, 2875, 2070, 1726, 1633, 1472, 1136, 1083, 826 cm^{-1}; ^{1}H NMR (600 MHz, $CDCl_3$) δ 4.16–4.10 (m, 2H), 4.07 (dd, *J*=7.2, 4.1 Hz, 1H), 4.02 (dd, *J*=10.0, 4.8 Hz, 1H), 3.73 (ddd, *J*=10.7, 9.6, 4.8 Hz, 1H), 3.71 (dd, *J*=10.0, 10.0 Hz, 1H), 3.54 (ddd, *J*=9.6, 9.6, 4.9 Hz, 1H), 3.47 (dd, *J*=12.7, 5.5 Hz, 1H), 3.43 (d, *J*=9.3 Hz, 1H) 3.29 (ddd, *J*=12.0, 9.7, 4.1 Hz, 1H), 3.07 (d, *J*=9.2 Hz, 1H), 3.00 (dd, *J*=14.0, 4.0 Hz, 1H), 2.75 (dd, *J*=17.2, 5.5 Hz, 1H), 2.42 (dd, *J*=17.2, 12.7 Hz, 1H), 2.22–2.13 (m, 3H), 1.95 (ddd, *J*=14.1, 13.7, 6.5 Hz, 1H), 1.71 (ddd, *J*=11.7, 11.7, 11.6 Hz, 1H), 1.65 (dd, *J*=12.0, 11.7 Hz, 1H), 1.29 (s, 3H), 1.20 (s, 3H), 1.15 (s, 9H), 1.01 (s, 9H), 0.97 (s, 9H), 0.88 (t, *J*=7.9 Hz, 9H), 0.52 (q, *J*=7.9 Hz, 6H); ^{13}C NMR (150 MHz, $CDCl_3$) δ 207.1, 178.5, 83.2, 78.5, 78.0, 77.8, 77.4, 76.6, 74.4, 73.8, 72.8, 69.8, 67.7, 60.6, 42.9, 41.0, 38.8, 33.3, 30.2, 27.6 (3C), 27.24 (3C), 27.18 (3C), 22.7, 20.1, 15.6, 10.4, 6.8 (3C), 5.0 (3C); HRMS (ESI) calcd for $C_{38}H_{68}O_{10}Si_2Na$ [(M+Na$^+$)] 763.4243, found 763.4235.

To a suspension of Ph_3PCH_3Br (56.6 mg, 0.158 mmol) in THF (300 μL) at 0 °C was added NaHMDS (1.0 M solution in THF, 153 μL, 0.153 mmol), and the resultant mixture was stirred at 0 °C for 30 min. To this suspension was added a solution of the above ketone (39.1 mg, 0.158 mmol) in THF (230 μL). The resultant solution was stirred at 0 °C for 1 h before it was quenched with saturated aqueous NH_4Cl solution. The mixture was extracted twice with EtOAc, and the organic layer was washed with brine, dried over Na_2SO_4, filtered, and concentrated under reduced pressure. Purification of the residue by column chromatography (silica gel, 0–10% EtOAc/hexanes) gave an *exo*-olefin (32.5 mg, 83%) as a colorless oil: $[\alpha]_D^{25}$ −23.6 (*c* 0.26, $CHCl_3$); IR (film) 2955, 2360, 1731, 1474, 1161, 1082, 827 cm^{-1}; ^{1}H NMR (600 MHz, $CDCl_3$) δ 4.85 (s, 1H), 4.80 (s, 1H), 4.21–4.14 (m, 3H), 4.02 (dd, *J*=10.0, 4.8 Hz, 1H), 3.72 (m, 1H), 3.71 (dd, *J*=10.0, 10.0 Hz, 1H), 3.53 (ddd, *J*=9.7, 9.6, 4.9 Hz, 1H), 3.42 (d, *J*=9.3 Hz, 1H), 3.26 (ddd, *J*=12.1, 9.6, 4.1 Hz, 1H), 3.09 (dd, *J*=10.7, 4.4 Hz, 1H), 3.07 (dd, *J*=10.3, 4.4 Hz, 1H), 3.04 (dd, *J*=9.7, 9.7 Hz, 1H), 2.43 (dd, *J*=13.7, 4.5 Hz, 1H), 2.30 (dd, *J*=13.7, 13.1 Hz, 1H), 2.18 (ddd, *J*=15.8, 4.1, 4.1 Hz, 1H), 2.08 (m, 1H), 2.08 (dd, *J*=13.0, 4.5 Hz, 1H), 1.80 (ddd, *J*=17.2, 10.6, 5.8 Hz, 1H), 1.70 (ddd, *J*=11.7, 11.7, 11.6 Hz, 1H), 1.51 (dd, *J*=11.7, 11.3 Hz, 1H), 1.23 (s, 3H), 1.19 (s, 3H), 1.17 (s, 9H), 1.01 (s, 9H), 0.97 (s, 9H), 0.91 (t, *J*=7.9 Hz, 9H), 0.55 (q, *J*=7.9 Hz, 6H); ^{13}C NMR (150 MHz, $CDCl_3$) δ 178.5, 144.9, 109.9, 83.2, 81.9, 78.3, 77.9, 77.4, 77.0, 73.8, 73.0, 69.7, 67.7, 67.1, 61.3, 43.3, 38.7, 34.7, 33.2, 30.8, 27.5 (3C), 27.2 (3C), 27.1 (3C), 22.6, 20.0, 15.8, 10.3, 6.8 (3C), 4.9 (3C); HRMS (ESI) calcd for $C_{39}H_{70}O_9Si_2Na$ [(M+Na)$^+$] 761.4451, found 761.4468.

To a solution of the above *exo*-olefin (22.0 mg, 29.8 μmol) in CH_2Cl_2 (0.5 mL) at −78 °C was added DIBALH (1.04 M solution in hexane, 143 μL, 0.149 mmol). The resultant solution was stirred at −78 °C for 2 h before it was quenched with MeOH. The mixture was diluted with saturated aqueous potassium sodium tartrate solution and EtOAc, and stirred at room temperature overnight. The layers were separated, and the organic layer was washed with brine, dried over Na_2SO_4, filtered, and concentrated under reduced pressure. Purification of the residue by column chromatography (silica gel, 10–30% EtOAc/hexanes) gave alcohol **48** (18.7 mg, 96%) as a colorless oil: $[\alpha]_D^{25}$ −22.7 (*c* 0.67, $CHCl_3$); IR (film) 3565, 2950, 2875, 2351, 1472, 1136, 1081, 1062, 826 cm^{-1}; ^{1}H NMR (600 MHz, $CDCl_3$) δ 4.86 (s, 1H), 4.79 (s, 1H), 4.32 (d, *J*=7.9 Hz, 1H), 4.02 (dd, *J*=10.3, 4.8 Hz, 1H), 3.81–3.68 (m, 3H), 3.70 (dd, *J*=10.3, 10.0 Hz, 1H), 3.54 (ddd, *J*=9.8, 9.7, 4.8 Hz, 1H), 3.43 (d, *J*=9.3 Hz, 1H), 3.27 (ddd, *J*=11.6, 9.7, 4.1 Hz, 1H), 3.12 (dd, *J*=12.7, 4.5 Hz, 1H), 3.07 (dd, *J*=12.4, 3.8 Hz, 1H), 3.05 (dd, *J*=9.6, 9.3 Hz, 1H), 2.76 (br s, 1H), 2.43 (dd, *J*=13.4, 4.5 Hz, 1H), 2.30 (dd, *J*=13.1, 12.7 Hz, 1H), 2.18 (ddd, *J*=9.2, 4.4, 4.1 Hz, 1H), 2.10 (dd, *J*=11.3, 4.4 Hz, 1H), 1.97 (m, 1H), 1.86 (dddd, *J*=9.3, 9.1, 7.9, 4.5 Hz, 1H), 1.69 (ddd, *J*=11.7, 11.7, 11.6 Hz, 1H), 1.56 (dd, *J*=11.7, 11.3 Hz, 1H), 1.29 (s, 3H), 1.19 (s, 3H), 1.01 (s, 9H), 0.97 (s, 9H), 0.91 (t, *J*=7.9 Hz, 9H), 0.55 (q, *J*=7.9 Hz, 6H); ^{13}C NMR

(150 MHz, $CDCl_3$) δ 144.4, 110.5, 83.2, 81.4, 78.3, 77.8, 77.4, 76.8, 73.8, 73.5, 71.7, 69.7, 67.7, 61.4, 43.4, 34.4, 33.6, 33.2, 27.5 (3C), 27.1 (3C), 22.6, 20.0, 16.0. 10.3, 6.8 (3C), 4.9 (3C); HRMS (ESI) calcd for $C_{34}H_{63}O_8Si_2$ [$(M+H)^+$] 655.4056, found 655.4069.

4.1.29. Methyl ketone ***36***. To a solution of alcohol **48** (9.2 mg, 14 μmol) in CH_2Cl_2 (0.5 mL) was added Dess–Martin periodinane (17.9 mg, 42.3 μmol). The resultant mixture was stirred at room temperature for 25 min before it was quenched with a 1:1 mixture of saturated aqueous $NaHCO_3$ solution and saturated aqueous $Na_2S_2O_3$ solution (2 mL). The mixture was extracted with EtOAc, and the organic layer was washed with brine, dried over Na_2SO_4, filtered, and concentrated under reduced pressure. The crude aldehyde thus obtained was used in the next reaction without further purification.

To a solution of the above crude aldehyde in Et_2O (0.5 mL) at −78 °C was added MeMgBr (3.0 M solution in Et_2O, 47 μL, 0.14 mmol), and the resultant solution was stirred at −78 °C for 15 min before it was quenched with saturated aqueous NH_4Cl solution. The mixture was extracted twice with EtOAc, and the organic layer was washed with brine, dried over Na_2SO_4, filtered, and concentrated under reduced pressure. The residue was filtered through a short pad of silica gel to give a crude alcohol, which was used in the next reaction without further purification.

To a solution of the above alcohol (9.2 mg, 14 μmol) in CH_2Cl_2 (0.5 mL) was added Dess–Martin periodinane (12.4 mg, 29.2 μmol). The resultant solution was stirred at room temperature for 25 min before it was quenched with a 1:1 mixture of saturated aqueous $NaHCO_3$ solution and saturated aqueous $Na_2S_2O_3$ solution (2 mL). The mixture was extracted with EtOAc, and the organic layer was washed with brine, dried over Na_2SO_4, filtered, and concentrated under reduced pressure. Purification of the residue by column chromatography (silica gel, 0–15% EtOAc/hexanes) gave methyl ketone **36** (4.8 mg, 51% for the three steps) as a colorless oil: $[\alpha]_D^{23}$ −12.4 (*c* 0.48, $CHCl_3$); IR (film) 2951, 1721, 1471, 1083, 1011, 826, 744 cm^{-1}; ^1H NMR (600 MHz, C_6D_6) δ 4.66 (s, 1H), 4.57 (dd, *J*=7.6, 4.1 Hz, 1H), 4.45 (s, 1H), 4.26 (dd, *J*=10.0, 4.9 Hz, 1H), 3.89 (dd, *J*=10.0, 10.0 Hz, 1H), 3.79 (ddd, *J*=10.7, 10.1, 4.8 Hz, 1H), 3.73 (ddd, *J*=9.6, 9.6, 4.8 Hz, 1H), 3.50 (d, *J*=9.3 Hz, 1H), 3.14 (ddd, *J*=11.7, 9.6, 4.1 Hz, 1H), 3.07 (dd, *J*=9.2, 9.2 Hz, 1H), 3.05 (dd, *J*=12.4, 4.4 Hz, 1H), 2.78 (dd, *J*=12.4, 3.8 Hz, 1H), 2.51 (dd, *J*=13.0, 4.4 Hz, 1H), 2.44 (dd, *J*=15.5, 8.3 Hz, 1H), 2.32 (dd, *J*=13.0 Hz, 1H), 2.27 (dd, *J*=15.5, 4.1 Hz, 1H), 2.24 (ddd, *J*=11.7, 4.5, 4.1 Hz, 1H), 2.14 (dd, *J*=11.3, 4.1 Hz, 1H), 1.84 (ddd, *J*=12.0, 11.7, 11.3 Hz, 1H), 1.75 (s, 3H), 1.60 (dd, *J* = 11.7 Hz, 11.3 Hz, 1H), 1.28 (s, 3H), 1.18 (s, 3H), 1.14 (s, 9H), 1.12 (t, *J*=7.9 Hz, 9H), 1.08 (s, 9H), 0.78 (q, *J*=7.9 Hz, 6H); ^{13}C NMR (150 MHz, C_6D_6) δ 204.5, 145.1, 109.6, 83.8, 82.2, 78.5, 78.4, 77.9, 77.1, 74.4, 73.3, 70.3, 68.2, 68.0, 45.8, 43.8, 35.1, 33.7, 30.6, 27.7 (3C), 27.3 (3C), 22.8, 20.1, 15.7, 10.5, 7.2 (3C), 5.5 (3C); HRMS (ESI) calcd for $C_{35}H_{62}O_8Si_2Na$ [$(M+Na)^+$] 689.3875, found 689.3885.

4.1.30. Trisubstituted olefin ***5***. To a solution of *i*-Pr_2NH (25 μL, 0.18 mmol) in THF (300 μL) at 0 °C was added *n*-BuLi (2.6 M in hexane, 62 μL, 0.16 mmol). After being stirred at 0 °C for 30 min, the solution was cooled to −78 °C. To the solution was added a solution of phenyltetrazolyl sulfone **44** (71.3 mg, 0.180 mmol) in THF (300 μL), and the resultant solution was stirred at −78 °C for 30 min. This cold solution was then transferred to a suspension of methyl ketone **36** (4.0 mg, 6.0 μmol) and anhydrous $CeCl_3$ (44.3 mg, 0.180 mmol) in THF (600 μL) at −78 °C. The reaction mixture was gradually allowed to warm to 0 °C over 2 h before it was quenched with saturated aqueous NH_4Cl solution. The mixture was filtered through a pad of Celite, and the filtrate was extracted twice with EtOAc. The organic layer was washed with brine, dried over Na_2SO_4, filtered, and concentrated under reduced pressure. Purification of the residue by column chromatography (silica gel, 0–5% Et_2O/hexanes) gave (*E*)-olefin **5** (2.9 mg, 58%) and (*Z*)-olefin **49** (0.9 mg, 18%) as colorless oils, respectively. Data for (*E*)-olefin **5**: $[\alpha]_D^{24}$ −23.1 (*c* 0.3, $CHCl_3$); IR (film) 3441, 2954, 1645, 1471, 1083, 835 cm^{-1}; ^1H NMR (600 MHz, C_6D_6) δ 5.09 (d, *J*=8.2 Hz, 1H), 4.82 (s, 1H), 4.77 (s, 1H), 4.26 (dd, *J*=10.0, 4.8 Hz, 1H), 4.14 (dd, *J*=8.6, 3.4 Hz, 1H), 3.90 (dd, *J*=10.0, 10.0 Hz, 1H), 3.79 (ddd, *J*=11.0, 9.6, 4.4 Hz, 1H), 3.73 (ddd, *J*=10.0, 9.6, 4.8 Hz, 1H), 3.56 (d, *J*=9.3 Hz, 1H), 3.51 (dd, *J*=9.6, 5.9 Hz, 1H), 3.39 (dd, *J*=9.6, 7.2 Hz, 1H), 3.21 (ddd, *J*=11.6, 9.6, 4.4 Hz, 1H), 3.14 (dd, *J*=12.7, 4.5 Hz, 1H), 3.09 (dd, *J*=9.6, 9.3 Hz, 1H), 2.82 (dd, *J*=12.4, 3.8 Hz, 1H), 2.68 (m, 1H), 2.58 (dd, *J*=13.1, 4.5 Hz, 1H), 2.45 (dd, *J*=13.4, 3.4 Hz, 1H), 2.37 (dd, *J*=13.1, 12.7 Hz, 1H), 2.32 (dd, *J*=13.4, 8.6 Hz, 1H), 2.25 (ddd, *J*=11.7. 4.4, 3.8 Hz, 1H), 2.18 (dd, *J*=11.4, 4.4 Hz, 1H), 1.85 (ddd, *J*=12.4, 11.7, 11.0 Hz, 1H), 1.69–1.65 (m, 4H), 1.27 (s, 3H), 1.21 (s, 3H), 1.14 (s, 9H), 1.13 (t, *J*=7.9 Hz, 9H), 1.08 (s, 9H), 1.05 (d, *J*=6.9 Hz, 3H), 0.99 (s, 9H), 0.78 (q, *J*=7.9 Hz, 6H), 0.07 (s, 3H), 0.07 (s, 3H); ^{13}C NMR (150 MHz, C_6D_6) δ 146.0, 132.8, 130.1, 110.0, 83.8, 82.3, 78.5, 78.4, 77.9, 77.2, 74.4, 72.9, 70.3, 69.4, 68.4, 68.2, 43.9, 42.5, 35.9, 35.5, 33.8, 27.7 (3C), 27.3 (3C), 26.1 (3C), 22.8, 20.1, 18.5, 17.7, 16.9, 15.9, 10.5, 7.2 (3C), 5.5 (3C), −5.1, −5.2; HRMS (ESI) calcd for $C_{45}H_{84}O_8Si_3Na$ [$(M+Na)^+$] 859.5366, found 859.5388. Data for (*Z*)-olefin **49**: $[\alpha]_D^{24}$ −12.4 (*c* 0.1, $CHCl_3$); IR (film) 2951, 2361, 1698, 1507, 1220, 1082, 841, 773 cm^{-1}; ^1H NMR (600 MHz, C_6D_6) δ 5.12 (d, *J*=9.6 Hz, 1H), 4.78 (s, 1H), 4.74 (s, 1H), 4.26 (dd, *J*=10.3, 4.8 Hz, 1H), 4.11 (d, *J*=8.9 Hz, 1H), 3.89 (dd, *J*=10.0, 10.0 Hz, 1H), 3.78 (ddd, *J*=9.6, 9.3, 5.2 Hz, 1H), 3.73 (dd, *J*=9.7, 4.5 Hz, 1H), 3.69 (dd, *J*=9.7, 5.2 Hz, 1H), 3.56 (d, *J*=8.9 Hz, 1H), 3.35 (dd, *J*=9.3, 7.9 Hz, 1H), 3.18 (ddd, *J*=11.7, 9.6, 4.1 Hz, 1H), 3.14–3.10 (m, 2H), 2.79 (dd, *J*=12.4, 3.4 Hz, 1H), 2.75 (m, 1H), 2.57 (dd, *J*=13.1, 4.5 Hz, 1H), 2.45 (dd, *J*=13.7, 10.0 Hz, 1H), 2.39–2.34 (m, 2H), 2.22 (ddd, *J*=12.8, 4.4, 4.4 Hz, 1H), 2.18 (dd, *J*=11.3. 4.1 Hz, 1H), 1.84 (ddd, *J*=11.7, 11.7, 11.3 Hz, 1H), 1.77 (d, *J*=1.4 Hz, 3H), 1.70 (dd, *J*=12.1, 11.6 Hz, 1H), 1.31 (s, 3H), 1.18 (s, 3H), 1.14 (s, 9H), 1.13 (d, *J*=6.5 Hz, 3H), 1.12 (t, *J*=7.9 Hz, 9H), 1.08 (s, 9H), 1.00 (s, 9H), 0.78 (q, *J*=7.9 Hz, 6H), 0.11 (s, 3H), 0.11 (s, 3H); ^{13}C NMR (150 MHz, C_6D_6) δ 146.2, 132.8, 130.3, 109.9, 83.9, 82.3, 78.5, 78.3, 77.8, 77.2, 74.4, 72.9, 70.3, 69.0, 68.3, 68.2, 44.0, 35.7, 35.3, 34.9, 33.7, 27.7 (3C), 27.3 (3C), 26.2 (3C), 24.3, 22.9, 20.1, 18.6, 17.9, 15.8, 10.4, 7.2 (3C), 5.5 (3C), −5.0, −5.3; HRMS (ESI) calcd for $C_{45}H_{84}O_8Si_3Na$ [$(M+Na)^+$] 859.5366, found 859.5392.

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Supplementary data

Supplementary data associated with this article can be found, in the online version, at doi:10.1016/j.tet.2011.05.082.

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