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Ring Opening of Alkynyl Sugars by Nicholas Reaction--Application to Enantioselective Synthesis of Oxepane Subunits of Marine trans-fused Polyether Toxins[1]

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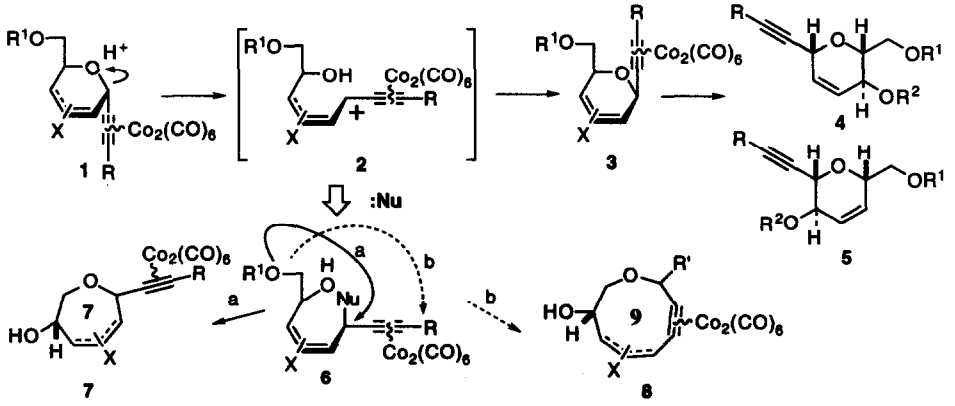
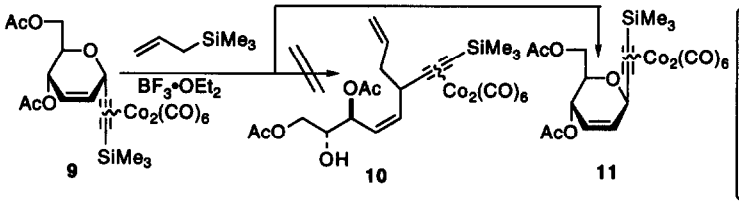
Abstract: Pyranose ring of cobalt-complexed alkynyl sugars was cleaved by Nicholas reaction. The reaction of **22** was diastereoselective and this selectivity was presumably due to steric interaction between cobalt acetylene moiety and *tert*-butyldiphenylsilyloxy function. The resulting linear cobalt complex **23** was modified and converted into dehydrooxepane unit of ciguatoxin by Nicholas reaction.

Sugars are frequently fixed in the tautomeric forms[2] and used as enantiopure building blocks for syntheses of naturally occurring compounds.[3] In order to expand synthetic utility of sugars, we have recently reported a simple synthetic method of β-alkynyl glycosides (**4** or **5** in Scheme 1) by epimerizing α-alkynyl glycosides[4] through dicobalt hexacarbonyl complexes (**1** and **3**).[5] During investigation of the epimerization, we wonder if the reaction of the intermediate cation **2** with a nucleophile could give the ring opening products **6** which would be attractive acyclic building blocks because of those asymmetric carbons, existence of reactive propargyl positions, and easily manipulative cobalt acetylene moiety. For example such acyclic cobalt complexes could be easily converted to several kinds of ether rings (**7** or **8**) by intramolecular Nicholas reaction.[6] On the basis of this idea, we have recently reported a short communication[7] about a new conversion method of a pyranose ring to 7-membered ring. In this article, we detail this methodology and its stereochemistry.



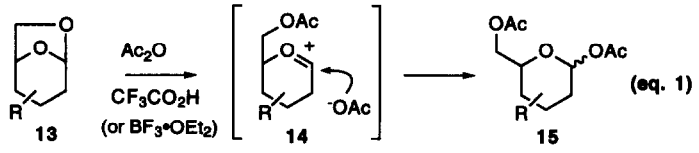
Scheme 1

Ring opening condition The reaction of propargyl cation stabilized by cobalt-complexed acetylene moiety with nucleophile has been developed by Nicholas and co-workers.[6] We applied their reaction condition, the treatment with excess allylsilane under Lewis acidic condition, to our cobalt-complexed alkynyl sugar **9**[5] to expect the corresponding ring opening product (**10** in Scheme 2). However, the only product obtained was β-epimer **11**, which shows that the reaction of the cation **12** with intramolecular borate is more favorable than that with intermolecular nucleophile (allylsilane) as illustrated in Fig 1.



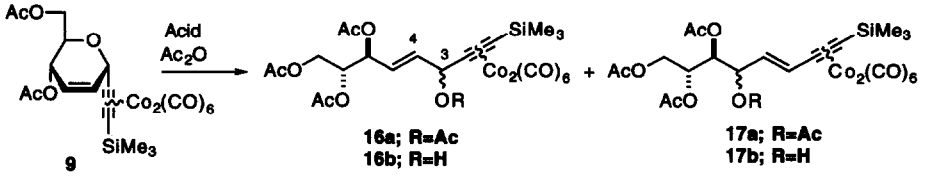
Scheme 2 **Fig 1**

In our laboratory, 1,6-anhydro sugar **13** derived from levoglucosenone was treated with acids such as trifluoroacetic acid or BF_3•OEt_2 in acetic anhydride to be cleaved its 1,6-anhydro bridge.[8] In this reaction, since the C-6 oxygen atom in **13** was protected in its acetate form, 1,6-anhydro ring was cleaved exclusively to afford **15** (eq. 1).



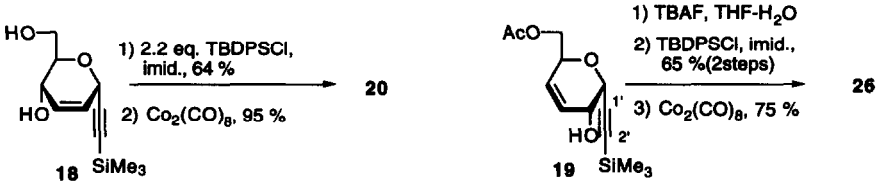
This reaction condition was applied to **9** with investigating various acids, temperatures and workup methods as summarized in Table 1.

Table 1. Ring opening reaction of **9** with various acids and acetic anhydride



entry	acid (equiv.)	workup	temp (°C)	products (% yield) 16a	16b	17a	17b
1	CF_3CO_2H (13)	$NaHCO_3$aq	0~rt	10			
2	BF_3•OEt_2 (1)	$NaHCO_3$aq	0	complex mixture			
3	0.1 M TfOH (3) in ClF_2CCCl_2F	$NaHCO_3$aq	-40	11	11	39	9
4	1.0 M TfOH (3) in ClF_2CCCl_2F	$NaHCO_3$aq	-40	16	27	18	24
5	TfOH (3)	Et_3N	-40	86			
6	TfOH (1)	Et_3N	-20	95			

Although the reaction with BF_3•OEt_2 and Ac_2O (entry 2) resulted in a complex mixture containing decomplexed product of **9**, the reaction with CF_3CO_2H (entry 1) afforded ring opening product **17a** with shifting the double bond in low yield. On the other hand, when 0.1 M solution of trifluoromethanesulfonic acid (TfOH) in ClF_2CCCl_2F was used, ring opening products were major as a mixture of **16a**, **16b**, **17a**, and **17b** (entry 3). The higher concentration of acid resulted in the higher ratio of the products **16** (entry 4). Use of TfOH without dilution and changing aqueous workup to treatment with triethylamine (Et_3N) to accelerate the addition of acetic acid were effective to afford only **16a** as a 1:1 diasteromeric mixture at 3-position (entry 5). When 1 equiv. of TfOH was used at -20 °C and the reaction was quenched with Et_3N, the best yield of **16a** (95 %, entry 6) was obtained. The isomerization of *cis*-olefin to *trans*[9] demonstrates that not only cobalt moiety but also π-electrons of the double bond take part in stabilizing intermediate cation. In order to clarify the scope and limitation of the reaction, other substrates were examined. Cobalt complexes **20** and **26** were prepared as illustrated in Scheme 3. Treatment of diol **18**[5] with 2.2 equiv. of *tert*-butyldiphenylchlorosilane (TBDPSCl) provided the bis-silyl ether in 64 % yield which was converted into the cobalt complex **20** using $Co_2(CO)_8$ in 95 % yield. Silylacetylene **19**[5] was treated with tetrabutylammonium fluoride (TBAF) in aqueous THF solution to afford the ethynyl derivative whose hydroxyl function was protected with TBDPSCl to give the silyl ether in 65 % overall yield. The ether was reacted with $Co_2(CO)_8$ to afford the cobalt complex **26** in 75 % yield.



Scheme 3

Cobalt complexes **20**, **22**,[5] **24**,[5] and **26** were reacted under similar condition to afford the corresponding ring opening products in good yield as summarized in Table 2. In order to confirm the structures, all linear cobalt complexes (**16a**, **21**, **25**, and **27**) except **23**[10] were decomplexed with iodine in good yield to give acyclic acetylene derivatives (**28**, **29**, **30**, and **31**), respectively. Cobalt complex **20** was also reacted easily to afford **21** (entry 2) having *trans*-olefin[11] in the same way as **16a**. The complexes **22**, **24**, and **26** which have different unsaturated ($\Delta_{3,4}$) system required stronger reaction condition since they have no π-electrons stabilizing the intermediate cation. Treatment of these complexes with more TfOH (3.0 equiv. ~ 5.5 equiv.) at -40 °C afforded the corresponding acyclic cobalt complexes (**23** in 84 % yield, **25** in 54 % yield, and **27** in 71 % yield). Although all products were diasteromeric mixture at 3-position, the selectivity of **23** was pretty good, 94 : 6 (entry 3). Since the selectivities of **25** and **27**, which have smaller substituent in R or R', were lower (53 : 47 and 88 : 12, respectively) than that of **23**, the interaction between C-4 and C-1 substituents (R and R') is presumably responsible for this selectivity. This will be discussed later.

Table 2. Ring opening of cobalt-complexed alkynyl sugars and corresponding acetylene derivatives

entry	substrates	TfOH(equiv.)	temp.(°C)	products (% yield, ds ratio#1)	acetylene (% yield#2)
1	**9; R=Ac**	1.0	-20	**16a; 95 % (50 : 50)**	**28 (90 %)**
2	**20; R=TBDPS**	1.0	0	**21; 70 % (70 : 30)**	**29 (96 %)**
3	**22; R=TBDPS, R'=SiMe$_3$**	3.0	-40	**23; 84 % (94 : 6)**	
4	**24; R=Ac, R'=SiMe$_3$**	5.5	-40	**25; 54 % (53 : 47)**	**30 (66%)**
5	**26; R=TBDPS, R'=H**	4.4	-40	**27; 71 % (88 : 12)**	**31 (87%)**

#1; All diasteroisomer ratios were determined by nmr, #2; The yields were of decomplexation with iodine

Stereochemistry in ring opening reaction In order to explain the high diastereofacial selectivity of the ring opening reaction in **22**, the stereochemistry at the 3-position of **23** was determined by modified Mosher method.[12] DIBAL reduction of triacetate **23** (94 : 6 diastereomeric mixture) afforded triol **32** as stable reddish brown crystals. Treatment of the crude crystals with 2,2-dimethoxypropane and pyridinium *p*-toluenesulfonate (PPTS) gave a mixture of two separable acetonides which was purified by silica gel chromatography to afford the major diasteromer **33** as a pure form in 74 % overall yield (Scheme 4).

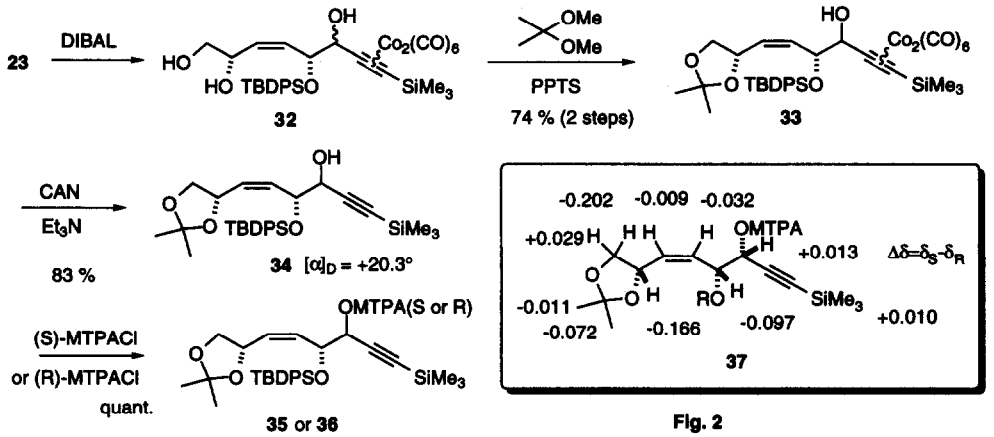


Fig. 2

Scheme 4

The cobalt-complexed acetylene **33** was decomplexed with ceric ammonium nitrate (CAN) and triethylamine to produce **34** ($[\alpha]_D^{24}$=+20.3 °) in 83 % yield. The alcohol **34** was converted into the corresponding (S)- and (R)-MTPA ester (**35** and **36**) by treatment with (S)-MTPACl and (R)-MTPACl, respectively. Judging from the δ value differences (Δδ=δS-δR) between the two MTPA esters, illustrated in Fig. 2, the stereochemistry at the 3-position in the major diastereomer of **23** was determined as S configuration. In other words, the major was 3,4-*syn* diol derivative. This stereochemical outcome suggested us a mechanism of the selectivity as follows. The conformation of **22** was assigned in **22a** as illustrated in Fig. 3 by nmr analysis.[5] Since d-electrons of the cobalt atom oriented in anti-periplanar of cleaved C-O bond should assist the ring opening, there are two possible ring opening pathways, derived from different conformation (as shown in Newman projection **22b** and **22c**) in transition state, to produce two kinds of intermediate ring opening cation (*syn*-cation **38**, **39** and *anti*-cation **40**, **41**). Schreiber and co-workers[13] have shown by nmr analysis that interconversion between *syn*-cation and *anti*-cation needs high energy; however the antarafacial migration of the alkylidene ligand from one cobalt tricarbonyl unit to the other occurs easily (**38** ↔ **39** or **40** ↔ **41**). The conformation of C-4 asymmetric center in these cations should be like that illustrated since the bulkiest substituent, *tert*-butyldiphenylsilyloxy function (TBDPSO), is away from trimethylsilyl function in *syn*-cation or carbon monoxide in *anti*-cation to diminish steric interaction. The reaction of acetoxy anion with the *syn*-cation **38** or the *anti*-cation **40** in which the anion can approach from less hindered side is expected to be faster than that of **39** or **41** and leads to the 3,4-*syn* diol derivative. This explanation seems to be compatible with the observation that changing TBDPS function or $SiMe_3$ function to smaller substituent (Ac or H) results in lower selectivity (entry 4, 5 in Table 2).

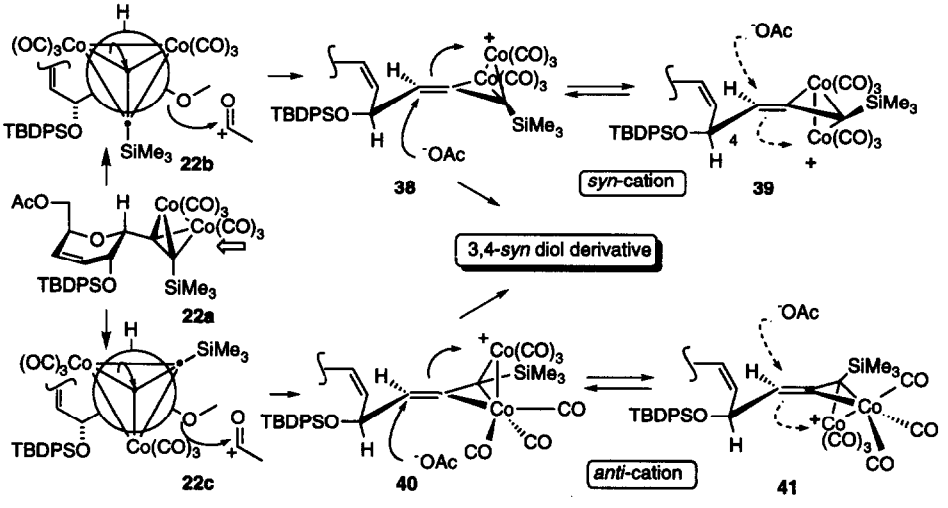
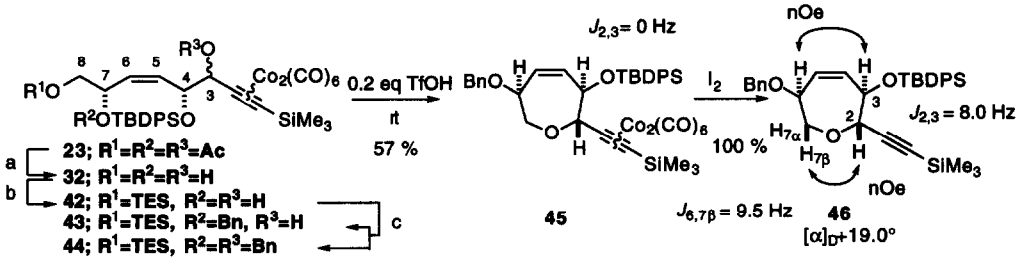


Fig. 3

Application of the new acyclic building block to oxepane subunit of trans-fused marine toxin The cobalt complex **23** particularly appealed to us as a starting material of recyclization because of the better yield (84 %) and existence of *cis*-olefin. Treatment of **23** with excess DIBAL at -78 °C gave triol **32** whose primary hydroxyl group was selectively silylated using chlorotriethylsilane and 1,2,2,6,6-pentamethylpiperidine[14] to afford **42** in 96 % yield.[15]



Reagents ; (a) DIBAL, 89 %; (b) TESCl, PMP, 96 %; (c) benzyl trichloroacetimidate, TfOH, **43** (63 %) and **44** (9 %).

Scheme 5

In order to conduct intramolecular Nicholas reaction[6] between carbon atom at 3-position and oxygen atom at 8-position, the C-7 hydroxyl function in **42** was benzylated with 10 equiv. of benzyl trichloroacetimidate[16] and catalytic amount of TfOH to give a mixture of monoether **43**[17] (63 %) and diether **44** (9 %). The longer reaction time to obtain **44** exclusively did not result in clean reaction. Treatment of **43** with 0.2 equiv. of TfOH at rt afforded dehydrooxepane **45** as a sole cyclization product in 57 % isolated yield. Cobalt complex **45** was decomplexed by oxidation with iodine to afford **46** {$[\alpha]_D^{23}$=+19.0° (*c* 0.78 $CHCl_3$)} in quantitative yield (Scheme 5). The *trans*-configuration of C-2 and C-3 substituents in **46** was confirmed by the coupling constant $J_{2,3}$= 8.0 Hz and $J_{6,7\beta}$= 9.5 Hz, which were consistent with the value having been reported by Nicolaou.[18] The stereochemistry of **46** was also confirmed by observing two nOe's between H_2-$H_{7\beta}$ and H_3-H_4 as illustrated in Scheme 5.

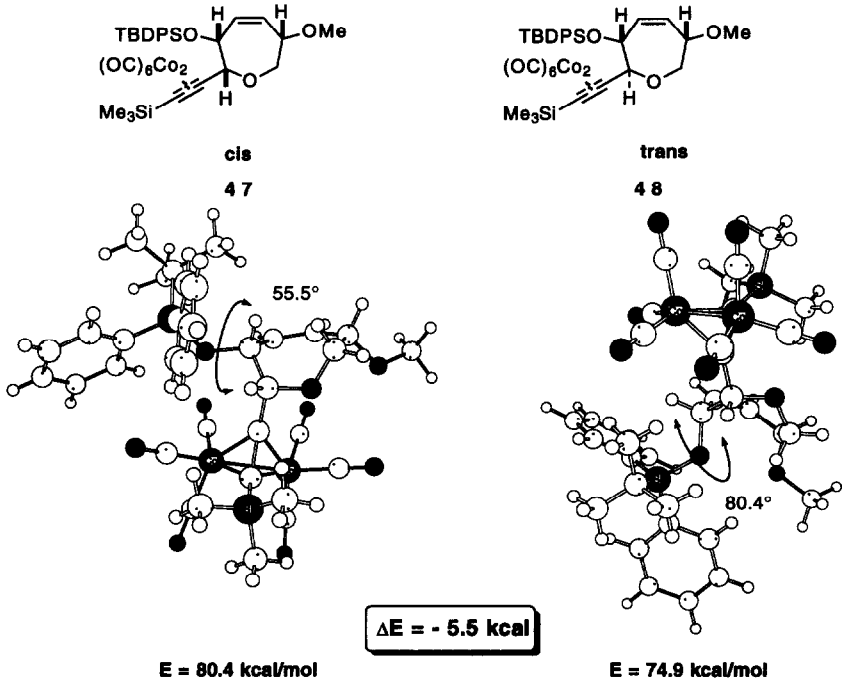


Fig. 4 Energy-minimized (Dreiding II/POLYGRAF) structures of **47** and **48**

Apparently this highly selective cyclization was thermodynamically controlled. The thermodynamic stability difference between **45** and its isomer would be due to the 1,2-interaction between cobalt acetylene moiety and TBDPS function. In an attempt to explain the outcome of the selectivity, energy minimization of *cis* (**47**) and *trans* (**48**) dehydrooxepane units having methoxy function instead of benzyloxy was carried out[19] using the POLYGRAF[20] and illustrated in Fig. 4. The dihedral angle through H_2-C_2-C_3-H_3 in *trans* isomer **48** was calculated at 80.4°, which almost agreed with the fact of the $J_{2,3}$ value being 0 Hz in **45**. In order to diminish the 1,2-steric interaction, the two bulky substituents in the *trans*-dehydrooxepane unit **48** were found to be in *anti* position each other. On the other hand, the substituents in the *cis*-dehydrooxepane unit **47** seemed to be congested each other. The steric energy difference between *cis* and *trans* was calculated at 5.5 kcal/mol, which agreed with the stereoselective cyclization from **43** to **45** under thermodynamic condition. Dehydrooxepane subunit **46** is of extreme interests as a candidate of precursor not only for D or E ring of ciguatoxin but also other marine toxins as an attractive synthetic intermediate.

To the best of our knowledge the stabilization[22] of propargyl cation by acetylene-dicobalt hexacarbonyl complex made it first possible to cleave pyranose ring of C-glycosides and recyclize in other sized ring. Basically the current method could be applied to other medium sized rings. Besides the linear cobalt complexes obtained by the ring opening reaction could also be utilized for synthesizing a variety of naturally occurring products because of those asymmetric carbons and easily manipulative acetylene moiety.

EXPERIMENTAL SECTION

General Techniques Melting points were recorded on a Yanaco MP-S3 melting point apparatus and are not corrected. Infrared spectra were recorded on a JASCO FT/IR-8300 spectrophotometer and are reported in wave number (cm^{-1}). Proton NMR (^1H NMR) spectra were recorded on JEOL EX-270 (270 MHz). Carbon NMR (^{13}C NMR) spectra were recorded on JEOL EX-270 (67.9 MHz). Low-resolution EI and FAB mass spectra were obtained with a JEOL JMS-D 100 and a DX-705, respectively. High-resolution mass spectra (HRMS) were recorded on a JEOL DX-705L and reported in m/z. Optical rotation was determined with a JASCO DIP-370 digital polarimeter. Elemental analysis were performed by Analytical Laboratory at Faculty of Agriculture, Nagoya University to which the authors gratefully acknowledges.Unless otherwise noted, non aqueous reaction were carried out under nitrogen or argon atmosphere. THF was distilled from potassium metal/benzophenone ketyl. Benzene was dried over Na metal and used without distillation. DMSO was distilled from CaH_2. DMF and CH_2Cl_2 were dried over MS 4Å. Nitromethane and pivaloylchloride were distilled before using. Pyridine and Et_3N was dried over KOH and used without distillation. All other commercially obtained reagents were used as received. Analytical thin-layer chromatography (TLC) was carried out by precoated silica gel plates (Art 5715). Preparative thin-layer chromatography (PLC) was carried out by precoated silica gel plates (Art 5774), or prepared silica gel (Art 7747). Silica gel for column chromatography was supplied from Fuji Devison (BW 820-MH).

Cobalt complex 20. A solution of diol **18** (407 mg, 1.8 mmol) and imidazole (612 mg, 9.0 mmol) in DMF (30 ml) at 0 °C was added *t*-butyldiphenylchlorosilane (1.03 ml, 3.96 mmol). After stirred for 17.5 h at rt, the reaction mixture was poured into cooled water and extracted with ether. The extract was washed with brine, dried and concentrated to dryness. Chromatography of the residue with ether/hexane (1/4) gave corresponding bis-silyl ether (805.7 mg, 1.15 mmol, y. 64 %) and silyl ether (285.3 mg, 0.61 mmol, y. 34 %). *Bis-silyl ether;* IR (KBr) ν_{max} 2170 (C≡C) cm^{-1} ^1H NMR ($CDCl_3$, 270 MHz) δ 0.21 (9H, s, TMS), 0.97 (9H, s, t-Bu), 1.05 (9H, s, t-Bu), 3.61 (1H, dd, *J* = 11.0, 6.5 Hz, H-6), 4.00 (1H, dd, *J* = 11.0, 1.5 Hz, H-6), 4.02 (1H, ddd, *J* = 8.0, 6.5, 1.5 Hz, H-5), 4.16 (1H, dm, *J* = 8.0 Hz, H-4), 4.85 (1H, brs, H-1), 5.57 (1H, brd, *J* = 10.0 Hz, H-2), 5.63 (1H, dm, *J* = 10.0 Hz, H-3), 7.23-7.72 (20H, m, aromatic). EI-MS *m/z* 702 (M^+), 687. HRMS calcd for $C_{43}H_{54}O_3Si_3$ 702.3381, found 702.3356. $[\alpha]_D^{26}$ -21.8° (*c* 0.88, $CHCl_3$). *Silyl ether;* ^1H NMR ($CDCl_3$, 270 MHz) δ 0.17 (9H, s, TMS), 1.09 (9H, s, t-Bu), 3.78-4.01 (3H, m, H-5 and H-6), 4.25 (1H, brd, *J* = 6.0 Hz, H-4), 4.86 (1H, br, H-1), 5.78 (1H, ddd, *J* = 10.0, 3.0, 1.5 Hz, H-2), 5.83 (1H, dm, *J* = 10.0 Hz, H-3), 7.36-7.74 (10H, m, aromatic). To a solution of the bis-silyl ether (732.4 mg, 1.04 mmol) in CH_2Cl_2 (1 ml) at rt was added, *via* cannula, a solution of dicobalt octacarbonyl (428 mg, 1.25 mmol) in CH_2Cl_2 (10 ml). After stirred for 2 h, the reaction mixture was concentrated. Chromatography of the residue with hexane/ether (29 / 1) provided dicobalt hexacarbonyl adduct **20** (982.4

mg, 0.994 mmol, y. 95 %) as a reddish brown oil. IR (KBr) ν_{max} 2089, 2052, 2026 (C≡O) cm^{-1}. ^1H NMR ($CDCl_3$, 270 MHz) δ 0.30 (9H, s, TMS), 0.96 (9H, s, t-Bu), 1.03 (9H, s, t-Bu), 3.80 (1H, dd, *J* = 11.0, 2.5 Hz, H-6), 3.95-4.01 (1H, m, H-5), 4.05 (1H, dd, *J* = 11.0, 3.0 Hz, H-6), 4.55 (1H, brd, *J* = 6.0 Hz, H-4), 5.30 (1H, brs, H-1), 5.68 (2H, br,H-2 and H-3), 7.27-7.72 (20H, m, aromatic).

Cobalt complex 26 To a solution of **19** (106 mg, 0.396 mmol) in aqueous THF (THF/H_2O=10/1, 4.4 ml) at rt was added 1 M solution of TBAF in THF (0.38 ml, 0.38 mmol). After stirred for 30 min, the reaction mixture was poured into cooled saturated NH_4Cl solution and extracted. The extract was washed with brine, dried and concentrated to dryness. The resulting acetylene alcohol (61.5 mg) was used for next reaction without further purification. To a solution of the alcohol (61.5 mg) and imidazole (107 mg, 1.572 mmol) in DMF (5 ml) at 0 °C was added TBDPSCl (0.09 ml, 0.346 mmol). After stirred at rt for 24 h, the reaction mixture was poured into cooled water and extracted with ether. The extract was washed with brine, dried and concentrated to dryness. The resulting crude oil was purified by PLC (ether/hexane=1/1) to afford silyl ether (111.9 mg, 0.258 mmol, y. 65 % overall) as a colorless oil. *Silyl ether;* IR (KBr) ν_{max} 3289 (≡C-H), 2113 (C≡C) 1744 (C=O) cm^{-1} ^1H NMR ($CDCl_3$, 270 MHz) δ 1.10 (9H, s, t-Bu), 2.03 (3H, s, Ac), 2.47 (1H, d, *J* = 2.0 Hz, H-2'), 4.01 (1H, dd, *J* = 12.0, 7.0 Hz, H-6), 4.11 (1H, dd, *J* = 12.0, 3.0 Hz, H-6), 4.40-4.46 (1H, m, H-2), 4.52 (1H, dd, *J* = 6.0, 2.0 Hz, H-1), 4.55-4.63 (1H, m, H-5), 5.64 (1H, dt, *J* = 10.5, 1.5 Hz, H-4), 5.83 (1H, brd, *J* = 10.5 Hz, H-3), 7.35-7.80 (10H, m, aromatic). EI-MS *m/z* 434 (M^+), 377, 317. HRMS calcd for $C_{26}H_{30}O_4Si$ 434.1913, found 434.1937. calc for $C_{22}H_{21}O_4Si$ (M^+-t-Bu) 377.1209, found 377.1215. $[\alpha]_D^{25}$ -37.3° (*c* 1.39, $CHCl_3$). To a solution of the silyl ether (79.5 mg, 0.183 mmol) in CH_2Cl_2 (1 ml) at rt was added, *via* cannula, a solution of dicobalt octacarbonyl (75 mg, 0.219 mmol) in CH_2Cl_2 (1 ml). After stirred for 13 h, the reaction mixture was concentrated. Chromatography of the residue with hexane/ether (1/0~3/1) provided dicobalt hexacarbonyl adduct **26** (99.4 mg, 0.138 mmol, y. 75 %) as a reddish brown oil. IR (KBr) ν_{max} 2094, 2056, 2024 (C≡O) 1747 (C=O) cm^{-1}. ^1H NMR ($CDCl_3$, 270 MHz) δ 1.11 (9H, s, t-Bu), 1.97 (3H, s, Ac), 3.96 (1H, dd, *J* = 11.5, 7.0 Hz, H-6), 4.20 (1H, dd, *J* = 11.5, 3.0 Hz, H-6), 4.60-4.68 (1H, m, H-5), 4.75 (2H, brs, H-2, H-1), 5.60 (1H, dd, *J* = 10.5, 2.0 Hz, H-4), 5.81 (1H, brd, J = 10.5 Hz, H-3), 6.16 (1H, s, H-2'), 7.30-7.80 (10 H, m, aromatic).

*General procedure of ring opening reaction (preparation of **16, 21, 23, 25, and 27**)* To a degassed solution of cobalt-complexed alkynyl sugar (0.157 mmol) in acetic anhydride (5 ml) at -20 °C was added TfOH (0.17 mmol). After stirred for 1 h at -20 °C, triethylamine (2.2 mmol) was added and warmed to rt. The reaction mixture was poured into cooled sat. $NaHCO_3$ and dichloromethane, and then extracted with ether. The extract was washed with $NaHCO_3$ and brine, dried and concentrated to dryness. The resulting crude oil was chromatographed with ether/hexane to afford the corresponding ring opening product. The each reaction condition was described in Table 2.

*Cobalt complex **16a**.* Yield; 95 %. The following spectral data were taken from a mixture of diastereomers (50 : 50). IR (KBr) ν_{max} 2092, 2053, 2025 (C≡O), 1749 (C=O) cm^{-1}. ^1H NMR ($CDCl_3$, 270MHz) δ 0.29 (9H, s, TMS), 2.01 and 2.03 (3H, s, OAc, two isomers), 2.05 (3H, s, OAc), 2.07 and 2.08 (3H, 2 × s, OAc, two isomers), 2.13 (3H, s, OAc), 4.14 (1H, dd, *J* = 12.0, 6.0 Hz, H-8), 4.23 (1H, d,*J* = 12.0, 4.0 Hz, H-8), 5.14-5.24 (1H, m, H-7), 5.56-5.64 (1H, m, H-6),5.84-5.92 (2H, m, H-4 and H-5), 6.47-6.53 (1H, br, H-3).

*Cobalt complex **21**.* Yield; 70 %. The following spectral data were taken from a mixture of diastereomers (70 : 30). IR (KBr) ν_{max} 2091, 2053, 2025 (C≡O), 1746 (C=O) cm^{-1}. *Major isomer;* ^1H NMR ($CDCl_3$, 270MHz) δ 0.21 (9H, s, TMS), 0.97 (9H, s, t-Bu), 0.99 (9H, s, t-Bu), 1.85 (3H, s, OAc), 2.01 (3H, s, OAc), 3.74-3.81 (2H, m, H-8), 4.46 (1H, ddd, *J* =6.5, 4.0, 1.0 Hz, H-6), 5.00-5.09 (1H, m, H-7), 5.39 (1H, ddd, *J* = 15.5, 6.0, 1.0 Hz, H-4), 5.82 (1H, ddd, *J* = 15.5, 6.5, 1.0 Hz, H-5), 6.30 (1H, dd, *J* =6.0, 1.0 Hz, H-3), 7.25-7.75 (20H, m, aromatic). *Minor isomer;* ^1H NMR ($CDCl_3$, 270 MHz) same as the major isomer or not seen, except δ 0.22 (9H, s, TMS), 0.96 (9H, s, t-Bu), 1.01 (9H, s, t-Bu), 1.84 (3H, s, OAc), 1.93 (3H, s, OAc), 3.83-3.88 (2H, m, H-8), 4.37 (1H, dd, *J* = 7.5, 3.0 Hz, H-6), 5.21 (1H, ddd, *J* = 15.5, 7.0, 0.5 Hz, H-4), 5.92 (1H, ddd, *J* = 15.5, 7.5, 0.5 Hz, H-5), 6.37 (1H, brd, *J* = 7.0 Hz, H-3).

*Cobalt complex **23**.* Yield; 84 %. The following spectral data were taken from a mixture of diastereomers (94 : 6). IR (KBr) ν_{max} 2090, 2053, 2025 (C≡O), 1749 (C=O) cm^{-1}. *Major isomer;* ^1H NMR ($CDCl_3$, 270MHz) δ 0.30 (9H, s, TMS), 1.08 (9H, s, t-Bu), 1.85 (3H, s, OAc), 1.92 (3H, s, OAc), 2.01 (3H, s, OAc), 4.02 (1H, dd, *J* = 12.0, 6.0 Hz, H-8), 4.19 (1H, dd,*J* = 12.0, 3.0 Hz, H-8), 4.58 (1H, dd, *J* = 7.5, 6.0 Hz, H-4), 5.57 (1H, dd, *J* = 11.0, 9.0 Hz, H-6), 5.78 (1H, dd, *J* = 11.0, 7.5 Hz, H-5), 5.80-5.89 (1H, m, H-7), 6.41 (1H, d, *J* = 6.0 Hz, H-3), 7.30-7.80 (10H, m, aromatic). ^{13}C NMR ($CDCl_3$, 67.9 MHz) δ 1.08 (3C), 19.2, 20.5, 20.6, 20.8, 27.1 (3C), 64.9, 67.6, 72.4, 76.7, 79.9, 103.1, 127.6 (2C), 127.7 (2C), 127.8, 129.9 (2C), 132.5, 132.7, 134.0, 135.9 (2C), 136.1 (2C), 136.2, 168.9, 169.5, 170.4, 199.8 (br). *Minor isomer;* ^1H NMR ($CDCl_3$, 270 MHz) same as the major isomer or not seen, except δ 1.09 (9H, s, t-Bu). ^{13}C NMR ($CDCl_3$, 67.9 MHz) same as the major isomer or not seen, except δ 27.2.

Cobalt complex 25. Yield; 54 %. The following spectral data were taken from a mixture of diastereomers (53 : 47). IR (KBr) ν_{max} 2092, 2053, 2026 (C≡O), 1749 (C=O) cm^{-1}. *Major isomer;* ^1H NMR ($CDCl_3$, 270MHz) δ 0.34 (9H, s, TMS), 2.05 (3H, s, OAc), 2.07 (3H, s, OAc), 2.09 (3H, s, OAc), 2.14 (3H, s, OAc), 4.11 (1H, dd, *J* = 12.0, 1.5 Hz, H-8), 4.25 (1H, dd,*J* = 12.0, 4.0 Hz, H-8), 5.60-5.98 (4H, m, H-4, H-5, H-6 and H-7), 6.41 (1H, d, *J* = 4.0 Hz, H-3). *Minor isomer;* ^1H NMR ($CDCl_3$, 270 MHz) same as the major isomer or not seen, except δ 0.33 (9H, s, TMS), 2.11 (3H, s, OAc), 4.15 (1H, dd, *J* = 11.5, 2.0 Hz, H-8), 4.27 (1H, dd, *J* = 11.5, 3.5 Hz, H-8), 6.18 (1H, d, *J* = 5.0 Hz, H-3).

Cobalt complex 27. Yield; 71 %. The following spectral data were taken from a mixture of diastereomers (88 : 12). IR (KBr) ν_{max} 2097, 2056, 2031 (C≡O), 1749 (C=O) cm^{-1}. *Major isomer;* ^1H NMR ($CDCl_3$, 270MHz) δ 1.05 (9H, s, t-Bu), 1.93 (3H, s, OAc), 1.98 (3H, s, OAc), 2.00 (3H, s, OAc), 3.85 (1H, dd, *J* = 12.0, 6.5 Hz, H-8), 4.21 (1H, dd,*J* = 12.0, 3.0 Hz, H-8), 4.74 (1H, ddd, *J* = 9.0, 6.5, 0.5 Hz, H-4), 5.35 (1H, dd, *J* = 11.0, 8.5 Hz, H-6), 5.41-5.53 (1H, m, H-7), 5.62 (1H, dd, *J* = 11.0, 9.0 Hz, H-5), 5.98 (1H, d, J = 6.5 Hz, H-3), 6.02 (1H, s, H-1), 7.30-7.80 (10 H, m, aromatic). *Minor isomer;* ^1H NMR ($CDCl_3$, 270 MHz) same as the major isomer or not seen, except δ 1.06 (9H, s, t-Bu), 1.84 (3H, s, OAc), 1.89 (3H, s, OAc), 2.02 (3H, s, OAc), 4.06 (1H, dd, *J* = 12.0, 6.0 Hz, H-8), 4.13 (1H, dd, *J* = 12.0, 3.0 Hz, H-8), 4.63 (1H, dd, *J* = 8.0, 6.5 Hz, H-3), 5.70 (1H, *J* = 11.0, 8.0 Hz, H-5), 6.03 (1H, s, H-1), 6.19 (1H, d, *J* = 6.5 Hz, H-3).

Decomplexation of 16a, 21, 25, and 27 Compounds, **16a**, **21**, **25**, and **27** were decomplexed with iodine by the same way as reported in ref. 5 to afford **28**, **29**, **30**, and **31**, respectively.

Silylacetylene 28. Yield; 90 %. The following spectral data were taken from a mixture of diastereomers. IR (KBr) ν_{max} 2180 (C≡C), 1752 (C=O) cm^{-1}. ^1H NMR ($CDCl_3$, 270 MHz) δ 0.18 (9H, s, TMS), 2.04 (3H, s, OAc), 2.06 (3H, s, OAc), 2.07 (s, OAc, one isomer), 2.09 (s, OAc, the other isomer), 2.08 (3H, s, OAc), 4.14 (dd, *J* = 12.0, 4.0 Hz, H-8, one isomer), 4.17 (dd, *J* = 12.0, 2.0 Hz, H-8, the other isomer), 4.20 (1H, dd, *J* = 12.0, 6.0 Hz, H-8), 5.17-5.24 (1H, m, H-7), 5.50-5.57 (1H, m, H-6), 5.82 (1H, dd, *J* = 15.0, 5.0 Hz, H-4), 5.87-6.00 (2H, m, H-3 and H-5). EI-MS *m/z* 412 (M^+), 369, 353. HRMS calcd for $C_{19}H_{28}O_8Si$ 412.1553, found 412.1574.

Silylacetylene 29. Yield; 96 %. The following spectral data were taken from a mixture of diastereomers. IR (KBr) ν_{max} 2180 (C≡C), 1748 (C=O) cm^{-1}. *Major isomer;* ^1H NMR ($CDCl_3$, 270 MHz) δ 0.17 (9H, s, TMS), 0.98 (9H, s, t-Bu), 1.00 (9H, s, t-Bu), 1.90 (3H, s, OAc), 2.00 (3H, s, OAc), 3.70-3.82 (2H, m, H-8), 4.29-4.37 (1H, m, H-6), 5.06-5.13 (1H, m, H-7), 5.26 (1H, ddd, *J* = 15.5, 6.0, 0.5 Hz, H-4), 5.64 (1H, dm, *J* = 6.0 Hz, H-3), 5.83 (1H, ddd, *J* = 15.5, 7.0, 1.0 Hz, H-5), 7.26-7.80 (20H, m, aromatic). *Minor isomer;* ^1H NMR ($CDCl_3$, 270 MHz) same as the major isomer or not seen, except δ 0.99 (9H, s, t-Bu), 1.99 (3H, s, OAc), 5.31 (1H, ddd, *J* = 15.5, 6.0, 0.5 Hz, H-4), 5.83 (1H, ddd, *J* = 15.5, 7.5, 1.0 Hz, H-5). Anal. calcd for $C_{47}H_{60}O_6Si_3$: C, 70.12; H, 7.52. Found: C, 69.91; H, 7.65.

Silylacetylene 30. Yield; 66 %. The following spectral data were taken from a mixture of diastereomers. IR (KBr) ν_{max} 2184 (C≡C), 1752 (C=O) cm^{-1}. *Major isomer;* ^1H NMR ($CDCl_3$, 270 MHz) δ 0.16 (9H, s, TMS), 2.07, 2.08, 2.09 and 2.10 (12H, 4xs, OAc), 4.11 (1H, dd, *J* = 12.0, 7.0 Hz, H-8), 4.27 (1H, dd, *J* = 12.0, 3.5 Hz, H-8), 5.56 (1H, d, *J* = 6.0 Hz, H-3), 5.64-5.94 (4H, m, H-4, H-5, H-6 and H-7). *Minor isomer;* ^1H NMR ($CDCl_3$, 270 MHz) same as the major isomer or not seen, except δ 0.17 (9H, s, TMS), 4.17 (1H, dd, *J* = 12.0, 6.5 Hz, H-8), 4.24 (1H, dd, *J* = 12.0, 4.0 Hz, H-8), 5.62 (1H, d, *J* = 4.0 Hz, H-3). EI-MS *m/z* 412 (M^+), 397, 353. HRMS calcd for $C_{19}H_{28}O_8Si$ 412.1553, found 412.1556.

Silylacetylene 31. Yield; 87 %. The following spectral data were taken from a mixture of diastereomers. IR (KBr) ν_{max} 3287(≡C-H), 2127 (C≡C), 1745 (C=O) cm^{-1}. *Major isomer;* ^1H NMR ($CDCl_3$, 270 MHz) δ 1.06 (9H, s, t-Bu), 1.89 (3H, s, OAc), 1.92 (3H, s, OAc), 2.01 (3H, s, OAc), 2.43 (1H, d, *J* = 2.0 Hz, H-1), 3.91 (1H, dd, *J* = 11.5, 6.0 Hz, H-8), 4.12 (1H, dd, *J* = 11.5, 3.5 Hz, H-8), 4.85 (1H, dd, *J* = 9.0, 3.5 Hz, H-4), 5.26 (1H, dd, *J* = 3.5, 2.0 Hz, H-3), 5.40-5.53 (2H, m, H-6, H-7), 5.80 (1H, dd, *J* = 10.0, 9.0 Hz, H-5), 7.30-7.80 (10 H, m, aromatic). *Minor isomer;* ^1H NMR ($CDCl_3$, 270 MHz) same as the major isomer or not seen, except δ 1.03 (9H, s, t-Bu), 1.56 (3H, s, OAc), 1.84 (3H, s, OAc), 2.00 (3H, s, OAc), 2.41 (1H, d, *J* = 2.5 Hz, H-1), 4.76 (1H, dd, *J* = 9.0, 7.0 Hz, H-4), 5.30 (1H, dd, *J* = 7.0, 2.5 Hz, H-3). EI-MS *m/z* 479 (M^+ -57), 439, 419, 379, 359. HRMS calcd for $C_{26}H_{27}O_7Si$ (M^+-t-Bu) 479.1526, found 479.1533.

Acetonide 33. To a solution of crude **23** (purity; 77 %, 1.77 g, 1.526 mmol) in dichloromethane (40 ml) at -78 °C was added DIBAL (1.0 M in toluene, 17.8 ml, 17.8 mmol). After stirred for 10 min, the reaction mixture was poured into aqueous tartaric acid solution (10 %), stirred, and extracted with ether. The extract was washed with $NaHCO_3$ and brine, dried and concentrated to dryness to afford a crude triol (1.23 g) which was used for next reaction without further purification. To a solution of the crude triol **32** (100 mg, 0.13 mmol) in dichloromethane (1 ml) at rt was added PPTS (33 mg, 0.13 mmol) and 2,2-dimethoxypropane (0.08 ml, 0.65 mmol). After stirred for 2.5 h at rt, the reaction mixture was poured into cooled aqueous $NaHCO_3$ and extracted with ether. The extract was washed with brine, dried and concentrated to dryness. The residue was purified with PLC (ether/hexane=1/4) to give a pure **33** (74.9 mg, 0.093 mmol, y. 74 % 2 steps) and its

C_3 diastereoisomer (4.9 mg, 0.006 mmol, y. 5 % 2 steps). *35;* IR (KBr) ν_{max} 3440 (OH), 2088, 2049, 2021 (C≡O) cm^{-1}. ^1H NMR ($CDCl_3$, 270MHz) δ 0.29 (9H, s, TMS), 1.10 (9H, s, t-Bu), 1.28 and 1.33 (6H, sx2, Me), 2.67 (1H, d, *J*= 4.0 Hz, OH), 3.36 (1H, t, *J* = 8.0 Hz, H-8), 3.87 (1H, dd,*J* = 8.0, 6.0 Hz, H-8), 4.42 (1H, dd, *J* = 8.0, 6.0 Hz, H-4), 4.64 (1H, td, *J* = 8.0, 6.0 Hz, H-7), 4.89 (1H, dd, *J* = 6.0, 4.0 Hz, H-3), 5.49 (1H, dd, *J*= 11.0, 8.5 Hz, H-6), 5.64 (1H, dd, *J* = 11.0, 8.0 Hz, H-5), 7.30-7.80 (10H, m, aromatic). *Minor diastereomer:* IR (KBr) ν_{max} 3452 (OH), 2089, 2050, 2024 (C≡O) cm^{-1}. ^1H NMR ($CDCl_3$, 270MHz) δ 0.23 (9H, s, TMS), 1.10 (9H, s, t-Bu), 1.26 and 1.35 (6H, sx2, Me), 3.18 (1H, d, *J*= 8.5 Hz, OH), 3.38 (1H, t, *J* = 8.0 Hz, H-8), 3.80 (1H, dd,*J* = 8.0, 6.0 Hz, H-8), 4.52-4.62 (1H, m, H-7), 4.60 (1H, dd, *J* = 8.5, 3.5 Hz, H-3), 4.70 (1H, ddd, *J* = 8.0, 3.5, 0.5 Hz, H-4), 5.59 (1H, ddd, *J* = 11.5, 8.5, 0.5 Hz, H-6), 5.80 (1H, ddd, *J*= 11.5, 8.0, 1.0 Hz, H-5), 7.30-7.80 (10H, m, aromatic).

Triol 32. The crude triol was crystallized from hexane to afford pure **32** as reddish brown crystals; The following spectral data were taken from a mixture of diastereomers; dec.> 120 °C. IR (KBr) ν_{max} 3448 (OH), 2088, 2051, 2025 (C≡O) cm^{-1}. *Major isomer;* ^1H NMR ($CDCl_3$, 270MHz) δ 0.31 (9H, s, TMS), 1.09 (9H, s, t-Bu), 1.35 (1H, d, J = 2.5 Hz, OH-7), 1.84 (1H, t, J = 5.5 Hz, OH-8), 3.30 (1H, d, J = 7.5 Hz, OH-3), 3.32-3.43 (2H, m, H-8), 3.90-4.01 (1H, m, H-7), 4.63 (1H, dd, J = 9.0, 4.5 Hz, H-4), 4.94 (1H, dd, *J* = 7.5, 4.5 Hz, H-3), 5.34 (1H, dd,*J* = 11.5, 8.5 Hz, H-6), 5.65 (1H, dd, J = 11.5, 9.0 Hz, H-5), 7.30-7.80 (10H, m, aromatic). *Minor isomer;* ^1H NMR ($CDCl_3$, 270 MHz) same as the major isomer or not seen. Anal. Calcd for $C_{33}H_{38}O_{10}Si_2Co_2$: C, 51.56; H, 4.99. Found: C, 51.60; H, 4.80.

Acetonide 34. To a solution of **33** (77.9 mg, 0.096 mmol) and triethylamine (0.03 ml, 0.22 mmol) in acetone (5 ml) at 0 °C was added CAN (0.16 g, 0.29 mmol). After 1 h, since the reaction was not completed, two small spoonful of CAN were added and stirred for 0.5 h at 0 °C. The reaction mixture was concentrated and aqueous $NaHCO_3$ solution was added. The mixture was extracted with ether and the extract was washed with brine, dried and concentrated to dryness. The residue was purified by PLC (ether/hexane=1/4) to afford **34** (37.4 mg, 0.072 mmol, y. 83 %). IR (KBr) ν_{max} 3450 (OH), 2172 (C≡C) cm^{-1}. ^1H NMR ($CDCl_3$, 270MHz) δ 0.17 (9H, s, TMS), 1.06 (9H, s, t-Bu), 1.25 and 1.33 (6H, sx2, Me), 2.32 (1H, d, *J*= 6.5 Hz, OH), 3.31 (1H, t, *J* = 8.0 Hz, H-8), 3.81 (1H, dd,*J* = 8.0, 6.0 Hz, H-8), 4.09 (1H, td, *J* = 8.0, 6.0 Hz, H-7), 4.24 (1H, dd, *J* = 6.5, 5.5 Hz, H-3), 4.38 (1H, dd, *J* = 9.5, 5.5 Hz, H-4), 5.50 (1H, dd, *J*= 11.5, 8.0 Hz, H-6), 5.69 (1H, ddd, *J* = 11.5, 9.5, 1.0 Hz, H-5), 7.30-7.80 (10H, m, aromatic). ^{13}C NMR ($CDCl_3$, 67.9 MHz) δ -0.23 (3C), 19.4, 25.9, 26.6, 26.9 (3C), 66.6, 69.4, 71.9, 72.1, 91.1, 103.5, 109.2, 127.6 (2C), 127.8 (2C), 129.8, 129.9, 131.0, 131.4, 133.0, 133.1, 135.8 (2C), 135.9 (2C). EI-MS *m/z* 522 (M^+), 507, 465. HRMS calcd for $C_{30}H_{42}O_4Si_2$ 522.2621, found 522.2615. calc for $C_{22}H_{21}O_4Si$ (M^+-t-Bu) 377.1209, found 377.1215. $[\alpha]_D^{24}$ +20.3° (*c* 1.14, $CHCl_3$).

(S or R)-Mosher ester 35 or 36. To a solution of **34** (9 mg, 0.017 mmol) in dichloromethane (0.5 ml) at rt was added (R)-MTPACl (15 µl, 0.078 mmol), triethylamine (10.5 µl, 0.078 mmol) and catalytic amount of DMAP. After stirred for 2.5 h, the reaction mixture was concentrated and purified by PLC (ether/hexane=1/4) to afford nearly pure **36** (14.1 mg). Acetonide **34** was also reacted with (S)-MTPACl as above to give **35** (10.5 mg). *36:* ^1H NMR ($CDCl_3$, 270MHz) δ 0.148 (9H, s, TMS), 1.039 (9H, s, t-Bu), 1.235 and 1.301 (6H, sx2, Me), 3.135 (1H, t, *J* = 8.0 Hz, H-8), 3.56 (3H, d, *J*= 1.0 Hz, OMe), 3.659 (1H, dd,*J* = 8.0, 6.0 Hz, H-8), 4.086 (1H, td, *J* = 8.0, 6.0 Hz, H-7), 4.544 (1H, dd, *J* = 9.0, 4.0 Hz, H-4), 5.323 (1H, d, *J* = 4.0 Hz, H-3), 5.393 (1H, dd, *J*= 11.5, 8.0 Hz, H-6), 5.670 (1H, dd, *J* = 11.5, 9.0 Hz, H-5), 7.30-7.80 (15H, m, aromatic). *35:* ^1H NMR ($CDCl_3$, 270MHz) δ 0.158 (9H, s, TMS), 1.021 (9H, s, t-Bu), 1.163 and 1.290 (6H, sx2, Me), 3.164 (1H, t, *J* = 8.0 Hz, H-8), 3.457 (1H, dd,*J* = 8.0, 6.0 Hz, H-8), 3.55 (3H, d, *J*= 1.0 Hz, OMe), 3.920 (1H, td, *J* = 8.0, 6.0 Hz, H-7), 4.447 (1H, ddd, *J* = 9.5, 4.0, 0.5 Hz, H-4), 5.336 (1H, d, *J* = 4.0 Hz, H-3), 5.384 (1H, ddd, *J*= 11.5, 8.0, 0.5 Hz, H-6), 5.638 (1H, dd, *J* = 11.5, 9.0, 1.0 Hz, H-5), 7.30-7.70 (15H, m, aromatic).

Triethylsilyl ether 42. To a solution of triol **32** (768 mg, 1.0 mmol, diasteromeric mixture) in dichloromethane (20 ml) at -78 °C was added 1,2,2,6,6-pentamethylpiperidine (0.36 ml, 2 mmol) and chlorotriethylsilane (0.25 ml, 1.5 mmol). The mixture was warmed to rt and stirred for 16 h. The reaction mixture was poured into cooled saturated aqueous $NaHCO_3$, and extracted with ether. The extract was washed with brine, dried and concentrated to dryness. Chromatography of the crude product with ether/hexane (1/5) afforded **42** (845.4 mg, 0.959 mmol, y. 96 %) as a reddish brown oil: The following spectral data were taken from a mixture of diastereomers. IR (KBr) ν_{max} 3428 (OH), 2087, 2049, 2021 (C≡O) cm^{-1}. *Major isomer;* ^1H NMR ($CDCl_3$, 270MHz) δ 0.30 (9H, s, TMS), 0.53 (6H, q, *J* = 8.0 Hz, Si*CH*$_2$CH$_3$), 0.89 (9H, t, *J*= 8.0 Hz, SiCH2*CH3*), 1.09 (9H, s, t-Bu), 2.12 (1H, d, *J* = 3.0 Hz, OH-7), 3.09 (1H, d, *J* = 6.0 Hz, OH-3), 3.26 (1H, dd, *J* = 10.0, 7.0 Hz, H-8), 3.44 (1H, dd, *J* = 10.0, 5.0 Hz, H-8), 4.08-4.19 (1H, m, H-7), 4.67 (1H, dd, *J* = 8.5, 5.0 Hz, H-4), 4.94 (1H, dd, *J* = 6.0, 5.0 Hz, H-3), 5.43 (1H, dd,*J* = 11.5, 8.0 Hz, H-6), 5.63 (1H, dd, J = 11.5, 8.5 Hz, H-5). 7.30-7.80 (10H, m, aromatic) *Minor isomer;* ^1H NMR ($CDCl_3$, 270 MHz) same as the major isomer or not seen.

Benzyl ether 43. To a solution of **42** (270.1 mg, 0.306 mmol) and trichloroacetimidate (0.57 ml, 3.07 mmol) in cyclohexane (6 ml) and dichloromethane (1.5 ml) at 0 °C was added 0.1 M solution of trifluoromethanesulfonic acid in CCl_2FCClF_2 (1.5 ml, 0.15 mmol). After stirred 3.5 h at rt, he mixture was

poured into saturated aqueous $NaHCO_3$ at 0 °C. The organic layer was separated and the water layer was extracted with ether. The combined organic layer was washed with brine, dried and concentrated to dryness. Chromatography of the crude product with hexane/ether (1/0~100/4) afforded **43** (188.2 mg, 0.194 mmol, y. 63 %) and a mixture of **44** and unreacted trichloroacetimidate, which was purified with PLC (ether/hexane=1/8) to give dibenzyl ether **44** (29 mg, 0.027 mmol, y. 9 %). ***43:*** The following spectral data were taken from a mixture of diastereomers. IR (KBr) ν_{max} 3400 (OH), 2087, 2049, 2021 (C≡O) cm^{-1}. ***Major isomer;*** ^1H NMR ($CDCl_3$, 270MHz) δ 0.35 (9H, s, TMS), 0.50 (6H, q, *J* = 8.0 Hz, Si*CH*$_2$CH$_3$), 0.83 (9H, t, *J*= 8.0 Hz, SiCH2*CH3*), 1.07 (9H, s, t-Bu), 3.16 (1H, d, *J* = 8.5 Hz, OH), 3.44 (1H, dd, *J* = 10.0, 3.5 Hz, H-8), 3.54 (1H, dd, *J* = 10.0, 5.0 Hz, H-8), 3.65-3.74 (1H, m, H-7), 3.74 (1H, d, *J* = 11.5 Hz, *CH*$_2$Ph), 3.95 (1H, d, *J* = 11.5 Hz, *CH*$_2$Ph), 4.69 (1H, dd, *J* = 9.5, 3.5 Hz, H-4), 4.96 (1H, dd, *J* = 8.5, 3.5 Hz, H-3), 5.50 (1H, dd, *J* = 11.5, 9.0 Hz, H-6) 5.87 (1H, dd, *J* = 11.5, 9.5 Hz, H-5), 7.00-7.75 (15H, m, aromatic) ***Minor isomer;*** ^1H NMR ($CDCl_3$, 270 MHz) same as the major isomer or not seen. ***44:*** The following spectral data were taken from a mixture of diastereomers. ***Major isomer;*** ^1H NMR ($CDCl_3$, 270MHz) δ 0.37 (9H, s, TMS), 0.46 (6H, q, *J* = 8.0 Hz, Si*CH*$_2$CH$_3$), 0.84 (9H, t, *J*= 8.0 Hz, SiCH2*CH3*), 1.08 (9H, s, t-Bu), 3.26 (1H, dd, *J* = 11.0, 6.0 Hz, H-8), 3.43 (1H, dd, *J* = 11.0, 2.0 Hz, H-8), 3.66-3.74 (1H, m, H-7), 3.74 (1H, d, *J* = 11.0 Hz, *CH*$_2$Ph), 3.84 (1H, d, *J* = 12.5 Hz, *CH*$_2$Ph), 3.94 (1H, d, *J* = 11.0 Hz, *CH*$_2$Ph), 4.04 (1H, d, *J* = 12.5 Hz, *CH*$_2$Ph), 4.57 (1H, d, *J* = 3.0 Hz, H-3), 4.70 (1H, dd, *J* = 8.5, 3.0 Hz, H-4), 5.61 (1H, dd, *J* = 11.0, 9.0 Hz, H-6) 5.81 (1H, dd, *J* = 11.0, 8.5 Hz, H-5), 6.90-7.80 (20 H, m, aromatic). ***Minor isomer;*** ^1H NMR ($CDCl_3$, 270 MHz) same as the major isomer or not seen.

*Dehydrooxepane **45**.* To a degassed solution of **43** (36.5 mg, 0.038 mmol) in dichloromethane (4 ml) at rt was added a 0.1 M solution of trifluoromethanesulfonic acid in CCl_2FCClF_2 (0.08 ml, 0.008mmol). After stirred for 2.5 h at rt, the mixture was poured into saturated aqueous $NaHCO_3$ at 0 °C. The organic layer was separated and the water layer was extracted with ether. The combined organic layer was washed with brine and dried over anhydrous sodium sulfate. Evaporation of the solvent gave the crude oil, which was purified by PLC (ether/hexane =1/7) to afford **45** (18.2 mg, 0.022 mmol, y. 57 %) as a reddish brown oil: IR (KBr) ν_{max} 2089, 2051, 2026 (C≡O) cm^{-1}. ^1H NMR ($CDCl_3$, 270MHz) δ 0.11 (9H, s, TMS), 1.11 (9H, s, t-Bu), 4.71 (1H, *J*= 12.0 Hz, *CH2*Ph), 4.08-4.24 (2H, m, H-6 and H-7), 4.41 (1H, d, *J* = 8.0 Hz, H-3), 4.66 (1H, *J*= 12.0 Hz, *CH2*Ph), 4.81-4.94 (1H, m, H-7), 5.31 (1H, s, H-2), 5.44 (1H, ddd, *J*= 11.5 , 8.0, 1.0 Hz, H-4), 5.9 (1H, ddd, *J* = 11.5 3.0 2.5 Hz, H-5), 7.20-7.80 (15H, m, aromatic).

*Dehydrooxepane **46**.* To a solution of **45** (25 mg, 0.03 mmol) in dry THF (0.5 ml) at 0 °C was added iodine (113 mg, 0.44 mmol) . After stirred for 2.0 h at rt, the mixture was poured into a mixture of saturated aqueous $NaHCO_3$ and saturated aqueous Na_2SO_3 (ca. 1v/1v) at 0 °C, and then extracted with ether. The combined organic layer was washed with brine, dried and concentrated to dryness. The crude oil was purified by PLC (ether/hexane=1/3) to afford **46** (15.5 mg, 0.028 mmol, y. 93 %) as a colorless oil: IR (KBr) ν_{max} 2177 (C≡C), 1113, 843, 702 cm^{-1}. ^1H NMR ($CDCl_3$, 270 MHz) δ 0.14 (9H, s, TMS), 1.08 (9H, s, t-Bu), 3.52 (1H, dd, *J* = 13.0, 9.5 Hz, H-7), 4.00-4.08 (2H, m, H-6 and H-7), 4.32 (1H, d, *J* = 8.0 Hz, H-2), 4.44 (1H, d, *J* = 12.0 Hz, *CH*$_2$Ph), 4.52 (1H, d, *J* = 12.0 Hz, *CH*$_2$Ph), 4.53 (1H, dm, *J* = 8.0 Hz, H-3), 5.48 (1H, dt, *J* = 12.0, 2.0 Hz, H-4), 5.58 (1H, brd, *J* = 12.0 Hz, H-5), 7.20-7.80 (15H, m, aromatic). ^{13}C NMR ($CDCl_3$, 67.9 MHz) δ -0.2 (3C), 19.4, 27.0 (3C), 71.2, 72.2, 74.7, 75.8, 90.4, 103.9, 127.5 (2C), 127.6 (2c), 127.7, (2C), 127.73, 128.4 (2C), 129.68, 129.7, 131.2, 132.9, 133.7, 134.1, 136.0 (2C), 136.2 (2C), 137.9. One carbon could not be observed. It may overlap with $CHCl_3$. EI-MS *m/z* 554 (M^+), 497. HRMS calcd for $C_{34}H_{42}O_3Si_2$ 554.2672, found 554.2658. $[\alpha]_D^{23}$ +19.0° (*c* 0.78, $CHCl_3$).

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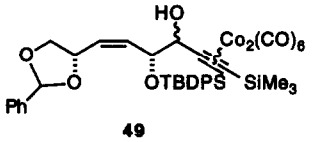

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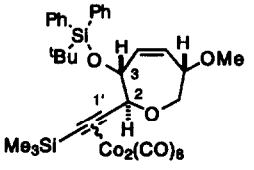

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