Pergamon

Tetrahedron, Vol. 52, No. 46, pp. 14437-14458, 1996

0040-4020/96 $15.00 + 0.00

PII: S0040-4020(96)00876-9

Synthesis of C-Aryl Glycosides Related to the Chrysomycins

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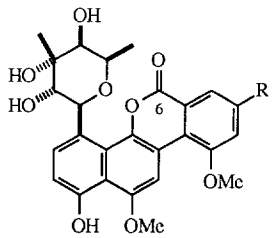
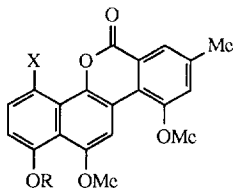
*Abstract: A synthesis of chrysomycin substructure **44** is described in which a Ramberg-Backlund reaction plays a key role. Electrochemical oxidation of **44** provided **45**, and unsuccessful attempts to convert **45** to chrysomycin B (**2**) are presented.* Copyright © 1996 Elsevier Science Ltd

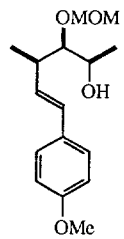
Introduction. Chrysomycin A (**1**) and chrysomycin B (**2**) are two members of what is commonly called the gilvocarcin family of C-aryl glycoside antitumor antibiotics.[1,2] Syntheses of the aglycones of **1** and **2** have been reported and there has been one report of a synthesis of methyl β-D-virenoside, the carbohydrate portion of these natural products.[3-5] No total syntheses of these C-aryl glycosides, however, have been reported. We became interested in these compounds as synthetic targets because of their interesting structures and biological activity.[6,7] Our early studies focused on preparing the aglycone of chrysomycin B (**3**) and also upon developing methods for *de novo* synthesis of the carbohydrate portion of **1** and **2**.[8,9] For example, it was shown that alkene **4** could be converted to virenose derivative **5** via a stereoselective sequence of reactions.[9] It was our hope that this chemistry could be used to prepare an aglycone derivative of type **6** which might be carried on to the natural products using an olefination-cyclization sequence similar to that used in the preparation of **5**. This paper describes studies directed toward these objectives and delineates some of the problems encountered along the way.



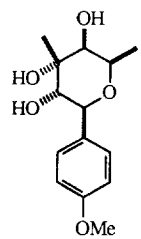
1 R = $CH=CH_2$
2 R = Me



3 R = X = H
6 X = CHO



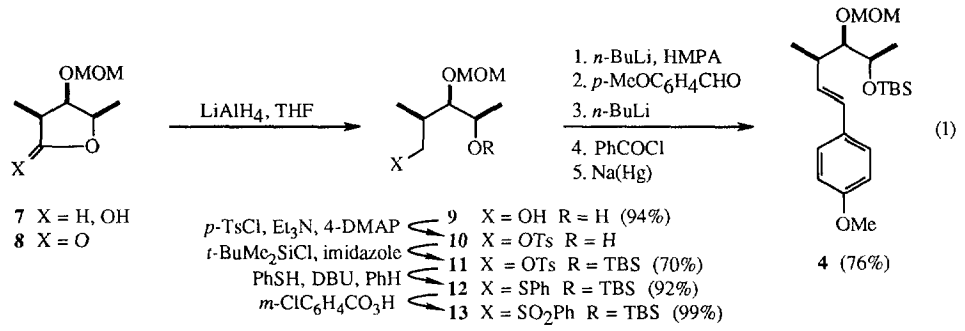
4



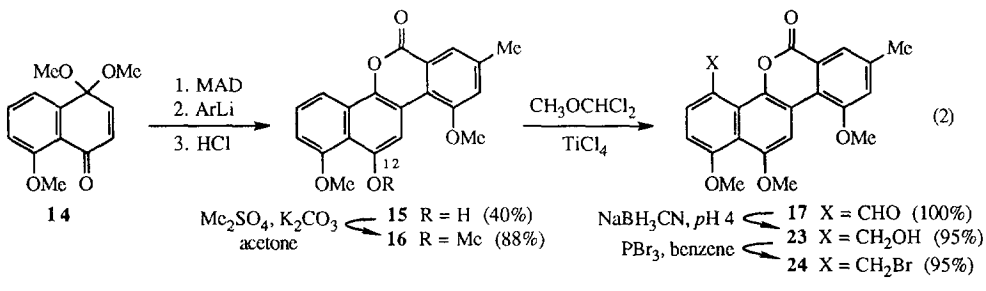
5

Julia-Lythgoe Olefination Approach. Our previous approach to **4** involved coupling diethyl *p*-methoxybenzylphosphonate to lactol **7**.[9] This route, however, was plagued by low yields (27-32%), so a more efficient procedure was sought. It turned out that a Julia-Lythgoe olefination worked nicely when the carbohydrate portion played the role of nucleophile toward *p*-methoxybenzaldehyde as the electrophile (equation 1).[10] Thus, reduction of lactone **8** with lithium aluminum hydride gave diol **9**

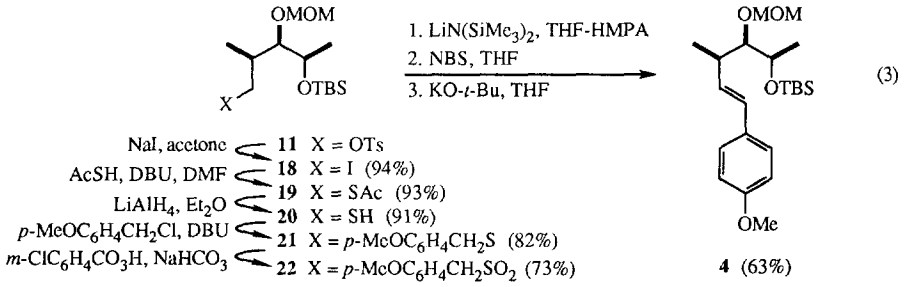
(94%). Treatment of **9** with *p*-toluenesulfonyl chloride, 4-DMAP, and triethylamine gave tosylate **10**. This material tended to cyclize to the tetrahydrofuran, but could be converted to **11** in 70% overall yield if treated immediately with *t*-butyldimethylchlorosilane and imidazole.[11] Treatment of **11** with thiophenol and DBU in benzene gave sulfide **12** (91%) and oxidation with *m*-chloroperoxybenzoic acid gave sulfone **13** (99%).[12] Metallation of **13** using *n*-butyllithium in THF-HMPA, followed by addition of *p*-methoxybenzaldehyde gave a mixture of diasteromeric β-hydroxy sulfones, which were converted to the corresponding benzoates and reduced with sodium amalgam to provide **4** in 76% yield.[13]



With a promising coupling procedure in hand, aglycone derivative **17** was prepared as described in equation 2. Treatment of a complex between naphthoquinone ketal **14** and methylaluminum bis(2,6-di-*tert*-butyl-4-methylphenoxide) (MAD)[14] with the aryllithium reagent derived from 2-(3-methoxy-5-methylphenyl)-4,4-dimethyl-Δ^2-oxazoline[15] gave a product of conjugate addition which, upon treatment with aqueous hydrochloric acid afforded **15** in 40% overall yield.[16] Methylation of the C(12) phenol gave **16** (88%). Reaction of **16** with dichloromethyl methyl ether and titanium tetrachloride, followed by acidic hydrolysis, gave aldehyde **17** in quantitative yield.[17] Unfortunately, all attempts to couple the carbanion derived from sulfone **13** with aldehyde **17** met with failure. It was decided that the hindered nature of the aldehyde (a 1,8-disubstituted naphthalene derivative) or its ambident electrophilic nature or its poor solubility in organic solvents was responsible for this failure. Based on these working hypotheses, we decided to examine an intramolecular strategy for coupling an appropriate aldehyde to a possible carbohydrate precursor.

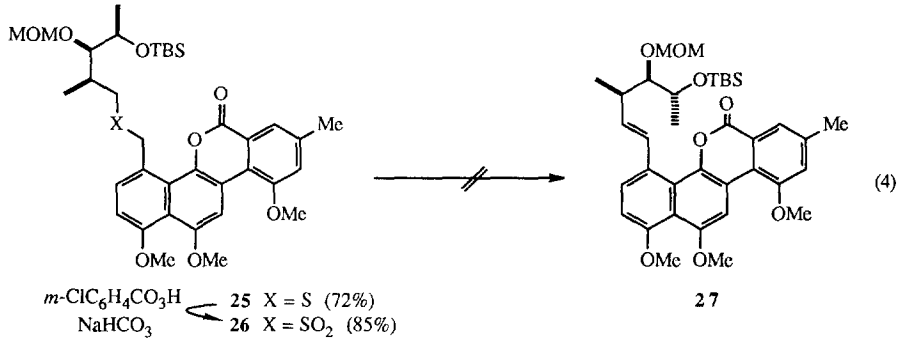


Ramberg-Backlund Approach. We next turned to the Ramberg-Backlund reaction as a coupling method.[18] A protocol was initially developed by performing yet another synthesis of **4** (equation 3). Treatment of tosylate **11** with sodium iodide in acetone provided iodide **18** in 94% yield.[19] Thiolacetic acid and DBU in DMF converted both tosylate **11** and iodide **18** into thioester **19** in 93% yield. Reduction of thioester **19** with lithium aluminum hydride gave thiol **20** in 91% yield. Although **20** was sensitive to oxidative dimerization, it did react with *p*-methoxybenzyl chloride in the presence of DBU to provide sulfide **21** in 82% yield.[20] Oxidation of **21** provided sulfone **22** (73%). Sequential treatment of **22** with lithium hexamethyldisilazide, N-bromosuccinimide, and potassium *tert*-butoxide in tetrahydrofuran gave **4** in 63% overall yield.



(3)

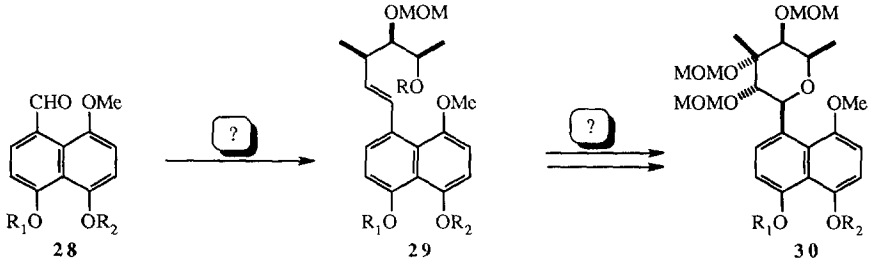
We next turned to the preparation of sulfone **26** (equation 4). This was accomplished by treating sulfide **20** with bromide **24**, available in two steps from **17** as shown in equation 2, to provide **25** (72%). Oxidation of **25** using *m*-chloroperoxybenzoic acid gave **26**. Although **26** had excellent solubility properties in organic solvents, it unfortunately did not provide the desired olefin **27** under a variety of Ramberg-Backlund reaction conditions.[21] Although a variety of product mixtures were usually obtained, in alkoxide mediated processes aldehyde **17** was always the lone isolable aromatic product. This result suggested oxidative chemistry was occuring at the benzylic position, but a cleavage event preceeded Ramberg-Backlund closure.



(4)

Preparation of C-Aryl Glycoside 45. We were suspicious that the lactone group in **26** was the source of problems under the basic Ramberg-Backlund conditions and thus, we evaluated the plan set forth in Scheme 1. It was our hope that a napthaldehyde of type **28** could be coupled with sulfide **17** to produce **29**. Completion of the carbohydrate portion of the chrysomycins would afford **30**, and if oxidation of **30** to an appropriate naphthoquinone ketal (*vide infra*) could be accomplished, it might be possible to proceed to the target structures (**1** and **2**) via previously established MAD-mediated conjugate addition procedures.[8]

Scheme 1

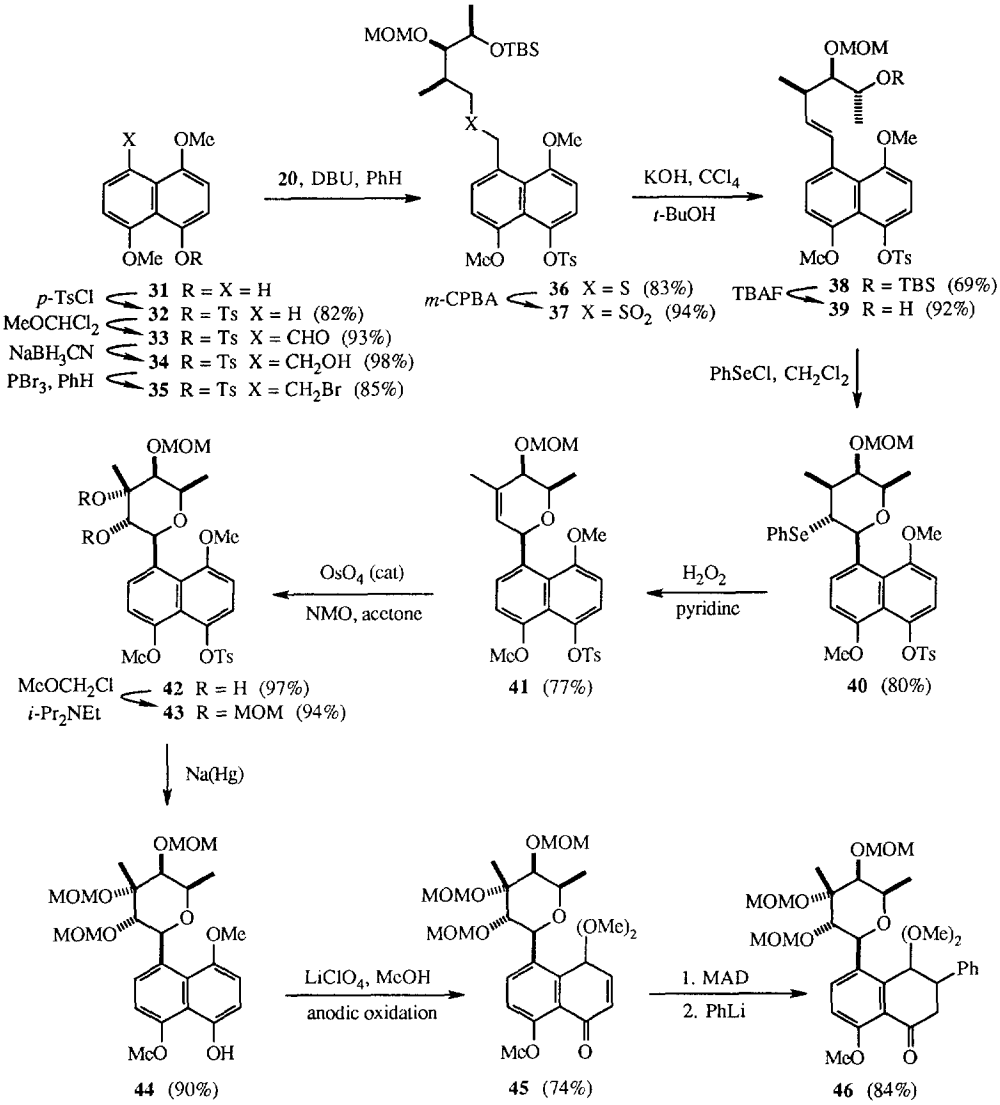


This scenario met with some success and some problems as described in Scheme 2. We set sulfone **37** as our initial Ramberg-Backlund substrate. Protection of naphthol **31**[22] as a tosylate was accomplished in 82% yield. Formylation of tosylate **32** gave aldehyde **33** (93%). Reduction of **33** using sodium cyanoborohydride at pH 4 gave alcohol **34** (98%),[23] which was converted to bromide **35** (85%) using phosphorus tribromide in benzene. S-Alkylation of **17** using bromide **35** provided **36** (83%) and oxidation of the sulfide completed the synthesis of sulfone **37** (94%). Fortunately, treatment of **37** with potassium hydroxide in *tert*-butanol and carbon tetrachloride provided Ramberg-Backlund product **38** in 69% yield.[24] Thus, it appears that substrate substitution pattern (1,8-disubstituted naphthalene) was not responsible for the aforementioned failed coupling reactions, and that the lactone was most likely the source of problems.

Construction of the carbohydrate portion of the chrysomycins was accomplished from **38** as follows. Removal of the silyl ether using tetra-*n*-butylammonium fluoride gave alcohol **39** (92%) and selenoetherification proceeded smoothly to afford tetrahydropyran **40** (80%) as a single diastereomer.[9,25] Oxidation of **40** followed by selenoxide elimination gave **41** in 77% yield.[26] Vicinal hydroxylation followed by protection of the intermediate diol **42** provided **43** in 91% overall yield.[27]

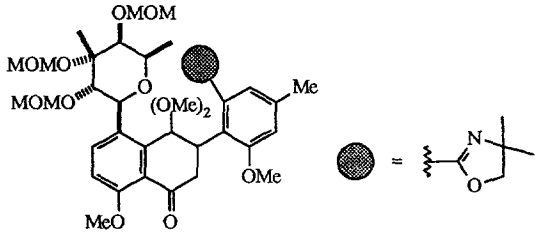
Our next objective was the oxidative conversion of **43** to naphthoquinone ketal **45**. Removal of the tosylate protecting group was accomplished using sodium amalgam to afford naphthol **44** in 90% yield.[28] Electrochemical oxidation of **44** gave the target enone **45** in 74% yield.[29]

Scheme 2



Conjugate Addition Studies. Attempts to introduce the lactone portion of the chrysomycin aglycone met with mixed results. We were fearful that the dense oxygenation in **45** might interfere with MAD-mediated conjugate addition reactions. However, we found that complexation of **45** with MAD followed by addition of excess phenyllithium gave product of conjugate addition **46** in 84% yield. Unfortunately, when the anion derived from 2-(3-methoxy-5-methylphenyl)-4,4-dimethyl-Δ^2-oxazoline was used, product of conjugate addition **47** was isolated in only 29% yield. Furthermore, it appeared

that **47** was sensitive to acid as a deuteriochloroform solution prepared for NMR work survived for no longer than six hours. We were unable to determine the exact nature of the decomposition products, but most discouraging was disappearance of the doublet (J = 11 Hz) due to the anomeric proton at δ 6.15 in the ^{1}H NMR spectrum of **47**. This suggested that the carbohydrate substructure might not survive the acidic conditions previously used to lactonize products of conjugate addition, for example *en route* from **14** to **15**. For this reason, it was decided to abandon this specific route to the chrysomycins.



47 (29%)

Conclusions. Although studies described here have not yet produced a synthesis of chrysomycin, it is nonetheless felt that this route still has promise. The studies described above suggest that in future work, preparation of the aglycone should preceed construction of the carbohydrate, but C(6) should be kept at the alcohol or aldehyde oxidation state. Application of the Ramberg-Backlund coupling procedure to such a substrate should have a good chance of success. The last stages of a synthesis would then involve oxidation at C(6) and deprotection of the C(1) hydroxyl group. This strategy is currently being investigated.

Experimental

All melting points are uncorrected. ^{1}H NMR spectra were taken on 200-300 MHz instruments and are reported as follows: chemical shift [multiplicity (s = singlet, d = doublet, t = triplet, q = quartet, qu = quintet, m = multiplet), coupling constants in hertz, integration]. ^{13}C NMR were taken at 63-75 MHz and are reported as follows: chemical shift (multiplicity). Solvents and reagents were dried and purified prior to use when deemed necessary: THF, diethyl ether, and diglyme were distilled from sodium metal; CH_2Cl_2, pyridine, triethylamine, PhH, and diisopropylamine were distilled from calcium hydride; hexamethylphosporic triamide, dimethylformamide, and dimethyl sulfoxide were distilled from calcium hydride and stored over 4 angstrom molecular sieves. *tert*-Butanol was distilled from magnesium sulfate. *p*-Toluenesulfonyl chloride and imidazole were recrystallized from PhH. 2,6-Di-*tert*-butyl-4-methylphenol was recrystallized 2-3 times from petroleum ether at -60°C and stored under a blanket of argon before use. Trimethylaluminum was purchased and used as received. Reactions requiring an inert atmosphere were run under a blanket of argon. All organolithiums were titrated with menthol prior to use using 1,10-phenanthroline as the indicator.[30]

(±)-(2*R,3*R**,4*R**)-3-(Methoxymethoxy)-2-methyl-1,4-pentanediol (9).** To a solution of 3.00 g (17.2 mmol) of furanone **8**[9] in 290 mL of THF at -78 °C was added 653 mg (17.2 mmol) of lithium aluminum hydride in a single portion. The resulting solution was stirred at -78 °C for 30 min, then warmed to rt and stirred 1 h. Saturated aqueous ammonium chloride (3 mL) was added with cooling in an ice bath, and the mixture was stirred for 90 min. The resulting slurry was filtered through 10 g of Celite and the filter cake was rinsed with 650 mL of CH_2Cl_2. The filtrate and washings were combined, dried ($MgSO_4$), and concentrated *in vacuo* to afford 2.85 g (94%) of diol **9** which could be used in subsequent reactions without further purification. If the crude product absorbed moisture (cloudy appearance) distillation from powdered 4A molecular sieves was necessary (85 °C at 0.05 mm Hg). On one occasion it was necessary to rigorously dry the diol. This was carried out by refluxing a 0.5 M solution of crude **9** in THF over about 20 mol% calcium sulfate for 24 h and then distilling under reduced pressure (85 °C, 0.05 mm Hg) from powdered sieves onto additional sieves and letting stand for 2 days: IR (neat) 3417 (broad) cm^{-1}; ^1H NMR ($CDCl_3$) δ 1.02 (d, *J* = 7.0 Hz, 3H), 1.19 (d, *J* = 6.5 Hz, 3H), 1.92 (m, 1H), 3.06 (bs, 2H), 3.24 (t, *J* = 4.7 Hz, 1H), 3.43 (s, 3H), 3.68 (dd, *J* = 11.2, 4.1 Hz, 1H), 3.56 (dd, *J* = 11.1, 5.1 Hz, 1H), 3.86 (m, 1H), 4.69 (d, *J* = 6.1 Hz, 1H), 4.74 (d, *J* = 6.1 Hz, 1H); ^{13}C NMR ($CDCl_3$) δ 15.2 (q), 20.1 (q), 37.3 (d), 56.2 (q), 64.0 (t), 68.2 (d), 89.0 (d), 99.3 (t); exact mass calcd. for $C_8H_{18}O_4$, *m/e* 178.1205, found *m/e* 178.1226.

(±)-(2*R,3*R**,4*R**)-4-(*tert*-Butyldimethylsiloxy)-3-(methoxymethoxy)-2-methyl-1-pentanol, *p*-toluenesulfonate (11).** To a solution of 1.78 g (10.0 mmol) of dry diol **9** in 40 mL of CH_2Cl_2 at -10 °C was added 3.80 g (20.0 mmol) of *p*-toluenesulfonyl chloride in a single portion. The slurry was stirred 5 min followed by the addition of 140 mg of 4-(dimethylamino)pyridine and 2.80 mL (2.02 g, 20.0 mmol) of triethylamine. The resulting solution was gradually warmed to 0 °C over a 9 h period after which 7.52 g (50.0 mmol) of *tert*-butyldimethylsilyl chloride and 4.08 g (60.0 mmol) of imidazole were added. The entire brew was stirred for 9 h at 0 °C or lower, then 2 h at rt. The reaction mixture was diluted with 75 mL of CH_2Cl_2 and washed with 35 mL of water. The aqueous phase was extracted with three 50-mL portions of CH_2Cl_2, dried ($MgSO_4$), and concentrated *in vacuo*. The residue was chromatographed over 100 g of silica gel (eluted with EtOAc-petroleum ether, 1:6) to furnish **11** contaminated with *tert*-butyldimethylsilyl residues. This material was purified by storing under high vacuum for 24 h to afford 3.14 g (70 %) of pure **11** as a colorless oil: IR (neat) 3050, 2930, 2889, 1177 cm^{-1}; ^1H NMR ($CDCl_3$) δ 0.02 (s, 3H), 0.04 (s, 3H), 0.87 (s, 9H), 1.01 (d, *J* = 6.9 Hz, 3H), 1.09 (d, *J* = 6.4 Hz, 3H), 2.09 (m, 1H), 2.44 (s, 3H), 3.19 (dd, *J* = 5.9, 5.1 Hz, 1H), 3.31 (s, 3H), 3.91 (m, 1H), 3.99 (dd, *J* = 9.4, 6.8 Hz, 1H), 4.13 (dd, *J* = 8.4, 4.1 Hz, 1H), 4.54 (d, *J* = 6.7 Hz, 1H), 4.61 (d, *J* = 6.7 Hz, 1H), 7.33 (d, *J* = 8.3 Hz, 2H), 7.80 (d, *J* = 8.3 Hz, 2H); ^{13}C NMR ($CDCl_3$) δ -4.8 (q), -4.6 (q), 15.2 (q), 17.9 (q), 18.9 (q), 21.6 (q), 25.8 (q), 34.0 (d), 55.8 (q), 69.6 (d), 72.9 (t), 84.2 (d), 98.2 (t), 127.9 (t), 129.7 (d), 133.3 (s), 144.6 (s).

(±)-*tert*-Butyl[(1*R,2*R**,3*S**)-2-(methoxymethoxy)-1,3-dimethyl-4-(phenylthio)butoxy]dimethylsilane (12).** To a solution of 206 μL (220 mg, 2.00 mmol) of thiophenol in 4 mL of benzene was added 298 μL (2.00 mmol, 304 mg) of DBU. The solution was stirred 5 min at 4 °C and a solution of 804 mg (2.00 mmol) of iodide **18** in 2 mL of benzene was added over a 5 min period. The resulting slurry was stirred at 4 °C for 3 h, filtered, and the filtrate was concentrated *in vacuo*. Chromatography of the residue over 50 g of silica gel (diethyl ether-petroleum ether, 1:20 as eluent) furnished 699 mg (91%) of **12** as a colorless oil: IR (neat) 3059, 2955, 1584, 1037 cm^{-1}; ^1H NMR ($CDCl_3$, 250 MHz) δ 0.06 (s, 3H), 0.07 (s, 3H), 0.87 (s, 9H), 1.08 (d, *J* = 6.4 Hz, 3H), 1.16 (d, *J* =

6.8 Hz, 3H), 2.03 (m, 1H), 2.74 (dd, J = 12.7, 9.3 Hz, 1H), 3.24 (m, 2H), 3.39 (s, 3H, OCH_3), 3.97 (m, 1H), 4.63 (d, J = 6.8 Hz, 1H), 4.76 (d, J = 6.8 Hz, 1H), 7.1-7.45 (m, 5H); ^{13}C NMR ($CDCl_3$, 62.9 MHz) δ -4.7 (q), -4.6 (q), 17.4 (q), 18.0 (s), 19.3 (q), 25.8 (q), 34.2 (d), 37.1 (t), 56.0 (q), 70.0 (d), 86.3 (d), 98.3 (t), 125.7 (d), 128.8 (d), 129.1 (d), 137.4 (s); exact mass calcd. for $C_{20}H_{36}O_3SiS$ *m/e* 384.2154, found *m/e* 384.2163.

(±)-*tert*-Butyl[(1R*,2R*,3S*)-2-(methoxymethoxy)-1,3-dimethyl-4-(phenylsulfonyl)butoxy]dimethylsilane (13). To a slurry of 1.89 g (22.5 mmol) of sodium bicarbonate in 33 mL of dichloromethane was added 1.23 g (3.23 mmol) of phenylsulfide **12** followed 5 min later by a solution of 1.11 g (6.44 mmol) of 99% *m*-CPBA in 32 mL of dichloromethane. The resulting slurry was stirred for 1 h at 0 °C, followed by 5 h at room temperature, and then quenched by the addition of 10 mL of saturated aqueous sodium bisulfite. The mixture was diluted with 100 mL of dichloromethane and washed with 50 mL of saturated aqueous sodium bicarbonate. The aqueous phase was extracted with three 100-mL portions of dichloromethane. The combined organic exracts were washed with 50 mL of brine, dried ($MgSO_4$), and concentrated in vacuo to afford 1.32 g (99%) of the sulfone **13** as a colorless oil. This material could be used in subsequent reactions without further purification, but could also be purified by chromatography over silica gel (eluted with EtOAc-pentane, 1:10): IR (neat) 3062, 2955, 1305 1035, cm^{-1}; ^1H NMR ($CDCl_3$, 300 MHz) δ 0.00 (s, 3H), 0.01 (s, 3H), 0.83 (s, 9H), 0.97 (d, J = 6.2 Hz, 3H), 1.20 (d, J = 6.8 Hz, 3H), 2.32 (m, 1H), 2.92 (dd, J = 14.5, 9.7 Hz, 1H), 3.11 (dd, J = 6.2, 3.9 Hz, 1H), 3.32 (s, 3H), 3.36 (d, J = 14.5 Hz, 1H), 3.72 (qu, J = 6.2 Hz, 1H), 4.53 (d, J = 6.7 Hz, 1H), 4.70 (d, J = 6.7 Hz, 1H), 7.13 (m, 1H), 7.28 (m, 2H), 7.38 (m, 2H); ^{13}C NMR ($CDCl_3$, 62.9 MHz) δ -4.8, (q), -4.6 (q), 17.9 (s), 18.9 (q), 19.2 (q), 25.8 (q), 29.4 (d), 55.9 (q), 55.8 (t), 69.7 (d), 86.3 (d), 98.2 (t), 127.9 (d), 129.2 (d), 133.5 (d), 140.1 (s); exact mass calcd. for $C_{19}H_{33}O_4SiS$ (M+-31) *m/e* 385.1869, found *m/e* 385.18

(±)-*tert*-Butyl[(1R*,2R*,3S*)-5-hydroxy-2-(methoxymethoxy)-1,3-dimethyl-5-(*p*-methoxyphenyl)-4-(phenylsulfonyl)pentoxy]dimethylsilane (four diastereomers) and **tert-Butyl[[*trans*-2-(methoxymethoxy)-5-(*p*-methoxyphenyl)-1,3-dimethyl-4-butenyl]oxy]dimethylsilane (4). Via Julia-Lythgoe:** To a solution of 208 mg (500 μmol) of sulfone **13** in 1.6 mL of THF and 440 μL of HMPA at -78 °C was added dropwise 405 μL (600 μmol) of a solution of 1.48 M *n*-BuLi in hexanes over 5 min. The bright yellow solution was stirred at or below -72 °C for 30 min followed by the addition of a solution of 84 μL (112 mg, 600 μmol) of 4-methoxybenzaldehyde in 900 μL of THF over a 5 min period. The resulting solution was stirred at -78 °C for 90 min and quenched with 1 mL of saturated aqueous ammonium chloride. The mixture was diluted with 10 mL of water and extracted with three 20-mL portions of diethyl ether. The combined organic extracts were dried ($MgSO_4$) and concentrated *in vacuo*. The residue was chromatographed over 20 g of silica gel (eluted with petroleum ether-EtOAc, 20:1) to afford 129 mg (47%) of a single β-hydroxysulfone: IR (neat) 3518 (broad), 3020, 2956, 1514 cm^{-1}; ^1H NMR ($CDCl_3$, 300 MHz) 0.01 (s, 3H), 0.04 (s, 3H), 0.83 (s, 9H), 0.97 (d, J = 6.3 Hz, 3H), 1.58 (d, J = 7.3 Hz, 3H), 2.56 (m, 1H), 3.28 (s, 3H), 3.74 (s, 3H), 3.83 (m, 2H), 4.02 (m, 2H), 4.66 (d, J = 6.2 Hz, 1H, OCH_2) 4.7 (d, J = 6.2 Hz, 1H), 5.12 (t, J = 0.9 Hz, 1H), 6.72 (m, 2H), 7.0 (m, 2H), 7.5-7.75 (m, 3H), 8.07 (m, 2H); ^{13}C NMR ($CDCl_3$, 62.9 MHz) δ -5.1 (q), -3.8 (q), 14.5 (q), 19.1 (q), 25.9 (q), 29.2 (s), 31.8 (d), 55.1 (q), 56.0 (q), 66.8 (d), 68.3 (d), 71.4 (d), 86.3 (d), 98.8 (t), 113.6 (d), 127.0 (d), 128.4 (d), 129.1 (d), 131.4 (s), 133.6 (d), 139.9 (s), 158.8 (s); exact mass calcd. for $C_{28}H_{44}O_5SiS$ *m/e* 520.2679, found *m/e* 520.2679.

Continued elution with petroleum ether-EtOAc, 8:1, gave 25 mg (9%) of a second β-hydroxysulfone: IR (neat) 3510 (broad), 2950, 1505 cm^{-1}; ^1H NMR ($CDCl_3$, 250 MHz) δ 0.07 (s, 3H), 0.08 (s, 3H), 0.91 (s, 9H), 1.19 (d, *J* = 6.4 Hz, 3H), 1.44 (d, *J* = 7.2 Hz, 3H), 3.24 (m, 1H), 3.38 (s, 3H), 3.59 (dd, *J* = 8.5, 4.3 Hz, 1H), 3.74 (s, 3H), 3.85-4.15 (m, 3H), 4.69 (d, *J* = 6.1 Hz, 1H), 4.72 (d, *J* = 6.1 Hz, 1H), 5.13 (bd, *J* = 8.8 Hz, 1H), 6.6 (m, 2H), 7.06 (m, 2H), 7.25-7.45 (m, 5H); ^{13}C NMR ($CDCl_3$, 62.9 MHz) δ -4.8 (q), -4.4 (q), 13.7 (q), 18.0 (s), 18.9 (q), 25.8 (q), 29.1 (s), 32.0 (d), 55.2 (q), 55.7 (q), 68.8 (d), 69.4 (q), 70.9 (d), 86.1 (d), 98.7 (t), 113.6 (d), 127.4 (d), 128.5 (d), 128.9 (d), 132.2 (d), 133.1 (s), 140.9 (s), 159.3 (s); exact mass calcd. for $C_{27}H_{43}O_5SiS$ (M-15) *m/e* 505.2444, found *m/e* 505.2437.

Further elution with petroleum ether-EtOAc (4:1) furnished 96 mg (35%) of the final two diastereomers as an inseparable mixture for a total of 250 mg (91%) of β-hydroxy sulfones: ^1H NMR ($CDCl_3$, 250 MHz) diagnostic signals at δ -0.12 (s, 3H), -0.50 (s, 3H), -0.49 (s, 3H), -0.20 (s, 3H), 0.73 (s, 9H), 0.81 (s, 9H), 0.98 (d, *J* = 6.2 Hz, 6H), 0.99 (d, *J* = 6.4 Hz, 3H), 1.26 (d, *J* = 6.8 Hz, 3H), 2.05 (m, 1H), 2.60 (m, 2H), 3.30 (s, 3H), 3.38 (s, 3H), 3.78 (s, 6H), 3.70-3.90 (m, 1H), 3.90-4.05 (m, 1H), 4.10 (m, 1H), 4.30 (m, 1H), 4.47 (d, *J* = 4.4 Hz, 1H), 4.55 (d, *J* = 4.4 Hz, 1H), 4.74 (d, 5.2 Hz, 1H), 4.79 (d, *J* = 5.2 Hz, 1H), 6.8 (m, 4H), 7.16 (m, 2H), 7.28 (m, 3H), 7.45-7.55 (m, 7H), 7.80 (m, 2H), 8.05 (m, 1H).

To a solution of 45 mg (82 μmol) of a mixture of β-hydroxy sulfones, prepared as described above, and approximately 2 mg of 1,10-phenanthroline in 300 μL of THF at -78 °C was added dropwise a solution of 1.48 M *n*-BuLi in hexanes until a dark color persisted (approximately 55-60 μL were required). The resulting solution was stirred 5 min at -78 °C and 19 μL (23 mg, 164 μmol) of benzoyl chloride was added. After warming to room temperature over a 3 h period, the reaction mixture was stirred for 2 h and then directly chromatographed over 8 g of silica gel (eluted with petroleum ether-EtOAc, 8:1) to afford diastereomeric benzoates. The residue was redissolved in 1.5 mL of methanol and treated with 55 mg of sodium hydrogen phosphate. The resulting solution was cooled to -18 °C and 450 mg of 5% sodium amalgam was added. The resulting mixture was stirred at -18 °C for 5.5 h, diluted with 5 mL of diethyl ether, and decanted from the residual mercury. The ether layer was washed with 5 mL of water, and the resulting aqueous layer was extracted with three 5-mL portions of diethyl ether. The combined organic layers were dried ($MgSO_4$) and concentrated in vacuo. The residue was chromatographed over 2 g of silica gel to afford 27 mg (84%) of alkene **4** as an approximately 1:8 mixture of *cis-trans* isomers as a colorless oil. Chromatography over silica gel (eluted with pentane-EtOAc, 10:1) provided a sample of the pure *trans* isomer: ^1H NMR ($CDCl_3$, 250 MHz) δ 0.04 (s, 3H), 0.05 (s, 3H), 0.88 (s, 9H), 1.16 (m, 6H), 2.57 (m, 1H), 3.25 (m, 1H), 3.41 (s, 3H), 3.81 (s, 3H), 3.88 (m, 1H), 4.66 (d, *J* = 6.6 Hz, 1H), 4.82 (d, *J* = 6.6 Hz, 1H), 6.13 (dd, *J* = 17.4, 8.5 Hz, 1H), 6.3 (d, *J* = 17.4 Hz, 1H), 6.83 (m, 2H), 7.29 (m, 2H). ^{13}C NMR ($CDCl_3$, 62.9 MHz) δ -4.7 (q), -4.6 (q), 18.0 (s), 19.1 (q), 19.7 (q), 25.9 (q), 38.8 (d), 55.3 (q), 56.0 (q), 70.7 (d), 86.4 (d), 98.3 (t), 113.9 (d), 127.1 (d), 129.1 (d), 130.6 (d), 130.7 (s), 158.7 (s).

The amount of trans isomer in the mixture was enriched as follows. To a solution of 31 mg (79 μmol) of an approximately 1:8 *cis-trans* mixture of **4** in 2.5 mL of benzene was added 5.0 μL (5.0 mg, 40 μmol) of thiophenol followed by 8 mg (47 μmol) of AIBN. The resulting solution was heated to 50 °C for 14 h, cooled to room temperature, and directly chromatographed over 1 g of silica gel (eluted with petroleum ether-diethyl ether, 50:1) to afford 16 mg (52%) of a 1:34 mixture of *cis-trans* isomers of **4** by GC analysis: phenyl-methyl silicone gum; temperature range 100-300 °C; rate of heating 10 °C/min; Z-

olefin R_t = 14.23 min, E-olefin R_t = 15.29 min. **Via Ramberg-Backlund**: To a solution of 56 mg (122 μmol) of sulfone **22** in 400 μL of THF and 50 μL of hexamethylphosphoramide at 0 °C was added 235 μL (146 μmol) of a 0.625 M stock solution of lithium hexamethyldisilazane in THF. The resulting dark red solution was stirred 1 h at 0 °C, then added dropwise via cannula to a vigorously stirred solution of NBS in 200 μL of tetrahydrofuran. The reaction mixture was stirred at room temperature for 2 h, diluted with 5 mL of diethyl ether and washed with 5 mL of water. The aqueous phase was extracted with two 10-mL portions of diethyl ether and the combined organic phases were washed with 10 mL of saturated aqueous brine, dried ($MgSO_4$) and concentrated *in vacuo*. The residue was chromatographed over 10 g of silica gel to afford 6.0 mg of a dibromo sulfone. Continued elution gave 39 mg of an inseparable mixture composed of an approximately 2:1 ratio of dibromo and monobromo sulfones. A 20 mg sample of the mixture was dissolved in THF and treated with 11 mg of potassium *tert*-butoxide in a single portion. The resulting solution was stirred 2 h and filtered through 1 g of silica gel. The silica gel was washed with 30 mL of diethyl ether and the combined filtrate and washings were concentrated *in vacuo*. The residue was chromatographed over 1 g of silica gel (eluted with diethyl ether-petroleum ether, 1:20) to afford 6.0 mg (63%) of the *trans*-alkene **4**.

12-Hydroxy-1,10-dimethoxy-8-methyl-6*H*-benzo[d]naphtho[1,2-*b*]pyran-6-one (15). To a solution of 937 mg (4.28 mmol) of 2-(3-methoxy-5-methylphenyl)-4,4-dimethyl-Δ^2-oxazoline in 15 mL of THF at -45 °C was added 2.7 mL (4.3 mmol) of *n*-BuLi (1.6 M in hexane) over a 10 min period followed by stirring for 1.5 h. In a separate reaction vessel, the MAD reagent was prepared by adding 2.14 mL (4.28 mmol) of Me_3Al (2.0 M. in toluene) to a solution of 1.87 g (8.56 mmol) of 2,6-di-*t*-butyl-4-methylphenol in 40 mL of toluene at rt with stirring for 20 min. The solution of MAD reagent was cooled to -78 °C and a solution of 500 mg (2.14 mmol) of monoketal **14** in 10 mL of toluene was added over a 10 min period. The aryl lithium derived from 2-(3-methoxy-5-methylphenyl)-4,4-dimethyl-Δ^2-oxazoline was then transfered to the MAD-monoketal complex via syringe over a 15 min period, allowed to stir for 5 min at -78 °C and quenched with 3 mL of water. The resulting slurry was filtered through a cake of celite and the filter cake was rinsed with 200 mL of CH_2Cl_2. The filtrate was dried (Na_2SO_4) and concentrated in vacuo. The residue was chromatographed over 50 g of silica gel (eluted with EtOAc-hexane, 1:3, followed by EtOAc-hexane, 1:1) to afford 899 mg of conjugate adduct as a foam. To a solution of the conjugate adduct in 15 mL of THF was added 2 mL of 5 N aqueous HCl. The solution was warmed under reflux for 30 min, allowed to cool to rt, diluted with 200 mL of CH_2Cl_2, and washed with 100 mL of saturated aqueous $NaHCO_3$. The aqueous phase was extracted with two 100-mL portions of CH_2Cl_2. The organic phases were combined, dried ($MgSO_4$), and concentrated in vacuo. The residue was rinsed with CH_2Cl_2-hexane (1:10) and the precipitate was collected to afford 287 mg (40% from **14**) of **15** as an orange solid: mp 277-280 °C; IR (KBr) 1718 cm^{-1}; ^1H NMR ($CDCl_3$) δ 2.52 (s, 3H), 4.1 (s, 3H), 4.15 (s, 3H), 6.9 (d, J = 8 Hz, 1H), 7.15 (s, 1H), 7.9 (s, 1H), 8.25 (d, J = 8 Hz, 1H), 8.45 (s, 1H), 9.1 (s, 1H); exact mass calcd. for $C_{20}H_{16}O_5$ *m/e* 336.0998, found *m/e* 337.1013.

1,10,12-Trimethoxy-8-methyl-6*H*-benzo[*d*]naphtho[1,2-*b*]pyran-6-one (16). To a slurry of 500 mg (1.49 mmol) of phenol **15** in 50 mL of acetone was added 1.2 mL (1.6 g, 7.44 mmol) of dimethyl sulfate and 1.0 g (7.4 mmol) of K_2CO_3. The mixture was warmed under reflux for 72 h, allowed to cool to rt, filtered, and the residual K_2CO_3 was rinsed with 200 mL of CH_2Cl_2. The filtrate was washed with 100 mL of 10% aqueous citric acid. The aqueous phase was extracted with 100 mL of CH_2Cl_2, the organic phases were combined, dried ($MgSO_4$), and concentrated in vacuo to afford 457

mg (88%) of **16** as a yellow solid: mp 245-246 °C (dec); IR (CH_2Cl_2) 1722 cm^{-1}; ^1H NMR ($CDCl_3$) δ 2.5 (s, 3H), 4.0 (s, 3H), 4.05 (s, 3H), 4.12 (s, 3H), 7.0 (d, *J* = 8 Hz, 1H), 7.15 (s, 1H), 7.51 (t, *J* = 8 Hz, 1H), 8.0 (s, 1H), 8.25 (d, *J* = 8 Hz, 1H), 8.49 (s, 1H); ^{13}C NMR ($CDCl_3$) δ 21.6, 56.3, 56.5, 56.8, 104.5, 108.0, 113.7, 114.9, 117.6, 118.2, 122.0, 122.8, 123.2, 126.7, 127.2, 139.8, 140.6, 152.8, 156.7, 157.2, 161.5; exact mass calcd. for $C_{21}H_{18}O_5$ *m/e* 350.1155, found *m/e* 350.1127.

4-Formyl-1,10,12-trimethoxy-8-methyl-6*H*-benzo[*d*]naphtho[1,2-*b*]pyran-6-one (17). To a solution of 100 mg (0.29 mmol) of **16** in 15 mL of CH_2Cl_2 at 0 °C was added 84 μL (1.01 mmol) of dichloromethyl methyl ether followed by 162 μL (1.45 mmol) of $TiCl_4$. The mixture was stirred at 0 °C for 30 min and quenched with 3 mL of 5% aqueous HCl followed by stirring for 5 min. The mixture was partitioned between 200 mL of CH_2Cl_2 and 100 mL of 5% aqueous HCl. The aqueous phase was extracted with 100 mL of CH_2Cl_2, the organic phases were combined, dried ($MgSO_4$), and concentrated in vacuo to afford 113 mg (100%) of aldehyde **17** as a yellow solid: mp 260 °C (dec); IR (KBr) 1718, 1670 cm^{-1}; ^1H NMR ($CDCl_3$) δ 2.5 (s, 3H), 4.00 (s, 3H), 4.01 (s, 3H), 4.1 (s, 3H), 7.0 (d, *J* = 8 Hz), 7.15 (s, 1H), 7.9 (s, 1H), 8.12 (d, *J* = 8 Hz, 1H), 8.51 (s, 1H), 11.1 (s, 1H); exact mass calcd. for $C_{22}H_{18}O_6$ m/e 378.1103, found *m/e* 378.1103; found: *m/e* 378.1100.

(±)-*tert*-Butyl[(1*R,2*R**,3*S**)-4-iodo-2-(methoxymethoxy)-1,3-dimethylbutoxy]dimethylsilane (18).** To a solution of 1.21 g (2.71 mmol) of tosylate **11** in 25 mL of acetone at 0 °C was added 4.50 g (30.0 mmol) of sodium iodide in five portions over ten minutes. The ice bath was removed and the orange solution was stirred at room temperature for 48 h. The resulting slurry was carefully concentrated and the residue was extracted with two 50-mL portions of diethyl ether. The combined ether layers were concentrated *in vacuo*, and the residue was chromatographed over 10 g of silica gel (eluted with diethyl ether-petroleum ether, 1:25) to afford 1.02 g (94%) of iodide **18** as a colorless oil: IR (neat) 2930, 2857, 1041 cm^{-1}; ^1H NMR ($CDCl_3$, 250 MHz) δ 0.07 (s, 6H), 0.89 (s, 9H), 1.10 (d, *J* = 6.7 Hz, 3H), 1.17 (d, *J* = 6.4 Hz, 3H), 1.72 (m, 1H), 3.18 (dd, *J* = 8.1, 4.4 Hz, 1H), 3.30 (dd, *J* = 9.5, 6.8 Hz, 1H), 3.35-3.43 (m, 4H, OCH_3), 4.00 (m, 1H), 4.64 (s, 2H); ^{13}C NMR ($CDCl_3$, 62.9 MHz) δ -4.8 (q), -4.5 (q), 15.6 (t), 18.0 (s), 18.7 (q), 18.9 (q), 25.8 (q), 36.1 (d), 55.9 (q), 67.4 (d), 85.5 (d), 98.3 (t); exact mass calcd. for $C_{13}H_{28}O_2SiI$ (M-31) *m/e* 371.0881, found *m/e* 371.0886.

(±)-(2*R,3*S**,4*S**)-4-(*tert*-Butyldimethylsiloxy)-3-(methoxymethoxy)-2-methyl-1-pentanethiol acetate (19).** To a solution of 2.12 g (1.95 mL, 35.4 mmol) of thiolacetic acid in 15 mL of DMF at 0 °C under argon was added 5.43 g (5.3 mL, 35.4 mmol) of DBU. The resulting dark blue solution was stirred for 15 min. To the resulting solution was added a solution of 4.51 g (10.11 mmol) of tosylate **11** in 30 mL of DMF. The reaction was stirred 8 h while warming to rt and then diluted with 250 mL of CH_2Cl_2. The resulting solution was washed with five 100-mL portions of water, then dried ($MgSO_4$), and concentrated in vacuo. The residue was chromatographed over 50 g of silica gel (eluted with petroleum ether-EtOAc; 40:1) to afford 3.30 g (93%) of thioester **19** as an oil. IR (neat) 2932, 1693, 1037 cm^{-1}; ^1H NMR ($CDCl_3$) δ 0.06 (s, 3H), 0.07 (s, 3H), 0.88 (s, 9H), 1.04 (d, *J* = 6.9 Hz, 3H), 1.16 (d, *J* = 6.4 Hz, 3H), 1.94 (m, 1H), 2.32 (s, 3H), 2.75 (dd, *J* = 13.4, 8.9 Hz, 1H), 3.19 (m, 2H), 3.39 (s, 3H), 4.00 (qu, *J* = 6.2 Hz, 1H), 4.62 (d, *J* = 6.7 Hz, 1H), 4.76 (d, *J* = 6.7 Hz, 1H); ^{13}C NMR ($CDCl_3$) δ -4.7 (q), -4.6 (q), 17.2 (q), 18.0 (s), 19.3 (q), 25.8 (q), 30.6 (q), 32.1 (t), 34.4 (d), 56.0 (q), 70.1 (d), 86.3 (d), 98.3 (t), 195.5 (s); exact mass calcd. for $C_{15}H_{31}O_3SSi$ (M-31) *m/e* 319.1763, found *m/e* 319.1733.

(±)-(2*R,3*S**,4*S**)-4-(*tert*-Butyldimethylsiloxy)-3-(methoxymethoxy)-2-methyl-1-pentanethiol (20).** To a -78 °C solution of 3.04 g (8.68 mmol) of thioacetate **19** in 80 mL of diethyl ether was added 650 mg (17.1 mmol) of $LiAlH_4$ in two portions. The resulting slurry was stirred 5 min at -78 °C then warmed to rt and stirred 30 min. The reaction was carefully neutralized by the cautious dropwise addition of 1.3 mL of 3N aqueous HCl. The resulting foamy solution was stirred for 2h at 0 °C and then filtered through a cake of Celite. The filter cake was rinsed with 100 mL of diethyl ether, and then 200 mL of CH_2Cl_2. The combined filtrate and washings were concentrated *in vacuo*. The residue was chromatographed over 100 g of silica gel (eluted with petroleum ether-ether, 50:1) to afford 2.42 g (91%) of the thiol **20** as a foul smelling oil: IR (neat) 2995, 2800, 1050 cm^{-1}; ^1H NMR ($CDCl_3$) δ 0.07 (s, 3H), 0.08 (s, 3H), 0.89 (s, 9H), 1.09 (d, J = 6.7 Hz, 3H), 1.15 (d, J = 8.0 Hz, 3H), 1.35 (t, J = 8.1 Hz, 1H), 1.94 (m, 1H), 2.54 (m, 1H), 2.75 (ddd, J = 12.0, 8.0, 3.3 Hz, 1H), 3.27 (dd, J = 6.0, 3.3 Hz, 1H), 3.39 (s, 3H), 3.96 (m, 1H), 4.63 (d, J = 6.7 Hz, 1H), 4.73 (d, J = 6.7 Hz, 1H); ^{13}C NMR ($CDCl_3$) δ -4.8 (q), -4.6 (q), 16.1 (q), 18.0 (s), 19.1 (q), 25.8 (q), 28.0 (t), 36.9 (d), 55.9 (q), 69.7 (d), 85.3 (d), 98.1 (t); exact mass calcd. for $C_{14}H_{31}O_3SSi$ (M-1) *m/e* 307.1863, found *m/e* 307.1814.

(±)-*tert*-Butyl[(1*R,2*R**,3*S**)-4-[(*p*-methoxybenzyl)thio]-2-(methoxymethoxy)-1,3-dimethylbutoxy]dimethylsilane (21) and (±)-Bis[(2*R**,3*S**,4*S**)-4-(*tert*-Butyldimethylsiloxy)-3-(methoxymethoxy)-2-methylpentyl] disulfide. Method A:** To a solution of 103 mg (334 μmol) of thiol **20** in degassed benzene was added 52 mg (334 μmol) of *p*-methoxybenzyl chloride followed by 50 mL (334 μmol) of DBU. The resulting solution was stirred at room temperature for 3 h and directly chromatographed over 10 g of silica gel (eluted with petroleum ether-diethyl ether, 15:1) to afford 125 mg (87%) of an inseparable mixture of sulfide **21** contaminated with a small amount (approximately 5%) of the disulfide: IR (neat) 2930, 1462, 1100, 1036 cm^{-1}; ^1H NMR ($CDCl_3$, 300 MHz) δ 0.05 (s, 3H), 0.06 (s, 3H), 0.90 (s, 9H), 1.13 (d, J = 6.4 Hz, 3H), 1.18 (d, J = 6.7 Hz, 3H), 2.07 (m, 1H), 2.52 (m, 1H), 3.00 (m, 1H), 3.22 (m, 1H), 3.40 (s, 3H), 3.95 (m, 1H), 4.65 (d, J = 6.4 Hz, 1H), 4.77 (d, J = 6.4 Hz, 1H); ^{13}C NMR ($CDCl_3$, 62.9 MHz) δ -4.7 (q), -4.6 (q), 17.3 (q), 18.0 (s), 19.5 (q), 25.8 (q), 34.1 (d), 34.2 (d), 42.0 (t), 42.8 (t), 55.9 (q), 70.2 (d), 86.4 (d), 98.4 (t); exact mass calcd. for $C_{14}H_{31}O_3SSi$ *m/e* 307.1863, found *m/e* 307.1814. This material could be used in subsequent reactions without further purification. However, complete removal of **20** could be effected in the following manner. A -78 °C solution of the above material in 3 mL of THF was treated with 10 mg (226 μmol) of lithium aluminum hydride and warmed to room temperature. After 30 min, GC analysis (phenyl methyl silicone gum; 100-300 °C; 10 °C/min; initial time 2.00 min; thiol **20** R_t = 8.38 min, sulfide **21** R_t = 16.60 min, disulfide R_t = 19.92) indicated the disulfide had been quantitatively converted to thiol **20**. The reaction mixture was quenched with one drop of saturated aqueous ammonium chloride with cooling by an ice bath. The resulting slurry was stirred 10 min and filtered through a cake of celite. The residue was chromatographed over 10 g of silica gel (eluted with petroleum ether-diethyl ether 30:1) to first afford 6 mg of thiol **20**. Further elution afforded 117 mg (82%) of disulfide free **21**. **Method B:** To a solution of 154 mg (1.0 mmol) of DBU in 3.0 mL benzene was added 154 mg (1.0 mmol) of *p*-methoxybenzenethiol in a single portion. The resulting solution of thiolate anion was stirred for 5 min and then 384 mg (1.0 mmol) of iodide **18** was added. The reaction mixture was stirred 8 h at room temperature and filtered through 2 g of silica gel. The filter plug was washed with 50 mL of diethyl ether and the combined filtrate and washings were concentrated in vacuo affording 317 mg (74%) of **21** that could be used in subsequent reactions without further purification: IR (neat) 3050, 2956, 1728, 1253 cm^{-1}; ^1H NMR ($CDCl_3$, 300 MHz) δ 0.03 (s, 3H), 0.04

(s, 3H), 0.87 (s, 9H), 1.08 (m, 6H), 1.91 (m, 1H), 2.31 (dd, J = 12.6, 9.2 Hz, 1H), 2.67 (dd, J = 12.6, 3.5 Hz, 1H), 3.15 (t, J = 5.5 Hz, 1H), 3.33 (s, 3H), 3.64 (s, 2H), 3.78 (s, 3H), 3.89 (m, 1H), 4.58 (d, J = 6.7 Hz, 1H), 4.69 (d, J = 6.7 Hz, 1H), 6.8 (m, 2H), 7.24 (m, 2H); ^{13}C NMR ($CDCl_3$, 75.47 MHz) δ -4.7 (q), -4.6 (q), 17.4 (q), 18.0 (s), 19.4 (q), 25.9 (q), 34.4 (d), 34.8 (t), 36.3 (t), 55.3 (q), 55.9 (q), 69.9 (d), 86.2 (d), 98.3 (t), 113.8 (d), 129.9 (d), 130.7 (s), 158.6 (s) exact mass calcd. for $C_{20}H_{36}O_3SSi$ (M-44) *m/e* 384.2220, found *m/e* 384.2187.

(±)-*tert*-Butyl[(1R*,2R*,3S*)-4-[(*p*-methoxybenzyl)sulfonyl]-2-(methoxymethoxy)-1,3-dimethylbutoxy]dimethylsilane (22). To a solution of 120 mg (280 mmol) of sulfide **21** in 2.5 mL of chloroform containing 172 mg (1.92 mmol) of solid sodium bicarbonate was added dropwise a solution of 143 mg (560 μmol) of 80% *m*-chloroperbenzoic acid in 3.0 mL of chloroform. The resulting slurry was stirred 2 h and diluted with 25 mL of saturated aqueous sodium bicarbonate. The entire mixture was extracted with four 40-mL portions of dichloromethane, and the combined organic phases were washed with 50 mL of brine, dried ($MgSO_4$), and concentrated *in vacuo*. The residue was chromatographed over 10 g of silica gel (eluted with petroleum ether-diethyl ether, 10:1, followed by EtOAc-petroleum ether, 4.5:1) to afford 94 mg (73%) of desired sulfone **22** as a colorless oil: IR (neat) 3020, 2956, 1727, 1514, 1258 cm^{-1}; ^{1}H NMR ($CDCl_3$, 300 MHz) δ 0.03 (s, 3H), 0.04 (s, 3H), 0.88 (s, 9H), 1.08 (d, J = 6.4 Hz, 3H), 1.28 (d, J = 7.2 Hz, 3H), 2.46 (m, 1H), 2.58 (dd, J = 15.3, 8.0 Hz, 1H), 3.13 (m, 2H), 3.34 (s, 3H), 3.65-3.85 (m, 1H), 3.82 (s, 3H), 4.16 (s, 2H), 4.56 (d, J = 6.4 Hz, 1H), 4.73 (d, J = 6.4 Hz, 1H), 6.92 (m, 2H), 7.34 (m, 2H); ^{13}C NMR ($CDCl_3$, 62.90 MHz) δ -4.8 (q), -4.7 (q), 17.9 (s), 18.8 (q), 19.3 (q), 25.7 (q), 28.8 (d), 53.2 (t), 55.2 (q), 55.9 (q), 60.1 (t), 69.7 (d), 86.1 (d), 98.1 (t), 114.1 (t), 120.0 (s), 131.8 (d), 160.1 (s); exact mass calcd. for $C_{21}H_{37}O_5SSi$ (M-31) *m/e* 429.2069, found *m/e* 429.2100.

4-(Hydroxymethyl)-1,10,12-trimethoxy-8-methyl-6*H*-benzo[*d*]naphtho[1,2-*b*]pyran-6-one (23). To a slurry of 130 mg (0.34 mmol) of aldehyde **17** in 40 mL of THF-water (5:1) was added 108 mg (1.7 mmol) of sodium cyanoborohydride followed by a trace of bromocresol green. To the resulting green solution was added aqueous 2 N HCl dropwise until the green solution turned yellow. The mixture was stirred for 4 h at rt and maintained at pH 4 by further addition of HCl when necessary. The solution was partitioned between 200 mL of CH_2Cl_2 and 100 mL of water. The aqueous phase was extracted with two 100-mL portions of CH_2Cl_2. The combined organic phases were dried ($MgSO_4$), and concentrated in vacuo to afford 124 mg (95%) of alcohol **23** as a yellow solid: mp 243-245 °C; ^{1}H NMR ($CDCl_3$) δ 2.5 (s, 3H), 3.25 (br s, 1H), 4.0 (s, 3H), 4.05 (s, 3H), 4.12 (s, 3H), 5.3 (br s, 2H), 6.92 (d, J = 8 Hz, 1H), 7.19 (s, 1H), 7.55 (d, J = 8 Hz), 7.9 (s, 1H), 8.51 (s, 1H); exact mass calcd. for $C_{22}H_{20}O_6$ *m/e* 380.1260, found *m/e* 380.1305.

4-(Bromomethyl)-1,10,12-trimethoxy-8-methyl-6*H*-benzo[*d*]naphtho[1,2-*b*]pyran-6-one (24). To a slurry of 130 mg (0.34 mmol) of alcohol **23** in 30 mL of benzene was added 97 μL (1.03 mmol) of PBr_3 in one portion. The mixture was stirred at room temperature for 1 h, diluted with 200 mL of CH_2Cl_2, and washed with 100 mL of water. The aqueous phase was extracted with two 50-mL portions of CH_2Cl_2, the organic phases were combined, dried ($MgSO_4$), and concentrated in vacuo to afford 128 mg (85%) of bromide **24** as a yellow solid: mp 164-165 °C (dec); ^{1}H NMR ($CDCl_3$) δ 2.5 (s, 3H), 3.98 (s, 3H), 4.02 (s, 3H), 4.1 (s, 3H), 5.05 (s, 2H), 6.9 (d, J = 8 Hz, 1H), 7.15 (d, J = 8 Hz, 1H), 7.95 (s, 1H), 8.6 (s, 1H); exact mass calcd. for $C_{22}H_{19}O_5{}^{81}Br$ *m/e* 444.0396, found *m/e* 444.0396.

(±)-4-[[[(2*R,3*S**,4*S**)-4-(*tert*-Butyldimethylsiloxy)-3-(methoxymethoxy)-2-methylpentyl]thio]methyl]-1,10,12-trimethoxy-8-methyl-6*H*-benzo[*d*]naphtho[1,2,*b*]pyran-6-one (25).** To a slurry of 11 mg (26 μmol) of bromide **24** in 400 μL of benzene was added 8.0 mg (26 μmol) of thiol **20** followed by 4.0 μL (4.0 mg, 26 μmol) of DBU. The yellow slurry was stirred at room temperature for 3 h, diluted with 250 μL of chloroform and chromatographed over 3 g of silica gel (eluted with diethyl ether-chloroform, 1:50) to afford 12 mg (72%) of sulfide **25** as a yellow green oil that slowly solidified: mp 106-115 °C; IR (neat) 2930, 1718 cm^{-1}; ^1H NMR ($CDCl_3$, 300 MHz) δ 0.03 (s, 3H), 0.05 (s, 3H), 0.86 (s, 9H), 1.03 (d, *J* = 6.8 Hz, 3H), 1.08 (d, 3H, *J* = 6.3 Hz), 1.92 (m, 1H), 2.35 (dd, *J* = 12.4, 9.4 Hz, 1H), 2.49 (s, 3H), 2.81 (dd, *J* = 12.6, 3.4 Hz, 1H), 3.13 (t, *J* = 5.5 Hz, 1H), 3.32 (s, 3H), 3.93 (m, 1H), 3.98 (s, 3H), 4.02 (s, 3H), 4.08 (s, 3H), 4.48-4.71 (m, 4H), 6.86 (d, *J* = 8.1 Hz, 1H), 7.17 (s, 1H), 7.32 (d, *J* = 8.3 Hz, 1H), 7.95 (s, 1H), 8.55 (s, 1H); ^{13}C NMR ($CDCl_3$, 62.9 MHz) δ -4.7 (q), -4.63 (q), 17.4 (q), 18.0 (s), 19.6 (q), 21.6 (q), 25.9 (q), 34.6 (d), 34.8 (t), 40.4 (t), 55.8 (q), 56.3 (q), 56.7 (q), 57.2 (q), 70.0 (d), 86.5 (d), 98.3 (t), 106.1 (d), 107.3 (d), 114.8 (s), 118.1 (d), 119.5 (s), 122.1 (s), 122.5 (d), 122.8 (s), 124.7 (s), 127.4 (s), 130.8 (d), 139.8 (s), 142.2 (s), 153.1 (s), 156.3 (s), 157.3 (s), 160.6 (s).

(±)-4-[[[(2*R,3*S**,4*S**)-4-(*tert*-Butyldimethylsiloxy)-3-(methoxymethoxy)-2-methylpentyl]sulfonyl]methyl]-1,10,12-trimethoxy-8-methyl-6*H*-benzo[*d*]naphtho[1,2,*b*]pyran-6-one (26).** To a solution of 16.8 mg (25 mmol) of sulfide **25** in 250 mL of chloroform was added 10.5 mg (125 mmol) of sodium bicarbonate followed by a solution of 12.5 mg (62.5 μmol) of *m*-chloroperbenzoic acid in 250 μL of chloroform. The resulting solution was warmed to room temperature and stirred for 3h, then directly chromatographed over 6 g of silica gel (eluted with chloroform-diethyl ether, 30:1) to afford 15.0 mg (85%) of the sulfone **26** as a yellow green oil. The oil crystallized on standing to afford a yellow green solid: mp 192-195 °C; IR (neat) 2990, 2970, 1750, 1720 cm^{-1}; ^1H NMR ($CDCl_3$, 300 MHz) δ 0.04 (s, 3H), 0.06 (s, 3H), 0.88 (s, 9H), 1.10 (d, *J* = 6.3 Hz, 3H), 1.31 (d, *J* = 6.8 Hz, 3H), 2.50 (s, 3H), 2.45-2.6 (m, 1H), 3.07 (dd, *J* = 13.9, 9.8 Hz, 1H), 3.18 (dd, *J* = 6.6, 3.7 Hz, 1H), 3.33 (s, 3H), 3.53 (d, *J* = 13.9 Hz, 1H), 3.91 (qu, *J* = 6.4 Hz, 1H), 4.00 (s, 6H), 4.06 (s, 3H), 4.54 (d, *J* = 6.7 Hz, 1H), 4.75 (d, *J* = 6.7 Hz, 1H), 5.30 (d, *J* =13.5 Hz, 1H), 5.42 (d, *J* = 13.5 Hz, 1H), 6.97 (d, *J* = 8.3 Hz, 1H), 7.17 (s, 1H), 7.52 (d, *J* = 8.3 Hz, 1H), 7.90 (s, 1H), 8.55 (s, 1H); ^{13}C NMR ($CDCl_3$, 62.9 MHz) δ -4.7 (q), 17.9 (s), 19.3 (q), 19.6 (q), 21.6 (q), 25.8 (q), 28.7 (d), 29.0 (s), 55.2 (t), 55.8 (q), 56.3 (q), 56.5 (q), 57.2 (q), 61.8 (t), 70.2 (d), 87.2 (d), 98.5 (t), 106.2 (d), 107.4 (d), 114.8 (s), 115.2 (s), 118.4 (d), 119.2 (s), 122.0 (s), 122.4 (d), 122.6 (s), 125.4 (s), 135.2 (d), 140.1 (s), 141.6 (s), 153.3 (s), 157.4 (s), 157.9 (s), 160.4 (s); $C_{22}H_{18}O_6Si$ (M-324) *m/e* 378.1085, *m/e* found 378.1094 (corresponds to aldehyde **17**).

4,8-Dimethoxy-1-naphthol, *p*-toluenesulfonate (32). To a solution of 1.00 g (4.9 mmol) of naphthol **31** in 20 mL of acetone at rt was added 6.76 g (49 mmol) of K_2CO_3 and 650 mg (3.18 mmol) of *p*-toluenesulfonyl chloride in one portion. The resulting mixture was heated under reflux for 0.5 h, and an additional 650 mg (3.18 mmol) of *p*-toluenesulfonyl chloride was added. The slurry was then heated under reflux for 8 h, cooled to rt, and filtered. The filter cake was rinsed with 50 mL of acetone, and the filtrate was washed with 100 mL of 10% citric acid, 100 mL of water and 100 mL of brine. The resulting organic phase was dried ($MgSO_4$) and concentrated in vacuo. The residue was chromatographed over 50 g of silica gel (eluted with petroleum ether-EtOAc-CH_2Cl_2, 10:1:1) to afford 1.34 g (82%) of tosylate **32** as white needles: mp 109-110 °C; IR (neat) 3000, 2955, 1599 cm^{-1}; ^1H NMR ($CDCl_3$) δ 2.40 (s, 3H), 3.86 (s, 3H), 3.94 (s, 3H), 6.60 (d, *J* = 8.5 Hz, 1H), 6.85 (m, 2H), 7.26 (d, *J* = 8.8 Hz, 2H), 7.35 (t, *J* = 8.5 Hz, 1H), 7.71 (d, *J* = 8.8 Hz, 2H), 7.81 (d, *J* = 8.5 Hz, 1H);

^{13}C NMR ($CDCl_3$) δ 21.6 (q), 55.5 (q), 55.7 (q), 103.1 (d), 107.3 (d), 114.3 (d), 119.4 (d), 120.2 (s), 126.2 (d), 128.2 (s), 128.4 (d), 129.3 (d), 134.0 (s), 138.6 (s), 144.5 (s), 154.1 (s), 155.3 (s); exact mass calcd. for $C_{19}H_{18}O_5S$ *m/e* 358.0874, found *m/e* 358.0874. Anal. calcd. for $C_{19}H_{18}O_5S$: C, 63.68; H, 5.06; found C, 63.45; H, 5.07.

5-Hydroxy-4,8-dimethoxy-1-naphthaldehyde, *p*-toluenesulfonate (33). To a 0 °C solution of 3.00 g (8.4 mmol) of tosylate **32** in 100 mL of CH_2Cl_2 was added 792 μL (958 mg, 8.4 mmol) of α,α-dichloromethyl methyl ether followed 5 min later by 2.30 mL (21.0 mmol) of titanium tetrachloride. The deep red solution was stirred for 1.5 h and then slowly poured into 300 mL of 5% aqueous hydrochloric acid. After stirring 10 min the layers were separated and the aqueous phase was extracted with two 100-mL portions of CH_2Cl_2. The combined organic phases were washed with two 200-mL portions of brine, dried ($MgSO_4$), and concentrated in vacuo. The crude solid was recrystallized from petroleum ether-EtOAc (2:1) to afford 1.19 g (93%) of aldehyde **33** as red needles: mp 172-174 °C, IR (neat) 3015, 2937, 1668 cm^{-1}; ^1H NMR ($CDCl_3$) δ 2.40 (s, 3H), 3.88 (s, 3H), 3.94 (s, 3H), 6.75-6.89 (m, 3H), 7.24-7.27 (m, 2H), 7.66-7.69 (m, 2H), 7.87 (d, *J* = 8.3, 1H), 10.82 (s, 1H); ^{13}C NMR ($CDCl_3$) δ 21.5 (q), 55.7 (q), 55.9 (q), 106.1 (d), 106.3 (d), 120.4 (d), 120.5 (s), 126.3 (s), 127.7 (s), 128.3 (d), 129.4 (d), 129.9 (d), 133.6 (s), 139.3 (s), 144.8 (s), 154.9 (s), 159.2 (s), 193.6 (d); exact mass calcd. for $C_{20}H_{18}O_6S$ *m/e* 386.0824, found *m/e* 386.0824. Anal. calcd. for $C_{20}H_{18}O_6S$: C, 62.17; H, 4.69; found C, 62.09; H 4.72.

5-(Hydroxymethyl)-4,8-dimethoxy-1-naphthol, 1-*p*-toluenesulfonate (34). To a slurry of 1.33 g (3.44 mmol) of aldehyde **33** in 43 mL of 5:1 THF-water, was added 650 mg (10.3 mmol) of sodium cyanoborohydride, a spatula tipfull of bromocresol green, and two drops of 5% aqueous hydrochloric acid such that the blue solution turned yellow. The resulting solution was stirred for 4h with additional 5% HCl being added as needed to maintain the yellow color. The reaction mixture was diluted with 100 mL of CH_2Cl_2, and washed with two 75-mL portions of water. The organic phase was dried ($MgSO_4$), and concentrated in vacuo to afford 1.53 g (98%) of crude **34**. This material was suitable for use in subsequent reactions without further purification. However, in a separate experiment, an analytical sample was prepared by chromatography over 50 g of silical gel (eluted with petroleum ether-EtOAc, 1:1) followed by recrystallization from ethanol to afford a cream colored solid: mp 129.5-130.5 °C; IR (neat) 3416 (broad), 2990, 1600 cm^{-1}; ^1H NMR ($CDCl_3$) δ 2.40 (s, 3H), 2.92 (bs, 1H), 3.82 (s, 3H), 3.92 (s, 3H), 4.94 (bs, 2H), 6.72-6.78 (m, 2H), 6.82 (d, *J* = 8.5 Hz, 1H), 7.24 (m, 2H), 7.34 (d, *J* = 8.3 Hz, 1H), 7.68 (m, 2H); ^{13}C NMR ($CDCl_3$) δ 21.6 (q), 55.6 (q), 55.2 (q), 67.0 (t), 105.5 (d), 106.7 (d), 119.7 (d), 121.8 (s), 126.7 (s), 128.4 (d), 128.7 (s), 129.4 (d), 129.8 (d), 133.9 (s), 139.7 (s), 144.6 (s), 154.8 (s), 155.5 (s); exact mass calcd. for $C_{20}H_{20}O_6S$ 388.0981 *m/e*, found *m/e* 388.0992. Anal. calcd. for $C_{20}H_{20}O_6S$: C, 61.84; H, 5.19; found C, 61.67; H, 5.18.

5-(Bromomethyl)-4,8-dimethoxy-1-naphthol, *p*-toluenesulfonate (35). To a solution of 1.53 g (3.94 mmol) of alcohol **34** in 39 mL of benzene was added 2.13 mL (3.17 g, 11.8 mmol) of PBr_3 in one portion. The resulting solution was stirred for 3h at rt, diluted with 100 mL of CH_2Cl_2, washed with two 50-mL portions of water, and 100 mL of brine. The organic phase was dried ($MgSO_4$) and concentrated in vacuo to afford 1.51 g (85%) of bromide **35** as a gray solid which was suitable for use in subsequent reactions without further purification: mp 124-127 °C (decomp); IR (neat) 3045, 2935, 2842, 1597, 1522 cm^{-1}; ^1H NMR ($CDCl_3$) δ 2.41 (s, 3H), 3.82 (s, 3H), 3.97 (s, 3H), 5.18 (s, 2H), 6.72-6.86 (m, 3H), 7.26 (m, 2H), 7.35 (d, *J* = 8.1 Hz, 1H), 7.69 (m, 2H); ^{13}C NMR ($CDCl_3$) δ 21.7 (q), 38.2 (t), 55.6 (q), 55.9 (q), 105.9 (d), 106.6 (d), 120.3 (d), 121.9 (s), 125.89 (s),

125.95 (s), 128.4 (d), 129.4 (d), 131.8 (d), 133.9 (s), 139.2 (s), 144.6 (s), 155.7 (s), 156.4 (s); exact mass calcd. for $C_{20}H_{19}O_5S^{79}Br$ *m/e* 450.0137, found *m/e* 450.0165.

(±)-5-[[[(2R*,3S*,4S*)-4-(*tert*-Butyldimethylsiloxy)-3-(methoxymethoxy)-2-methylpentyl]thio]methyl]-4,8-dimethoxy-1-naphthol, *p*-toluenesulfonate (36). To a slurry of 2.06 g of bromide **35** in 7 mL of degassed PhH was added 1.41 g (4.58 mmol) of thiol **20**. To the resulting slurry was added 705 mg (4.58 mmol) of DBU dropwise over 2 min. The resulting thick slurry was stirred for 5 min, diluted with 4 mL of PhH, and filtered. The filter cake was rinsed with 5 mL of PhH and the combined filtrate and washings were concentrated in vacuo to afford 2.57 g (83%) of sulfide **36** as a red oil. Although this material was suitable for use in further reactions without purification, an analytical sample was prepared by chromatography of a 300 mg sample over 20 g of silica gel (eluted with petroleum ether-EtOAc, 5:1): IR (neat) 2930, 1598, 1521, cm^{-1}; ^1H NMR ($CDCl_3$) δ 0.37 (s, 3H), 0.46 (s, 3H), 0.87 (s, 9H), 1.04 (d, *J* = 6.8 Hz, 3H), 1.08 (d, *J* = 6.3 Hz, 3H), 1.88-1.91 (m, 1H), 2.27 (dd, *J* = 12.6, 9.3 Hz, 1H), 2.42 (s, 3H), 2.73 (dd, *J* = 12.6, 3.4 Hz, 1H), 3.14 (t, *J* = 5.5 Hz, 1H), 3.31 (s, 3H), 3.83 (s, 3H), 3.91 (s, 3H), 3.85-3.95 (m, 1H), 4.12 (d, *J* = 13.3 Hz, 1H), 4.34 (d, *J* = 13.3 Hz, 1H), 4.55 (d, *J* = 6.7 Hz, 1H), 4.65 (d, *J* = 6.5 Hz, 1H), 6.64-6.72 (m, 3H), 7.1 (d, *J* = 8.5, 1H), 7.23-7.27 (m, 2H), 7.67-7.70 (d, *J* = 8.6, 2H); ^{13}C NMR ($CDCl_3$) δ -4.8 (q), -4.6 (q), 17.3 (q), 17.9 (s), 19.3 (q), 21.6 (q), 25.8 (q), 34.5 (t), 34.5 (d), 39.7 (t), 55.5 (q), 55.7 (q), 55.8 (q), 69.9 (d), 86.2 (d), 98.1 (t), 105.2 (d), 106.2 (d), 119.8 (d), 122.2 (s), 126.27 (s), 127.33 (s), 128.4 (d), 129.4 (d), 129.4 (d), 134.1 (s), 139.1 (s), 144.4 (s), 154.9 (s), 156.1 (s); exact mass calcd. for $C_{34}H_{50}O_8S_2Si$ *m/e* 678.2716, found *m/e* 678.2744.

(±)-5-[[[(2R*,3S*,4S*)-4-(*tert*-Butyldimethylsiloxy)-3-(methoxymethoxy)-2-methylpentyl]sulfonyl]methyl]-4,8-dimethoxy-1-naphthol, *p*-toluenesulfonate (37). To a solution of 2.54 g (3.75 mmol) of sulfide **36** at 0 °C in 100 mL of CH_2Cl_2 was added 1.58 g (18.75 mmol) of $NaHCO_3$ followed by 1.61 g (9.37 mmol) of 75% *m*-chloroperoxybenzoic acid (by iodometric titration) in one portion. The resulting slurry was stirred for 6h and then treated with 100 mL of saturated aqueous sodium thiosulfate. The mixture was vigorously stirred 45 min, the layers were separated, and the aqueous phase was extracted with three 200-mL portions of CH_2Cl_2. The combined organic layers were washed with 200 mL of saturated aqueous $NaHCO_3$, 50 mL of brine, dried ($MgSO_4$) and concentrated in vacuo. The residue was chromatographed over 75 g of silica gel (eluted with petroleum ether-EtOAc, 3:1) to afford 2.52 g (94%) of the desired sulfone **37** as an oil: IR (neat) 2972, 1598, 1523 cm^{-1}; ^1H NMR ($CDCl_3$) δ -0.08 (s, 3H), 0.06 (s, 3H), 0.85 (s, 9H), 1.04 (d, *J* = 6.3 Hz, 3H), 1.24 (d, *J* = 6.7 Hz, 3H), 2.43 (s, 3H), 2.43-2.62 (m, 1H), 2.61 (m, 1H), 3.08-3.16 (m, 2H), 3.25 (s, 3H), 3.73 (m, 1H), 3.85 (s, 3H), 3.97 (s, 3H), 4.47 (d, *J* = 6.6 Hz), 4.63 (d, *J* = 6.6 Hz, 1H), 5.07 (m, 2H), 6.72-6.86 (m, 3H), 7.27 (d, *J* = 7.8 Hz, 2H), 7.38 (d, *J* = 8.3 Hz, 1H), 7.69 (m, 2H); ^{13}C NMR ($CDCl_3$) δ -4.8 (q), -4.7 (q), 17.9 (s), 19.1 (q, 2 carbons), 21.6 (q), 25.8 (q), 28.5 (d), 53.6 (t), 55.6 (q), 55.7 (q), 55.8 (q), 61.9 (t), 69.8 (d), 86.3 (d), 98.1 (t), 105.9 (d), 106.6 (d), 116.2 (s), 120.2 (d), 121.9 (s), 126.7 (s), 128.39 (d), 129.44 (d), 133.5 (d), 133.9 (s), 139.4 (s), 144.0 (s), 155.3 (s), 156.5 (s).

(±)-5-[*trans*-(3R*,4R*,5R*)-5-(*tert*-Butyldimethylsiloxy)-4-(methoxymethoxy)-3-methyl-1-hexen-1-yl]-4,8-dimethoxy-1-naphthol, *p*-toluenesulfonate (38). To a solution of 2.52 g (3.54 mmol) of sulfone **37** in a mixture of 49 mL of *tert*-butanol and 120 mL of carbon tetrachloride was added 11.9 g (212 mmol) of freshly ground KOH. The resulting exothermic reaction attained a temperature of 38 °C with SO_2 being evolved over a 5h period. The resulting dark

brown solution was diluted with 600 mL of ether and washed with three 250-mL portions of water. The ether layer was washed with 200 mL of brine, dried ($MgSO_4$), and concentrated in vacuo. The residue was chromatographed over 75 g of silica gel (eluted with petroleum ether-EtOAc, 2:1) to afford 1.57 g (69%) of the E-alkene **38** as a colorless oil: IR (neat) 2930, 1594, 1519 cm^{-1}; ^1H NMR ($CDCl_3$) δ 0.66 (s, 6H), 0.90 (s, 9H), 1.19-1.24 (m, 6H), 2.42 (s, 3H), 2.65 (m, 1H), 3.29 (dd, *J* = 3.8, 6.8, 1H), 3.41 (s, 3H), 3.83 (s, 3H), 3.85 (s, 3H), 3.90-3.95 (m, 1H), 4.67 (d, *J* = 6.7, 1H), 4.84 (d, *J* = 6.7, 1H), 5.74 (dd, *J* = 15.4, 8.7, 1H), 6.63 (d, *J* = 8.6, 1H), 6.77-6.81 (m, 2H), 7.24-7.29 (m, 4H), 7.69-7.72 (m, 2H); ^{13}C NMR ($CDCl_3$) δ -4.64 (q, 2 carbons), 17.98 (s), 19.27 (q), 19.90 (q), 21.60 (q), 25.87 (q), 29.65 (s), 38.46 (d), 55.61 (q), 55.88 (q), 70.95 (d), 86.91 (d), 98.52 (t), 104.86 (d), 107.26 (d), 119.58 (d), 121.01 (s), 126.19 (s), 127.75 (d), 128.42 (d), 129.26 (s), 129.36 (s), 130.22 (d), 133.61 (d), 134.04 (s), 138.98 (s), 144.46 (s), 154.59 (s), 156.30 (s); exact mass calcd. for $C_{34}H_{48}O_8SSi$ *m/e* 644.2839, found *m/e* 644.2834. Anal. calcd. for $C_{34}H_{48}O_8SSi$ C, 63.32; H, 7.50; found C, 63.12; H, 7.50.

(±)-5-[(3*R,4*R**,5*R**)-*trans*-5-Hydroxy-4-(methoxymethoxy)-3-methyl-1-hexen-1-yl]-4,8-dimethoxy-1-naphthol, 1-*p*-toluenesulfonate (39).** To a solution of 100 mg (155 mmol) of *trans* olefin **38** in 500 mL of THF at rt was added 1.55 mL of a 1 M solution (1.55 mmol) of tetra-*n*-butylammonium fluoride in THF. The reaction mixture was stirred for 24 h at rt, diluted with 25 mL of CH_2Cl_2, and washed with three 10-mL portions of water. The organic residue was dried ($MgSO_4$), and concentrated in vacuo. The oily residue was chromatographed over 10 g of silica gel (eluted with petroleum ether-EtOAc, 1:1) to afford 76 mg (92%) of the desired alcohol **39** as an oil: IR (neat) 3452 (broad), 2964, 2842, 1593, 1519 cm^{-1}; ^1H NMR ($CDCl_3$) δ 1.19-2.25 (m, 6H), 2.42 (s, 3H), 2.61-2.67 (m, 1H), 3.22 (dd, *J* = 7.1, 2.3 Hz, 1H), 3.45 (s, 3H), 3.83 (s, 3H), 3.86 (s, 3H), 3.79-3.87 (m, 1H), 4.71 (d, *J* = 6.6 Hz, 1H), 4.83 (d, *J* = 6.6 Hz, 1H), 5.66 (dd, *J* = 15.5, 8.7 Hz, 1H), 6.63 (d, *J* = 8.5 Hz, 1H), 6.76-6.80 (m, 2H), 7.25-7.32 (m, 4H), 7.70 (d, *J* = 8.3 Hz, 2H), the hydroxyl proton was not observed; ^{13}C NMR ($CDCl_3$) δ 18.32 (q), 18.91 (q), 21.49 (q), 39.28 (d), 55.53 (q, 2 carbons), 55.81 (q), 68.44 (d), 91.18 (d), 98.92 (t), 104.84 (d), 107.13 (d), 119.56 (d), 120.95 (s), 126.06 (s), 127.8 (d), 128.32 (d), 128.72 (d), 128.85 (s), 129.28 (d), 133.98 (s), 134.30 (d), 138.93 (s), 144.39 (s), 154.70 (s), 156.11 (s); exact mass calcd. for $C_{28}H_{34}O_8S$ *m/e* 531.2053, found *m/e* 531.2021.

(±)-5-[(2*R,3*S**,4*R**,5*S**,6*S**)-Tetrahydro-5-(methoxymethoxy)-4,6-dimethyl-3-(phenylselenyl)-2*H*-pyran-2-yl]-4,8-dimethoxy-1-naphthol, *p*-toluenesulfonate (40).** To a -78 °C solution of 890 mg (1.68 mmol) of compound **39** in 18 mL of CH_2Cl_2 was added 645 mg (3.36 mmol) of PhSeCl in one portion. The resulting orange solution was stirred at -78 °C for 2.5 h, diluted with 250 mL of CH_2Cl_2, and washed with 100 mL of saturated aqueous $NaHCO_3$. The aqueous phase was extracted with two 100-mL portions of CH_2Cl_2 and the combined organic phases were washed with 100 mL of brine, dried ($MgSO_4$), and concentrated in vacuo. The residue was chromatographed over 50 g of silica gel (eluted with petroleum ether-EtOAc, 3:2) to afford 920 mg (80%) of the selenide **40** as a colorless oil: IR (neat) 2934, 1599, 1523 cm^{-1}; ^1H NMR ($CDCl_3$) δ 1.25 (d, *J* = 6.5 Hz, 3H), 1.38 (d, *J* = 6.7 Hz, 3H), 1.98-2.07 (m, 1H), 2.38 (s, 3H), 3.28 (m, 1H), 3.45-3.50 (m, 1H), 3.47 (s, 3H), 3.76 (s, 3H), 3.72-3.83 (m, 1H), 3.88 (s, 3H), 4.74 (d, *J* = 6.9 Hz, 1H), 4.78 (d, *J* = 6.9 Hz, 1H), 6.10 (d, *J* = 10.8 Hz, 1H), 6.60 (d, *J* = 8.5 Hz, 1H), 6.70 (d, *J* = 8.7 Hz, 1H), 6.86-6.89 (m, 3H), 6.98-7.19 (m, 3H), 7.23 (m, 2H), 7.55 (d, *J* = 8.5 Hz, 1H), 7.67 (m, 2H); ^{13}C NMR ($CDCl_3$) δ 18.0 (q), 18.8 (q), 21.5 (q), 42.6 (d), 54.3 (d), 55.4 (q), 55.4 (q), 56.3 (q), 76.5

(d), 79.9 (d), 80.9 (d), 98.8 (t), 105.3 (d), 106.7 (d), 119.0 (d), 120.8 (s), 126.9 (d), 127.2 (s), 127.6 (d), 128.3 (d), 128.4 (d), 129.2 (d), 129.7 (s), 133.9 (s), 135.0 (d), 139.3 (s), 144.3 (s), 155 0 (s), 156.0 (s), one aromatic singlet was not observed; exact mass calcd. for $C_{34}H_{38}O_8S^{80}Se$ *m/e* 686.1453, found *m/e* 686.1455; exact mass calcd. for $C_{34}H_{38}O_8S^{78}Se$ *m/e* 684.1460, found *m/e* 684.1471.

(±)-5-[(2*R,5*R**,6*R**)-5,6-Dihydro-5-(methoxymethoxy)-4,6-dimethyl-2*H*-pyran-2-yl]-4,8-dimethoxy-1-naphthol, *p*-toluenesulfonate (41).** To a 0 °C solution of 910 mg (1.32 mmol) of selenide **40** in 12 mL of THF, was added 214 mg (2.69 mmol) of pyridine, followed 10 min later by 1.54 mL of 30% aqueous hydrogen peroxide. The resulting solution was stirred at ice bath temperature for 2h, warmed to rt, and stirred 8h. The reaction mixture was diluted with 150 mL of CH_2Cl_2 and washed with 75 mL of saturated aqueous $NaHCO_3$. The aqueous layer was extracted with two 150-mL portions of CH_2Cl_2, and the combined organic phases were dried ($MgSO_4$), and concentrated in vacuo. The residue was chromatographed over 40 g of silica gel (eluted with petroleum ether-EtOAc, 3:2) to afford 539 mg (77%) of glycal **41** as a white solid: mp 155-157 °C; IR (neat) 2990, 1598, 1499 cm^{-1}; ^1H NMR ($CDCl_3$) δ 1.39 (d, *J* = 6.5 Hz, 3H), 1.82 (t, *J* = 1.6 Hz, 3H), 2.42 (s, 3H), 3.46 (s, 3H), 3.63 (s, 1H), 3.78 (s, 3H), 3.88 (s, 3H), 3.8-4.0 (m, 1H), 4.80 (d, *J* = 6.7 Hz, 1H), 4.84 (d, *J* = 6.7 Hz, 1H), 5.82 (t, *J* = 1.5 Hz, 1H), 6.25 (s, 1H), 6.67 (d, 1H, *J* = 8.6 Hz), 6.8 (m, 2H), 7.25 (apparent d, 2H), 7.71 (d, *J* = 6.5 Hz, 2H), 7.80 (d, *J* = 8.5 Hz, 1H); ^{13}C NMR ($CDCl_3$) δ 17.2 (q), 20.8 (q), 21.5 (q), 55.3 (q), 55.5 (q), 56.0 (q), 73.7 (d), 75.5 (d, 2 carbons), 96.8 (t), 104.8 (d), 107.4 (d), 119.2 (d), 121.8 (s), 125.8 (s), 126.4 (d), 128.3 (d), 129.2 (d), 129.8 (s), 130.1 (s), 130.8 (d), 134.0 (d), 139.3 (s), 144.4 (s), 154.5 (s), 155.5 (s); Anal. calcd. for $C_{28}H_{32}O_8S$ C, 63.62; H, 6.10; found C, 63.45; H, 6.11.

(±)-4,8-Dimethoxy-5-[(2*R,3*R**,4*R**,5*R**,6*S**)-tetrahydro-3,4-dihydroxy-5-(methoxymethoxy)-4,6-dimethyl-2H-pyran-2-yl]-1-naphthol, *p*-toluenesulfonate (42).** To a solution of 539 mg (1.02 mmol) of glycal **41** in 15 mL of acetone was added 144 mg (1.12 mmol) of N-methylmorpholine-N-oxide followed by 1.54 mL of a 2% (by weight) solution of osmium tetraoxide in *tert*-butanol. The resulting solution was stirred at rt for 88h gradually becoming black. The resulting solution was diluted with 100 mL of CH_2Cl_2 and washed with 50 mL of water. The aqueous phase was extracted with three 100-mL portions of CH_2Cl_2 and the combined extracts were dried ($MgSO_4$) and concentrated in vacuo. The residue was chromatographed over 30 g of silica gel to afford 555 mg (97%) of diol **42** as a white solid: mp 170-172 °C; IR (neat) 3539 (broad), 3010, 2977, 1597, 1524 cm^{-1}; ^1H NMR ($CDCl_3$) δ 1.25 (d, *J* = 6.5 Hz, 3H), 1.46 (s, 3H), 2.08 (bs, 1H), 2.43 (s, 3H), 2.63 (bs, 1H), 3.37 (s, 1H), 3.49 (s, 3H), 3.68 (bd, *J* = 9.6 Hz, 1H), 3.82 (s, 3H), 3.95 (s, 3H), 4.27 (m, 1H), 4.75 (d, *J* = 6.8 Hz, 1H), 4.81 (d, *J* = 6.8 Hz, 1H) 6.01 (d, *J* = 9.5 Hz, 1H), 6.70 (d, *J* = 8.6 Hz, 1H), 6.81 (d, *J* = 8.6 Hz, 1H), 6.90 (d, *J* = 8.4 Hz, 1H), 7.2 (apparent d, 2H), 7.70 (d, *J* = 8.2 Hz, 2H), 7.87 (d, *J* = 8.5 Hz, 1H); ^{13}C NMR ($CDCl_3$) δ 17.1 (q), 21.5 (q), 23.5 (q), 55.6 (q), 55.7 (q), 56.6 (q), 71.7 (d), 73.6 (s), 74.5 (d), 76.2 (d), 83.7 (d), 99.0 (t), 105.7 (d), 107.5 (d), 119.0 (d), 121.1 (s), 127.0 (s), 127.5 (d), 128.3 (d), 128.6 (s), 129.3 (d), 133.9 (s), 139.9 (s), 144.4 (s), 154.8 (s), 155.2 (s); exact mass calcd. for $C_{28}H_{34}O_{10}S$ *m/e* 562.1873, found *m/e* 562.1884.

(±)-4,8-Dimethoxy-5-[(2*R,3*R**,4*S**,5*R**,6*S**)-tetrahydro-3,4,5-tris(methoxymethoxy)-4,6-dimethyl-2*H*-pyran-2-yl]-1-naphthol, *p*-toluenesulfonate (43).** To a solution of 555 mg (988 mmol) of C-aryl glycoside **42** in 2.4 mL of CH_2Cl_2 at 0 °C was added 474 mg (5.9 mmol) of chloromethyl methyl ether followed by 752 mg (5.9 mmol) of ethyldiisopropylamine in single portions. The resulting solution was stirred for 1h at 0 °C then 2h at rt,

diluted with 100 mL of CH_2Cl_2 and washed with 50 mL of water. The aqueous phase was extracted with three 100-mL portions of CH_2Cl_2, and the combined organic layers were washed with 50 mL of brine, dried ($MgSO_4$), and concentrated in vacuo. The residue was chromatographed over 30 g of silica gel (eluted with petroleum ether-EtOAc, 1:1) to afford 600 mg (94%) of the protected C-glycoside **43** as a colorless oil: IR (neat) 3054, 2985, 1654 cm^{-1}; ^1H NMR ($CDCl_3$) δ 1.27 (d, J = 6.6 Hz, 3H), 1.47 (s, 3H), 2.39 (s, 3H), 2.87 (s, 3H), 3.39-3.53 (m, 3H), 3.45 (s, 3H, OCH_3), 3.49 (s, 3H), 3.61 (d, J = 6.7 Hz, 1H), 3.79 (s, 3H), 3.92 (s, 3H), 4.39 (m, 1H), 4.75 (m, 3H), 5.16 (d, J = 6.9 Hz, 1H), 6.54 (d, J = 9.5 Hz, 1H), 6.69 (d, J = 8.6 Hz, 1H), 6.83 (d, J = 8.5 Hz, 1H), 6.91 (d, J = 8.6 Hz, 1H), 7.20 (m, 2H), 7.63 (m, 2H), 7.86 (d, J = 8.5 Hz, 1H); ^{13}C NMR ($CDCl_3$) δ 17.2 (q), 18.6 (q), 21.5 (q), 55.5 (q, 2 carbons), 55.7 (q), 55.9 (q) 56.6 (q), 70.8 (d), 73.1 (d), 78.9 (s), 83.7 (d), 84.9 (d), 92.2 (t), 97.5 (t), 99.0 (t), 105.6 (d), 107.0 (d), 119.3 (d), 120.7 (s), 127.6 (d, 2 carbons), 128.4 (d), 129.1 (d), 129.7 (s), 133.8 (s), 139.0 (s), 144.3 (s), 155.0 (s), 156.4 (s); exact mass calcd. for $C_{32}H_{42}O_{12}S$ *m/e* 650.2404, found *m/e* 650.2400.

(±)-4,8-Dimethoxy-5-[(2*R,3*R**,4*S**,5*R**,6*S**)-tetrahydro-3,4,5-tris(methoxymethoxy)-4,6-dimethyl-2*H*-pyran-2-yl]-1-naphthol (44).** To a solution of 275 mg (423 mmol) of the protected C-glycoside **43** in 7.5 mL of ice-cold degassed THF-MeOH (1:1) under argon was added 30 mg of $NaHPO_4$ in one portion. To the resulting buffered solution was added 3.09 g of 5.25% sodium amalgam in approximately 50-mg portions over a 2 h period. The reaction mixture was stirrred an additional 1.5 h at 0 °C and then diluted with 30 mL of chloroform and quenched with 25 mL of ice/water. The mixture was stirred for 20 min, the layers were separated, and the aqueous phase was extracted with one 25-mL portion of chloroform. The combined organic extracts were dried ($MgSO_4$), and concentrated in vacuo. The residue was chromatographed over 10 g of silica gel (eluted with petroleum ether-EtOAc, 1:1) to afford 188 mg (90%) of naphthol **44** as a colorless oil: IR (neat) 3450 broad, 2957, 1631 cm^{-1}; ^1H NMR ($CDCl_3$) δ 1.24 (d, J = 6.6 Hz, 3H), 1.44 (s, 3H), 2.87 (s, 3H), 3.42 (s, 3H), 3.43 (m, 2H), 3.45 (s, 3H), 3.49 (d, J = 6.6 Hz, 1H), 3.64 (d, J = 6.6 Hz, 1H), 3.84 (s, 3H), 3.96 (s, 3H), 4.37 (m, 1H), 4.73-4.79 (m, 3H), 5.14 (d, J = 7.1 Hz, 1H), 6.58 (d, J = 9.4 Hz, 1H), 6.71 (d, J = 8.5 Hz, 1H), 6.81 (d, J = 8.5 Hz, 2H), 7.81 (d, J = 8.4 Hz, 1H), 9.32 (s, 1H); ^{13}C NMR ($CDCl_3$) δ 17.2 (q), 18.6 (q), 55.5 (q), 55.8 (q), 56.1 (q), 56.5 (q), 56.6 (q), 70.7 (d), 73.0 (d), 78.8 (s), 83.7 (d), 84.9 (d), 92.2 (t), 97.4 (t), 99.0 (t), 104.8 (d), 109.3 (d), 110.3 (d), 115.9 (s), 126.4 (d), 126.6 (s), 131.4 (s), 148.7 (s), 150.4 (s), 155.5 (s); exact mass calcd. for $C_{25}H_{36}O_{10}$ *m/z* 496.2294, found *m/z* 496.2301.

(±)-4,4,8-Trimethoxy-5-[(2*R,3*R**,4*S**,5*R**,6*S**)-tetrahydro-3,4,5-tris(methoxymethoxy)-4,6-dimethyl-2*H*-pyran-2-yl]-1-(4*H*)-naphthalenone (45).** A solution of 188 mg (379 mmol) of naphthol **44** in 85 mL of 2% $LiClO_4$/MeOH was electrochemically oxidized at a Pt gauze electrode for 20 min at 0.02 amps, followed by 25 min at 0.1 Amp. The reaction mixture was diluted with 60 mL of CH_2Cl_2 and washed with 40 mL of saturated aqueous $NaHCO_3$. The aqueous layer was extracted with 50 mL of CH_2Cl_2 and the combined extracts were dried (Na_2SO_4) and concentrated in vacuo. The residue was chromatographed over 10 g of activity grade II neutral alumina (eluted with petroleum ether-EtOAc, 10:1, followed by 3:1) to afford 147 mg (74%) of the naphthoquinone monoacetal **45** as a light green solid: mp 127-130 °C ; IR (CH_2Cl_2) 3010, 2938, 1673 cm^{-1}; ^1H NMR ($CDCl_3$) δ 1.11 (d, J = 6.6 Hz, 3H), 1.47 (s, 3H), 2.94 (s, 3H), 3.06 (s, 3H), 3.08 (s, 3H), 3.35 (s, 3H), 3.38 (m, 1H), 3.41 (s, 3H), 3.83-3.87 (m, 1H), 3.87 (s, 3H), 4.10 (d, J = 6.6 Hz, 1H), 4.18 (d, J = 6.6 Hz, 1H), 4.28 (m, 1H), 4.66-4.75 (m, 3H), 5.15 (d, J = 6.9 Hz, 1H), 5.96 (d, J

= 10.0 Hz, 1H), 6.43 (d, *J* = 10.3 Hz, 1H), 6.50 (d, *J* = 10.3 Hz, 1H), 7.04 (d, *J* = 8.9 Hz, 1H), 7.84 (d, *J* = 8.9 Hz, 1H); ^{13}C NMR ($CDCl_3$) δ 17.2 (q), 19.0 (q), 51.1 (q), 51.5 (q), 55.3 (q), 56.1 (q), 56.15 (q), 56.6 (q), 70.7 (d), 71.4 (q), 78.5 (s), 80.8 (d), 84.3 (d), 92.1 (t), 97.5 (s), 97.8 (t), 99.1 (t), 113.0 (d), 121.4 (s), 132.2 (s), 133.5 (d), 135.9 (d), 140.1 (s), 142.1 (d), 159.8 (s), 184.2 (s); exact mass calcd. for $C_{26}H_{38}O_{11}$ *m/e* 526.2377, found *m/e* 526.2396.

(±)-3,4-Dihydro-4,4,8-trimethoxy-3-phenyl-5-[(2*R,3*R**,4*S**,5*R**,6*S**)-tetrahydro-3,4,5-tris(methoxymethoxy)-4,6-dimethyl-2*H*-pyran-2-yl]-1(2*H*)-naphthalenone (46).** To a -78 °C solution of 26.3 mg (50 μmol) of quinone monoketal **45** in 0.63 mL of degassed toluene under argon was added 0.63 mL (100 μmol) of a 0.16 M stock solution of MAD (prepared by adding 16 mL of a 2 M solution (32 mmol) of Me_3Al in toluene to a degassed solution of 14.1 g (64 mmol) of 2,6-di-*tert*-butyl-4-methylphenol in 184 mL of toluene at rt) dropwise over a 2 min period). The black solution of MAD-ketone complex was stirred 20 min at -78 °C, and then 65 μL (117 μmol) of a 1.8 M solution of phenyllithium in cyclohexane-ether (70:30) was added dropwise over 5 min imparting a light yellow color to the reaction mixture. The reaction mixture was stirred 20 min, quenched with 1 mL of water, and stirred 1 h. The resulting slurry was filtered through 1 g of Celite, and the filter cake was rinsed with 100 mL of CH_2Cl_2. The filtrate and washings were decanted from the aqueous phase and concentrated in vacuo. The residue was chromatographed over 5 g of silica gel (eluted with petroleum ether-EtOAc, 1:1) to afford 25.4 mg (84%) of the conjugate adduct **46** as a colorless oil: IR (neat) 2961, 1710, 1693, 1685 cm^{-1}; ^{1}H NMR ($CDCl_3$) δ 1.13 (d, *J* = 6.6 Hz, 3H), 1.46 (s, 3H), 2.90 (dd, *J* = 16.5, 4.7 Hz, 1H), 2.99 (s, 3H), 3.02 (s, 3H), 3.16 (dd, *J* = 17.8, 7.8 Hz, 1H), 3.30-3.40 (m, 1H), 3.33 (s, 3H), 3.39 (s, 3H), 3.46 (s, 3H), 3.59 (d, *J* = 7.0 Hz, 1H), 3.78 (d, *J* = 7.0 Hz, 1H), 3.80-3.88 (m, 2H), 3.90 (s, 3H), 4.22 (m, 1H), 4.61 (d, *J* = 6.8 Hz, 1H), 4.70 (d, *J* = 6.8 Hz, 1H), 4.75 (d, *J* = 6.8 Hz, 1H), 5.01 (d, *J* = 6.8 Hz, 1H), 6.0 (d, *J* = 9.8 Hz, 1H), 7.08 (d, *J* = 9.0 Hz, 1H), 7.12-7.16 (m, 5H), 7.76 (d, *J* = 9.0 Hz, 1H); ^{13}C NMR ($CDCl_3$) δ 17.1 (q), 18.8 (q), 43.6 (t), 45.0 (d), 48.7 (q), 50.0 (q), 55.3 (q), 55.9 (q), 56.1 (q), 56.6 (q), 70.7 (d), 71.6 (d), 78.5 (s), 80.5 (d), 83.9 (d), 92.1 (t), 96.8 (t), 99.0 (t), 104.1 (s), 112.6 (d), 123.7 (s), 126.5 (d), 127.9 (d), 129.2 (d), 131.7 (s), 134.8 (d), 140.3 (s), 140.7 (s), 157.7 (s), 197.0 (s); exact mass calcd. for $C_{32}H_{44}O_{11}$ *m/e* 604.2883, found *m/e* 604.2882.

(±)-3-[2-(4,5-Dihydro-4,4-dimethyl-2-oxazolyl)-6-methoxy-4-methylphenyl]-3,4-dihydro-4,4,8-trimethoxy-5-[(2R*,3R*,4S*,5R*,6S*)-tetrahydro-3,4,5-tris(methoxymethoxy)-4,6-dimethyl-2*H*-pyran-2-yl]-1(2*H*)-naphthalenone (47). A stock solution of MAD was prepared by adding 16 mL (32.0 mmol) of a 2 M solution of trimethylaluminum in toluene to a solution of 14.08 g (64.0 mmol) of 2,6-di-*tert*-butyl-4-methylphenol in 184 mL of toluene. The resulting water-white solution was stirred for 2 h. A stock solution of the lithiated oxazoline was prepared by treating a solution of 219 mg (1.0 mmol) of 2-(3-methoxy-5-methylphenyl)-4,4-dimethyl-Δ^2-oxazoline in 5.4 mL of THF -45 °C with 637 μL (1.02 mmol) of a 1.6 M solution of *n*-butyllithium added dropwise over 10 min. The resulting orange-red lithiated oxazoline solution was stirred for 2 h at -45 to -50 °C. Meanwhile a solution of 20 mg (38 μmol) of naphthaleneone **45** in 500 μL of toluene was cooled to -78 °C to which was slowly added 590 μL (87.4 μmol) of 0.16 M MAD in toluene. The dark brown solution was stirred for 25 min, before 611 μL (87.4 μmol) of the 0.143 M oxazoline stock solution was added dropwise. By the end of the addition, the solution had become reddish-brown. The reaction was stirred for 15 min at -78 °C and then quenched with 1 mL of water. The resulting slurry was stirred for 30 min and the aqueous layer was extracted with three 2-mL portions of CH_2Cl_2. The combined organic phases were dried ($MgSO_4$) and concentrated in vacuo. The residue was

chromatographed over 750 mg of silica gel (eluted with petroleum ether-EtOAc, 1:2) to afford 8.0 mg (29%) of **47** as a yellow oil: IR (neat) 2950, 1695 cm^{-1}; ^1H NMR ($CDCl_3$) δ 1.08 (d, J = 6.6 Hz, 3H), 1.41 (s, 3H), 1.44 (s, 3H), 1.49 (s, 3H), 2.31 (s, 3H), 2.73 (dd, J = 17.1, 6.2 Hz, 1H), 2.74 (s, 3H), 2.93 (s, 3H), 3.05 (dd, J = 17.1, 11.4 Hz, 1H), 3.08 (s, 3H), 3.09 (s, 3H), 3.27 (s, 3H), 3.32 (s, 1H), 3.78 (d, J = 10.6 Hz, 1H), 3.44 (s, 3H), 3.84 (s, 3H), 3.95-4.15 (m, 5H), 4.47 (dd, J = 11.4, 6.2 Hz, 1H), 4.58 (d, J = 4.6 Hz, 1H), 4.65 (d, J = 5.3 Hz, 1H), 4.72 (d, J = 5.3 Hz, 1H), 5.03 (d, J = 4.6 Hz, 1H), 6.15 (d, J = 10.6 Hz, 1H), 6.55 (s, 1H), 6.98 (d, J = 7.5 Hz), 7.02 (s, 1H), 7.73 (d, J = 7.5 Hz, 1H); ^{13}C NMR ($CDCl_3$, 75.5 MHz) δ 17.0 (q), 19.1 (q), 21.0 (q), 28.1 (q), 30.2 (q), 42.2 (d), 43.2 (t), 48.0 (q), 49.1 (q), 54.5 (q), 55.2 (q), 55.9 (q), 56.4 (q), 56.6 (q), 67.7 (s), 70.5 (d), 71.0 (d), 78.9 (s), 79.2 (t), 81.7 (d), 84.0 (d), 92.0 (t), 97.9 (t), 99.0 (t), 104.2 (s), 110.1 (d), 112.7 (d), 121.9 (d), 124.6 (s), 130.4 (s), 130.7 (s), 133.6 (d), 137.8 (s), 144.0 (s), 154.9 (s), 158.1 (s), 163.5 (s), 198.8 (s), one aromatic singlet was not observed; exact mass calcd. for $C_{39}H_{53}NO_{13}$ (M-1) *m/e* 743.3601, found *m/e* 743.3559.

Acknowledgements. We thank Dr. Kurt Loening for help with nomenclature and Dr. John Swenton for helpful discussions.

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(*Received in USA* 14 *May* 1996; *revised* 25 *June* 1996; *accepted* 23 *September* 1996)