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Di- and tetrahydropyrans with orthogonally protected hydroxymethyl side chains: a synthetic route and the structure elucidation of an unexpected acetal cleavage product

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Abstract—A synthesis of dihydropyrans with orthogonally protected hydroxymethyl side chains is presented in this contribution. Key steps of the synthesis are the regioselective epoxide opening using vinyl cuprate reagents, selective protection of primary alcohols and ring closing metathesis. A strategy based on the intermediate formation of a rigid bicyclic acetal turned out to be unsuccessful due to the unexpected formation of an annellated furanopyran rearrangement product **6**. Elucidation of the structure was achieved using one- and two-dimensional NMR-methods. © 2002 Elsevier Science Ltd. All rights reserved.

1. Introduction

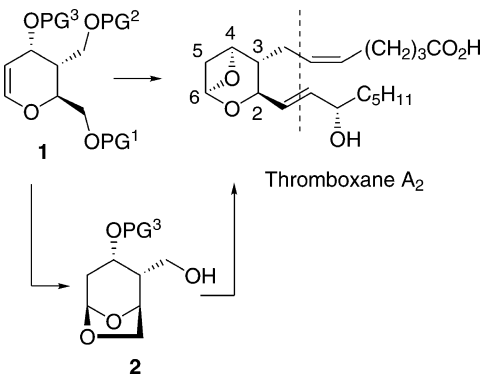
The synthesis of di- and tetrahydropyrans with two adjacent hydroxymethyl side chains has attracted some interest in natural products chemistry and especially in carbohydrate chemistry. For example, pyranoses containing a substituent at the C4 position have been used as building blocks for bridged disaccharides,[1–4] 1-methyl-carbapenems[5,6] and nucleoside analogues.[7] Fried et al. investigated the use of glycosides containing an alkoxymethyl side chain in the C4-position for the synthesis of analogues of thromboxanes.[8,9] Apart from the thromboxanes,[10] there is a variety of other interesting target molecules containing a tetrahydropyran core with two different adjacent functionalized side chains, e.g. phospholine,[11] the leustroducsins[12] and pironetin.[13] The structural pattern in question and its synthetic challenge is outlined in Scheme 1 for thromboxane A_2: a cyclic enol ether such as **1** would be ideally suited as a starting material for thromboxanes and structurally related compounds. If the three protecting groups PG^{1-3} are orthogonal, subsequent removal of PG^1 and PG^2, followed by elaboration of the side chain, should be possible. If PG^1 and PG^2 are non-orthogonal protecting groups, a differentiation of the hydroxymethyl side chains might be achieved by deprotection of both primary alcohols and conversion of the deprotected intermediate to the rigid bicyclic acetal **2**. Related approaches start from levoglucosane which is converted to intermediates with C4 side chains.[10,14]

In this contribution we describe approaches to dihydropyrans with differentiated hydroxymethyl side chains. These are based on concepts for the synthesis of densely functionalized di- and tetrahydropyrans developed over the past few years in our laboratory.[15]

2. Results and discussion

2.1. Investigation of the rigid bicyclic acetal pathway

We have previously described the acetal protected cyclic enol ether **4**, which is available from epoxide **3** in five steps.[15] Following the concept outlined above, we planned to use **4** as a precursor for **2**. For this purpose, the hydroxy functionality in **4** was protected as an allyl ether **5a**, which was then treated with methanol and *p*-TSA to deprotect the



Scheme 1.

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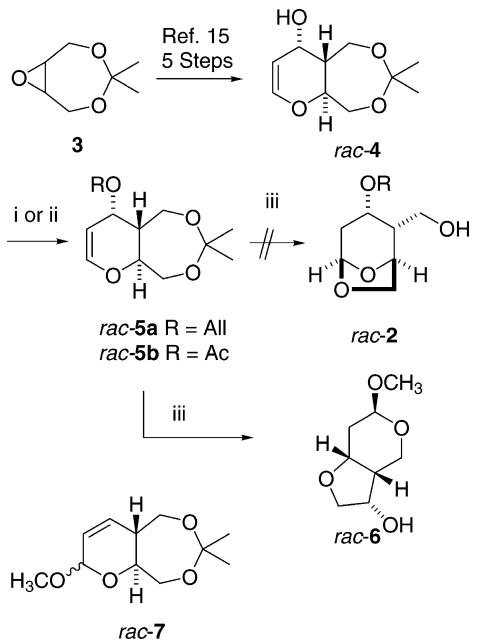


Scheme 2. (i) NaH, allyl bromide, THF, 65°C (71%); (ii) Ac_2O, NEt_3, DMAP, DCM, 0°C (57%); (iii) MeOH, *p*-TSA, DCM (61%).

primary alcohols. Under the same conditions, we hoped to achieve an intramolecular acetalization giving the desired bicyclic acetal **2** (Scheme 2).

From the reaction mixture a single product was isolated in fair yield, which, however, obviously was not the bicyclic acetal **2**. All signals for the allyloxy moiety are missing in the NMR-spectra, instead 1 equiv. of methanol was incorporated into the molecule. Additionally, for a bicyclic acetal such as **2** a δ_H value for the acetal proton of approximately 5.5 ppm has to be expected.[16] We observed a δ_H value of 4.63 ppm, which, together with a δ_C value of 98.3 ppm is indicative for the presence of a methyl acetal moiety. The combined use of H,H-correlation spectroscopy, H,C-correlation spectroscopy and H,C-long range correlation spectroscopy unrevealed the presence of a secondary alcohol and two $-CH_2O-$ moieties (^2J values of 12.2 and 9.5 Hz). The value of 12.2 Hz is indicative for a tetrahydropyran system, while a value of 9.5 Hz suggests the presence of a tetrahydrofuran ring. From the spectroscopical information and the HRMS data, we conclude that the product has a furanopyran structure **6**.

The relative configuration of **6** was elucidated by selective 1D NOE-experiments using shaped pulses and pulsed field gradients. H5 shows NOE effects to both protons H6 and

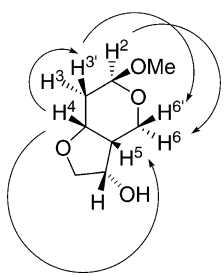
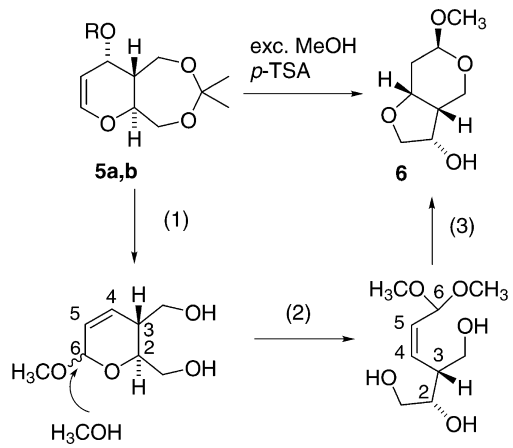


Figure 1. Selected NOE-interactions in **6**.



Scheme 3. Mechanistic proposal for the formation of **6**.

H6′, to H4 and to the C*H*OH signal. This is indicative for the assigned relative configuration, where H4, H5 and C*H*OH are on the same face of the molecule. A weak interaction between H2 and H6 suggests the relative configuration at C2. Important NOE interactions are summarized in Fig. 1, where the numbering scheme used here is illustrated.

Obviously, the allyloxy group serves as a leaving group in this case, thus, a similar outcome should be observed if the allyl moiety in **5a** is substituted by an acetyl group as in **5b**. Indeed, the same rearrangement product **6** results from **5b** upon treatment with methanol and *p*-TSA. In this experiment, a very small amount of a methyl acetal **7** was isolated, resulting from a Ferrier rearrangement.[17,18]

It is not clear whether **7** is an intermediate in the formation of **6** or a byproduct, however, based on this observation one possible mechanistic scenario could be the following (Scheme 3): in the first step, a Ferrier rearrangement and cleavage of the acetal occur (1), followed by cleavage of the methyl acetal ((2), attack of an additional equivalent of methanol at C6). Finally, an unsaturated oxocarbenium ion is formed by acid catalyzed abstraction of 1 equiv. of methanol, followed by formation of the C4–O bond and the C6–O bond (3).

2.2. The OBn/OTBS-protecting group combination

Starting from *Z*-butene-diol (**8**), the monoprotected alcohol **9**[19] was obtained following a procedure described in the literature for the corresponding *p*-bromobenzyl ether.[20] **9** was epoxidized with MCPBA to give the epoxide **10**,[21] which was converted to the homoallylic alcohol **11** in high regio- and diastereoselectivity by reaction with a cuprate reagent derived from vinyl magnesium chloride and copper iodide. If catalytic amounts of CuI are employed in the reaction, a complex mixture of products results, with the corresponding chlorohydrin being a major component. This finding is in contrast to observations recently reported by Jung et al. for a closely related reaction,[20] where a vinyl cuprate reagent derived from vinyl magnesium bromide and catalytic amounts of copper iodide was successfully used to prepare a homoallylic alcohol from the corresponding epoxide. In the next step, the primary alcohol in **11** had to be protected selectively with a protecting group orthogonal

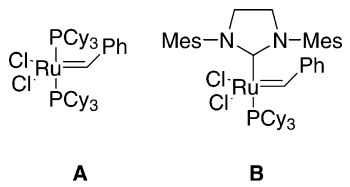
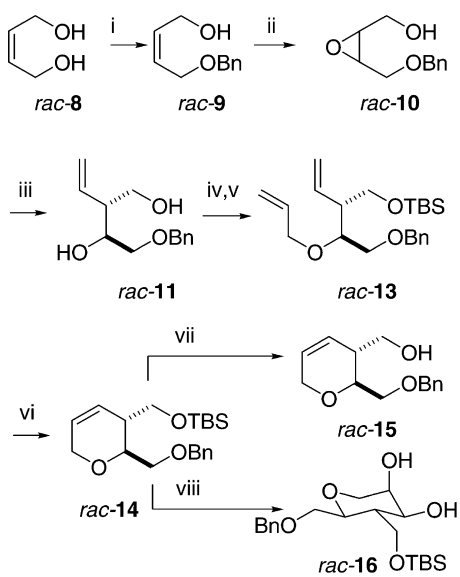
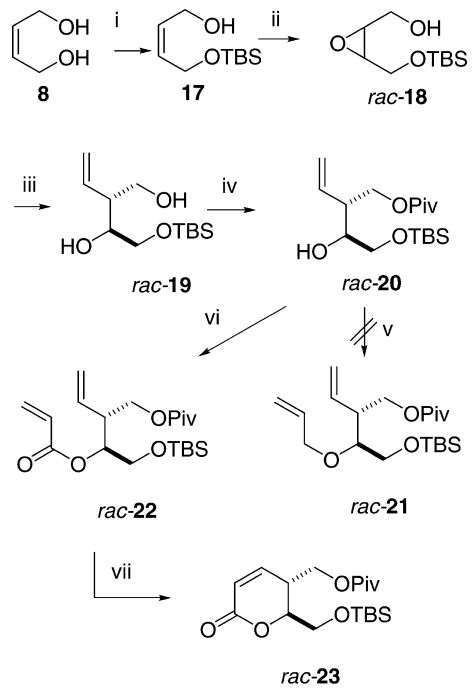


Figure 2. First (**A**) and second (**B**) generation Grubbs' catalyst.

to the benzyl group. Using the TBS group allows selective protection of the primary alcohol and selective deprotection. In the next step, allylation of the diprotected homoallylic alcohol **12** had to be achieved. It is known that TBS groups are often unstable at ambient temperature in the presence of strongly basic reagents such as NaH.[22] We were able to avoid any scrambling of protecting groups by conducting the allylation at 0°C using NaH and allyl bromide. Ring closing metathesis of the allylation product **13**, catalyzed by the ruthenium complex **A** (Fig. 2), is a facile process, leading to the dihydropyran **14**. At this step, we wanted to confirm the assumed location of the protecting groups in **14** (and hence the regioselectivity of the epoxide cleavage) by NMR-methods. Unfortunately, the NMR-spectra of **14** were not suited for this purpose due to overlapping signals in the ether region. To avoid this difficulty, the TBS group was cleaved off to leave the monoprotected dihydropyran **15** behind, which showed sufficiently separated signals in the ether region of the H NMR-spectrum to allow a complete signal assignment. NOE interactions between H4 and the CH_2OH moiety and a coupling between H3 and the CH_2OH substituent (observed in the H,H-COSY) are indicative for the location of the protecting groups. As an example for selective functionalization of the double bond in **14**, we investigated the osmium catalyzed dihydroxylation. Diol **16** is formed with a diastereomeric ratio of 7:1, the major diastereomer results from attack *trans* to the substituent at C3 (Scheme 4).



Scheme 4. (i) NaH, THF, benzyl bromide, 0°C (88%); (ii) MCPBA, DCM (88%); (iii) CuI, $H_2C{=}CHMgCl$, −40°C (66%); (iv) TBSCl, NEt_3, DMAP (76% of **12**); (v) NaH, allyl bromide, THF, 0°C (89%); (vi) **A** (3 mol%), DCM (97%); (vii) TBAF, THF (51%); (viii) $K_2Os(OH)_6$ (4.6 mol%), NMO (65%).



Scheme 5. (i) TBSCl, NEt_3, DCM (71%); (ii) $VO(acac)_2$ (5 mol%), *t*-BuOOH in decane, DCM, 40°C (87%); (iii) CuI, $H_2C{=}CHMgCl$, −40°C (68%); (iv) *t*-BuCOCl, NEt_3, DMAP, DCM (97%); (v) NaH, allyl bromide, THF, 0°C; (vi) $H_2C{=}CHCOCl$, NEt_3, DMAP, 0°C (80%); (vii) **B** (5 mol%), toluene, 110°C (84%).

2.3. The OTBS/OPiv protecting group combination

Monoprotected silyl ether **17**[23] was prepared from diol **8**. Epoxidation of **17** was achieved using catalytic amounts of $VO(acac)_2$ and *t*-butyl hydroperoxide to give **18**. This method appeared to be superior to the use of MCPBA in our hands. Epoxide opening with vinyl cuprate reagent gives the diol **19** in good yield and selectivity. The primary alcohol in **19** was selectively protected as a pivaloate. Unfortunately, attempted allylation under the conditions described above for the preparation of **13** did not give **21**. Instead, a complex mixture of products is formed, with two major products probably being the desired **21** and a regioisomer. Furthermore, products containing no pivaloate group appear to be present in the mixture. This observation is in accord with reports in the literature[24] that pivaloates might be cleaved in the presence of sodium alkoxides. Formation of the corresponding acrylate **22** from **20** proceeded smoothly in good yield. Ring closing metathesis of acrylates to unsaturated lactones has been investigated recently.[25–27] This process is not straightforward compared to the cyclization of simple allyl ethers, because inhibition of the catalyst by coordination will occur if the first generation Grubbs' catalyst is used.[28] This problem can be circumvented either by addition of a Lewis acid[29] or by using the second generation ruthenium catalyst **B** (Fig. 2).[30,31] Thus, in the presence of 5 mol% **B** the acrylate **22** was smoothly converted to the lactone **23** at elevated temperatures (Scheme 5). The location of the protecting groups in **23** was also checked using two-dimensional NMR-methods.

In conclusion, we have developed synthetic approaches to dihydropyrans with orthogonally protected hydroxymethyl side chains that are promising intermediates in the synthesis

of interesting target molecules containing the bishydroxymethyl di- or tetrahydropyran core. In the course of this project we discovered an interesting and unexpected rearrangement reaction and achieved the structural elucidation of the reaction product using modern one- and two-dimensional NMR-methods.

3. Experimental

3.1. General

All experiments were conducted in dry reaction vessels in an atmosphere of dry argon. Solvents were purified by standard procedures. ^{1}H NMR spectra were recorded at 200, 400, 500, or 600 MHz in $CDCl_3$ or C_6D_6 with $CHCl_3$ (δ=7.24) or C_6D_5H (δ=7.18) as internal standard. Coupling constants are given in Hz. ^{13}C NMR spectra were recorded at 50, 100, 125 or 150 MHz in $CDCl_3$ or C_6D_6 with $CDCl_3$ (δ=77.0 ppm) or C_6D_6 (δ=128.0 ppm) as internal standard. The number of coupled protons was analyzed by DEPT or APT experiments and is denoted by a number in parentheses following the δ_C value. Signal assignment for cyclic products follows a numbering scheme where the oxygen atom is numbered 1 and the α-carbon atom bearing a substituent C2 (see Scheme 1). Selective 1D NOE experiments were conducted using shaped pulses and pulsed field gradients at 600 MHz with a mixing time of 800 ms. 2D NOESY-spectra were obtained at 500 MHz with a mixing time of 1.5 s. IR spectra were recorded as films on NaCl or KBr plates. The peak intensities are defined as strong (s), medium (m) and weak (w). Mass spectra were obtained at 70 eV. References for known compounds are given with the experimental procedures. The ruthenium catalyst $Cl_2(Cy_3P)_2Ru$=CHPh (**A**)[32] was purchased from Fluka, the second generation catalyst **B** was prepared following a literature procedure.[31]

3.1.1. (4*S* *,4a*S* *,9a*S* *)-4-Allyloxy-7,7-dimethyl-4a,5,9,9a-tetrahydro-4*H*-1,6,8-trioxabenzocycloheptene (5a). To a solution of the alcohol **4**[15] (340 mg, 1.7 mmol) and allyl bromide (0.19 mL, 2.2 mmol) in dry THF (10 mL) was added NaH (60% dispersion in mineral oil, 102 mg, 2.5 mmol). The mixture was stirred at ambient temperature for 24 h. After this time the starting material was fully consumed as indicated by TLC. After aqueous workup the residue was purified by column chromatography to give the ether **5a** (290 mg, 71%). ^{1}H NMR (400 MHz, $CDCl_3$): δ 6.47 (d, 1H, *J*=6.3 Hz, H6), 5.86 (dddd, 1H, *J*=17.0, 10.6, 5.0, 4.8 Hz, C*H*=CH_2), 5.23 (ddm, 1H, *J*=17.0, 1.5 Hz, CH*H*=CH), 5.13 (ddm, 1H, *J*=10.6, 1.5 Hz, C*H*H=CH), 5.02 (dd, 1H, *J*=6.3, 5.0 Hz, H5), 4.07 (ddm, 1H, *J*=12.8, 5.0 Hz, OC*H*HCH=), 3.91–3.72 (6H, OCH*H*, H2, H4), 3.62 (dd, 1H, *J*=12.6, 3.5 Hz, OCH*H*), 1.73 (dddd, 1H, *J*=10.8, 10.8, 3.4, 3.4 Hz, H3), 1.32 (s, 3H, CH_3), 1.32 (s, 3H, CH_3). ^{13}C NMR (100 MHz, $CDCl_3$): δ 146.7 (1), 135.2 (1), 116.4 (2), 101.1 (1), 100.6 (0), 72.5 (1), 68.7 (2), 67.7 (1), 63.0 (2), 60.3 (2), 45.1 (1), 24.7 (3), 24.6 (3). IR (NaCl, neat): 2990 (m), 2942 (m), 2821 (m), 1637 (s), 1381 (m), 1372 (m), 1220 (s), 1081 (s), 839 (m) cm^{-1}. MS (EI): *m/z* 239 (M^+−1, 20%), 183 (50), 125 (85), 99 (100). Anal. calcd for $C_{13}H_{20}O_4$: C, 65.0%; H, 8.4%; found: C, 64.9%; H, 8.3%.

3.1.2. (4*S* *,4a*S* *,9a*S* *)-4-Acetoxy-7,7-dimethyl-4a,5,9,9a-tetrahydro-4*H*-1,6,8-trioxabenzocycloheptene (5b). To a solution of the alcohol **4** (200 mg, 1.0 mmol) and acetic anhydride (0.15 mL, 1.5 mmol) in dry DCM (10 mL) was added at 0°C triethyl amine (0.50 mL, 2.5 mmol) and DMAP (12 mg, 0.1 mmol). The mixture was stirred at ambient temperature for 6 h, after which time the starting material was fully consumed as indicated by TLC. After aqueous workup the residue was purified by column chromatography to give the ester **5b** (138 mg, 57%). ^{1}H NMR (400 MHz, $CDCl_3$): δ 6.50 (d, 1H, *J*=5.6 Hz, H6), 5.05 (dd, 1H, *J*=5.8, 5.5 Hz, H5), 3.85–3.55 (6H, OCH*H*, H2, H4), 2.01 (s, 3H, O=CCH_3), 1.87 (dddd, 1H, *J*=10.5, 10.5, 3.8, 3.8 Hz, H3), 1.34 (s, 3H, Me), 1.33 (s, 3H, Me). ^{13}C NMR (100 MHz, $CDCl_3$): δ 170.5 (0), 148.0 (1), 101.3 (0), 101.1 (1), 72.6 (1), 65.4 (1), 62.8 (2), 59.4 (2), 43.7 (1), 24.8 (3), 24.7 (3), 21.1 (3). IR (NaCl, neat): 2962 (s), 1741 (s), 1640 (s), 1081 (s) cm^{-1}. MS (EI): *m/z* 242 (M^+, 5%), 169 (25), 153 (25), 94 (100), 66 (40).

3.1.3. (3*S* *,3a*R* *,6*R* *,7a*R* *)-6-Methoxy-hexahydro-furo-[3,2]pyran-3-ol (6). To a solution of **5a** (110 mg, 0.46 mmol) and methanol (0.20 mL, 5.0 mmol) in DCM (5 mL) was added at ambient temperature *p*-toluene sulfonic acid (*p*-TSA) (10 mg, 0.05 mmol). The mixture was stirred for 15 h and then washed with aqueous $NaHCO_3$ solution. The aqueous layer was thoroughly extracted with ethyl acetate and the combined organic extracts were dried with $MgSO_4$. After column chromatography on silica using cyclohexane/ethyl acetate mixtures as eluent, **6** (50 mg, 61%) was isolated. Analogously, **5b** (130 mg, 0.54 mmol) can be converted to **6** (38 mg, 41%). Varying amounts of **7** (approximately 10%) can be isolated in these experiments. ^{1}H NMR (600 MHz, C_6D_6): δ 4.63 (dd, 1H, *J*=6.6, 4.8 Hz, H2), 4.04 (m, 1H, C*H*OH), 3.84 (dd, 1H, *J*=9.5, 2.2 Hz, OCH*H*), 3.83 (ddd, 1H, *J*=7.7, 4.4, 4.4 Hz, H4), 3.78 (dd, 1H, *J*=12.1, 3.3 Hz, H6), 3.71 (dd, 1H, *J*=12.1, 4.4 Hz, H6), 3.44 (dd, 1H, *J*=9.5, 5.1 Hz, OCH*H*), 3.17 (s, 3H, OMe), 2.77 (d, 1H, *J*=7.7 Hz, H4), 2.19 (ddd, 1H, *J*=14.7, 4.8, 4.8 Hz, H3), 1.72 (ddd, 1H, *J*=14.7, 6.6, 4.4 Hz, H3), 1.62 (dddd, 1H, *J*=7.7, 7.7, 4.4, 3.7 Hz, H5). ^{13}C NMR (100 MHz, C_6D_6): δ 98.3 (1, C2), 75.3 (2, O*C*H_2), 74.3 (1, *C*-OH), 73.6 (1, C4), 58.0 (2, C6), 54.9 (1, C2), 40.8 (1, C5), 32.3 (C3). IR (film): 3444 (s, br.), 2929 (s), 1044 (s) cm^{-1}. MS (EI): *m/z* 173 (M^+−1, 100%), 143 (25), 113 (25), 96 (20), 83 (65), 81 (45), 69 (100), 57 (45), 55 (80), 53 (40). HRMS (EI, 70 eV): calcd for $C_8H_{13}O_4$ (M^+−H): *m/z* 173.081, found 173.081. Spectroscopic data for **7** (1:1 mixture of diastereomers): ^{1}H NMR (500 MHz, $CDCl_3$): δ 6.08–6.00 (1H, H4/H5), 5.84–5.76 (1H, H4/H5), 4.80 (s, br., 1/2H, H6), 4.76 (d, 1/2H, *J*=2.5 Hz, H6), 4.18 ('q', 1/2H, *J*=7.0 Hz, H2), 4.01–3.89 (2H, –CHHO–), 3.80 (dd, 1/2H, *J*=8.0, 7.0 Hz, H2), 3.79–3.59 (2H, –CHHO–), 3.40 (s, 3/2H, OMe), 3.39 (s, 3/2H, OMe), 2.55 (m, 1/2H, H3), 2.12 (m, 1/2H, H3), 1.42 (s, 3/2H, Me), 1.39 (s, 3/2H, Me), 1.33 (s, 3/2H, Me), 1.31 (s, 3/2H, Me). ^{13}C NMR (125 MHz, $CDCl_3$): δ 129.9, 129.3, 127.0, 126.6 (1), 97.2, 97.2 (0), 95.1, 94.6 (1), 75.7, 75.7 (1), 67.5, 66.8, 58.8, 58.0 (2), 55.3, 55.3 (3), 38.0, 37.0 (1), 26.7, 26.5, 25.4, 25.2 (3). GC–MS (EI): first diastereomer *m/z* 213 (M^+−H, 5%), 183 (65, M^+−OMe), 101 (100); second diastereomer *m/z* 213 (M^+−H, 7%), 183 (100, M^+−OMe), 101 (65).

3.1.4. (*Z*)-4-Benzyloxy-but-2-en-1-ol (9). The title compound[19] was prepared following a slightly modified procedure published for the corresponding *p*-bromo benzyl ether.[20] To a suspension of NaH (60% dispersion in mineral oil, 4.80 g, 120 mmol) in THF (400 mL) was added *Z*-butene-1,4-diol (49.4 mL, 600 mmol) at 0°C. The mixture was warmed to ambient temperature, and stirring was continued for 30 min. After this time, benzyl bromide (11.9 mL, 100 mmol) was added. The reaction mixture was stirred for 20 h at ambient temperature. After evaporation of the THF the residue was taken up in ether (250 mL) and washed with water (4×100 mL). The organic layer was dried with $MgSO_4$, filtered and the solvent evaporated. The crude product was distilled (bp 97°C, 0.25 mbar) to yield **9** (15.6 g, 88%). ^{1}H NMR (400 MHz, $CDCl_3$): δ 7.29–7.24 (5H, Ph), 5.71 (dt, 1H, *J*=11.2, 6.0 Hz, HC=C*H*), 5.64 (dt, 1H, *J*=11.2, 6.0 Hz, HC=C*H*), 4.44 (s, 2H, OCH_2Ph), 4.05 (d, 2H, *J*=6.0 Hz, OCH_2HC=), 4.00 (d, 2H, *J*=6.0 Hz, OCH_2CH=), 2.83 (s, br., 1H, OH). ^{13}C NMR (100 MHz, $CDCl_3$): δ 137.6 (0), 132.3 (1), 128.3 (1), 127.6 (1), 127.6 (1), 72.2 (2), 63.4 (2), 58.1 (2).

3.1.5. ((2*S* *,3*R* *)-3-Benzyloxymethyl-oxiranyl)-methanol (10).[21] To a solution of **9** (3.56 g, 20 mmol) in DCM (50 mL) was added MCPBA (70% dispersion in water, 7.40 g, 30 mmol). After 1 h the starting material was completely converted and the reaction was quenched by addition of saturated Na_2SO_3 solution (30 mL). The mixture was diluted with ether, the organic layer was separated, dried with $MgSO_4$, filtered and the solvent was evaporated to give the epoxide **10** (3.41 g, 88%), which was sufficiently pure for preparative purposes. ^{1}H NMR (400 MHz, $CDCl_3$): δ 7.37–7.25 (5H, Ph), 4.59 (d, 1H, *J*=11.8 Hz, CH*H*–Ph), 4.51 (d, 1H, *J*=11.8 Hz, C*H*H–Ph), 3.71 (dd, 1H, *J*=12.8, 5.5 Hz, OCH*H*), 3.68 (dd, 1H, *J*=12.8, 5.8 Hz, OC*H*H), 3.67 (dd, 1H, *J*=11.3, 5.0 Hz, OCH*H*), 3.63 (dd, 1H, *J*=11.3, 5.0 Hz, C*H*H–OBn), 3.27 (ddd, 1H, *J*=6.0, 5.0, 5.0 Hz, CHO), 3.19 (ddd, 1H, *J*=6.0, 5.5, 5.5 Hz, CHO), 2.60 (s, br., 1H, OH). ^{13}C NMR (100 MHz, $CDCl_3$): δ 137.3 (0), 128.5 (1), 127.9 (1), 127.8 (1), 73.4 (2), 67.9 (2), 60.6 (2), 55.7 (1), 54.7 (1).

3.1.6. (2*R* *,3*S* *)-4-Benzyloxy-2-vinyl-butane-1,3-diol (11).[33] To a suspension of CuI (3.60 g, 18.9 mmol) in ether (70 mL) was added vinyl magnesium chloride (1.7 M solution in THF, 31.8 mL, 54.0 mmol) at −78°C. A solution of **10** (3.50 g, 18.0 mmol) in ether (20 mL) was added and the mixture was stirred at −40°C for 24 h. The reaction mixture was poured onto saturated NH_4Cl solution (100 mL) and all precipitates were filtered off. The organic layer was separated, and the aqueous layer was extracted twice with ethyl acetate. The combined organic layers were dried with $MgSO_4$, filtered, and the solvent was evaporated. The residue was purified by flash chromatography on silica to give **11** (2.64 g, 66%). ^{1}H NMR (400 MHz, $CDCl_3$): δ 7.36–7.26 (5H, Ph), 5.84 (ddd, 1H, *J*=17.3, 10.3, 9.0 Hz, C*H*=CH_2), 5.18 (dd, 1H, *J*=10.3, 1.8 Hz, C*H*H=CH), 5.13 (dd, 1H, *J*=17.3, 1.8 Hz, CH*H*=CH), 4.54 (d, 1H, *J*=11.8 Hz, C*H*H–Ph), 4.50 (d, 1H, *J*=11.8 Hz, CH*H*–Ph), 4.02 (ddd, 1H, *J*=7.2, 4.2, 4.2 Hz, C*H*OH), 3.71 (dd, 1H, *J*=10.8, 7.5 Hz, C*H*H–OH), 3.68 (dd, 1H, *J*=10.8, 6.0 Hz, CH*H*–OH), 3.46 (dd, 1H, *J*=9.6, 4.2 Hz, CH*H*–OBn), 3.44 (dd, 1H, *J*=9.6, 7.2 Hz, C*H*H–OBn), 3.15 (s, br., 2H, OH), 2.35 (dddd, 1H, *J*=9.0, 7.5, 6.0, 4.2 Hz, C*H*–Vn). ^{13}C NMR (100 MHz, $CDCl_3$): δ 137.7 (0), 134.6 (1), 128.4 (1), 127.7 (1), 127.7 (1), 118.7 (2), 73.3 (2), 72.7 (2), 70.8 (1), 64.0 (2), 48.7 (1).

3.1.7. (2*S* *,3*R* *)-1-Benzyloxy-3-(*t*-butyldimethyl-silanyloxymethyl)-pent-4-en-2-ol (12). To a solution of **11** (2.60 g, 11.7 mmol) and TBSCl (1.96 g, 13.0 mmol) in DCM (120 mL) was added triethyl amine (1.80 mL, 13.0 mmol), followed by DMAP (150 mg, 1.2 mmol). The mixture was stirred at ambient temperature for 24 h, washed with water, dried with $MgSO_4$, filtered and the solvent was evaporated. The residue was purified by flash chromatography on silica using cyclohexane/MTBE mixtures as eluent, to give **12** (3.00 g, 76%). ^{1}H NMR (400 MHz, $CDCl_3$): δ 7.34–7.30 (5H, Ph), 5.89 (ddd, 1H, *J*=17.3, 10.3, 9.0 Hz, C*H*=CH_2), 5.14 (dd, 1H, *J*=10.3, 2.0 Hz, C*H*H=CH), 5.09 (dd, 1H, *J*=17.3, 2.0 Hz, CH*H*=CH), 4.55 (d, 1H, *J*=11.8 Hz, C*H*H–Ph), 4.50 (d, 1H, *J*=11.8 Hz, CH*H*–Ph), 4.09 (m, 1H, C*H*OH), 3.76 (dd, 1H, *J*=9.8, 6.0 Hz, OC*H*H), 3.72 (dd, 1H, *J*=9.8, 4.5 Hz, OCH*H*), 3.48–3.44 (dd, 2H, OCH*H*), 2.93 (s, br., 1H, OH), 2.33 (m, 1H, C*H*–Vn), 0.87 (s, 9H, *t*-Bu), 0.03 (s, 6H, $SiMe_2$). ^{13}C NMR (100 MHz, $CDCl_3$): δ 138.1 (0), 135.0 (1), 128.4 (1), 127.7 (1), 127.6 (1), 118.0 (2), 73.3 (2), 72.8 (2), 71.0 (1), 65.5 (2), 48.0 (1), 25.8 (3), 18.2 (0), −5.6 (3), −5.6 (3). IR (film): 3481 (br w), 2961 (s), 2921 (s), 2865 (s), 1653 (w), 1472 (m), 1256 (s), 1097 (s), 1005 (m), 837 (s), 777 (s) cm^{-1}. MS (EI): *m*/*z* 337 (M^+, 5%), 91 (100), 75 (25). Anal. calcd for $C_{19}H_{32}O_3Si$: C, 67.8%; H, 9.6%; found: C, 67.7%; H, 9.6%.

3.1.8. [(*R* *)-2-((*S* *)-1-Allyloxy-2-benzyloxyethyl)but-3-enyloxy]-*t*-butyldimethylsilane (13). To a solution of **12** (1.37 g, 4.1 mmol) in THF (25 mL) was added NaH (60% dispersion in mineral oil, 250 mg, 6.4 mmol) and NaI (100 mg). The mixture was cooled to 0°C, and allyl bromide (0.55 mL, 6.2 mmol) was added. The mixture was allowed to warm to ambient temperature, and stirring was continued for 24 h. The reaction mixture was diluted with MTBE (100 mL) and washed with water. The organic layer was separated, the aqueous layer was extracted with MTBE, and the combined organic extracts were dried with $MgSO_4$. After filtration, the solvent was evaporated, and the residue was purified by flash chromatography on silica, using cyclohexane/MTBE mixtures as eluent, to give **13** (1.37 g, 89%). ^{1}H NMR (400 MHz, $CDCl_3$): δ 7.36–7.28 (5H, Ph), 5.93 (dddd, 1H, *J*=17.0, 9.8, 5.5, 5.0 Hz, CH_2–C*H*=CH_2), 5.76 (ddd, 1H, *J*=16.8, 10.3, 9.0 Hz, CH–C*H*=CH_2), 5.26 (ddm, 1H, *J*=17.0, 1.8 Hz, C*H*H=CH–CH_2), 5.16–5.05 (3H, C*H*H=CH–CH_2), 4.55 (d, 1H, *J*=12.0 Hz, C*H*H–Ph), 4.50 (d, 1H, *J*=12.0 Hz, CH*H*–Ph), 4.25 (dd, 1H, *J*=12.8, 5.5 Hz, CH*H*–CH=CH_2), 4.08 (dd, 1H, *J*=12.8, 5.0 Hz, C*H*H–CH=CH_2), 3.86 (m, 1H, C*H*–OAll), 3.73 (dd, 1H, *J*=9.5, 5.9 Hz, OC*H*H), 3.60–3.53 (2H, OCH*H*), 3.57 (dd, 1H, *J*=9.8, 6.5 Hz, OCH*H*), 3.50 (dd, 1H, *J*=9.8, 5.1 Hz, OC*H*H), 2.45 (dddd, 1H, *J*=9.0, 9.0, 5.9, 3.2 Hz, C*H*–Vn), 0.90 (s, 9H, *t*-Bu), 0.05 (s, 6H, $SiMe_2$). ^{13}C NMR (100 MHz, $CDCl_3$): δ 138.5 (0), 135.6 (1), 135.3 (1), 128.3 (1), 127.5 (1), 127.5 (1), 117.9 (2), 116.0 (2), 76.5 (1), 73.2 (2), 72.3 (2), 72.2 (2), 63.1 (2), 49.1 (1), 25.9 (3), 18.2 (0), −5.4 (3), −5.4 (3). IR (film): 2955 (s), 2928 (s), 2857 (s), 1471 (m), 1256 (m), 1097 (s), 837 (s) cm^{-1}. MS (EI): *m*/*z* 377 (M^+,

5%), 197 (10), 171 (10), 131 (15), 91 (100), 75 (25). Anal. calcd for $C_{22}H_{36}O_3Si$: C, 70.2%; H, 9.6%; found: C, 70.0%; H, 9.5%.

3.1.9. ((2*S,3*R**)-2-Benzyloxymethyl-3,6-dihydro-2*H*-pyran-3-ylmethoxy)*t*-butyl-dimethyl-silane (14).** To a solution of **13** (780 mg, 2.1 mmol) in DCM (20 mL) was added complex **A** (52 mg, 3.0 mol%). The mixture was stirred until the starting material was fully consumed as indicated by TLC (cyclohexane/MTBE 10:1). The solvent was evaporated, and the residue purified by flash chromatography on silica to give **14** (710 mg, 97%). Analytically pure **14** was obtained by additional Kugelrohr distillation (0.5 mbar, 180°C). ^{1}H NMR (400 MHz, $CDCl_3$): δ 7.36–7.27 (5H, Ph), 5.79 (dddd, 1H, *J*=10.3, 3.0, 2.0, 2.0 Hz, H5), 5.70 (dddd, 1H, *J*=10.3, 2.3, 2.3, 2.0 Hz, H4), 4.58 (s, 2H, C*H*$_2$Ph), 4.16 (dddd, 1H, *J*=16.6, 3.0, 3.0, 2.0 Hz, H6), 4.10 (dddd, 1H, *J*=16.6, 3.3, 2.3, 2.3 Hz, H6), 3.73–3.52 (4H, OC*H*H, H2), 3.48 (dd, 1H, *J*=10.0, 5.5 Hz, OCH*H*), 2.32 (m, 1H, H3), 0.86 (s, 9H, *t*-Bu), 0.03 (s, 6H, $SiMe_2$). ^{13}C NMR (100 MHz, $CDCl_3$): δ 138.3 (0), 128.3 (1), 127.7 (1), 127.5 (1), 127.1 (1), 125.9 (1), 74.9 (1), 73.4 (2), 71.3 (2), 64.5 (2), 64.3 (2), 38.8 (1), 25.8 (3), 18.2 (0), −5.5 (3), −5.5 (3). IR (film): 2954 (m), 2929 (m), 2857 (m), 1472 (w), 1255 (m), 1098 (m), 837 (s), 777 (m) cm^{-1}. MS (EI): *m*/*z* 349 (M^+, 25%), 91 (100), 73 (20). Anal. calcd for $C_{20}H_{32}O_3Si$: C, 68.9%; H, 9.3%; found: C, 68.7%; H, 9.1%.

3.1.10. ((2*S,3*R**)-2-Benzyloxymethyl-3,6-dihydro-2*H*-pyran-3-yl)-methanol (15).** To a solution of **14** (1.22 g, 3.5 mmol) in THF (50 mL) was added TBAF (1.90 g, 7.3 mmol). After 4 h the starting material was completely consumed as indicated by TLC. The reaction mixture was diluted with MTBE and washed with water. After usual workup, the residue was purified by flash chromatography on silica to give alcohol **15** (414 mg, 51%). ^{1}H NMR (400 MHz, $CDCl_3$): δ 7.35–7.24 (5H, Ph), 5.84 (dddd, 1H, *J*=10.3, 3.0, 2.3, 2.3 Hz, H5), 5.65 (dddd, 1H, *J*=10.3, 2.3, 2.3, 2.3 Hz, H4), 4.60 (d, 1H, *J*=12.1 Hz, CH*H*Ph), 4.55 (d, 1H, *J*=12.1 Hz, C*H*HPh), 4.16–4.12 (2H, H6), 3.68–3.61 (3H, H2, C*H*$_2$–OBn), 3.57–3.51 (2H, C*H*$_2$–OH), 2.47 (s, br., 1H, OH), 2.40 (m, 1H, H3). ^{13}C NMR (100 MHz, $CDCl_3$): δ 137.6 (0), 128.4 (1), 127.9 (1), 127.9 (1), 127.8 (1), 125.3 (1), 75.1 (1), 73.5 (2), 71.5 (2), 64.7 (2), 64.1 (2), 40.0 (1). IR (film): 3435 (w, br.), 2929 (m), 2867 (m), 1454 (w), 1096 (m), 699 (m) cm^{-1}. MS (EI): *m*/*z* 234 (M^+, 4), 173 (100).

3.1.11. (3*R,4*S**,5*S**,6*S**)-6-Benzyloxymethyl-5-(*t*-butyl-dimethylsilanyloxymethyl)-tetra-hydro-pyran-3,4-diol (16).** To a solution of **13** (590 mg, 1.7 mmol) in acetone (24 mL) and water (6 mL) was added *N*-methyl morpholine *N*-oxide (820 mg, 5.6 mmol), followed by $K_2Os(OH)_6$ (50 mg, 4.6 mol%). After stirring at ambient temperature for 4 h, the reaction was quenched by addition of aqueous Na_2SO_3 solution. Stirring was continued for 1 h, and the mixture was extracted with ethyl acetate. The combined organic layers were dried with $MgSO_4$, filtered and the solvent was evaporated. Upon flash chromatography on silica (cyclohexane/MTBE 1:1) **16** (417 mg, 65%) was obtained as a 7:1 mixture of diastereoisomers. NMR-data are given for the major diastereoisomer: ^{1}H NMR (600 MHz, $CDCl_3$): δ 7.34–7.24 (5H, Ph), 4.59 (d, 1H, *J*=12.0 Hz, C*H*HPh), 4.50 (d, 1H, *J*=12.0 Hz, CH*H*Ph), 4.06 (d, 1H, *J*=12.5 Hz, H6), 3.89 (dd, 1H, *J*=10.4, 3.2 Hz, C*H*H–OTBS), 3.75 (s, br., 1H, H5), 3.72 (dd, 1H, *J*=10.4 Hz, H4), 3.62 (dd, 1H, *J*=10.6, 2.5 Hz, C*H*H–OBn), 3.56–3.51 (2H, CH*H*OBn, CH*H*OTBS), 3.49 (d, 1H, *J*=12.5 Hz, H6), 3.35 (m, 1H, H2), 1.94 (m, 1H, H3), 0.84 (s, 9H, *t*-Bu), 0.01 (s, 3H, $SiMe_2$), −0.02 (s, 3H, $SiMe_2$). ^{13}C NMR (150 MHz, $CDCl_3$): δ 137.9 (0, *ipso*-C, Ph), 128.4 (1, Ph), 127.9 (1, Ph), 127.9 (1, Ph), 76.7 (1, C2), 73.5 (2, O*C*HHPh), 70.8 (1, C4), 70.5 (2, *C*HHOBn), 70.0 (2, C6), 67.9 (1, C5), 61.4 (2, *C*HHOTBS), 41.4 (1, C3), 25.8 (3, *t*-Bu), 18.1 (0, *t*-Bu), −5.7 (3, $SiMe_2$), −5.8 (3, $SiMe_2$). MS (EI, 70 eV): *m*/*z* 383 (M^+, 5%), 185 (15), 91 (100), 75 (15).

3.1.12. (*Z*)-4-*t*-Butyl-dimethylsilanyloxy)-but-2-ene-1-ol (17).[23] To a solution of **8** (19.2 mL, 233.0 mmol) in DCM (200 mL) was added triethyl amine (83.6 mL, 60.8 mmol), followed by *t*-butyl dimethyl silyl chloride (7.05 g, 46.8 mmol) and DMAP (570 mg, 4.6 mmol). The mixture was stirred at ambient temperature for 3 h and then washed with water. The organic layer was dried with $MgSO_4$, filtered and evaporated. The residue was purified by flash chromatography on silica using cyclohexane/MTBE mixtures as eluent to give **17** (6.69 g, 71%). ^{1}H NMR (400 MHz, $CDCl_3$): δ 5.67 (dt, 1H, *J*=11.3, 5.8 Hz, HC=C*H*), 5.62 (dt, 1H, *J*=11.3, 5.5 Hz, HC=C*H*), 4.22 (d, 2H, *J*=5.5 Hz, C*H*$_2$O), 4.15 (d, 2H, *J*=11.3, 5.8 Hz, C*H*$_2$O), 2.39 (s, br., 1H, OH), 0.87 (s, 9H, *t*-Bu), 0.05 (s, 6H, $SiMe_2$). ^{13}C NMR (100 MHz, $CDCl_3$): δ 131.2 (1), 130.0 (1), 59.5 (2), 58.7 (2), 25.8 (3), 18.4 (0), −5.3 (3).

3.1.13. [(2*S,3*R**)-3-(*t*-Butyl-dimethyl-silanyloxymethyl)-oxiranyl]methanol (18).**[23] To a solution of **17** (6.65 g, 32.9 mmol) in DCM (150 mL) was added *t*-butyl hydroperoxide (5.5 M solution in decane, 43.0 mmol, 7.80 mL), followed by $VO(acac)_2$ (436 mg, 5 mol%). The mixture was heated to reflux for 3 h, cooled to ambient temperature, and excess peroxide was destroyed by addition of aqueous solution of Na_2SO_3. After aqueous workup and evaporation of all volatiles, the residue was purified by flash chromatography on silica (cyclohexane/MTBE 2:1) to give **18** (6.24 g, 87%). ^{1}H NMR (400 MHz, $CDCl_3$): δ 3.89 (dd, 1H, *J*=11.8, 5.5 Hz, C*H*HOTBS), 3.76–3.72 (2H, C*H*HOH), 3.70 (dd, 1H, *J*=11.8, 5.2 Hz, C*H*HOTBS), 3.20–3.13 (2H, CHO), 2.47 (s, br., 1H, OH), 0.87 (s, 9H, *t*-Bu), 0.06 (s, 3H, $SiMe_2$), 0.05 (s, 3H, $SiMe_2$). ^{13}C NMR (100 MHz, $CDCl_3$): δ 61.6 (2), 60.8 (2), 56.3 (1), 56.0 (1), 25.8 (3), 18.2 (0), −5.3 (3), −5.5 (3).

3.1.14. (2*R,3*S**)-4-(*t*-Butyl-dimethyl-silanyloxy)-2-vinyl-butane-1,3-diol (19).** Following the procedure given above for the preparation of **11**, **18** (6.24 g, 28.6 mmol) was reacted with the vinyl cuprate reagent to give homoallylic alcohol **19** (4.76 g, 68%). ^{1}H NMR (200 MHz, $CDCl_3$): δ 5.85 (ddd, 1H, *J*=17.1, 10.5, 8.8 Hz, C*H*=CH$_2$), 5.20 (dd, 1H, *J*=10.5, 2.0 Hz, C*H*H=CH), 5.14 (ddd, 1H, *J*=17.1, 2.0, 0.7 Hz, CH*H*=CH), 3.87–3.50 (5H, C*H*HO, C*H*OH), 2.48 (s, br., 1H, OH), 2.36 (dddd, 1H, *J*=9.7, 8.8, 6.0, 3.4 Hz, C*H*CH=), 0.87 (s, 9H, *t*-Bu), 0.03 (s, 3H, $SiMe_2$), 0.03 (s, 3H, $SiMe_2$). ^{13}C NMR (100 MHz, $CDCl_3$): δ 134.9 (1), 118.6 (2), 72.6 (1), 65.3 (2), 64.3 (2), 48.5 (1), 25.8 (3), 18.2 (0), −5.4 (3), −5.4 (3). IR (film) 3386 (br, s), 2930 (s), 2858 (s), 1472 (m), 1255 (s), 1093 (s), 838 (s), 777 (s) cm^{-1}.

MS (EI) *m/z* 246 (M^+, 5%), 117 (10), 75 (100). Anal. calcd for $C_{12}H_{26}O_3Si$: C, 58.5%; H, 10.6%; found: C, 58.6%; H, 10.2%.

3.1.15. 2,2-Dimethylpropionic acid (*R* *)-2-[(*S* *)-2-(*t*-butyl-dimethyl-silanyloxy)-1-hydroxy-ethyl]-but-3-enyl ester (20). To a solution of **19** (3.25 g, 13.2 mmol) in DCM (50 mL) pivaloyl chloride (1.85 mL, 15.0 mmol) followed by triethyl amine (7.4 mL, 53 mmol) and DMAP (180 mg, 1.5 mmol) was added. The reaction mixture was stirred for 18 h at ambient temperature and then quenched by addition of aqueous Na_2CO_3 solution. The organic layer was separated, and the aqueous layer was extracted with ether. The combined organic extracts were washed with aqueous NH_4Cl solution, dried with $MgSO_4$, filtered and evaporated. The residue was purified by flash chromatography on silica using cyclohexane/MTBE (3:1) as eluent, giving **20** (4.23 g, 97%). ^{1}H NMR (400 MHz, $CDCl_3$): δ 5.78 (ddd, 1H, *J*=17.3, 10.3, 9.5 Hz, C*H*=CH_2), 5.16 (dd, 1H, *J*=10.3, 1.5 Hz, C*H*H=CH), 5.10 (dm, 1H, *J*=17.3 Hz, CH*H*=CH), 4.19 (dd, 1H, *J*=10.8, 7.0 Hz, C*H*H–OPiv), 4.09 (dd, 1H, *J*=10.8, 6.5 Hz, CH*H*–OPiv), 3.72 (ddd, 1H, *J*=7.8, 4.0, 4.0 Hz, C*H*–OH), 3.55 (dd, 1H, *J*=10.0, 4.0 Hz, CH*H*–OTBS), 3.50 (dd, 1H, *J*=10.0, 7.8 Hz, C*H*H–OTBS), 2.51 (dddd, 1H, *J*=9.5, 7.0, 6.5, 4.0 Hz, C*H*–Vn), 2.40 (s, br., 1H, OH), 1.16 (s, 9H, t-Bu–CO), 0.85 (s, 9H, *t*-Bu), 0.03 (s, 3H, $SiMe_2$), 0.03 (s, 3H, $SiMe_2$). ^{13}C NMR (100 MHz, $CDCl_3$): δ 178.5 (0), 134.1 (1), 118.7 (2), 70.8 (1), 65.2 (2), 64.3 (2), 45.7 (1), 38.8 (0), 27.2 (3), 25.8 (3), 18.2 (0), −5.4 (3), −5.4 (3). IR (film): 3512 (br w), 2958 (s), 2859 (m), 1732 (s), 1473 (m), 1285 (m), 1160 (s), 838 (s), 777 (m) cm^{-1}. MS (EI): *m/z* 331 (M^+, 5%), 313 (25), 229 (30), 75 (30), 57 (100). Anal. calcd for $C_{17}H_{34}O_4Si$: C, 61.8%; H, 10.4%; found: C, 62.2%; H, 10.0%.

3.1.16. Acrylic acid (1*S* *,2*R* *)-1-(*t*-butyldimethylsilanyl-oxymethyl)-2-(2,2-dimethyl-propanoyloxymethyl)-but-3-enyl ester (22). To a solution of **20** (1.40 g, 4.2 mmol) in DCM (50 mL) was added at 0°C triethyl amine (2.8 mL, 20.0 mmol) and acryloyl chloride (0.8 mL, 10.0 mmol), followed by DMAP (50 mg, 0.4 mmol). The mixture was stirred until the starting material was completely as indicated by TLC. The organic layer was washed with water, dried with $MgSO_4$, filtered and evaporated. The residue was purified by flash chromatography on silica using cyclohexane/MTBE mixtures, to give **22** (1.29 g, 80%). ^{1}H NMR (400 MHz, $CDCl_3$): δ 6.36 (d, 1H, *J*=17.2 Hz, COCH=CH_2), 6.08 (dd, 1H, *J*=17.2, 10.4 Hz, COC*H*=CH_2), 5.80 (d, 1H, *J*=10.4 Hz, COCH=CH_2), 5.71 (ddd, 1H, *J*=17.3, 10.3, 9.3 Hz, CHC*H*=CH_2), 5.18 (d, 1H, *J*=10.3 Hz, CHCH=CH_2), 5.16 (d, 1H, *J*=17.3 Hz, CHCH=CH_2), 4.07 (dd, 1H, *J*=11.1, 6.8 Hz, CH*H*OPiv), 4.02 (dd, 1H, *J*=11.1, 7.0 Hz, C*H*HOPiv), 3.67 (dd, 1H, *J*=10.5, 5.8 Hz, CH*H*OTBS), 3.61 (dd, 1H, *J*=110.5, 5.8 Hz, CH*H*OTBS), 2.83 (m, 1H, C*H*CH=CH_2), 1.16 (s, 9H, OPiv), 0.84 (s, 9H, OTBS), 0.00 (s, 3H, $SiMe_2$), 0.00 (s, 3H, $SiMe_2$). ^{13}C NMR (100 MHz, $CDCl_3$): δ 178.2 (0), 165.3 (0), 133.4 (1), 130.9 (2), 128.3 (1), 119.4 (2), 72.7 (1), 63.6 (2), 62.0 (2), 42.8 (1), 38.7 (0), 27.1 (3), 25.7 (3), 18.1 (0), −5.5 (3), −5.5 (3). IR (film): 2958 (s), 2931 (s), 1732 (s), 1638 (s), 1623 (m), 1406 (s), 1189 (s). FAB-HRMS: calcd for $C_{20}H_{36}O_5NaSi$(M^++Na) 407.2230, found 407.2249.

3.1.17. 2,2-Dimethylpropionic acid (2*S* *,3*R* *)-2-(*t*-butyl-dimethyl-silanyloxymethyl)-6-oxo-3,6-dihydro-2-pyran-3-ylmethyl ester (23). To a solution of the acrylate **22** (384 mg, 1.0 mmol) in toluene (50 mL) was added the ruthenium complex **B** (42 mg, 5 mol%). The mixture was heated to reflux for 5 h. After this time the starting material was completely converted. The solvent was evaporated, and the residue purified by flash chromatography on silica to give **23** (300 mg, 84%). ^{1}H NMR (500 MHz, $CDCl_3$): δ 6.72 (dd, 1H, *J*=10.0, 3.7 Hz, H4), 6.03 (dd, 1H, *J*=10.0, 2.0 Hz, H5), 4.41 (ddd, 1H, *J*=6.7, 4.5, 4.5 Hz, H2), 4.22 (dd, 1H, *J*=11.5, 5.5 Hz, C*H*HOPiv), 4.18 (dd, 1H, *J*=11.5, 4.7 Hz, C*H*HOPiv), 3.82 (d, 2H, *J*=4.5 Hz, CHHOTBS), 3.02 (m, 1H, H3), 1.16 (s, 9H, OPiv), 0.85 (s, 9H, OTBS), 0.05 (s, 3H, $SiMe_2$), 0.04 (s, 3H, $SiMe_2$). ^{13}C NMR (125 MHz, $CDCl_3$): δ 178.1 (0, $COBu^t$), 162.6 (0, C6), 145.1 (1, C4), 121.9 (1, C5), 79.0 (1, C2), 62.7 (2, CHHO), 62.7 (2, CHHO), 38.9 (0, OPiv), 34.6 (1, C3), 27.1 (3, OPiv), 25.7 (3, OTBS), 18.2 (0, OTBS), −5.4 (3, $SiMe_2$), −5.5 (3, 3, $SiMe_2$). IR (film): 2957 (s), 2930 (s), 1733 (s), 1481 (s), 1282 (s), 1146 (s), 835 (s). FAB-HRMS: calcd for $C_{18}H_{32}O_5NaSi$ (M^++Na) 379.1917, found 379.1949.

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