Chemical and Biological studies of Nakiterpiosin and Nakiterpiosinone

Shuanhu Gao, Qiaoling Wang, Lily Jun-Shen Huang, Lawrence Lum and Chuo Chen*

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References


6g. Tremblay, M. R.; Nevalainen, M.; Nair, S. J.; Porter, J. R.; Castro, A. C.; Behnke, M. L.; Yu, L.-
Hoyt, J.; Foley, M. A.; Read, M. A.; Sydor, J. R.; Tong, J. K.; Palombella, V. J.; McGovern, K.;
Table S1. $^1$H NMR chemical shifts and coupling constants of nakiterpiosinone

<table>
<thead>
<tr>
<th></th>
<th>Natural sample*</th>
<th>Synthetic 2†</th>
<th>Natural sample*</th>
<th>Synthetic 2†</th>
</tr>
</thead>
<tbody>
<tr>
<td>1a</td>
<td>2.10 (dd 12.8)</td>
<td>2.10 (d 13.0)</td>
<td>15</td>
<td>7.36 (d 8.3)</td>
</tr>
<tr>
<td>1b</td>
<td>2.39 (ddd 12.8, 6.0, 1.4)</td>
<td>2.39 (ddd 13.0, 6.0, 1.2)</td>
<td>16</td>
<td>7.92 (d 8.3)</td>
</tr>
<tr>
<td>2</td>
<td>4.58 (dd 6.0, 6.0)</td>
<td>4.58 (dd 6.0, 6.0)</td>
<td>18</td>
<td>2.72 (s)</td>
</tr>
<tr>
<td>3</td>
<td>4.22 (dd 6.0, 1.4)</td>
<td>4.22 (dd 6.0, 1.2)</td>
<td>19</td>
<td>1.31 (s)</td>
</tr>
<tr>
<td>4</td>
<td>20</td>
<td>3.89 (dd, 10.1, 3.2)</td>
<td>3.89 (dd, 10.1, 3.2)</td>
<td></td>
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<tr>
<td>5</td>
<td>21</td>
<td>6.33 (d, 10.1)</td>
<td>6.35 (d, 10.1)</td>
<td></td>
</tr>
<tr>
<td>6</td>
<td>4.71 (dd 2.3, 1.4)</td>
<td>4.71 (dd 3.2, 2.4)</td>
<td>22</td>
<td>4.41 (dd 8.3, 3.2)</td>
</tr>
<tr>
<td>7a</td>
<td>2.46 (ddd 13.8, 11.9, 2.3)</td>
<td>2.45 (ddd 13.8, 12.3, 3.2)</td>
<td>23</td>
<td>3.92 (dd 8.3, 8.2, 3.7)</td>
</tr>
<tr>
<td>7b</td>
<td>2.77 (ddd 13.8, 2.3, 1.4)</td>
<td>2.77 (ddd 13.8, 2.4, 2.4)</td>
<td>24a</td>
<td>1.73 (ddd 13.3, 8.2, 8.2)</td>
</tr>
<tr>
<td>8</td>
<td>3.58 (m)</td>
<td>3.60 (ddd, 12.3, 9.2, 2.4)</td>
<td>24b</td>
<td>2.30 (ddd 13.3, 9.2, 3.7)</td>
</tr>
<tr>
<td>9</td>
<td>2.96 (d 9.2)</td>
<td>2.96 (d 9.2)</td>
<td>25</td>
<td>2.69 (m)</td>
</tr>
<tr>
<td>26</td>
<td>1.14 (d 7.3)</td>
<td>1.14 (d 7.3)</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

* Recorded at 800 MHz as reported by Uemura et al. (Ref 1). † Recorded at 500 MHz.

Note: The $^{13}$C NMR spectrum of the natural sample of nakiterpiosinone has not been reported.
**Table S2.** Ratios of the hemiacetal to aldehyde form of 3 at different temperature as judged by $^1$H NMR spectra.

<table>
<thead>
<tr>
<th>temp (°C)</th>
<th>T (K)</th>
<th>1/T</th>
<th>hemiacetal:aldehyde</th>
<th>ln K</th>
</tr>
</thead>
<tbody>
<tr>
<td>-10</td>
<td>263.15</td>
<td>0.00380</td>
<td>5.69:1</td>
<td>1.739</td>
</tr>
<tr>
<td>0</td>
<td>273.15</td>
<td>0.00366</td>
<td>5.08:1</td>
<td>1.624</td>
</tr>
<tr>
<td>10</td>
<td>283.15</td>
<td>0.00353</td>
<td>4.46:1</td>
<td>1.496</td>
</tr>
<tr>
<td>20</td>
<td>293.15</td>
<td>0.00341</td>
<td>3.62:1</td>
<td>1.288</td>
</tr>
<tr>
<td>25</td>
<td>298.15</td>
<td>0.00335</td>
<td>3.29:1</td>
<td>1.191</td>
</tr>
<tr>
<td>30</td>
<td>303.15</td>
<td>0.00330</td>
<td>3.10</td>
<td>1.131</td>
</tr>
</tbody>
</table>

\[
\Delta G = -RT \ln(K) = \Delta H - T \Delta S
\]

\[
\ln(K) = -\frac{\Delta H}{RT} + \frac{\Delta S}{R}
\]

\[
-\frac{\Delta H}{R} = 1261.9; \quad \Delta S/R = -3.017
\]

\[
\Delta H = -2.5 \text{ kcal/mol}; \quad \Delta S = -6.0 \text{ cal/mol·K}
\]
Scheme S1. Synthesis of model substrates: 7, 8, 9, 10.

Scheme S2. The synthesis of model substrates: 11 (syn-syn) and 14 (anti-anti).

Scheme S3. The synthesis of model substrates: 12 (syn-anti) and 13 (anti-syn).
Scheme S4. The synthesis of model substrates: 15 (anti-anti-cis).

Scheme S5. The synthesis of model substrates: 16 (anti-anti-trans).


S10
Table S3. Yamamoto pinacol-type rearrangement of chiral epoxide.

<table>
<thead>
<tr>
<th>Entry</th>
<th>Lewis Acid</th>
<th>Equivalent</th>
<th>Temp.</th>
<th><strong>38</strong>-<strong>38a</strong> Conversion</th>
<th>Workup (Purification)</th>
<th>Note</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>(4-Br-2,6-BrPhO)AlMe</td>
<td>0.2</td>
<td>-78 °C</td>
<td>100:0 40%</td>
<td>NaF, H₂O (chromatography)</td>
<td>92% ee <strong>37</strong> → 71% ee <strong>38</strong></td>
</tr>
<tr>
<td>2</td>
<td>(4-Br-2,6-BrPhO)AlMe</td>
<td>2.0</td>
<td>-78 °C</td>
<td>100:0 100%</td>
<td>NaF, H₂O (chromatography)</td>
<td>92% ee <strong>37</strong> → 71% ee <strong>38</strong></td>
</tr>
<tr>
<td>3</td>
<td>(4-Br-2,6-BrPhO)AlMe</td>
<td>2.0</td>
<td>-78 °C</td>
<td>100:0 100%</td>
<td>1 N HCl (without purification)</td>
<td>92% ee <strong>37</strong> → 90% ee <strong>38</strong></td>
</tr>
<tr>
<td>4</td>
<td>Cr(TPP)(OTf)</td>
<td>0.05</td>
<td>83 °C</td>
<td>3:1 100%</td>
<td>---</td>
<td>92% ee <strong>37</strong> → 78% ee <strong>38</strong></td>
</tr>
</tbody>
</table>

Table S4. Lewis acid-promoted vinylogous Mukaiyama aldol reaction.

<table>
<thead>
<tr>
<th>Entry</th>
<th>Lewis Acid</th>
<th>Equivalent</th>
<th><strong>38</strong></th>
<th><strong>39</strong> 23-epi-<strong>39</strong> Conversion</th>
<th>Note</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Yb(OTf)₃</td>
<td>0.2</td>
<td><strong>38</strong></td>
<td>2.8:1 40%</td>
<td>—</td>
</tr>
<tr>
<td>2</td>
<td>Sc(OTf)₃</td>
<td>0.2</td>
<td><strong>38</strong></td>
<td>4:1 71%</td>
<td>—</td>
</tr>
<tr>
<td>3</td>
<td>LiClO₄</td>
<td>0.2</td>
<td><strong>38</strong></td>
<td>2.8:1 40%</td>
<td>No reaction</td>
</tr>
<tr>
<td>4</td>
<td>CcCl₃</td>
<td>0.2</td>
<td><strong>38</strong></td>
<td>4:1 71%</td>
<td>No reaction</td>
</tr>
<tr>
<td>5</td>
<td>TiCl₄</td>
<td>0.2</td>
<td><strong>38</strong></td>
<td>2.8:1 40%</td>
<td>No reaction</td>
</tr>
<tr>
<td>6</td>
<td>In(OTf)₃</td>
<td>0.2</td>
<td><strong>38</strong></td>
<td>4:1 71%</td>
<td>Messy</td>
</tr>
<tr>
<td>7</td>
<td>Ag(OTf)</td>
<td>0.2</td>
<td><strong>38</strong></td>
<td>2.8:1 40%</td>
<td>Messy</td>
</tr>
<tr>
<td>8</td>
<td>Cu(OTf)₂</td>
<td>0.2</td>
<td><strong>38</strong></td>
<td>4:1 71%</td>
<td>Messy</td>
</tr>
<tr>
<td>9</td>
<td>TMSOTf</td>
<td>0.2</td>
<td><strong>38</strong></td>
<td>2.8:1 40%</td>
<td>—</td>
</tr>
<tr>
<td>10</td>
<td>Zn(OTf)₂</td>
<td>0.2</td>
<td><strong>38</strong></td>
<td>4:1 71%</td>
<td>—</td>
</tr>
<tr>
<td>11</td>
<td>ZrCl₁</td>
<td>0.2</td>
<td><strong>38</strong></td>
<td>2.8:1 40%</td>
<td>—</td>
</tr>
<tr>
<td>12</td>
<td>Bi(OTf)₃</td>
<td>0.1</td>
<td><strong>38</strong></td>
<td>4:1 71%</td>
<td>Ref. 3</td>
</tr>
<tr>
<td>13</td>
<td>Sn(OTf)₂</td>
<td>0.2</td>
<td><strong>38</strong></td>
<td>4:1 71%</td>
<td>—</td>
</tr>
<tr>
<td>14</td>
<td>Sn(OTf)₂</td>
<td>2.0</td>
<td><strong>38</strong></td>
<td>4:1 71%</td>
<td>—</td>
</tr>
<tr>
<td>15</td>
<td>BF₃•Et₂O</td>
<td>1.5</td>
<td><strong>38</strong></td>
<td>4:1 71%</td>
<td>—</td>
</tr>
</tbody>
</table>
Table S5. Optimization of the model carbonylative cross coupling reaction.

<table>
<thead>
<tr>
<th>Entry</th>
<th>Pd</th>
<th>Ligand</th>
<th>Additive</th>
<th>Solvent</th>
<th>Temp.</th>
<th>Time</th>
<th>TBS-49a</th>
<th>Note</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>0.3 eq Pd(OAc)₂</td>
<td>0.6 eq P(Ph)₃</td>
<td>---</td>
<td>THF</td>
<td>23 °C</td>
<td>12 h</td>
<td>---</td>
<td>No reaction</td>
</tr>
<tr>
<td>2</td>
<td>0.3 eq Pd(OAc)₂</td>
<td>0.6 eq P(Ph)₃</td>
<td>---</td>
<td>THF</td>
<td>23 °C</td>
<td>12 h</td>
<td>---</td>
<td>No reaction</td>
</tr>
<tr>
<td>3</td>
<td>0.3 eq Pd(OAc)₂</td>
<td>0.6 eq P(Ph)₃</td>
<td>1.5 eq CuCl</td>
<td>DMSO</td>
<td>55 °C</td>
<td>2 h</td>
<td>---</td>
<td>No reaction</td>
</tr>
<tr>
<td>4</td>
<td>0.3 eq Pd(OAc)₂</td>
<td>0.6 eq P(Ph)₃</td>
<td>1.5 eq CuCl</td>
<td>DMSO</td>
<td>55 °C</td>
<td>2 h</td>
<td>---</td>
<td>No reaction</td>
</tr>
<tr>
<td>5</td>
<td>0.3 eq Pd(OAc)₂</td>
<td>0.6 eq P(Ph)₃</td>
<td>1.5 eq CuCl</td>
<td>DMSO</td>
<td>55 °C</td>
<td>2 h</td>
<td>---</td>
<td>No reaction</td>
</tr>
<tr>
<td>6</td>
<td>0.3 eq Pd(OAc)₂</td>
<td>0.6 eq P(Ph)₃</td>
<td>1.5 eq CuCl</td>
<td>DMSO</td>
<td>55 °C</td>
<td>2 h</td>
<td>---</td>
<td>No reaction</td>
</tr>
<tr>
<td>7</td>
<td>0.3 eq Pd(OAc)₂</td>
<td>0.6 eq P(Ph)₃</td>
<td>1.5 eq CuCl</td>
<td>DMSO</td>
<td>55 °C</td>
<td>2 h</td>
<td>---</td>
<td>No reaction</td>
</tr>
<tr>
<td>8</td>
<td>1.2 eq Pd(OAc)₂</td>
<td>3 eq P(Ph)₃</td>
<td>---</td>
<td>THF</td>
<td>23 °C</td>
<td>12 h</td>
<td>---</td>
<td>No reaction</td>
</tr>
<tr>
<td>9</td>
<td>1.2 eq Pd(OAc)₂</td>
<td>3 eq P(Ph)₃</td>
<td>---</td>
<td>THF</td>
<td>23 °C</td>
<td>12 h</td>
<td>---</td>
<td>No reaction</td>
</tr>
<tr>
<td>10</td>
<td>1.2 eq Pd(OAc)₂</td>
<td>3 eq P(Ph)₃</td>
<td>---</td>
<td>THF</td>
<td>23 °C</td>
<td>12 h</td>
<td>---</td>
<td>No reaction</td>
</tr>
<tr>
<td>11</td>
<td>1.1 eq Pd(PPh₃)Cl₂</td>
<td>---</td>
<td>---</td>
<td>THF</td>
<td>50 °C</td>
<td>12 h</td>
<td>---</td>
<td>No reaction</td>
</tr>
<tr>
<td>12</td>
<td>1.0 eq Pd(PPh₃)Cl₂</td>
<td>2.0 eq P(Ph)₃</td>
<td>1.5 eq CuCl</td>
<td>DMSO</td>
<td>55 °C</td>
<td>2 h</td>
<td>---</td>
<td>No reaction</td>
</tr>
<tr>
<td>13</td>
<td>1.0 eq Pd(PPh₃)Cl₂</td>
<td>2.0 eq P(Ph)₃</td>
<td>1.5 eq CuCl</td>
<td>DMSO</td>
<td>55 °C</td>
<td>2 h</td>
<td>---</td>
<td>No reaction</td>
</tr>
<tr>
<td>14</td>
<td>1.1 eq Pd(PPh₃)Cl₂</td>
<td>---</td>
<td>---</td>
<td>THF</td>
<td>50 °C</td>
<td>12 h</td>
<td>---</td>
<td>No reaction</td>
</tr>
<tr>
<td>15</td>
<td>1.1 eq Pd(PPh₃)Cl₂</td>
<td>---</td>
<td>6 eq CuCl; 6 eq LiCl</td>
<td>THF</td>
<td>50 °C</td>
<td>5 h</td>
<td>---</td>
<td>15% conversion</td>
</tr>
<tr>
<td>16</td>
<td>1.1 eq Pd(PPh₃)Cl₂</td>
<td>---</td>
<td>6 eq CuCl; 6 eq LiCl</td>
<td>DMSO</td>
<td>50 °C</td>
<td>70 min</td>
<td>0:100</td>
<td>100% conversion</td>
</tr>
<tr>
<td>17</td>
<td>2.0 eq Pd(PPh₃)Cl₂</td>
<td>---</td>
<td>6 eq CuCl; 6 eq LiCl</td>
<td>DMSO</td>
<td>50 °C</td>
<td>30 min</td>
<td>1:1</td>
<td>100% conversion</td>
</tr>
<tr>
<td>18</td>
<td>0.2 eq Pd(PPh₃)Cl₂</td>
<td>---</td>
<td>1.5 eq CuCl</td>
<td>DMSO</td>
<td>55 °C</td>
<td>2 h</td>
<td>100:0</td>
<td>7% conversion</td>
</tr>
<tr>
<td>19</td>
<td>1.5 eq Pd(PPh₃)Cl₂</td>
<td>---</td>
<td>1.5 eq CuCl</td>
<td>DMSO</td>
<td>55 °C</td>
<td>45 min</td>
<td>100:0</td>
<td>100% conversion</td>
</tr>
</tbody>
</table>

* For the preparation of stannane 32b and 48.

Scheme S10. Model carbonylative cross coupling reaction and photo-Nazarov reaction.
**Figure S1.** The ORTEP representation of the key synthetic intermediates with the thermal ellipsoids drawn at 50% probability level.
General Experimental Procedures. All reactions were performed in glassware under a positive pressure of argon. Liquids and solvent were transferred via syringe. Organic solutions were concentrated by rotary evaporator at ca. 30 mmHg. Flash column chromatography was performed as described by Still (Still, W. C.; Kahn, M.; Mitra, A. J. Org. Chem. 1978, 43, 2923–2925), employing EMD RP–18 silica gel 60 (230–400 mesh ASTM). TLC analyses were performed on EMD 250 μm Silica Gel 60 F254 plates and visualized by quenching of UV fluorescence (λmax = 254 nm), or by staining ceric ammonium molybdate. 1H and 13C NMR spectra were recorded on a Varian Inova-400 or Mercury-300 spectrometer. Chemical shifts for 1H and 13C NMR spectra are reported in ppm (δ) relative to residue protium in the solvent (CDCl3; δ 7.26, 77.00 ppm; methanol-d4: δ 3.31, 49.5 ppm) and the multiplicities are presented as follows: s = singlet, d = doublet, t = triplet, m = multiplet. Infrared spectra were recorded on a Perkin-Elmer 1000 series FTIR. Mass spectra were acquired on a Shimadzu 2010 LC-MS or through the University of Illinois Urbana-Champaign Mass Spectrometer Facility using the indicated ionization method.

Alcohol 7. To a solution of bromide 85 (0.0050 g, 0.015 mmol, 1.0 equiv) in anhydrous tetrahydrofuran (0.2 mL) was slowly added a solution of L-selectride (1.0 M in tetrahydrofuran, 17 μL, 0.017 mmol, 1.1 equiv) at -78 °C. After stirring at -78 °C for 30 min, sodium perborate monohydrate (0.0045 g, 0.045 mmol, 3.0 equiv) and a 20:1 (v:v) mixture of tetrahydrofuran:water (0.2 mL) were added. The mixture was allowed to warm to 23°C and water (1 mL) was added. The biphasic mixture was extracted with ethyl acetate (5 mL), and the organic phase was dried over anhydrous sodium sulfate, filtered, concentrated, and purified by silica gel column chromatography (25% ethyl acetate–hexanes) to give 7 as colorless oil (0.0047 g, 95 %): Rf =0.53 (50 % ethyl acetate–hexane); 1H NMR (500 MHz, CDCl3) δ 4.55 (d, J = 6.6 Hz, 1H), 4.54 (d, J = 5.7 Hz, 1H), 4.38 (dd, J = 5.6, 12.2 Hz, 1H), 4.31 (d, J = 5.7 Hz, 1H), 3.41 (ddd, J = 1.9, 3.2, 10.6 Hz, 1H), 3.27 (d, J = 10.6 Hz, 1H), 2.73 (dd, J = 6.6, 12.7 Hz, 1H), 2.52 (dd, J = 4.5, 13.9 Hz, 1H), 2.26 (ddd, J = 3.2, 6.2, 13.9 Hz, 1H), 1.83 – 1.70 (m, 2H), 1.57 (s, 3H), 1.30 (s, 3H), 1.11 (s, 3H), 1.06 (d, J = 12.7 Hz, 1H); 13C NMR (125 MHz, CDCl3) δ 112.4, 87.5, 82.9, 81.9, 78.2, 74.6, 45.6, 43.7, 37.5, 30.6, 29.5, 25.4, 24.8, 21.6; MS(ES)+ calcd for C14H21BrNaO4 (M+Na)+ 355.05, found 354.90.

Alcohol 8. To a solution of bromide 29 (0.0070 g, 0.021 mmol, 1.0 equiv) in anhydrous tetrahydrofuran (0.2 mL) was slowly added a solution of L-selectride (1.0 M in tetrahydrofuran, 23 μL, 0.023 mmol, 1.1 equiv) at -78 °C. After stirring at -78 °C for 30 min, sodium perborate monohydrate (0.0063 g, 0.063 mmol, 3.0 equiv) and a 20:1 (v:v) mixture of tetrahydrofuran:water (0.2 mL) were added. The mixture was allowed to warm to 23°C and water (1 mL) was added. The biphasic mixture was extracted with ethyl acetate (5 mL), and the organic phase was dried over anhydrous sodium sulfate, filtered, concentrated, and purified by silica gel column chromatography (25% ethyl acetate–hexanes) to give 8 as colorless oil (0.0063 g, 89 %): Rf =0.55 (50 % ethyl acetate–hexane); 1H NMR (500 MHz, CDCl3) δ 4.69 (ddd, J = 1.3, 2.8, 3.2 Hz, 1H), 4.65 (d, J = 5.6 Hz, 1H), 4.36 (d, J = 6.8 Hz, 1H), 4.28 (d, J = 5.6 Hz, 1H), 3.41 (dd, J = 10.9, 2.8 Hz, 1H), 3.16 (d, J = 10.9 Hz, 1H), 2.70 (dd, J = 6.8, 12.8 Hz, 1H), 2.44 (ddt, J = 1.3, 3.5, 15.4 Hz, 1H), 2.24 (tt, J = 2.8, 14.1 Hz, 1H), 2.01 (ddd, J = 3.0, 5.6, 15.4 Hz, 1H), 1.81 (dd, J = 3.2, 14.1 Hz, 1H), 1.57 (s, 3H), 1.34 (s, 3H), 1.32 (s, 3H), 0.97 (d, J = 12.8 Hz, 1H); 13C NMR (125 MHz, CDCl3) δ 111.5, 88.8, 83.2, 81.7, 79.4, 74.2, 42.6, 36.9, 25.9, 25.3, 25.2, 24.6, 21.8; MS(ES)+ calcd for C14H21BrNaO4 (M+Na)+ 355.05, found 355.07.

Acetal 9. A solution of 85 (0.0080 g, 0.024 mmol, 1.0 equiv) in trifluoroacetic acid/methylene chloride/water (9:1 v/v/v, 0.2 mL) was stirred at 23 °C for 4 h. The solvent was then evaporated under vacuo and the residue was dried using high vacuum for
2 h to give the crude diol 85a which was directly used in the next step without purification. To a solution of crude 85a obtained above in acetone/pH 7.4 buffer (2:1 v/v, 0.2 mL) was added sodium periodate (0.0103 g, 0.048 mmol, 2.0 equiv) at 23 °C. After stirring for 50 min, the suspension was diluted with water (2 mL) and extracted with ethyl acetate (3 mL×3), and the combined organic phase was dried over anhydrous sodium sulfate, filtered, concentrated to give crude dialdehyde 85b which was directly used in the next step without purification. To a solution of crude 85b obtained above and triethylsilane (4.6 μL, 0.029 mmol, 1.2 equiv) in methylene chloride (0.2 mL) was slowly added boron trifluoride diethyl etherate (5.9 μL in 0.15 mL anhydrous methylene chloride, 0.048 mmol, 2.0 equiv) at 23 °C. After stirring at same temperature for 2 h, a saturated aqueous solution of sodium bicarbonate (1.5 mL) was added. The biphasic mixture was extracted with ethyl acetate (3 mL×3), and the organic phase was dried over anhydrous sodium sulfate, filtered, concentrated, and purified by silica gel column chromatography (20% ethyl acetate–hexanes) to give 9 as colorless oil (0.0040 g, 58% over three steps): Rf = 0.15 (50% ethyl acetate–hexanes); 1H NMR (500 MHz, CDCl3) δ 5.33 (d, J = 4.3 Hz, 1H), 4.76 (dd, J = 5.5, 11.6 Hz, 1H), 4.24 (d, J = 8.0 Hz, 1H), 3.93 (d, J = 11.4 Hz, 1H), 3.60 (d, J = 11.4 Hz, 1H), 3.19 (dd, J = 8.0, 12.6 Hz, 1H), 3.13 (d, J = 4.3 Hz, 1H), 2.69 – 2.61 (m, 1H), 2.47 – 2.34 (m, 3H), 1.92 (dd, J = 1.4, 12.6 Hz, 1H), 1.50 (s, 3H); 13C NMR (125 MHz, CDCl3) δ 218.2, 117.5, 108.4, 98.8, 73.9, 71.1, 48.3, 39.2, 39.1, 30.6, 19.4; MS(ES)⁺ calcd for C11H15BrNaO (M+Na)⁺ 313.01, found 312.85.

Acetal 10. A solution of bromide 29 (0.045 g, 0.14 mmol, 1.0 equiv) in trifluoroacetic acid/methanol chloride/water (9:1:1 v/v/v, 0.5 mL) was stirred at 23 °C for 4 h. The solvent was then evaporated under vacuo and the residue was dried using high vacuum for 2 h to give the crude diol 29a which was directly used in the next step without purification. To a solution of crude 29a obtained above in acetone/pH 7.4 buffer (2:1 v/v, 0.5 mL) was added sodium periodate (0.060 g, 0.28 mmol, 2.0 equiv) at 23 °C. After stirring for 50 min, the suspension was diluted with water (2 mL) and extracted with ethyl acetate (3 mL×3), and the combined organic phase was dried over anhydrous sodium sulfate, filtered, concentrated, and purified by silica gel column chromatography (20% ethyl acetate–hexanes) to give 9 as colorless oil (0.0040 g, 58% over three steps): Rf = 0.15 (50% ethyl acetate–hexanes); 1H NMR (500 MHz, CDCl3) δ 5.33 (d, J = 4.3 Hz, 1H), 4.76 (dd, J = 5.5, 11.6 Hz, 1H), 4.24 (d, J = 8.0 Hz, 1H), 3.93 (d, J = 11.4 Hz, 1H), 3.60 (d, J = 11.4 Hz, 1H), 3.19 (dd, J = 8.0, 12.6 Hz, 1H), 3.13 (d, J = 4.3 Hz, 1H), 2.69 – 2.61 (m, 1H), 2.47 – 2.34 (m, 3H), 1.92 (dd, J = 1.4, 12.6 Hz, 1H), 1.50 (s, 3H); 13C NMR (125 MHz, CDCl3) δ 218.2, 117.5, 108.4, 98.8, 73.9, 71.1, 48.3, 39.2, 39.1, 30.6, 19.4; MS(ES)⁺ calcd for C11H15BrNaO (M+Na)⁺ 313.01, found 312.85.

TBS Ether 88. To a solution of the 2-methyl cinnamyl alcohol 86 (3.0 g, 20.3 mmol, 1.0 equiv) in methylene chloride (120 mL) was added 3-chloroperoxybenzoic acid (assay ≤77%, 5.5 g, 24.3 mmol, 1.2 equiv) at 0 °C. After stirring at same temperature for 2 h, the mixture was diluted with ethyl acetate (150 mL) and washed with saturated sodium bicarbonate (40 mL×2) and saturated sodium thiosulfate (40 mL×2) and dried over anhydrous sodium sulfate, filtered, concentrated, and directly used in the next step without purification. To a solution of the crude epoxide 87 (3.1 g, 18.9 mmol, 1.0 equiv) in anhydrous dimethylformamide (9 mL) were successively added imidazole (3.1 g, 45.4 mmol, 2.4 equiv) and t-butyldimethylsilyl chloride (3.4 g, 20.3 mmol, 1.0 equiv). After stirring for 1 h, the mixture was diluted with ethyl acetate (150 mL) and washed with saturated sodium bicarbonate (40 mL×2) and saturated sodium thiosulfate (40 mL×2) and dried over anhydrous sodium sulfate, filtered, concentrated, and purified silicagel column chromatography (20% ethyl acetate–hexanes) to give 10 as colorless oil (0.021 g, 52% over three steps): Rf = 0.51 (50% ethyl acetate–hexanes); 1H NMR (500 MHz, CDCl3) δ 5.33 (d, J = 4.3 Hz, 1H), 4.76 (dd, J = 5.5, 11.6 Hz, 1H), 4.24 (d, J = 8.0 Hz, 1H), 3.93 (d, J = 11.4 Hz, 1H), 3.60 (d, J = 11.4 Hz, 1H), 3.19 (dd, J = 8.0, 12.6 Hz, 1H), 3.13 (d, J = 4.3 Hz, 1H), 2.69 – 2.61 (m, 1H), 2.47 – 2.34 (m, 3H), 1.92 (dd, J = 1.4, 12.6 Hz, 1H), 1.50 (s, 3H); 13C NMR (125 MHz, CDCl3) δ 218.2, 117.5, 108.4, 98.8, 73.9, 71.1, 48.3, 39.2, 39.1, 30.6, 19.4; MS(ES)⁺ calcd for C11H15BrNaO (M+Na)⁺ 313.01, found 313.03.

S16
22.7 mmol, 1.2 equiv) at 23 °C. After stirring at same temperature for 30 min, the mixture was diluted with ethyl acetate (200 mL) and washed with brine (30 mL×5), dried over anhydrous sodium sulfate, filtered, concentrated, and purified by silica gel column chromatography (gradient hexane → 3% ethyl acetate–hexanes) to give 88 as colorless oil (4.8 g, 85% over 2 steps): Rf = 0.58 (10 % ethyl acetate-hexane); 1H NMR (400 MHz, CDCl3) δ 7.33 – 7.21 (m, 5H), 4.01 (dd, J = 2.1, 2.8 Hz, 1H), 3.98 (dd, J = 4.0, 6.0 Hz, 1H), 3.10 (td, J = 2.1, 4.0 Hz, 1H), 2.47 (s, 3H), 1.00 (s, 9H), 0.19 (s, 3H), 0.19 (s, 3H). 13C NMR (100 MHz, CDCl3) δ 135.8, 135.5, 129.7, 127.5, 126.0, 124.3, 63.1, 61.7, 54.1, 25.8, 18.8, 18.3, -5.3, -5.4; MS(ES)+ calcd for C16H27O2Si (M+H)+ 279.18, found 279.10.

**Aldehyde 89.** A solution of 4-bromo-2,6-di-tert-butylphenol (16.4 g, 57.6 mmol, 4.0 equiv) in anhydrous methylene chloride (500 mL) was degassed using freeze-pump-thaw. A solution of trimethylaluminium (2.0 M in hexane, 14.4 mL, 28.8 mmol, 2.0 equiv) was added. The mixture was stirred at - 78 °C for 10 min before addition of sodium fluoride (3.6 g, 86.4 mmol, 1.3 equiv) at - 78 °C under argon. The mixture was stirred at this temperature for 30 min, then added at 23 °C. After stirring at same temperature for 1 h, the solution was cooled to - 78 °C and a solution of 86 (4.0 g, 14.4 mmol, 1.0 equiv) in anhydrous methylene chloride (10 mL) was slowly added. The mixture was stirred at - 78 °C for 10 min before addition of sodium fluoride (3.6 g, 86.4 mmol, 6.0 equiv) and water (2.1 mL, 115.2 mmol, 8.0 equiv). The mixture was allowed to warm to 23 °C and stirred for 10 min. Filtered the resulted suspension and washed with methylene chloride (100 mL), the combined filtrates were concentrated, and purified by silica gel column chromatography (gradient hexane → 2% ethyl acetate–hexanes) to give 89 as colorless oil (3.4 g, 85%): Rf = 0.53 (10 % ethyl acetate-hexane); 1H NMR (400 MHz, CDCl3) δ 9.83 (d, J = 1.6, 1H), 7.32 – 7.22 (m, 4H), 7.13 (dd, J = 3.7, 5.2 Hz, 1H), 4.33 (dd, J = 7.3, 10.0 Hz, 1H), 4.08 (dt, , J = 1.6, 5.7, 7.3 Hz, 1H), 3.95 (dd, J = 5.7, 10.0 Hz, 1H), 2.44 (s, 3H), 0.89 (s, 9H), 0.05 (s, 3H), 0.03 (s, 3H); 13C NMR (100 MHz, CDCl3) δ 200.5, 137.4, 132.2, 130.8, 128.1, 127.6, 126.3, 124.3, 63.0, 57.1, 25.8, 19.9, 18.2, -5.60, -5.64; MS(ES)+ calcd for C16H27O2Si (M+H)+ 279.18, found 279.10.

**Furanone 90a and 90b.** To a solution of furanone (0.8 g, 9.4 mmol, 1.3 equiv) in anhydrous tetrahydrofuran (30 mL) was added lithium bis(trimethylsilyl)amide (1.0 M in hexane, 9.4 mL, 9.4 mmol, 1.3 equiv) at - 78 °C under argon. The mixture was stirred at this temperature for 30 min, then added 87 (2.0 g, 7.2 mmol, 1.0 equiv) in anhydrous tetrahydrofuran (5 mL) was added. After stirring at - 78 °C for 1 h, saturated ammonium chloride (30 mL) was added and the mixture was allowed to warm to 23 °C. The biphasic mixture was extracted with ethyl acetate (20 mL×3), and the combined organic phase was washed with brine (30 mL), dried over anhydrous sodium sulfate, filtered, concentrated, and purified by silica gel column chromatography (gradient 10% → 20% ethyl acetate–hexanes) to give 90a (1.2 g), 90b (0.6 g 72% total yield) as colorless oil: 90a Rf = 0.16 (30 % ethyl acetate-hexane); 1H NMR (400 MHz, CDCl3) δ 7.44 (dd, J = 1.6, 5.7 Hz, 1H), 7.33 – 7.18 (m, 4H), 6.18 (dd, J = 2.1, 5.7 Hz, 1H), 4.73 (dd, J = 1.6, 3.5 Hz, 1H), 4.67 (bs, 1H), 4.49 (dd, J = 1.6, 9.7 Hz, 1H), 4.16 (t, J = 10.1 Hz, 1H), 3.94 (dd, J = 4.0, 10.1 Hz, 1H), 3.63 (td, J = 4.0, 9.7 Hz, 1H), 2.57 (s, 3H), 0.99 (s, 9H), 0.17 (s, 6H); 13C NMR (125 MHz, CDCl3) δ 173.3, 154.0, 137.1, 136.2, 131.2, 132.7, 126.4, 126.2, 122.3, 83.6, 75.5, 67.8, 44.4, 25.7, 20.0, 18.0, -5.7, -5.8; MS(ES)+ calcd for C16H23O3Si (M+Na)+ 305.12, found 305.10; 90b Rf = 0.20 (30 % ethyl acetate-hexane); 1H NMR (500 MHz, CDCl3) δ 7.44 (dd, J = 1.4, 5.8, 1H), 7.35 (d, J = 6.8, 1H), 7.30 – 7.22 (m, 3H), 6.09 (dd, J = 2.0, 5.8 Hz, 1H), 5.06 (dd, J = 1.4, 2.0 Hz, 1H), 4.50 (dt, J = 3.7, 7.5 Hz, 1H), 4.33 (d, J = 3.7 Hz, 1H), 4.08 (ddd, J = 5.8, 10.3 Hz, 2H), 3.41 (td, J = 5.8, 7.5 Hz, 1H), 2.45 (s, 3H), 0.97 (s, 9H), 0.11 (s, 3H), 0.10 (s, 3H); 13C NMR (100 MHz, CDCl3) δ 172.8, 153.3, 135.9, 135.7, 130.9, 127.2, 127.1, 126.3, 121.9, 85.0, 74.7, 66.4, 43.8, 25.7, 19.8, 18.0, -5.8; MS(ES)+ calcd for C20H30NaO4Si (M+Na)+ 385.18, found 385.30.
Lactone 91. To a solution of 90a (1.1 g, 3.0 mmol, 1.0 equiv) and palladium on carbon (10 wt. %, 0.32 g, 0.1 equiv) in anhydrous methanol (15 mL) was evacuated and refilled with hydrogen three times. After stirring at 23 °C for 12 h, the mixture was filtered with a celite column, and washed with methanol (15 mL). The filtrates were concentrated, and purified by silica gel column chromatography (15% → 20% ethyl acetate–hexanes) to give 91 as colorless oil (1.1 g, 98%): \( R_f = 0.60 \) (50% ethyl acetate–hexane); \(^1\)H NMR (500 MHz, CDCl\(_3\)) \( \delta = 7.21 – 7.17 \) (m, 1H), 7.16 – 7.11 (m, 2H), 7.04 – 6.99 (m, 1H), 4.63 (s, 1H), 4.10 (d, \( J = 9.8 \) Hz, 1H), 4.07 (dd, \( J = 4.3 \), 8.5 Hz, 1H), 4.00 (dd, \( J = 3.9 \), 10.2 Hz, 1H), 3.45 (td, \( J = 3.9 \), 9.9 Hz, 1H), 2.73 – 2.65 (m, 1H), 2.44 (s, 3H), 2.38 – 2.22 (m, 2H), 2.11 – 2.00 (m, 1H), 0.90 (s, 9H), 0.08 (s, 3H); \(^13\)C NMR (125 MHz, CDCl\(_3\)) \( \delta = 178.2, 137.2, 136.6, 131.0, 127.0, 126.5, 126.1, 79.6, 78.6, 68.2, 43.8, 28.4, 25.8, 23.7, 20.0, 18.1, -5.6, -5.7; MS(ES)\(^+\) calef for \( \text{C}_{20}\text{H}_{32}\text{NaO}_{4}\text{Si} \) (M+Na)\(^+\) 387.20, found 387.05.

TBS Ether 92. To a solution of 91 (1.0 g, 2.7 mmol, 1.0 equiv) in anhydrous methylene chloride (15 mL) was added 2,6-lutidine (0.94 mL, 8.1 mmol, 3.0 equiv) at 23 °C. After stirring at this temperature for 30 min, the mixture was cooled down to 23 °C and water (15 mL) was added. The biphasic mixture was extracted with ethyl acetate (30 mL), and the organic phase was washed with brine (30 mL), dried over anhydrous sodium sulfate, filtered, concentrated, and purified by silica gel column chromatography (5% ethyl acetate–hexanes) to give 92 as colorless oil (1.2 g, 94%): \( R_f = 0.70 \) (30% ethyl acetate–hexane); \(^1\)H NMR (400 MHz, CDCl\(_3\)) \( \delta = 7.17 – 7.06 \) (m, 4H), 4.55 (dd, \( J = 5.5 \), 6.8, 8.3 Hz, 1H), 4.18 (dd, \( J = 6.5 \), 9.5 Hz, 1H), 3.95 (t, \( J = 5.5 \), 1H), 3.79 (dd, \( J = 5.5 \), 9.5 Hz, 1H), 3.32 (dd, \( J = 5.5 \), 11.5 Hz, 1H), 2.54 – 2.40 (m, 2H), 2.37 (s, 3H), 2.29 – 2.18 (m, 1H), 2.08 – 1.92 (m, 1H), 0.92 (s, 9H), 0.84 (s, 9H), 0.11 (s, 3H), -0.09 (s, 3H), -0.09 (s, 3H), -0.13 (s, 3H); \(^13\)C NMR (100 MHz, CDCl\(_3\)) \( \delta = 176.7, 139.0, 136.2, 130.3, 127.9, 126.4, 125.6, 82.6, 75.6, 63.0, 44.8, 29.0, 26.1, 25.8, 24.7, 19.9, 18.4, 18.1, -3.7, -4.6, -5.8, -5.8; MS(ES)\(^+\) calef for \( \text{C}_{22}\text{H}_{37}\text{O}_{3}\text{Si} \) (M-57)\(^+\) 421.22, found 421.25.

Alcohol 93. A solution of 92 (1.0 g, 2.1 mmol, 1.0 equiv) in a 3:2:2 mixture of acetic acid:tetrahydrofuran:water (10 mL) was stirred at 60 °C for 12 h. Then, acetic acid was evaporated under vacuo and the residue was diluted with ethyl acetate (70 mL) and washed with a saturated solution of sodium bicarbonate (25 mL) and dried over anhydrous sodium sulfate, filtered, concentrated, and purified by silica gel column chromatography (25% ethyl acetate–hexanes) to give 93 as colorless oil (0.66 g, 87%): \( R_f = 0.30 \) (30% ethyl acetate–hexane); \(^1\)H NMR (400 MHz, CDCl\(_3\)) \( \delta = 7.20 – 7.10 \) (m, 4H), 4.38 (dd, \( J = 5.0 \), 7.6 Hz, 1H), 4.05 – 3.97 (m, 2H), 3.80 (dt, \( J = 6.2 \), 5.0 Hz, 1H), 3.38 (q, \( J = 6.2 \) Hz, 1H), 2.46 – 2.39 (m, 2H), 2.36 (s, 3H), 2.16 – 2.05 (m, 2H), 1.98 – 1.85 (m, 1H), 0.92 (s, 9H), 0.13 (s, 3H), 0.01 (s, 3H); \(^13\)C NMR (100 MHz, CDCl\(_3\)) \( \delta = 176.6, 138.0, 136.7, 130.8, 127.2, 126.8, 126.1, 82.0, 76.4, 63.63, 45.0, 28.7, 25.9, 24.1, 19.8, 18.2, -3.8, -4.5; MS(ES)\(^+\) calef for \( \text{C}_{20}\text{H}_{32}\text{NaO}_{4}\text{Si} \) (M+Na)\(^+\) 387.20, found 387.70.

Aldehyde 94. To a solution of 93 (0.6 g, 1.6 mmol, 1.0 equiv) in anhydrous methylene chloride (10 mL) was added Dess-Martin periodinane (1.0 g, 2.4 mmol, 1.5 equiv) at 23 °C. After stirring for 5 min, a solution of water (43.2 μL, 2.4 mmol, 1.5 equiv) was added. The suspension was stirred for another 30 min, an aqueous solution of 1:1 10% sodium bisulfate/saturated sodium bicarbonate (10 mL) was then added. After stirring for another 10 min, the biphasic mixture was extracted with ethyl acetate (10 mL × 3), the organic phase was washed with saturated sodium bicarbonate (15 mL), dried over anhydrous sodium sulfate, filtered, concentrated, and purified by silica gel column chromatography (15% ethyl acetate–hexanes) to give 94 as colorless oil (0.53 g, 91%): \( R_f = 0.45 \) (30% ethyl acetate–hexane); \(^1\)H NMR (400 MHz, CDCl\(_3\)) \( \delta = 9.76 \) (d, \( J = 3.0 \) Hz, 1H).
Hz, 1H), 7.25 – 7.10 (m, 4H), 4.46 (dd, J = 2.9, 8.5 Hz, 1H), 4.26 (d, J = 2.9 Hz, 1H), 4.23 (dd, J = 9.1, 6.0, 3.0 Hz, 1H), 2.55 – 2.33 (m, 3H), 2.44 (s, 3H), 2.08 – 1.98 (m, 1H), 0.89 (s, 9H), 0.17 (s, 3H), 0.08 (s, 3H); 13C NMR (100 MHz, CDCl3) δ 198.4, 176.3, 137.9, 131.4, 131.2, 128.5, 127.8, 126.3, 80.2, 74.0, 58.0, 28.4, 25.8, 23.4, 20.0, 18.2, -4.0, -4.1; MS(ES)+ calcd for C16H21O4Si (M-57)+ 305.12, found 305.05.

**TBS ether 95.** To a solution of triphenyl phosphite (289.5 μL, 1.1 mmol, 2.0 equiv) in anhydrous methylene chloride (10 mL) was induced chlorine at – 78 °C until the solution became yellow. The color was discharged by argon bubbling (1 min). Then, freshly distilled triethylamine (306.6 μL, 2.2 mmol, 4.0 equiv) and a solution of 94 (0.20 g, 0.55 mmol, 1.0 equiv) in anhydrous methylene chloride (2 mL) was added at same temperature. The mixture was allowed to warm to 23 °C and stirred for 30 min. Then, heated the solution to 40 °C and stirred for 10 min. The solvent was evaporated in vacuo and the residue was purified by silica gel column chromatography (5% ethyl acetate–hexanes) to give 95 as colorless oil (0.19 g, 87%): Rf =0.55 (30 % ethyl acetate-hexane).

**1H NMR (400 MHz, CDCl3) δ 7.48 (d, J = 7.8, 1H), 7.28 – 7.18 (m, 3H), 6.36 (dd, J = 1.0, 3.2, 1H), 4.21 – 4.14 (m, 2H), 4.02 (dd, J = 3.2, 9.2, 1H), 2.48 (s, 3H), 2.44 – 2.36 (m, 2H), 2.10 – 1.96 (m, 1H), 1.95 – 1.83 (m, 1H), 0.97 (s, 9H), 0.30 (s, 3H), 0.22 (s, 3H);**

**13C NMR (100 MHz, CDCl3) δ 176.1, 139.2, 133.1, 131.1, 130.0, 128.0, 125.5, 80.6, 75.12, 75.06, 52.3, 28.8, 26.2, 23.7, 20.7, 18.7, -3.6, -3.9; **MS(ES)+ calcd for C20H30Cl2NaO3Si (M+Na)+ 439.12, found 439.55.

**Alcohol 11.** To a solution of 95 (0.15 g, 0.36 mmol, 1.0 equiv) in anhydrous tetrahydrofuran (5 mL) was added a solution of tetrabutylammonium fluoride solution (1.0 M, in tetrahydrofuran, 0.40 mL, 0.40 mmol, 1.1 equiv) at 23 °C. After stirring at 23 °C for 15 min, calcium carbonate (0.18 g, 1.8 mmol, 5.0 eq), Dowex 50WX8-400 (0.25 g, 0.622 g/mmol TBAF) and methanol (2.5 mL) were added. The mixture was stirred at same temperature for 15 min and filtered through a pad of Celite and washed with methanol (5 mL). The combined filtrates were concentrated, and purified by silica gel column chromatography (35% ethyl acetate–hexanes) to give 11 as white solid (0.098 g, 82%). Recrystallization from 10% ethyl acetate–hexanes gave single crystals suitable for X-ray analysis. Rf = 0.26 (40 % ethyl acetate–hexanes); 1H NMR (400 MHz, CD3OD) δ 7.57 – 7.53 (m, 1H), 7.26 – 7.18 (m, 3H), 6.61 (d, J = 3.3 Hz, 1H), 4.104 (dt, J = 8.15, 5.42, 0.95 Hz, 1H), 4.097 (dd, J = 0.95, 10.4 Hz, 1H), 3.98 (dd, J = 3.3, 10.4 Hz, 1H), 2.60 – 2.50 (m, 1H), 2.46 (s, 3H), 2.45 – 2.35 (m, 1H), 2.24 – 2.07 (m, 2H); 13C NMR (125 MHz, CD3OD) δ 180.7, 140.9, 135.1, 132.3, 130.3, 129.4, 127.2, 82.2, 77.3, 75.4, 52.8, 29.7, 25.0, 21.2; MS(ES)+ calcd for C14H16Cl2NaO3 (M+Na)+ 325.04, found 325.40.

**Ketone 96.** To a solution of 11 (0.050 g, 0.16 mmol, 1.0 equiv) in anhydrous methylene chloride (3 mL) was added Dess-Martin periodinane (0.105 g, 0.25 mmol, 1.5 equiv) at 23 °C. After stirring for 5 min, a solution of water (4.5 μL, 0.25 mmol, 1.5 equiv) was added. The suspension was stirred for another 30 min, an aqueous solution of 1:1 10% sodium bisulfate/saturated sodium bicarbonate (3 mL) was then added. After stirring for another 10 min, the
biphasic mixture was extracted with ethyl acetate (10 mL×3), the organic phase was washed with saturated sodium bicarbonate (15 mL), dried over anhydrous sodium sulfate, filtered, concentrated, and purified by silica gel column chromatography (25% ethyl acetate–hexanes) to give 96 as colorless oil (0.042 g, 87%): Rf =0.30 (40% ethyl acetate–hexane); 1H NMR (400 MHz, CDCl3) δ 7.29 – 7.22 (m, 2H), 7.17 (dd, J = 1.8, 7.5 Hz, 1H), 7.10 (dd, J = 1.2, 7.5 Hz, 1H), 6.20 (d, J = 10.2 Hz, 1H), 5.13 (d, J = 10.2 Hz, 1H), 4.66 (dd, J = 6.9, 7.8 Hz, 1H), 2.59 (s, 3H), 2.58 – 2.48 (m, 2H), 2.48 – 2.34 (m, 2H); 13C NMR (100 MHz, CDCl3) δ 203.5, 175.3, 138.9, 131.7, 130.7, 129.1, 126.7 (2C), 80.6, 72.3, 59.8, 27.4, 24.3, 20.2; MS(ES)+ calcld for C14H14Cl2NaO3 (M+Na)+ 323.03, found 323.05.

**Alcohol 14.** To a solution of 96 (0.025 g, 0.083 mmol, 1.0 equiv) in tetrahydrofuran: ethanol (2 mL) was added sodium borohydride (0.0041 g, 0.11 mmol, 1.3 equiv) at –78 °C. The solution was stirred at this temperature for 15 min before addition of acetone (0.5 mL). The mixture was allowed to warm to 23 °C and evaporated the solvent under vacuo. The residue was diluted with ethyl acetate (10 mL) and saturated ammonium chloride (5 mL), and the organic phase was collected and dried over anhydrous sodium sulfate, filtered, concentrated, and purified by silica gel column chromatography (35% ethyl acetate–hexanes) to give 14 as colorless oil (0.023 g, 91%): Rf =0.32 (40% ethyl acetate–hexane); 1H NMR (500 MHz, CDCl3) δ 7.80 – 7.73 (m, 1H), 7.22 – 7.15 (m, 3H), 6.33 (d, J = 8.4 Hz, 1H), 4.35 – 4.29 (m, 2H), 3.78 – 3.74 (m, 1H), 2.53 – 2.48 (m, 2H), 2.40 (s, 3H), 2.16 – 2.01 (m, 2H); 13C NMR (125 MHz, CD3OD) 180.2, 139.6, 137.0, 132.1, 130.1, 129.2, 127.6, 84.5, 77.2, 75.4, 52.9, 29.9, 25.3, 21.2; MS(ES)+ calcld for C14H16Cl2NaO3 (M+Na)+ 325.04, found 325.36.

**Lactone 97.** To a solution of 90b (0.6 g, 1.7 mmol, 1.0 equiv) in anhydrous tetrahydrofuran (10 mL) was slowly added a solution of L-selectride (1.0 M in tetrahydrofuran, 1.9 mL, 1.9 mmol, 1.1 equiv) at -78 °C. After stirring at -78 °C for 30 min, sodium perborate monohydrate (0.5 g, 5.1 mmol, 3.0 equiv) and a 20:1 (v:v) mixture of tetrahydrofuran:water (5 mL) were added. The mixture was allowed to warm to 23°C and water (15 mL) was added. The biphasic mixture was extracted with ethyl acetate (15 mL×3), and the organic phase was washed with saturated sodium bicarbonate (15 mL), dried over anhydrous sodium sulfate, filtered, concentrated, and purified by silica gel column chromatography (15% → 20% ethyl acetate–hexanes) to give 97 as colorless oil (0.56 g, 97%): Rf =0.55 (50% ethyl acetate–hexane); 1H NMR (500 MHz, CDCl3) δ 7.20 – 7.11 (m, 4H), 4.54 (dd, J = 2.5, 9.5 Hz, 1H), 4.24 (dddd, J = 2.5, 5.6, 7.9 Hz, 1H), 4.15 (bs, 1H), 3.97 (dd, J = 8.0, 10.1 Hz, 1H), 3.88 (dd, J = 4.6, 10.1 Hz, 1H), 3.11 (ddd, J = 4.6, 8.0, 9.5 Hz, 1H), 2.66-2.57 (m, 1H), 2.44 – 2.34 (m, 2H), 2.34 (s, 3H), 1.98-1.88 (m, 1H), 0.89 (s, 9H), 0.03 (s, 6H); 13C NMR (125 MHz, CD3OD) δ 177.5, 136.3, 135.6, 130.8, 127.3, 127.0, 126.5, 80.9, 75.1, 67.4, 43.5, 28.6, 25.8, 20.8, 19.9, 18.1, -5.71, -5.73; MS(ES)+ calcld for C20H32NaO4Si (M+Na)+ 387.20, found 387.95.

**TBS Ether 98.** To a solution of 97 (0.5 g, 1.4 mmol, 1.0 equiv) in anhydrous methylene chloride (10 mL) was added 2,6-lutidine (0.49 mL, 4.2 mmol, 3.0 equiv) at 23 °C. The mixture was heated to 40 °C and added t-butyldimethylsilyl trifluoromethanesulfonate (0.55 mL, 2.4 mmol, 1.7 equiv). After stirring at this temperature for 30 min, the mixture was cooled down to 23 °C and water (10 mL) was added. The biphasic mixture was extracted with ethyl acetate (20 mL), and the organic phase was washed with brine (15 mL), dried over anhydrous sodium sulfate, filtered, concentrated, and purified by silica gel column chromatography (5% ethyl acetate–hexanes) to give 98 as colorless oil (0.59 g, 89%): Rf =0.70 (30% ethyl acetate–hexane); 1H NMR (500 MHz, CDCl3) δ 7.19 – 7.08 (m, 4H), 4.56 (dd, J = 1.2, 10.1 Hz, 1H), 4.28 (t, J = 6.8 Hz, 1H), 3.90 – 3.84 (m, 2H), 2.98 (ddd, J = 4.2, 5.8, 10.1 Hz, 1H), 2.48 – 2.32 (m, 3H), 2.30 (s, 3H), 1.82 – 1.72 (m, 1H), 0.94 (s, 9H), 0.76 (s, 9H), 0.18 (s, 3H), 0.14 (s, 3H), -0.25 (s, 3H), -0.28 (s, 3H); 13C NMR (100 MHz, CDCl3) δ 176.9, 138.0, 136.1, 130.3, 127.7, 126.4, 125.9, 81.2, 71.2.
Alcohol 99. A solution of 98 (0.5 g, 1.0 mmol, 1.0 equiv) in a 3:2:2 mixture of acetic acid:tetrahydrofuran:water (5 mL) was stirred at 60 °C for 12 h. Then, acetic acid was evaporated under vacuo and the residue was diluted with ethyl acetate (50 mL) and washed with a saturated solution of sodium bicarbonate (15 mL) and dried over anhydrous sodium sulfate, filtered, concentrated, and purified by silica gel column chromatography (15% ethyl acetate–hexanes) to give 99 as colorless oil (0.32 g, 89 %): \( R_f = 0.45 \) (30 % ethyl acetate–hexane).

\[ ^1H \text{ NMR (400 MHz, CDCl}_3 \delta 7.23–7.11 (m, 4H), 4.50 (dd, } J = 1.5, 10.4 \text{ Hz, 1H}), 4.19 (t, } J = 6.9 \text{ Hz, 1H), 3.93 (dd, } J = 4.6, 10.3 \text{ Hz, 1H), 3.78 (dd, } J = 56.1, 10.3 \text{ Hz, 1H), 3.07 (ddd, } J = 4.6, 6.1, 10.4 \text{ Hz, 1H), 2.50–2.34 (m, 3H), 2.32 (s, 3H), 1.93–1.82 (m, 2H), 0.94 (s, 9H), 0.19 (s, 3H), 0.14 (s, 3H); ^{13}C \text{ NMR (100 MHz, CDCl}_3 \delta 176.8, 136.9, 136.4, 131.0, 127.0, 126.8, 126.6, 80.9, 73.0, 64.4, 45.3, 28.5, 25.9, 19.9, 19.8, 18.1, -4.0, -4.7; MS(ES)^+ \text{ calcld for } C_{22}H_{37}O_4Si_2(M\text{-}57)^+ 421.22, \text{ found } 421.30. \]

Aldehyde 100. To a solution of 99 (0.30 g, 0.8 mmol, 1.0 equiv) in anhydrous methylene chloride (5 mL) was added Dess-Martin periodinane (0.52 g, 1.2 mmol, 1.5 equiv) at 23 °C. After stirring for 5 min, water (21.6 μL, 1.2 mmol, 1.5 equiv) was added. The suspension was stirred for another 30 min, an aqueous solution of 1:1 10% sodium bisulfate to saturated sodium bicarbonate (5 mL) was then added. After stirring for another 10 min, the biphasic mixture was extracted with ethyl acetate (10 mL×2), the combined organic phase was washed with saturated sodium bicarbonate (15 mL), dried over anhydrous sodium sulfate, filtered, concentrated, and purified by silica gel column chromatography (15% ethyl acetate–hexanes) to give 100 as colorless oil (0.26 g, 90 %): \( R_f = 0.52 \) (30 % ethyl acetate–hexane).

\[ ^1H \text{ NMR (400 MHz, CDCl}_3 \delta 9.67 (d, } J = 3.5 \text{ Hz, 1H), 7.26–7.19 (m, 4H), 4.98 (dd, } J = 1.6, 9.8 \text{ Hz, 1H), 4.23 (td, } J = 1.6, 7.9 \text{ Hz, 1H), 3.86 (dd, } J = 3.5, 9.8 \text{ Hz, 1H), 2.54–2.38 (m, 3H), 2.36 (s, 3H), 1.89–1.80 (m, 1H), 0.89 (s, 9H), 0.16 (s, 3H), 0.14 (s, 3H); ^{13}C \text{ NMR (100 MHz, CDCl}_3 \delta 197.1, 176.4, 136.8, 131.5, 130.4, 128.2, 128.1, 126.9, 80.2, 71.0, 58.0, 28.5, 25.8, 20.0, 19.8, 18.1, -4.0, -4.8; MS(ES)^+ \text{ calcld for } C_{16}H_{21}O_4Si (M-57)^+ 305.12, \text{ found } 305.10. \]

TBS ether 101. To a solution of triphenyl phosphite (146.7 μL, 0.56 mmol, 2.0 equiv) in anhydrous methylene chloride (10 mL) was induced chlorine at – 78 °C until the solution became yellow. The color was discharged by argon bubbling (1 min). Then, freshly distilled triethylamine (156.1 μL, 1.12 mmol, 4.0 equiv) and a solution of 100 (0.10 g, 0.28 mmol, 1.0 equiv) in anhydrous methylene chloride (1 mL) was added at same temperature. The mixture was allowed to warm to 23 °C and stirred for 30 min. Then, heated the solution to 40 °C and stirred for 10 min. The solvent was evaporated in vacuo and the residue was purified by silica gel column chromatography (15% ethyl acetate–hexanes) to give 101 as colorless oil (0.10 g, 0.28 mmol, 1.0 equiv) in anhydrous methylene chloride (1 mL) was added at same temperature. The mixture was allowed to warm to 23 °C and stirred for 30 min. Then, heated the solution to 40 °C and stirred for 10 min. The solvent was evaporated in vacuo and the residue was purified by silica gel column chromatography (5% ethyl acetate–hexanes) to give 101 as colorless oil (0.10 g, 90 %): \( R_f = 0.62 \) (30 % ethyl acetate–hexane).

\[ ^1H \text{ NMR (400 MHz, CDCl}_3 \delta 7.55–7.49 (m, 1H), 7.26 (s, 3H), 6.41 (d, } J = 3.1 \text{ Hz, 1H), 4.67 (dd, } J = 1.7, 10.1 \text{ Hz, 1H), 4.11 (ddd, } J = 1.7, 7.0, 8.7 \text{ Hz, 1H), 3.57 (dd, } J = 3.1, 10.1 \text{ Hz, 1H), 2.51–2.27 (m, 3H), 2.41 (s, 3H), 1.80–1.70 (m, 1H), 0.95 (s, 9H), 0.28 (s, 3H), 0.17 (s, 3H); ^{13}C \text{ NMR (100 MHz, CDCl}_3 \delta 176.3, 137.8, 131.8, 131.1, 129.1, 128.2, 126.0, 80.7, 74.7, 72.5, 51.5, 28.7, 26.2, 20.6, 19.9, 18.5, -3.8, -4.8; MS(ES)^+ \text{ calcld for } C_{20}H_{30}Cl_2NaO_3Si (M+Na)^+ 439.12, \text{ found } 439.10. \]

Alcohol 12. To a solution of 101 (0.10 g, 0.24 mmol, 1.0 equiv) in anhydrous tetrahydrofuran (5 mL) was added a solution of tetrabutylammonium fluoride solution (1.0 M, in tetrahydrofuran, 0.26 mL, 0.26 mmol, 1.1 equiv) at 23 °C. After stirring at 23 °C for 15 min, calcium carbonate (0.12 g, 1.2 mmol, 5.0 equiv), Dowex 50WX8-400
(0.16 g, 0.622 g/mmol TBAF) and methanol (2.5 mL) were added. The mixture was stirred at same temperature for 15 min and filtered through a pad of Celite and washed with methanol (5 mL). The combined filtrates were concentrated, and purified by silica gel column chromatography (35% ethyl acetate–hexanes) to give 12 as colorless oil (0.059 g, 82%). $R_f = 0.30$ (40% ethyl acetate–hexanes); $^1$H NMR (400 MHz, CD$_2$OD) $\delta$ 7.61 – 7.55 (m, 1H), 7.28 – 7.21 (m, 3H), 6.63 (d, $J = 3.6$ Hz, 1H), 4.47 (dd, $J = 2.1$, 10.3 Hz, 1H), 4.16 (dd, $J = 2.1$, 6.0, 8.1 Hz, 1H), 3.69 (dd, $J = 3.6$, 10.3 Hz, 1H), 2.59 – 2.41 (m, 2H), 2.40 (s, 3H), 2.38 – 2.27 (m, 1H), 1.98 – 1.87 (m, 1H); $^13$C NMR (125 MHz, CD$_2$OD) $\delta$ 180.5, 139.9, 134.3, 132.4, 130.4, 129.6, 127.4, 82.9, 77.0, 73.6, 52.0, 30.0, 22.0, 21.2; MS(ES)$^+$ cals for C$_{14}$H$_{16}$Cl$_2$NaO$_3$ (M+Na)$^+$ 325.04, found 325.00.

**Ketone 102.** To a solution of 12 (0.030 g, 0.10 mmol, 1.0 equiv) in anhydrous methylene chloride (2 mL) was added Dess-Martin periodinane (0.064 g, 0.15 mmol, 1.5 equiv) at 23 °C. After stirring for 5 min, a solution of water (2.7 μL, 0.15 mmol, 1.5 equiv) in methylene chloride (2.7 mL) was added. The suspension was stirred for another 30 min, an aqueous solution of 1:1 10% sodium bisulfate/saturated sodium bicarbonate (3 mL) was then added. After stirring for another 10 min, the biphasic mixture was extracted with ethyl acetate (10 mL×3), the organic phase was washed with saturated sodium bicarbonate (15 mL), dried over anhydrous sodium sulfate, filtered, concentrated, and purified by silica gel column chromatography (25% ethyl acetate–hexanes) to give 100 as colorless oil (0.028 g, 92%): $R_f = 0.30$ (40% ethyl acetate–hexane); $^1$H NMR (400 MHz, CDCl$_3$) $\delta$ 7.29 – 7.21 (m, 2H), 7.15 (t, $J = 7.5$ Hz, 1H), 7.01 (d, $J = 7.5$ Hz, 1H), 6.20 (d, $J = 10.2$ Hz, 1H), 5.08 (d, $J = 10.2$ Hz, 1H), 4.82 (dd, $J = 3.9$, 9.4 Hz, 1H), 2.56 (s, 3H), 2.51 – 2.38 (m, 1H), 2.21 – 2.01 (m, 2H), 1.59 – 1.39 (m, 1H); $^13$C NMR (100 MHz, CDCl$_3$) $\delta$ 204.7, 175.0, 139.4, 132.2, 129.6, 129.4, 126.7, 126.6, 81.3, 72.2, 60.6, 25.9, 25.6, 20.1; MS(ES)$^+$ cals for C$_{14}$H$_{16}$Cl$_2$NaO$_3$ (M+Na)$^+$ 323.03, found 323.05.

**Alcohol 103.** To a solution of 102 (0.030 g, 0.10 mmol, 1.0 equiv) in a 10:3 tetrahydrofuran:ethanol (3 mL) was added sodium borohydride (0.0049 g, 0.13 mmol, 1.3 equiv) at –78 °C. The solution was stirred at this temperature for 15 min before addition of acetone (0.5 mL). The mixture was allowed to warm to 23 °C and evaporated the solvent under vacuo. The residue was diluted with ethyl acetate (10 mL) and saturated ammonium chloride (5 mL), and the organic phase was collected and dried over anhydrous sodium sulfate, filtered, concentrated, and purified by silica gel column chromatography (35% ethyl acetate–hexanes) to give 13 as colorless oil (0.028 g, 93%): $R_f = 0.30$ (40% ethyl acetate–hexane); $^1$H NMR (500 MHz, CD$_2$OD) $\delta$ 7.62 – 7.58 (m, 1H), 7.21 – 7.11 (m, 3H), 6.29 (d, $J = 10.2$ Hz, 1H), 4.42 (dd, $J = 3.2$, 7.4 Hz, 1H), 3.98 (q, $J = 7.4$ Hz, 1H), 3.76 (dd, $J = 3.2$, 10.2 Hz, 1H), 2.46 – 2.40 (m, 2H), 2.42 (s, 3H), 2.04 – 1.90 (m, 2H); $^13$C NMR (75 MHz, CD$_2$OD) $\delta$ 179.9, 139.8, 137.1, 132.0, 130.3, 129.1, 127.4, 82.9, 77.5, 73.8, 54.7, 29.4, 25.7, 21.1; MS(ES)$^+$ cals for C$_{14}$H$_{16}$Cl$_2$NaO$_3$ (M+Na)$^+$ 325.04, found 325.80.

**Furanone 103.** To a solution of aldehyde 89 (1.0 g, 3.6 mmol, 1.0 equiv) and 2-(trisopropylsiloxy)-3-methyl-furan (1.1 g, 4.3 mmol, 1.2 equiv) in anhydrous methanol (20 mL) was added boron trifluoride etherate (0.95 mL, 4.3 mmol, 1.2 equiv) at -78 °C under argon. After stirring at same temperature for 4 h, saturated sodium bicarbonate (15 mL) was added and the mixture was then warmed to 23 °C. The biphasic mixture was extracted with ethyl acetate (15 mL×2), and the organic phase was washed with brine (15 mL), dried over anhydrous sodium sulfate, filtered, concentrated, and purified by silica gel column chromatography (gradient 10% → 20% ethyl acetate–hexanes) to give 103 as colorless oil (0.88 g) and another diastereomer (0.22 g, total yield 81%). 103: $R_f = 0.33$ (40% ethyl acetate–hexane); $^1$H NMR (500 MHz, CDCl$_3$) $\delta$ 7.23 – 7.19 (m, 1H), 7.18 – 7.15 (m, 2H), 7.11 – 7.07 (m, 1H), 6.90 (t, $J = 1.7$ Hz, 1H), 4.46 (dd, $J = 1.7$, 13.9 Hz, 1H), 4.33 (dt, $J = 2.4$, 4.1 Hz, 9.9, 1H), 4.05 (t, $J = 10.1$ Hz, 1H), 3.83 (dd, $J = 4.0$, 10.1 Hz, 1H),
Ketone 105. To a solution of 103 (0.12 g, 0.32 mmol, 1.0 equiv) and platinum oxide (0.014 g, 0.064 mmol, 0.2 equiv) in ethyl acetate (15 mL) was evacuated and refilled with hydrogen three times. After stirring at 23 °C for 12 h, the mixture was filtered with a celite column, and washed with ethyl acetate (10 mL). The filtrates were concentrated and directly used in the next step without purification; To a solution of above crude product 104 in anhydrous methylene chloride (10 mL) was added Dess-Martin periodinane (0.20 g, 0.48 mmol, 1.5 equiv) at 23 °C. After stirring for 5 min, a solution of water (4.1 μL, 0.48 mmol, 1.5 equiv) in methylene chloride (0.4 mL) was added. The suspension was stirred for another 30 min, an aqueous solution of 1:1 10% sodium bisulfate/saturated sodium bicarbonate (8 mL) was then added. After stirring for another 10 min, the biphasic mixture was extracted with ethyl acetate (10 mL×3), the organic phase was washed with saturated sodium bicarbonate (10 mL), dried over anhydrous sodium sulfate, filtered, concentrated, and purified by silica gel column chromatography (10% → 20% ethyl acetate–hexanes) to give 105 as colorless oil (0.086 g, 72 % over 2 steps): Rf =0.5 (40 % ethyl acetate-hexane). ¹H NMR (500 MHz, CDCl₃) δ 7.22 (d, J = 7.1 Hz, 1H), 7.17 (td, J = 1.5, 7.1 Hz, 1H), 7.13 (td, J = 1.5, 7.7 Hz, 1H), 7.08 (dd, J = 1.5, 7.7 Hz, 1H), 4.61 (d, J = 7.1 Hz, 1H), 4.58 (ddd, J = 9.4, 5.2, 4.1 Hz, 1H), 4.19 (dd, J = 5.2, 9.4 Hz, 1H), 2.70 – 2.52 (m, 2H), 2.51 (s, 3H), 1.91 (dt, J = 10.5, 12.7 Hz, 1H), 1.28 (d, J = 7.0 Hz, 3H), 0.83 (s, 9H). ¹³C NMR (125 MHz, CDCl₃) δ 206.3, 178.3, 137.6, 132.2, 131.1, 127.7, 127.1, 126.2, 79.4, 51.7, 34.6, 32.6, 25.8, 20.0, 18.2, 15.1. -5.59, -5.64; MS(ES)⁺ calcd for C₁₇H₂₃O₄Si (M+Na)⁺ 401.21, found 401.14.

Alcohol 106. To a solution of 105 (0.075 g, 0.20 mmol, 1.0 equiv) and platinum oxide (0.0098 g, 0.26 mmol, 1.3 equiv) at −78 °C. The solution was stirred at this temperature for 15 min before addition of acetone (0.3 mL). The mixture was allowed to warm to 23 °C and evaporated the solvent under vacuo. The residue was diluted with ethyl acetate (10 mL) and saturated ammonium chloride (5 mL), and the organic phase was collected and dried over anhydrous sodium sulfate, filtered, concentrated, and purified by silica gel column chromatography (25% ethyl acetate–hexanes) to give 106 as colorless oil (0.071 g, 94 %): Rf =0.41 (40 % ethyl acetate-hexane). ¹H NMR (500 MHz, CDCl₃) δ 7.48 – 7.44 (m, 1H), 7.20 – 7.13 (m, 3H), 4.34 (m, 2H), 3.93 (dd, J = 7.3, 10.3 Hz, 1H), 3.83 (dd, J = 4.4, 10.3 Hz, 1H), 3.29 (dt, J = 4.4, 7.2 Hz, 1H), 2.67 (d, J = 2.9 Hz, 1H), 2.63 – 2.54 (m, 1H), 2.36 (s, 3H), 2.27 (ddd, J = 5.2, 8.9, 12.6 Hz, 1H), 1.84 (td, J = 9.4, 12.6 Hz, 1H), 1.25 (d, J = 7.1 Hz, 3H), 0.88 (s, 9H), 0.01 (s, 3H), 0.00 (s, 3H); ¹³C NMR (125 MHz, CDCl₃) δ 179.4, 136.89, 136.93, 130.5, 128.3, 126.9, 125.9, 78.7, 74.1, 65.6, 43.7, 35.4, 32.1, 25.8, 20.2, 18.2, 15.1, -5.6, -5.6; MS(ES)⁺ calcd for C₂₁H₃₄NaO₄Si (M+Na)⁺ 401.21, found 401.20.

TBS Ether 107. To a solution of 106 (0.065 g, 0.17 mmol, 1.0 equiv) in anhydrous methylene chloride (1.5 mL) was added 2,6-lutidine (60.1 μL, 0.51 mmol, 3.0 equiv) at 23 °C. The mixture was heated to 40 °C and added tert-butylimidemethylsilyl trifluoromethanesulfonate (66.4 μL, 0.29 mmol, 1.7 equiv). After stirring at this temperature for 30 min, the mixture was cooled down to 23 °C and water (1 mL) was added. The biphasic mixture was extracted with ethyl acetate (5 mL), and the organic phase was washed with brine (3 mL), dried over anhydrous sodium sulfate, filtered, concentrated, and purified by silica gel column chromatography (5% ethyl acetate–hexanes) to give 107 as colorless oil (0.070 g, 84 %): Rf =0.70 (30 % ethyl acetate-
Alcohol 108. A solution of 107 (0.063 g, 0.13 mmol, 1.0 equiv) in a 3:2:2 mixture of acetic acid: tetrahydrofuran:water (3 mL) was stirred at 60 °C for 12 h. Then, acetic acid was evaporated under vacuo and the residue was diluted with ethyl acetate (10 mL) and washed with a saturated solution of sodium bicarbonate (5 mL) and dried over anhydrous sodium sulfate, filtered, concentrated, and purified by silica gel column chromatography (25% ethyl acetate–hexanes) to give 108 as colorless oil (0.045 g, 92 %): \( R_f = 0.42 \) (40 % ethyl acetate-hexane). \(^1\)H NMR (400 MHz, CDCl\(_3\)) \( \delta \) 7.38 – 7.34 (m, 1H), 7.21 – 7.14 (m, 3H), 4.49 (dd, \( J = 2.3, 5.6 \) Hz, 1H), 4.39 (ddd, \( J = 2.3, 6.0, 10.3 \) Hz, 1H), 3.95 (dt, \( J = 7.1, 10.5 \) Hz, 1H), 3.80 (dt, \( J = 10.5, 4.5 \) Hz, 1H), 3.31 (dd, \( J = 7.1, 12.9 \) Hz, 1H), 2.57 (m, 1H), 2.37 (s, 3H), 1.94 – 1.77 (m, 2H), 1.74 (dd, \( J = 7.6 \) Hz, 3H), 0.84 (s, 9H), 0.26 (s, 3H), 0.11 (s, 3H); \(^{13}\)C NMR (100 MHz, CDCl\(_3\)) \( \delta \) 178.9, 137.2, 137.0, 130.7, 127.6, 127.1, 126.2, 80.0, 72.58, 64.3, 45.9, 35.7, 30.3, 26.0, 25.8, 20.4, 18.3, 18.2, 14.86, -4.2, -5.2, -5.4, -5.4; MS(ES)\(^+\) calcd for \( \text{C}_{27}\text{H}_{49}\text{O}_{4}\text{Si} (\text{M} + \text{Na})^+ \) 493.32, found 493.05.

Aldehyde 109. To a solution of 108 (0.038 g, 0.10 mmol, 1.0 equiv) in anhydrous methylene chloride (1 mL) was added Dess-Martin periodinane (0.064 g, 0.15 mmol, 1.5 equiv) at 23 °C. After stirring for 5 min, a solution of water (2.7 μL, 15 mmol, 1.0 equiv) in anhydrous methylene chloride (1 mL) was added. Dess-Martin periodinane (0.064 g, 0.15 mmol, 1.0 equiv) was added at same temperature. The mixture was allowed to warm to 23 °C and stirred for 30 min. Then, heated the solution to 40 °C and stirred for another 30 min. After stirring for another 10 min, the biphasic mixture was extracted with ethyl acetate (8 mL), the organic phase was washed with saturated sodium bicarbonate (4 mL), dried over anhydrous sodium sulfate, filtered, concentrated, and purified by silica gel column chromatography (15% ethyl acetate–hexanes) to give 109 as colorless oil (0.037 g, 97 %): \( R_f = 0.52 \) (40 % ethyl acetate-hexane). \(^1\)H NMR (500 MHz, CDCl\(_3\)) \( \delta \) 9.66 (d, \( J = 1.2 \) Hz, 1H), 7.25 – 7.19 (m, 4H), 4.73 (dd, \( J = 2.6, 7.9 \) Hz, 1H), 4.51 (dd, \( J = 2.6, 5.7, 10.5 \) Hz, 1H), 3.93 (dd, \( J = 1.2, 7.9 \) Hz, 1H), 2.68 – 2.59 (m, 1H), 2.38 (s, 3H), 2.12 (dd, \( J = 5.8, 8.7, 12.2 \) Hz, 1H), 1.97 (dd, \( J = 12.2 \) Hz, 1H), 1.25 (d, \( J = 7.1 \) Hz, 3H), 0.70 (s, 9H), 0.02 (s, 3H), -0.40 (s, 3H); \(^{13}\)C NMR (125 MHz, CDCl\(_3\)) \( \delta \) 199.1, 178.7, 138.3, 131.3, 131.2, 129.3, 128.1, 126.5, 78.9, 71.7, 57.2, 35.4, 29.7, 25.8, 20.2, 18.0, 15.0, -4.4, -5.5; MS(ES)\(^+\) calcd for \( \text{C}_{21}\text{H}_{32}\text{NaO}_{4}\text{Si} (\text{M} + \text{K})^+ \) 417.19, found 417.15.

TBS ether 110. To a solution of triphenyl phosphite (47.1 μL, 0.18 mmol, 2.0 equiv) in anhydrous methylene chloride (2 mL) was induced chlorine at – 78 °C until the acid was evaporated under vacuo and the residue was diluted with ethyl acetate (10 mL) and washed with a saturated solution of sodium bicarbonate (5 mL) and dried over anhydrous sodium sulfate, filtered, concentrated, and purified by silica gel column chromatography (5% ethyl acetate–hexanes) to give 110 as colorless oil (0.038 g, 97 %): \( R_f = 0.65 \) (30 % ethyl acetate-hexane). \(^1\)H NMR (500 MHz, CDCl\(_3\)) \( \delta \) 7.50 (d, \( J = 7.7 \) Hz, 1H), 7.24 – 7.14 (m, 3H), 5.97 (d, \( J = 10.1 \) Hz, 1H), 4.88 (t, \( J = 2.9 \) Hz, 1H), 4.09 (dd, \( J = 2.9, 5.5, 10.8 \) Hz, 1H), 3.67 (dd, \( J = 2.9, 10.1 \) Hz, 1H), 2.47 – 2.34 (m, 1H), 2.40 (s, 3H), 1.46 (dd, \( J = 10.8, 12.8 \) Hz, 1H), 1.16 (m, 1H), 1.09 (d, \( J = 7.0 \) Hz, 3H), 0.96 (s, 9H), 0.26 (s, 3H), 0.11 (s, 3H); \(^{13}\)C NMR (125 MHz, CDCl\(_3\)) \( \delta \)
178.5, 137.3, 134.9, 130.6, 128.7, 128.0, 126.0, 80.3, 75.1, 72.8, 53.6, 35.5, 30.9, 26.2, 20.7, 18.6, 14.5, -4.0, -4.8; MS(ES)^+ calcd for C_{21}H_{33}ClO_3Si (M+H)^+ 431.16, found 431.13.

**Alcohol 15.** To a solution of 110 (0.030 g, 0.07 mmol, 1.0 equiv) in anhydrous tetrahydrofuran (3 mL) was added a solution of tetrabutylammonium fluoride solution (1.0 M, in tetrahydrofuran, 7.7 μL, 0.077 mmol, 1.1 equiv) at 23 °C. After stirring at 23 °C for 15 min, calcium carbonate (0.035 g, 0.35 mmol, 5.0 eq), Dowex 50WX8-400 (0.048 g, 0.622 g/mmol TBAF) and methanol (1 mL) were added. The mixture was stirred at same temperature for 15 min and filtered through a pad of Celite and washed with methanol (2 mL). The combined filtrates were concentrated, and purified by silica gel column chromatography (30% ethyl acetate–hexanes) to give 15 as white solid (0.018 g, 83 %). Recrystallization from 10% ethyl acetate–hexanes gave single crystals suitable for X-ray analysis. Rf = 0.28 (40 % ethyl acetate–hexanes); ^1H NMR (500 MHz, CD_3OD) δ 7.60 (dd, J = 2.4, 5.9 Hz, 1H), 7.20 – 7.12 (m, 3H), 6.29 (d, J = 10.2 Hz, 1H), 4.40 (dd, J = 3.1, 7.4 Hz, 1H), 3.85 (ddd, J = 5.8, 7.4, 10.0 Hz, 1H), 3.78 (dd, J = 3.1, 10.2 Hz, 1H), 2.64 – 2.53 (m, 1H), 2.42 (s, 3H), 2.10 (ddd, J = 5.8, 8.8, 12.1 Hz, 1H), 1.61 (td, J = 10.1, 12.1 Hz, 1H), 1.15 (d, J = 7.1 Hz, 3H); ^13C NMR (100 MHz, CD_3OD) δ 182.0, 139.8, 137.2, 132.0, 130.3, 129.1, 127.5, 80.6, 77.5, 74.3, 54.8, 36.9, 35.3, 21.1, 15.8; MS(ES)^+ calcd for C_{15}H_{18}Cl_2NaO_3 (M+Na)^+ 339.05, found 339.10.

**Lactone 111.** To a solution of 103 (0.5 g, 1.3 mmol, 1.0 equiv) in anhydrous tetrahydrofuran (10 mL) was slowly added a solution of L-selectride (1.0 M in tetrahydrofuran, 1.4 mL, 1.4 mmol, 1.1 equiv) at -78 °C. After stirring at -78 °C for 30 min, sodium perborate monohydrate (0.4 g, 3.9 mmol, 3.0 equiv) and a 20:1 (v:v) mixture of tetrahydrofuran:water (5 mL) were added. The mixture was allowed to warm to 23°C and water (15 mL) was added. The biphasic mixture was extracted with ethyl acetate (15 mL×3), and the organic phase was dried over anhydrous sodium sulfate, filtered, concentrated, and purified by silica gel column chromatography (20% ethyl acetate–hexanes) to give 111 as colorless oil (0.44 g, 90 %): Rf = 0.40 (40 % ethyl acetate-hexane); ^1H NMR (400 MHz, CDCl_3) δ 7.24 – 7.12 (m, 3H), 7.05 – 7.00 (m, 1H), 4.78 (s, 1H), 4.14 (d, J = 9.9 Hz, 1H), 4.01 (t, J = 10.2 Hz, 1H), 3.80 (dd, J = 3.7, 10.2 Hz, 1H), 3.46 (td, J = 3.7, 9.9 Hz, 1H), 2.99 (ddd, J = 2.1, 7.4 Hz, 1H), 2.46 (s, 3H), 2.50 – 2.41 (m, 1H), 1.79 (dt, J = 9.3, 12.2 Hz, 1H), 1.18 (d, J = 7.4 Hz, 3H), 0.92 (s, 9H), 0.10 (s, 3H), 0.09 (s, 3H); ^13C NMR (100 MHz, CDCl_3) δ 181.3, 137.2, 136.5, 131.1, 127.0, 126.5, 126.1, 79.5, 77.2, 68.4, 43.5, 34.1, 32.8, 25.8, 20.1, 18.1, 16.4, -5.6, -5.7; MS(ES)^- calcd for C_{17}H_{25}O_4Si (M-57)^- 321.15, found 321.40.

**Ketone 112.** To a solution of 111 (0.2 g, 0.53 mmol, 1.0 equiv) in anhydrous methylene chloride (5 mL) was added Dess-Martin periodinane (0.34 g, 0.79 mmol,
1.5 equiv) at 23 °C. After stirring for 5 min, a solution of water (14.2 μL, 0.79 mmol, 1.5 equiv) was added. The suspension was stirred for another 30 min, an aqueous solution of 1:1 10% sodium bisulfate/saturated sodium bicarbonate (5 mL) was then added. After stirring for another 10 min, the biphasic mixture was extracted with ethyl acetate (10 mL×2), the organic phase was washed with saturated sodium bicarbonate (10 mL), dried over anhydrous sodium sulfate, filtered, concentrated, and purified by silica gel column chromatography (15% ethyl acetate–hexanes) to give 112 as colorless oil (0.18 g, 92 %): \( RF = 0.41 \) (40 % ethyl acetate–hexane). \(^1\)H NMR (500 MHz, CDCl\(_3\)) \( \delta 7.40 – 7.37 \) (m, 1H), 7.21 – 7.13 (m, 3H), 4.57 (ddd, \( J = 5.4, 8.9 \) Hz, 1H), 4.29 (t, \( J = 5.4 \) Hz, 1H), 3.90 (dd, \( J = 7.5, 10.4 \) Hz, 1H), 3.78 (dd, \( J = 4.2, 10.4 \) Hz, 1H), 3.26 (td, \( J = 4.5, 6.8 \) Hz, 1H), 2.80–2.70 (m, 1H), 2.66 (s, 1H), 2.51 – 2.45 (m, 1H), 2.37 (s, 3H), 1.78 (dt, \( J = 8.2, 13.0 \) Hz, 1H), 1.22 (d, \( J = 7.3 \) Hz, 3H), 0.88 (s, 9H), 0.01 (s, 3H), 0.00 (s, 3H); \(^{13}\)C NMR (125 MHz, CDCl\(_3\)) \( \delta 207.1, 178.8, 137.3, 132.3, 131.0, 127.8, 127.0, 126.3, 79.3, 64.4, 52.0, 32.2, 32.6, 25.8, 20.0, 18.2, 15.3, -5.65, -5.67; MS(ES)\(^+\) calcd for C\(_{21}\)H\(_{34}\)O\(_3\)Si (M+Na\(^+\)) 401.21, found 401.15.

**TBS Ether 114.** To a solution of 113 (0.11 g, 0.29 mmol, 1.0 equiv) in anhydrous methylene chloride (5 mL) was added 2,6-lutidine (0.10 mL, 0.87 mmol, 3.0 equiv) at –78 °C. The solution was stirred at this temperature for 15 min before addition of acetone (1.5 mL). The mixture was allowed to warm to 23 °C and evaporated the solvent under vacuo. The residue was diluted with ethyl acetate (15 mL) and saturated ammonium chloride (7 mL), and the organic phase was collected and dried over anhydrous sodium sulfate, filtered, concentrated, and purified by silica gel column chromatography (5% ethyl acetate–hexanes) to provide 114 as colorless oil (0.10 g, 0.20 mmol, 1.0 equiv); \( RF = 0.68 \) (30 % ethyl acetate–hexane). \(^1\)H NMR (400 MHz, CDCl\(_3\)) \( \delta 7.38 – 7.33 \) (m, 1H), 7.17 – 7.09 (m, 3H), 4.64 (td, \( J = 3.0, 7.4 \) Hz, 1H), 4.51 (dd, \( J = 3.0, 5.4 \) Hz, 1H), 3.86 (dd, \( J = 9.0, 10.4 \) Hz, 1H), 3.58 (dd, \( J = 4.6, 10.4 \) Hz, 1H), 3.12 (dt, \( J = 5.4, 9.0 \) Hz, 1H), 2.63 – 2.53 (m, 1H), 2.42 – 2.35 (m, 1H), 2.35 (s, 3H), 1.41 (ddd, \( J = 4.4, 7.4, 12.2 \) Hz, 1H), 1.21 (d, \( J = 7.5 \) Hz, 3H), 0.88 (s, 9H), 0.81 (s, 9H), 0.05 (s, 3H), 0.02 (s, 3H), 0.01 (s, 3H), -0.17 (s, 3H); \(^{13}\)C NMR (100 MHz, CDCl\(_3\)) \( \delta 180.5, 137.0, 136.9, 130.6, 127.8, 126.9, 126.0, 78.7, 74.2, 65.4, 44.1, 34.1, 30.5, 25.8, 20.2, 18.1, 16.2, -5.6, -5.7; MS(ES)\(^+\) calcd for C\(_{23}\)H\(_{39}\)O\(_4\)Si\(_2\) (M+Na\(^+\)) 435.24, found 435.90.

**Alcohol 115.** A solution of 114 (0.10 g, 0.20 mmol, 1.0 equiv) in a 3:2:2 mixture of acetic acid:tetrahydrofuran:water (5 mL) was stirred at 60 °C for 12 h. Then, acetic acid was evaporated under vacuo and the residue was diluted with ethyl acetate (20 mL) and washed with a saturated solution of sodium bicarbonate (10 mL) and dried.
over anhydrous sodium sulfate, filtered, concentrated, and purified by silica gel column chromatography (20% ethyl acetate–hexanes) to give 115 as colorless oil (0.061 g, 80%): \( \text{Rf} = 0.40 \) (40 % ethyl acetate-hexane). \(^{1}\text{H} \text{NMR} (500 \text{ MHz, CDCl}_3) \delta = 7.35 - 7.32 \text{ (m, 1H), 7.20 - 7.14 \text{ (m, 3H), 4.55 (td, } J = 2.7, 7.3, 1 \text{H), 4.42 (dd, } J = 2.7, 5.6, 1 \text{H), 3.94 (dt, } J = 7.3, 10.7, 1 \text{H), 3.80 (ddd, } J = 3.8, 6.9, 10.7, 1 \text{H), 3.32 (dd, } J = 7.3, 12.8, 1 \text{H), 2.65 - 2.57 \text{ (m, 1H), 2.42 (ddd, } J = 7.3, 9.8, 12.8, 1 \text{H), 2.37 (s, 3H), 1.52 (dd, } J = 4.1, 6.9, 1 \text{H), 1.47 (ddd, } J = 4.8, 7.6, 12.8, 1 \text{H), 1.22 (d, } J = 7.5, 3 \text{H), 0.84 (s, 9 \text{H), 0.06 (s, 3 \text{H), -0.11 (s, 3 \text{H); } 13\text{C} \text{NMR} (125 \text{ MHz, CDCl}_3) \delta = 100.0, 137.3, 130.7, 127.6, 127.0, 127.0, 126.1, 79.9, 73.3, 63.7, 45.9, 34.7, 29.1, 26.0, 20.2, 18.1, 16.8, -4.4, -5.0; MS(ES)\(^+\) calcd for C\(_{21}\)H\(_{34}\)NaO\(_4\)Si (M+Na\(^+\)) 401.21, found 401.60.

Aldehyde 116. To a solution of 115 (0.055 g, 0.14 mmol, 1.0 equiv) in anhydrous methylene chloride (3 mL) was added Dess-Martin periodinane (0.089 g, 0.21 mmol, 1.5 equiv) at 23 °C. After stirring for 5 min, a solution of water (3.8 \text{ mL}) was added a solution of tetrabutylammonium fluoride solution (0.048 g, 0.622 g/mmoll TBAF) and methanol (1 mL) were added. The mixture was stirred at same temperature for 15 min and filtered through a pad of Celite and washed with methanol (2 mL). The combined filtrates were concentrated, and purified by silica gel column chromatography (30 % ethyl acetate–hexanes) to give 116 as white solid (0.020 g, 90%). Recrystallization from 10% ethyl acetate–hexanes to give 116 as colorless oil (0.052 g, 98 %): \( \text{Rf} = 0.50 \) (40 % ethyl acetate-hexane). \(^{1}\text{H} \text{NMR} (500 \text{ MHz, CDCl}_3) \delta = 7.06 - 7.03 \text{ (m, 3H), 7.00 - 6.97 \text{ (m, 3H), 6.72 - 6.69 \text{ (m, 3H), 6.58 - 6.55 \text{ (m, 3H), 5.98 (d, } J = 4.8, 9 \text{H), 0.84 (s, 9 \text{H), -0.11 (s, 3 \text{H); } 13\text{C} \text{NMR} (100 \text{ MHz, CDCl}_3) \delta = 179.2, 179.5, 138.4, 131.2, 131.1, 129.7, 128.1, 126.4, 79.0, 72.3, 57.2, 34.5, 29.1, 25.8, 20.2, 18.0, 17.0, -4.6, -5.2; MS(ES)\(^+\) calcd for C\(_{17}\)H\(_{22}\)O\(_4\)Si (M+H\(^+\)) 319.14, found 319.05.

TBS ether 117. To a solution of triphenyl phosphite (51.5 \mu L, 0.2 mmol, 2.0 equiv) in anhydrous methylene chloride (3 mL) was induced chlorine at – 78 °C until the solution became yellow. The color was discharged by argon bubbling (1 min). Then, freshly distilled triethylamine (55.7 \mu L, 0.4 mmol, 4.0 equiv) and a solution of triphenyl phosphite (51.5 \mu L, 0.077 mmol, 1.1 equiv) at 23 °C. After stirring at 23 °C for 5 min, calcium carbonate (0.035 g, 0.35 mmol, 5.0 eq), Dowex 50WX8-4 (1.0 M, in tetrahydrofuran, 7.7 \text{ mL}) was added. The suspension was stirred for another 10 min. The solvent was evaporated in vacuo and the residue was purified by silica gel column chromatography (15% ethyl acetate–hexanes to give 117 as white solid (0.052 g, 98 %): \( \text{Rf} = 0.20 \) (10% ethyl acetate-hexane); \(^{1}\text{H} \text{NMR} (500 MHz, CDCl\(_3\)) \delta = 7.48 (d, J = 7.7, 1H), 7.24 - 7.13 (m, 3H), 5.94 (d, J = 10.1, 1H), 4.78 (t, J = 3.3, 1H), 4.20 (td, J = 4.3, 7.3, 1H), 3.69 (dd, J = 2.5, 10.1, 1H), 2.52 - 2.44 (m, 1H), 2.42 (s, 3H), 2.11 - 2.01 (m, 2H), 1.14 (d, J = 7.5, 3H), 0.94 (d, J = 4.8, 9H), 0.27 (s, 3H), 0.13 (s, 3H); \(^{13}\text{C} \text{NMR} (125 MHz, CDCl\(_3\)) \delta = 179.3, 137.7, 134.6, 130.7, 128.7, 127.9, 125.8, 80.0, 75.2, 72.9, 53.4, 34.2, 29.9, 29.1, 26.1, 20.6, 18.6, 16.5, -4.3, -4.5; MS(ES)\(^+\) calcd for C\(_{21}\)H\(_{33}\)Cl\(_2\)O\(_3\)Si (M+H\(^+\)) 431.16, found 431.00.

Alcohol 16. To a solution of 117 (0.030 g, 0.07 mmol, 1.0 equiv) in anhydrous tetrahydrofuran (3 mL) was added a solution of tetrabutylammonium fluoride solution (1.0 M, in tetrahydrofuran, 7.7 \mu L, 0.077 mmol, 1.1 equiv) at 23 °C. After stirring at 23 °C for 15 min, calcium carbonate (0.035 g, 0.35 mmol, 5.0 eq), Dowex 50WX8-400 (0.048 g, 0.622 g/mmoll TBAF) and methanol (1 mL) were added. The mixture was stirred at same temperature for 15 min and filtered through a pad of Celite and washed with methanol (2 mL). The combined filtrates were concentrated, and purified by silica gel column chromatography (30 % ethyl acetate–hexanes) to give 16 as white solid (0.020 g, 90%). Recrystallization from 10% ethyl acetate–hexanes to
hexanes gave single crystals suitable for X-ray analysis. \( R_f = 0.25 \) (40 % ethyl acetate–hexanes); \( R_f = 0.25 \) (40 % ethyl acetate–hexanes); \( ^1H \) NMR (500 MHz, CD\(_3\)OD) \( \delta 7.61 – 7.58 \) (m, 1H), 7.21 – 7.13 (m, 3H), 6.28 (d, \( J = 10.1 \) Hz, 1H), 4.40 (dd, \( J = 3.2, 7.8 \) Hz, 1H), 4.00 (td, \( J = 3.9, 8.0 \) Hz, 1H), 3.74 (dd, \( J = 3.2, 10.1 \) Hz, 1H), 2.74 – 2.65 (m, 1H), 2.43 (s, 3H), 2.26 (ddd, \( J = 3.9, 9.4, 13.2 \) Hz, 1H), 1.65 (dt, \( J = 8.3, 13.2 \) Hz, 1H), 1.13 (d, \( J = 7.3 \) Hz, 3H); \( ^13C \) NMR (125 MHz, CD\(_3\)OD) \( \delta 182.6, 139.9, 137.0, 132.0, 130.3, 129.2, 127.5, 80.7, 77.6, 73.0, 54.6, 35.1, 32.8, 21.1, 16.6; MS(ES)\(^+\) calcd for C\(_{15}\)H\(_{18}\)Cl\(_2\)NaO\(_3\) (M+Na)\(^+\) 339.05, found 339.20.

TBS ether 118. To a solution of 25 (0.12 g, 0.62 mmol, 1.0 equiv) in anhydrous dimethylformamide (3 mL) was added imidazole (0.11 g, 1.55 mmol, 2.5 equiv) and \( t \)-butyldimethylsilyl chloride (0.11 g, 0.74 mmol, 1.2 equiv) at 23 °C. After stirring at this temperature for 30 min, the mixture was diluted with ethyl acetate (25 mL) and washed with brine (10 mL×5), dried over anhydrous sodium sulfate, filtered, concentrated, and purified by silica gel column chromatography (6 % ethyl acetate–hexanes) to give 118 as colorless oil (0.15 g, 81 %): \( R_f = 0.64 \) (20 % ethyl acetate-hexane); \( ^1H \) NMR (500 MHz, CDCl\(_3\)) \( \delta 7.33 \) (dd, \( J = 0.8, 1.8 \) Hz, 1H), 6.30 (dd, \( J = 1.8, 3.2 \) Hz, 1H), 6.17 (d, \( J = 3.2 \) Hz, 1H), 5.92 (s, 1H), 5.74 – 5.73 (m, 1H), 4.78 (t, \( J = 6.2 \) Hz, 1H), 2.81 – 2.68 (m, 2H), 2.16 – 2.05 (m, 2H), 1.86 (s, 3H), 0.87 (s, 9H), 0.03 (s, 3H), -0.07 (s, 3H); \( ^13C \) NMR (125 MHz, CDCl\(_3\)) \( \delta 201.6, 156.7, 144.4, 141.4, 124.5, 110.0, 106.0, 67.5, 32.9, 31.3, 25.8, 18.2, 17.6, -5.0, -5.2; MS(ES)\(^+\) calcd for C\(_{17}\)H\(_{28}\)NaO\(_3\)Si (M+Na)\(^+\) 331.17, found 331.95.

TBS ether 119. To a solution of the 118 (0.15 g, 0.49 mmol, 1.0 equiv) in anhydrous methylene chloride (15 mL) at -78 °C was slowly added a solution of dimethylaluminum chloride solution (1.0 M in hexane, 0.74 mL, 0.74 mmol, 1.5 equiv) over 30 min. The reaction mixture was slowly warmed up to -30 °C and stirred for an additional 3 h. Saturated sodium bicarbonate (5 mL) was added at -30 °C, the mixture was warmed to 23 °C. The layers were separated and the aqueous phase was extracted with ethyl acetate (5 mL×3). The combined organic phase was dried over anhydrous sodium sulfate, filtered, concentrated, and purified by silica gel column chromatography (10% ethyl acetate–hexanes) to give 117 as white solid (0.067 g) and diasteromer (0.017 g, total yield 56 %); \( R_f = 0.59 \) (20 % ethyl acetate–hexane); \( ^1H \) NMR (500 MHz, CDCl\(_3\)) \( \delta 6.47 \) (dt, \( J = 1.6, 3.0 \) Hz, 1H), 6.43 (d, \( J = 1.1, 5.8 \) Hz, 1H), 4.83 (dd, \( J = 1.6, 5.1 \) Hz, 1H), 4.31 (t, \( J = 2.7 \) Hz, 1H), 3.11 (td, \( J = 5.4, 14.3 \) Hz, 1H), 2.83 (dd, \( J = 5.1, 11.8 \) Hz, 1H), 2.24 (dt, \( J = 3.1, 14.0 \) Hz, 1H), 2.11 (tt, \( J = 3.1, 14.3 \) Hz, 1H), 1.95 (ddt, \( J = 2.7, 5.4, 14.0 \) Hz, 1H), 1.21 (s, 3H), 0.99 (d, \( J = 11.8 \) Hz, 1H), 0.96 (s, 9H), 0.17 (s, 3H), 0.16 (s, 3H); \( ^13C \) NMR (126 MHz, CDCl\(_3\)) \( \delta 213.7, 138.4, 133.4, 92.6, 78.8, 67.5, 54.4, 37.8, 32.9, 29.2, 25.7, 23.6, 18.0, -4.49, -5.02; MS(ES)\(^+\) calcd for C\(_{17}\)H\(_{28}\)NaO\(_3\)Si (M+Na)\(^+\) 331.17, found 331.10.

TES ether 120. To a solution of 25 (0.12 g, 0.62 mmol, 1.0 equiv) in anhydrous dimethylformamide (3 mL) was added imidazole (0.11 g, 1.55 mmol, 2.5 equiv) and triethylsilyl chloride (125 \( \mu \)L, 0.74 mmol, 1.2 equiv) at 23 °C. After stirring at this
temperature for 30 min, the mixture was diluted with ethyl acetate (25 mL) and washed with brine (10 mL×5), dried over anhydrous sodium sulfate, filtered, concentrated, and purified by silica gel column chromatography (5% ethyl acetate–hexanes) to give 120 as colorless oil (0.15 g, 80 %); \( Rf = 0.64 \) (20 % ethyl acetate-hexane); \(^1\)H NMR (400 MHz, CDCl\(_3\)) \( \delta \) 7.34 (dd, \( J = 0.8, 1.7 \) Hz, 1H), 6.30 (dd, \( J = 1.7, 3.2 \) Hz, 1H), 6.18 (d, \( J = 3.1 \) Hz, 1H), 5.92 (dd, \( J = 0.8, 1.6 \) Hz, 1H), 5.74 (dd, \( J = 0.8, 1.6 \) Hz, 1H), 4.77 (t, \( J = 6.4 \) Hz, 1H), 2.83 – 2.67 (m, 2H), 2.18 – 2.04 (m, 2H), 1.86 (s, 3H), 0.89 (t, \( J = 7.9 \) Hz, 9H), 0.54 (q, \( J = 7.9 \) Hz, 6H); \(^{13}\)C NMR (100 MHz, CDCl\(_3\)) \( \delta \) 210.5, 156.6, 144.4, 141.4, 124.4, 110.0, 106.0, 67.2, 33.0, 31.2, 17.6, 6.7, 4.6; MS(ES)\(^+\) calcd for C\(_{17}H_{28}NaO_{3}Si (M+Na)\(^+\) 331.17, found 331.95.

**TES ether 121.** To a solution of the 120 (0.13 g, 0.42 mmol, 1.0 equiv) in anhydrous methylene chloride (15 mL) at -78 °C was slowly added a solution of dimethylaluminum chloride solution (1.0 M in hexane, 0.63 mL, 0.63 mmol, 1.5 equiv) over 30 min. The reaction mixture was slowly warmed up to -30 °C and stirred for an additional 3 h. Saturated sodium bicarbonate (5 mL) was added at -30 °C, the mixture was warmed to 23 °C. The layers were separated and the aqueous phase was extracted with ethyl acetate (5 mL×3). The combined organic phase was dried over anhydrous sodium sulfate, filtered, concentrated, and purified by silica gel column chromatography (10% ethyl acetate–hexanes) to give 121 as colorless oil (0.083 g, 64 %); \( Rf = 0.52 \) (20% ethyl acetate–hexanes); \(^1\)H NMR (400 MHz, CDCl\(_3\)) \( \delta \) 6.46 (dt, \( J = 1.3, 5.8 \) Hz, 1H), 6.45 (d, \( J = 5.8 \) Hz, 1H), 4.82 (dd, \( J = 1.3, 5.0 \) Hz, 1H), 4.34 (t, \( J = 2.7 \) Hz, 1H), 3.12 (td, \( J = 5.6, 14.2 \) Hz, 1H), 2.82 (dd, \( J = 5.0, 11.7 \) Hz, 1H), 2.23 (dt, \( J = 3.4, 14.0 \) Hz, 1H), 2.11 (tdd, \( J = 2.4, 3.4, 14.2 \) Hz, 1H), 1.95 (ddt, \( J = 2.7, 5.6, 14.0 \) Hz, 1H), 1.20 (s, 3H), 1.01 (t, \( J = 7.9 \) Hz, 9H), 0.99 (d, \( J = 11.7 \) Hz, 1H), 0.70 (q, \( J = 7.9 \) Hz, 6H); \(^{13}\)C NMR (100 MHz, CDCl\(_3\)) \( \delta \) 213.7, 138.2, 133.4, 92.6, 78.8, 67.4, 54.4, 37.8, 32.9, 29.4, 23.4, 6.9, 4.9; MS(ES)\(^+\) calcd for C\(_{17}H_{28}NaO_{3}Si (M+Na)\(^+\) 331.17, found 331.30.

**TIPS ether 122.** To a solution of 25 (0.14 g, 0.72 mmol, 1.0 equiv) in anhydrous dimethylformamide (3 mL) was added imidazole (0.12 g, 1.8 mmol, 2.5 equiv) and triisopropylsilyl chloride (183 μL, 0.86 mmol, 1.2 equiv) at 23 °C. After stirring at this temperature for 30 min, the mixture was diluted with ethyl acetate (25 mL) and washed with brine (10 mL×5), dried over anhydrous sodium sulfate, filtered, concentrated, and purified by silica gel column chromatography (5 % ethyl acetate–hexanes) to give 122 as colorless oil (0.21 g, 84 %); \( Rf = 0.64 \) (20 % ethyl acetate-hexane); \( Rf = 0.70 \) (30 % ethyl acetate-hexane); \(^1\)H NMR (500 MHz, CDCl\(_3\)) \( \delta \) 7.33 (dd, \( J = 0.8, 1.8 \) Hz, 1H), 6.29 (dd, \( J = 1.8, 3.2 \) Hz, 1H), 6.19 (d, \( J = 3.2 \) Hz, 1H), 5.88 (t, \( J = 1.3 \) Hz, 1H), 5.72 (dd, \( J = 0.6, 1.3 \) Hz, 1H), 4.92 (t, \( J = 6.0 \) Hz, 2H), 2.76 (dd, \( J = 6.0, 9.0, 17.1 \) Hz, 1H), 2.65 (dd, \( J = 6.0, 9.0, 17.1 \) Hz, 1H), 2.14 (m, 2H), 1.85 (s, 3H), 1.05 (s, 9H), 1.03 (s, 9H), 0.98 (s, 3H); \(^{13}\)C NMR (125 MHz, CDCl\(_3\)) \( \delta \) 201.6, 156.7, 144.4, 141.2, 124.4, 109.9, 106.2, 67.7, 32.6, 31.8, 18.0, 17.7, 17.9, 12.3; MS(ES)\(^+\) calcd for C\(_{20}H_{34}NaO_{3}Si (M+Na)\(^+\) 373.22, found 373.90.

**TIPS ether 123.** To a solution of the 122 (0.14 g, 0.4 mmol, 1.0 equiv) in anhydrous methylene chloride (15 mL) at -78 °C was slowly added a solution of dimethylaluminum chloride solution (1.0 M in hexane, 0.6 mL, 0.6 mmol, 1.5 equiv) over 30 min. The reaction mixture was slowly warmed up to -30 °C and stirred for an additional 3 h. Saturated sodium bicarbonate (5 mL) was added at -30 °C, the mixture was warmed to 23 °C. The layers were separated and the aqueous phase was extracted with ethyl acetate (5 mL×3). The combined organic phase was dried over anhydrous sodium sulfate, filtered, concentrated, and purified by silica gel column chromatography (10 % ethyl acetate–hexanes) to give 123 as colorless oil (0.084 g, 60 %); \( Rf = 0.51 \) (20% ethyl acetate–hexanes); \(^1\)H NMR (400 MHz, CDCl\(_3\)) \( \delta \) 6.55 (d, \( J = 5.8 \) Hz, 1H), 6.49 (dd, \( J = 1.6, 5.8 \) Hz, 1H), 4.83 (dd, \( J = 1.6, 5.1 \) Hz, 1H), 4.49 (t, \( J = 2.6 \) Hz, 1H), 3.16 (td, \( J = 5.8, 14.1 \) Hz, 1H), 2.84 (dd, \( J = 5.1, 11.7 \) Hz, 1H), 2.25 (dt, \( J = 3.2, 14.1 \) Hz, 1H), 2.16 – 2.12 (m, 1H), 2.12 – 2.02 (m,
1H), 1.56 (s, 3H), 1.24 (s, 3H), 1.14 (s, 9H), 1.13 (s, 9H), 1.00 (d, J = 11.7 Hz, 1H); 13C NMR (100 MHz, CDCl3) δ 213.7, 138.3, 133.5, 92.9, 78.7, 68.1, 54.3, 37.8, 33.0, 29.4, 23.7, 18.2, 17.7, 12.7; MS(ES)+ calcd for C20H34NaO3Si (M+Na)+ 373.22, found 373.80.

Stannane 32b. To a solution of 32 (0.14 g, 0.7 mmol, 1.0 equiv) in anhydrous dimethylformamide (2 mL) was added imidazole (0.12 g, 1.75 mmol, 2.5 equiv) and t-butyldimethylsilyl chloride (0.13 g, 0.84 mmol, 1.2 equiv) at 23 °C. After stirring at this temperature for 30 min, the mixture was diluted with ethyl acetate (25 mL) and washed with brine (10 mL × 5), dried over anhydrous sodium sulfate, filtered, concentrated to give crude 32a as colorless oil which was directly used in the next step without purification. To a solution crude 32a in anhydrous tetrahydrofuran (3 mL) was added n-butyl lithium (2.5 M in hexane, 0.31 mL, 0.77 mmol, 1.9 equiv) at −78 °C under argon. The mixture was stirred at same temperature for 15 min before a solution of trimethyltin chloride (1.0 M in tetrahydrofuran, 0.77 mL, 0.77 mmol, 1.1 equiv) was added at −78 °C. After stirring for another 30 min at same temperature, saturated ammonium chloride (3 mL) was added and the mixture was warmed to 23 °C. The biphase mixture was extracted with ethyl acetate (15 mL), and the organic phase was washed with brine (10 mL), dried over anhydrous sodium sulfate, filtered, concentrated to give crude 32b as colorless oil which is pure enough for directly used in the next reaction; 1H NMR (500 MHz, CDCl3) δ 7.41 (d, J = 7.3 Hz, 1H), 7.32 (d, J = 7.3 Hz, 1H), 7.19 (t, J = 7.3 Hz, 1H), 4.70 (s, 2H), 2.33 (s, 3H), 0.94 (s, 9H), 0.37–0.25 (m, 9H), 0.10 (s, 6H); 13C NMR (125 MHz, CDCl3) δ 142.7, 141.3, 138.8, 134.6, 127.0, 125.4, 63.8, 26.0, 21.2, 18.4, −5.3, −8.5.

Stannane 48. To a solution of crude 32b in anhydrous tetrahydrofuran (2 mL) was added a solution of tetramethylammonium fluoride (1.0 M in tetrahydrofuran, 0.7 mL, 0.7 mmol, 1.0 equiv) at 23 °C. After stirring at 23 °C for 15 min, calcium carbonate (0.35 g, 3.5 mmol, 5.0 equiv), Dowex 50WX8-400 (0.43 g, 0.622 g/mmol TBAF) and methanol (2 mL) were added. The mixture was stirred at same temperature for 15 min and filtered through a pad of Celite and washed with methanol (1.5 mL). The combined filtrates were concentrated, and purified by silica gel column chromatography (10% ethyl acetate–hexanes) to give 48 as colorless oil (0.17 g, 87% over 3 steps); Rf = 0.30 (30% ethyl acetate–hexanes); 1H NMR (500 MHz, CDCl3) δ 7.39 (dd, J = 7.3, 1.1 Hz, 1H), 7.34 (d, J = 7.3 Hz, 1H), 7.20 (t, J = 7.3 Hz, 1H), 4.71 (d, J = 5.8 Hz, 2H), 2.44 (s, 3H), 1.66 (dd, J = 5.8, 4.6 Hz, 1H), 0.40–0.27 (m, 9H); 13C NMR (125 MHz, CDCl3) δ 143.6, 142.5, 138.2, 135.5, 128.3, 125.6, 64.3, 21.3, −8.5; MS(ES)+ calcd for C11H19OSn (M+H)+ 287.05, found 287.13.

Enone 49. A dried vial (4 mL) with 30 (0.038 g, 0.082 mmol, 1.0 equiv), tetrakis[triphenylphosphine]palladium (0.142 g, 0.123 mmol, 1.5 equiv) and copper(I) chloride (0.014 g, 0.123 mmol, 1.5 equiv) was evacuated and refilled with carbon monoxide three times. To this vial was added degassed dimethyl sulfoxide (150 μL), and the mixture was heated to 55 °C. A solution of 48 (0.028 g, 0.098 mmol, 1.2 equiv) in degassed dimethyl sulfoxide (100 μL) was added at same temperature. The suspension was stirred at 55 °C for 45 min. The mixture was then cooled to 23 °C and directly purified by silica gel column chromatography (gradient 10% → 15% ethyl acetate–hexanes) to give 49 and as colorless oil (0.025 g, 66%); Rf = 0.21 (40% ethyl acetate–hexanes); 1H NMR (400 MHz, CDCl3) δ 7.44 (d, J = 7.5 Hz, 1H), 7.23 (t, J = 7.5 Hz, 1H), 7.11 (dd, J = 7.5, 0.9 Hz, 1H), 6.40–6.37 (dd, J = 6.0, 2.2, 1.3 Hz, 1H), 4.89 (d, J = 5.5 Hz, 1H), 4.75–4.71 (m, 2H), 4.46 (d, J = 5.5 Hz, 1H), 4.29 (d, J = 6.2 Hz, 1H), 3.12 (dd, J = 5.1, 2.2 Hz, 1H), 2.80 (dd, J = 6.0, 1.3 Hz, 1H), 2.26–2.20 (m, 1H), 2.23 (s, 3H), 1.80 (d, J = 13.5 Hz, 1H), 1.66 (s, 3H), 1.51 (s, 3H), 1.37 (s, 3H); 13C NMR (75 MHz, CDCl3) δ 202.7, 144.4, 141.6, 141.2, 139.5, 133.3, 128.5, 126.6, 125.4, 111.8, 87.4, 82.9, 79.9, 79.8, 63.3, 58.2, 43.2, 41.9, 40.6, 33.2, 26.0, 25.4, 22.1; MS(ES)+ calcd for C23H28BrO5 (M+H)+ 463.11, found 463.17.

S30
Ketone 50. A solution of 49 (0.010 g, 0.022 mmol, 1.0 equiv) in anhydrous acetonitrile (10 mL) was degassed by bubbling argon through the solution for 30 min. The solution was then photolyzed at 23 °C in a Rayonet chamber reactor at 350 nm for 3 h. The solution was then poured into a saturated aqueous solution of ammonium chloride (5 mL) and extracted with ethyl acetate (8 mL×3), the organic phase was dried over anhydrous sodium sulfate, filtered, concentrated. The residue was then dissolved in a mixture of 0.2 % diisopropylamine in anhydrous methanol (5 mL). The solution was heated to 50 °C and reacted for 2 h. The solvent was then evaporated in vacuo and the residue was purified by silica gel column chromatography (gradient 10% → 15% ethyl acetate–hexanes) to give 50 as colorless solid (0.006 g, 60%). Recrystallization from 30% ethyl acetate–hexanes gave single crystals suitable for X-ray analysis. 

$$R_f = 0.25 \text{ (40% ethyl acetate–hexanes)};$$

$^1$H NMR (400 MHz, CDCl$_3$) $\delta$ 7.59 (d, $J = 7.7$ Hz, 1H), 7.27 (d, $J = 7.7$ Hz, 1H), 4.87 (t, $J = 2.5$ Hz, 1H), 4.77 (d, $J = 5.4$ Hz, 1H), 4.76 (s, 2H), 4.37 (d, $J = 6.4$ Hz, 1H), 4.29 (d, $J = 5.4$ Hz, 1H), 3.67 – 3.59 (m, 1H), 2.82 (dt, $J = 14.0$, 2.5 Hz, 1H), 2.76 (d, $J = 9.2$ Hz, 1H), 2.63 (s, 3H), 2.37 (dd, $J = 13.2$, 6.4 Hz, 1H), 2.33 – 2.27 (m, 1H), 1.57 (s, 3H), 1.43 (s, 3H), 1.37 (d, $J = 13.2$ Hz, 1H), 1.36 (s, 3H);

$^{13}$C NMR (75 MHz, CDCl$_3$) $\delta$ 204.5, 152.1, 138.8, 136.7, 135.0, 126.0, 111.2, 88.6, 83.0, 81.4, 80.4, 63.2, 62.6, 47.8, 42.0, 40.0, 35.9, 35.2, 26.0, 25.2, 17.2, 12.9; MS(ES)$^+$ calcd for C$_{23}$H$_{28}$BrO$_5$ (M+H)$^+$ 463.11, found 463.08.

TES ether 10a. To a solution of 10 (0.023 g, 0.079 mmol, 1.0 equiv) in anhydrous dimethylformamide (0.4 mL) was added imidazole (0.043 g, 0.63 mmol, 8.0 equiv) and triethylsilyl chloride (53 μL, 0.32 mmol, 4.0 equiv) at 23 °C. Then, the mixture was heated to 45 °C and stirred at this temperature for 30 min, the mixture was diluted with ethyl acetate (30 mL) and washed with brine (10 mL×5), dried over anhydrous sodium sulfate, filtered, concentrated to give 10a as colorless oil (0.032 g, 100 %) which is directly used in the next step without purification: $R_f = 0.35 \text{ (20% ethyl acetate–hexanes);}$

$^1$H NMR (500 MHz, CDCl$_3$) $\delta$ 5.29 (s, 1H), 4.61 (ddd, $J = 1.4$, 2.7, 3.4 Hz, 1H), 4.13 (d, $J = 7.9$ Hz, 1H), 4.02 (d, $J = 10.9$ Hz, 1H), 3.11 – 3.03 (m, 2H), 2.50 (tt, $J = 3.4$, 14.6 Hz, 1H), 2.36 (dt, $J = 4.2$, 15.8 Hz, 1H), 2.12 (ddt, $J = 2.7$, 5.4, 14.6 Hz, 1H), 1.81 (d, $J = 12.8$ Hz, 1H), 1.55 (s, 3H), 1.03 (t, $J = 7.9$ Hz, 9H), 0.78 – 0.73 (q, $J = 7.9$ Hz, 6H); $^{13}$C NMR (125 MHz, CDCl$_3$) $\delta$ 213.7, 90.9, 84.1, 74.0, 63.8, 57.3, 50.0, 39.9, 34.5, 27.7, 21.0, 6.8, 4.8; MS(ES)$^+$ calcd for C$_{17}$H$_{29}$BrNaO$_4$Si (M+Na)$^+$ 427.09, found 427.10.

Triflate 58. To a solution of 10a (0.015 g, 0.037 mmol, 1.0 equiv) in anhydrous tetrahydrofuran (5 mL) was added potassium bis(trimethylsilyl)amide (0.5 M in toluene,0.19 mL, 0.093 mmol, 4.0 equiv) at –78 °C under argon. The mixture was stirred at same temperature for 30 min before a solution of N-phenyltrifluoromethanesulfonylimide (0.024 g, 0.067 mmol, 1.8 equiv) in anhydrous tetrahydrofuran (0.5 mL) was added at –78 °C. After
stirring for another 30 min at the same temperature. The biphasic mixture was extracted with ethyl acetate (10 mL×2), and the organic phase was washed with brine (10 mL), dried over anhydrous sodium sulfate, filtered, concentrated, and purified by silica gel column chromatography (gradient 5% ethyl acetate–hexanes) to give 58 as colorless oil (0.017 g, 88 %): $R_f = 0.55$ (20% ethyl acetate–hexanes); $^1$H NMR (400 MHz, CDCl₃) $\delta$ 5.63 (dd, $J = 0.8, 2.0, 6.3$ Hz, 1H), 5.23 (s, 1H), 4.42 (dd, $J = 0.8, 1.7, 4.6$ Hz, 1H), 4.20 (dt, $J = 0.9, 7.8$ Hz, 1H), 4.10 (dd, $J = 0.9, 11.1$ Hz, 1H), 3.21 (dd, $J = 0.9, 11.1$ Hz, 1H), 3.06 (dd, $J = 2.0, 4.6, 18.5$ Hz, 1H), 2.58 (dd, $J = 1.7, 6.3, 18.5$ Hz, 1H), 2.43 (dd, $J = 7.8, 12.6$ Hz, 1H), 1.86 (d, $J = 12.6$ Hz, 1H), 1.68 (s, 3H), 1.02 (t, $J = 7.5$ Hz, 3H), 0.32 (s, 9H); $^{13}$C NMR (125 MHz, CDCl₃) $\delta$ 74.0, 72.4, 64.0, 51.8, 45.2, 44.9, 44.4, 33.6, 31.4, 31.3, 19.8, 17.2, 16.1, 6.8, 4.8; MS(ES)$^+$ calcd for C₁₈H₃₈BrCl₂O₇Si (M+Na)$^+$ 731.06, found 731.20.

Enone 58. A dried vial (4 mL) with 57 (0.010 g, 0.019 mmol, 1.0 equiv), tetrakis[triphenylphosphine]palladium (0.032 g, 0.028 mmol, 1.5 equiv) and copper(I) chloride (0.0028 g, 0.022 mmol, 1.5 equiv) was added to degassed dimethyl sulfoxide (150 μL), and the mixture was heated to 55 °C. A solution of 47a (0.011 g, 0.022 mmol, 1.2 equiv) in degassed dimethyl sulfoxide (90 μL) was added at 25 °C. The mixture was then cooled to 23 °C and water (1.5 mL) was added. The mixture was stirred for another 30 min at the same temperature. The biphasic mixture was extracted with ethyl acetate (10 mL×2), and the organic phase was washed with brine (10 mL), dried over anhydrous sodium sulfate, filtered, concentrated, and purified by silica gel column chromatography (gradient 5% ethyl acetate–hexanes) to give 58 as colorless oil (0.017 g, 88 %): $R_f = 0.55$ (20% ethyl acetate–hexanes); $^1$H NMR (400 MHz, CDCl₃) $\delta$ 5.63 (dd, $J = 0.8, 2.0, 6.3$ Hz, 1H), 5.23 (s, 1H), 4.42 (dd, $J = 0.8, 1.7, 4.6$ Hz, 1H), 4.20 (dt, $J = 0.9, 7.8$ Hz, 1H), 4.10 (dd, $J = 0.9, 11.1$ Hz, 1H), 3.21 (dd, $J = 0.9, 11.1$ Hz, 1H), 3.06 (dd, $J = 2.0, 4.6, 18.5$ Hz, 1H), 2.58 (dd, $J = 1.7, 6.3, 18.5$ Hz, 1H), 2.43 (dd, $J = 7.8, 12.6$ Hz, 1H), 1.86 (d, $J = 12.6$ Hz, 1H), 1.68 (s, 3H), 1.02 (t, $J = 7.5$ Hz, 3H), 0.32 (s, 9H); $^{13}$C NMR (125 MHz, CDCl₃) $\delta$ 74.0, 72.4, 64.0, 51.8, 45.2, 44.9, 44.4, 33.6, 31.4, 31.3, 19.8, 17.2, 16.1, 6.8, 4.8; MS(ES)$^+$ calcd for C₁₈H₃₈BrCl₂O₇Si (M+Na)$^+$ 731.06, found 731.20.

Stannane 47a. To a solution of 47 (0.015 g, 0.025 mmol, 1.0 equiv) in anhydrous tetrahydrofuran (0.2 mL) was added a solution of tetrabutylammonium fluoride (1.0 M in tetrahydrofuran, 25 μL, 0.025 mmol, 1.0 equiv) at 23 °C. After stirring at 23 °C for 15 min, calcium carbonate (0.012 g, 0.12 mmol, 5.0 eq), Dowex 50WX8-400 (0.015 g, 0.025 mmol, 1.0 equiv), and methanol (0.2 mL) were added. The mixture was stirred at the same temperature for 15 min and filtered through a pad of Celite and washed with methanol (1.5 mL). The combined filtrates were concentrated, and purified by silica gel column chromatography (30% ethyl acetate–hexanes) to give 47a as colorless oil (0.017 g, 99 %): $R_f = 0.83$ (20% ethyl acetate–hexanes); $^1$H NMR (500 MHz, CDCl₃) $\delta$ 7.47 (d, $J = 7.5$ Hz, 1H), 7.39 (dd, $J = 3.3, 9.9$ Hz, 6H); $^{13}$C NMR (125 MHz, CDCl₃) $\delta$ 144.3, 135.8, 133.8, 129.0, 127.2, 125.7, 125.5, 91.1, 82.0, 77.8, 74.9, 74.0, 72.4, 64.0, 51.8, 45.2, 44.9, 44.4, 33.6, 31.4, 31.3, 19.8, 17.2, 16.1, 6.8, 4.8; MS(ES)$^+$ calcd for C₁₈H₃₈BrCl₂O₇Si (M+Na)$^+$ 559.04, found 558.90.
Nakiterpiosin. A solution of 58 (0.0020 g, 0.0027 mmol, 1.0 equiv) in anhydrous acetonitrile (2 mL) was degassed by bubbling argon through the solution for 30 min. The solution was then photolyzed at 23 °C in a Rayonet chamber reactor at 350 nm for 3 h. The solution was then poured into a saturated aqueous solution of ammonium chloride (2 mL) and extracted with ethyl acetate (5 mL×3), the organic phase was dried over anhydrous sodium sulfate, filtered, concentrated. The residue was then dissolved in a mixture of 0.2 % disopropylamine in anhydrous methanol (2 mL). The solution was heated to 50 °C and reacted for 2 h. The solvent was then evaporated in vacuo and the residue was directly used in the next step without purification; To a solution of crude product obtain above in anhydrous tetrahydrofuran (0.2 mL) was added a solution of tetrabutylammonium fluoride (1.0 M in tetrahydrofuran, 3.0 μL, 0.003 mmol, 1.1 equiv) at 23 °C. After stirring at 23 °C for 15 min, calcium carbonate (0.0014 g, 0.0135 mmol, 5.0 eq), Dowex 50WX8-400 (0.0002 g, 0.622 g/mmol TBAF) and methanol (0.2 mL) were added. The mixture was stirred at same temperature for 15 min and filtered through a pad of Celite and washed with methanol (3 mL). The combined filtrates were concentrated, and purified by silica gel column chromatography (50% ethyl acetate–hexanes) to give 1 as colorless solid (0.0009 g, 55% over 2 steps). Recrystallization from 30% ethyl acetate–hexanes gave single crystals suitable for X-ray analysis: Rf = 0.19 (50 % ethyl acetate–hexanes); FTIR (neat, cm-1) 3422, 2924, 2852, 1770, 1033; 1H NMR (600 MHz, CD3OD) δ 7.90 (d, J = 8.0 Hz, 1H), 7.34 (d, J = 8.0 Hz, 1H), 6.32 (d, J = 10.0 Hz, 1H), 5.29 (s, 1H), 4.71 (dd, J = 3.4, 2.5 Hz, 1H), 4.41 (dd, J = 7.9, 3.2 Hz, 1H), 4.25 (d, J = 7.8 Hz, 1H), 4.10 (d, J = 11.0 Hz, 1H), 3.93 (ddd, J = 8.1, 7.9, 3.9 Hz, 1H), 3.89 (dd, J = 10.0, 3.2 Hz, 1H), 3.55 (ddd, J = 12.7, 9.4, 2.3 Hz, 1H), 3.12 (dd, J = 11.0, 1.0 Hz, 1H), 2.75 (ddd, J = 13.7, 2.5, 2.3 Hz, 1H), 2.72 (s, 3H), 2.73–2.69 (m, 1H), 2.70 (d, J = 9.4 Hz, 1H), 2.61 (dd, J = 12.4, 7.8 Hz, 1H), 2.29 (ddd, J = 13.7, 12.7, 3.4 Hz, 1H), 2.06 (dd, J = 12.4, 1.0 Hz, 1H), 1.72 (ddd, J = 13.2, 8.2, 8.1 Hz, 1H), 1.51 (s, 3H), 1.15 (d, J = 7.3 Hz, 3H); 13C NMR (100 MHz, CD3OD) δ 206.4, 182.4, 154.2, 140.5, 137.5, 136.7, 135.9, 122.4, 93.0, 85.2, 80.5, 77.4, 76.9, 73.0, 65.6, 65.3, 53.7, 53.3, 46.6, 43.5, 36.9, 36.8, 35.1, 33.0, 16.6, 16.2, 14.3; HRMS(ES)+ calcd for C27H32BrCl2O7 (M+H)+ 617.0708, found 617.0682.

Diol 26a. To a solution of 26 (0.35 g, 1.8 mmol, 1.0 equiv) in a 9:1 mixture of acetone/water (8 mL) was added osmium tetroxide solution (0.4 M in water, 0.9 mL, 0.36 mmol, 0.2 equiv.) and N-methylmorpholine N-oxide (0.32 g, 2.7 mmol, 1.5 equiv) at 23 °C. After stirring for 12 h at 23 °C, saturated aqueous sodium sulfite (5 mL) was added and stirred for 30 min. The solvent was evaporated in vacuo, the residue was diluted with water (10 mL) and extracted with ethyl acetate (20 mL×5). The combined organic extracts were dried over anhydrous sodium sulfate, filtered, concentrated, and purified by silica gel column chromatography (gradient 50% ethyl acetate–
hexanes→ 100% ethyl acetate) to give 26a as colorless oil (0.32 g, 77%). $R_f = 0.22$ (100% ethyl acetate–hexanes); $^1$H NMR (400 MHz, CDCl$_3$) $\delta$ 4.62 (dd, $J = 5.1$, 11.6 Hz, 1H), 4.38 (d, $J = 6.0$ Hz, 1H), 4.32 (d, $J = 6.7$ Hz, 1H), 3.86 (d, $J = 6.0$ Hz, 1H), 2.88 (dd, $J = 6.7$, 13.2 Hz, 1H), 2.65 (dd, $J = 5.7$, 14.6 Hz, 1H), 2.44 (dd, $J = 3.2$, 14.6 Hz, 1H), 2.22 (ddt, $J = 3.2$, 5.1, 14.0 Hz, 1H), 2.04 (ddt, $J = 5.7$, 11.6, 14.0 Hz, 1H), 1.21 (s, 3H), 0.96 (d, $J = 13.2$ Hz, 1H); $^{13}$C NMR (100 MHz, CDCl$_3$) $\delta$ 209.7, 89.03, 80.2, 74.8, 73.1, 67.8, 54.7, 35.9, 35.7, 29.6, 20.4; MS(ES)$^+$ calcd for C$_{11}$H$_{16}$NaO$_5$ (M+Na)$^+$ 251.09, found 250.95.

**Alcohol 59.** To a solution of 26a (0.31 g, 1.35 mmol, 1.0 equiv) in acetonitrile (6 mL) was added 2,2-dimethoxypropane (0.33 mL, 2.7 mmol, 2.0 equiv) and camphorsulfonic acid (0.012 g, 0.054 mmol, 0.04 equiv) at 23 °C. After stirring at this temperature for 12 h, the mixture was concentrated to give 59 as colorless oil (0.36 g, 99%): $R_f = 0.25$ (50% ethyl acetate–hexane); $^1$H NMR (400 MHz, CDCl$_3$) $\delta$ 4.75 (d, $J = 5.6$ Hz, 1H), 4.65 (s, 1H), 4.62 (dd, $J = 5.0$, 11.4 Hz, 1H), 4.39 (d, $J = 6.6$ Hz, 1H), 4.34 (dd, $J = 1.0$, 5.6 Hz, 1H), 2.83 (dd, $J = 6.6$, 13.2 Hz, 1H), 2.60 (dd, $J = 5.6$, 14.8 Hz, 1H), 2.44 (dt, $J = 3.5$, 14.8 Hz, 1H), 2.22 – 2.01 (m, 2H), 1.53 (s, 3H), 1.32 (s, 3H), 1.20 (s, 3H), 0.95 (d, $J = 13.2$ Hz, 1H); $^{13}$C NMR (100 MHz, CDCl$_3$) $\delta$ 210.3, 112.4, 87.6, 83.5, 81.9, 77.9, 67.4, 53.9, 36.0, 35.8, 29.1, 25.5, 24.6, 20.4; MS(ES)$^+$ calcd for C$_{14}$H$_{20}$NaO$_5$ (M+Na)$^+$ 291.12, found 291.05.

**TES ether 59a.** To a solution of 59 (0.35 g, 1.3 mmol, 1.0 equiv) in anhydrous dimethylformamide (6 mL) was added imidazole (0.22 g, 3.25 mmol, 2.5 equiv) and triethylsilyl chloride (0.26 mL, 1.56 mmol, 1.2 equiv) at 23 °C. After stirring at this temperature for 3 h, the mixture was diluted with ethyl acetate (100 mL) and washed with brine (20 mL×5), dried over anhydrous sodium sulfate, filtered, concentrated, and purified by silica gel column chromatography (40% ethyl acetate–hexane) to give 59a as colorless oil (0.46 g, 92%): $R_f = 0.50$ (30% ethyl acetate–hexane); $^1$H NMR (400 MHz, CDCl$_3$) $\delta$ 4.51 (d, $J = 5.5$ Hz, 1H), 4.47 (t, $J = 5.7$ Hz, 1H), 4.22 (d, $J = 5.5$ Hz, 1H), 4.18 (d, $J = 6.2$ Hz, 1H), 2.54 (dd, $J = 6.2$, 12.8 Hz, 1H), 2.42 (t, $J = 6.6$, Hz 2H), 2.01 (dd, $J = 6.6$, 12.9 Hz, 2H), 1.38 (s, 3H), 1.19 (s, 3H), 1.12 (s, 3H), 0.87 (t, $J = 7.9$ Hz, 9H), 0.56 (q, $J = 7.9$ Hz, 6H), 0.56 (d, $J = 12.9$ Hz, 1H); $^{13}$C NMR (100 MHz, CDCl$_3$) $\delta$ 210.9, 111.3, 89.2, 83.1, 80.0, 78.1, 66.1, 53.4, 36.0, 34.0, 29.4, 25.7, 24.7, 21.5, 6.7, 4.7; MS(ES)$^+$ calcd for C$_{20}$H$_{34}$NaO$_5$Si (M+Na)$^+$ 405.21, found 405.20.

**Alcohol 60.** To a solution of 59a (0.44 g, 1.14 mmol, 1.0 equiv) in anhydrous tetrahydrofuran (10 mL) was slowly added a solution of L-selectride (1.0 M in tetrahydrofuran, 2.3 mL, 2.28 mmol, 2 equiv) at -78 °C. After stirring at -78 °C for 30 min, sodium perborate monohydrate (0.34 g, 3.42 mmol, 3.0 equiv) and a 20:1 (v:v) mixture of tetrahydrofuran:water (2 mL) were added. The mixture was allowed to warm to 23 °C and water (10 mL) was added. The biphasic mixture was extracted with ethyl acetate (30 mL), and the organic phase was dried over anhydrous sodium sulfate, filtered, concentrated, and purified by silica gel column chromatography (20% ethyl acetate–hexanes) to give 60 as colorless oil (0.42 g, 95%): $R_f = 0.38$ (30% ethyl acetate–hexane); $^1$H NMR (400 MHz, CDCl$_3$) $\delta$ 4.44 (d, $J = 5.5$ Hz, 1H), 4.39 (dd, $J = 3.2$, 6.7 Hz, 1H), 4.33 – 4.30 (m, 2H), 3.99 (d, $J = 11.7$ Hz, 1H), 3.34 (d, $J = 7.1$ Hz, 1H), 2.48 (dd, $J = 6.2$, 12.1 Hz, 1H), 1.99 – 1.82 (m, 3H), 1.72 – 1.62 (m, 1H), 1.48 (s, 3H), 1.28 (s, 3H), 1.01 (s, 3H), 0.98 (t, $J = 7.9$ Hz, 9H), 0.71 – 0.63 (m, 6H); $^{13}$C NMR (75 MHz, CDCl$_3$) $\delta$ 111.2, 87.8, 83.5, 80.8, 78.4, 73.7, 66.4, 44.1, 37.0, 26.2, 25.9, 25.7, 24.9, 22.5, 6.9, 4.8; MS(ES)$^+$ calcd for C$_{20}$H$_{36}$NaO$_5$Si (M+Na)$^+$ 407.22, found 407.20.
Silyl ether 60a. To a solution of 60 (0.41 g, 1.06 mmol, 1.0 equiv) and 2,6-lutidine (0.74 mL, 6.36 mmol, 6.0 equiv) in anhydrous methylene chloride (10 mL) was slowly added t-butyldimethylsilyl trifluoromethanesulfonate (0.73 mL, 3.18 mmol, 3 equiv) at 0°C. Then, the mixture was allowed to warm up to 23°C and a stirred 30 min, and water (10 mL) was added. The biphasic mixture was extracted with ethyl acetate (30 mL), and the organic phase was washed with brine (15 mL), dried over anhydrous sodium sulfate, filtered, concentrated, and purified by silica gel column chromatography (6% ethyl acetate–hexanes) to give 60a as colorless oil (0.53 g, 100%); Rf = 0.88 (30% ethyl acetate–hexane); 1H NMR (400 MHz, CDCl3) δ 4.55 (d, J = 5.4 Hz, 1H), 4.26 (d, J = 5.9 Hz, 1H), 4.22 (d, J = 5.4 Hz, 1H), 4.12 (dd, J = 7.2, 9.7 Hz, 1H), 3.35 (dd, J = 3.6, 10.2 Hz, 1H), 2.19 (dd, J = 5.9, 12.7 Hz, 1H), 1.99 – 1.90 (m, 1H), 1.85 – 1.73 (m, 2H), 1.46 (s, 3H), 1.46 – 1.39 (m, 1H), 1H), 1.24 (s, 3H), 1.01 (s, 3H), 0.97 (t, J = 7.9 Hz, 9H), 0.86 (s, 9H), 0.82 (d, J = 12.7, 1H), 0.63 (m, 6H), 0.02 (s, 6H); 13C NMR (75 MHz, CDCl3) δ 110.7, 89.1, 83.0, 81.4, 79.1, 74.6, 66.1, 46.9, 35.4, 28.7, 27.5, 26.1, 25.7, 24.6, 22.9, 18.0, 7.0, 4.9, -3.9, -5.0; MS(ES)+ calcd for C28H50NaO5Si2 (M+Na)+ 521.31, found 521.35.

Alcohol 60b. To a solution of 60a (0.52 g, 1.03 mmol, 1 equiv) in acetonitrile (250 mL) was added hydrofluoride pyridine (1.6 mL) at 23°C. After stirring at this temperature for 2 h, trimethylsilyl methoxide (7 mL) was added and the mixture was stirred for 1 h. Then, solvent was evaporated in vacuo, the residue was diluted with ethyl acetate (100 mL) and washed with saturated sodium bicarbonate (30 mL). The organic phase was dried over anhydrous sodium sulfate, filtered, concentrated, and purified by silica gel column chromatography (15% ethyl acetate–hexanes) to give 60b as colorless oil (0.38 g, 96%). Rf = 0.50 (30% ethyl acetate–hexanes); 1H NMR (400 MHz, CDCl3) δ 4.66 (d, J = 5.5 Hz, 1H), 4.36 (s, 1H), 4.32 (d, J = 6.4 Hz, 1H), 4.20 (d, J = 5.5 Hz, 1H), 4.20 (dd, J = 5.3, 11.2 Hz, 1H), 3.40 (dd, J = 6.4, 12.2 Hz, 1H), 2.18 – 2.06 (m, 1H), 1.79 – 1.67 (m, 2H), 1.68 – 1.57 (m, 1H), 1.52 (s, 3H), 1.29 (s, 3H), 1.01 (s, 3H), 0.90 (s, 9H), 0.78 (d, J = 12.2 Hz, 1H), 0.03 (s, 6H); 13C NMR (75 MHz, CDCl3) δ 111.4, 86.5, 83.6, 83.4, 78.5, 74.5, 68.0, 45.0, 36.3, 28.0, 25.8, 25.6, 24.5, 22.5, 18.0, -4.1, -5.2; MS(ES)+ calcd for C26H36NaO5Si (M+Na)+ 407.22, found 407.15.

Ketone 61. To a solution of 60b (0.37 g, 0.96 mmol, 1.0 equiv) in anhydrous methylene chloride (105 mL) was added Dess-Martin periodinane (0.81 g, 1.9 mmol, 2.0 equiv) at 23°C. After stirring for 5 min, water (34 μL, 1.9 mmol, 2.0 equiv) was added. The suspension was stirred for another 2 h, an aqueous solution of 1:1 10% sodium bisulfate/saturated sodium bicarbonate (10 mL) was then added. After stirring for another 10 min, the biphasic mixture was extracted with ethyl acetate (20 mL×2), the organic phase was washed with saturated sodium bicarbonate (20 mL), dried over anhydrous sodium sulfate, filtered, concentrated, and purified by silica gel column chromatography (10% ethyl acetate–hexanes) to give 61 as colorless oil (0.30 g, 82%); Rf = 0.65 (30% ethyl acetate–hexane); 1H NMR (400 MHz, CDCl3) δ 4.71 (d, J = 5.4 Hz, 1H), 4.37 (d, J = 5.8 Hz, 1H), 4.26 (d, J = 5.4 Hz, 1H), 3.36 (dd, J = 3.6, 12.2 Hz, 1H), 2.73 (ddd, J = 0.9, 8.7, 16.8 Hz, 1H), 2.45 (ddd, J = 3.6, 9.5, 12.5 Hz, 1H), 2.39 (dd, J = 5.8, 13.0 Hz, 1H), 2.26 (ddd, J = 8.1, 9.5, 16.8 Hz, 1H), 1.60 (ddd, J = 0.9, 8.1, 12.5 Hz, 1H), 1.38 (s, 3H), 1.25 (s, 3H), 1.00 (s, 3H), 0.94 (d, J = 13.0 Hz, 1H), 0.82 (s, 9H), -0.00 (s, 3H), -0.03 (s, 3H); 13C NMR (100 MHz, CDCl3) δ 208.0, 111.8, 92.6, 82.4, 81.1, 77.6, 75.0, 51.8, 36.8, 34.6, 29.0, 25.9, 25.6, 24.9, 22.7, 17.9, -4.0, -5.0; MS(ES)+ calcd for C26H34NaO5Si (M+Na)+ 405.21, found 405.20.

Bromide 62. A solution of hydrazine (0.5 mL, 15.6 mmol, 20.0 equiv) and flame dried powdered 4Å molecular sieves (0.10 g) in anhydrous methanol (10 mL) was stirred at 23°C for 30 min. To this solution was added 61 (0.30 g, 0.78 mmol, 1.0 equiv) in anhydrous methanol (1 mL) at 23°C. The mixture was stirred at same temperature for 3 h
and filtered with a celite column and washed with ether (10 mL). The filtrate was concentrated and dried using high vacuum for 1 h to give a crude hydrazone which is directly used in the next step without purification. To a solution of crude hydrazone in anhydrous ether (10 mL) was added potassium t-butoxide (0.35 g, 3.12 mmol, 4.0 equiv) and bromine (0.1 mL, 1.95 mmol, 2.5 equiv) at 23 °C under argon. The mixture was stirred at this temperature for 1 h and water (8 mL) was added. The biphasic mixture was extracted with ethyl acetate (10 mL×2), the organic phase was washed with saturated sodium bicarbonate (10 mL), dried over anhydrous sodium sulfate, filtered, concentrated, and purified by thin layer chromatography (30 % ethyl acetate-hexane) to give 62 as colorless oil (0.22 g, 63 % over 2 steps): Rf =0.50 (20 % ethyl acetate-hexane); 1H NMR (400 MHz, CDCl3) δ 6.34 (d, J = 5.1 Hz, 1H), 4.65 (d, J = 5.2 Hz, 1H), 4.37 (d, J = 5.2 Hz, 1H), 4.31 (d, J = 5.8 Hz, 1H), 3.56 (t, J = 3.8 Hz, 1H), 2.40 – 2.28 (m, 2H), 2.19 (ddd, J = 2.7, 6.1, 17.7 Hz, 1H), 1.57 (s, 3H), 1.30 (s, 3H), 1.07 (d, J = 12.4 Hz, 1H), 1.04 (s, 3H), 0.87 (s, 9H), 0.03 (s, 3H), 0.02 (s, 3H); 13C NMR (101 MHz, CDCl3) δ 132.3, 117.6, 112.0, 84.4, 83.6, 82.6, 79.1, 72.9, 46.5, 36.9, 33.6, 25.9, 25.7, 25.1, 23.3, 18.0, -4.4, -5.0.

**Alcohol 62a.** To a solution of 62 (0.21 g, 0.47 mmol, 1.0 equiv) in anhydrous tetrahydrofuran (5 mL) was added a solution of tetrabutylammonium fluoride (1.0 M in tetrahydrofuran, 0.52 mL, 0.52 mmol, 1.1 equiv) at 23 °C. After stirring at 23 °C for 15 min, calcium carbonate (0.24 g, 2.35 mmol, 5.0 eq), Dowex 50WX8-400 (0.32 g, 0.622 g/mmol TBAF) and methanol (3 mL) were added. The mixture was stirred at same temperature for 15 min and filtered through a pad of Celite and washed with methanol (3 mL). The combined filtrates were concentrated and purified by silica gel column chromatography (30% ethyl acetate–hexanes) to give 62a as colorless oil (0.22 g, 63 % over 2 steps): Rf =0.15 (30 % ethyl acetate–hexanes); 1H NMR (400 MHz, CDCl3) δ 6.53 (t, J = 4.4 Hz, 1H), 4.69 (d, J = 5.6 Hz, 1H), 4.46 (d, J = 6.4 Hz, 1H), 4.41 (d, J = 5.6 Hz, 1H), 3.51 (dt, J = 2.5, 10.1 Hz, 1H), 3.22 (d, J = 10.1 Hz, 1H), 2.56 (dd, J = 6.4, 12.5 Hz, 1H), 2.41 (dd, J = 2.5, 4.4 Hz, 2H), 1.58 (s, 3H), 1.32 (s, 3H), 1.22 (d, J = 12.5 Hz, 1H), 1.09 (s, 3H); 13C NMR (100 MHz, CDCl3) δ 135.2, 115.7, 112.5, 84.6, 83.6, 81.7, 79.1, 72.7, 45.4, 36.8, 33.8, 25.8, 25.2, 21.9; MS(ES)^+ calcd for C14H13BrNaO4 (M+Na)^+ 353.04, found 353.00.

**Enone 63.** To a solution of 62a (0.14 g, 0.42 mmol, 1.0 equiv) in anhydrous methylene chloride (5 mL) was added Dess-Martin periodinane (0.090 g, 0.27 mmol, 1.0 equiv) in anhydrous tetrahydrofuran (5 mL) was slowly added a solution of L-selectride (1.0 M in tetrahydrofuran, 0.52 mL, 0.52 mmol, 1.1 equiv) at 23 °C. After stirring at 23 °C for 15 min, sodium perborate monohydrate (0.081 g, 0.81 mmol, 3.0 equiv) and a 20:1 (v:v) mixture of tetrahydrofuran:water (2 mL) were added. The mixture was allowed to warm to 23°C and water (5 mL) was added. The biphasic mixture was extracted with ethyl acetate (20 mL), and the organic phase was
dried over anhydrous sodium sulfate, filtered, concentrated, and purified by silica gel column chromatography (20 % ethyl acetate–hexanes) to give 63 as colorless solid (0.079 g, 88 %). Recrystallization from diethyl ether gave single crystals suitable for X-ray analysis. \( R_f = 0.12 \) (20 % ethyl acetate–hexane); \(^1\)H NMR (400 MHz, CDCl\(_3\)) \( \delta \) 4.74 (dd, \( J = 8.4, 4.4 \) Hz, 1H), 4.62 (d, \( J = 5.6 \) Hz, 1H), 4.39 (d, \( J = 6.6 \) Hz, 1H), 4.34 (d, \( J = 5.6 \) Hz, 1H), 2.85 (dd, \( J = 13.1, 6.6 \) Hz, 1H), 2.64--2.54 (m, 3H), 2.52--2.41 (m, 1H), 1.56 (s, 3H), 1.31 (s, 3H), 1.24 (s, 3H), 1.08 (d, \( J = 13.1 \) Hz, 1H); \(^{13}\)C NMR (100 MHz, CDCl\(_3\)) \( \delta \) 209.8, 112.7, 87.8, 83.2, 80.5, 77.9, 54.5, 42.9, 37.5, 36.7, 33.4, 25.6, 25.1, 21.2; MS(ES)\(^+\) calcd for \( \text{C}_{14}\text{H}_{10}\text{BrNaO}_4 \) (M+Na\(^+\)) 353.04, found 353.00.

Ketone 83 exists as a conformational mixture. The boat–chair ratio is close to 1:1 with perhaps a slight excess of the boat form. The first picture shown is the fit by least-squares of selected atoms of the boat form (dashed lines) onto equivalent atoms of the chair form (solid lines). The main differences are in the orientation of the cyclohexanone ring and the configuration at C-6 where the Br atom is attached.

Triflate 64. To a solution of 83 (0.035 g, 0.10 mmol, 1.0 equiv) in anhydrous tetrahydrofuran (3 mL) was added potassium bis(trimethylsilyl)amide (0.5 M in toluene, 0.3 mL, 0.15 mmol, 1.5 equiv) at \(-78^\circ\)C under argon. The mixture was stirred at same temperature for 30 min before a solution of N-phenyltrifluoromethanesulfonimide (0.039 g, 0.11 mmol, 1.1 equiv) in anhydrous tetrahydrofuran (0.5 mL) was added at \(-78^\circ\)C. After stirring for another 30 min at same temperature, a solution of aqueous saturated ammonium chloride (3 mL) was added and the mixture was warmed to 23 °C. The biphasic mixture was extracted with ethyl acetate (10 mL x 2), and the organic phase was washed with brine (10 mL), dried over anhydrous sodium sulfate, filtered, concentrated, and purified by silica gel column chromatography (gradient 5% → 10% ethyl acetate–hexanes) to give 64 as colorless oil (0.035 g, 76%): \( R_f = 0.40 \) (20% ethyl acetate–hexanes); \(^1\)H NMR (400 MHz, CDCl\(_3\)) \( \delta \) 5.56 (dd, \( J = 2.2, 6.0 \) Hz, 1H), 4.77 (d, \( J = 5.6 \) Hz, 1H), 4.51 (d, \( J = 6.2 \) Hz, 1H), 4.38 (d, \( J = 5.6 \) Hz, 1H), 4.36 (d, \( J = 6.0 \) Hz, 1H), 3.02 (ddd, \( J = 2.2, 11.2, 17.4 \) Hz, 1H), 2.83 (dt, \( J = 6.0, 17.4 \) Hz, 1H), 2.10 (dd, \( J = 6.2, 12.8 \) Hz,
0.10 (s, 3H); 3.81 (d, J = 7.48 Hz, 1H), 3.91 (d, J = 8.0 Hz, 1H), 4.08 (ddd, J = 10.0, 6.5, 3.3, 0.9 Hz, 1H), 3.07–3.05 (m, 1H), 2.46 (s, 3H), 1.81 (ddd, J = 6.5, 5.2, 1.1 Hz, 1H, OCH). 13C NMR (100 MHz, CDCl3) δ 137.4, 135.4, 132.0, 127.3, 125.5, 123.8, 61.34, 61.28, 54.3, 18.4; MS(ES)+ calcd for C10H11BrNaO2 (M+Na)+ 264.98, found 265.45.

**Epoxide 122.** To a solution of diethyl-L-tartrate (0.20 mL, 1.19 mmol, 0.18 equiv) and powdered 4Å molecular sieves (0.2 g) in anhydrous methylene chloride (20 mL) was added a solution of titanium(IV) isopropoxide (0.22 mL, 0.91 mmol, 0.15 equiv) in anhydrous methylene chloride (1 mL) at -20 °C under argon. Then, an anhydrous solution of tert-butyl hydroperoxide (5.5 M in decane, 2.4 mL, 13.2 mmol, 2.0 equiv) was slowly added. After stirring at same temperature for 2 h, the mixture was diluted with ethyl acetate (100 mL) and washed with brine (15 mL × 5), dried over anhydrous sodium sulfate, filtered, concentrated, and purified by silica gel column chromatography (gradient 2% → 5% ethyl acetate–hexanes) to give 122 as colorless oil (1.53 g, 96%, 91% ee as determined by HPLC: chiralcel OD-H column, 12% iso-propanol–hexane, 1 mL/min, tR(minor) = 7.8 min, tR(major) = 11.8 min). Rf = 0.23 (30% ethyl acetate–hexanes). 1H NMR (400 MHz, CDCl3) δ 7.50 (d, J = 8.0 Hz, 1H), 7.21 (d, J = 7.7 Hz, 1H), 7.05 (dd, J = 8.0, 7.7 Hz, 1H), 4.10–4.08 (m, 1H), 4.07–4.05 (m, 1H), 3.87 (dddd, J = 10.0, 6.5, 3.3, 0.9 Hz, 1H), 3.07–3.05 (m, 1H), 2.46 (s, 3H), 1.81 (ddd, J = 6.5, 5.2, 1.1 Hz, 1H, OCH). 13C NMR (100 MHz, CDCl3) δ 137.4, 135.4, 132.0, 127.3, 125.5, 123.8, 61.34, 61.28, 54.3, 18.4; MS(ES)+ calcd for C10H11BrNaO2 (M+Na)+ 264.98, found 265.45.

**TBS Ether 123.** To a solution of the alcohol 122 (1.2 g, 4.96 mmol, 1.0 equiv) in dimethylformamide (3 mL) were successively added imidazole (0.81 g, 11.9 mmol, 2.4 equiv) and tert-butyltrimethylsilyl chloride (0.9 g, 5.95 mmol, 1.2 equiv) at 23 °C. After stirring at same temperature for 2 h, the mixture was diluted with ethyl acetate (100 mL) and washed with brine (15 mL × 5), dried over anhydrous sodium sulfate, filtered, concentrated, and purified by silica gel column chromatography (gradient 2% → 5% ethyl acetate–hexanes) to give 123 as colorless oil (1.71 g, 97%, 91% ee as determined by HPLC: chiralcel OD-H column, 12% iso-propanol–hexane, 1 mL/min, tR(minor) = 7.8 min, tR(major) = 11.8 min). Rf = 0.23 (30% ethyl acetate–hexanes). 1H NMR (400 MHz, CDCl3) δ 7.50 (d, J = 8.0 Hz, 1H), 7.21 (d, J = 7.7 Hz, 1H), 7.05 (dd, J = 8.0, 7.7 Hz, 1H), 4.10–4.08 (m, 1H), 4.07–4.05 (m, 1H), 3.87 (dddd, J = 10.0, 6.5, 3.3, 0.9 Hz, 1H), 3.07–3.05 (m, 1H), 2.46 (s, 3H), 1.81 (ddd, J = 6.5, 5.2, 1.1 Hz, 1H, OCH). 13C NMR (100 MHz, CDCl3) δ 137.4, 135.4, 132.0, 127.3, 125.5, 123.8, 61.34, 61.28, 54.3, 18.4; MS(ES)+ calcd for C10H11BrNaO2 (M+Na)+ 264.98, found 265.45.

**Aldehyde ent-38.** A solution of 4-bromo-2,6-di-tert-butylphenol (2.15 g, 7.52 mmol, 4.0 equiv) in anhydrous methylene chloride (60 mL) was degassed using freeze-pump-thaw. A solution of trimethylaluminum (2.0 M in hexane, 1.88 mL, 3.76 mmol, 2.0 equiv) was then added at 23 °C. After stirring at same temperature for 1 h, the solution was cooled to –78 °C and a solution of 123 (0.76 g, 1.88 mmol, 1.0 equiv) in anhydrous methylene chloride (3 mL) was slowly added. The mixture was stirred at –78 °C for 10 min before addition of hydrochloric acid (1 N, 30 mL) at same temperature. The mixture was allowed to warm to 23 °C and stirred for 10 min, then extracted with methylene chloride (50 mL). The organic phase was dried over anhydrous sodium sulfate, filtered, concentrated to give crude ent-38 as yellow oil which was directly used in the next step without purification (90% ee as determined by the corresponding benzoyl ester with HPLC: chiralpak AD-H, 0.2% iso-propanol–hexanes, 0.8 mL/min, tR(major) = 15.3 min, tR(minor) = 16.0 min). Rf = 0.47 (10% ethyl acetate–hexanes). 1H NMR (400 MHz, CDCl3) δ 9.76 (d, J = 1.4 Hz, 1H), 7.51 (dd, J = 6.6, 2.7 Hz, 1H), 7.05 (dd, J = 7.8, 6.6 Hz, 1H), 7.04 (d, J = 7.8 Hz, 1H), 4.24 (dd, J = 10.1, 6.9 Hz, 1H), 4.08 (ddd, J = 6.9, 5.9, 1.4 Hz, 1H), 3.70 (dd, J = 10.1, 5.8 Hz, 1H), 2.47 (s, 3H), 0.83 (s, 9H), –0.01 (s, 3H), –0.03 (s, 3H); 13C NMR (100 MHz, CDCl3) δ 199.9, 137.0, 135.1, 132.1, 127.6, 127.2,
Furanone 65. To a solution of crude aldehyde *ent*-38 and 2-(triisopropylsiloxy)-3-methylfuran (0.57 g, 2.26 mmol, 1.2 equiv) in anhydrous methylene chloride (20 mL) was added boron trifluoride etherate (0.35 mL, 2.82 mmol, 1.5 equiv) at -78 °C under argon. After stirring at same temperature for 4 h, saturated sodium bicarbonate (15 mL) was added and the mixture was then warmed to 23 °C. The biphasic mixture was extracted with ethyl acetate (15 mL × 2), and the organic phase was washed with brine (15 mL), dried over anhydrous sodium sulfate, filtered, concentrated, and purified by silica gel column chromatography (gradient 5% → 15% ethyl acetate–hexanes) to give 65 (0.12 g 90% ee as determined by HPLC: chiralcel OD-H, 1.5% *iso*-propanol–hexane, 1.1 mL/min, tr(t) = 12.1 min tr(2) = 15.4 min) and its diastereomer (0.48 g, 72% total yield) as colorless oil: 65 Rf = 0.28 (30% ethyl acetate-hexane); 1H NMR (500 MHz, CDCl₃) δ 7.47 (d, J = 8.0 Hz, 1H), 7.27 (d, J = 8.0 Hz, 1H), 7.03 (t, J = 8.0 Hz, 1H), 6.91 (t, J = 1.7 Hz, 1H), 4.83 (dt, J = 1.7, 4.9 Hz, 1H), 4.25 (dd, J = 4.9, 7.3 Hz, 1H), 3.99 (qd, J = 5.5, 10.3 Hz, 2H), 3.39 (ddd, J = 5.5, 7.3 Hz, 1H), 2.44 (s, 3H), 1.83 (t, J = 1.7, 3H), 0.87 (s, 9H), 0.01 (s, 3H), -0.00 (s, 3H); 13C NMR (125 MHz, CDCl₃) δ 173.9, 145.6, 139.6, 135.5, 131.2, 130.4, 127.0, 126.5, 126.2, 82.5, 73.7, 65.4, 44.7, 25.5, 19.2, 17.8, 10.4, -5.96, -5.99; MS(ES)+ calcd for C₂₁H₂₃BrNaO₄Si (M+Na)+ 479.11, found 479.05.

Lactone 65a. To a solution of 65 (0.68 g, 1.50 mmol, 1.0 equiv) and platinum oxide (0.068 g, 0.3 mmol, 0.2 equiv) in ethyl acetate (30 mL) was evacuated and refilled with hydrogen three times. After stirring at 23 °C for 12 h, the mixture was filtered with a celite column, and washed with ethyl acetate (10 mL). The filtrates were concentrated and purified by silica gel column chromatography (10% ethyl acetate–hexanes) to give 65a (0.64 g, 94%) as colorless oil: Rf = 0.33 (30% ethyl acetate-hexane); 1H NMR (500 MHz, CDCl₃) δ 7.47 (dd, J = 0.9, 7.9 Hz, 1H), 7.21 (d, J = 7.9 Hz, 1H), 7.03 (t, J = 7.9 Hz, 1H), 4.47 (dd, J = 3.3, 9.1 Hz, 1H), 4.13 (ddd, J = 3.3, 6.5, 9.7 Hz, 1H), 3.97 – 3.89 (m, 2H), 3.66 (s, 1H), 3.17 (dt, J = 5.6, 9.1 Hz, 1H), 2.62 – 2.51 (m, 1H), 2.44 (s, 3H), 2.09 – 1.96 (m, 2H), 1.25 (dd, J = 7.1 Hz, 3H), 0.85 (s, 9H), -0.03 (s, 6H); 13C NMR (125 MHz, CDCl₃) δ 179.2, 139.1, 135.5, 131.4, 127.2, 126.8, 126.4, 78.6, 72.6, 66.2, 44.4, 35.3, 29.3, 25.7, 19.4, 18.0, 15.1, -5.7, -5.8; MS(ES)+ calcd for C₂₁H₂₃BrNaO₄Si (M+Na)+ 479.12, found 479.05.

TBS ether 66. To a solution of 65a (0.58 g, 1.27 mmol, 1.0 equiv) in anhydrous methylene chloride (10 mL) was added 2,6-lutidine (0.57 g, 2.26 mmol, 1.2 equiv) in anhydrous methylene chloride (20 mL) was added 2,6-lutidine (0.89 mL, 7.62 mmol, 6.0 equiv) and 2-(triisopropylsiloxy)-3-methylfuran (0.58 g, 1.27 mmol, 1.0 equiv) in anhydrous methylene chloride (10 mL) was added 2,6-lutidine (0.89 mL, 7.62 mmol, 6.0 equiv). After stirring at this temperature for 30 min, the mixture was cooled down to 23 °C and water (10 mL) was added. The biphasic mixture was extracted with ethyl acetate (20 mL), and the organic phase was washed with brine (10 mL), dried over anhydrous sodium sulfate, filtered, concentrated, and purified by silica gel column chromatography (gradient 3% → 6% ethyl acetate–hexanes) to give 66 as colorless oil (0.62 g, 86%): Rf = 0.68 (30% ethyl acetate-hexane); 1H NMR (500 MHz, CDCl₃) δ 7.44 (d, J = 7.8 Hz, 1H), 7.15 (d, J = 7.8 Hz, 1H), 7.01 (t, J = 7.8 Hz, 1H), 4.53 (dd, J = 1.5, 9.0 Hz, 1H), 4.08 (ddd, J = 1.4, 5.8, 10.2 Hz, 1H), 3.90 – 3.82 (m, 2H), 3.05 (ddd, J = 3.9, 5.9, 9.9 Hz, 1H), 2.57 – 2.45 (m, 1H), 2.43 (s, 3H), 2.05 (q, J = 11.9 Hz, 1H), 1.90 (ddd, J = 6.0, 9.0, 11.9 Hz, 1H), 1.21 (d, J = 7.0 Hz, 3H), 0.93 (s, 9H), 0.75 (s, 9H), 0.16 (s, 3H), 0.13 (s, 3H), -0.24 (s, 3H), -0.27 (s, 3H); 13C NMR (125 MHz, CDCl₃) δ 179.0, 140.3, 135.9, 131.0, 127.0, 126.9, 126.2, 78.6, 70.5, 64.2, 46.4, 35.2, 28.4, 26.1, 25.8, 19.5, 18.3, 18.1, 15.0, -3.8, -4.7, -5.8, -5.9; MS(ES)+ calcd for C₂₇H₄₂BrNaO₄Si₂ (M+Na)+ 593.21, found 593.10.
Alcohol 66a. A solution of 66 (0.60 g, 1.05 mmol, 1.0 equiv) in a 3:2:2 mixture of acetic acid:tetrahydrofuran:water (5 mL) was stirred at 60 °C for 12 h. Then, acetic acid was evaporated under vacuo and the residue was diluted with ethyl acetate (50 mL) and washed with a saturated solution of sodium bicarbonate (15 mL) and dried over anhydrous sodium sulfate, filtered, concentrated, and purified by silica gel column chromatography (25% ethyl acetate–hexanes) to give 66a as colorless oil (0.38 g, 79%): $R_f$ = 0.22 (30% ethyl acetate-hexane); $^1$H NMR (500 MHz, CDCl$_3$) $\delta$ 7.49 (dd, $J$ = 0.9, 7.8 Hz, 1H), 7.18 (d, $J$ = 7.8 Hz, 1H), 7.07 (t, $J$ = 7.8 Hz, 1H), 4.50 (dd, $J$ = 1.6, 10.1 Hz, 1H), 4.04 (dd, $J$ = 1.8, 6.2, 10.1 Hz, 1H), 3.93 (dd, $J$ = 4.7, 10.8 Hz, 1H), 3.82 (dd, $J$ = 5.9, 10.8 Hz, 1H), 3.14 (dt, $J$ = 4.7, 5.9 Hz, 1H), 2.59 – 2.49 (m, 1H), 2.45 (s, 3H), 2.13 – 2.00 (m, 1H), 1.23 (d, $J$ = 7.0 Hz, 3H), 0.93 (s, 9H), 0.18 (s, 3H), 0.14 (s, 3H); $^{13}$C NMR (125 MHz, CDCl$_3$) $\delta$ 178.8, 139.3, 136.0, 131.6, 127.6, 126.9, 126.2, 78.5, 72.4, 64.4, 35.2, 28.6, 26.3, 20.5, 18.5, 14.8, –3.6, –4.9; MS(ES)$^+$ calcd for C$_{21}$H$_{33}$BrNaO$_4$Si (M+Na)$^+$ 477.11, found 477.05.

Aldehyde 67. To a solution of 66a (0.35 g, 0.77 mmol, 1.0 equiv) in anhydrous methylene chloride (10 mL) was added Dess-Martin periodinane (0.49 g, 1.16 mmol, 1.5 equiv) at 23 °C. After stirring for 5 min, a solution of water (21 μL, 1.16 mmol, 1.5 equiv) was added. The suspension was stirred for another 30 min, an aqueous solution of 1:1 10% sodium bisulfate/saturated sodium bicarbonate (5 mL) was then added. After stirring for another 10 min, the biphasic mixture was extracted with ethyl acetate (10 mL×3), the organic phase was washed with saturated sodium bicarbonate (15 mL), dried over anhydrous sodium sulfate, filtered, concentrated, and purified by silica gel column chromatography (15% ethyl acetate–hexanes) to give 67 as colorless oil (0.38 g, 79%): $R_f$ = 0.40 (30% ethyl acetate-hexane); $^1$H NMR (500 MHz, CDCl$_3$) $\delta$ 9.68 (d, $J$ = 3.2 Hz, 1H), 7.54 (d, $J$ = 7.5 Hz, 1H), 7.18 (d, $J$ = 7.5 Hz, 1H), 7.11 (t, $J$ = 7.5 Hz, 1H), 4.94 (dd, $J$ = 1.7, 9.7 Hz, 1H), 4.06 (dd, $J$ = 1.7, 6.0, 10.3 Hz, 1H), 3.92 (dd, $J$ = 3.2, 9.7 Hz, 1H), 2.61 – 2.51 (m, 1H), 2.48 (s, 3H), 2.08 (q, $J$ = 12.4 Hz, 1H), 1.98 (dd, $J$ = 6.0, 9.1, 12.4 Hz, 1H), 1.24 (d, $J$ = 7.1 Hz, 3H), 0.88 (s, 9H), 0.15 (s, 3H), 0.13 (s, 3H); $^{13}$C NMR (101 MHz, CDCl$_3$) $\delta$ 196.9, 178.5, 136.6, 132.7, 132.6, 127.8, 127.6, 127.3, 77.7, 70.7, 58.6, 35.2, 28.6, 25.9, 19.8, 18.2, 15.0, –3.8, –4.9; MS(ES)$^+$ calcd for C$_{21}$H$_{33}$BrNaO$_4$Si (M+Na)$^+$ 477.11, found 477.05.

Bromide 67a. To a solution of triphenyl phosphite (0.37 mL, 1.4 mmol, 2.0 equiv) in dry methylene chloride (5 mL) was induced chlorine at –78 °C until the solution became yellow. The color was discharged by argon bubbling (1 min). Then, freshly distilled triethylamine (0.39 mL, 2.8 mmol, 4.0 equiv) and a solution of 66a (0.60 g, 1.05 mmol, 1.0 equiv) in anhydrous methylene chloride (5 mL) was stirred at 60 °C for 12 h. Then, acetic acid:tetrahydrofuran:water (5 mL) was stirred at 60 °C for 12 h. Then, acetic acid was evaporated under vacuo and the residue was diluted with ethyl acetate (50 mL) and washed with a saturated solution of sodium bicarbonate (15 mL) and dried over anhydrous sodium sulfate, filtered, concentrated, and purified by silica gel column chromatography (10% ethyl acetate–hexanes) to give 67a as colorless oil (0.32 g, 0.70 mmol, 1.0 equiv) in dry methylene chloride (0.5 mL) was added at same temperature. The mixture was allowed to warm to 23 °C and stirred for 30 min. Then, heated the solution to 40 °C and stirred for 10 min. The solvent was evaporated in vacuo and the residue was purified by silica gel column chromatography (25% ethyl acetate–hexanes) to give 67a as colorless oil (0.33 g, 92%): $R_f$ = 0.60 (30% ethyl acetate-hexane); $^1$H NMR (400 MHz, CDCl$_3$) $\delta$ 7.60 (dd, $J$ = 8.0, 0.9 Hz, 1H), 7.48 (dd, $J$ = 7.9, 0.9 Hz, 1H), 7.12 (dd, $J$ = 8.0, 7.9 Hz, 1H), 6.41 (d, $J$ = 3.1 Hz, 1H), 4.62 (dd, $J$ = 10.1, 1.8 Hz, 1H), 3.95 (dd, $J$ = 10.7, 5.8, 1.8 Hz, 1H), 3.67 (dd, $J$ = 10.1, 3.1 Hz, 1H), 2.51 (s, 3H), 2.54 – 2.46 (m, 1H), 2.00 (dd, $J$ = 12.0, 12.0, 10.7 Hz, 1H), 1.86 (dd, $J$ = 12.0, 8.8, 5.8 Hz, 1H), 1.22 (d, $J$ = 7.1 Hz, 3H), 0.95 (s, 9H), 0.27 (s, 3H), 0.15 (s, 3H); $^{13}$C NMR (100 MHz, CDCl$_3$) $\delta$ 178.4, 137.6, 133.6, 132.9, 128.4, 126.9, 126.9, 78.0, 74.4, 72.2, 52.2, 35.3, 28.6, 26.3, 20.5, 18.5, 14.8, –3.6, –4.9; MS(ES)$^+$ calcd for C$_{21}$H$_{33}$BrC$_{12}$NaO$_3$Si (M+Na)$^+$ 531.05, found 531.20. Deprotection of the TBS ether followed by recrystallization from 10% ethyl acetate–hexanes gave single crystals suitable for X-ray analysis.
Stannane 68. A solution of 67a (0.050 g, 0.098 mmol, 1.0 equiv), tetrakis[triphenylphosphine]palladium (0.051 g, 0.044 mmol, 0.45 equiv) and hexamethylditin (0.061 mL, 0.294 mmol, 3.0 equiv) in anhydrous 1,4-dioxane (1 mL) was degassed using freeze-pump-thaw. The mixture was then heated to 100 °C and stirred for 5 h. The solution was cooled to 23 °C, filtered with a celite column and washed with ethyl acetate (10 mL). The combined filtrates were evaporated in vacuo and purified by silica gel column chromatography (gradient 3% → 8% ethyl acetate–hexanes) to give 68 as colorless oil (0.031 g, 53%): \( R_f = 0.70 \) (30% ethyl acetate–hexanes); \( ^1H \) NMR (500 MHz, CDCl\(_3\)) \( \delta 7.48 \) (d, \( J = 7.6 \) Hz, 1H), 7.43 (dd, \( J = 1.1, 7.6 \) Hz, 1H), 7.22 (t, \( J = 7.6 \) Hz, 1H), 6.42 (d, \( J = 3.1 \) Hz, 1H), 4.66 (dd, \( J = 1.7, 10.0 \) Hz, 1H), 4.04 (ddd, \( J = 1.7, 5.8 \) Hz, 10.7, 1H), 3.62 (dd, \( J = 3.1, 10.0 \) Hz, 1H), 2.56 – 2.48 (m, 1H), 2.48 (s, 3H), 2.00 (q, \( J = 12.0 \) Hz, 1H), 1.88 (ddd, \( J = 5.8, 8.9, 12.0 \) Hz, 1H), 1.22 (d, \( J = 7.1 \) Hz, 3H), 0.96 (s, 9H), 0.33 (s, 9H), 0.28 (s, 3H), 0.15 (s, 3H); \( ^{13}C \) NMR (75 MHz, CDCl\(_3\)) \( \delta 178.7, 144.5, 143.9, 136.0, 131.4, 129.6, 78.3, 74.9, 72.3, 51.8, 35.3, 28.7, 26.3, 23.2, 18.5, 14.9, -3.6, -4.9, -8.2; MS(ES)\(^+\) calcd for C\(_{24}\)H\(_{40}\)Cl\(_2\)NaO\(_3\)SiSn (M+Na)\(^+\) 617.10, found 617.00.

Enone 69. A dried vial (4 mL) with 64 (0.015 g, 0.034 mmol, 1.0 equiv), tetrakis[triphenylphosphine]palladium (0.059 g, 0.051 mmol, 1.5 equiv) and copper(I) chloride (0.051 g, 0.051 mmol, 1.5 equiv) was evacuated and refilled with carbon monoxide three times. To this vial was added degassed dimethyl sulfoxide (0.16 mL), and the mixture was heated to 55 °C. A solution of 68 (0.026 g, 0.044 mmol, 1.3 equiv) in degassed dimethyl sulfoxide (0.12 mL) was added at same temperature. The suspension was stirred at 55 °C for 45 min. The mixture was then cooled to 23 °C and water (2 mL) was added. The mixture was diluted with ethyl acetate (8 mL), and the organic phase was dried over anhydrous sodium sulfate, filtered, concentrated, and purified by silica gel column chromatography (25% ethyl acetate–hexanes) to give an inseparable 9:1 mixture of 69 and its diastereomer as colorless oil (0.026 g, 61%) \( R_f = 0.25 \) (30% ethyl acetate–hexanes); \( ^1H \) NMR (400 MHz, CDCl\(_3\)) \( \delta 7.57 \) (d, \( J = 7.7 \) Hz, 1H), 7.08 (d, \( J = 7.7 \) Hz, 1H), 6.42 (d, \( J = 2.9 \) Hz, 1H), 6.22 (dd, \( J = 2.3, 5.6 \) Hz, 1H), 4.86 (d, \( J = 5.6 \) Hz, 1H), 4.67 (d, \( J = 10.0 \) Hz, 1H), 4.51 – 4.42 (m, 3H), 3.98 (dd, \( J = 5.6, 10.0 \) Hz, 1H), 3.59 (dd, \( J = 2.9, 10.0 \) Hz, 1H), 3.06 (dd, \( J = 2.3, 11.3, 19.3 \) Hz, 1H), 2.84 (dt, \( J = 5.6, 19.3 \) Hz, 1H), 2.49 (dt, \( J = 8.2, 12.4 \) Hz, 1H), 2.23 (s, 2H), 2.16 – 1.93 (m, 2H), 1.91 – 1.80 (m, 1H), 1.58 (s, 3H), 1.42 (s, 3H), 1.40 (d, \( J =12.4 \) Hz, 1H), 1.34 (s, 3H), 1.21 (d, \( J = 7.0 \) Hz, 3H), 0.95 (s, 9H), 0.28 (s, 3H), 0.15 (s, 3H); \( ^{13}C \) NMR (125 MHz, CDCl\(_3\)) \( \delta 199.3, 178.4, 145.0, 144.0, 141.5, 134.6, 132.8, 130.2, 126.7, 125.3, 112.4, 86.3, 82.9, 81.2, 79.2, 78.1, 74.7, 72.2, 50.8, 46.4, 42.2, 40.8, 37.3, 35.3, 28.7, 26.3, 25.8, 25.2, 22.6, 18.5, 16.9, 14.8, -3.6, -4.9; MS(ES)\(^+\) calcd for C\(_{36}\)H\(_{48}\)BrCl\(_2\)NaO\(_2\)Si (M+Na)\(^+\) 793.17, found 793.20.
Ketone 70. A solution of 69 (0.013 g, 0.017 mmol, 1.0 equiv) in an 2:1 mixture of methanol:acetonitrile (13 mL) was degassed by bubbling argon through the solution for 30 min. The solution was then photolyzed at 0 °C in a Rayonet chamber reactor at 350 nm for 2 h. The solution was then passed through a silica gel column and washed with ethyl acetate (15 mL), the organic phase was concentrated and dissolved in a mixture of 0.2 % disopropylamine in anhydrous methanol (8 mL). The solution was heated to 50 °C and reacted for 2 h. The solvent was then evaporated in vacuo and the residue was purified by preparative thin layer chromatography (30% ethyl acetate–hexanes) to give 70 as colorless oil (0.0081 g, 64% over two steps): Rf = 0.20 (30% ethyl acetate–hexanes); MS(ES)\(^+\) calcd for C\(_{36}\)H\(_{49}\)BrCl\(_2\)NaO\(_7\)Si (M+Na)\(^+\) 793.17, found 793.15.

\[\text{epi-Nakiterpiosin 3.} \quad \text{A solution of 70 (0.008 g, 0.010 mmol, 1.0 equiv) in trifluoroacetic acid/methylene chloride/water (9:1:1 v/v/v, 0.2 mL) was stirred at 23 °C for 30 min. The solvent was then evaporated under vacuo and the residue was dried using high vacuum for 2 h to give the crude diol 70a which was directly used in the next step without purification. To a solution of crude 70a obtained above in acetone/pH 7.4 buffer (2:1 v/v, 0.2 mL) was added sodium periodate (0.0043 g, 0.020 mmol, 2.0 equiv) at 23 °C. After stirring for 50 min, the suspension was diluted with water (2 mL) and extracted with ethyl acetate (3 mL×3), and the combined organic phase was dried over anhydrous sodium sulfate, filtered, concentrated, and directly used in the next step without purification. To a solution of crude 71 obtained above and triethylsilane (1.9 \(\mu\)L, 0.012 mmol, 1.2 equiv) in methylene chloride (0.2 mL) was slowly added boron trifluoride diethyl etherate (2.4 \(\mu\)L in 0.10 mL anhydrous methylene chloride, 0.020 mmol, 2.0 equiv) at 23 °C. After stirring at same temperature for 2 h, a saturated aqueous solution of sodium bicarbonate (1.5 mL) was added. The biphasic mixture was extracted with ethyl acetate (3 mL×3), and the organic phase was dried over anhydrous sodium sulfate, filtered, concentrated, and directly used in the next step without purification. To a solution of crude acetal obtained above in anhydrous tetrahydrofuran (0.2 mL) was added a solution of tetrabutylammonium fluoride (1.0 M in tetrahydrofuran, 11.0 \(\mu\)L, 0.011 mmol, 1.1 equiv) at 23 °C. After stirring at 23 °C for 15 min, calcium carbonate (0.050 g, 0.050 mmol, 5.0 eq), Dowex 50WX8-400 (0.0068 g, 0.622 g/mmol TBAF) and methanol (0.2 mL) were added. The mixture was stirred at same temperature for 15 min and filtered through a pad of Celite and washed with methanol (2 mL). The combined filtrates were concentrated, and purified by silica gel column chromatography (50% ethyl acetate–hexanes) to give epi-Nakiterpiosin 3 as colorless oil (0.0026 g, 43 % over 4 steps): Rf = 0.20 (50 % ethyl acetate–hexanes); \(^1\)H NMR (500 MHz, CD\(_3\)OD) \(\delta\) 7.86 (d, \(J\) = 8.0 Hz, 1H), 7.43 (d, \(J\) = 8.0 Hz, 1H), 6.66 (d, \(J\) = 3.6 Hz, 1H), 5.37 (s, 1H), 4.74 (dd, \(J\) = 12.3, 5.1 Hz, 1H), 4.52 (dd, \(J\) = 10.2, 2.3 Hz, 1H), 4.27 (d, \(J\) = 7.4 Hz, 1H), 4.02 (ddd, \(J\) = 9.1, 2.7 Hz, 1H), 2.94 (ddd, \(J\) = 12.0, 5.1, 2.7 Hz, 1H), 2.75 (d, \(J\) = 9.1 Hz, 1H), 2.68 (s, 3H), 2.67 (dd, \(J\) = 12.3, 7.4 Hz, 1H), 2.66–2.58 (m, 1H), 2.22 (ddd, \(J\) = 12.3, 12.0, 12.0 Hz, 1H), 2.21 (d, \(J\) = 12.3 Hz, 1H), 2.03–1.97 (m, 2H), 1.44 (s, 3H), 1.19 (d, \(J\) = 7.1 Hz, 3H); \(^{13}\)C NMR (125 MHz, CD\(_3\)OD) \(\delta\) 206.1, 182.2, 154.0, 140.5, 136.9, 136.1, 134.6, 122.6, 100.2, 86.1, 80.6, 76.7, 76.4, 72.9, 72.2, 65.5, 51.8, 50.8, 44.5, 41.4, 39.39, 39.37, 36.9, 30.3, 15.87, 15.85, 14.7; MS(ES)\(^+\) calcd for C\(_{27}\)H\(_{31}\)BrCl\(_2\)NaO\(_5\) (M+Na)\(^+\) 639.05, found 639.17.
\]
Iodide 73. To a solution of alcohol 26 (0.037 g, 0.19 mmol, 1.0 equiv) in acetic acid (0.8 mL) was added silver acetate (0.064 g, 0.38 mmol, 2.0 equiv) and iodine (0.051 g, 0.20 mmol, 1.05 equiv) at 23°C. After stirring at same temperature for 15 min, a solution of water (3.42 µL, 0.19 mmol, 1.0 equiv) in acetic acid (0.2 mL) was added. The mixture was heated to 90°C and stirred for 2 hours. Then, the mixture was cooled to 23°C, solvent was evaporated in vacuo and the residue was diluted with ethyl acetate (15 mL) and washed with saturated sodium bicarbonate (7 mL). The organic phase was dried over anhydrous sodium sulfate, filtered, concentrated, and purified by silica gel column chromatography (45% ethyl acetate–hexanes) to give 73 as colorless oil (0.28 g, 70%): \( R_f = 0.35 \) (50% ethyl acetate–hexane); \(^1\)H NMR (500 MHz, CDCl\(_3\)) \( \delta \) 5.64 (s, 1H), 4.51 (dd, \( J = 7.8, 16.5, 1H \)), 4.15 (s, 1H), 2.86 (d, \( J = 4.6, 1H \)), 2.71 – 2.62 (m, 2H), 2.43 (dd, \( J = 2.2, 7.1, 16.5, 1H \)), 2.38 (d, \( J = 13.4, 1H \)), 2.35 – 2.30 (m, 1H), 2.29 (d, \( J = 7.8, 1H \)), 2.08 (s, 3H), 1.42 (dd, \( J = 4.6, 13.4, 1H \)), 1.22 (s, 3H); \(^{13}\)C NMR (125 MHz, CDCl\(_3\)) \( \delta \) 207.8, 169.4, 97.8, 90.8, 65.6, 54.0, 49.1, 34.9, 34.2, 30.6, 24.7, 21.3, 15.4; MS(ES)\(^+\) calcd for C\(_{15}\)H\(_{18}\)IO\(_5\) (M+H)\(^+\) 381.02, found 380.95.

Triflate 74. To a solution of 27 (0.30 g, 0.77 mmol, 1.0 equiv) in anhydrous tetrahydrofuran (6 mL) was added potassium bis(trimethylsilyl)amide (0.5 M in toluene, 2.3 mL, 1.16 mmol, 1.5 equiv) at \(-78\) °C under argon. The mixture was stirred at same temperature for 30 min before a solution of N-phenyltrifluoromethanesulfonimide (0.302 g, 0.85 mmol, 1.1 equiv) in anhydrous tetrahydrofuran (2 mL) was added at \(-78\) °C. After stirring for another 30 min at same temperature, a solution of aqueous saturated ammonium chloride (8 mL) was added and the mixture was warmed to 23 °C. The biphasic mixture was extracted with ethyl acetate (15 mL×2), and the organic phase was washed with brine (10 mL), dried over anhydrous sodium sulfate, filtered, concentrated, and purified by silica gel column chromatography (gradient 5% → 10% ethyl acetate–hexanes) to give 74 as colorless oil (0.28 g, 70%): \( R_f = 0.30 \) (30% ethyl acetate–hexanes); \(^1\)H NMR (500 MHz, CDCl\(_3\)) \( \delta \) 8.09 (d, \( J = 7.6 \) Hz, 1H), 7.73 – 7.63 (m, 3H), 6.50 (dd, \( J = 5.8, 1.4 \) Hz, 1H), 6.22 (d, \( J = 5.8 \) Hz, 1H), 5.53 (dd, \( J = 5.9, 2.5 \) Hz, 1H), 5.43 (dd, \( J = 10.0, 6.7 \) Hz, 1H), 5.02 (dd, \( J = 5.0, 1.4 \) Hz, 1H), 3.96 (s, 3H), 2.72 – 2.60 (m, 2H), 2.23 (dd, \( J = 11.8, 5.0 \) Hz, 1H), 1.21 (d, \( J = 11.8, 1H \)), 1.16 (s, 3H); \(^{13}\)C NMR (125 MHz, CDCl\(_3\)) \( \delta \) 167.2, 153.1, 138.2, 134.7, 133.8, 133.0, 132.5, 131.0, 130.1, 129.2, 118.2 (q, \( J = 320 \) Hz), 101.6, 91.6, 78.4, 73.9, 53.4, 48.3, 39.0, 26.9, 22.4; MS(ES)\(^+\) calcd for C\(_{20}\)H\(_{22}\)F\(_3\)O\(_5\)S\(_2\) (M+H)\(^+\) 525.05, found 525.10.

Alocoloh 75. To a solution of 74 (0.27 g, 0.51 mmol, 1.0 equiv) in anhydrous tetrahydrofuran (10 mL) was added 9-BBN (4.08 mL, 2.04 mmol, 4.0 equiv) at 23°C. After stirring at same temperature for 15 min, the mixture was heated to 50°C and reacted for 2 hours. Then, the mixture was cooled to 0°C and 3 N sodium hydroxide (3 mL) was added 9-BBN (4.08 mL, 2.04 mmol, 4.0 equiv) at 23°C. After stirring at same temperature for 15 min, the mixture was heated to 50°C and stirred for another 30 min before a solution of aqueous saturated ammonium chloride (8 mL) was added and the mixture was warmed to 23°C. The biphasic mixture was extracted with ethyl acetate (15 mL×2), and the organic phase was washed with brine (10 mL), dried over anhydrous sodium sulfate, filtered, concentrated, and purified by silica gel column chromatography (20% ethyl acetate–hexanes) to give 75 as colorless oil (0.27 g, 97%): \( R_f = 0.58 \) (50% ethyl acetate–hexanes); \(^1\)H NMR (500 MHz, CDCl\(_3\)) \( \delta \) 8.09 (d, \( J = 7.6 \) Hz, 1H), 7.75 – 7.64 (m, 3H), 5.53 (dd, \( J = 5.9, 2.3 \) Hz, 1H), 5.01 (dd, \( J = 10.0, 6.6 \) Hz, 1H), 4.39 (d, \( J = 6.4 \) Hz, 1H), 3.98 (s, 3H), 3.93 (m, 1H), 2.83 – 2.67 (m, 2H), 2.33 (d, \( J = 7.6, 1H \)), 2.20 (dd, \( J = 6.9, 14.6, 1H \)), 2.10 (dd, \( J = 6.4, 13.1 \) Hz, 1H), 1.65 (d, \( J = 14.6 \) Hz, 1H), 1.22 (s, 3H), 1.19 (d, \( J = 13.1 \) Hz, 1H); \(^{13}\)C NMR (125 MHz, CDCl\(_3\)) \( \delta \) 167.2, 151.6, 134.3, 133.9, 132.9, 131.0, 129.6, 129.4, 118.2 (q, \( J = 320 \) Hz), 110.7, 88.2, 82.9, 74.7, 74.0, 53.5, 49.0, 38.1, 37.5, 27.8, 21.4; MS(ES)\(^+\) calcd for C\(_{26}\)H\(_{22}\)F\(_3\)O\(_{10}\)S\(_2\) (M+H)\(^+\) 543.06, found 543.10.
**Ketone 76.** To a solution of 75 (0.22 g, 0.41 mmol, 1.0 equiv) in anhydrous methylene chloride (5 mL) was added Dess-Martin periodinane (0.35 g, 0.82 mmol, 2.0 equiv) at 23 °C. After stirring for 5 min, water (11 μL, 0.62 mmol, 1.5 equiv) was added. The suspension was stirred for another 2 h, an aqueous solution of 1:1 10% sodium bisulfate/saturated sodium bicarbonate (5 mL) was then added. After stirring for another 10 min, the biphasic mixture was extracted with ethyl acetate (10 mL×2), the organic phase was washed with saturated sodium bicarbonate (8 mL), dried over anhydrous sodium sulfate, filtered, concentrated and purified by silica gel column chromatography (gradient 10% ethyl acetate–hexanes) to give crude 76 as colorless oil which was directly used in the next step. \(^1\)H NMR (500 MHz, CDCl\(_3\)) \(\delta 8.10 (d, J = 7.8\) Hz, 1H), 7.76 – 7.66 (m, 3H), 5.61 (dd, \(J = 6.4, 2.1\) Hz, 1H), 5.13 (dd, \(J = 10.4, 6.4\) Hz, 1H), 4.46 (d, \(J = 6.7\) Hz, 1H), 3.96 (s, 3H), 3.27 (s, 3H), 3.16 (ddd, \(J = 6.2, 1.0, 1.9\) Hz, 1H), 2.40 (dd, \(J = 13.0, 6.9\) Hz, 1H), 2.39 (d, \(J = 18.0\) Hz, 1H), 1.61 (d, \(J = 13.0\) Hz, 1H), 1.54 (s, 3H); \(^13\)C NMR (100 MHz, CDCl\(_3\)) \(\delta 208.5, 171.1, 167.0, 150.6, 134.1, 132.9, 131.2, 130.0, 129.4, 118.2 (q, \(J = 320\) Hz), 111.2, 88.8, 80.8, 73.7, 53.4, 49.5, 40.3, 39.1, 26.5, 21.1; MS(ES)\(^+\) calcd for C\(_{20}\)H\(_{20}\)F\(_3\)O\(_3\)S\(_2\) (M+H\(^+)\) 541.04, found 541.10.

**Bromide 77.** To a solution of 76 in 2-heptanone (5 mL) was added lithium bromide (0.18 g, 2.05 mmol, 4.0 equiv) at 23 °C. The mixture was heated to 120 °C and reacted at the same temperature for 12 h. After cooling the solution to 23 °C, water (10 mL) were added. The aqueous layer was extracted with ethyl acetate (15 mL×2). The combined extracts were dried over anhydrous sodium sulfate, filtered, concentrated and purified by silica gel column chromatography (gradient 10% ethyl acetate–hexanes) to give 77 as colorless oil (0.0106 g, 64%): \(R_f = 0.48\) (30% ethyl acetate–hexanes); \(^1\)H NMR (500 MHz, CDCl\(_3\)) \(\delta 5.69 (dd, J = 6.2, 1.8\) Hz, 1H), 4.44 (d, \(J = 4.8\) Hz, 1H), 4.40 (d, \(J = 6.9\) Hz, 1H), 3.24 (ddd, \(J = 18.8, 4.8, 1.8\) Hz, 1H), 2.90 (d, \(J = 18.0\) Hz, 1H), 2.75 (ddd, \(J = 18.8, 6.2, 1.0\) Hz, 1H), 2.40 (dd, \(J = 13.0, 6.9\) Hz, 1H), 2.39 (d, \(J = 18.0\) Hz, 1H), 1.61 (d, \(J = 13.0\) Hz, 1H), 1.54 (s, 3H); \(^13\)C NMR (125 MHz, CDCl\(_3\)) \(\delta 208.5, 171.1, 167.0, 150.6, 134.1, 132.9, 131.2, 130.0, 129.4, 118.2 (q, \(J = 320\) Hz), 111.2, 88.8, 80.8, 73.7, 53.4, 49.5, 40.3, 39.1, 26.5, 21.1; MS(ES)\(^+\) calcd for C\(_{20}\)H\(_{20}\)F\(_3\)O\(_3\)S\(_2\) (M+Na\(^+)\) 426.94, found 427.25.

**Bromide 78.** To a solution of 77 (0.069 g, 0.17 mmol, 1.0 equiv) in anhydrous Methanol (8 mL) was added a solution of potassium hydroxide (0.034 g, 0.61 mmol, 3.6 equiv) and phenyliodine (III) diacetate (0.068 g, 0.20 mmol, 1.2 equiv) in Methanol (4 mL) at 0 °C. The mixture was allowed to warm to 23 °C and stirred at this temperature for 3 hours. Then, water (15 mL) was added and the mixture was extracted with ethyl ether (15 mL×2). The combined extracts were dried over anhydrous sodium sulfate, filtered, concentrated, and purified by silica gel column chromatography (gradient 0% → 25% ethyl acetate–hexanes) to give 78 as colorless oil (0.060 g, 75%): \(R_f = 0.43\) (40% ethyl acetate–hexanes); \(^1\)H NMR (500 MHz, CDCl\(_3\)) \(\delta 5.61 (dd, J = 6.0, 1.9\) Hz, 1H), 4.34 (d, \(J = 6.2\) Hz, 1H), 4.31 (d, \(J = 4.9\) Hz, 1H), 3.88 (d, \(J = 5.5\) Hz, 1H), 3.37 (s, 3H), 3.27 (s, 3H), 3.16 (ddd, \(J = 18.7, 4.9, 1.9\) Hz, 1H), 2.82 (d, \(J = 5.5\) Hz, 1H), 2.69 (ddd, \(J = 18.7, 6.0, 0.9\) Hz, 1H), 2.19 (dd, \(J = 12.7, 6.2\) Hz, 1H), 1.81 (d, \(J = 12.7\) Hz, 1H), 1.71 (s, 3H); \(^13\)C NMR (125 MHz, CDCl\(_3\)) \(\delta 152.3, 110.5, 103.7, 87.0, 81.8, 80.8, 50.9, 48.9, 46.36, 43.6, 39.1, 31.5, 19.8; MS(ES)\(^+\) calcd for C\(_{14}\)H\(_{13}\)BrF\(_3\)O\(_3\)S (M+H\(^+)\) 446.98, found 465.00.

**Ketone 79.** A solution of 78 (0.055 g, 0.010 mmol, 1.0 equiv) in trifluoroacetic acid/methylene chloride/water (9:1:1 v/v/v, 0.5 mL) was stirred at 23 °C for 30 min. The solvent was then evaporated under vacuo and the residue was dried using high vacuum for 2 h to give the pure 79 as colorless oil (0.050 g, 100%): \(R_f = 0.45\) (40% ethyl acetate–hexanes); \(^1\)H NMR (500 MHz, CDCl\(_3\)) \(\delta 5.70 (dd, J = 6.2, 1.7\) Hz, 1H), 4.53 (d, \(J = 7.1\) Hz, 1H), 4.48 (d, \(J = 4.8\) Hz, 1H), 4.41 (s, 1H), 3.26 (ddd, \(J = 18.7, 4.8, 1.7\) Hz, 1H), 2.95 (d,
Diol 80. To a solution of 79 (0.049 g, 0.116 mmol, 1.0 equiv) in a 10:3 tetrahydrofuran:Methanol (1 mL) was added sodium borohydride (0.0057 g, 0.15 mmol, 1.3 equiv) at –78 °C. The solution was stirred at this temperature for 15 min before addition of acetone (0.3 mL). The mixture was allowed to warm to 23 °C and evaporated the solvent under vacuo. The residue was diluted with ethyl acetate (15 mL) and saturated ammonium chloride (5 mL) and the organic phase was collected and dried over anhydrous sodium sulfate, filtered, concentrated, and to give crude 80 as colorless oil which was directly used in the next step without purification. 1H NMR (500 MHz, CDCl3) δ 5.59 (dd, J = 6.0, 1H), 4.51 (t, J = 5.8 Hz, 1H), 4.33 – 4.28 (m, 1H), 4.26 (d, J = 5.1 Hz, 1H), 3.88 (dd, J = 9.1, 4.5 Hz, 1H), 3.14 (dddd, J = 18.9, 5.1, 2.0 Hz, 1H), 3.02 (d, J = 4.5 Hz, 1H), 3.00 (d, J = 3.2 Hz, 1H), 2.70 (dd, J = 18.9, 6.0 Hz, 1H), 2.20 (d, J = 12.7 Hz, 1H), 2.08 (dd, J = 12.7, 5.8 Hz, 1H), 1.72 (s, 3H); 13C NMR (125 MHz, CDCl3) δ 152.8, 118.3 (q, J = 320 Hz), 109.8, 86.7, 78.2, 76.7, 76.2, 67.6, 46.8, 45.0, 37.0, 31.6, 19.8; MS(ES)+ calcd for C12H11BrF3O6S (M-H)+ 420.96, found 421.00. Protection of the diol as acetoniide followed by recrystallization from ether gave single crystals suitable for X-ray analysis.

TES ether 81. To a solution of crude 80 in anhydrous methylene chloride (2 mL) was added 2,6-lutidine (0.04 mL, 0.35 mmol, 3.0 equiv) at 23 °C. Then, the mixture was cooled down to 0 °C and triethylsilyl trifluoromethanesulfonate (0.032 mL, 0.139 mmol, 1.2 equiv) was added. After stirring at this temperature for 30 min, the mixture was warmed to 23 °C and stirred for another 30 min, then, water (5 mL) was added. The biphasic mixture was extracted with ethyl acetate (15 mL), and the organic phase was washed with brine (5 mL), dried over anhydrous sodium sulfate, filtered, concentrated, and purified by silica gel column chromatography (gradient 2% → 8% ethyl acetate–hexanes) to give 81 as colorless oil (0.053 g, 85 % over 2 steps): Rf = 0.43 (20 % ethyl acetate-hexane); 1H NMR (500 MHz, CDCl3) δ 5.59 (dd, J = 1.7, 6.0, 1H), 4.39 (dt, J = 3.2, 6.3, 1H), 4.26 (dd, J = 5.0, 9.0, 1H), 4.17 (d, J = 5.0, 1H), 3.77 (dd, J = 6.6, 9.0, 1H), 3.12 (dddd, J = 1.7, 5.1, 18.6, 1H), 2.98 (d, J = 6.6, 1H), 2.69 (dd, J = 6.0, 18.6, 1H), 2.05 (d, J = 3.0, 2H), 1.68 (s, 3H), 0.98 (t, J = 8.0, 9H), 0.65 (q, J = 8.0, 6H); 13C NMR (125 MHz, CDCl3) δ 152.8, 118.3 (q, J = 320 Hz), 109.4, 86.7, 78.2, 76.4, 68.2, 46.8, 43.8, 37.3, 31.8, 19.8, 6.5, 4.6; MS(ES)+ calcd for C18H27BrF3O6SSi (M-H)+ 535.04, found 535.00.
**Enone 82.** A dried vial (4 mL) with 81 (0.005 g, 0.009 mmol, 1.0 equiv), tetrakis[triphenylphosphine]palladium (0.016 g, 0.014 mmol, 1.5 equiv) and copper(I) chloride (0.0014 g, 0.051 mmol, 1.5 equiv) was evacuated and refilled with carbon monoxide three times. To this vial was added degassed dimethyl sulfoxide (0.08 mL), and the mixture was heated to 55 °C. A solution of 47 (0.007 g, 0.012 mmol, 1.3 equiv) in degassed dimethyl sulfoxide (0.08 mL) was added at same temperature. The suspension was stirred at 55 °C for 1 h. The mixture was then cooled to 23 °C and directly purified by silica gel column chromatography (gradient 5% → 10% ethyl acetate–hexanes) to give 82 as colorless oil (0.003 g, 41%).

**Ketone 83.** A solution of 82 (0.008 g, 0.011 mmol, 1.0 equiv) in anhydrous acetonitrile (8 mL) was degassed by bubbling argon through the solution for 30 min. The solution was then photolyzed at 23 °C in a Rayonet chamber reactor at 350 nm for 3 h. The solution was then poured into a saturated aqueous solution of ammonium chloride (6 mL) and extracted with ethyl acetate (8 mL×3), the organic phase was dried over anhydrous sodium sulfate, filtered, concentrated, purified by silica gel column chromatography (10% ethyl acetate–hexanes) to give 83 as colorless oil (0.0056 g, 69%).

**Nakiterpiosinone 2.** To a solution of 83 (0.005 g, 0.006 mmol, 1.0 equiv) in anhydrous methylene chloride (0.2 mL) was added Dess–Martin periodinane (0.005 g, 0.012 mmol, 2.0 equiv) at 23 °C. After stirring for 5 min, water (0.16 µL, 0.009 mmol, 1.5 equiv) was added. The suspension was stirred for another 30 min, an aqueous solution of 1:1 10% sodium bisulfate/saturated sodium bicarbonate (0.5 mL) was then added. After stirring for another 10 min, the mixture was diluted with water (2 mL) and the biphasic mixture was extracted with ethyl acetate (5 mL×2), the organic phase was washed with saturated sodium bicarbonate (2 mL), dried over anhydrous sodium sulfate, filtered, concentrated, the crude ketone 84 was directly used in the next step; To a solution of 84 in anhydrous tetrahydrofuran (0.2 mL) was added a solution of tetrabutylammonium fluoride (1.0 M in tetrahydrofuran, 12.0 µL, 0.012 mmol, 2.0 equiv) at 23 °C. After stirring at 23 °C for 15 min, calcium carbonate (0.060 g, 0.060 mmol, 5.0 eq) Dowex 50WX-400 (0.0075 g, 0.622 g/mmol TBAF) and methanol (0.2 mL) were added. The mixture was stirred at same temperature for...
15 min and filtered through a pad of Celite and washed with methanol (2 mL). The combined filtrates were concentrated, and purified by silica gel column chromatography (50% ethyl acetate–hexanes) to give **Nakiterpiosinone 2** as colorless oil (0.0030 g, 82% over 2 steps): \( R_f = 0.24 \) (50% ethyl acetate–hexanes); FTIR (neat, cm\(^{-1}\)) 2922, 1767, 1710, 1047; \(^1\)H NMR (500 MHz, CD\(_3\)OD) \( \delta \) 7.92 (d, \( J = 8.0 \) Hz, 1H) 7.35 (d, \( J = 8.0 \) Hz, 1H) 6.35 (d, \( J = 10.1 \) Hz, 1H) 4.71 (dd, \( J = 3.2, 2.4 \) Hz, 1H) 4.58 (dd, \( J = 6.0, 6.0 \) Hz, 1H) 4.40 (dd, \( J = 8.0, 3.2 \) Hz, 1H) 4.22 (dd, \( J = 6.0, 1.2 \) Hz, 1H) 3.91 (ddd, \( J = 8.3, 8.2, 3.8 \) Hz, 1H) 3.89 (dd, \( J = 10.1, 3.2 \) Hz, 1H) 3.60 (ddd, \( J = 12.3, 9.2, 2.4 \) Hz, 1H) 2.96 (d, \( J = 9.2 \) Hz, 1H) 2.77 (ddd, \( J = 13.8, 2.4, 2.4 \) Hz, 1H) 2.72 (s, 3H) 2.69 (m, 1H) 2.45 (ddd, \( J = 13.8, 12.3, 3.2 \) Hz, 1H) 2.39 (ddd, \( J = 13.0, 6.0, 1.2 \) Hz, 1H) 2.30 (ddd, \( J = 13.2, 9.3, 3.8 \) Hz, 1H) 2.10 (d, \( J = 13.0 \) Hz, 1H) 1.72 (ddd, \( J = 13.2, 8.2, 8.2 \) Hz, 1H) 1.31 (s, 3H) 1.14 (d, \( J = 7.3 \) Hz, 1H); \(^{13}\)C NMR (125 MHz, CD\(_3\)OD) \( \delta \) 209.6, 206.2, 182.4, 154.1, 140.5, 137.7, 136.2, 136.0, 122.4, 90.0, 80.4, 78.04, 78.03, 77.4, 73.0, 63.4, 53.3, 46.7, 45.5, 39.0, 38.2, 36.3, 35.1, 33.0, 17.8, 16.6, 14.3; HRMS(ES)\(^+\) calcd for C\(_{27}\)H\(_{30}\)BrCl\(_2\)O\(_7\) (M+H)\(^+\) 615.0552, found 615.0568.

**Cell cycle analysis.** HeLa cells were seeded at \( 2 \times 10^4 \) cell/cm\(^2\) density in a 6-well plate and grew for 24 h to establish the log phase of growth. The media was then replaced and nakiterpiosin (375 nM) was added. After incubating for another 16 h, cells were harvested, fixed and permeabilized with cold ethanol and stained with propidium iodide (20 \( \mu \)g/mL, BD Pharmingen). Flow cytometry was carried out on a BD FACSCalibur machine and collected data were analyzed by the FlowJo software using the Dean–Jett–Fox model.

**Tubulin polymerization assay.** In vitro microtubule polymerization assays was performed using the HTS-Tubulin Polymerization Assay Kit (Cytoskeleton) according to manufacturer’s instructions. Assays were performed at 34 \( ^\circ \)C using a BMG Fluostar Plate Reader. Results represent average of duplicate experiments. All compounds were tested at 5 \( \mu \)M final concentration.