Available online at www.sciencedirect.com
ScienceDirect
Tetrahedron Letters
Tetrahedron Letters 48 (2007) 6905–6911

A cross-metathesis approach for the synthesis of tedanolide and 13-deoxytedanolide: stereoselective synthesis of the C3–C16 segment☆

Vijay Kumar Nyavanandi,[a,b] Prabhakar Nadipalli,[a] Srinivas Nanduri,[a] Andra Naidu[b] and Javed Iqbal[a,*]

[a]*Discovery Chemistry, Discovery Research, Dr. Reddy's Laboratories Ltd., Miyapur, Hyderabad 500 049, India*
[b]*Jawaharlal Nehru Technological University, Kukatpally, Hyderabad 500 072, India*

Received 26 June 2007; revised 18 July 2007; accepted 25 July 2007
Available online 28 July 2007

Abstract—A unified synthetic strategy has been devised for the synthesis of both tedanolide and 13-deoxytedanolide, which involves a cross-metathesis reaction as the key step. We report herein the stereoselective synthesis of the C3–C16 segment (+)-**5b** and subsequent manipulation of the C12–C13 double bond leading to the preparation of both tedanolides.

Tedanolide (**1**), an antitumour macrolide was isolated from a prevalent Caribbean sponge *Tedania ignis* by Schmitz et al.[1] in 1984. In 1991, a closely related macrolide 13-deoxytedanolide (**2**) was discovered from the Japanese sponge *Mycale adhaerens*, by Fusetani et al.[2] These two polyketides exhibit remarkable cytotoxicity against P388 murine leukemia cells at pico to nanomolar ranges, and Fusetani et al. were able to identify the 60S large ribosomal subunit as the molecular target of (+)-13-deoxytedanolide (**2**).[3] Recently, tedanolide C (**3**) was reported by Ireland et al.,[4] which differs in the oxygenation and methylation pattern. The challenging structural complexity of the tedanolides in combination with their promising biological profile has prompted several research groups to investigate the synthesis of these natural products,[5] resulting in a variety of fragment syntheses as well as fundamental studies. Consequently, two total syntheses of (+)-13-deoxytedanolide (**2**) were reported in 2003 and 2005 by Smith and Roush, respectively.[6] The first total synthesis of (+)-tedanolide was reported by Kalesse et al.[7] (see Fig. 1).

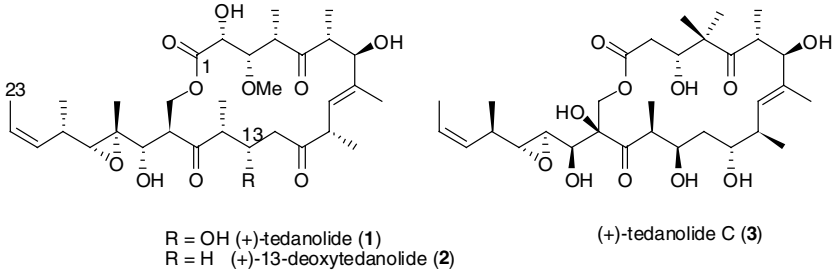
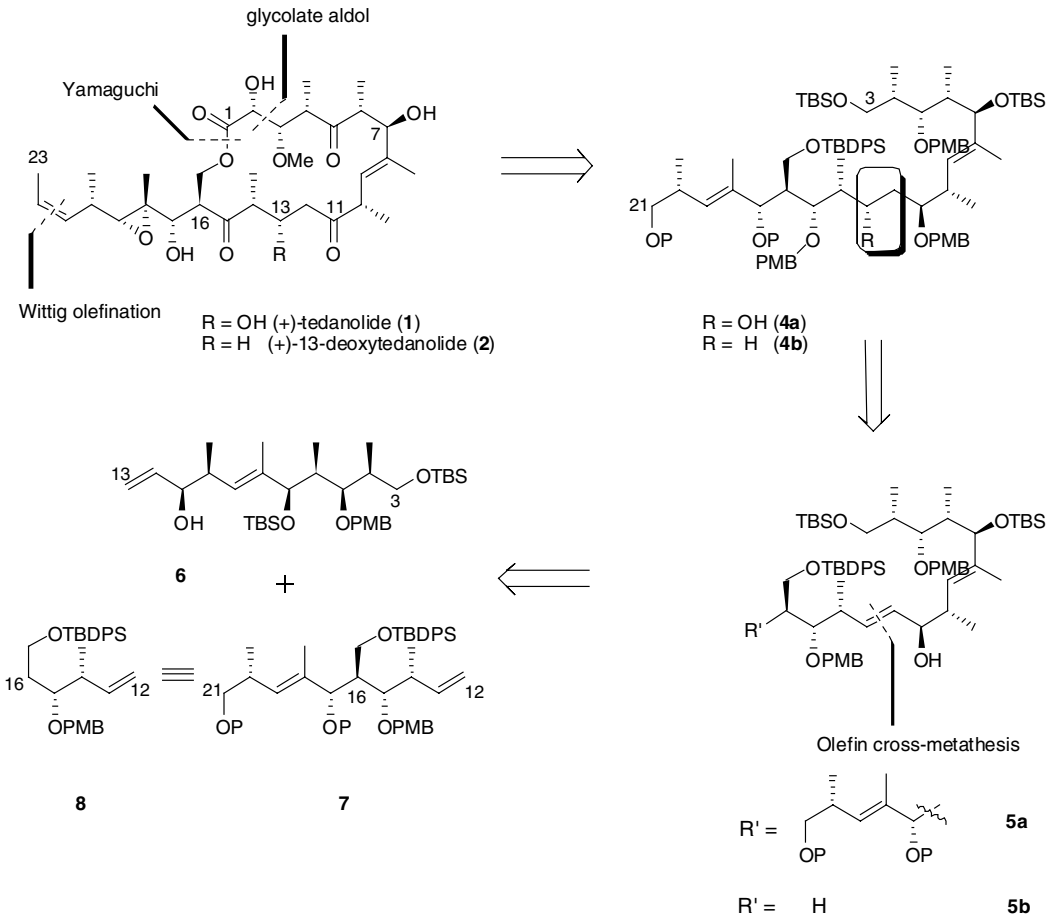


Figure 1. Structures of tedanolides.

Keywords: Tedanolide; Stereoselective; Aldol; Cross-metathesis.
☆ DRL Publication number 641.
* Corresponding author. Tel.: +91 40 23045439; fax: +91 40 2304 5438; e-mail: javediqbaldrf@hotmail.com

0040-4039/$ - see front matter © 2007 Elsevier Ltd. All rights reserved.
doi:10.1016/j.tetlet.2007.07.156



Scheme 1. Retrosynthesis of tedanolides **1** and **2**.

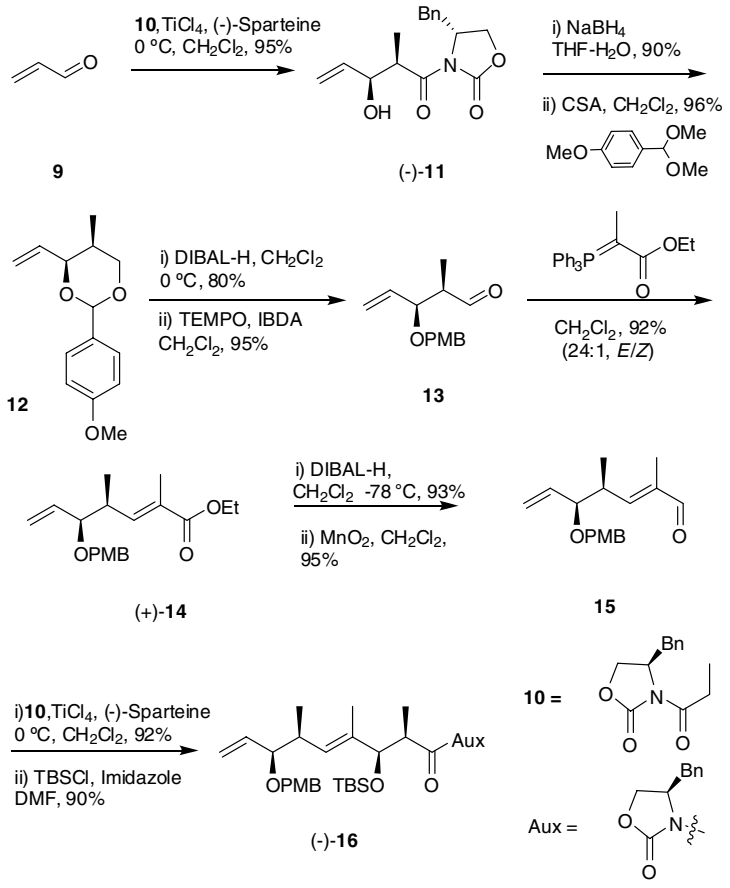
Almost every group chose to disconnect the natural product at the C12–C13 bond, with the plan of eventually using some type of aldol coupling to form this bond once the synthesis of the two fragments had been completed. In continuation of our efforts[5v] towards the total synthesis of tedanolides, we have devised a unified synthetic strategy, our retrosynthesis of tedanolides **1** and **2** is shown in Scheme 1.

Our retrosynthetic strategy for tedanolides **1** and **2** involves disconnections leading to two fragments **6** (C3–C13), and **7** (C12–C21) as shown in Scheme 1. Fragments **6** and **7** were designed to be connected by olefin cross-metathesis to give **5a**. Subsequently, the C12–C13 double bond in **5a** is planned to be manipulated utilizing the C11 allylic alcohol to afford the C3–C21 segments **4a** and **4b** of both the tedanolides. Later, an asymmetric glycolate aldol reaction to install the remaining two stereocentres at C2 and C3, followed by a Wittig olefination at C21 are expected to give the carbon back-bone of the tedanolides. In order to establish our synthetic strategy, we report herein the stereoselective synthesis of the C3–C16 segment **5b** and subsequent manipulation of the C12–C13 double bond to afford the C3–C16 segments of both the tedanolides. We have utilized Crimmins asymmetric aldol protocol as the main tool to synthesize fragments **6** and **8**.

The synthesis began with a Crimmins asymmetric aldol reaction[8] between **9** and imide **10** to afford the Evans' *syn* aldol product (−)-**11** with high diastereoselectivity[9] (Scheme 2). This was converted into a cyclic acetal **12** by reductive removal of chiral auxiliary ($NaBH_4$)[10] followed by cyclic acetal formation (*p*-anisaldehyde dimethylacetal/CSA) on the resulting diol. Selective unmasking of the primary alcohol with DIBAL-H[11] followed by TEMPO oxidation[12] gave aldehyde **13** in good yield, which was subjected to a Wittig olefination[13] resulting in (+)-**14** in 92% yield (24:1 *E*/*Z*). The α,β-unsaturated ester was reduced with DIBAL-H[14] to the allylic alcohol and then oxidized with MnO_2[15] to the corresponding aldehyde **15** in excellent yield.

A second Crimmins asymmetric aldol[9] protocol with imide **10** followed by a silyl protection of the secondary hydroxyl group afforded (−)-**16**.

Subsequently, (−)-**16** was reduced with $NaBH_4$ and the resulting primary alcohol was oxidized with TEMPO to afford aldehyde **17**. Another iterative Crimmins asymmetric aldol protocol[9] with imide **10** and subsequent reduction ($NaBH_4$) gave diol (+)-**18** in very good yield and diastereoselectivity. The C5 hydroxyl group was protected as OPMB ether (−)-**19** by converting the diol



Scheme 2.

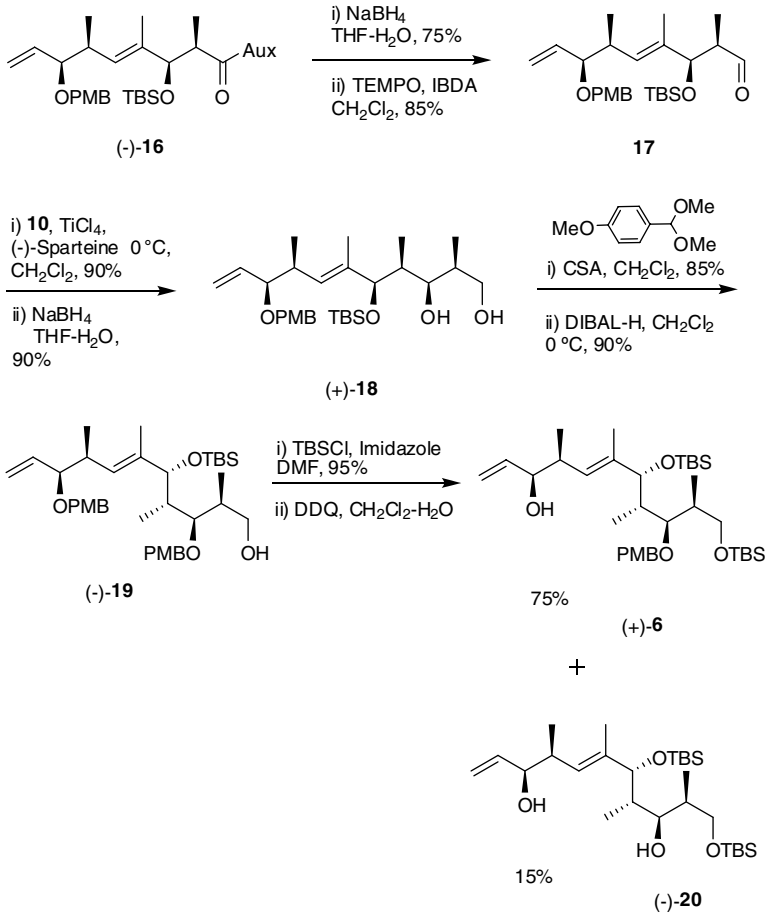
into a cyclic acetal (*p*-anisaldehyde dimethylacetal/CSA) followed by DIBAL-H reduction. Protection of the primary alcohol as an OTBS ether and oxidative removal (DDQ) of the allylic OPMB ether selectively resulted in the desired fragment (+)-**6**[16] along with 15% of diol (−)-**20**[17] (Scheme 3).

On the other hand, the straightforward synthesis of fragment **8** is illustrated in Scheme 4. Accordingly, **21** was subjected to Crimmins aldol reaction with imide **22** to furnish the Evans' *syn*-aldol adduct,[18,9b] which upon reduction with $NaBH_4$ yielded diol (−)-**23** in excellent yield and diastereoselectivity. The C15-OPMB protection was carried out by cyclic acetal formation with anisaldehyde dimethyl acetal followed by regioselective opening with DIBAL-H (93%, two steps) to give (+)-**24**. Oxidation of the primary alcohol with TEMPO followed by a Wittig reaction on the resulting aldehyde with $Ph_3P{=}CH_2{\cdot}HBr$ and *n*-BuLi in THF afforded the fragment (+)-**8**[19] in 85% yield (Scheme 4).

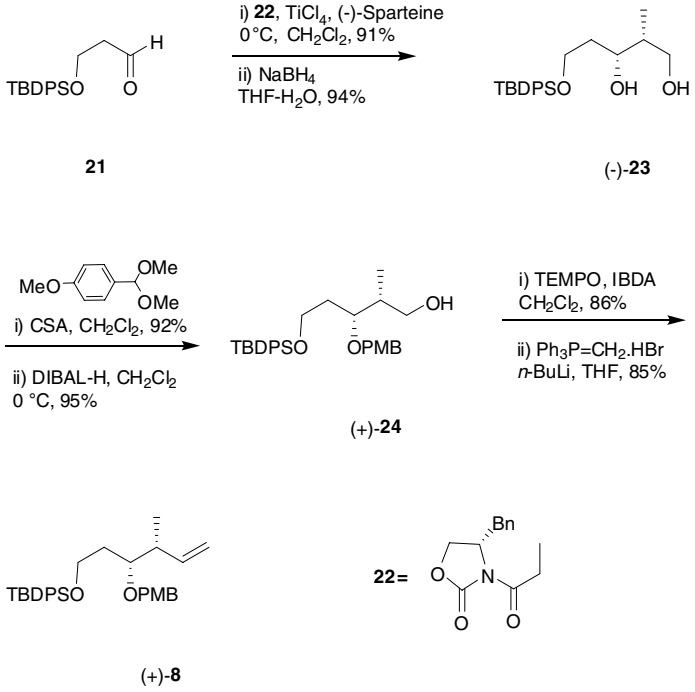
With the two fragments **6** and **8** in hand, the stage was set for the important cross-metathesis reaction. When we carried out this reaction with 10 mol% of Grubb's 2nd generation catalyst in refluxing dichloromethane,[20] to our surprise, we only obtained the homo-dimer product (+)-**25**[21] of fragment **6** and none of the desired product. Starting material **6** was also recovered in small amounts. On the other hand, we carried out a cross-metathesis reaction between fragments **8** and (−)-**20** (a minor product obtained in the DDQ step), and to our delight we obtained the desired product (+)-**26**[22] in 60% yield along with a small amount of homo-dimer (+)-**25**. Based on these results, we converted allylic alcohol (−)-**6** into (−)-**20** with DDQ in 92% yield and subsequent cross-metathesis reaction with **8** gave (+)-**26** in good yield (Scheme 5).

The initial success in the olefin cross-metathesis reaction encouraged us to transform fragment (+)-**26** into the C3–C16 segments of both the tedanolides. Accordingly, the allylic alcohol group in (+)-**26** was oxidized with DMP and the resulting α,β-unsaturated double bond was selectively reduced with $NiCl_2{\cdot}6H_2O/NaBH_4$ to afford the C3–C16 segment of 13-deoxytedanolide (+)-**27**.[23] On the other hand, we converted (+)-**26** into the C3–C16 segment of tedanolide (−)-**28**[24] by epoxidation of allylic alcohol with *m*CPBA(Scheme 6).

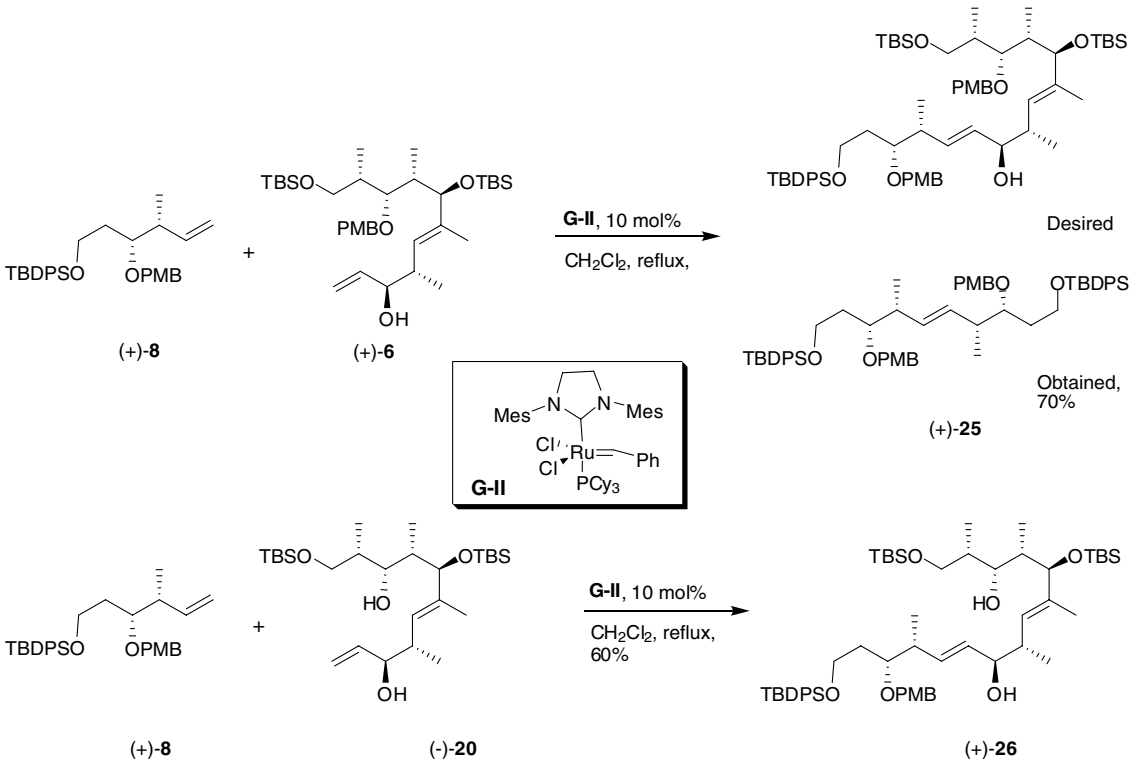
In summary, we have successfully developed a convergent synthetic route towards the tedanolides by synthesizing the C3–C16 segments (+)-**27** and (−)-**28** from key intermediate (+)-**26**. Efforts are currently being directed towards the total syntheses of both the tedanolides, utilizing the above strategy.



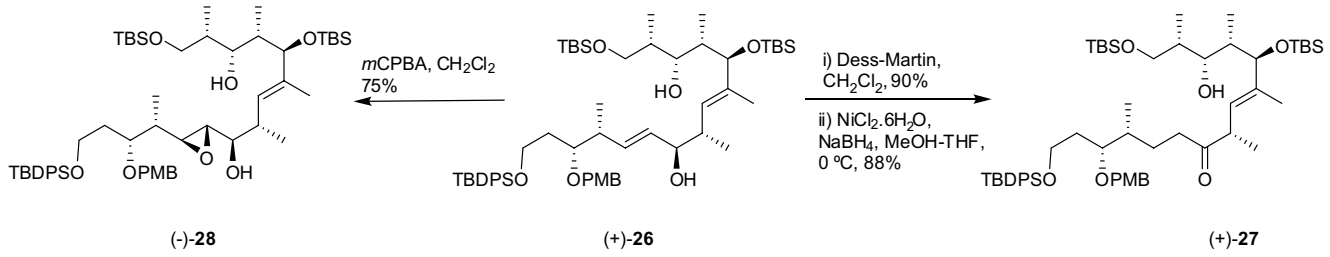
Scheme 3.



Scheme 4.



Scheme 5.



Scheme 6.

Acknowledgement

We thank Dr. Reddy's Laboratories Ltd. for supporting this research work.

References and notes

1. Schmitz, F. J.; Gunasekera, S. P.; Yalamanchili, G.; Hossain, M. B.; Van der Helm, D. *J. Am. Chem. Soc.* **1984**, *106*, 7251.
2. Fusetani, N.; Sugawara, T.; Matsunaga, S.; Hirota, H. *J. Org. Chem.* **1991**, *56*, 4971.
3. (a) Nishimura, S.; Matsunaga, S.; Yoshida, M.; Hirota, H.; Yokoyama, S.; Fusetani, N. *Bioorg. Med. Chem.* **2005**, *13*, 449; (b) Nishimura, S.; Matsunaga, S.; Yoshida, M.; Nakao, Y.; Hirota, H.; Fusetani, N. *Bioorg. Med. Chem.* **2005**, *13*, 455.
4. Chevallier, C.; Bugni, T. S.; Feng, X.; Harper, M. K.; Orendt, A. M.; Ireland, C. M. *J. Org. Chem.* **2006**, *71*, 2510.
5. (a) Matsushima, T.; Horita, K.; Nakajima, N.; Yonemitsu, O. *Tetrahedron Lett.* **1996**, *37*, 385; (b) Matsushima, T.; Mori, M.; Nakajima, N.; Maeda, H.; Uenishi, J.; Yonemitsu, O. *Chem. Pharm. Bull.* **1998**, *46*, 1335; (c) Liu, J. F.; Abiko, A.; Pei, Z.; Buske, D. C.; Masamune, S. *Tetrahedron Lett.* **1998**, *39*, 1873; (d) Taylor, R. E.; Ciavarri, J. P.; Hearn, B. R. *Tetrahedron Lett.* **1998**, *39*, 9361; (e) Roush, W. R.; Lane, G. C. *Org. Lett.* **1999**, *1*, 95; (f) Matsushima, T.; Mori, M.; Zheng, B. Z.; Maeda, H.; Nakajima, N.; Uenishi, J.; Yonemitsu, O. *Chem. Pharm. Bull.* **1999**, *47*, 308; (g) Jung, M. E.; Karama, U.; Marquez, R. *J. Org. Chem.* **1999**, *64*, 663; (h) Matsushima, T.; Zheng, B. Z.; Maeda, H.; Nakajima, N.; Uenishi, J.; Yonemitsu, O. *Synlett* **1999**, 780; (i) Smith, A. B., III; Lodise, S. A. *Org. Lett.* **1999**, *1*, 1249; (j) Zheng, B. Z.; Maeda, H.; Mori, M.; Kusaka, S. i.; Yonemitsu, O.; Matsushima, T.; Nakajima, N.; Uenishi, J. *Chem. Pharm. Bull.* **1999**, *47*, 1288; (k) Jung, M. E.; Marquez, R. *Tetrahedron Lett.* **1999**, *40*, 3129; (l) Matsushima, T.; Nakajima, N.; Zheng, B. Z.; Yonemitsu, O. *Chem. Pharm. Bull.* **2000**, *48*, 855; (m) Zheng, B. Z.; Yamauchi, M.; Dei, H.; Kusaka, S. i.; Matsui, K.; Yonemitsu, O. *Tetrahedron Lett.* **2000**, *41*, 6441; (n) Zheng, B. Z.; Yamauchi, H.; Dei, H.; Yonemitsu, O. *Chem. Pharm. Bull.* **2000**, *48*, 1761; (o) Jung, M. E.; Marquez, R. *Org. Lett.* **2000**, *2*, 1669; (p) Jung, M. E.; Lee, C. P. *Org. Lett.* **2001**, *3*, 333; (q) Loh, T.

P.; Feng, L. C. *Tetrahedron Lett.* **2001**, *42*, 6001; (r) Loh, T. P.; Feng, L. C. *Tetrahedron Lett.* **2001**, *42*, 3223; (s) Matsui, K.; Zheng, B. Z.; Kusaka, S. i.; Kuroda, M.; Yoshimoto, K.; Yamada, H.; Yonemitsu, O. *Eur. J. Org. Chem.* **2001**, 3615; (t) Hearn, B. R.; Ciavarri, J. P.; Taylor, R. E. *Org. Lett.* **2002**, *4*, 2953; (u) Wong, C. M.; Loh, T. P. *Tetrahedron Lett.* **2006**, *47*, 4485; (v) Iqbal, J.; Nyavanandi, V. K.; Nanduri, S.; Vasudev, R.; Naidu, A. *Tetrahedron Lett.* **2006**, *47*, 6667.

6. (a) Smith, A. B., III; Adams, C. M.; Barbosa, S. A. L.; Degnan, P. *J. Am. Chem. Soc.* **2003**, *125*, 350; (b) Smith, A. B., III; Adams, C. M.; Barbosa, S. A. L.; Degnan, P. *Proc. Natl. Acad. Sci. U.S.A.* **2004**, *101*, 12042; (c) Julian, L. D.; Newcom, J. S.; Roush, W. R. *J. Am. Chem. Soc.* **2005**, *127*, 6186.
7. Ehrlich, G.; Hassfeld, J.; Eggert, U.; Kalesse, M. *J. Am. Chem. Soc.* **2006**, *128*, 14038.
8. Crimmins, M. T.; King, B. W.; Tabet, E. A.; Chaudhary, K. *J. Org. Chem.* **2001**, *66*, 894.
9. (a) Evans, D. A.; Gage, J. R.; Leighton, J. L. *J. Am. Chem. Soc.* **1992**, *114*, 9434; (b) The other diastereomer was not observed in the crude NMR.
10. Prashad, M.; Har, D.; Kim, H. Y.; Repic, O. *Tetrahedron Lett.* **1998**, *39*, 7067–7070.
11. Takano, S.; Akiyama, M.; Sato, S.; Ogasawara, K. *Chem. Lett.* **1983**, 1593.
12. De Mico, A.; Margarita, R.; Parlanti, L.; Vescovi, A.; Piancatelli, G. *J. Org. Chem.* **1997**, *62*, 6974–6977.
13. Li, D. R.; Tu, Y. Q.; Lin, G. Q.; Zhou, W. S. *Tetrahedron Lett.* **2003**, *44*, 8729.
14. Kiyooka, S. I.; Hena, M. A. *J. Org. Chem.* **1999**, *64*, 5511.
15. Shishido, K.; Takahashi, K.; Fukumoto, K.; Kametani, T.; Honda, T. *J. Org. Chem.* **1987**, *52*, 5704.
16. *Spectral data for* (+)-**6**: $[\alpha]_D^{25}$ 20.0 (*c* 0.5, $CHCl_3$); ^1H NMR (400 MHz, $CDCl_3$) δ 7.24 (d, $J = 8.4$ Hz, 2H), 6.86 (d, $J = 8.4$ Hz, 2H), 5.67 (ddd, $J = 17.2$ Hz, 10.4 Hz, 8.0 Hz, 1H), 5.23 (dd, $J = 10.4$ Hz, 1.6 Hz, 1H), 5.18 (dd, $J = 17.2$ Hz, 1.6 Hz, 1H), 5.09 (d, $J = 10.0$ Hz, 1H), 4.51 (d, $J = 11.6$ Hz, 1H), 4.24 (d, $J = 11.6$ Hz, 1H), 3.84 (d, $J = 8.0$ Hz, 1H), 3.80 (s, 3H), 3.50 (d, $J = 4.4$ Hz, 2H), 3.44 (t, $J = 8.0$ Hz, 1H), 3.36 (m, 1H), 2.62 (m, 1H), 1.94 (d, $J = 4.8$ Hz, 1H), 1.73 (m, 2H), 1.55 (d, $J = 1.2$ Hz, 3H), 1.00 (d, $J = 6.8$ Hz, 3H), 0.95 (d, $J = 6.4$ Hz, 3H), 0.92 (d, $J = 6.4$ Hz, 3H), 0.89 (s, 9H), 0.87 (s, 9H), 0.037 (s, 3H), 0.034 (s, 3H), 0.02 (s, 3H), −0.04 (s, 3H); ^{13}C NMR (50 MHz, $CDCl_3$) δ 159.0, 137.8, 136.8, 130.7, 129.3, 128.9, 118.0, 113.7, 84.3, 82.2, 73.3, 69.7, 65.9, 55.2, 39.2, 38.3, 37.2, 29.6, 25.8, 18.2, 18.1, 16.8, 13.8, 11.7, 9.3, −4.3, −4.9, −5.4, −5.5; IR (neat, cm^{-1}) 3604, 3523, 2953, 2929, 1612, 1514, 1465, 1249, 1066, 1043, 837; HRMS (ESI-TOF) *m*/*z* $(M+Na)^+$ calcd for $C_{35}H_{64}O_5Si_2Na$, 643.4190; obsd 643.4213.
17. *Spectral data for* (−)-**20**: $[\alpha]_D^{25}$ −3.6 (*c* 0.5, $CHCl_3$); ^1H NMR (400 MHz, $CDCl_3$) δ 5.87 (ddd, $J = 16.8$ Hz, 10.4 Hz, 6.4 Hz, 1H), 5.23 (td, $J = 17.2$ Hz, 1.6 Hz, 1H), 5.17 (d, $J = 10.4$ Hz, 1H), 5.13 (td, $J = 10.8$ Hz, 1.2 Hz, 1H), 3.92 (m, 2H), 3.53 (dd, $J = 4.8$ Hz, 2.0 Hz, 2H), 3.42 (dd, $J = 7.6$ Hz, 2.8 Hz, 1H), 2.60 (m, 1H), 2.15 (br s, 1H), 1.74 (m, 2H), 1.62 (br s, 1H), 1.57 (d, $J = 1.6$ Hz, 3H), 1.00 (d, $J = 6.8$ Hz, 3H), 0.96 (d, $J = 6.8$ Hz, 3H), 0.92 (d, $J = 6.4$ Hz, 3H), 0.88 (s, 18H), 0.03 (s, 6H), −0.007 (s, 3H), −0.03 (s, 3H); ^{13}C NMR (50 MHz, $CDCl_3$) δ 159.0, 137.8, 136.8, 130.7, 129.3, 128.9, 118.0, 113.7, 84.3, 82.2, 73.3, 69.7, 65.9, 55.2, 39.2, 38.3, 37.2, 29.6, 25.8, 18.2, 18.1, 16.8, 13.8, 11.7, 9.3, −4.3, −4.9, −5.4, −5.5; IR (neat, cm^{-1}) 3604, 3523, 2953, 2929, 1612, 1514, 1465, 1249, 1066, 1043, 837; HRMS (ESI-TOF) *m*/*z* $(M+Na)^+$ calcd for $C_{27}H_{56}O_4Si_2Na$, 523.3615; obsd 523.3614.
18. Smith, A. B., III; Minbiole, K. P.; Verhoest, P. R.; Schelhaas, M. *J. Am. Chem. Soc.* **2001**, *123*, 10942.
19. *Spectral data for* (+)-**8**: $[\alpha]_D^{25}$ 29.8 (*c* 0.5, $CHCl_3$); ^1H NMR (400 MHz, $CDCl_3$) δ 7.65 (m, 4H), 7.43–7.33 (m, 6H), 7.17 (d, $J = 8.4$ Hz, 2H), 6.81 (d, $J = 8.8$ Hz, 2H), 5.84 (ddd, $J = 16.8$ Hz, 10.4 Hz, 6.8 Hz, 1H), 5.02 (ddd, $J = 5.2$ Hz, 3.2 Hz, 2.0 Hz, 1H), 4.99 (d, $J = 0.8$ Hz, 1H), 4.47 (d, $J = 10.8$ Hz, 1H), 4.37 (d, $J = 10.8$ Hz, 1H), 3.77 (s, 3H), 3.76 (m, 2H), 3.52 (m, 1H), 2.47 (m, 1H), 1.77 (m, 1H), 1.63 (m, 1H), 1.05 (s, 9H), 1.02 (d, $J = 6.8$ Hz, 3H); ^{13}C NMR (50 MHz, $CDCl_3$) δ 159.0, 140.7, 135.5, 133.9, 133.9, 131.0, 129.5, 129.3, 127.6, 114.4, 113.6, 79.3, 71.6, 60.7, 55.2, 40.7, 34.3, 26.8, 19.1, 15.4; IR (neat, cm^{-1}) 2956, 2929, 2856, 1612, 1514, 1427, 1247, 1111, 1087, 821; HRMS (ESI-TOF) *m*/*z* $(M+Na)^+$ calcd for $C_{31}H_{40}O_3SiNa$, 511.2644; obsd 511.2662.
20. Nolen, E. G.; Kurish, A. J.; Potter, J. M.; Donahue, L. A.; Orlando, M. D. *Org. Lett.* **2005**, *7*, 3383.
21. *Spectral data for* (+)-**25**: $[\alpha]_D^{25}$ 26.2 (*c* 1.0, $CHCl_3$); ^1H NMR (400 MHz, $CDCl_3$) δ 7.64 (m, 8H), 7.41–7.32 (m, 12 H), 7.15 (d, $J = 8.4$ Hz, 4H), 6.79 (d, $J = 8.8$ Hz, 4H), 5.45 (dd, $J = 4.0$ Hz, 1.6 Hz, 2H), 4.46 (d, $J = 11.2$ Hz, 2H), 4.34 (d, $J = 11.2$ Hz, 2H), 3.76 (s, 6H), 3.74 (m, 4H), 3.49 (m, 2H), 2.44 (m, 2H), 1.75 (m, 2H), 1.64 (m, 2H), 1.03 (s, 18H), 0.99 (d, $J = 6.8$ Hz, 6H); ^{13}C NMR (50 MHz, $CDCl_3$) δ 158.9, 135.5, 133.99, 133.93, 132.1, 131.1, 129.5, 129.2, 127.5, 113.6, 79.7, 71.6, 60.7, 55.1, 39.6, 34.4, 26.8, 19.1, 15.9; IR (neat, cm^{-1}) 2958, 2931, 2858, 1612, 1514, 1467, 1427, 1247, 1109, 1087, 1037, 823; HRMS (ESI-TOF) *m*/*z* $(M+H)^+$ calcd for $C_{60}H_{77}O_6Si_2$, 949.5259; obsd 949.5255.
22. *Spectral data for* (+)-**26**: $[\alpha]_D^{25}$ 19.4 (*c* 0.5, $CHCl_3$); ^1H NMR (400 MHz, $CDCl_3$) δ 7.64 (m, 4H), 7.43–7.33 (m, 6H), 7.16 (d, $J = 8.4$ Hz, 2H), 6.81 (d, $J = 8.4$ Hz, 2H), 5.68 (dd, $J = 15.2$ Hz, 7.2 Hz, 1H), 5.49 (dd, $J = 15.6$ Hz, 6.4 Hz, 1H), 5.27 (d, $J = 9.6$ Hz, 1 H), 4.46 (d, $J = 10.8$ Hz, 1H), 4.36 (d, $J = 10.8$ Hz, 1H), 3.95 (m, 2H), 3.77 (s, 3H), 3.75 (m, 2H), 3.54 (d, $J = 4.4$, 2H), 3.49 (m, 2H), 2.60 (m, 1H), 2.50 (m, 1H), 2.40 (br s, 1H), 1.76 (m, 2H), 1.60 (m, 2H), 1.58 (d, $J = 0.8$ Hz, 3H), 1.04 (s, 9H), 1.01 (d, $J = 6.8$ Hz, 3H), 0.97 (d, $J = 6.4$ Hz, 3H), 0.93 (d, $J = 6.8$ Hz, 3H), 0.92 (d, $J = 6.8$ Hz, 3H), 0.89 (s, 9H), 0.88 (s, 9H), 0.03 (s, 9H), −0.01 (s, 3H); ^{13}C NMR (50 MHz, $CDCl_3$) δ 159.0, 137.2, 135.5, 134.3, 133.9, 130.9, 130.6, 129.5, 129.3, 128.4, 127.6, 113.6, 81.4, 79.3, 74.4, 71.5, 66.4, 60.6, 55.2, 39.3, 39.2, 38.3, 37.9, 34.1, 26.8, 25.8, 19.1, 18.2, 18.1, 15.8, 15.6, 13.3, 12.4, 9.0, −4.2, −4.9, −5.52, −5.55; IR (neat, cm^{-1}) 3028, 2922, 2862, 1778, 1699, 1476, 1454, 1390, 1352, 1217, 1107, 1076, 1051, 1051, 975; HRMS (ESI-TOF) *m*/*z* $(M+Na)^+$ calcd for $C_{56}H_{92}O_7Si_3Na$, 983.6049; obsd 983.6087.
23. *Spectral data for* (+)-**27**: $[\alpha]_D^{25}$ 56.7 (*c* 0.8, $CHCl_3$); ^1H NMR (400 MHz, $CDCl_3$) δ 7.65 (m, 4H), 7.43–7.33 (m, 6H), 7.16 (d, $J = 8.8$ Hz, 2H), 6.81 (d, $J = 8.4$ Hz, 2H), 5.28 (d, $J = 10.0$ Hz, 1H), 4.44 (d, $J = 10.8$ Hz, 1H), 4.34 (d, $J = 11.2$ Hz, 1H), 3.97 (d, $J = 5.6$ Hz, 1H), 3.78 (s, 3H), 3.74 (m, 1H), 3.56 (t, $J = 4.0$ Hz, 2H), 3.54–3.45 (m, 2H), 3.38 (m, 1H), 2.45 (m, 2H), 2.35 (m, 1H), 1.80 (m, 4H), 1.70 (m, 3H), 1.61 (d, $J = 1.2$ Hz, 3H), 1.12 (d, $J = 6.8$ Hz, 3H), 1.04 (s, 9H), 0.97 (d, $J = 6.8$ Hz, 3H), 0.91 (d, $J = 6.4$ Hz, 3H), 0.89 (s, 9H), 0.88 (s, 9H), 0.85 (d, $J = 7.2$ Hz, 3H), 0.04 (s, 6H), 0.03 (s, 3H), −0.05 (s, 3H); ^{13}C NMR (50 MHz, $CDCl_3$) δ 211.7, 158.9, 138.5, 135.5, 133.9, 133.8, 131.1, 129.5, 129.2, 127.5, 126.0, 113.6, 80.4, 79.3, 74.8, 71.4, 66.6, 60.8, 55.1, 45.7, 39.1, 38.1, 35.2, 33.5, 31.8, 29.6, 29.3, 26.8, 25.9, 25.8, 22.6, 19.1, 18.19, 18.1, 16.2, 15.2, 14.0, 13.0, 12.7, 8.6, 0.9, −4.3, −5.0, −5.54, −5.58; IR (neat, cm^{-1}) 3504, 2929, 2856, 1712, 1612, 1512, 1465, 1249, 1109, 1072, 1039, 837; HRMS (ESI-TOF) *m*/*z*

$(M+Na)^+$ calcd for $C_{56}H_{92}O_7Si_3Na$, 983.6049; obsd 983.6088.

24. *Spectral data for* (−)-**28**: $[\alpha]_D^{25}$ −3.8 (*c* 0.5, $CHCl_3$); ^1H NMR (400 MHz, $CDCl_3$) δ 7.65 (m, 4H), 7.44–7.34 (m, 6H), 7.16 (d, $J = 8.4$ Hz, 2H), 6.81 (d, $J = 8.8$ Hz, 2H), 5.29 (d, $J = 10.0$ Hz, 1H), 4.46 (d, $J = 11.2$ Hz, 1H), 4.43 (d, $J = 11.2$ Hz, 1H), 3.99 (d, $J = 7.6$ Hz, 1H), 3.78 (s, 3H), 3.75 (m, 4H), 3.59–3.50 (m, 3H), 3.36 (dd, $J = 7.6$, 2.8 Hz, 1H), 3.02 (dd, $J = 7.6$ Hz, 2.0 Hz, 1H), 2.91 (t, $J = 2.0$ Hz, 1H), 2.85 (br s, 1H), 2.77 (m, 1H), 1.80 (m, 3H), 1.60 (d, $J = 0.8$ Hz, 3H), 1.58 (m, 2H), 1.07 (d, $J = 7.2$ Hz, 3H), 1.05 (s, 9H), 0.99–0.82 (m, 30 H), 0.07 (s, 3H), 0.05 (s, 3H), −0.01 (s, 3H); ^{13}C NMR (50 MHz, $CDCl_3$) δ 159.0, 138.2, 135.5, 133.78, 133.74, 130.9, 129.5, 129.3, 129.2, 129.1, 127.9, 127.6, 113.6, 81.8, 74.0, 72.2, 72.0, 66.0, 60.7, 57.3, 56.8, 55.1, 39.5, 38.8, 38.3, 37.5, 34.8, 31.8, 29.6, 29.3, 26.8, 25.8, 22.6, 19.1, 18.2, 18.1, 16.3, 14.0, 13.8, 11.9, 10.4, 9.0, 0.9, −4.3, −4.9, −5.5; IR (neat, cm^{-1}) 3462, 2956, 2856, 1612, 1512, 1465, 1427, 1388, 1251, 1109, 1074, 1041, 837; HRMS (ESI-TOF) *m*/*z* $(M+Na)^+$ calcd for $C_{56}H_{92}O_8Si_3Na$, 999.5998; obsd 999.6030.