Internal Diels−Alder Cycloaddition with a *Z*-Dienophile: Synthesis of (±)-α-Oplopenone

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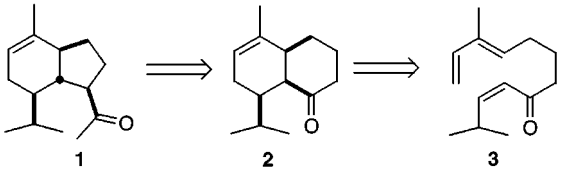
The preparation of the *Z*-triene **3** is described. Internal Diels−Alder cycloaddition of **3** proceeds smoothly in the presence of $BF_3{\cdot}OEt_2$ to give **2**. Ketone **2** is converted by epimerization, carbonyl extrusion, and homologation to the sesquiterpene (±)-α-oplopenone (**1**).

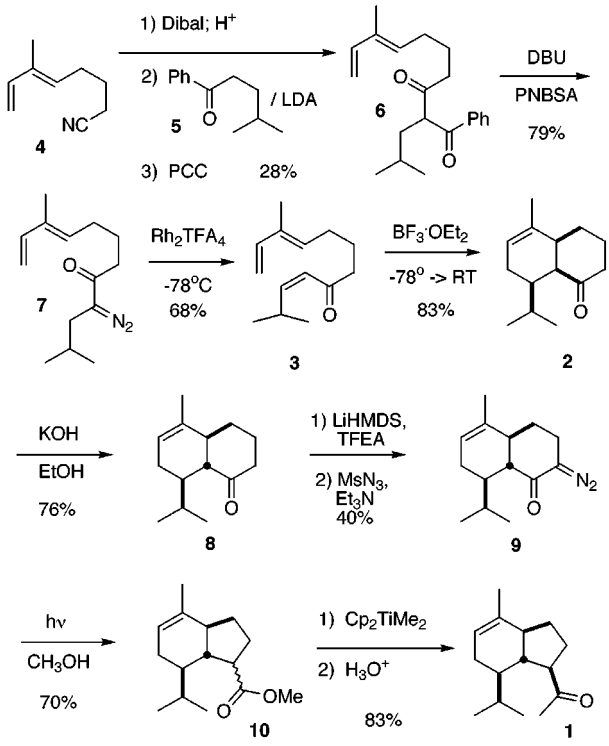
Although the internal Diels−Alder reaction is now well-described[1] as a method for the construction of both carbocycles and heterocycles,[2] the use of a *Z*-enone as the dienophile had not been reported.[3] There were a variety of reasons this might be so: pure *Z*-enones can be difficult to prepare, the β-substituent of the *Z*-enone will inhibit conjugation of the ketone with the alkene, making the enone less reactive as a dienophile, and the β-substituent of the *Z*-enone would be likely to encumber the expected endo transition state. Despite these difficulties, we were intrigued by the possibility of such a cycloaddition (e.g. **3** → **2**), as it would allow facile entry both to the



1 **2** **3**

cadinanes and to the oplopanes, exemplified by the sesquiterpene ketone α-oplopenone (**1**). We have prepared triene **3** and have found that it can indeed be induced to cyclize smoothly to the bicyclic ketone **2**. We have established the relative configuration of ketone **2** by carrying it on to (±)-α-oplopenone (**1**).[3] We note that after we had established this cycloaddition, the Diels−Alder cycloaddition of another *Z*-enone was reported.[4]

Scheme 1



Preparation of Triene 3. We chose to prepare the *Z*-enone of **3** by rhodium-catalyzed elimination[5] of the α-diazoketone **7** (Scheme 1). We had envisioned preparing the requisite benzoylketone **6** by sequential alkylation of benzoylacetone,[6] but in this case the alkylation approach failed. We therefore essayed an alternative approach,[7] aldol condensation of the enolate of ketone **5**[8]

(1) For reviews of the intramolecular Diels−Alder reaction, see: (a) Oppolzer, W. *Angew. Chem., Int. Ed. Engl.* **1977**, *16*, 10. (b) Oppolzer, W. *Synthesis* **1978**, 793. (c) Funk, R.; Vollhardt, P. C. *Chem. Soc. Rev.* **1980**, *9*, 41. (d) Brieger, G.; Bennett, J. N. *Chem. Rev.* **1980**, *80*, 63. (e) Taber, D. F. *Intramolecular Diels−Alder and Alder Ene Reactions*; Springer-Verlag: New York, 1984. (f) Fallis, A. G. *Can. J. Chem.* **1984**, *62*, 183. (g) Ciganek, E. *Org. Reac.* **1984**, *32*, 1. (h) Salakhov, M. S.; Ismailov, S. A. *Russ. Chem. Rev.* **1986**, *55*, 1145. (i) Craig, D. *Chem. Soc. Rev.* **1987**, *16*, 187. (j) Roush, W. R. In *Comprehensive Organic Synthesis;* Trost, B. M., Fleming, I., Eds.; Pergamon: New York, 1992; Vol. 5, p 513.

(2) For more recent examples of internal Diels−Alder cycloadditions, see: (a) Wilson, S. R.; Di Grandi, M. J. *J. Org. Chem.* **1991**, *56*, 4766. (b) Dolata, D. P.; Harwood: L. M. *J. Am. Chem. Soc.* **1992**, *114*, 10738. (c) Tsang, R.; Fraser-Reid, B. *J. Org. Chem.* **1992**, *57*, 1065. (d) Takahashi, T.; Sakamoto, Y.; Doi, T. *Tetrahedron Lett.* **1992**, *33*, 3519. (e) Herscovici, J.; Delatre, S.; Boumaiza, L.; Antonakis, K. *J. Org. Chem.* **1993**, *58*, 3928. (f) Roush, W. R.; Warmus, J. S.; Works, A. B. *Tetrahedron Lett.* **1993**, *34*, 4427. (g) Marko, I.; Seres, P.; Evans, G. R.; Swarbrick, T. M. *Tetrahedron Lett.* **1993**, *34*, 7305. (h) Paquette, L. A., Wang, T.-Z.; Sivik, M. R. *J. Am. Chem. Soc.* **1994**, *116*, 11323. (i) Maruoka, K.; Imoto, H.; Yamamoto, H. *J. Am. Chem. Soc.* **1994**, *116*, 12115. (j) Journet, M.; Malacria, M. *J. Org. Chem.* **1994**, *59*, 6885. (k) Grieco, P. A.; Handy, S. T.; Beck, J. P. *Tetrahedron Lett.* **1994**, *35*, 2663. (l) Spino, C.; Tu, N. *Tetrahedron Lett.* **1994**, *35*, 3683. (m) Tahri, A.; Uguen, D.; De Cian, A.; Fischer, J. *Tetrahedron Lett.* **1994**, *35*, 3945. (n) Hanna, I.; Lallemand, J.-Y.; Wlodyka, P. *Tetrahedron Lett.* **1994**, *35*, 6685. (o) Shea, K. J.; Gauthier, D. R., Jr. *Tetrahedron Lett.* **1994**, *35*, 7311. (p) Hunt, I. R.; Rogers, C.; Woo, S.; Rauk, A.; Keay, B. A. *J. Am. Chem. Soc.* **1995**, *117*, 1049, and references cited therein.

(3) For the isolation and structural determination of α-oplopenone, see: De Pascale-T., J.; Vicente, S.; Gonzalez, M. S.; Bellido, I. S. *Phytochemistry* **1983**, *22*, 2235. No synthetic efforts toward α-oplopenone had been described prior to the work reported here.

(4) Araki, Y.; Konoike, T. *J. Org. Chem.* **1997**, *62*, 5299.

(5) Taber, D. F.; Herr, R. J.; Pack, S. K.; Geremia, J. M. *J. Org. Chem.* **1996**, *61*, 2908.

(6) Taber, D. F.; Gleave, D. M.; Moody, K.; Hennessy, M. J. *J. Org. Chem.* **1995,** *60*, 2283.

(7) A more straightforward variation would be to condense the enolate of **5** with nitrile **4** to give the diketone **6** directly. Our repeated attempts to effect such a condensation were unfortunately unavailing.

(8) Broekhof, N. L. J. M.; van Elburg, P.; Hoff, D. J.; van der Gen, A. *Recueil* **1984**, *103*, 317.

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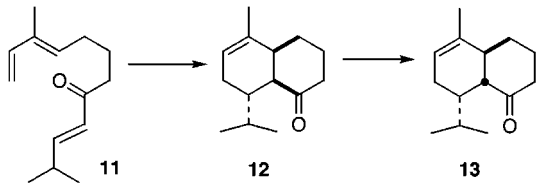
with the aldehyde derived from nitrile **4**.[9] Nitrile **4** was a 2:1 mixture of *Z*/*E* isomers. Only the former participated in the eventual Diels−Alder reaction.

The aldehyde derived from Dibal reduction was both volatile and unstable, so it was used directly in the aldol condensation. Oxidation of the mixture of aldol products then gave the desired benzoyl ketone **6**.

We have found since we published our procedure for diazoketone synthesis[6] that the reaction in fact proceeds most efficiently under somewhat more dilute conditions than those we had originally described. The product diazoketone **7** is quite stable, but as a matter of routine practice it was protected from laboratory light, and used directly in the next reaction. Rhodium-catalyzed elimination[5] of **7** proceeded smoothly, to give the *Z*-enone **3**.

Cyclization of Triene 3. The preparation of the isomeric *E*-enone **11**, cyclization to **12**, and epimerization of **12** to **13** were reported several years ago,[10] in conjunction with a projected synthesis of chiloscyphone.[11] In-



deed, enone **11** was not isolated, but in fact cyclized spontaneously to **12**. Triene **3**, in contrast, was stable at room temperature. Attempted heating of **3**, even in the presence of radical inhibitors, gave only destruction of the starting material. We were pleased to observe, however, that treatment of **3** with a full equivalent of $BF_3{\cdot}Et_20$ at −78 °C followed by warming to room temperature gave smooth conversion to the cis bicyclic ketone **2**. The yield reported for this cycloaddition is based on the *E*-diene component of triene **3**.

The relative configuration of the cyclization product **2** was established by comparison of its spectroscopic data and the data for the epimerization product **8** to the data reported for **12** and **13**. It was possible that the exposure to $BF_3{\cdot}Et_20$ had converted **3** to **11**, which had then cyclized. The ^{1}H and ^{13}C spectra of **2** and **12** were, however, quite different. Most striking were the ^{1}H chemical shifts for the vinyl protons (δ 5.51 for **2**, δ 5.34 for **12**) and the ^{13}C chemical shifts for the downfield methines (δ 49.4 and 45.0 for **2**, δ 54.5 and 44.2 for **12**).

Synthesis of (±)-α-Oplopenone (1). Epimerization of the cis ketone **2** indeed gave a 2:1 equilibrium mixture of ketones, easily separated by silica gel chromatography, in which the trans ketone **8** predominated. Diazo transfer to this ketone by the method of Danheiser[12] proceeded in modest yield to give the α-diazoketone **9**, which was converted via Wolff rearrangement to the methyl ester **10**. Finally, methylenation of **10** in accordance with the Petasis[13] modification of the Tebbe reaction followed by treatment of the product enol ether with aqueous acid gave (±)-α-oplopenone (**1**) as a 4:1 mixture of diastereomers. The ^{1}H NMR signals for the major diastereomer were congruent with those reported.[3]

Conclusion. It is apparent that *Z*-enones, even with sterically demanding β-substituents, can indeed serve as efficient dienophiles in the internal Diels−Alder cycloaddition reaction. This is particularly significant for sesquiterpene synthesis, as **2** and **12** represent complementary stereochemical series.

Experimental Section

General. ^{1}H NMR and ^{13}C NMR spectra were obtained as solutions in deuteriochloroform ($CDCl_3$). ^{13}C multiplicities were determined with the aid of a JVERT pulse sequence, differentiating the signals for methyl and methine carbons as "d", from methylene and quaternary carbons as "u". The infrared (IR) spectra were determined as neat oils. Mass spectra (MS) were obtained at an ionizing potential of 15 eV. Substances for which C, H analyses are not reported were purified as specified and gave spectroscopic data consistent with being >95% of the assigned structure. The R_f values indicated refer to thin-layer chromatography (TLC) on 2.5 × 10 cm, 250 μm analytical plates coated with silica gel GF, unless otherwise noted, and developed in the solvent system indicated. Column chromatography was carried out with Merck 35−60 mesh silica gel, following the procedure described by Taber.[14] The solvent mixtures used are volume/volume mixtures. All glassware was flame dried under a dry nitrogen stream immediately before use. Tetrahydrofuran (THF), diethyl ether and 1, 2-dimethoxyethane (DME) were distilled from sodium metal/benzophenone ketyl under dry nitrogen. Dichloromethane (CH_2Cl_2) and toluene were distilled from calcium hydride under dry nitrogen. All reaction mixtures were stirred magnetically, unless otherwise noted.

Diketone 6. A solution of nitrile **4** (779.1 mg, 5.76 mmol) in 11 mL of dry CH_2Cl_2 was cooled to −78 °C, and diisobutylaluminum hydride (DIBAL) (1.0 M in CH_2Cl_2, 7.50 mL) was added dropwise. The reaction mixture was allowed to warm to ambient temperature and stirred overnight. Methanol (3 mL), was added followed by water (3 mL), and the mixture was stirred for 20 min. Filtration and evaporation gave the crude aldehyde, which was filtered through a pad of silica gel to give a colorless oil (358 mg, 45%). TLC R_f (5% *tert*-butyl methyl ether (MTBE)/petroleum ether) = 0.33; ^{1}H NMR δ 9.72 (s, 1H), 6.7 (dd, J = 17.5, 10.7 Hz, $^1/_3$H), 6.32 (dd, J = 17.5, 10.7 Hz, $^2/_3$H), 5.45 (t, J = 7.2 Hz, $^2/_3$H), 5.30 (t, J = 7.2 Hz, $^1/_3$H), 5.22 (d, J = 17.5 Hz, $^1/_3$H), 5.15 (d, J = 17.5 Hz, $^2/_3$H), 5.14 (d, J = 10.7 Hz, $^1/_3$H), 5.05 (d, J = 10.7 Hz, $^2/_3$H), 2.45 (m, 2H), 2.20 (m, 2H), 1.77 (m, 5H).

A solution of ketone **5** (1.963 g, 11.14 mmol) in 60 mL of THF was added dropwise over 15 min to a solution of LDA prepared from diisopropylamine (2.16 mL, 15.4 mmol) and n-BuLi (2.40 M in hexanes, 5.83 mL, 14.0 mmol) in 120 mL of THF at −78 °C. After 1 h, a solution of anhydrous LiBr (1.26 g, 14.5 mmol) and the above aldehyde (1.40 g, 10.1 mmol) in 60 mL of THF was added dropwise over 10 min, and the mixture was stirred for 0.5 h at −78 °C. The reaction was quenched by the addition of 120 mL of saturated aqueous NH_4Cl, and the mixture was allowed to warm to ambient temperature. The reaction mixture was then partitioned between 20% MTBE/petroleum ether and, sequentially, water and brine. The organic layer was dried (Na_2SO_4), concentrated and

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(10) Gras, J. L. *J. Org. Chem.* **1981,** *46*, 3738.
(11) For a synthesis of authentic chiloscyphone, see: Piers, E.; Tse, H. L. A. *Can. J. Chem.* **1993**, *71*, 983.
(12) Danheiser, R. L.; Miller, R. F.; Brisbois, R. G.; Park, S. Z. *J. Org. Chem.* **1990**, *55*, 1959.
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(14) Taber, D. F. *J. Org. Chem.* **1982**, *47*, 1351.

chromatographed to give the aldol product (2.32 g, 73%) as a colorless oil. TLC R_f (10% MTBE/petroleum ether) = 0.20.

To a mixture of pyridinium chlorochromate (PCC) (1.33 g, 61.5 mmol), NaOAc (1.33 g), and 4 Å sieve (1.33 g) in 200 mL of CH_2Cl_2 at ambient temperature was added a solution of the aldol product (9.67 g, 30.8 mmol) in 100 mL of CH_2Cl_2. After 3 h, the solvent was evaporated and the resultant oil was chromatographed directly to give the diketone **6** (8.13 g, 85%) as a colorless oil. TLC R_f (10% MTBE/petroleum ether) = 0.58; IR (film) 2957, 1721, 1677, 1596, 1448 cm^{-1}; ^1H NMR δ 7.95 (d, J = 7.2 Hz, 2H), 7.54 (m, 3H), 6.62 (dd, J = 17.5, 10.7 Hz, $^1/_3$H), 6.28 (dd, J = 17.5, 10.7 Hz, $^2/_3$H), 5.33 (t, J = 7.2 Hz, $^2/_3$H), 5.23 (t, J = 7.2 Hz, $^1/_3$H), 5.14 (d, J = 17.5 Hz, $^1/_3$H), 5.03 (d, J = 17.5 Hz, $^2/_3$H), 5.02 (d, J = 10.7 Hz, $^1/_3$H), 4.89 (d, J = 10.7 Hz, $^2/_3$H), 4.52 (t, J = 7.0 Hz, 1H), 2.45 (m, 2H), 1.4−2.1 (m, 10 H), 0.90 (d, J = 6.0 Hz, 3H), 0.87 (d, J = 5.8 Hz, 3H); ^{13}C NMR (μ) δ 205.9, 196.3, 136.5, 134.7, 133.0, 113.6, 110.7, 39.8, 39.7, 37.6, 27.2, 26.3, 23.4, 23.1; ^{13}C NMR (d) δ 141.2, 133.5, 133.4, 131.7, 129.8, 128.8, 128.5, 127.9, 61.1, 26.5, 22.5, 22.4, 19.6, 11.5; EI MS (*m*/*z* (rel intens)) 212 (4.5), 293 (15), 269 (20), 133 (68), 105 (100); HRMS (calcd for $C_{21}H_{28}O_2$), 312.2089. Found, 312.2097.

Diazoketone 7. DBU (diazabicycloundecene) (7.83 g, 51.4 mmol) was added to a solution of diketone **6** (8.03 g, 25.7 mmol) in 400 mL of CH_2Cl_2 at 0 °C. After 10 min, PNBSA (4-nitrobenzenesulfonyl azide) (11.7 g, 51.4 mmol) in 100 mL of CH_2Cl_2 was added. The mixture was stirred for 1 h and then was quenched with 200 mL of 10% aqueous NaOH solution. The organic layer was separated, and the aqueous layer was extracted twice with CH_2Cl_2. The combined organic layers were dried (Na_2SO_4), concentrated, and chromatographed (with 1% triethylamine (TEA) in the eluent) to give **7** (4.72 g, 79%) as a yellow oil. TLC R_f (10% MTBE/petroleum ether) = 0.42; IR (film) 2958, 2063, 1640, 1465 cm^{-1}; ^1H NMR δ 6.72 (dd, J = 17.5, 10.7 Hz, $^1/_3$H), 6.37 (dd, J = 17.5, 10.7 Hz, $^2/_3$H), 5.43 (t, J = 7.2 Hz, $^2/_3$H), 5.32 (t, J = 7.2 Hz, $^1/_3$H), 5.17 (d, J = 17.5 Hz, $^1/_3$H), 5.06 (d, J = 17.5 Hz, $^2/_3$H), 5.05 (d, J = 10.7 Hz, $^1/_3$H), 4.92 (d, J = 10.7 Hz, $^2/_3$H), 2.45 (m, 2H), 2.16 (m, 4H), 1.80 (m, 5H), 0.95 (d, J = 6.6 Hz, 5H); ^{13}C NMR (μ) δ 193.9, 134.9, 133.4, 113.7, 110.8, 37.2, 37.0, 31.4, 27.5, 26.6, 24.8, 24.5; ^{13}C NMR (d) δ 141.3, 133.4, 131.8, 129.8, 21.9, 19.7, 11.6.

Triene 3. To a solution of diazoketone **7** (218 mg, 0.93 mmol) in 21 mL of dry CH_2Cl_2 at −78 °C under N_2 was added dropwise a chilled solution (0 °C) of 2 mg of dirhodium tetrakis(trifluoroacetate) in 1 mL of CH_2Cl_2. The mixture was stirred for 1 h, concentrated in vacuo, and immediately chromatographed to provide triene **3** (131 mg, 68%) as a pale yellow oil. TLC R_f (10% MTBE/petroleum ether) = 0.66; IR (film) 2964, 1693, 1618, 1466 cm^{-1}; ^1H NMR δ 6.72 (dd, J = 17.5, 10.7 Hz, $^1/_3$H), 6.36 (dd, J = 17.5, 10.7 Hz, $^2/_3$H), 5.98 (d, J = 11.4 Hz, 1H), 5.83 (dd, J = 11.4, 9.8 Hz, 1H), 5.45 (t, J = 7.2 Hz, $^2/_3$H), 5.35 (t, J = 7.2 Hz, $^1/_3$H), 5.18 (d, J = 17.5 Hz, $^1/_3$H), 5.07 (d, J = 17.5 Hz, $^2/_3$H), 5.06 (d, J = 10.7 Hz, $^1/_3$H), 4.93 (d, J = 10.7 Hz, $^2/_3$H), 3.53 (m, 1H), 2.44 (m, 2H), 2.17 (m, 2H), 1.6−1.8 (m, 5H), 0.99 (d, J = 6.5 Hz, 6H); ^{13}C NMR (μ) δ 201.4, 134.9, 133.4, 113.6, 110.7, 43.5, 43.4, 27.5, 26.6, 24.0, 23.7; ^{13}C NMR (d) δ 154.9, 154.8, 141.4, 133.6, 132.2, 130.3, 124.5, 27.8, 22.3, 19.8, 11.7; EI MS (*m*/*z* (rel intens)) 206 (16), 191 (3.4), 163 (26), 108 (100); HRMS, calcd for $C_{14}H_{22}O$, 206.1671; found, 206.1653.

Cis Ketone 2. To a solution of triene **3** (165 mg, 0.80 mmol) in 5.5 mL of dry CH_2Cl_2 at −78 °C was added $BF_3{\cdot}OEt_2$ (0.098 mL, 0.80 mmol) in 2.5 mL of CH_2Cl_2. The reaction mixture was then warmed to ambient temperature and stirred for 3 h, after which it was cooled in an ice/water bath. The chilled reaction mixture was partitioned between saturated aqueous $NaHCO_3$ and CH_2Cl_2. The combined organic extracts were dried (Na_2SO_4), concentrated, and chromatographed to give **2** (91 mg, 55%, 83% based on the *E* component of the diene) as a colorless oil. TLC R_f (5% MTBE/petroleum ether) = 0.33; IR (film) 2958, 2866, 1708, 1440 cm^{-1}; ^1H NMR δ 5.51 (s, 1H), 2.72 (m, 2H), 2.24 (m, 6H), 1.6−2.0 (m, 4H), 1.64 (s, 3H), 0.89 (d, J = 6.7 Hz, 3H), 0.83 (d, J = 6.7 Hz, 3H); ^{13}C NMR (μ) δ 211.4, 132.6, 43.0, 27.9 (2), 22.7; ^{13}C NMR (d) δ 126.9, 49.4, 45.0, 43.8, 29.7, 21.6, 21.3, 20.1; EI MS (*m*/*z* (rel intens)) 206 (6.4), 191 (1.2), 163 (100); HRMS, calcd for $C_{14}H_{22}O$, 206.1671; Found, 206.1676.

Trans Ketone 8. A solution of the cis ketone **2** (29 mg, 0.14 mmol) in 0.33 mL of ethanol, 0.043 mL of water, and 37 mg of KOH was warmed to reflux for 5.5 h. The resultant mixture was partitioned between ether and brine. The combined organic extracts were dried (Na_2SO_4) and concentrated, and the residual oil was chromatographed to give the recovered cis ketone **2** (8 mg) and the trans ketone **8** (14 mg, 76% yield based on cis ketone not recovered). TLC R_f (5% MTBE/petroleum ether) = 0.30; IR (film) 2959, 1714, 1464, 1436 cm^{-1}; ^1H NMR δ 5.45 (s, 1H), 2.4 (m, 4H), 2.2 (m, 3H), 1.8−2.0 (m, 4H), 1.66 (s, 3H), 1.4 (m, 1H), 0.88 (d, J = 7.0 Hz, 3H), 0.62 (d, J = 7.0 Hz, 3H); ^{13}C NMR (μ) δ 213.7, 134.2, 43.3, 30.3, 28.3, 22.6; ^{13}C NMR (d) δ 122.7, 55.6, 48.8, 36.3, 25.7, 21.1, 20.8, 15.0; EI MS (*m*/*z* (rel intens)) 206 (5.5), 163 (22), 150(100); HRMS, Calcd for $C_{14}H_{22}O$, 206.1671, Found, 206.1661.

Trans Diazoketone 9. To a stirred solution of trans ketone **8** (27 mg, 0.13 mmol) in 1 mL of THF at −78 °C was added LiHMDS (lithium bis(trimethylsilyl)amide) (0.20 mL, 1.03 M in THF, 0.21 mmol) dropwise. The temperature was raised to −40 °C, and the mixture was stirred for 1 h. The temperature was lowered to −78 °C, and trifluoroethyl trifluoroacetate (35 μL, 0.26 mmol) was added. At this point, the cooling bath was removed and the mixture was allowed to stir at ambient temperature for 3 h. The mixture was partitioned between 3 M aqueous HCl and CH_2Cl_2, dried (Na_2SO_4), and concentrated to a yellow-brown oil.

The crude diketone was diluted in 2 mL of CH_3CN and to this was added Et_3N (30 μL, 0.22 mmol), H_2O (2.5 μL, 0.14 mmol), and a solution of MsN_3 (25 mg, 0.21 mmol) in 0.4 mL CH_3CN. After 20 h at ambient temperature, the mixture was evaporated. The crude oil was partitioned between ether and 3 M aqueous NaOH, dried (Na_2SO_4), and evaporated. Chromatography yielded **9** (12 mg, 40% for the two steps) as a yellow oil. TLC R_f (10% MTBE/petroleum ether) = 0.34; IR (film) 2081, 1621 cm^{-1}; ^1H NMR δ 5.44 (bs, 1H), 2.64 (ddd, J = 13.7, 10.7, 5.0 Hz, 1H), 2.6−2.5 (m, 3H), 2.1−1.9 (m, 4H), 1.67 (bs, 3H), 1.8−1.5 (m, 2H), 0.91 (d, J = 6.6 Hz, 3H), 0.89 (d, J = 6.8 Hz, 3H); ^{13}C NMR (μ) δ 196.7, 132.6, 24.4, 24.0, 19.1; ^{13}C NMR (d) δ 124.4, 48.2, 39.3, 35.1, 27.0, 20.9, 20.8, 20.2; EI MS (*m*/*z* (rel intens)) 204 (M^+, 25), 176 (26), 161 (29), 147 (14), 133 (100), 119 (16), 105 (46); HRMS, Calcd for $C_{14}H_{20}O$ (loss of N_2), 204.1513, Found, 204.1503.

Methyl Ester 10. A threaded Pyrex test tube, charged with a yellow solution of diazoketone **9** (10 mg, 0.049 mmol) in 15 mL of MeOH, was irradiated in a Rayonet apparatus for 16 h. The now-colorless solution was evaporated to a crude oil and chromatographed to yield **10** (7.0 mg, 70%) as a clear oil which was a 4:1 mixture of diastereomers. TLC R_f (10% MTBE/petroleum ether) = 0.81; IR (film) 1737 cm^{-1}; ^1H NMR δ 5.35 (bs, 1H), 3.65 (s, 2.4H), 3.62 (s, 0.6H), 2.9 (m, 0.2H), 2.65 (dt, J = 8.3, 5.4 Hz, 0.8H), 2.5 (m, 0.2H), 2.4 (m, 1H), 2.26 (ddd, J = 9.9, 8.2, 5.4 Hz, 0.8H), 2.1−1.7 (m, 6H), 1.63 (bs, 3H), 1.4 (m, 0.2H), 1.3−1.2 (m, 1H), 1.1 (m 0.8H), 0.90 (d, J = 6.9 Hz, 2.4H), 0.85 (d, J = 6.8 Hz, 0.6H), 0.76 (d, J = 6.8 Hz, 0.6H), 0.75 (d, J = 6.8 Hz, 2.4H); ^{13}C NMR (for the major isomer; μ) δ 177.5, 135.3, 31.4, 29.4, 23.6; ^{13}C NMR (d) δ 120.5, 51.6, 47.8, 44.2, 44.1, 40.7, 28.0, 22.1, 21.6, 16.6; EI MS (*m*/*z* (rel intens)) 236 (21), 205 (6), 204 (6), 193 (66), 161 (30), 133 (100), 107 (43); HRMS, Calcd for $C_{15}H_{24}O_2$, 236.1776, Found, 236.1764.

(±)-α-Oplopenone (1). Methyl ester **10** (6.59 mg, 0.0279 mmol) was dissolved in a toluene solution of Cp_2TiMe_2 (0.20 mL, 0.50 M, 100 mmol) and heated at 90 °C for 12 h. After the solution had cooled to ambient temperature, it was diluted with 2 mL of THF and 2 mL of a 1:1 mixture of saturated aqueous Na_2SO_4 and 10% aqueous H_2SO_4. The mixture was stirred for 1 h, after which it was partitioned between ether and H_2O. The combined organic layers were dried (Na_2SO_4) and concentrated, and the residue was chromatographed to yield a clear oil which was predominately a 4:1 mixture of the two diastereomers of (±)-α-oplopenone (5.10 mg, 83% for the two steps). TLC R_f (2% MTBE/petroleum ether) = 0.25; IR

(film) 1709 cm^{-1}; ^1H NMR (CCl_4) δ 5.31 (bs, 1H), 2.9 (m, 0.2H), 2.70 (dt, J = 8.3, 4.7 Hz, 0.8H), 2.5 (m, 0.2H), 2.3 (m, 1.8H), 2.12 (s, 0.6H), 2.09 (s, 2.4H), 2.1−1.5 (m, 5H), 1.62 (bs, 3H), 1.5−1.1 (m, 3H), 0.94 (d, J = 6.9 Hz, 2.4H), 0.89 (d, J = 6.6 Hz, 0.6H), 0.8 (m, 3H); ^1H NMR ($CDCl_3$) δ 5.37 (bs, 1H, shoulder at 5.34), 2.9 (m, 0.2H), 2.80 (dt, J = 8.3, 4.3 Hz, 0.8H), 2.6 (m, 0.2H), 2.4 (m, 0.2H), 2.3 (m, 1.6H), 2.20 (s, 0.6H), 2.16 (s, 2.4H), 2.1−1.5 (m, 5H), 1.62 (s, 2.4H), 1.54 (s, 0.6H), 1.5−1.1 (m, 3H), 0.91 (d, J = 6.9 Hz, 2.4H), 0.86 (d, J = 6.6 Hz, 0.6H), 0.8 (m, 3H); ^{13}C NMR (for the major isomer, $CDCl_3$; μ) δ 211.3, 135.4, 31.4, 29.1, 23.6; ^{13}C NMR (d) δ 120.6, 56.6, 44.4, 41.9, 40.7, 28.7, 27.4, 22.1, 21.7, 16.6; EI MS (*m*/*z* (rel intens)): 220 (37), 177 (69), 159 (100), 107 (37); HRMS, Calcd for $C_{15}H_{24}O$, 220.1827; Found, 220.1811.

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Supporting Information Available: Figures of ^1H and ^{13}C NMR spectra for all new compounds (17 pages). This material is contained in libraries on microfiche, immediately follows this article in the microfilm version of the journal, and can be ordered from the ACS; see any current masthead page for ordering information.

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