Use of Conjugated Dienones in Cyclialkylations: The Total Syntheses of (±)-Barbatusol, (±)-Pisiferin, (±)-Deoxofaveline, (±)-Xochitlolone, and (±)-Faveline†

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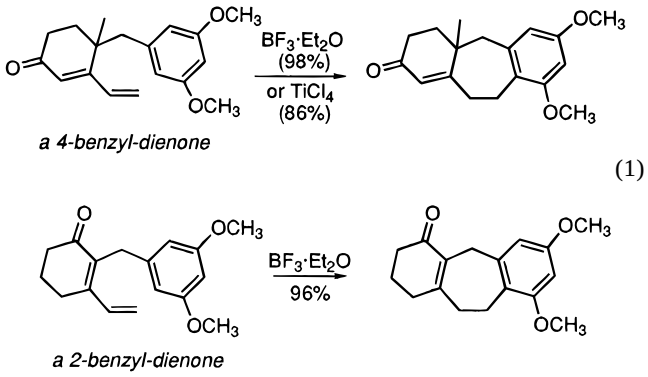
Concise syntheses of five tricyclic diterpenoids are reported. The key reaction in each synthesis is a cyclialkylation of a functionalized arene with a Lewis acid-activated conjugated dienone to generate a 6,7,6-fused tricycle.

Recently we reported that tricycles containing a central cycloheptane ring can be prepared by the Lewis acid-catalyzed intramolecular alkylation of electron-rich arenes with conjugated dienones (eq 1).[1] The ability of



this method to prepare functionalized 6,7,6-fused tricycles is the basis for each of the syntheses discussed here (Figure 1).[2,3] The first synthesis discussed is that of (±)-barbatusol (**1**),[4] a diterpene known to lower blood pressure in mice.[5] We also present the syntheses of (±)-pisiferin (**2**),[6] (±)-deoxofaveline (**3**),[7] faveline (**4**),[8] as well as the first total synthesis of xochitlolone (**5**).[9]

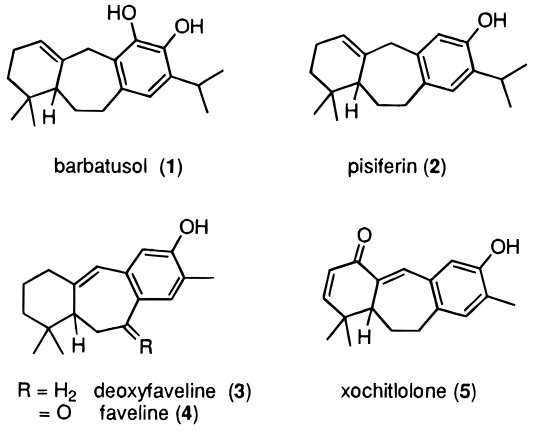
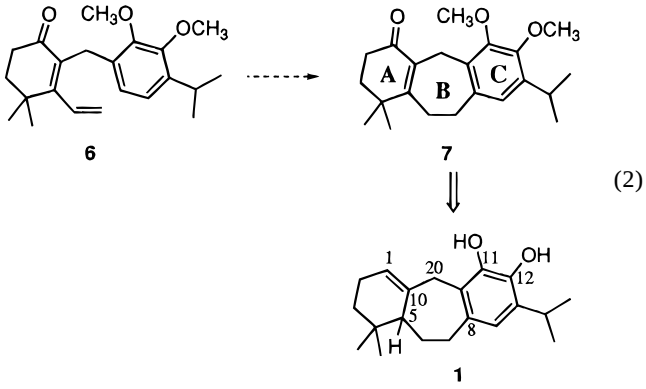


Figure 1.

Synthesis of (±)-Barbatusol. Our approach to barbatusol features the cyclialkylation of 2-benzyl-dienone **6** to produce tricycle **7** (eq 2).[10] Enone **7** is an attractive synthetic intermediate because it contains the entire carbocyclic framework of barbatusol, a suitably substituted "C" ring, and sufficient functionality within the "A" ring to permit the introduction of the acid-sensitive trisubstituted C(1),C(10)-double bond.



Our synthesis began with 3-isopropylveratrole (**8**).[11] The 3-isopropylveratrole was treated with *n*-butyllithium to form the anion[12] shown (Scheme 1), which was then

† (a) Presented in part at 44th Southeastern−26th Middle Atlantic Regional Meeting of the American Chemical Society, December 8, 1992; ORG Abstract No. 411. (b) Taken in part from the MS theses of Terry Lee Feltman, The University of Georgia, 1993, and Sam Duncan, Jr., The University of Georgia, 1992. (c) Taken in part from the Ph.D. Dissertation of Rodgers Hicks, The University of Georgia, 1996.

⊗ Abstract published in *Advance ACS Abstracts,* October 15, 1996.

(1) Majetich, G.; Zhang,Y.; Feltman, T. L.; Belfoure, V. *Tetrahedron Lett.* **1993**, *34,* 441.

(2) For a preliminary account of our barbatusol synthesis, see: (a) Majetich, G.; Zhang, Y.; Feltman, T. L.; Duncan, S. G., Jr. *Tetrahedron Lett.* **1993**, *34,* 445. (b) All structures drawn here represent racemates, with only one enantiomer shown. (c) Reaction conditions have not been optimized. (d) All yields are isolated yields.

(3) For a recent application of our cyclialkylation strategy, see: Wang, X.; Pan, X.; Zhang, C.; Chen, Y. *Synth. Commun.* **1995**, *25,* 3413.

(4) For the isolation of barbatusol, see: Kelecom, A. *Tetrahedron* **1983**, *39,* 3603.

(5) (a) Steven, R. V.; Bisacchi, G. S. *J. Org. Chem.* **1982**, *47,* 2396. (b) Edwards, J. D.; Cashaw, J. L. *Ibid.* **1955**, *20,* 847.

(6) For the isolation of pisiferin, see: (a) Yatagai, M.; Takahashi, T. *Phytochemistry* **1980**, *19,* 1149. (b) Hasegawa, S.; Hirose, Y.; Yatagai, M.; Takahashi, T. *Chem. Lett.* **1984**, 1837.

(7) For the isolation of deoxofaveline and faveline, see: Endo, Y.; Ohta, T.; Nozoe, S. *Tetrahedron Lett.* **1991**, *32,* 3083.

(8) Deoxofaveline and faveline have known activity against P-388 murine leukemia cells with IC_{50}'s of 1.0 and 18.6 μg/mL, respectively.[7]

(9) For the isolation of xochitlolone, see: Dominguez, X. A.; Sanchez, H. V.; Espinosa, G. B.; Villarreal, A. M.; Guerra, N. E. *Rev. Quim. Latin. Amer.* **1990**, *21,* 26.

(10) For the first synthesis of barbatusol, see: Koft, E. *Tetrahedron* **1987**, *43,* 5775.

(11) For an efficient, three-step preparation of 3-isopropylveratrole, see: Majetich, G.; Liu, S. *Synth. Commun.* **1993**, *23,* 2331.

(12) (a) Meyer, N.; Seebach, D. *Angew. Chem. Int., Ed. Engl.* **1978**, *17,* 521. (b) Taber, D. F.; Dunn, B. S.; Mack, J. F.; Saleh, S. A. *J. Org. Chem.* **1985**, *50,* 1987.

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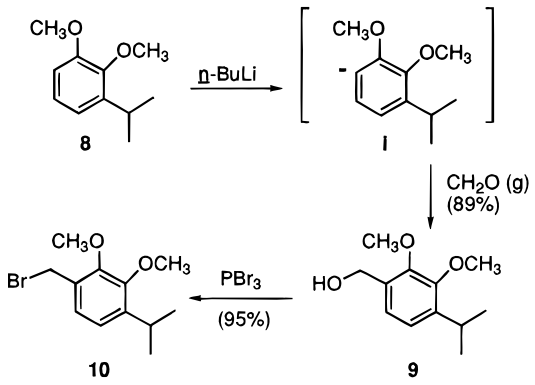
Scheme 1



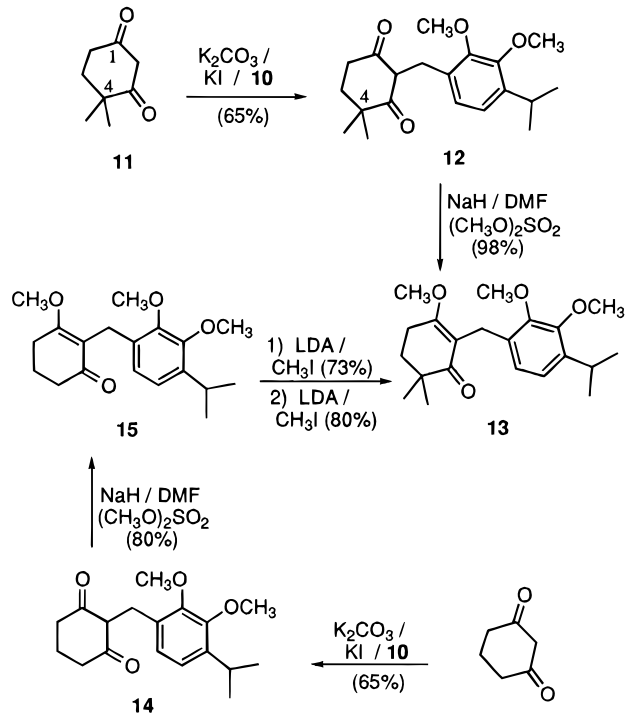
quenched with gaseous formaldehyde (generated by heating paraformaldehyde to 135 °C) to yield the benzylic alcohol **9** in 86% yield.[13] Alcohol **9** was treated with phosphorus tribromide to produce bromide **10** in 95% yield.

The next step required the alkylation of 4,4-dimethyl-1,3-cyclohexanedione (**11**) with bromide **10**. The use of typical conditions for the C-alkylation of cyclic 1,3-diones gave either O-alkylation or bis-alkylation. However, the use of a concentrated solution of compounds **11** and **10** in a 20% aqueous solution of potassium carbonate yielded mono-alkylated dione **12** in 65% yield, or 98% based on unreacted **11** (Scheme 2).[14] Treatment of dione **12** with sodium hydride and dimethyl sulfate in DMF gave a single enol ether, which we assumed to be compound **13** because of the steric congestion of the *gem*-dimethyls at C(4). The specificity of this O-alkylation was easily confirmed. Kinetically controlled bis-alkylation[15] of enone **15** resulted in the exclusive formation of **13**, confirming this structural assignment. The preparation of **15** is straightforward, as shown in Scheme 2.

1,2-Addition of vinylmagnesium bromide to **13**, followed by mild acid hydrolysis, completed the preparation of cyclization precursor **6** (Scheme 3). Not surprisingly, the presence of the *gem*-dimethyls at C(6) necessitated activation of the carbonyl by using cerium chloride[16] to facilitate Grignard addition.

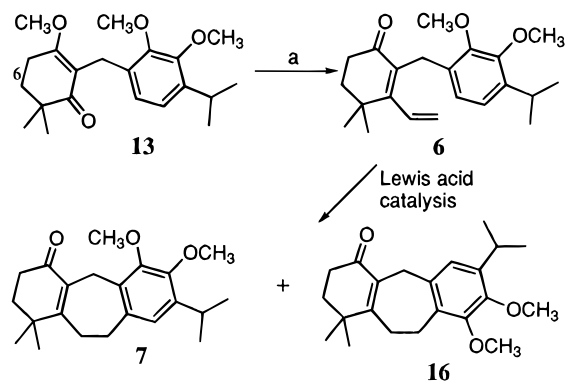
In our preliminary studies, a simplified analogue of **6**, devoid of the *gem*-dimethyl and isopropyl substitutents, cyclized easily and in high yield, regardless of the Lewis acid employed. We expected the cyclization of **6** to be straightforward; instead, this cyclization proved to be catalyst dependent. Mild Lewis acids, such as trimethylaluminum or zinc bromide, failed to promote cyclialkylation. The use of boron trifluoride etherate gave a 4.5:1 ratio of enones **16** and **7**, respectively, while the use of titanium tetrachloride gave the same mixture of isomers with opposite selectivity. Further experiments revealed that reexposure of enone **16** to excess Lewis acid does not result in the formation of enone **7**, nor does **7** rearrange to isomer **16** under identical conditions. We were unable to rigorously establish the structures of enones **7** and **16** using 2D NMR techniques. However, our structural assignment for these enones was based on a comparison of the chemical shift of the aromatic proton absorption for enones **7** and **16** with the aromatic

Scheme 2



proton of dimethoxybarbatusol, an intermediate in Koft's synthesis.[17] Our mechanistic analysis of these results is discussed in a separate section.

Scheme 3



BF_3-Et_2O (rt, 10 h) (16%) of **7**; (74%) of **16** (**7** : **16** = 1 : 4.5)

$TiCl_4$ (-78 °C, 1 h) (75%) of **7**; (15%) of **16** (**7** : **16** = 5 : 1)

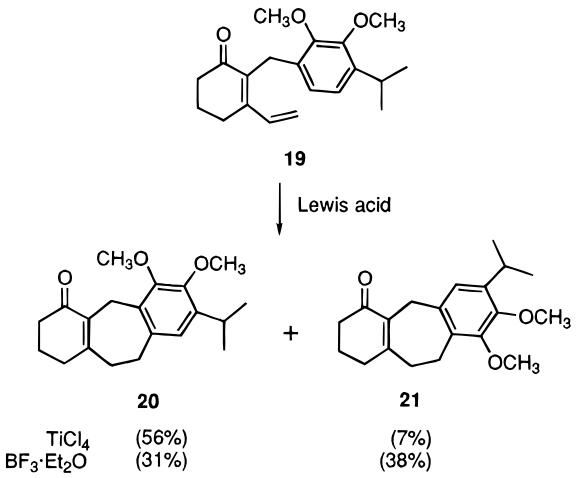
a) Vinylmagnesium Bromide, $CeCl_3$, H^+ (74%);

We verified our structural assignments for enone **7** by completing the synthesis of barbatusol. This was achieved by using a modified Wolff−Kishner reduction of enone **7**,[18] reducing the C(1) carbonyl and resulting in the migration of the C(5),C(10)-double bond to the C(1),C(10)-position (cf. **17**, Scheme 4). During the isolation of barbatusol, Kelecom and co-workers observed that the C(1),C(10)-double bond readily becomes conjugated upon exposure to acidic conditions. Koft found that the demethylation of **17** could not be achieved without double

(13) Lower yields of benzyl alcohol **9** were obtained when paraformaldehyde was used.
(14) Stetter, H.; Dierichs, W. *Chem. Ber.* **1952**, *85*, 1061.
(15) Stork, G.; Danheiser, R. *J. Org. Chem.* **1973**, *38*, 1775.
(16) Imamoto, T.; Kusumoto, T.; Yokoyama, M. *J. Chem. Soc., Chem. Commun.* **1982**, 1042.
(17) A single crystal X-ray diffraction study confirmed our structural assignment for tricyclic enone **16** after our synthesis of barbatusol had been achieved.
(18) Hutchins, R. O.; Milewski, C. A.; Maryanoff, B. E. *J. Am. Chem. Soc.* **1973**, *95*, 3662.

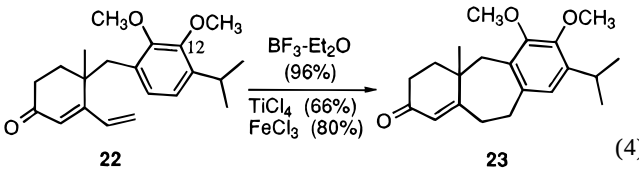
bond isomerization using acidic reagents [BBr_3, TMSI, or HI].[10] Nevertheless, Koft established that demethylation of the methyl ethers could be achieved without isomerization using basic conditions developed by Feutrill and Mirrington.[19] Thus, heating dimethyl ether **17** with EtSNa in DMF resulted in the isolation of racemic barbatusol in 65% yield, along with a 25% yield of an inseparable mixture of mono-methylated products (**18a** and **18b**). The NMR, infrared, and mass spectra of **1** were all identical with those reported by both Koft and Kelecom,[4,10] thereby confirming our synthesis. In the course of this investigation we found that warm solutions of L-Selectride or Super-Hydride in THF efficiently demethylate methyl phenyl ethers.[20] Although this new deprotection method is quite general, treatment of **17** with excess L-Selectride followed by heating for 48 h at reflux gave only a 45% yield of barbatusol, along with a 46% yield of phenols **18a** and **18b**. Further demethylation of **18a** and **18b** was not examined.

Fundamental Mechanistic Studies. We sought to learn what structural features, if any, were responsible for the formation of the rearranged products in the cyclialkylation of **6**. Benzyl-dienone **19** was prepared in order to test whether the *gem*-dimethyl moiety at C(4) in **6** was influencing the product distribution. This premise proved to be wrong as can be seen in eq 3.



(3)

We were curious whether substrate **22**, a 4-benzyl-dienone, would also generate a mixture of cyclialkylation products. Instead, this cyclialkylation furnished only tricycle **23**, regardless of the catalyst used (eq 4).

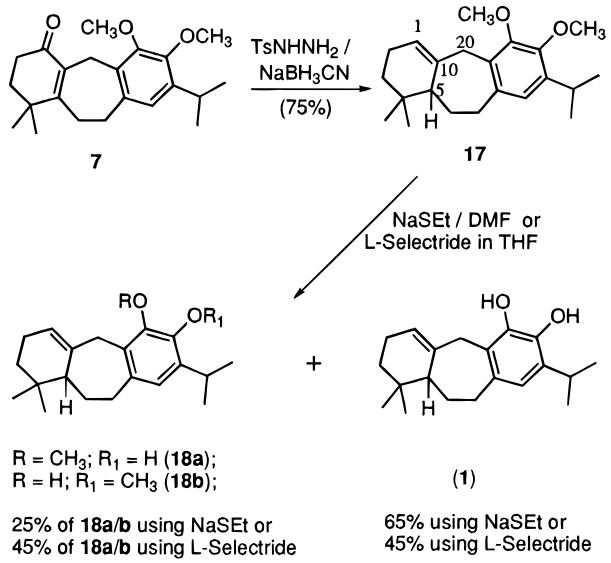


(4)

Scheme 5 presents three additional results which helped us to gain an understanding of these processes. The failure of dialkyl-substituted arene **24** to cyclize, even under harsh conditions, indicates that the two alkyl substitutents alone do not activate the arene sufficiently to promote cyclization. Chlorinated Lewis acids tend to promote 1,6-Michael addition of chloride ion when the cyclialkylation is sluggish or not geometrically possible.

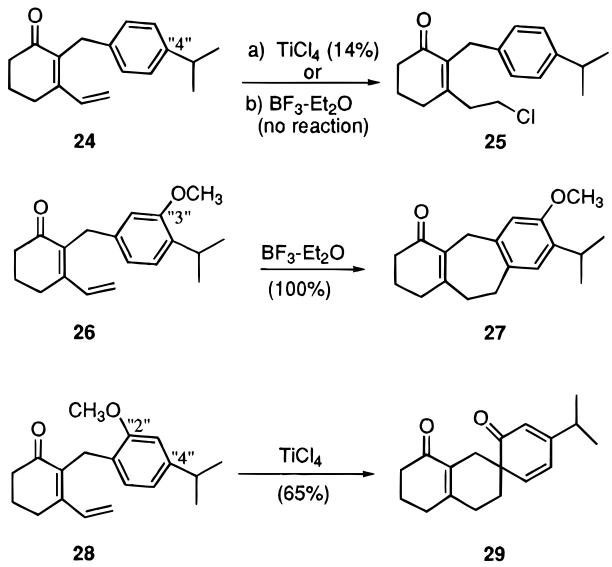
(19) Feutrill, G. I.; Mirrington, R. N. *Tetrahedron Lett.* **1970**, 1327.
(20) Majetich, G.; Zhang, Y.; Wheless, K. *Tetrahedron Lett.* **1994**, *35*, 8727.

Scheme 4



Thus, we were not surprised that the use of $TiCl_4$ gave only enone **25**, albeit in poor yield. Substrates **26** and **28** contain trisubstituted arenes, which differ only in the position of the methoxy group. The cyclization of **26** proceeds without the formation of rearranged products, but this is not the case with substrate **28**, which gives spiro-fused dienone **29** in 65% yield. Reexposure of tricycle **29** to either protic or Lewis acids does not result in further reaction.

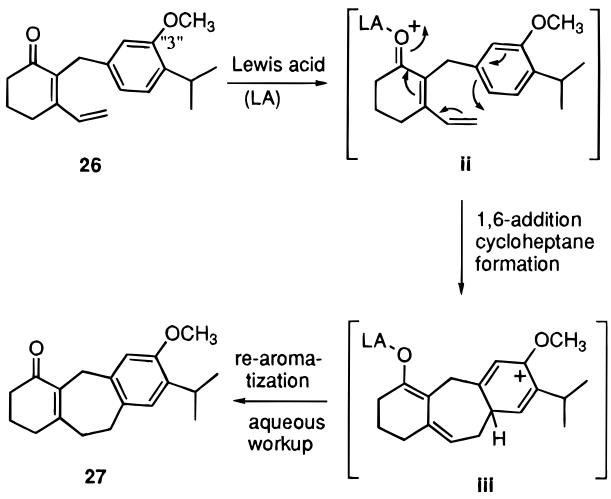
Scheme 5



Substituted 4-benzyl-dienones and most 2-benzyl-dienones undergo rapid cycloheptane annulation when the "3" position of the arene bears an electron-donating group. The mechanism shown in Scheme 6 for the cyclization of substrate **26** is representative of such substrates. Electrophilic addition of the activated conjugated dienone (**ii**) occurs para to the methoxy group to form a seven-membered ring and a resonance-stabilized carbocation intermediate (**iii**), which loses a proton to reestablish aromaticity. [Cation **iii** is conceptually similiar to the carbocation intermediate involved in the dienone−phenol rearrangement.[21]]

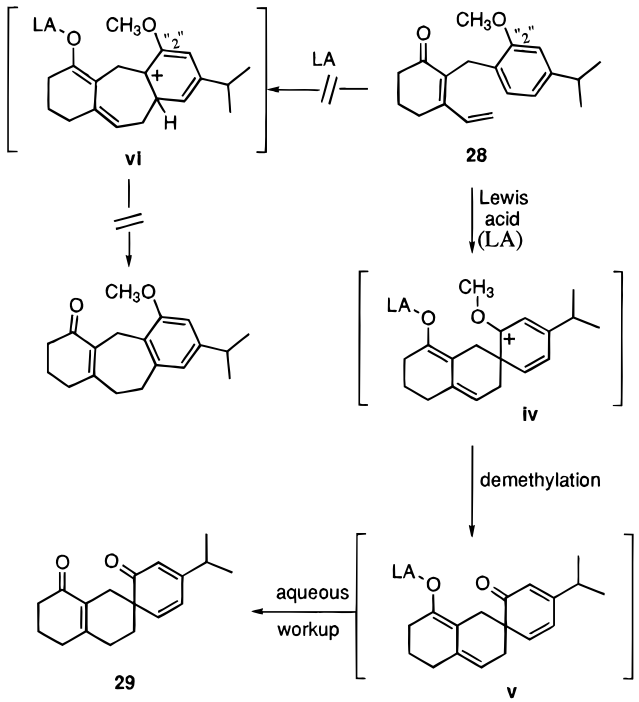
Although substrate **28** has an electron-rich arene, the activating groups direct substitution toward geometri-

Scheme 6



cally inaccessible positions, which precludes cycloheptane formation (Scheme 7). Nevertheless, treatment of **28** with $TiCl_4$ results in the formation of spiro-fused enone **29**. The isolation of tricycle **29** can be explained only via an *ipso*-attack mechanism. Six-membered rings form more easily than seven-membered rings. Thus, *ipso*-attack leads to cyclohexane formation via carbocation **iv** and its resonance contributors, whereas cycloheptane formation leads to a less stable carbocation (i.e., **vi**) and its various canonical forms.[22] Lewis-acid-catalyzed demethylation of intermediate **iv** generates **v**, which provides enone **29** on workup.

Scheme 7



Substrate **6**, whose cyclization is the key step in our barbatusol synthesis, has an arene unit substituted with four electron-donating groups. Since the "2" methoxy and

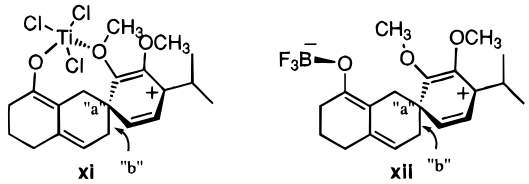


Figure 2.

the "4" isopropyl groups activate positions which are geometrically precluded to the activated dienone moiety, we expected the "3" methoxy group to dictate the formation of only enone **7** (cf. **26** → **27**, Schemes 5 and 6). Instead, cyclization catalyzed by $TiCl_4$ and $BF_3{-}Et_2O$ gave mixtures of isomeric enones **7** and **16**, a rearranged product (cf. Scheme 3). Once again, an *ipso*-attack mechanism, followed by a skeletal rearrangement, accounts for the production of these enones (Scheme 8). *Ipso*-attack by the arene on the electrophilic dienone unit leads to the formation of cation **viii**, which can generate intermediates **ix** or **x** by migration of the "a" or "b" bond, respectively. Since both of these bonds are allylic and primary, they are equally likely to migrate. In rearrangements where there are two or more potential migrating groups, the geometry of the molecule often governs which group migrates (for example, a Beckmann rearrangement). We believe that in the $TiCl_4$-catalyzed reaction an eight-membered ring chelate is formed (**xi**, Figure 2), and that its geometry favors the migration of the "b" bond instead of the "a" bond to generate a nine-membered ring chelate. In contrast, the use of $BF_3{-}Et_2O$ as catalyst leads to the formation of a noncyclic complex **xii**. As a consequence of minimizing the nonbonded steric interactions between the Lewis acid and the carbocyclic framework, this complex assumes a geometry which presumably favors the migration of the "a" bond.

The Syntheses of (±)-Deoxofaveline and (±)-Pisiferin. Our routes to prepare deoxofaveline (**3**) and pisiferin (**2**) closely parallel our barbatusol work and are therefore presented together in Scheme 9. Our synthesis of deoxofaveline[23a] will be discussed first. 3-Methoxy-4-methylbenzoic acid (**32**) was converted to conjugated aryldienone **37**, the requisite cyclization precursor in five steps and 50% overall yield. Cyclialkylation of dienone **37** produced tricycle **38** in excellent yield. Three additional transformations were required to complete a synthesis of **3**: (1) a Wolff–Kishner reduction of enone **38**; (2) the isomerization of the C(1),C(10)-double bond of tricycle **39**, and (3) the deprotection of the methyl ether. The use of excess boron tribromide during the demethylation of **39** should also cause the migration of the trisubstituted double bond to a styrenyl position, thereby furnishing **3** directly. This transformation occurs, albeit in less than 5% yield.

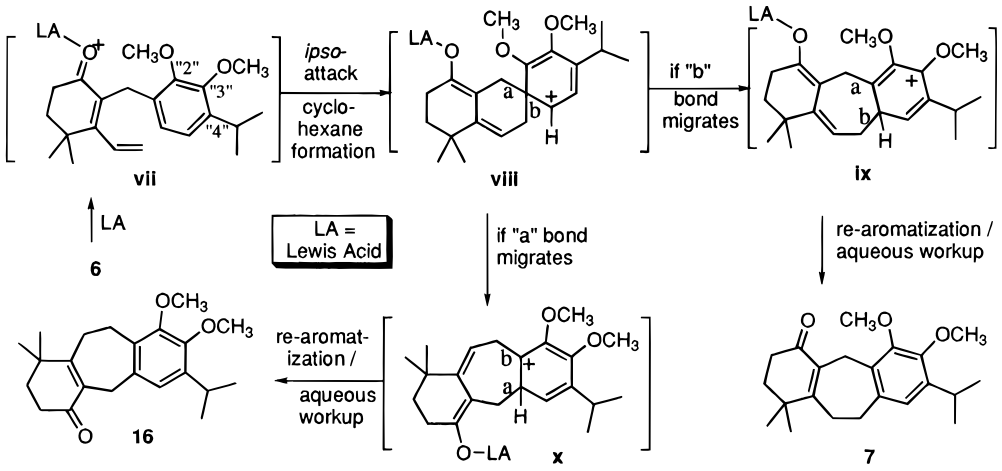
Concurrent with our synthesis of deoxofavaline, a cyclialkylation-based synthesis of pisiferin was also underway.[23b] In contrast to our deoxofaveline synthesis which was trouble free, the deprotection of pisiferin methyl ether (**45**) with NaSEt in DMF gave an inseparable mixture of pisiferin in 68% yield along with a 17% yield of the isomer in which the trisubstituted double bond had migrated to a styrenyl position, i.e., isopisiferin (**46**). Others have also observed that such unwanted

(21) (a) Arnold, R. T.; Buckley, J. S., Jr. *J. Am. Chem. Soc.* **1949**, *71*, 1781. (b) Wilds, A. L.; Djerassi, C. *Ibid.* **1946**, *68*, 1712, 1715. (c) Arnold, R. T.; Buckley, J. S., Jr.; Richter, J. *Ibid.* **1947**, *69*, 2322.

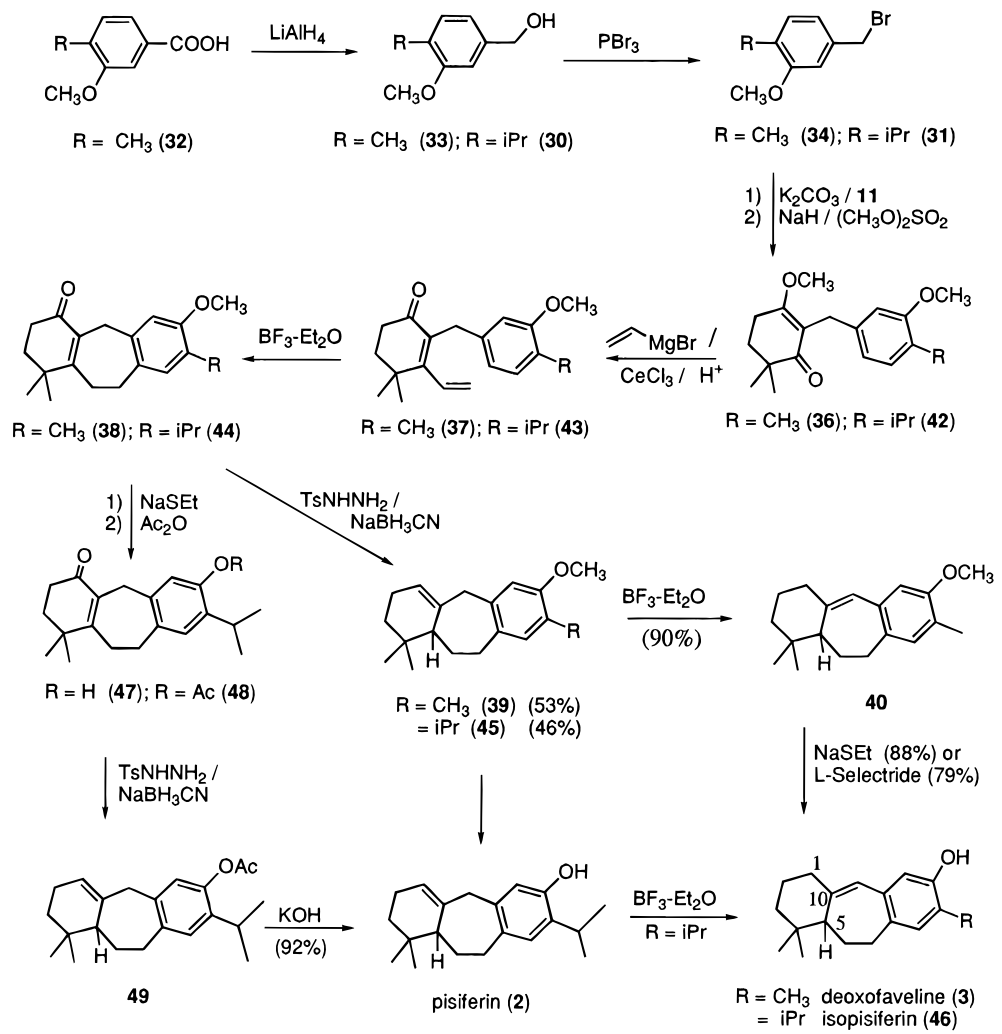
(22) For a related example of *ipso*-attack in a similar system, see: Burnell, R. H.; Jean, M.; Poirier, D. *Can. J. Chem.* **1987**, *65*, 775.

(23) (a) For the first synthesis of deoxofaveline, see: Ghosh, A.; Ray, C.; Ghatak, U. *Tetrahedron Lett.* **1992**, *33*, 655. (b) For the first synthesis of pisiferin, see: Matsumoto, T.; Imai, S.; Yoshinari, T.; Matsuno, S. *Bull. Chem. Soc. Jpn.* **1986**, *59*, 3103.

Scheme 8



Scheme 9

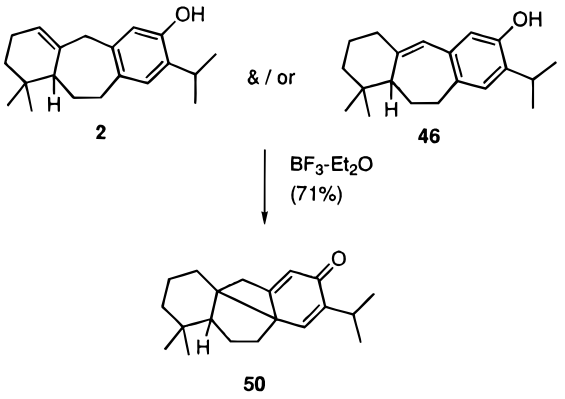


isomers can not be separated. For example, in Kametani's synthesis of pisiferin, their synthetic material was contaminated with about 10% of the C(5),C(10)-double bond isomer of **2**.[24] Surprisingly, pisiferin could not be isomerized cleanly into isopisiferin at ambient temperatures (cf. **39** → **40**),[25] while more vigorous reaction conditions produced tetracyclic dienone **50** (eq 5). These deprotection problems were avoided by unmasking the methyl ether prior to the Wolff−Kishner reduction (cf. **44**) and then acetylating the intermediate phenol (cf. **48**).

Syntheses of (±)-Xochitlolone and (±)-Faveline. The most direct way to synthesize faveline would involve a selective benzylic oxidation of deoxofaveline (cf. **39** → **52**, Scheme 10).[26,27] In practice only the C(1) position was oxidized independent of the choice of oxidant and whether or not the C(12) hydroxyl group was protected. Attempts

(24) Kametani, T.; Kondoh, H.; Tsubuki, M.; Honda, T. *J. Chem. Soc., Perkin Trans. 1* **1990**, 5.

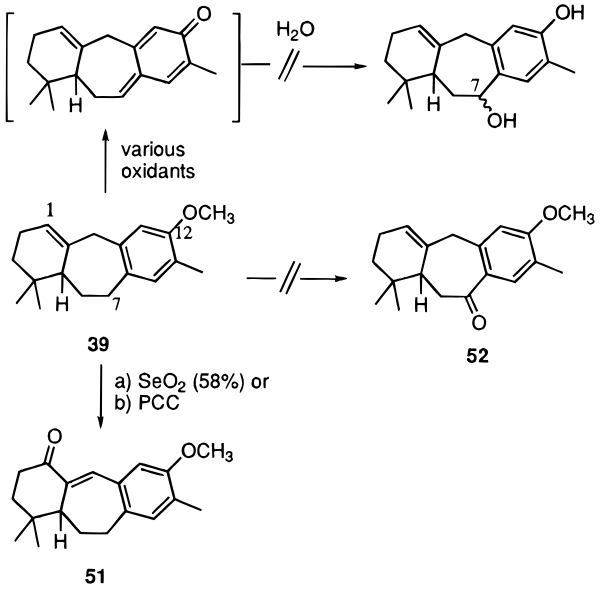
(25) For a synthesis of isopisiferin, see: Deb, S.; Bhattacharjee, G.; Ghatak, U. R. *J. Chem. Soc., Perkin Trans. 1* **1990**, 1453.



(5)

were then made to introduce a hydroxyl group at C(7) by adding water in Michael-fashion to the quinone methide, derived from deoxofaveline (Scheme 10);[28] this approach, however, was also not successful.

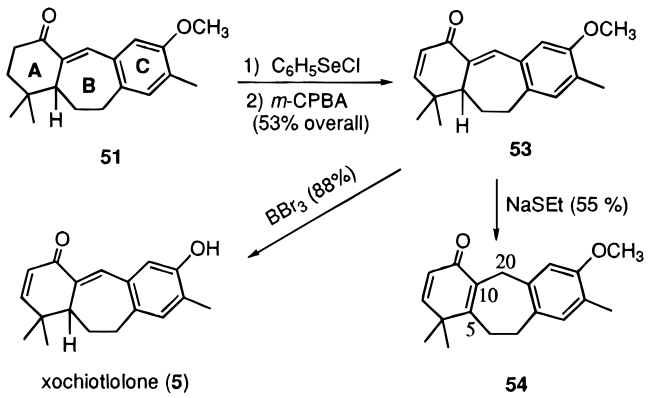
Scheme 10



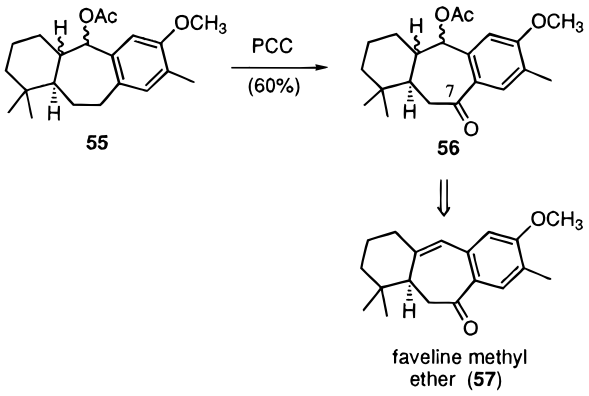
Although enone **51** was not a useful intermediate for our faveline synthesis, it does possess many of the salient features of the diterpenoid xochitlolone (**5**). Indeed, only three more reactions were required to complete a synthesis of **5** from enone **51**. The first two transformations involved the introduction of an α,β-unsaturated double bond within the "A" ring, while the last step was the liberation of the phenol in the presence of the sensitive dienone unit (Scheme 11). Heating dienone **53** with sodium ethanethiolate in DMF produced dienone **54**, wherein the C(10),C(20)-double bond unexpectedly isomerized to the C(5),C(10)-position. Instead, treatment with BBr_3 at low temperatures rapidly effected the desired ether cleavage cleanly. Our synthetic (±)-xochitlolone exhibited spectral data identical to those reported for the natural material.[9]

One of our main objectives thoroughout this project was to synthesize faveline, because of its promising antileukemia activity. It was therefore not surprising

Scheme 11



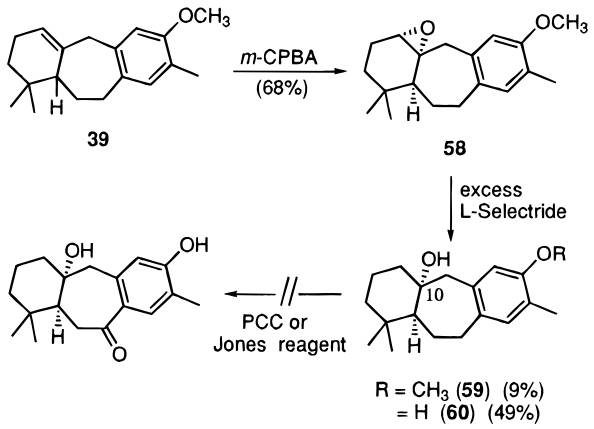
that others were also trying to synthesize faveline. In their synthesis of faveline methyl ether (**57**), Ghatak, Ray, and Ghosh reported that acetate **55** could be oxidized to ketone **56** in 60% yield (eq 6).[22] They also observed that the demethylation of **57** to faveline was plagued by many side reactions. Their results prompted



(6)

us to prepare substrate **59** with a tertiary hydroxyl group at C(10), which we expected would permit the desired benzylic oxidation at C(7) and facilitate the introduction of the styrenyl double bond (Scheme 12). Toward this end, alkene **39** was epoxidized and then treated with excess of L-Selectride to furnish tertiary alcohol **59**. Note that under these reaction conditions deprotection of the methyl phenyl ether was the major product.[20] However, attempts to oxidize the C(7)-methylene of **59** gave complex mixtures of unidentifiable products.

Scheme 12



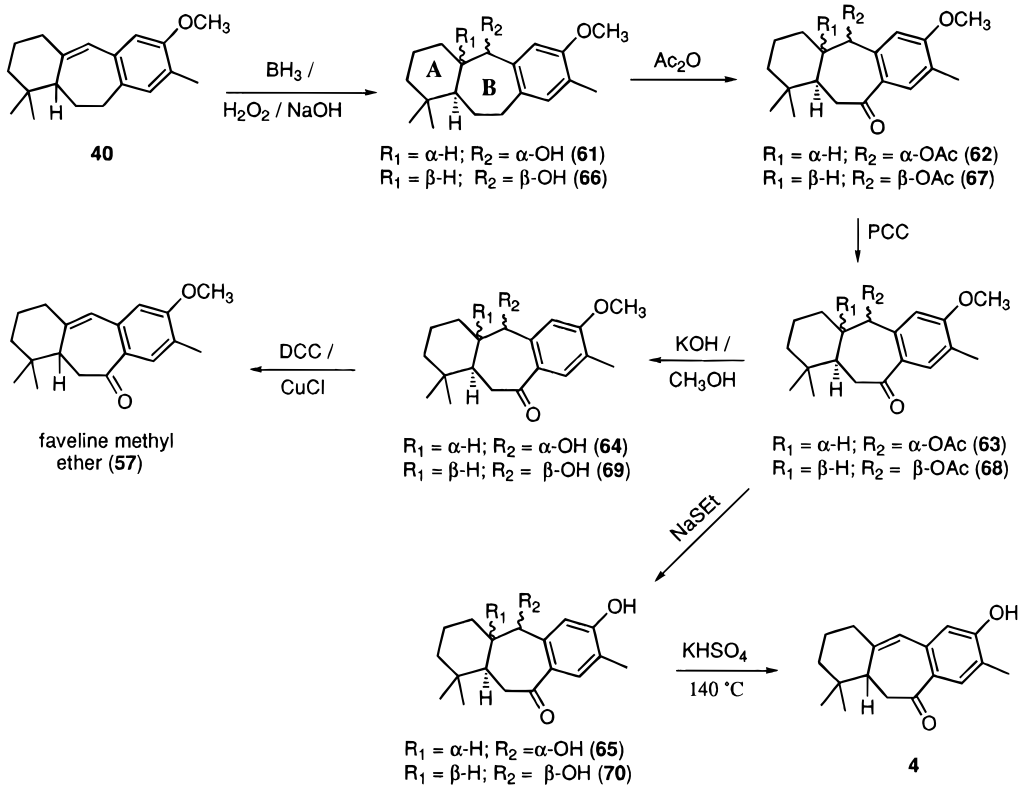
We decided to exploit Ghatak's finding that acetate **55** can be oxidized at C(7) using mild conditions. Hydro-

(26) For an unsuccessful approach toward faveline, see: Ho, T.-L.; Chen, C.-K. *Tetrahedron* **1995**, *51*, 5819.

(27) For the first synthesis of faveline, see: Ghosh, A. K.; Mukhopadhyay, C.; Ghatak, U. R. *J. Chem. Soc., Perkin Trans. 1* **1994**, 327.

(28) (a) Zanarotti, A. *J. Org. Chem.* **1985**, *50*, 941. (b) Angle, S. R.; Turnbull, K. D. *J. Am. Chem. Soc.* **1989**, *111*, 1136.

Scheme 13



boration of deoxofaveline methyl ether (**40**) gave a 2:1 mixture of benzylic alcohols with the diastereomer **61** having a cis A/B ring fusion as the major isomer (Scheme 13). The alcohols were then separated and acetylated. It was hoped that thexylborane would improve the selectivity of the hydroboration. This more bulky borane, however, reacted only sluggishly with **40**.

Acetates **62** and **67** were oxidized separately using pyridinium chlorochromate (PCC) in methylene chloride at reflux and saponified to provide alcohols **64** and **69**. We have developed neutral conditions for the dehydration of tertiary and benzylic alcohols in good yield using mild heating (typically <100 °C).[29] The application of this dehydration procedure to benzylic alcohols **64** and **69** produced (±)-faveline methyl ether (**57**) in good yield. We were able to complete a synthesis of faveline by unmasking both the C(20) hydroxyl group and the C(12) phenol using sodium ethanethiolate, followed by the dehydration of alcohols **65** and **70** with potassium hydrogen sulfate at 140 °C for 4 h. The NMR, infrared, and mass spectra of our synthetic racemic faveline were identical with those first reported by Nozoe[7] and more recently by Ghatak.[27]

The ability of this cyclialkylation-based annulation strategy to prepare functionalized tricylic skeletons has permitted the efficient synthesis of (±)-barbatusol (eight steps, 15% overall yield), (±)-pisiferin (nine steps, 11% overall yield), (±)-deoxofaveline (nine steps, 13% overall yield), (±)-xochiotlolone (11 steps, 7% overall yield) and (±)-faveline (13 steps, 2% overall yield). Other applications of this new annulation strategy for natural product synthesis have already been achieved,[30] or are forthcoming.

(29) Majetich, G.; Hicks, R. Carbodiimide-Promoted Dehydration of Alcohols. Manuscript is in preparation.

Experimental Section

General. All reactions were run under an inert atmosphere of nitrogen and monitored by TLC analysis until the starting material was completely consumed. Unless otherwise indicated, all ethereal workups consisted of the following procedure: the reaction was quenched at rt with saturated aqueous ammonium chloride. The organic solvent was removed under reduced pressure on a rotary evaporator, and the residue was taken up in ether, washed with brine, and dried over anhydrous magnesium sulfate. Filtration, followed by concentration at reduced pressure on a rotary evaporator and at 1 torr to constant weight, afforded a crude residue which was purified by flash chromatography using NM silica gel 60 (230−400 mesh ASTM) and distilled reagent grade hexanes and diethyl ether. Microanalysis was performed by Atlantic Microlab, Inc., Atlanta, GA. Proton NMR spectra were obtained in $CDCl_3$ and were calibrated using trace $CHCl_3$ present (δ 7.27) as an internal reference.

2,3-Dimethoxy-4-isopropylphenylmethyl Alcohol (9). 3-Isopropylveratrole (**8**) (13.25 g, 73.6 mmol) was dissolved in 130 mL of dry ether containing TMEDA (22.2 mL, 147 mmol) under an atmosphere of nitrogen and was allowed to stir 1.5 h at rt. *n*-Butyllithium (103 mmol, 42 mL of 2.5 M solution in hexanes) was added slowly and the mixture was stirred for 90 min at rt, after which it was treated at rt with excess gaseous formaldehyde (generated from paraformaldehyde via pyrolysis at 135 °C). Standard ethereal workup, followed by chromatography (elution with H:E, 5:1), gave 13.65 g (89%) of 2,3-dimethoxy-4-isopropylbenzyl alcohol (**9**) which was homogeneous by TLC analysis (H:E, 1:1, R_f **8** = 0.76, R_f **9** = 0.10): ^{1}H NMR (250 MHz) δ 1.22 (d, 6 H, J = 6.8 Hz), 3.25−3.45 (m,

(30) For a concise synthesis of the triterpene perovskone featuring a cyclialkylation strategy, see: (a) Majetich, G.; Zhang, Y. *J. Am. Chem. Soc.* **1994**, *116*, 4979. For a synthesis of (±)-nimbidiol featuring a cyclialkylation strategy, see: (b) Majetich, G.; Siesel, D. *Synlett* **1995**, 559. For cyclialkylations of conjugated dienones and furans, see: (c) Majetich, G.; Zhang, Y.; Liu, S. *Tetrahedron Lett.* **1994**, *35*, 4887. For the use of cyclialkylations to prepare functionalized hydrophenanthrenes, see: (d) Majetich, G.; Liu, S.; Siesel, D. *Tetrahedron Lett.* **1995**, *36*, 4749.

(31) Dhekne, V. V.; Rao, A. S. *Synth. Commun.* **1978**, *8*, 135.

1 H), 3.86 (s, 3 H), 3.93 (s, 3 H), 4.67 (s, 2 H), 6.95 (d, 1 H, J = 8.0 Hz), 7.01 (dd, 2 H, J = 14.6 Hz, 8.0 Hz), 7.07 (d, 1 H, J = 8.0 Hz); ^{13}C NMR (62.9 MHz) 157.0 (s), 150.2 (s), 143.0 (s), 132.1 (s), 123.7 (d), 121.4 (d), 61.6 (t), 60.6 (q), 60.6 (q) (the two methoxy signals overlap), 26.7 (d), 23.5 (q) ppm; IR (film) 3550−3200, 1620 cm^{-1}. Anal for $C_{12}H_{18}O_3$. Calcd: C, 68.53%, H, 8.63%. Found: 68.44%, H, 8.66%.

2,3-Dimethoxy-4-isopropylphenylmethyl Bromide (10). To a cooled (0 °C) solution of 2.1 g (10 mmol) of alcohol **9** in 100 mL of dry ether was added phosphorus tribromide (0.96 mL, 10 mmol). Although reaction was essentially complete after addition was finished, the reaction mixture was allowed to stir at rt for 2 h. Standard ethereal workup afford 2.58 g (95%) of bromide **10** which was homogeneous by TLC analysis (H:E, 2.5:1, R_f **9** = 0.21, R_f **10** = 0.89): ^{1}H NMR (300 MHz) δ 1.22 (d, 6 H, J = 6.8 Hz), 3.25−3.40 (m, 1 H), 3.86 (s, 3 H), 3.99 (s, 3 H), 4.56 (s, 2 H), 6.96 (d, 1 H, J = 8.0 Hz), 7.09 (d, 1 H, J = 8.0 Hz); ^{13}C NMR (75.5 MHz) 151.3 (s), 150.5(s), 144.2 (s), 129.4 (s), 125.6 (d), 121.5 (d), 60.6(q), 60.5 (q) (the two methoxy signals overlap), 28.6 (t), 26.8 (d), 23.4 (q) ppm; IR (film) 1461, 1410, 1044, 1012 cm^{-1}. Anal, for $C_{12}H_{17}BrO_2$. Calcd: C, 52.70%, H, 6.30%. Found: 52.83%, H, 6.23%.

4,4-Dimethyl-2-(2,3-dimethoxy-4-isopropylphenylmethyl)-1,3-cyclohexanedione (12). To 2.00 g of 4,4-dimethyl-1,3-cyclohexanedione (**11**) (13.96 mmol, Aldrich) dissolved in 20% aqueous K_2CO_3 (3.09 mL, 5.58 mmol) at rt were added KI (233 mg, 1.40 mmol) and bromide **10** (3.29 g, 15.29 mmol). The reaction mixture was stirred overnight. The aqueous solution was extracted with ether (150 mL) and then washed with aqueous 5% NaOH to remove unreacted **11**. The aqueous phase was acidified with aqueous 10% HCl and then extracted with ether (3 × 75 mL). The combined ethereal extracts were dried over anhydrous $MgSO_4$ and concentrated. The crude residue was dissolved in 5 mL of ether and 2 mL of hexanes, and the resulting solution was stored overnight at −20 °C. Filtration afforded 3.02 g (65%) of crystalline **12** which was homogenous by TLC analysis (H:E, 4:1, R_f **12** = 0.24): mp 124−125 °C; ^{1}H NMR (300 MHz) δ 1.08 (s, 6 H), 1.10−1.25 (m, 6 H), 1.74 (t, 2 H, J = 6.0 Hz), 2.40 (t, 2 H, J = 6.0 Hz), 3.27 (heptet, 1 H, J = 7.0 Hz), 3.50 (s, 0.8 H), 3.52 (s, 1.2 H), 3.81 (s, 1.2 H), 3.83 (s, 1.8 H), 4.00 (s, 1.2 H), 4.01 (s, 0.8 H), 6.85−6.95 (m, 1 H), 7.10−7.20 (m, 1 H), 8.93 (s, 0.6 H), 9.09 (s, 0.4 H); ^{13}C NMR (75.5 MHz) 202.6, 197.5, 177.6, 170.1, 149.6, 148.2, 140.9, 131.4, 131.3, 126.4 (d), 126.1 (d), 122.6 (d), 122.5 (d), 113.2, 112.7, 61.4 (q), 60.8 (q), 39.5, 35.6, 35.3 (t), 34.1 (t), 33.8 (t), 26.6 (d), 25.8 (d), 25.7 (t), 24.9 (q), 23.5 (q), 21.7 (t), 21.3 (t) ppm; IR (KBr) 3400−3030 (br), 1619 (br) cm^{-1}. Anal. for $C_{20}H_{28}O_4$: Calcd: C, 72.22%; H, 8.52%. Found: C, 72.10%; H, 8.44%. These data represent a mixture of enols.

6,6-Dimethyl-2-(2,3-dimethoxy-4-isopropylphenylmethyl)-3-methoxy-2-cyclohexenone (13). To a suspension of NaH (80% dispersion in mineral oil, 125 mg, 4.16 mmol) in 10 mL of DMF at 0 °C was added dione **12** (1.16 g, 3.47 mmol) in 15 mL of DMF over a 30-min period. Dimethyl sulfate (0.37 mL, 3.82 mmol) was then added, and the resulting mixture was stirred for 12 h. The reaction mixture was diluted with ether, washed sequentially with aqueous 10% HCl and saturated aqueous Na_2CO_3, dried over anhydrous magnesium sulfate, concentrated, and chromatographed (elution with H:E, 3:1) to give 1.18 g of **13** (98%) which was homogeneous by TLC analysis (H:E, 1:1, R_f **12** = 0.24, R_f **13** = 0.56): ^{1}H NMR (300 MHz) δ 1.13 (s, 6 H), 1.18 (d, 6 H, J = 7.0 Hz), 1.88 (t, 2 H, J = 6.2 Hz), 2.65 (t, 2 H, J = 6.2 Hz), 3.26 (heptet, 1 H, J = 7.0 Hz), 3.62 (s, 2 H), 3.76 (s, 3 H), 3.85 (s, 3 H), 3.90 (s, 3 H), 6.59 (d, 1 H, J = 8.0 Hz), 6.80 (d, 1 H, J = 8.3 Hz); ^{13}C NMR (75.5 MHz) 202.6 (s), 170.6 (s), 150.8 (s), 150.2 (s), 139.6 (s), 132.3 (s), 122.8 (d), 120.6 (d), 115.6 (s), 60.6 (q), 59.9 (q), 54.8 (q), 39.4 (s), 34.3 (t), 26.5 (d), 24.5 (q), 23.5 (q), 22.0 (t), 21.4 (t) ppm; IR (film) 1616, 1452, 1364, 1244 cm^{-1}. Anal. for $C_{21}H_{30}O_4$. Calcd: C, 72.79%, H, 8.73%. Found: 72.95%, H, 8.90%.

2-(2,3-Dimethoxy-4-isopropylphenylmethyl)-1,3-cyclohexanedione (14). To 2.00 g of 1,3-cyclohexanedione (13.96 mmol) dissolved in aqueous 20% K_2CO_3 (3.09 mL, 5.58 mmol) at rt were added KI (233 mg, 1.40 mmol) and bromide **10** (3.29 g, 15.29 mmol). The reaction mixture was stirred overnight. Standard ethereal workup provided 3.80 g of a crude residue which was dissolved in 5 mL of ether and 2 mL of hexanes, and the resulting solution was stored overnight at −20 °C. Filtration afforded 3.02 g (65%) of **14** which was homogenous by TLC analysis (H:E, 4:1, R_f **14** = 0.24): ^{1}H NMR (300 MHz) δ 1.19 (d, 6 H, J = 7.0 Hz), 1.81 (heptet, 2 H, J = 6.4 Hz), 2.37 (br t, 4 H, J = 6.4 Hz), 3.26 (heptet, 1 H, J = 7.0 Hz), 3.54 (s, 1 H), 3.83 (s, 3 H), 4.02 (s, 3 H), 6.94 (d, 1 H, J = 8 Hz), 7.18 (d, 1 H, J = 8 Hz); ^{13}C NMR (75.5 MHz) 149.7 (s), 148.1 (s), 141.1 (s), 131.8 (s), 126.2 (d), 122.6 (d), 114.7 (s), 61.5 (q), 60.8 (q), 26.6 (t), 23.4 (q), 20.9 (t), 20.4 (t) ppm.

2-(2,3-Dimethoxy-4-isopropylphenylmethyl)-3-methoxy-2-cyclohexenone (15). To a suspension of NaH (80% dispersion in mineral oil, 125 mg, 4.16 mmol) in 10 mL of DMF at 0 °C was added dione **14** (1.16 g, 3.47 mmol) in 15 mL of DMF over a 30-min period. Dimethyl sulfate (0.37 mL, 3.82 mmol) was then added and the resulting mixture stirred overnight. The reaction was diluted with ether, washed sequentially with aqueous 10% HCl and saturated aqueous Na_2CO_3, dried over anhydrous magnesium sulfate, concentrated, and chromatographed (elution with H:E, 3:1) to give 92 mg of **15** (80%) which was homogeneous by TLC analysis (H:E, 1:1, R_f **14** = 0.24, R_f **15** = 0.56): ^{1}H NMR (300 MHz) δ 1.17 (d, 6 H, J = 6.9 Hz), 2.03 (heptet, 2 H, J = 7.1 Hz), 2.39 (t, 2 H, J = 7.1 Hz), 2.62 (t, 2 H, J = 7.1 Hz), 3.25 (heptet, 1 H, J = 6.9 Hz), 3.62 (s, 2 H), 3.76 (s, 3 H), 3.84 (s, 3 H), 3.88 (s, 3 H), 6.65 (d, 1 H, J = 8.0 Hz), 6.80 (d, 1 H, J = 8.0 Hz); ^{13}C NMR (75.5 MHz) 197.8 (s), 172.7 (s), 150.8 (s), 150.1 (s), 139.6 (s), 132.1 (s), 123.2 (d), 120.5 (d), 117.9 (s), 60.5 (q), 59.8 (q), 55.1 (q), 36.3 (t), 26.5 (d), 24.8 (t), 23.55 (q), 21.0 (t), 20.7 (t) ppm.

Preparation of 13 from 15. To a solution of LDA, prepared from 99 μL (0.70 mmol) of diisopropylamine in 5 mL of THF and 280 μL (0.70 mmol) of *n*-butyllithium (2.5 M in hexanes), at −78 °C was added a solution of 195 mg (0.59 mmol) of **15** in 1 mL of THF over a 10-min period. After an additional 1 h at −78 °C, iodomethane (110 mg, 0.77 mmol) was added, and the reaction mixture was allowed to warm slowly to rt over a 12-h period. Standard ethereal workup, followed by chromatography (elution with H:E, 5:1), afforded 150 mg (73%) of 2-(2,3-dimethoxy-4-isopropylphenylmethyl)-3-methoxy-6-methyl-2-cyclohexenone which was homogeneous by TLC analysis (H:E, 1:1, R_f **15** = 0.35, R_f 6-mono-methylated adduct = 0.43): ^{1}H NMR (250 MHz) δ 1.18 (d, 6 H, J = 7.0 Hz), 1.17 (d, 3 H, J = 6.5 Hz), 1.69−1.85 (m, 1 H), 2.15 (dt, 1 H, J = 13.1 Hz, 4.7 Hz), 2.26−2.40 (m, 1 H), 2.52−2.78 (m, 2 H), 3.26 (heptet, 1 H, J = 6.9 Hz), 3.62 (d, 2 H, J = 3.7 Hz), 3.78 (s, 3 H), 3.86 (s, 3 H), 3.90 (s, 3 H), 6.63 (d, 1 H, J = 8.0 Hz), 6.80 (d, 1 H, J = 8.0 Hz).

To a solution of LDA, prepared from 100 μL (0.70 mmol) of diisopropylamine in 5 mL of THF and 280 μL (0.70 mmol) of *n*-butyllithium (2.5 M in hexanes), at −78 °C was added a solution of 150 mg (0.43 mmol) of the above alkylated material in 1 mL of THF over a 10-min period. After an additional 1 h at −78 °C, iodomethane (110 mg, 0.77 mmol) was added, and the reaction mixture was allowed to warm slowly to rt over a 3-h period. Standard ethereal workup, followed by chromatography (elution with H:E, 5:1), afforded 127 mg (80%) of enone **13** which was identical to that previously characterized.

4,4-Dimethyl-2-(2,3-dimethoxy, 4-isopropylphenylmethyl)-3-vinyl-2-cyclohexenone (6). A solution of 1.18 g (3.28 mmol) of enone **13** and $CeCl_3$ (161 mg, 0.66 mmol) in 25 mL of ether at rt was treated dropwise with 5.0 mL (5.00 mmol) of vinylmagnesium bromide (1.0 M in THF) over a 5-min period. The reaction mixture was stirred at rt for a 1-h period. Standard ethereal workup, followed by purification by chromatography (elution with H:E, 4:1), provided 830 mg (74%) of conjugated dienone **6** which was homogeneous by TLC analysis (H:E, 2:1, R_f **13** = 0.37, R_f **6** = 0.68): ^{1}H NMR (300 MHz) δ 1.18 (d, 6 H, J = 6.8 Hz), 1.24 (s, 3 H), 1.94 (t, 2 H, J = 6.9 Hz), 2.55 (t, 2 H, J = 6.8 Hz), 3.17−3.35 (m, 1 H), 3.68 (s, 2 H), 3.85 (s, 3 H), 3.88 (s, 3 H), 5.13 (dd, 1H, J = 17.8 Hz, 1.9 Hz), 5.35 (dd, 1 H, J = 12.0 Hz, 1.7 Hz), 6.35 (dd, 1 H, J = 17.8 Hz, 12.0 Hz), 6.53 (d, 1 H, J = 8.1 Hz), 6.82 (d, 1H, J = 8.1 Hz); ^{13}C NMR (75.5 MHz) 198.5, 163.4, 150.4, 150.2, 139.9, 133.4, 132.3, 132.2, 122.6, 120.7, 119.5, 60.5, 59.7, 37.2,

35.4, 34.4, 27.2, 26.5, 26.2, 23.5 ppm; IR (film) 1669, 1451, 1408, 1269 cm^{-1}. Anal. for $C_{22}H_{30}O_3$. Calcd: C, 77.10%, H, 8.80%. Found: 76.95%, H, 8.90%.

11,12-Dimethoxy-9(10→20)-10αH-abeo-abieta-5(10),8,11,13-tetraen-1-one (7) and 8,9-Dimethoxy-1,1-dimethyl-7-isopropyl-1,2,10,11-tetrahydro-5*H*-dibenzo[*a,d*]cyclohepten-4-one (16). To a solution of **6** (4.0 g, 11.70 mmol) in 100 mL of CH_2C1_2 at −78 °C was added 4.0 mL of $TiCl_4$ (36.60 mmol), and the reaction mixture was allowed to warm to rt over a 1-h period. Standard ethereal workup, followed by chromatography (elution H:E, 4:1), provided 600 mg (15%) of 8,9-dimethoxy-1,1-dimethyl-7-isopropyl-1,2,10,11-tetrahydro-5*H*-dibenzo[*a*,*d*]cyclohepten-4-one (**16**) which was homogeneous by TLC analysis (H:E, 1:1, R_f **6** = 0.68, R_f **16** = 0.62): ^{1}H NMR (250 MHz) δ 1.15−1.25 (m, 12 H), 1.82 (t, 2 H, J = 6.9 Hz), 2.50 (t, 2 H, J = 6.8 Hz), 2.70 (br t, 2 H, J = 6.4 Hz), 3.00 (br t, 2 H, J = 6.5 Hz), 3.21−3.30 (m, 1 H), 3.79 (s, 2 H), 3.83 (s, 6 H), 6.82 (s, 1 H).

Continued elution afforded 3.0 g (75%) of 1,12-dimethoxy-9(10→20)-10αH-abeo-abieta-5(10),8,11,13-tetraen-1-one (**7**) which was homogeneous by TLC analysis (H:E, 1:1, R_f **7** = 0.53): ^{1}H NMR (250 MHz) δ 1.17 (s, 6 H), 1.20 (d, 6 H, J = 7.0 Hz), 1.80 (t, 2 H, J = 6.9 Hz), 2.50 (t, 2 H, J = 6.9 Hz), 2.67 (t, 2 H, J = 6.3 Hz), 2.99 (t, 2 H, J = 6.3 Hz), 3.28 (heptet, 1 H, J = 7.0 Hz), 3.82 (s, 3 H), 3.85 (s, 3 H), 3.91 (s, 2 H), 6.70 (s, 1 H); ^{13}C NMR (75.5 MHz) 197.4 (s), 165.2 (s), 150.2 (s), 148.6 (s), 140.1 (s), 136.1 (s), 133.1 (s), 130.2 (s), 121.1 (d), 60.9 (q), 60.8 (q), 37.1 (t), 36.4 (s), 34.3 (t), 30.9 (t), 29.4 (t), 26.7 (d), 26.6 (q), 23.6 (q), 20.2 (t) ppm; IR (film) 1660, 1048, 727 cm^{-1}.

Cyclization of 6 Using Boron Trifluoride Etherate. To a solution of **6** (80 mg) in 3 mL of CH_2Cl_2 at rt was added 95 μL of boron trifluoride etherate (0.58 mmol), and the reaction mixture was stirred for 10 h. Standard ethereal workup, followed by purification by silica gel chromatography (elution with H:E, 4:1), afforded 59 mg (74%) of enone **16** and 15 mg (16%) of enone **7**.

11,12-Dimethoxy-9(10→20)-10αH-abeo-abieta-1(10),8,11,13-tetraene (barbatusol dimethyl ether, 17). Enone **7** (743 mg, 2.17 mmol) was heated at reflux for 30 min with 606 mg (3.25 mmol) of tosylhydrazine in 10 mL of absolute ethanol. Evaporation of the solvent and elution of the residue through a plug of silica gel afforded the crude hydrazone, which was used without further purification or characterization (H:E, 5:1, R_f hydrazone = 0.32, R_f **7** = 0.85).

The hydrazone was stirred under nitrogen in 9 mL of DMF and 9 mL of sulfolane containing 50 mg of bromocresol green. The mixture was warmed to 100 °C, and sodium cyanoborohydride (1.36 g, 21.70 mmol) was added, followed by sufficient 2 N HCl to give a tan color. Heating was continued for 40 min during which time several portions of 2 N HCl were added to maintain the proper acidity, as indicated by the tan color. The mixture was cooled, poured into water, and extracted with ether. The residue obtained was dried over anhydrous magnesium sulfate, filtered, and concentrated. The resulting residue was chromatographed to give 528 mg (75%) of barbatusol dimethyl ether (**17**) which was homogeneous by TLC analysis (H:E, 1:1, R_f hydrazone = 0.32, R_f **17** = 0.80): ^{1}H NMR (250 MHz) δ 0.87 (s, 3 H), 0.89 (s, 3 H), 0.92−0.99 (m, 2 H), 1.19 (d, 6 H, J = 8.0 Hz), 1.12−1.38 (m, 8 H), 1.79 (d, 1 H, J = 12.1 Hz), 1.90−2.15 (m, 3 H), 2.77−2.84 (td, 2 H, J = 8.6 Hz, 3.0 Hz), 3.03 (d, 1 H, J = 14.4 Hz), 3.27 (heptet, 1 H, J = 6.9 Hz), 3.83 (s, 3 H), 3.85 (s, 3 H), 5.50 (br t, 1 H), 6.72 (s, 1 H); ^{13}C NMR (75.5 MHz) 149.5, 148.7, 139.2, 138.3, 137.9, 132.4, 121.6, 121.3, 60.7, 60.6, 51.4, 35.3, 35.1, 32.1, 31.3, 30.0, 27.6, 27.2, 26.6, 23.8, 23.5, 23.2 ppm.

(±)-Barbatusol (1). Barbatusol dimethyl ether (**17**) (710 mg, 2.20 mmol) was combined with ethanethiol (3.0 mL, 36.00 mmol) and 800 mg of sodium hydride (80% dispersion in oil) in 20 mL of freshly distilled DMF. The reaction mixture was refluxed under nitrogen for 5 h and acidified with 2 N HCl. Standard ethereal workup, followed by purification by chromatography on silica gel (elution with H:E, 10:1), gave 170 mg (25%) of phenols **18a** and **18b** as an inseparable mixture which was homogenous by TLC analysis (H:E, 5:1, R_f **17** = 0.95, R_f **18a/b** = 0.56): ^{1}H NMR (300 MHz) δ 0.88 (s, 3 H), 0.92 (s, 3 H), 1.25 (d, 6 H, J = 6.9 Hz), 1.72−2.15 (m, 5 H), 2.60−2.90 (m, 3 H), 3.00−3.15 (m, 1 H), 3.15−3.35 (m, 2 H), 3.78 (s, 3 H), 5.52 (br s, 1 H), 5.62 (s, 0.4 H), 5.69 (s, 0.6 H), 6.52 (s, 0.6 H), 6.71 (s, 0.4 H). These data represent a mixture of phenols **18a** and **18b**.

Continued elution (H:E, 10:1) afforded 425 mg (65%) of racemic barbatusol which was homogeneous by TLC analysis (H:E, 5:1, R_f **17** = 0.94, R_f **1** = 0.22): ^{1}H NMR (300 MHz) δ 0.88 (s, 3 H), 0.92 (s, 3 H), 1.11−1.43 (m, 8 H), 1.81 (br d, 1 H, J = 12.0 Hz), 1.92−2.07 (m, 3 H), 2.74−2.82 (m, 2 H), 3.05−3.12 (m, 2 H), 3.68 (d, 1 H, J = 14.9 Hz), 4.94 (br s, 1 H), 5.28 (br s, 1 H), 5.51 (br t, 1 H), 6.52 (s, 1 H); ^{13}C NMR (75.5 MHz) 140.3 (s), 139.0 (s), 138.0 (s), 134.6 (s), 131.0 (s), 124.4 (s), 121.2 (d), 117.6 (d), 77.2 (s), 50.8 (d), 35.3 (t), 34.5 (t), 32.1 (s), 31.2 (t), 30.5 (t), 27.5 (q), 27.2 (q), 23.2 (t), 22.8 (q), 22.5 (q) ppm; IR (film) 3500−3100 (br), 1446, 1282, 998 cm^{-1}.

Deprotection of 17 Using L-Selectride. To 41 mg of **17** (0.125 mmol) in 4.0 mL of dry glyme was added 750 μL of L-Selectride (1.0 M, 0.75 mmol), and the resulting mixture was refluxed (90 °C) until TLC analysis indicated that the reaction was complete (2 days). The reaction mixture was cooled to 0 °C and diluted with 50 mL of ether, and the resulting mixture was quenched slowly with water. Standard ethereal workup, followed by chromatography (elution with H:E, 10:1), gave 18 mg of phenols **18a** and **18b** (45%) as an inseparable mixture.

Continued elution (H:E, 5:1) provided 17 mg (45%) of racemic-barbatusol which was identical to that described above.

2-(2,3-Dimethoxy-4-isopropylphenylmethyl)-3-vinyl-2-cyclohexenone (19). A solution of 1.18 g (3.28 mmol) of enone **15** and $CeCl_3$ (161 mg, 0.66 mmol) in 25 mL of ether at 0 °C was treated dropwise with 5.0 mL (5.0 mmol) of vinylmagnesium bromide (1.0 M in THF) over a 5-min period. The reaction mixture was stirred for 3 h with slow warming to rt. It was then diluted with ether (30 mL), and 10 mL of a solution of aqueous 10% HCl was added. After 5 min of vigorous stirring, the phases were separated, and the ethereal phase was washed with saturated aqueous sodium bicarbonate, saturated aqueous NH_4Cl, dried over anhydrous magnesium sulfate, filtered, and then concentrated. Purification by chromatography (elution with H:E, 4:1) provided 830 mg (74%) of conjugated dienone **19** which was homogeneous by TLC analysis (H:E, 2:1, R_f **15** = 0.37, R_f **19** = 0.68): ^{1}H NMR (300 MHz) δ 1.18 (d, 6 H, J = 6.6 Hz), 2.06 (heptet, 1 H, J = 6.4 Hz), 2.50 (t, 1 H, J = 6.4 Hz), 2.60 (t, 1 H, J = 6.4 Hz), 3.26 (heptet, 1 H, J = 6.6 Hz), 3.81 (s, 2 H), 3.86 (s, 3 H), 3.91 (s, 3 H), 5.44 (d, 1 H, J = 11.2 Hz), 5.70 (d, 1 H, J = 17.6 Hz), 6.60 (d, 1 H, J = 8.2 Hz), 6.84 (d, 1 H, J = 8.2 Hz), 6.96 (dd, 1 H, J = 17.6 Hz, 11.2 Hz); ^{13}C NMR (75.5 MHz) 199.4 (s), 151.0 (s), 150.5 (s), 150.2 (s), 140.3 (s), 135.1 (d), 135.1 (s) (the preceding signals overlap), 131.4 (s), 123.3 (d), 120.8 (d), 120.6 (t), 60.5 (q), 60.0 (q), 38.0 (t), 26.6 (d), 25.5 (t), 23.5 (t), 23.5 (q) (the preceding signals overlap), 21.5 (t) ppm.

Cyclization of 19 using BF_3−Et_2O. To a solution of **19** (26 mg, 0.08 mmol) in 3 mL of CH_2Cl_2 at rt was added 50 μL of BF_3−Et_2O. The resulting mixture was refluxed for 50 h. Standard ethereal workup, followed by chromatography (elution with H:E, 2:1), gave 10 mg (38%) of 8,9-dimethoxy-7-isopropyl-1,2,10,11-tetrahydro-5*H*-dibenzo[*a*,*d*]cyclohepten-4-one (**21**) which was homogeneous by TLC analysis (H:E, 2:1, R_f **19** = 0.68, R_f **21** = 0.55): ^{1}H NMR (250 MHz) δ 1.20 (d, 6 H, J = 7.2 Hz), 1.50 (heptet, 2 H, J = 6.5 Hz), 2.21 (t, 2 H, J = 6.5 Hz), 2.43 (t, 2 H, J = 6.2 Hz), 2.55 (t, 2 H, J = 6.5 Hz), 3.06 (t, 2 H, J = 6.2 Hz), 3.28 (heptet, 1 H, J = 7.2 Hz), 3.78 (s, 2 H), 3.83 (s, 3 H), 3.84 (3 H), 6.84 (s, 1 H); ^{13}C NMR (75.5 MHz) 198.4 (s), 157.7 (s), 149.8 (s), 148.8 (s), 140.1 (s), 137.4 (s), 132.6 (s), 131.8 (s), 121.6 (d), 60.8 (q), 37.8 (t), 35.9 (t), 33.0 (t), 28.2 (t), 26.6 (d), 23.6 (q), 22.5 (t), 22.0 (t) ppm.

Continued elution (H:E, 2:1) gave 8 mg (31%) of 6,7-dimethoxy-8-isopropyl-1,2,10,11-tetrahydro-5*H*-dibenzo[*a*,*d*]-cyclohepten-4-one (**20**) which was homogeneous by TLC analysis (H:E, 2:1, R_f **19** = 0.68, R_f **20** = 0.52): ^{1}H NMR (250 MHz) δ 1.22 (d, 6 H, J = 7.2 Hz), 1.88 (heptet, 2 H, J = 6.5 Hz), 2.20 (t, 2 H, J = 6.5 Hz), 2.42 (t, 2 H, J = 6.5 Hz), 2.54 (t, 2 H, J = 6.5 Hz), 2.98 (t, 2 H, J = 6.5 Hz), 3.30 (heptet, 1 H, J = 7.1 Hz), 3.76 (s, 3 H), 3.84 (s, 3 H), 3.90 (s, 2 H), 6.78 (s, 1 H); ^{13}C

NMR (62.9 MHz) 197.4 (s), 158.0 (s), 157.8 (s), 149.8 (s), 148.6 (s), 140.0 (s), 137.4 (s), 132.4 (s), 132.2 (s), 120.2 (d), 60.9 (q), 60.8 (q), 37.7 (t), 36.3 (t), 33.0 (t), 29.6 (t), 26.5 (d), 23.6 (q), 22.0 (t), 19.3 (t) ppm.

Cyclization of 19 Using $TiCl_4$. To a solution of **19** (45 mg, 0.14 mmol) in 3 mL of CH_2Cl_2 was added 90 μL of $TiCl_4$ (0.82 mmol) at −78 °C. The reaction mixture was warmed to 0 °C over a 90-min period, stirred at 0 °C for a 30-min period, and then stirred at rt for 4 h. Standard ethereal workup, followed by chromatography (elution with H:E, 2:1), afforded 2.1 mg (7%) of **21** and 25.2 mg (56%) of **20**, both of which were identical to that previously characterized.

4-(2,3-Dimethoxy-4-isopropylphenylmethyl)-4-methyl-3-vinyl-2-cyclohexenone (22). To a solution of LDA, prepared from diisopropylamine (700 μL, 5.0 mmol) in 15 mL of THF and 2.0 mL (5.00 mmol) of *n*-butyllithium (2.5 M in hexanes), at −78 °C was added a solution of 660 mg (4.28 mmol) of 3-ethoxy-6-methyl-2-cyclohexenone in 6 mL of THF over a 50-min period. After an additional 1 h at −78 °C, bromide **10** (1.27 g, 4.64 mmol) was added and the reaction mixture was warmed to rt over a 12-h period. Standard ethereal workup, followed by chromatograpy (elution with H:E, 1:1), afforded 490 mg (74%) of 3-ethoxy-6-(2,3-dimethoxy-4-isopropylphenylmethyl)-6-methyl-2-cyclohexenone which was homogeneous by TLC analysis (H:E, 1:1, R_f enone = 0.35, R_f alkylated adduct = 0.43): ^{1}H NMR (250 MHz) δ 1.00 (s), 1.13 (d, 6 H, J = 7.0 Hz), 1.29 (t, 3 H, J = 7.0 Hz), 1.52−1.68 (m, 1 H), 1.71−1.86 (m, 1 H), 2.22−2.51 (m, 2 H), 2.76 (d, 1 H, J = 11.4 Hz), 2.85 (d, 1 H, J = 11.4 Hz), 3.21 (heptet, 1 H, J = 7.0 Hz), 3.73 (s, 3 H), 3.75 (s, 3 H), 3.83 (q, 2 H, J = 7.0 Hz), 5.24 (s, 1 H); ^{13}C NMR (62.9 MHz) 203.6 (s), 175.7 (s), 151.7 (s), 150.0 (s), 140.6 (s), 128.9 (s), 126.9 (d), 120.1 (d), 101.2 (d), 63.8 (t), 60.2 (q), 59.7 (q), 44.5 (s), 35.4 (t), 31.2 (t), 26.4 (d), 25.9 (t), 23.3 (q), 22.4 (q), 13.9 (q) ppm.

A solution of 280 mg (0.81 mmol) of the above enone in 15 mL of ether at 0 °C was treated dropwise with 2.0 mL (2.00 mmol) of vinylmagnesium bromide (1.0 M in THF) over a 5-min period. The reaction mixture was warmed to rt over a 12-h period. Standard ethereal workup, followed by chromatography (elution with H:E, 2:1), provided 262 mg (98%) of dienone **22** which was homogeneous by TLC analysis (H:E, 2:1, R_f enone = 0.37, R_f **22** = 0.68): ^{1}H NMR (300 MHz) δ 1.06 (s, 3 H), 1.18 (d, 6 H, J = 7.0 Hz), 1.61−1.72 (m, 1 H), 1.94 (dt, 1 H, J = 17.5 Hz, 5.3 Hz), 2.54 (ddd, 1 H, J = 17.1 Hz, 11.4 Hz, 5.3 Hz), 2.76 (d, 1 H, J = 13.3 Hz), 2.85 (d, 1 H, J = 13.4 Hz), 3.27 (heptet, 1 H, J = 7.0 Hz), 3.49 (s, 3 H), 5.36 (dd, 1 H, J = 10.9 Hz, 1.4 Hz), 5.71 (dd, 1 H, J = 16.7 Hz, 1.4 Hz), 6.12 (s, 1 H), 6.53 (dd, 1 H, J = 16.7 Hz, 10.9 Hz), 6.79 (d, 1 H, J = 8.0 Hz), 6.85 (d, 1 H, J = 8.0 Hz); ^{13}C NMR (62.9 MHz) 199.9 (s), 165.8 (s), 151.8 (s), 150.3 (s), 141.5 (s), 134.4 (d), 128.2 (s), 126.5 (d), 123.4 (d), 120.3 (d), 119.9 (t), 60.3 (q), 59.9 (q), 38.9 (s), 36.6 (t), 34.1 (t), 33.6 (t), 26.6 (d), 25.2 (q), 23.4 (q) ppm.

6,7-Dimethoxy-8-isopropyl-4a-methyl-4,4a,10,11-tetrahydro-5*H*-dibenzo[*a*,*d*]cyclohepten-2-one (23). To a solution of **22** (84 mg, 0.26 mmol) in 3 mL of CH_2Cl_2 was added 150 μL of BF_3-Et_2O, and the resulting mixture was refluxed for 12 h. Standard ethereal workup, followed by chromatrography (elution with H:E, 1:1), afforded 81 mg (96%) of **23** which was homogeneous by TLC analysis (H:E, 1:1, R_f **22** = 0.51, R_f **23** = 0.46): ^{1}H NMR (250 MHz) δ 1.09 (s, 3 H), 1.21 (dd, 6 H, J = 7.1 Hz, 3.4 Hz), 1.89 (dt, 1 H, J = 13.5 Hz, 5.1 Hz), 2.03 (ddd, 1 H, J = 15.0 Hz, 12.4 Hz, 5.3 Hz), 2.35−2.58 (m, 3 H), 2.69 (d, 1 H, J = 13.9 Hz), 2.71−2.96 (m, 2 H), 3.00 (d, 1 H, J = 13.9 Hz), 3.28 (heptet, 1 H, J = 7.1 Hz), 3.81 (s, 3 H), 3.83 (s, 3 H), 5.75 (s, 1 H), 6.72 (s, 1 H); ^{13}C NMR (62.9 MHz) 199.8 (s), 171.4 (s), 151.2 (s), 148.6 (s), 140.6 (s), 136.6 (s), 128.6 (s), 126.6 (d), 121.2 (d), 60.5 (q), 60.3 (q), 38.9 (s), 37.3 (t), 37.2 (t), 34.3 (t), 34.3 (t) (the two preceding signals overlap), 33.5 (t), 26.6 (d), 23.5 (q), 23.0 (q) ppm.

Preparation of 23 Using $TiCl_4$. To a solution of dienone **22** (80 mg, 0.24 mmol) in 5 mL of CH_2Cl_2 was added 150 μL of $TiCl_4$ (1.37 mmol) at −78 °C and the reaction mixture was warmed to 0 °C over a 90-min period. The reaction was stirred an additional 5 h at 0 °C before TLC analysis indicated that reaction was complete. Standard ethereal workup, followed by chromatography (elution with H:E, 2:1), gave 51 mg (66%) of **23**, which was identical to that previously prepared.

Preparation of 23 Using $FeCl_3$. To a solution of $FeCl_3$ (25 mg) in 2 mL of CH_2Cl_2 was added dienone **22** (49 mg, 0.15 mmol) in 1 mL of CH_2Cl_2. The resulting mixture was stirred at rt for 12 h. Standard ethereal workup and chromatography gave 39 mg (80%) of enone **23**, which was identical to that previously characterized.

2-(4-Isopropylphenylmethyl)-3-vinyl-2-cyclohexenone (24). To sodium borohydride (2.57 g, 68.00 mmol) in 175 mL of absolute ethanol at 0 °C was added 4-isopropylbenzaldehyde (20.0 g, 0.135 mol, Eastman) over a 5-min period. The reaction mixture was concentrated under reduced pressure to half volume, and 100 mL of water was added. Standard ethereal workup, followed by chromatography (elution with H:E, 10:1), gave 19.00 g (94%) of 4-isopropylphenylmethyl alcohol which was homogeneous by TLC analysis (H:E, 1:1, R_f aldehyde = 0.82, R_f alcohol = 0.50): ^{1}H NMR (250 MHz) δ 1.28 (d, 6 H, J = 6.9 Hz), 2.29 (br s, 1 H), 2.94 (heptet, 1 H, J = 6.9 Hz), 4.63 (s, 2 H), 7.24 (d, 2 H, J = 8.2 Hz), 7.30 (d, 2 H, J = 8.2 Hz); ^{13}C NMR (62.9 MHz) 148.3 (s), 138.2 (s), 127.1 (d), 126.5 (d), 65.0 (t), 33.8 (d), 23.9 (q) ppm.

To a solution of 18.71 g (0.125 mol) of the above alcohol in 200 mL of dry ether at 0 °C was added phosphorus tribromide (5.90 mL, 62 mmol) over a 5-min period. Standard ethereal workup, followed by chromatograpy (elution with H:E, 1:1), afforded 22.33 g (84%) of 4-isopropylphenylmethyl bromide which was homogeneous by TLC analysis (H:E, 5:1, R_f alcohol = 0.12, R_f bromide = 0.85): ^{1}H NMR (250 MHz) δ 1.35 (d, 6 H, J = 6.2 Hz), 2.91 (heptet, 1 H, J = 6.2 Hz), 4.51 (s, 2 H), 7.14 (d, 2 H, J = 7.8 Hz), 7.35 (d, 2 H, J = 7.8 Hz); ^{13}C NMR (62.9 MHz) 149.3 (s), 135.1 (s), 129.0 (d), 126.9 (d), 33.9 (d), 33.8 (t), 23.9 (q) ppm.

1,3-Cyclohexanedione (5.25 g, 46.80 mmol) was dissolved in 10 mL of absolute methanol. To this solution was added 5.00 g of the above benzyl bromide (23.50 mmol), 1.95 g of KI (11.71 mmol), and 3.24 g of K_2CO_3 (23.42 mmol). The reaction mixture was then stirred for a 3-h period. The reaction mixture was diluted with 50 mL of water and extracted twice with 50 mL of a 1:1 mixture of ethyl acetate and ether. The organic phase was extracted with saturated aqueous $NaHCO_3$ to remove unreacted 1,3-cyclohexanedione. The sodium salt of the alkylated dione was extracted into aqueous 5% NaOH. This solution was acidified by addition of aqueous 10% HCl and extracted with 50 mL of a 1:1 mixture of ethyl acetate and ether. The combined organic extracts were dried over anhydrous magnesium sulfate and concentrated. The white solid residue was recrystallized from ethanol/water (1:3) to give 3.80 g (66%) of 2-(4-isopropylphenylmethyl)-1,3-cyclohexanedione which was homogeneous by TLC analysis (ether, R_f dione = 0.35): mp 171−172.5 °C; ^{1}H NMR (250 MHz) δ 1.22 (d, 6 H, J = 6.9 Hz), 1.92 (tt, 2 H, J = 6.4 Hz, 6.4 Hz), 2.43 (t, 4 H, J = 6.4 Hz), 2.46 (heptet, 1 H, J = 6.9 Hz), 3.63 (s, 2 H), 7.09 (d, 2 H, J = 8.2 Hz), 7.16 (d, 2 H, J = 8.2 Hz); ^{13}C NMR (62.9 MHz) 204.0 (s), 146.1 (s), 137.9 (s), 128.9 (d), 126.3 (d), 115.5 (s), 33.5 (d), 27.0 (t), 24.0 (q), 20.6 (t), 20.6 (t) (the two preceding signals overlap) ppm.

To a suspension of NaH (57% dispersion in mineral oil, 690 mg, 16.43 mmol) in 10 mL of DMF at 0 °C was added the above dione (2.50 g, 10.21 mmol) in 25 mL of DMF over a 30-min period. Dimethyl sulfate (1.30 mL, 13.32 mmol) was then added and the resulting mixture was stirred for 3 h. Standard ethereal workup, followed by chromatography (elution with H:E, 3:1), gave 2.17 g (82%) of 2-(4-isopropylphenylmethyl)-3-methoxy-2-cyclohexenone which was homogeneous by TLC analysis (ether, R_f dione = 0.66, R_f enol ether = 0.43): ^{1}H NMR (300 MHz) δ 1.22 (d, 6 H, J = 6.9 Hz) 2.00 (tt, 2 H, J = 6.2 Hz, 6.2 Hz), 2.37 (t, 2 H, J = 6.2 Hz), 2.59 (t, 2 H, J = 6.2 Hz), 2.85 (heptet, 1 H, J = 6.9 Hz), 3.59 (s, 2 H), 3.82 (s, 3 H), 7.08 (d, 2 H, J = 8.2 Hz), 7.18 (d, 2 H, J = 8.2 Hz); ^{13}C NMR (62.9 MHz) 198.0 (s), 172.7 (s), 145.7 (s), 138.8 (s), 128.5 (d), 126.0 (d), 119.1 (s), 55.2 (q), 36.2 (t), 33.6 (d), 27.2 (t), 24.8 (t), 24.0 (q), 20.7 (t) ppm.

A solution of 4.09 g (15.8 mmol) of the above enone and 390 mg of $CeCl_3$ (1.58 mmol) in 53 mL of ether at rt was treated dropwise with 31.6 mL (31.60 mmol) of vinylmagnesium

bromide (1.0 M in THF) over a 5-min period. The reaction mixture was stirred for 5 min. Standard ethereal workup, followed by chromatography (elution with H:E, 10:1), provided 3.30 g (82%) of conjugated dienone **24** which was homogeneous by TLC analysis (H:E, 1:2, R_f enone = 0.23, R_f **24** = 0.80): ^{1}H NMR (250 MHz) δ 1.23 (d, 6 H, J = 6.9 Hz), 1.95−2.15 (m, 2 H), 2.50 (t, 2 H, J = 6.1 Hz), 2.59 (t, 2 H, J = 6.1 Hz), 2.86 (heptet, 1 H, J = 6.9 Hz), 4.81 (s, 2 H), 5.49 (d, 1 H, J = 11.0 Hz), 5.71 (d, 1 H, J = 17.3 Hz), 6.90−7.15 (m, 5 H); ^{13}C NMR (62.9 MHz) 199.5 (s), 150.5 (s), 146.1 (s), 137.5 (s), 135.5 (s), 135.0 (d), 128.1 (d), 126.3 (d), 120.9 (t), 38.1 (t), 33.6 (d), 29.5 (t), 25.5 (t), 24.0 (q), 21.9 (t) ppm. Anal. for $C_{22}H_{30}O_3$. Calcd: C, 84.99%, H, 8.72%. Found: 84.75%, H, 8.80%.

Attempted Cyclization of 24 Using $TiCl_4$. To a solution of substrate **24** (400 mg, 1.57 mmol) dissolved in 10 mL of CH_2Cl_2 was added 520 μL (4.70 mmol) of $TiCl_4$ at −78 °C. The reaction mixture was warmed to 20 °C over a 7-h period. The reaction was then stirred for an additional 5 h at 0 °C. Standard ethereal workup, followed by chromatography (elution with H:E, 10:1), gave 65 mg (14%) of 2-(4-isopropylphenylmethyl)-3-(2-chloroethyl)-2-cyclohexenone (**25**), which was homogeneous by TLC analysis: ^{1}H NMR (250 MHz) δ 1.22 (d, 6 H, J = 6.9 Hz), 1.90−2.10 (m, 2 H), 2.35−2.55 (m, 4 H), 2.75−2.95 (m 3 H), 3.52 (t, 2 H, J = 7.4 Hz), 3.70 (s, 2 H), 7.04 (d, 2 H, J = 8.3 Hz), 7.11 (d, 2 H, J = 8.3 Hz).

Reaction of 24 Using BF_3−Et_2O. To a solution of **24** (100 mg, 0.39 mmol) in 4 mL of CH_2Cl_2 was added 145 μL (1.18 mmol) of BF_3−Et_2O. The reaction mixture was stirred for 6 h at rt and then refluxed for a 7-h period. Standard ethereal workup furnished only unreacted **24**.

2-(3-Methoxy-4-isopropylphenylmethyl)-3-vinyl-2-cyclohexenone (26). To a solution of 3.30 g (18.31 mmol) of 4-isopropyl-3-methoxybenzyl alcohol (**30**)[31] in 75 mL of dry ether at 0 °C was added phosphorus tribromide (2.10 mL, 22.00 mmol) over a 5-min period. The reaction mixture was stirred at rt for 10 h. Standard ethereal workup, followed by chromatography (elution with H:E, 20:1), afforded 3.50 g (79%) of 3-methoxy-4-isopropylphenylmethyl bromide (**31**) which was homogeneous by TLC analysis (H:E, 9.75:0.25, R_f alcohol = 0.05, R_f bromide = 0.43): ^{1}H NMR (300 MHz) δ 1.18 (d, 6 H, J = 6.8 Hz), 3.23−3.30 (m, 1 H), 3.83 (s, 3 H), 4.48 (s, 2 H), 6.85 (s, 1 H), 6.94 (d, 1 H, J = 7.9 Hz), 7.14 (d, 1 H, J = 7.8 Hz).

Bromide **31** (0.50 g, 2.06 mmol) was dissolved in 0.5 mL of water and 0.5 mL of THF. 1,3-Cyclohexanedione (0.46 g, 4.11 mmol), K_2CO_3 (0.57 g, 4.11 mmol), and KI (173 mg, 1.03 mmol) were then added and the mixture was stirred at rt for 12 h. The reaction was quenched with 2 mL of saturated NH_4Cl. Mixture was extracted with ether (3 × 10 mL). The organic phase was extracted with saturated aqueous $NaHCO_3$ to remove unreacted 1,3-cyclohexanedione. The sodium salt of the alkylated dione was then extracted into aqueous 5% NaOH. This solution was acidified by the addition of aqueous 10% HCl and extracted twice with 50 mL of a 1:1 mixture of ethyl acetate and ether. The combined organic extracts were dried over anhydrous magnesium sulfate and concentrated. The white solid residue was recrystallized from methanol: water (1:1) to give 243 mg (43%) of 2-(4-isopropyl-3-methoxyphenylmethyl)-1,3-cyclohexanedione which was homogeneous by TLC analysis (ether, R_f dione = 0.35): mp 178−179 °C; ^{1}H NMR (250 MHz) δ 1.15 (d, 6 H, J = 6.8 Hz), 1.96 (quintet, 2 H, J = 6.5 Hz), 2.42 (t, 4 H, J = 6.5 Hz), 3.42−3.50 (m, 0.5 H), 3.15−3.25 (m, 1 H), 3.63 (s, 2 H), 3.70 (s, 3 H), 6.23 (s, 0.5 H), 6.70 (s, 1 H), 6.75 (d, 1 H, J = 7.5 Hz), 7.07 (d, 1 H, J = 7.7 Hz); ^{13}C NMR (62.9 MHz) 188.0 (s), 156.8 (s), 138.8 (s), 134.6 (s), 125.8 (d), 120.1 (d), 115.4 (s), 110.9 (d), 55.3 (q), 32.6 (t), 32.6 (t) (the two preceding signals overlap), 27.5 (t), 26.4 (d), 22.7 (q), 20.6 (t) ppm.

To a suspension of degreased NaH (57% dispersion in mineral oil, 151 mg, 3.60 mmol) in 5 mL of dry DMF at 0 °C was added the above dione (617 mg, 2.25 mmol) in 5 mL of DMF over a 5-min period. The resulting solution was stirred at rt for 30 min. Dimethyl sulfate (369 mg, 2.93 mmol) was then added, and the resulting mixture was stirred at rt for 1 h. The reaction mixture was diluted with ether, washed sequentially with aqueous 10% HCl and saturated aqueous Na_2CO_3, dried over anhydrous magnesium sulfate, concentrated, and chromatographed (elution with H:E, 3:1) to give 477 mg (74%) of 2-(4-isopropyl-3-methoxyphenylmethyl)-3-methoxy-2-cyclohexenone which was homogeneous by TLC analysis (H:E, 1:2, R_f dione = 0.75, R_f enol ether = 0.18): mp 94−96 °C; ^{1}H NMR (250 MHz) δ 1.18 (d, 6 H, J = 6.9 Hz), 1.95−2.10 (m, 2 H), 2.38 (t, 2 H, J = 6.2 Hz), 2.60 (t, 2 H, J = 6.2 Hz), 3.25 (heptet, 1 H, J = 6.9 Hz), 3.59 (s, 2 H), 3.81 (s, 3 H), 3.83 (s, 3 H), 6.75−6.85 (m, 2 H), 7.05 (d, 1 H, J = 7.7 Hz); ^{13}C NMR (62.9 MHz) 197.9 (s), 172.5 (s), 156.3 (s), 140.0 (s), 133.8 (s), 125.3 (d), 120.4 (d), 119.0 (s), 111.2 (d), 55.2 (q), 55.2 (q) (the methoxyl signals overlap), 36.2 (t), 27.5 (t), 26.3 (d), 24.8 (t), 22.7 (q), 20.7 (t) ppm.

A solution 470 mg of the above enone in 15 mL of THF was treated dropwise with 3.30 mL (3.30 mmol) of vinylmagnesium bromide (1.0 M in THF) over a 5-min period. The reaction mixture was stirred at rt for 5 min and then quenched with ice and diluted with 20 mL of ether and 10 mL of 10% aqueous HCl. Standard ethereal workup, followed by purification by chromatography (elution with H:E, 10:1), provided 410 mg (88%) of conjugated dienone **26** which was homogeneous by TLC analysis (H:E, 1:2, R_f **26** = 0.79): ^{1}H NMR (250 MHz) δ 1.17 (d, 6 H, J = 6.9 Hz), 1.95−2.15 (m, 4 H), 2.50 (t, 2 H, J = 6.1 Hz), 2.59 (t, 2 H, J = 6.1 Hz), 3.20 (heptet, 1 H, J = 6.9 Hz), 3.79 (s, 3 H), 3.80 (s, 2 H), 5.49 (d, 1 H, J = 11.0 Hz), 5.71 (d, 1 H, J = 16.8 Hz), 6.63−6.75 (m, 2 H), 7.04 (dd, 1 H, J =16.8 Hz, 11.0 Hz), 7.06 (d, 1 H, J = 7.7 Hz); ^{13}C NMR (62.9 MHz) 199.5 (s), 156.6 (s), 150.6 (s), 138.7 (s), 135.5 (s), 135.1 (d), 134.3 (s), 125.7 (d), 120.9 (t), 119.9 (d), 110.7 (d), 55.2 (q), 38.1 (t), 29.8 (t), 26.4 (d), 25.6 (t), 22.7 (q), 21.9 (t) ppm.

7-Methoxy-8-isopropyl-1,2,10,11-tetrahydro-5*H*-dibenzo[*a*,*d*]cyclohepten-4-one (27). To a solution of dienone **26** (52 mg, 0.18 mmol) in 2 mL of dry CH_2Cl_2 was added BF_3−Et_2O (77 mg, 0.54 mmol). The reaction was refluxed for 12 h. Standard ethereal workup, and purification by chromatography (elution with H:E, 5:1), provided 52 mg (100%) of **27** which was homogeneous by TLC analysis (H:E, 5:1, R_f **26** = 0.48, R_f **27** = 0.40): ^{1}H NMR (250 MHz) δ 1.21 (d, J = 6.9 Hz), 1.80−2.00 (m, 2 H), 2.21 (t, 2 H, J = 5.8 Hz), 2.43 (t, 2 H, J = 6.2 Hz), 2.55 (t, 2 H, J = 6.7 Hz), 2.98 (t, 2 H, J = 6.7 Hz), 3.29 (heptet, 1 H, J = 6.9 Hz), 3.81 (s, 5 H), 6.73 (s, 1 H), 6.99 (s, 1 H); ^{13}C NMR (62.9 MHz) 198.3 (s), 157.9 (s), 154.9 (s), 138.8 (s), 134.7 (s), 132.5 (s), 125.5 (d), 111.1 (d), 55.4 (q), 37.7 (t), 36.5 (t), 33.0 (t), 30.2 (t), 28.1 (t), 26.3 (d), 22.7 (q), 21.9 (t) (two aryl signals overlap) ppm; GC-MS (m/z) 284 (M^+, 9%), 122 (100%).

2-(2-Methoxy-4-isopropylphenylmethyl)-3-vinyl-2-cyclohexenone (28). To a solution of 3-isopropylphenol (20.00 g, 0.147 mol, Aldrich) and NaOH (7.36 g, 0.184 mol) in 250 mL of absolute ethanol was added dimethyl sulfate (35.0 mL, 0.36 mol) over a 5-min period. The reaction mixture was refluxed for 2 h. The reaction mixture was concentrated to half volume under reduced pressure and the resulting mixture was diluted with 100 mL of water. Standard ethereal workup provided 21.0 g of 3-isopropylanisole (95%), which was homogenous by TLC analysis (H:E, 1:1, R_f phenol = 0.61, R_f anisole = 0.87): ^{1}H NMR (300 MHz) δ 1.26 (d, 6 H, J = 6.9 Hz), 2.90 (heptet, 1 H, J = 6.9 Hz), 3.83 (s, 3 H), 6.70-6.89 (m, 3 H), 7.22 (t, 1 H, J = 7.5 Hz).

To 3-isopropylanisole (10.00 g, 66.60 mmol) dissolved in 150 mL of dry ether was added 20.00 mL of TMEDA (0.13 mol). The resulting mixture was cooled to −78 °C and 35.0 mL of 2.5 M *n*-butyllithium in hexanes (86.61 mmol) was added slowly. The mixture was allowed to warm to rt over 2 h, after which it was treated at rt with excess gaseous formaldehyde (generated from 6.0 g of paraformaldehyde via pyrolysis at 135 °C). The reaction was quenched with saturated aqueous NH_4Cl. Standard ethereal workup, followed by chromatography (elution with H:E, 5:2), gave 10.51 g (88%) of a 1:1 mixture of 2-methoxy-4-isopropylphenylmethyl alcohol and 2-methoxy-6-isopropylphenylmethyl alcohol which was inseparable based on TLC analysis (H:E, 1:1, R_f anisole = 0.94, R_f alcohols = 0.34): ^{1}H NMR (300 MHz) δ 1.26 (d, 3 H, J = 6.9 Hz), 1.27 (d, 3 H, J = 6.9), 2.46 (br s, 2 H), 2.91 (heptet, 0.5 H, J = 6.9 Hz), 3.32 (heptet, 0.5 H, J = 6.9 Hz), 3.86 (s, 3 H), 3.88 (s, 3 H),

4.65 (s, 1 H), 4.80 (s, 1 H), 6.65−6.85 (m, 1.5 H), 6.95 (d, 0.5 H, J = 7.3 Hz), 7.15−7.30 (m, 1 H).

To a solution of 10.52 g (58.31 mmol) of the above mixture of alcohols in 200 mL of dry ether at 0 °C was added 2.77 mL of phosphorus tribromide (29.22 mmol) over a 5-min period. Standard ethereal workup, followed by chromatography (elution with H:E, 1:1), provided 11.56 g (81%) of an inseparable mixture of 2-methoxy-4-isopropylphenylmethyl bromide and 2-methoxy-6-isopropylphenylmethyl bromide (1:1) which was homogenous by TLC analysis (H:E, 5:3, R_f bromide = 0.82): ^{1}H NMR (250 MHz) δ 1.27 (d, 3 H, J = 6.9 Hz), 1.30 (d, 3 H, J = 6.9 Hz), 2.91 (heptet, 0.5 H, J = 6.9 Hz), 3.31 (heptet, 0.5 H, J = 6.9 Hz), 3.90 (s, 1.5 H), 3.91 (s, 1.5 H), 4.59 (s, 1 H), 4.74 (s, 1 H), 6.72−6.94 (m, 2 H), 7.20−7.35 (m, 1 H).

To 2.77 g of 1,3-cyclohexanedione (24.73 mmol) was added 1.71 g of solid K_2CO_3 (12.30 mmol) dissolved in 4.5 mL of water. To the resulting solution was added 3.00 g of the above mixture of bromides (12.34 mmol). The reaction mixture was stirred for a period of 8 h. The aqueous solution was diluted with 50 mL of water and extracted with 50 mL of a 1:1 mixture of THF and ether. The organic phase was extracted with saturated aqueous $NaHCO_3$ to remove unreacted 1,3-cyclohexanedione, then extracted again with aqueous 5% NaOH. The resulting solution was acidified by addition of aqueous 10% HCl and extracted with 50 mL of a 1:1 mixture of THF and ether. The combined organic extracts were dried over anhydrous magnesium sulfate and concentrated. Titeration of the crude residue with a 3:1 mixture of H:E separated the alkylated product derived from 2-methoxy-6-isopropylphenylmethyl bromide and the desired adduct. The remaining solid residue was recrystallized from methanol:water (1:1) to give 760 mg (22%) of 2-(2-methoxy-4-isopropylphenylmethyl)-1,3-cyclohexanedione which was homogeneous by TLC analysis (ether, R_f dione = 0.64): mp 166−168 °C; ^{1}H NMR (300 MHz) δ 1.24 (d, 6 H, J = 6.9 Hz), 1.85−2.15 (m, 2 H), 2.33 (t, 2 H, J = 6.9 Hz), 2.41 (t, 1 H, J = 6.3 Hz), 2.87 (heptet, 1 H, J = 6.9 Hz), 3.58 (s, 2 H), 3.97 (s, 3 H), 6.75 (d, 1 H, J = 1.2 Hz), 6.82 (dd, 1 H, J = 7.7 Hz, 1.2 Hz), 7.41 (d, 1 H, J = 7.7 Hz); ^{13}C NMR (62.9 MHz) 198.2 (s), 172.0 (s), 154.6 (s), 148.5 (s), 131.6 (d), 126.0 (s), 120.0 (d), 115.1 (s), 108.7 (d), 55.7 (q), 36.6 (t), 34.1 (t), 28.7 (t), 23.9 (q), 20.5 (t), 20.4 (t) ppm.

To a suspension of NaH (57% dispersion in mineral oil, 172 mg, 4.08 mmol) in 3 mL of DMF at 0 °C was added the above dione (700 mg, 2.55 mmol) in a mixture of 7 mL of DMF and 3 mL of THF over a 30-min period. Dimethyl sulfate (313 μL, 3.32 mmol) was then added, and the resulting mixture was stirred for 3 h. The reaction mixture was diluted with ether, washed sequentially with aqueous 10% HCl and saturated aqueous Na_2CO_3, dried over anhydrous magnesium sulfate, concentrated, and chromatographed (elution with H:E, 1:2) to give 564 mg of 2-(2-methoxy-4-isopropylphenylmethyl)-3-methoxy-2-cyclohexenone (76%) which was homogeneous by TLC analysis (ether, R_f dione = 0.62, R_f enol ether = 0.38): ^{1}H NMR (250 MHz) δ 1.23 (d, 6 H, J = 6.9 Hz), 1.95−2.15 (m, 2 H), 2.42 (t, 2 H, J = 7.1 Hz), 2.63 (t, 2 H, J = 6.1 Hz), 2.85 (heptet, 1 H, J = 6.9 Hz), 3.58 (s, 2 H), 3.74 (s, 3 H), 3.85 (s, 3 H), 6.65−6.75 (m, 2 H), 6.8 (d, 2 H, J = 8.2 Hz); ^{13}C NMR (62.9 MHz) 197.9 (s), 172.9 (s), 157.1 (s), 147.1 (s), 127.3 (d), 126.1 (s), 117.7 (d), 117.3 (s), 108.5 (d), 55.2 (q), 36.3 (t), 34.9 (d), 24.9 (t), 24.0 (q), 21.1 (t), 20.8 (t) ppm.

A solution of 470 mg (1.63 mmol) of the above enone and 40 mg of $CeCl_3$ (0.163 mol) in 5 mL of dry ether at rt was treated dropwise with 3.20 mL (3.20 mmol) of vinylmagnesium bromide (1.0 M in THF) over a 5-min period, and the resulting mixture was stirred for 5 additional min. Standard ethereal workup, followed by chromatography (elution with H:E, 5:1), provided 336 mg (82%) of dienone **28** which was homogeneous by TLC analysis (H:E, 1:2, R_f enone = 0.13, R_f **28** = 0.77): ^{1}H NMR (250 MHz) δ 1.23 (d, 6 H, J = 6.9 Hz), 1.95−2.15 (m, 2 H), 2.52 (t, 2 H, J = 6.2 Hz), 2.09 (t, 2 H, J = 6.4 Hz), 2.86 (heptet, 1 H, J = 6.9 Hz), 3.76 (s, 2 H), 3.87 (s, 3 H), 5.41 (dd, 1 H, J = 11.1 Hz, 0.8 Hz), 5.66 (dd, 1 H, J = 17.4 Hz, 1.0 Hz), 6.65−6.75 (m, 2 H), 6.81 (d, 1 H, 8.0 Hz), 6.94 (dd, 1 H, J = 17.4 Hz, 11.1 Hz); ^{13}C NMR (62.9 MHz) 199.5 (s), 156.8 (s), 150.1 (s), 147.7 (s), 135.1 (s), 128.2 (d), 125.6 (s), 120.2 (t), 118.0 (d), 108.4 (d), 55.2 (q), 38.1 (t), 34.1 (d), 25.5 (t), 24.0 (q), 23.4 (t), 21.9 (t) ppm.

Spiro[4-isopropylcyclohexadienone-1,2′-(1′H)-1′,3′,4′,5′,6′,7′-hexahydronapthalen-8′-one (29). To a solution of **28** (75 mg, 0.26 mmol) in 2 mL of CH_2Cl_2 was added 87 μL of $TiCl_4$ (150 mg, 79.00 mmol) at −78 °C, and the reaction mixture was warmed to 0 °C over a 3-h period. Standard ethereal workup, followed by chromatography (elution with H:E, 5:1), gave 45.5 mg (65%) of **29** which was homogeneous by TLC analysis (H:E, 1:1, R_f **28** = 0.67, R_f **29** = 0.15): mp 90.5−92.5°C; ^{1}H NMR (300 MHz) δ 1.19 (d, 6 H, J = 6.8 Hz), 1.50−1.65 (m, 1 H), 1.75−2.10 (m, 3 H), 2.25−2.65 (m, 9 H), 5.90 (br s, 1 H), 6.16 (dd, 1 H, J = 9.8 Hz, 1.5 Hz), 6.33 (d, 1 H, J = 9.8 Hz); ^{13}C NMR (62.9 MHz) 205.1 (s), 198.4 (s), 162.0 (s), 154.6 (s), 143.2 (d), 129.5 (s), 122.8 (d), 120.1 (d), 47.8 (s), 37.9 (t), 34.1 (d), 30.9 (t), 30.3 (t), 30.2 (t), 28.8 (t), 22.3 (t), 20.7 (q) ppm; IR (Nujol mull) 1650, 1454, 1385 cm^{-1}; MS (m/z): 270 (14%), 149 (100%), 136 (54%).

3-Methoxy-4-methylphenylmethyl Alcohol (33). To a suspension of $LiAlH_4$ (460 mg, 12.00 mmol) in 25 mL of THF at 0 °C was added dropwise a solution of 3-methoxy-4-methylbenzoic acid (**32**) (1.0 g, 6.01 mmol, Aldrich) in 15 mL of THF. The reaction mixture was warmed to rt over a 10-h period and standard ethereal workup afforded 934 mg of residue. Purification using chromatography (elution with H:E, 3:1) yielded 887 mg (97%) of benzyl alcohol **33**, which was homogeneous by TLC analysis (H:E, 1:2, R_f **32** = 0.20, R_f **33** = 0.43): ^{1}H NMR (250 MHz) δ 2.23 (s, 3 H), 3.85 (s, 3 H), 4.67 (s, 2 H), 6.84 (d, 1 H, J = 7.6 Hz), 6.89 (s, 1 H), 7.13 (d, 1 H, J = 7.4 Hz); ^{13}C NMR (62.9 MHz) 157.9 (s), 139.7 (s), 130.6 (d), 126.1 (s), 118.7 (d), 108.7 (d), 65.5 (t), 55.2 (q), 16.1 (q) ppm; IR (film) 3403, 1258 cm^{-1}. Anal. for $C_9H_{12}O_2$. Calcd: C, 76.56, H, 6.43. Found: C, 76.90, H, 6.59.

3-Methoxy-4-methylphenylmethyl Bromide (34). Alcohol **33** (880 mg, 5.8 mmol) was dissolved in 25 mL of ether, and the resulting solution was cooled to 0 °C. Phosphorus tribromide (1.72 g, 6.4 mmol) dissolved in 10 mL of ether was added dropwise over a 30-min period. The resulting mixture was stirred for 8 h. Standard ethereal workup afforded 1.27 g of a pale yellow oil. Purification by chromatography (elution with H:E, 15:1) gave 1.14 g (92%) of benzyl bromide **34** which was homogeneous by TLC analysis (H:E, 3:1, R_f **33** = 0.03, R_f **34** = 0.74): ^{1}H NMR (250 MHz) δ 2.23 (s, 3 H), 3.85 (s, 3 H), 4.67 (s, 2 H), 6.84 (d, 1 H, J = 7.6 Hz), 6.89 (s, 1 H), 7.13 (d, 1 H, J = 7.4 Hz); ^{13}C NMR (62.9 MHz) 157.9 (s), 139.8 (s), 130.6 (d), 126.0 (s), 118.7 (d), 108.7 (d), 65.5 (t), 55.2 (q), 16.1 (q) ppm; IR (film) 3401, 1258 cm^{-1}.

4,4-Dimethyl-2-(3-methoxy-4-methylphenylmethyl)-1,3-cyclohexanedione (35). Dione **11** (1.31 g, 9.31 mmol) was dissolved in 2.0 mL of aqueous 20% K_2CO_3 solution (3.80 mmol). Bromide **34** (2.03 g, 9.31 mmol) was added to the mixture. After 5 min solid KI (1.62 g, 4.7 mmol) was added, and the reaction was stirred for 10 h. The reaction mixture was diluted with 30 mL of ether and washed twice with 10 mL of aqueous 10% HCl. The solution was then washed with saturated aqueous $NaHCO_3$ solution to remove any unreacted **11**. The ethereal phase was washed with aqueous 20% KOH to extract the dione into the aqueous layer. The aqueous layer was then acidified with concentrated HCl to a pH of 2. Standard ethereal workup, followed by chromatography (elution with H:E, 2:1), yielded 1.43 g (56%) of product. TLC analysis revealed the residue to be homogeneous (H:E, 1:1, R_f **35** = 0.35): ^{1}H NMR (250 MHz) δ 1.18 (s, 6 H), 1.83 (t, 2 H, J = 6.5 Hz), 2.16 (s, 3 H), 2.49 (t, 2 H, J = 6.2 Hz), 3.65 (s, 2 H), 3.78 (s, 3 H), 6.63 (s, 1 H), 6.71 (d, 1 H, J = 7.5 Hz), 7.03 (d, 1 H, J = 7.5 Hz); ^{13}C NMR (62.9 MHz) 169.8 (s), 158 (s), 130.7 (d), 120.5 (d), 119.6 (d), 113.5 (s), 111.2 (d), 110.0 (d), 55.2 (q), 36.8 (t), 34.2 (t), 32.2 (t), 27.9 (t), 27.3 (t), 25.7 (q), 24.9 (q), 15.9 (q) ppm; IR (film) 3390, 1643, 1374 cm^{-1}. Anal. for $C_{16}H_{22}O_3$. Calcd: C, 73.24, H, 8.46. Found: C, 73.01, H, 8.39.

6,6-Dimethyl-2-(3-methoxy-4-methylphenylmethyl)-3-methoxy-2-cyclohexenone (36). To NaH (125 mg, 3.78 mmol of an 80% dispersion in mineral oil) in 40 mL of DMF at 0 °C was added a solution of dione **35** (500 mg, 1.8 mmol) in 10 mL of DMF over a 30-min period. The resulting mixture was stirred for 3 h, and then dimethyl sulfate (250 mg, 1.98

mmol) was added and the reaction was stirred overnight. Saturated aqueous ammonium chloride (2 mL) was used to quench the reaction. Standard ethereal workup gave 422 mg of a crude residue which was purified by chromatography (elution with H:E, 5:1) to yield 386 mg (75%) of a homogeneous product by TLC analysis (H:E, 2:1, R_f **35** = 0.13, R_f **36** = 0.29): ^{1}H NMR (250 MHz) δ 1.11 (s, 6 H), 1.83 (t, 2 H, J = 6.2 Hz), 2.15 (s, 3 H), 2.49 (t, 2 H, J = 6.3 Hz), 3.58 (s, 2 H), 3.78 (s, 3 H), 3.80 (s, 3 H), 6.70 (d, 1 H, J = 7.8 Hz), 6.74 (s, 1 H), 6.96 (d, 1 H, J = 7.5 Hz); ^{13}C NMR (62.9 MHz) 202.6 (s), 169.9 (s), 157.3 (s), 140.7 (s), 129.9 (d), 123.2 (s), 120.1 (d), 117.0 (s), 110.6 (d), 55.1 (q), 54.8 (q), 39.3 (s), 34.2 (t), 28.0 (t), 24.5 (q), 21.9 (t), 15.8 (q) ppm; IR (film) 3440, 2957, 1616, 1366, 1250 cm^{-1}.

4,4-Dimethyl-2-(3-methoxy-4-methylphenylmethyl)-3-vinyl-2-cyclohexenone (37). To a solution of enol ether **36** (300 mg, 1.0 mmol) in 15 mL of ether were added vinylmagnesium bromide (2.1 mL of a 1 M solution in THF) and cerium chloride (190 mg, 0.77 mmol). The resulting solution was then stirred at rt for 8 h. Standard ethereal workup, followed by chromatography (H:E, 5:1), yielded 290 mg (88%) of product which was homogeneous by TLC analysis (H:E, 5:1, R_f **37** = 0.29): ^{1}H NMR (250 MHz) δ 1.22 (s, 6 H), 1.90 (t, 2 H, J = 7.0 Hz), 2.14 (s, 3 H), 2.53 (t, 2 H, J = 7.0 Hz), 3.68 (s, 2 H), 3.79 (s, 3 H), 5.18 (dd, 1 H, J = 18.0 Hz, 1.8 Hz), 5.41 (dd, 1 H, J = 10.9 Hz, 2.0 Hz), 6.38 (dd, 1 H, J = 17.7 Hz, 11.8 Hz), 6.55 (d, 1 H, J = 7.8 Hz), 6.63 (s, 1 H), 6.97 (d, 1 H, J = 7.6 Hz); ^{13}C NMR (62.9 MHz) 198.7 (s), 163.3 (s), 157.5 (s), 140.3 (s), 133.6 (d), 132.9 (s), 130.2 (d), 123.6 (s), 119.8 (t), 119.4 (d), 110.2 (d), 77.2 (d), 55.1 (q), 37.3 (t), 35.5 (s), 34.5 (t), 34.5 (t), 32.1 (t), 27.2 (q), 15.1 (q) ppm. Anal. for $C_{19}H_{24}O_2$. Calcd: C, 80.23, H, 8.51. Found: C, 79.87, H, 8.22.

7-Methoxy-1,1,8-trimethyl-1,2,10,11-tetrahydro-5*H*-dibenzo[*a*,*d*]cyclohepten-4-one (38). To dienone **37** (200 mg, 0.70 mmol) dissolved in 50 mL of CH_2Cl_2 was added BF_3-Et_2O (120 mg, 0.85 mmol). The reaction was stirred until TLC analysis indicated the reaction was complete (5 min). Standard ethereal workup and chromatography (H:E, 6:1) yielded 192 mg (97%) of tricycle **38** which was homogeneous by TLC analysis (H:E, 2:1, R_f **37** = 0.42, R_f **38** = 0.35): ^{1}H NMR (250 MHz) δ 1.18 (s, 6 H), 1.80 (t, 2 H, J = 6.9 Hz) 2.17 (s, 3 H), 2.50 (t, 2 H, J = 6.8 Hz), 2.69 (t, 2 H, J = 6.4 Hz), 2.98 (t, 2 H, J = 6.4 Hz), 3.80 (s, 5 H), 6.68 (s, 1 H), 6.86 (s, 1 H); ^{13}C NMR (62.9 MHz) 197.4 (s), 165.0 (s), 155.6 (s), 136.7 (s), 133.7 (s), 131.1 (d), 130.7 (s), 124.2 (s), 111.4 (d), 55.3 (q), 36.9 (t), 36.3 (s), 34.1 (t), 29.9 (t), 29.3 (t), 26.6 (q), 15.6 (q) ppm. Anal. for $C_{19}H_{22}O_2$. Calcd: C, 80.23, H, 8.51. Found: C, 80.03, H, 8.24.

7-Methoxy-1,1,8-trimethyl-1,2,3,10,11,11a-hexahydro-5*H*-dibenzo[*a*,*d*]cycloheptene (39). Enone **38** (540 mg, 1.9 mmol) was refluxed with tosylhydrazine (530 mg, 2.85 mmol) in 10 mL of dry ethanol for 3 h. The solvent was removed, and the residue was passed through a silica gel column (hexanes:ethyl acetate, 5:1) to yield a homogeneous product by TLC analysis (H:E, 5:1, R_f **38** = 0.64, R_f hydrazone = 0.01). The crude tosylhydrazone was stirred in 5 mL of DMF and 5 mL of sulfolane containing 25 mg of bromocresol green. The mixture was warmed to 110 °C, and sodium cyanoborohydride (1.19 g, 6.4 mmol) was added followed by sufficient aqueous 10% HCl to maintain a tan color. Stirring was continued for 90 min, and the mixture was cooled to rt, diluted with water, and extracted with ether. The residue was chromatographed (elution with H:E, 20:1) to yield 237 mg (53%) of product which was homogeneous by TLC analysis (H:E, 5:1, R_f **39** = 0.86): $_1$H NMR (250 MHz) δ 0.89 (s, 3 H), 0.92 (s, 3 H), 1.08−1.22 (m, 3 H), 1.28−1.39 (m, 2 H), 1.98−2.11(m, 2 H), 2.17 (s, 3 H), 2.78 (t, 1 H, J = 7.0 Hz), 3.33 (s, 2 H), 3.84 (s, 3 H), 5.45 (t, 1 H, J = 4.0 Hz), 6.62 (s, 1 H), 6.88 (s, 1 H) ppm; ^{13}C NMR (62.9 MHz) 156.3 (s), 139.9 (s), 138.6 (s), 132.9 (s), 131.6 (d), 123.3 (s), 121.1 (d), 110.1 (d), 55.4 (q), 51.8 (d), 45.2 (t), 34.1 (t), 32.1 (s), 31.1 (t), 30.5 (t), 27.8 (q), 27.1 (q), 23.2 (t), 15.6 (q) ppm.

Deoxofaveline Methyl Ether (40). To 28 mg of ether **39** (0.10 mmol) dissolved in 1 mL of dry CH_2Cl_2 was added 35 μL of BF_3-Et_2O (0.24 mol). The resulting mixture was stirred overnight at rt. Standard ethereal workup and chromatography (elution with H:E, 3:1) yielded 26 mg (90%) of a homogeneous product by TLC analysis (hexanes, R_f **39** = 0.46, R_f **40** = 0.37): ^{1}H NMR (250 MHz) δ 0.72 (s, 3 H), 1.00 (s, 3 H), 1.35−1.70 (m, 8 H), 2.18 (s, 3 H), 2.20−2.35 (m, 3 H), 2.35−2.48 (m, 1 H), 2.56−2.72 (m, 3 H), 3.82 (s, 3 H), 6.35 (s, 1 H), 6.62 (s, 1 H), 6.81 (s, 1 H); ^{13}C NMR (62.9 MHz) 155.6 (s), 144.7 (s), 134.8 (s), 134.7 (s), 130.2 (d), 125.2 (d), 123.7 (s), 112.0 (d), 55.4 (q), 54.9 (d), 42.3 (t), 41.1 (t), 36.6 (s), 32.6 (t), 30.4 (t), 30.3 (q), 24.4 (t), 20.3 (q), 15.7 (q) ppm.

(±)-Deoxofaveline (3). Ethanethiol (130 mg, 2.00 mmol) was added to 42 mg of NaH (80% dispersion in mineral oil, 1.28 mmol) in 1 mL of DMF at rt and stirred for 2 h. The mixture was heated to 110 °C, and ether **39** (14.0 mg, 0.052 mmol) was added over a 5-min period. The mixture was heated at 130 °C for 5 h and acidified with aqueous 10% HCl. The reaction mixture was diluted with water (10 mL), followed by standard ethereal workup and chromatography (elution with H:E, 15:1), to yield 11.7 mg (88%) of (±)-deoxofaveline which was homogeneous by TLC analysis (H:E, 5:1, R_f **40** = 0.46, R_f **3** = 0.34): ^{1}H NMR (250 MHz) δ 0.71 (s, 3 H), 1.00 (s, 3 H), 1.38−1.68 (m, 6 H), 2.20 (s, 3 H), 2.23−2.32 (m, 2 H), 2.33−2.42 (m, 1 H), 2.52−2.71 (m, 3 H), 6.24 (s, 1 H), 6.56 (s, 1 H), 6.78 (s, 1 H); ^{13}C NMR (62.9 MHz) 152.2 (s), 144.9 (s), 135.8 (s), 134.7 (s), 130.2 (d), 124.6 (d), 120.5 (s), 116.4 (d), 54.8 (q), 42.2 (d), 41.0 (t), 36.6 (s), 32.5 (t), 30.2 (t), 30.2 (t) (the two preceding signals overlap), 24.3 (t), 20.2 (q), 15.2 (q) ppm.

Demethylation of 40 Using L-Selectride. To 12 mg of **36** (0.055 mmol) dissolved in 1.5 mL of dry THF was added 110 μL of L-Selectride (1.0 M, 0.11 mmol), and the resulting mixture was refluxed (67 °C) until TLC analysis indicated that the reaction was complete (24 h). The reaction mixture was cooled to 0 °C and diluted with 50 mL of ether. Standard ethereal workup, followed by chromatography (elution with H:E, 5:1), gave 8.9 mg (79%) of (±)-deoxofaveline which was identical to that prepared previously.

4,4-Dimethyl-2-(4-isopropyl-3-methoxyphenylmethyl)-1,3-cyclohexanedione (41). To 1.38 g of **11** (9.84 mmol) suspended in 1.5 mL of water was added 1.36 g of K_2CO_3 (9.84 mmol), 0.41 g of KI (2.47 mmol), and 1.20 gram of bromide **31** (4.94 mmol). The reaction mixture was stirred at rt for a 24-h period and then diluted with 90 mL of water and 3 mL of 10% aqueous HCl. Standard ethereal workup furnished 0.81 g of a crude residue which was chromatographed (elution with H:E = 3:2) to give 0.70 g of **41** (75% yield based on recovered **31**). This material was homogeneous by TLC analysis (H:E = 1:1, R_f **41** = 0.24): mp 169.5−170.5 °C (recrystallized from EtOH) as colorless needles; ^{1}H NMR δ 1.12 (s, 3 H), 1.17 (d, 6 H, J = 6.7 Hz), 1.28 (s, 3 H), 1.67 (m, 1 H), 2.05 (m, 1 H), 2.51 (m, 1 H), 2.71 (m, 1 H), 3.17 (d, 2 H, J = 5.6 Hz), 3.24 (septet, 1 H, J = 7.0 Hz), 3.87 (s, 3 H), 6.66 (s, 1 H), 6.74 (d, 1 H, J = 7.6 Hz), 7.07 (d, 1 H, J = 7.6 Hz); ^{13}C NMR (75.5 MHz) 204.4 (s), 157.2 (s), 134.7 (s), 126.3 (d), 125.8 (s), 120.8 (s), 119.8 (d), 113.3 (s), 111.6 (s), 110.3 (d), 66.7 (d), 55.3 (q), 36.9 (s), 34.4 (t), 32.3 (t), 27.8 (t), 27.1 (t), 26.4 (d), 25.7 (t), 25.0 (q), 24.0 (t), 22.7 (q) ppm; IR (film) 3424, 2952, 1639, 1558, 1372, 1253, 1194, 996 cm^{-1}; MS (m/z) 302 (M$^+$, 64%), 287 (83%), 175 (100%), 161 (42%), 115, (23%); Anal. for $C_{19}H_{26}O_3$. Calcd: C, 75.46, H, 8.67. Found: C, 77.21, H, 8.54.

6,6-Dimethyl-2-(4-isopropyl-3-methoxyphenylmethyl)-3-methoxy-2-cyclohexenone (42). To a suspension of NaH (60% dispersion of mineral oil, 190 mg, 4.75 mmol) in 4 mL of dry DMF at 0 °C was added dione **41** (893 mg, 2.95 mmol) in 7 mL of DMF over a 5-min period. The resulting solution was stirred at rt for 3 h. Dimethyl sulfate (560 mg, 4.44 mmol) was then added, and the resulting mixture was stirred at rt for 15 h. The reaction mixture was diluted with 30 mL of water and washed with saturated $CuSO_4$ (3 × 20 mL). Standard ethereal workup provided 0.91 g of a crude residue which was chromatographed (elution with H:E = 2:1) to give 880 mg of enol ether **42** (94%). The material was homogeneous by TLC analysis (H:E = 2:1, R_f **42** = 0.30): ^{1}H NMR (300 MHz) δ 1.11 (s, 6 H), 1.18 (d, 6 H, J = 7.0 Hz), 1.84 (t, 2 H, J = 6.4 Hz), 2.60 (t, 2 H, J = 6.4 Hz), 3.24 (septet, 1 H, J = 7.0 Hz), 3.58 (s, 2 H), 3.78 (s, 3 H), 3.79 (s, 3 H), 6.70−6.75 (m, 2 H), 7.03 (d, 1 H, J = 8.1 Hz); ^{13}C NMR (75.5 MHz) 202.6 (s), 170.0 (s), 156.4 (s), 140.2 (s), 133.6 (s), 125.3 (d), 120.3 (d), 116.8 (s), 110.9 (d), 55.2 (q), 54.8 (q), 39.3 (s), 34.2 (t), 28.0 (t), 26.4 (d),

24.6 (q), 22.7 (q), 22.0 (t) ppm; IR (film) 2956, 2867, 1788, 1612, 1502, 1460, 1416, 1364, 1247, 1095, 1038 cm^{-1}; MS (*m/z*) 316 (M^+, 61%), 301 (69%), 43 (100%); Anal. for $C_{20}H_{28}O_3$. Calcd: C, 75.91, H, 8.92. Found: C, 76.21, H, 9.02.

4,4-Dimethyl-2-(4-isopropyl-3-methoxyphenylmethyl)-3-vinyl-2-cyclohexenone (43). A solution of 1.00 g (3.16 mmol) of enol ether **42** in 40 mL of ether was added to a flask containing 630 mg of $CeCl_3$ (2.56 mmol). The resulting mixture was treated with 6.64 mL of vinylmagnesium bromide (6.64 mmol, 1.0 M in THF) at rt over 5-min period. The reaction mixture was stirred at rt for 10 h and quenched with ice. Standard ethereal workup provided an oily residue which was chromatographed (elution with H:E = 3:1) to provide 782 mg of **43** (78%). This material was homogeneous by TLC analysis (H:E = 2:1, R_f **43** = 0.52): ^{1}H NMR (250 MHz) δ 1.16 (d, 6 H, J = 6.7 Hz), 1.21 (s, 6 H), 1.91 (t, 2 H, J = 6.9 Hz), 2.54 (t, 2 H, J = 6.9 Hz), 3.20−3.25 (m, 1 H), 3.68 (s, 2 H), 3.78 (s, 3 H), 5.18 (dd, 1 H, J = 1.78 Hz, 1.7 Hz), 5.39 (dd, 1 H, J = 12.0 Hz, 1.7 Hz), 6.37 (dd, 1 H, J = 17.8 Hz, 12.0 Hz), 6.58−6.63 (m, 2 H), 7.04 (d, 1 H, J = 7.6 Hz); ^{13}C NMR (62.9 MHz) 198.7 (s), 163.2 (s), 156.6 (s), 139.5 (s), 134.0 (s), 133.6 (d), 132.8 (s), 125.7 (d), 119.8 (d), 119.7 (t), 110.5 (d), 55.2 (q), 37.3 (t), 35.5 (s), 34.5 (t), 32.0 (t), 27.3 (q), 26.4 (d), 22.7 (q) ppm; IR (film) 2959, 2867, 1668, 1609, 1502, 1461, 1415, 1250, 1094, 1040, 928, 730 cm^{-1}; MS, *m/z* 312 (M^+, 12%), 269 (18%), 180 (54%), 135 (100%).

12-Methoxy-9(10→20)-5α*H*-abeo-abieta-5(10),8,11,13-tetraen-1-one (44). A solution of 71 μL of BF_3-Et_2O (0.58 mmol) was added dropwise to a solution of 150 mg of **43** (0.48 mmol) in 30 mL of dry CH_2Cl_2 at rt. The resulting mixture was stirred at rt for a 90-min period and then quenched with 3 mL of saturated aqueous $NaHCO_3$. Standard ethereal workup afforded 144 mg of crude residue. Purification by means of chromatography (elution with H:E = 4:1) gave 121 mg of **44** (83%) which was homogeneous by TLC analysis (H:E = 4:1, R_f **44** = 0.23): mp 123−124 °C; ^{1}H NMR (250 MHz) δ 1.17 (s, 6 H), 1.18 (d, 6 H, J = 7.0 Hz), 1.82 (t, 2 H, J = 6.8 Hz), 2.65−2.73 (m, 2 H), 2.95−3.03 (m, 2 H), 3.24 (septet, 1 H, J = 7.0 Hz), 3.79 (s, 5 H), 6.67 (s, 1 H), 6.87 (s, 1 H); ^{13}C NMR (62.9 MHz) 197.5 (s), 165.2 (s), 154.7 (s), 136.3 (s), 134.8 (s), 133.7 (s), 131.0 (s), 126.7 (d), 111.9 (d), 55.5 (q), 37.0 (t), 36.4 (s), 34.2 (t), 30.3 (t), 29.4 (t), 29.3 (t), 26.6 (q), 26.4 (d), 22.8 (q) ppm; IR (film) 2957, 2926, 2865, 1661, 1611, 1504, 1462, 1362, 1268, 1247, 1180, 1110, 1068 cm^{-1}; MS, *m/z* 312 (M^+, 100%), 297 (87%), 269 (52%), 55 (31%); Anal. for $C_{21}H_{28}O_2$. Calcd: C, 80.73, H, 9.03. Found: C, 80.50, H, 8.88.

(±)-Pisiferin Methyl Ether (45). Enone **44** (486 mg, 1.56 mmol) and tosylhydrazine (350 mg, 1.88 mmol) were dissolved in 10 mL of absolute ethanol and stirred at rt for 12 h. The solvent was evaporated, and to the resulting residue were added 12 mL of DMF and 12 mL of sulfolane containing 4 mg of bromocresol green. The mixture was warmed to 105 °C, and sodium cyanoborohydride (420 mg, 6.68 mmol) was added, followed by sufficient 2 N HCl to give a tan color. Heating at 110 °C was continued for 7 h during which time several portions of 2 N HCl were added to maintain the proper acidity, as indicated by the tan color. The mixture was cooled, poured into water, and extracted with ether. The residue obtained was dried over anhydrous magnesium sulfate, filtered, and concentrated. The resulting residue was chromatographed to give 287 mg (46%) of pisiferin methyl ether (**45**) which was homogeneous by TLC analysis (H:E, 4:1, R_f **45** = 0.77): ^{1}H NMR (300 MHz) δ 0.89 (s, 3 H), 0.93 (s, 3 H), 1.18 (d, 3 H, J = 7.0 Hz), 1.20 (d, 3 H, J = 7.0 Hz), 1.75−1.85 (m, 1 H), 1.85−2.15 (m, 3 H), 2.81 (m, 2 H), 3.25 (septet, 1 H, J = 7.0 Hz), 3.32 (s, 2 H), 3.82 (s, 3 H), 5.45 (t, 1 H, J = 4.0 Hz), 6.63 (s, 1 H), 6.91 (s, 1 H).

Demethylation of Ether (45). Ethanethiol (0.35 mL, 4.39 mmol) was added to 112 mg of NaH (60% dispersion in mineral oil, 2.81 mmol) in 3 mL of DMF at rt and stirred for 30 min. The mixture was heated to reflux, and ether **45** (70 mg, 0.34 mmol) dissolved in 1 mL of DMF was added. The resulting mixture was refluxed for 4 h, cooled to 0 °C, diluted with water (10 mL), and acidified with aqueous 10% HCl. Standard ethereal workup and chromatography (elution with H:E, 6:1), yielded 57 mg (85%) of a 4:1 mixture of pisiferin (**2**) and isopisiferin (**46**) which was homogeneous by TLC analysis (H:E, 5:1, R_f **2/46** = 0.28):

2: ^{1}H NMR (250 MHz) δ 0.89 (s, 3 H), 0.92 (s, 3 H), 1.22 (d, 3 H, J = 6.9 Hz), 1.24 (d, 3 H, J = 6.9 Hz), 1.75−1.85 (m, 1 H), 1.85−2.15 (m, 3 H), 2.75−2.85 (m, 2 H), 3.13 (septet, 1 H, J = 6.9 Hz), 3.25 (br s, 2 H), 5.42 (t, 1 H, J = 4 Hz), 6.53 (s, 1 H), 6.89 (s, 1 H).

46: ^{1}H NMR (250 MHz) δ 0.70 (s, 3 H), 0.98 (s, 3 H), 1.22 (d, 3 H, J = 6.9 Hz), 1.25 (d, 3 H, J = 6.9 Hz), 1.35−1.75 (m, 4 H), 2.10−2.40 (m, 4 H), 2.50−2.72 (m, 3 H), 3.13 (septet, 1 H, J = 6.9 Hz), 6.23 (s, 1 H), 6.51 (s, 1 H), 6.82 (s, 1 H).

Isomerization of Pisiferin to Isopisiferin. Ten milligrams of an inseparable mixture of pisiferin and isopisiferin (7:1) was dissolved in 3 mL of CH_2Cl_2 and cooled to 0 °C, and 150 μL (1.22 mmol) of BF_3-Et_2O was added. The reaction mixture was stirred at rt for 2 days and then quenched with saturated aqueous $NaHCO_3$ (2 mL). Standard ethereal workup gave 11 mg of a crude residue which was chromatograhed (elution with H:E, 9:1) to give 9.0 mg of an inseparable mixture of pisiferin (**2**) and isopisiferin (**46**) in the ratio of 1:7, respectively.

Conversion of 2/46 into Tetracyclic Dienone 50. Ten milligrams of an inseparable mixture of pisiferin and isopisiferin (7:1) was dissolved in 3 mL of CH_2Cl_2, and 150 μL (1.22 mmol) of BF_3-Et_2O was added. The reaction mixture was refluxed for a 20-h period, cooled to 0 °C, and quenched by the addition of 3 mL of saturated aqueous $NaHCO_3$. Standard ethereal workup gave 11 mg of a crude residue which was chromatograhed (elution with H:E, 7:1) to give 7.1 mg of tetracyclic dienone **50** (71%) which was homogeneous by TLC analysis (H:E, 7:1, R_f **50** = 0.28): mp 107−108 °C [lit. mp 107−109 °C];[23b] ^{1}H NMR (250 MHz) δ 0.95 (s, 3 H), 1.03 (s, 3 H), 1.05 (d, 3 H, J = 6.9 Hz), 1.07 (d, 3 H, J = 6.9 Hz), 1.18−1.50 (m, 5 H), 1.60−1.90 (m, 7 H), 2.01 (t, 1 H, J = 9.9 Hz), 2.98 (septet, 1 H, J = 6.9 Hz), 6.22 (s, 1 H), 6.39 (s, 1 H).

12-Acetoxy-9(10→20)-5α*H*-abeo-abieta-5(10),8,11,13-tetraen-1-one (48). To a solution of 300 μL of ethanethiol (4.11 mmol) in 2 mL of DMF was added dropwise to a cold solution (0 °C) of 82 mg of NaH (60% dispersion in mineral oil, 2.05 mmol) suspended in 4 mL of DMF. The resulting mixture was then stirred at rt for 10 min, followed by the addition of a solution of 38 mg of **44** (0.12 mmol) dissolved in 0.5 mL of DMF. The mixture was refluxed for a 5-h period. Standard ethereal workup gave 124 mg of the phenol product which was homogeneous by TLC analysis (H:E = 1:1, R_f **47** = 0.26). This compound proved to be unstable; therefore, it was used directly in the next reaction without further purification or characterization.

The above crude phenol was dissolved in 1.5 mL of acetic anhydride and 1.5 mL of pyridine. The reaction mixture was heated at 80 °C for 2 h, cooled to rt, and diluted with water (5 mL). Standard ethereal workup afforded 44 mg of a crude residue which was purified by means of chromatography (elution with H:E = 4:1) to give 33 mg **48** (80%) which was homogeneous by TLC analysis (H:E = 4:1, R_f **48** = 0.20): mp 108−109 °C; ^{1}H NMR (250 MHz) δ 1.16 (s, 6 H), 1.17 (d, 6 H, J = 7.0 Hz), 1.19 (t, 2 H, J = 7.0 Hz), 2.30 (s, 3 H), 2.47 (t, 2 H, J = 7.0 Hz), 2.64−2.67 (m, 2 H), 2.92 (septet, 1H, J = 7.0 Hz), 2.95−3.05 (m, 2 H), 3.77 (s, 2 H), 6.79 (s, 1 H), 6.97 (s, 1 H); ^{13}C NMR (62.9 MHz) 197.3 (s), 170.0 (s), 164.8 (s), 145.8 (s), 137.9 (s), 137.6 (s), 137.0 (s), 133.3 (s), 127.0 (d), 123.1 (d), 36.9 (t), 36.4 (s), 34.1 (t), 30.6 (t), 29.1 (t), 28.9 (t), 27.1 (d), 26.6 (q), 23.0 (q), 20.9 (q) ppm; IR (film) 2957, 2868, 1757, 1662, 1501, 1459, 1364, 1212, 1088, 1056 cm^{-1}; MS (*m/z*) 340 (M^+, 9%), 298 (62%), 43 (100%).

12-Acetoxy-9(10→20)-10α*H*-abeo-abieta-1(10),8,11,13-tetraene (49). A mixture of 24 mg of enone **48** (0.07 mmol) and 27 mg of tosylhydrazine (0.09 mmol) dissolved in 2 mL of absolute ethanol was stirred at rt for a 12-h period. Evaporation of the solvent gave the crude hydrazone, which was then dissolved in 1 mL of DMF and 1 mL of sulfolane. To this solution was added 1 mg of bromocresol green and then 21 mg of sodium cyanoborohydride (0.33 mmol). The resulting mixture was heated to 100 °C when sufficient 10% aqueous HCl was added to obtain a tan-yellow color. The reaction mixture was stirred at 110 °C for 2.5 h and then cooled to rt.

Standard ethereal workup afforded 19 mg of an oily residue which was purified by chromatography (elution with H:E, 5:1) to give 10 mg of **49** (43%) which was homogeneous by TLC analysis (H:E = 4:1, R_f **49** = 0.80): ^{1}H NMR (250 MHz) δ 0.88 (s, 3 H), 0.91 (s, 3 H), 1.17 (d, 3 H, J = 7.0 Hz), 1.20 (d, 3 H, J = 7.0 Hz), 2.31 (s, 3 H), 2.80−2.85 (m, 2 H), 2.94 (septet, 1 H, J = 6.9 Hz), 3.29 (s, 2 H), 5.41 (t, 1 H, J = 4.0 Hz), 6.73 (s, 1 H), 6.99 (s, 1 H).

(±)-Pisiferin (2). Ten milligrams of acetate **48** was dissolved in 2 mL of absolute ethanol saturated with NaOH. The reaction mixture was then gently refluxed for a 6-h period. The reaction mixture was then cooled to 0 °C and acidified with 10% aqueous HCl. Standard ethereal workup gave a colorless oil. Purificaton by chromatography (elution with H:E, 5:1) gave 8.0 mg of **2** (92%) as a colorless oil which was homogeneous by TLC analysis (H:E = 5:1, R_f **2** = 0.28): ^{1}H NMR (250 MHz) δ 0.88 (s, 3 H), 0.91 (s, 3 H), 1.22 (d, 3 H, J = 7.0 Hz), 1.24 (d, 3 H, J = 7.0 Hz), 1.75−1.83 (m,1 H), 1.85−2.05 (m, 3 H), 2.75−2.81 (m, 2 H), 3.12 (septet, 1 H, J = 7.0 Hz), 3.24 (br s, 2 H), 4.51 (br s, 1 H), 5.41 (t, 1 H, J = 4.0 Hz), 6.53 (s,1 H), 6.88 (s, 1 H).

7-Methoxy-1,1,8-trimethyl-1.10.11.11a-tetrahydro-2*H*-dibenzo[*a,d*]cyclohepten-4-one (51). To a solution of **39** (72 mg, 0.27 mmol) in 3 mL of CH_2Cl_2 were added 143 mg of PCC (0.67 mmol) and 143 mg of Celite, and the resulting mixture was refluxed for 8 h. Standard ethereal workup followed by chromatography (elution with H:E, 5:1) gave 18 mg (25%) of unreacted **39** and 42 mg (55% yield or 80% yield based on mass balance) of enone **51** which was homogeneous by TLC analysis (H:E, 2:1, R_f **51** = 0.40): ^{1}H NMR (300 MHz) δ 0.91 (s, 3 H), 1.06 (s, 3 H), 1.65−1.92 (m, 3 H), 2.21 (s, 3 H), 2.24−2.36 (m, 1 H), 2.37−2.48 (m, 1 H), 2.50−2.62 (m, 2 H), 2.65−2.75 (m, 2 H), 3.82 (s, 3 H), 6.79 (s, 1 H), 6.93 (s, 1 H), 7.56 (d, 1 H, J = 2.1 Hz); ^{13}C NMR (75.5 MHz) 202.0 (s), 155.9 (s), 139.1 (s), 138.8 (d), 135.0 (s), 133.2 (s), 131.3 (s), 127.6 (s), 113.9 (d), 55.3 (d), 50.0 (q), 35.9 (t), 35.3 (t), 32.9 (t), 32.8 (s), 31.2 (t), 29.2 (q), 22.8 (q), 16.0 (q) ppm; IR (film) 2926, 1680, 1504, 884 cm^{-1}; ESI-MS (m/z) 285 (MH$^+$, 100%).

Preparation of 51 Using SeO_2. To a stirred solution of enone **39** (14 mg, 0.05 mmol) in 2 mL of absolute ethanol was added selenium dioxide (8 mg, 0.074 mmol), and the mixture was refluxed for 2 h. Standard ethereal workup, followed by chromatography (elution with H:E, 5:1), gave 8.0 mg of dienone **51** (58%) which was identical to that previously described.

Xochitlolone Methyl Ether (53). To a stirred solution of enone **51** (70 mg, 0.25 mmol) in 3 mL of ethyl acetate was added phenylselenyl chloride (47 mg, 0.25 mmol), and the resulting mixture was stirred for 5 min at 0 °C. TLC analysis indicated the complete conversion of **51** to the phenylselenylated adduct [H:E, 2:1, R_f **51** = 0.40, R_f selenylated cmpd = 0.71]. The mixture was maintained at 0 °C while a solution of *m*-CPBA (42.0 mg, 0.246 mmol) dissolved in 1 mL of ethyl acetate was added dropwise and the resulting mixture was stirred for a 30-min period. Standard ethereal workup, followed by chromatography (elution with H:E, 5:1), gave 37 mg of dienone **53** (53%) which was homogeneous by TLC analysis (H:E, 2:1, R_f selenylated cmpd = 0.71, R_f **53** = 0.39): ^{1}H NMR (250 MHz) δ 0.95 (s, 3 H), 1.25 (s, 3 H), 1.65−1.85 (m, 1 H), 2.21 (s, 3 H), 2.24−2.40 (m, 1 H), 2.65−3.00 (m, 3 H), 3.82 (s, 3 H), 6.11 (d, 1 H, J = 9.9 Hz), 6.79 (d, 1 H, J = 9.9 Hz), 6.87 (s, 1 H), 6.89 (s, 1 H), 7.66 (d, 1 H, J = 2.3 Hz); ^{13}C NMR (62.9 MHz) 190.0 (s), 161.7 (d), 155.9 (s), 137.7 (d), 136.4 (s), 135.9 (s), 132.2 (s), 131.0 (d), 127.8 (s), 127.3 (d), 115.2 (d), 55.4 (q), 52.1 (d), 38.0 (s), 32.9 (t), 28.0 (t), 28.0 (q), 22.2 (q), 16.0 (q) (the overlapping signals at 28.0 are resolved by a DEPT experiment) ppm; IR (film) 2954, 1662, 1595, 1509, 1244, 1125, 827 cm^{-1}; ESI-MS (m/z) 283 (MH$^+$, 100%).

7-Methoxy-1,1,8-trimethyl-10,11-dihydro-2*H*-dibenzo-[*a,d*]cyclohepten-4-one (54). To a stirred suspension of 15 mg of NaH (0.39 mmol) in 0.5 mL of dry DMF at 0 °C was added ethanethiol (42 μL, 0.56 mmol) in 0.5 mL of DMF. The mixture was allowed to warm to rt over a 3-h period. A solution of dienone **53** (16 mg, 0.056 mmol) dissolved in 0.5 mL of DMF was added in one portion to the reaction and the resulting mixture heated at 100 °C for a 90-min period. The reaction mixture was cooled to rt, after which standard ethereal workup and purification via chromatography (elution with H:E, 2:1) gave 8.1 mg of dienone **54** (55%) which was homogeneous by TLC analysis [H:E, 2:1, R_f **54** = 0.20]: ^{1}H NMR (300 MHz) δ 1.26 (s, 6 H), 2.75−2.88 (m, 2 H), 2.98−3.08 (m, 2 H), 3.81 (s, 3 H), 3.94 (s, 2 H), 6.22 (d, 1 H, J = 9.9 Hz), 6.71 (s, 1 H), 6.72 (d, 1 H, J = 9.9 Hz), 6.83 (s, 1 H).

(±)-Xochitlolone (5). To a stirred solution of dienone **53** (35 mg, 0.124 mmol) in 5 mL of dry CH_2Cl_2 at −78 °C was added boron tribromide (248 μL, 0.248 mmol of a 1.0 M solution in CH_2Cl_2). The resulting mixture was allowed to warm to 10 °C over a 2-h period. Standard ethereal workup and chromatography gave 8 mg (23%) of the unreacted substrate and 22 mg (66% yield, 88% yield based on mass balance) of racemic **5** which was homogeneous by TLC analysis (H:E, 1:2, R_f **53** = 0.71, R_f **5** = 0.51): mp 234−236 °C; ^{1}H NMR (250 MHz) δ 0.94 (s, 3 H), 1.26 (s, 3 H), 1.65−1.85 (m, 1 H), 2.15−2.40 (m, 1 H), 2.26 (s, 3 H), 2.62−3.00 (m, 4 H), 6.13 (d, 1 H, J = 9.6 Hz), 6.84 (d, 1 H, J = 9.6 Hz), 6.88 (s, 1 H), 6.96 (br s, 1 H), 7.10 (s, 1 H), 7.75 (d, 1 H, J = 2.3 Hz); ^{13}C NMR (62.9 MHz) 190.8 (s), 162.9 (d), 152.9 (s), 138.7 (d), 135.8 (s), 135.7 (s), 132.0 (s), 131.1 (d), 127.1 (d), 126.0 (s), 120.4 (d), 52.1 (d), 38.2 (s), 33.0 (t), 27.9 (q), 27.8 (t), 22.1 (q), 15.8 (q) ppm; IR (KBr pellet) 3265, 1654, 1571, 1418, 1270, 1124, 875 cm^{-1}; ESI-MS (m/z) 269 (MH$^+$, 100%).

11a(*R),4(*S**),4a(*S**)-4,4a-Epoxy-7-methoxy-1,1,8-trimethyl-1,2,3,4,4a,10,11,11a-octahydro-5*H*-dibenzo[*a,d*]-cycloheptene (58).** To a cold solution (0 °C) of 38 mg of olefin **39** (0.14 mmol) in 10 mL of dry CH_2Cl_2 were added 56 mg of 85% mCPBA and 44 mg of Na_2CO_3. The reaction mixture was stirred at rt for 3 h and then diluted with 30 mL of petroleum ether. Standard ethereal workup provided 14 mg of crude residue which was chromatographed (elution with H:E, 7:1) to furnish 26 mg (68%) of epoxide **58** which was homogeneous by TLC analysis (H:E, 7:1, R_f **39** = 0.90, R_f **58** = 0.65): ^{1}H NMR (250 MHz) δ 0.75 (s, 3 H), 0.88 (s, 3 H), 1.15−1.95 (m, 7 H), 2.18 (s, 3 H), 2.50−2.80 (m, 4 H), 3.32 (d, 1 H, J = 15.8 Hz), 3.79 (s, 3 H), 6.52 (s, 0.8 H), 6.56 (s, 0.2 H), 6.90 (s, 0.8 H), 6.85 (s, 0.2 H). This data represents a 4:1 mixture of diastereomers.

11a(*R),4a(*S**)-4a,7-Dihydroxy-1,1,8-trimethyl-1,2,3,4,4a,10,11,11a-octahydro-5*H*-dibenzo[*a,d*]cycloheptene (60).** To 65 mg of a 4:1 mixture of epoxides **58** (0.21 mmol) dissolved in 3.0 mL of dry THF was added 1.10 mL of L-Selectride (1.0 M, 1.10 mmol), and the resulting mixture was refluxed (67 °C) until TLC analysis indicated that the reaction was complete (48 h). The reaction mixture was cooled to 0 °C and diluted with 50 mL of ether, and the resulting mixture was quenched slowly with water. Standard ethereal workup, followed by chromatography (elution with H:E, 4:1), gave 5.0 mg (9%) of 11a(*R**),4a(*S**)-4a-hydroxy-7-methoxy-1,1,8-trimethyl-1,2,3,4,4a,10,11,11a-octahydro-5*H*-dibenzo[*a,d*]cycloheptene (**59**) which was homogeneous by TLC analysis (H:E, 3:1, R_f **59** = 0.32): ^{1}H NMR (250 MHz) δ 0.89 (s, 3 H), 0.93 (s, 3 H), 1.18−1.65 (m, 6 H), 1.70−2.06 (m, 3 H), 2.18 (s, 3 H), 2.47−2.82 (m, 3 H), 3.03 (d, 1 H, J = 14.1 Hz), 3.80 (s, 3 H), 6.61 (s, 1 H), 6.89 (s, 1 H); ^{13}C NMR (62.9 MHz) 155.8 (s), 135.3 (s), 134.2 (s), 130.8 (d), 124.5 (s), 113.9 (d), 70.6 (s), 57.9 (q), 55.3 (q), 51.2 (t), 42.4 (t), 42.0 (t), 34.9 (t), 34.2 (s), 32.1 (d), 24.0 (t), 21.5 (q), 18.6 (t), 15.5 (q) ppm. This data represents a single compound.

Continued elution (H:E, 4:1) provided 27 mg of alcohol-phenol **60** (49%) which was homogenous by TLC analysis (H:E, 3:1, R_f **60** = 0.11): ^{1}H NMR (250 MHz) δ 0.71 (s, 3 H), 1.00 (s, 3 H), 1.38−1.68 (m, 6 H), 2.20 (s, 3 H), 2.23−2.32 (m, 2 H), 2.33−2.42 (m, 1 H), 2.52−2.71 (m, 3 H), 6.24 (s, 1 H), 6.56 (s, 1 H), 6.78 (s, 1 H). This data represents a single compound.

11a(*R),4a(*S**),5(*S**)-5-Hydroxy-7-methoxy-1,1,8-trimethyl-1,2,3,4,4a,10,11,11a-octahydro-5*H*-dibenzo[*a,d*]-cycloheptene (61) and 4a(*R**),5(*R**),11a(*R**)-5-Hydroxy-7-methoxy-1,1,8-trimethyl-1,2,3,4,4a,10,11,11a-octahydro-5*H*-dibenzo[*a,d*]cycloheptene (66).** To a solution of **40** (534 mg, 1.61 mmol) in 10 mL of THF was added diborane (16.1 mL, 16.1 mmol of a 1.0 M solution in THF), and the resulting mixture was refluxed for a 7-h period and then cooled to 0 °C. Aqueous NaOH (16 mL, 32 mmol of a 2 M solution) and hydrogen peroxide (12 mL, 119 mmol of 30% aqueous solution)

were added, and the mixture was warmed to rt and stirred for a 2-h period. Standard ethereal workup, followed by chromatography (H:E, 4:1), gave 110 mg (24%) of alcohol **66** which was homogeneous by TLC analysis (H:E, 1:1, R_f **66** = 0.31): ^{1}H NMR (250 MHz) δ 0.72 (s, 3 H), 0.94 (s, 3 H), 1.10−1.21 (m, 2 H), 1.23−1.40 (m, 6 H), 1.45−1.60 (m, 3 H), 2.19 (s, 3 H), 2.65−2.75 (m, 2 H), 3.85 (s, 3 H), 4.64 (d, 1 H, J = 8.3 Hz), 6.85 (s, 1 H), 7.08 (s, 1 H).

Continued elution (H:E, 1:1) provided 230 mg of alcohol **61** (50%) which was homogeneous by TLC analysis (H:E, 3:1, R_f **61** = 0.22): ^{1}H NMR (300 MHz) δ 0.86 (br s, 3 H), 1.01 (br s, 3 H), 1.05−1.15 (m, 2 H), 1.16−1.40 (m, 4 H), 1.42−1.60 (m, 5 H), 1.75 (br s, 1 H), 2.18 (s, 3 H), 3.82 (s, 1 H), 4.57 (d, 1 H, J = 6.3 Hz), 6.72 (br s, 1 H), 6.85 (s, 1 H).

11a(*R),4(*S**),4a(*S**)-5-Acetoxy-7-methoxy-1,1,8-trimethyl-1,2,3,4,4a,10,11,11a-octahydro-5*H*-dibenzo[*a*,*d*]cycloheptene (62).** To a solution of alcohol **61** (196 mg, 0.680 mmol) in 6 mL of CH_2Cl_2 were added TEA (0.2 mL), DMAP (4 mg, 0.036 mmol), and acetic anhydride (128 μL, 0.88 mmol). The resulting mixture was stirred for 2 h. Standard ethereal workup, followed by chromatography (H:E, 5:1), gave 209 mg (93%) of the **62**, an oil which was homogeneous by TLC analysis (H:E, 2:1, R_f **62** = 0.72): ^{1}H NMR (250 MHz) δ 0.89 (s, 3 H), 1.00 (s, 3 H), 1.05−2.00 (m, 10 H), 2.09 (s, 3 H), 2.17 (s, 3 H), 3.81 (s, 3 H), 5.67 (d, 1 H, J = 6.3 Hz), 6.67 (s, 3 H), 6.86 (s, 1 H); ^{13}C NMR (62.9 MHz) 155.3 (s), 134.5 (s), 131.8 (d), 125.8 (s), 81.2 (br), 55.4 (q), 45.7 (br), 36.7 (br), 34.0 (t), 32.8 (br), 30.4 (q), 27.3 (q), 24.3 (br), 23.4 (br), 22.0 (t), 21.3 (q), 15.7 (q) ppm. Note: Six peaks observed were so broadened by conformational interconversion that they were not detected by DEPT for determination of the multiplicity. The four remaining signals were not detected. IR (film) 1736, 1511, 1368, 1238, 733 cm^{-1}; GC-MS (*m*/*z*) 330 (0.4%), 270 (39%), 201 (37%), 43 (100%). Anal. Calcd for $C_{21}H_{30}O_3$: C, 76.3; H, 9.15. Found: C, 76.26; H, 9.13.

4a(*R),5(*R**),11a(*R**)-5-Acetoxy-7-methoxy-1,1,8-trimethyl-1,2,3,4,4a,10,11,11a-octahydro-5*H*-dibenzo[*a*,*d*]cycloheptene (67).** To a solution of alcohol **66** (127 mg, 0.44 mmol) in 3 mL of CH_2Cl_2 were added TEA (0.1 mL), DMAP (4 mg, 0.034 mmol), and acetic anhydride (83 μL, 0.88 mmol). The resulting mixture was stirred at rt for a 30-min period. Standard ethereal workup, followed by chromatography (H:E, 4:1), gave 112 mg (77%) of acetate **67** which was homogeneous by TLC analysis (H:E, 2:1, R_f **67** = 0.72). An analytical sample was recrystallized isothermally from ether: mp 137−138 °C; ^{1}H NMR (300 MHz) δ 0.73 (s, 3 H), 0.93 (s, 3 H), 0.95−1.80 (m, 8 H), 1.95−2.15 (m, 2 H), 2.17 (s, 6 H), 2.70−2.92 (m, 2 H), 3.82 (s, 3 H), 5.79 (d, 1 H, J = 7.6 Hz); ^{13}C NMR (62.9 MHz) 169.9 (s), 155.8 (s), 137.8 (s), 132.6 (s), 131.2 (d), 124.9 (s), 107.0 (d), 77.5 (d), 55.4 (q), 52.2 (d), 43.0 (d), 42.2 (t), 34.1 (s), 32.4 (t), 30.9 (q), 30.2 (t), 27.0 (t), 21.7 (t), 21.1 (q), 20.4 (q), 15.7 (q) (the benzylic methine at 77.5 overlaps the $CDCl_3$ triplet, but is detected by DEPT) ppm; IR (KBr pellet) 1734, 1503, 1277, 1244, 1094 cm^{-1}; GC-MS (*m*/*z*) 330 (M^+, 0.1%), 270 (27%), 201 (19%), 43 (100%). Anal. Calcd for $C_{21}H_{30}O_3$: C, 76.3; H, 9.15. Found: C, 76.22; H, 9.11.

11a(*R),4(*S**),4a(*S**)-5-Acetoxy-7-methoxy-1,1,8-trimethyl-1,2,3,4,4a,10,11,11a-octahydro-5*H*-dibenzo[*a*,*d*]cyclohepten-10-one (63).** To a solution of acetate **62** (66 mg, 0.200 mmol) in 3 mL of CH_2Cl_2 were added PCC (323 mg, 1.50 mmol) and Celite (323 mg). The mixture was refluxed for 48 h. Standard ethereal workup, followed by chromatography (elution with H:E, 4:1), gave 13 mg (20%) of unreacted **62** and 25 mg (36% yield, 56% based on mass balance) of ketone **63** which was homogeneous by TLC analysis (H:E, 2:1, R_f **63** = 0.31). An analytical sample was recrystallized isothermally from ether: mp 177−179 °C; ^{1}H NMR (250 MHz) δ 0.90 (s, 3 H), 0.94 (s, 3 H), 1.10−1.90 (m, 6 H), 2.11−2.33 (m, 2 H), 2.19 (s, 3 H), 2.20 (s, 3 H), 2.56−2.82 (m, 2 H), 3.88 (s, 3 H), 5.74 (d, 1 H, J = 9.4 Hz), 6.72 (s, 1 H), 7.47 (d, 1 H, J = 0.5 Hz); ^{13}C NMR (62.9 MHz) 204.5 (s), 169.9 (s), 161.0 (s), 137.4 (s), 130.9 (d), 128.3 (s), 126.0 (s), 104.8 (d), 77.7 (d), 55.3 (q), 41.4 (d), 38.9 (t), 38.6 (d), 34.4 (t), 33.1 (s), 29.9 (q), 26.9 (q), 24.9 (t), 21.0 (q), 20.8 (t), 15.6 (q) ppm; IR (KBr pellet) 1734, 1666, 1603, 1236, 1051 cm^{-1}; GC-MS (*m*/*z*) 344 (4%), 302 (14%), 284 (38%), 202 (25%), 43 (100%). Anal. Calcd for $C_{21}H_{28}O_4$: C, 73.2; H, 8.19. Found: C, 73.14; H, 8.21.

4a(*R),5(*R**),11a(*R**)-5-Acetoxy-7-methoxy-1,1,8-trimethyl-1,2,3,4,4a,10,11,11a-octahydro-5*H*-dibenzo[*a*,*d*]cyclohepten-10-one (68).** To a solution of acetate **67** (100 mg, 0.303 mmol) in 3 mL of CH_2Cl_2 were added PCC (489 mg, 2.27 mmol) and Celite (489 mg). The mixture was refluxed for 24 h. Standard ethereal workup, followed by chromatography (elution with H:E, 4:1), gave 27 mg of unreacted **67** (27%) and 34 mg of ketone **68** (33% yield, 60% based on mass balance) which was homogeneous by TLC analysis (H:E, 2:1, R_f **68** = 0.31). An analytical sample was recrystallized isothermally from ether: mp 124−126 °C; ^{1}H NMR (250 MHz) δ 0.88 (s, 6 H), 1.00−1.75 (m, 6 H), 1.85−2.05 (m, 2 H), 1.94 (s, 3 H), 2.22 (s, 3 H), 2.62−2.86 (m, 2 H), 3.90 (s, 3 H), 5.60 (s, 1 H), 6.67 (s, 1 H), 7.49 (s, 1 H); ^{13}C NMR (62.9 MHz) 206.0 (s), 169.8 (s), 160.1 (s), 135.9 (s), 131.5 (s), 129.8 (s), 127.2 (s), 110.8 (d), 81.6 (d), 55.6 (q), 46.1 (d), 43.1 (d), 41.0 (t), 40.9 (t), 33.4 (s), 31.5 (t), 30.1 (q), 22.4 (t), 21.3 (q), 19.8 (q), 15.8 (q) ppm; IR (KBr pellet) 1735, 1669, 1606, 1236 cm^{-1}; GC-MS (*m*/*z*) 344 (15%), 302 (33%), 284 (17%), 149 (22%), 43 (100%). Anal. Calcd for $C_{21}H_{28}O_4$: C, 73.2; H, 8.19. Found: C, 73.15; H, 8.20.

11a(*R),4(*S**),4a(*S**)-5-Hydroxy-7-methoxy-1,1,8-trimethyl-1,2,3,4,4a,10,11,11a-octahydro-5*H*-dibenzo[*a*,*d*]cyclohepten-10-one (64).** To a solution of acetate **63** (19 mg, 0.055 mmol) was added 3 mL of a 2% solution of KOH in methanol, and the mixture was stirred at rt for 2 h. The solvent was removed at reduced pressure, and the residue was chromatographed (elution with H:E, 5:1) to give 15 mg of alcohol **64** (90%) which was homogeneous by TLC analysis (H:E, 1:1, R_f **64** = 0.36): ^{1}H NMR (250 MHz) δ 0.87 (s, 3 H), 0.92 (s, 3 H), 1.05−2.10 (m, 9 H), 2.21 (s, 3 H) 2.40−2.70 (m, 2 H), 3.93 (s, 3 H), 4.43 (d, 1 H, J = 9.0 Hz), 7.12 (s, 1 H), 7.53 (s, 1 H).

4a(*R),5(*R**),11a(*R**)-5-Hydroxy-7-methoxy-1,1,8-trimethyl-1,2,3,4,4a,10,11,11a-octahydro-5*H*-dibenzo[*a*,*d*]cyclohepten-10-one (69).** Thirty-five milligrams of acetate **68** (0.102 mmol) were dissolved in 1 mL of a 2% solution of KOH in methanol, and the mixture was stirred at rt for a 30-min period. The solvent was removed at reduced pressure, and the residue was chromatographed (elution with H:E, 1:1) to give 29 mg of alcohol **69** (85%) which was homogeneous by TLC analysis (H:E, 1:2, R_f **69** = 0.47): ^{1}H NMR (250 MHz) δ 0.85 (s, 3 H), 0.89 (s, 3 H), 0.95−2.06 (m, 8 H), 2.45−3.00 (m, 2 H), 3.88 (s, 8 H), 4.60 (s, 1 H), 6.55 (s, 1 H), 7.45 (s, 1 H).

(±)-Faveline Methyl Ether (57) by Dehydration of (64). To a solution of alcohol **64** (14 mg, 0.046 mmol) and DCC (13 mg, 0.064 mmol) in 0.1 mL of THF was added CuCl (1 mg, 0.009 mmol). The solvent was removed under reduced pressure, and the residue was heated to 90 °C for 4 h. Chromatography of the crude residue (elution with H:E, 10:1) provided 10 mg of faveline methyl ether (**57**) (76%) which was homogeneous by TLC analysis (H:E, 1:1, R_f **57** = 0.82): mp 136−138 °C [lit. for (±)-**4** is 139−140 °C;[22] 135−136 °C for (−)-**4**[7]]: ^{1}H NMR (250 MHz) δ 0.76 (s, 3 H), 1.13 (s, 3 H), 1.40−1.51 (m, 2 H), 1.55−1.85 (m, 3 H), 1.60 (s, 3 H), 2.19 (s, 3 H), 2.20−2.50 (m, 3 H), 3.03 (dd, 2 H, J = 6.1 Hz, 1.1 Hz), 3.88 (s, 3 H), 6.30 (s, 1 H), 7.63 (s, 1 H); GC-MS (*m*/*z*) 284 (69%), 215 (73%), 202 (100%), 173 (85%).

(±)-Faveline Methyl Ether (57) by Dehydration of (69). To a solution of alcohol **69** (20 mg, 0.066 mmol) and DCC (19 mg, 0.092 mmol) in 0.1 mL of THF was added CuCl (1 mg, 0.009 mmol). The solvent was removed at reduced pressure, and the residue was heated to 90 °C for a 14-h period. Chromatography of the resulting residue (elution with H:E, 10:1) gave 12 mg of **57** (64%) which was identical to that prepared from **64**.

11a(*R),4(*S**),4a(*S**)-5,7-Dihydroxy-1,1,8-trimethyl-1,2,3,4,4a,10,11,11a-octahydro-5*H*-dibenzo[*a*,*d*]cyclohepten-10-one (65).** Sodium hydride (36 mg, 0.90 mmol of 60% dispersion in mineral oil) was suspended in 1.5 mL of DMF. Ethanethiol (111 μL, 1.50 mmol) was then added to the reaction, and the resulting mixture was stirred for 1 h. A solution of ether **63** (52 mg, 0.150 mmol) dissolved in 1.5 mL of DMF was added, and the mixture was heated to 135 °C for 3 h and then acidified by addition of 10% aqueous HCl.

Standard ethereal workup, followed by chromatography (H:E, 5:1 gradient elution to 1:2), gave 32 mg of keto-alcohol **65** (74%) which was homogeneous by TLC analysis (H:E, 1:2, R_f **65** = 0.20): ^{1}H NMR (250 MHz) δ 0.85 (s, 3 H), 0.88 (s, 3 H), 1.08−1.40 (m, 4 H), 1.42−1.70 (m, 2 H), 1.85−2.25 (m, 2 H), 2.26 (s, 3 H), 2.30−2.68 (m, 2 H), 4.12 (d, 1 H, J = 9.0 Hz), 7.10 (s, 1 H), 7.42 (d, 1 H, J = 0.6 Hz).

4a(*R),5(*R**),11a(*R**)-5,7-Dihydroxy-1,1,8-trimethyl-1,2,3,4,4a,10,11,11a-octahydro-5*H*-dibenzo[*a,d*]cyclohepten-10-one (70).** Sodium hydride (11 mg, 0.28 mmol of 60% dispersion in mineral oil) was suspended in 0.5 mL of DMF. Ethanethiol (35 μL, 0.46 mmol) was then added to the reaction, and the resulting mixture was stirred for 1 h. A solution of ether **68** (16 mg, 0.046 mmol) dissolved in 0.5 mL of DMF was added, and the resulting mixture was heated to 135 °C for 3 h and then acidified by addition of 10% aqueous HCl. Standard ethereal workup, followed by chromatography (H:E, 5:1 gradient elution to 1:2), gave 9 mg of **70** (67%) which was homogeneous by TLC analysis (H:E, 1:2, R_f **68** = 0.66, R_f **70** = 0.20): ^{1}H NMR (250 MHz) δ 0.85 (s, 3 H), 0.88 (s, 3 H), 1.00−2.05 (m, 8 H), 2.50−2.95 (m, 2 H), 4.51 (s, 1 H), 6.54 (s, 1 H), 7.45 (s, 1 H).

(±)-Faveline from 65. Thirty-two milligrams of $KHSO_4$ (0.12 mmol) and 32 milligrams of benzylic alcohol **65** (0.11 mmol) were heated under continous N_2 stream in 140 °C oil bath for 2 h. Chromatography (H:E, 2:1) gave 18 mg of racemic faveline (60%) which was homogeneous by TLC analysis (H:E, 1:2, R_f **65** = 0.17, R_f **4** = 0.67): mp 194−196 °C; ^{1}H NMR (250 MHz) δ 0.76 (s, 3 H), 1.12 (s, 3 H), 1.35−1.51 (m, 2 H), 1.53−1.72 (m, 4 H), 2.23 (s, 3 H), 2.25−2.45 (m, 3 H), 3.03 (dd, 2 H, J = 5.7 Hz, 0.6 Hz), 5.44 (s, 1 H), 6.20 (s, 1 H), 6.60 (s, 1 H), 7.64 (s, 1 H); ^{13}C NMR (62.9 MHz) 202.0 (s), 157.8 (s), 147.7 (s), 136.6 (s), 132.0 (d), 129.9 (s), 124.9 (d), 122.0 (s), 118.0 (d), 51.2 (d), 43.0 (t), 42.4 (t), 40.1 (t), 38.4 (s), 28.9 (q), 25.0 (t), 20.7 (q), 15.1 (q) ppm; GC-MS (*m*/*z*) 159 (67%), 188 (100%), 201 (67%), 270 (69%).

(±)-Faveline from 70. Nine milligrams of $KHSO_4$ (0.066 mmol) and nine milligrams of benzylic alcohol **70** (0.031 mmol) were heated under a continous N_2 stream in 140 °C oil bath for 2 h. Chromatography (H:E, 2:1) provided 7 mg of racemic **4** (83%) which was identical to that prepared from **65**.

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Supporting Information Available: NMR spectra for obtained compounds (77 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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