# Synthesis of Antibiotics WS 5995 A and C and Related Compounds by Palladium-Catalyzed Coupling of 2-Bromonaphthoquinones with Organostannanes

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The synthesis of arylnaphthoquinones can be performed simply by using as the key reaction the Pd(0)- and Cu(I)-catalyzed coupling of arylstannanes with 2-bromonaphthoquinones as the electrophiles. The palladium-catalyzed coupling reaction is general and allows for the functionalization of the unprotected quinone nucleus with alkyl, alkenyl, and aryl substituents. The coupling process tolerates the presence of a chelated *peri* hydroxyl and steric crowding of a 2,6-disubstituted arylstannane, although the preparation of a 2,6,2′,6′-tetrasubstituted biaryl by coupling of 2-bromo-3,5-bis(acetyloxy)-1,4-naphthoquinone as the electrophile with 2,6-disubstituted arylstannanes was unsuccessful. The syntheses of quinonoid antibiotics WS 5995 A and C was accomplished by using this method as the key step. Benz[*b*]phenanthridinone **1**, hypothetical intermediate in the biosynthesis of benz[*b*]phenanthridine alkaloids, was also prepared from antibiotic WS 5995 C or by addition of ammonia to the 2-aryl-1,4-naphthoquinone **41** followed by heterocyclization.

## Introduction

The preparation of quinonoid natural products usually proceeds by functionalization of an aromatic intermediate, followed by an oxidation in the later stages of the synthesis to uncover the quinone nucleus.[1] On the other hand, methods for the direct functionalization of quinones by reaction with suitable nucleophiles are rather limited.[2] Therefore, the development of more general methodology for the carbon–carbon bond formation on a functionalized unprotected quinone is of considerable interest. Recently, we have communicated a procedure for the selective alkylation, alkenylation, and arylation of naphthoquinones under mild conditions by a variation of the palladium-catalyzed Stille coupling reaction between 2-bromonaphthoquinones and tetraorganostannanes.[3] In most cases, better results were obtained by using CuBr as the cocatalyst. The alternative procedure, palladium-catalyzed coupling of stannylquinones with allyl or aryl electrophiles, has been recently developed by Liebeskind.[4]

Benzo[*b*]phenanthridinone **1** was proposed by Gould as a key intermediate in the biosynthesis of the kinamycin antibiotics, cyanamides of benzo[*b*]carbazoles.[5] However, the intermediacy of **1** in the biosynthesis of the kinamycins is not consistent with the recent reformulation of the kinamycins as 5-diazobenzo[*b*]fluorenes.[6,7] Quinone **1** is related to the natural products phenanthroviridine (**2**),[8,9] its aglycone phananthroviridone (**3**),[6,10] and jadomycin (**4**).[11] Additionally, three naturally occurring pigments, antibiotics WS-5995 A (**5**), B (**6**), and C (**7**) isolated from a *Streptomyces auranticolor* species,[12] possess a related 2-aryl-1,4-naphthoquinone structure. Also related to these compounds are the gilvocarcins, which contain a reduced 2-arylnaphthalene chromophore.[13] Herein we report full details on the synthesis of the title antibiotics and benzo[*b*]phenanthridinone **1**[14] by using as the key step our method of arylation of 2-bromonaphthoquinones by palladium- and copper-catalyzed coupling with organostannanes.[3]

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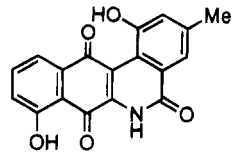
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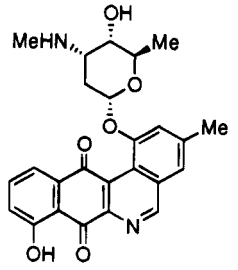
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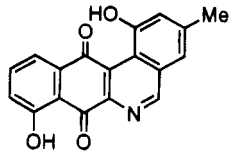
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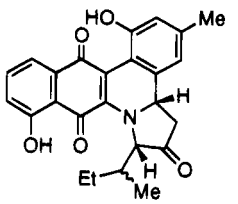
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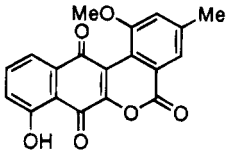
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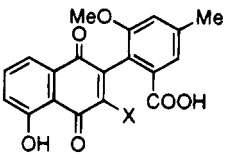
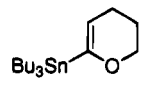

6 : X = H
7 : X = OH

## Results and Discussion

In the retrosynthetic analysis for benzo[*b*]phenanthridinone **1** the key carbon–carbon bond between the 1,4-naphthoquinone and the 2-aryl can be derived by a palladium-catalyzed Stille coupling reaction[15,16] from an electrophilic 2-bromo-5-hydroxy-1,4-naphthoquinone (2-bromojuglone) (**8**)[17] and a 2,4,6-trisubstituted arylstannane. The coupling of **8** with tetramethyl, tetrabutyl, phenyltributylstannane, and stannanes **9-13** proceeds in the presence of $Pd(PPh_3)_4$ or $Pd(dppf)Cl_2$ (dppf = 1,1'-bis(diphenylphosphino)ferrocene) as the catalysts in 1,4-dioxane under reflux to give the substituted derivatives **14-21** in good yields (Scheme 1).[3] In most cases better results were obtained by the addition of CuBr as the cocatalyst, leading to higher yields and shorter reaction times. Other palladium-catalyzed coupling reactions have also been shown to proceed more cleanly in the presence of Cu(I).[18] For the alkylation with tetraalkylstannanes, shorter reaction times were observed by using $Pd(dppf)Cl_2$ as the catalyst. The formation of biaryls **19-21** is noteworthy since the carbon–carbon formation takes place on a severely hindered environment. Better yields were obtained in the coupling of **8** with **13** with an *ortho* MOM ether relative to the methyl ether **12**. Additional examples with 2-bromonaphthoquinone (**22**) and 2-bromo-8-hydroxy-6-methoxynaphthoquinone (**24**) as the electrophiles are summarized in Scheme 1.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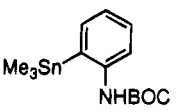
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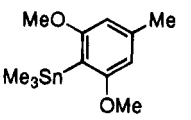
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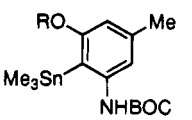
12 : R = Me
13 : R = MOM

We decided to attempt the synthesis of **1** by heterocyclization of a derivative of antibiotic WS-5995 C (**7**). For the synthesis of **7**, we first explored the utility of a 2,3,5-trisubstituted 1,4-naphthoquinone as the electrophile in the coupling reaction. The selected 2-bromo-3,5-bis(acetyloxy)-1,4-naphthoquinone (**27**)[19] was readily prepared from **8** in three steps as shown in Scheme 2. Bromination of **8** with $Br_2$ in AcOH for 3 h gave dibromojuglone **28**, contaminated with small amounts of 2,3,6-tribromo-5-hydroxy-1,4-naphthoquinone.[20] The byproduct was difficult to separate by chromatography or recrystallization. However, treatment of crude **28** with 10% NaOH in EtOH, followed by acetylation afforded **27** in 60% overall yield (Scheme 2). Quinone **27** coupled with stannane **10**[21] in the presence of Pd(0) and Cu(I)[3] to give the arylnaphthoquinone derivative **29** in 60% yield. Products derived from partial deacetylation of both the starting material and the arylated derivative were also observed in the crude reaction mixture. Unfortunately, no coupling product could be isolated when acetoxybromoquinone **27** was treated with sterically hindered 2,6-disubstituted arylstannanes such as **12**, **13**, or **30** required for the synthesis of the antibiotics WS 5995 and related compounds.

The required substituted arylstannane **30** was prepared from 3-hydroxy-5-methylbenzoic acid[22] by quantitative methylation with $Me_2SO_4$ in aqueous NaOH under reflux followed by standard formation of the amide *via* the acid chloride (96%). Directed *ortho*-lithiation[23] with *tert*-BuLi, followed by reaction with $Me_3SnCl$, gave rise to **30** in 92% yield. Bromojuglone **8** reacted with **30** in 1,4-dioxane under reflux for 3 h in the presence of Pd(0) and Cu(I) as the catalysts to give **31** in 82% yield (Scheme 3). Additionally, variable amounts (2–10%) of a byproduct were detected in the crude reaction mixtures. Based on the spectroscopic data, structure **32**, isomeric with **31**, was assigned for this derivative. This spiro compound **32** arises by a Michael-type addition of the amide nitrogen to C-2 of the quinone. However, formation of byproduct **32** was of no consequence since under the basic conditions required for the next step, both **31** and **32** converged to give the same product. Epoxidation of the

(15) Stille, J. K. *Angew. Chem., Int. Ed. Engl.* **1986**, *25*, 508.
(16) For recent improvevents in the efficacy of this coupling reaction, see: Farina, V.; Krishnan, B.; Marshalll, D. R.; Roth, G. P. *J. Org. Chem.* **1993**, *58*, 5434, and references cited therein.
(17) Grunwell, J. R.; Karipides, A.; Wigal, C. T.; Heinzman, S. W.; Parlow, J.; Surso, J. A.; Clayton, L.; Fleitz, F. J.; Daffner, M.; Stevens, J. E. *J. Org. Chem.* **1991**, *56*, 91.
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(19) Thomson, R. H. *J. Org. Chem.* **1948**, *13*, 377. Thomson, R. H. *J. Org. Chem.* **1948**, *13*, 870.
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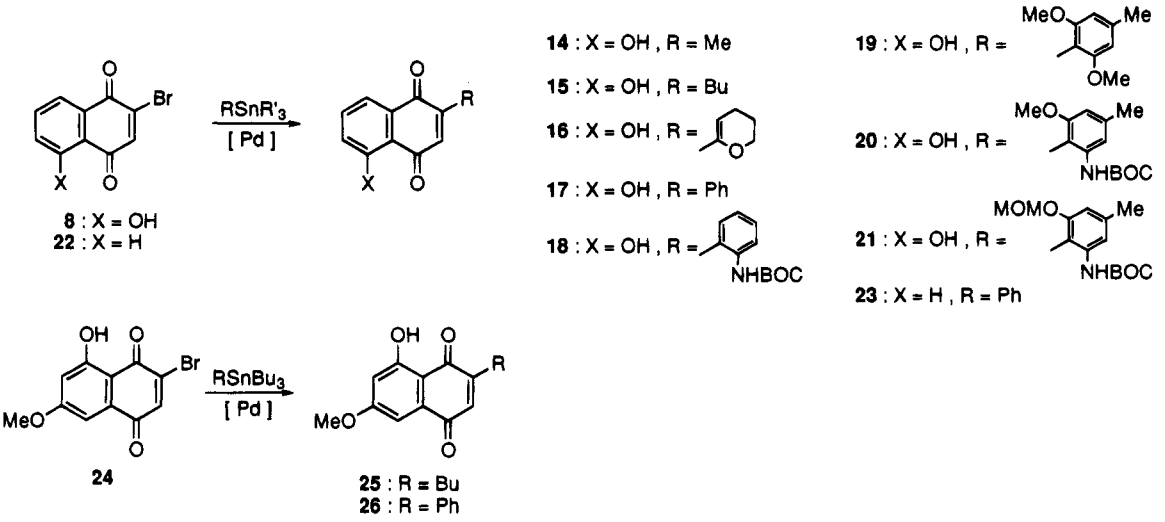
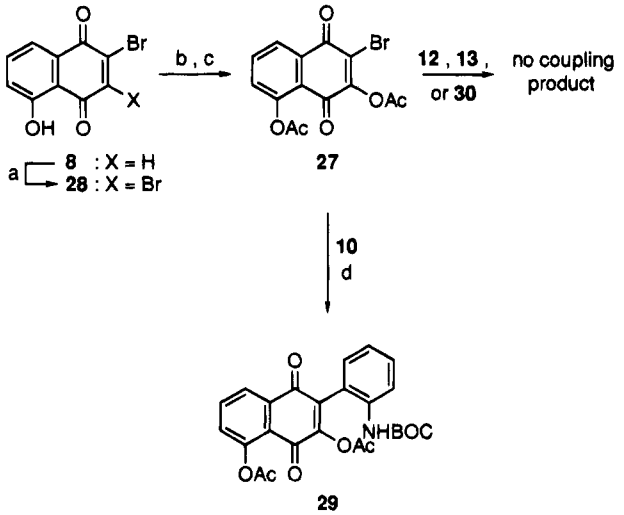
**Scheme 1**




**Scheme 2**

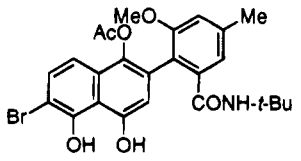


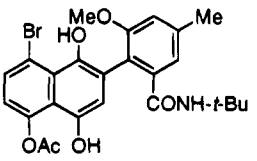

[a] (a) $Br_2$, AcOH, reflux; (b) NaOH, THF, 23 °C; (c) $Ac_2O$, $H_2SO_4$ (cat.), 23 °C; 60% (three steps); (d) $Pd(PPh_3)_4$ (5%), CuBr (5%), dioxane, reflux, 60%.

naphthoquinone with *tert*-butyl hydroperoxide and aqueous benzyltrimethylammonium hydroxide proceeded in THF at room temperature to give a mixture of diastereomeric epoxides. These epoxides suffered substantial decomposition on attempted chromatographic purification. However, treatment of the crude mixture of labile epoxides with aqueous $HClO_4$ in 1,4-dioxane under reflux led to the formation of antibiotic WS-5995 C (**7**) in 98% yield by concomitant hydrolysis of the epoxide and the carboxamide. The synthesis of this natural compound was thus accomplished in just three steps in 80% overall yield from known 2-bromojuglone (**8**).[24]

Lactonization of **7** with trifluoroacetic anhydride at room temperature, according to the described procedure,[24b] gave the trifluoroacetate of antibiotic WS-5995 A. Mild methanolysis of this intermediate afforded **5** in quantitative yield.[24]

The hydrolysis of the *tert*-butylamide of coupling product **31** would furnish antibiotic WS-5995 B (**6**). However, **31** was recovered unchanged after being treated with a variety of protic or Lewis acids or suffered extensive decomposition under more severe conditions. Spiro derivative **32** was inert under acidic reaction conditions. Cleavage of the carboxamide of **31** by *N*-nitrosation with nitrous acid or $N_2O_4$[25] was also fruitless. Treatment of **31** with $POCl_3$, in an attempt to obtain the nitrile,[26] led also to formation of spiro derivative **32** in low yield. Finally, reaction with HBr in AcOH at room temperature yielded a bromonaphthalene **33**, which still retained the secondary carboxamide. Although the spectroscopic data, including NOE enhancements, are also consistent with the formulation of this biaryl as **34**, the observation of a 9 Hz coupling between two naphthalene hydrogens favors structure **33**.[27] Mechanistically, the bromonaphthalene probably arises by oxidation of bromide to $Br_2$ by the quinone, with concomitant reduction of **31** to the naphthohydroquinone, followed by an aromatic electrophilic substitution. The isolation of a single monoacetate is surprising, although it may result from the selective hydrolysis of the triacetate during the aqueous workup or chromatographic purification.




The completion of the synthesis of **1** required the selective conversion of the C-3 hydroxyl into a leaving group for the introduction of the amino functionality. For that purpose, reaction of **7** with diazomethane, as reported,[24b] gave the methoxy ester **35**. However, this reaction was difficult to reproduce giving rise to highly

(24) For previous synthesis, see: (a) Tanaka, H.; Itoh, Y.; Ikushima, H.; Okamoto, M.; Kawai, Y.; Imanaka, H. *Tetrahedron Lett.* **1980**, *21*, 4359. (b) Ikushima, H.; Takase, S.; Kawai, Y.; Itoh, Y.; Okamoto, M.; Tanaka, H.; Imanaka, H. *Agric. Biol. Chem.* **1983**, *47*, 2231. (c) Watanabe, M.; Date, M.; Furukawa, S. *Chem. Pharm. Bull.* **1989**, *37*, 292. (d) McKenzie, T. C.; Choi, W.-B. *Synth. Commun.* **1989**, *19*, 1523.

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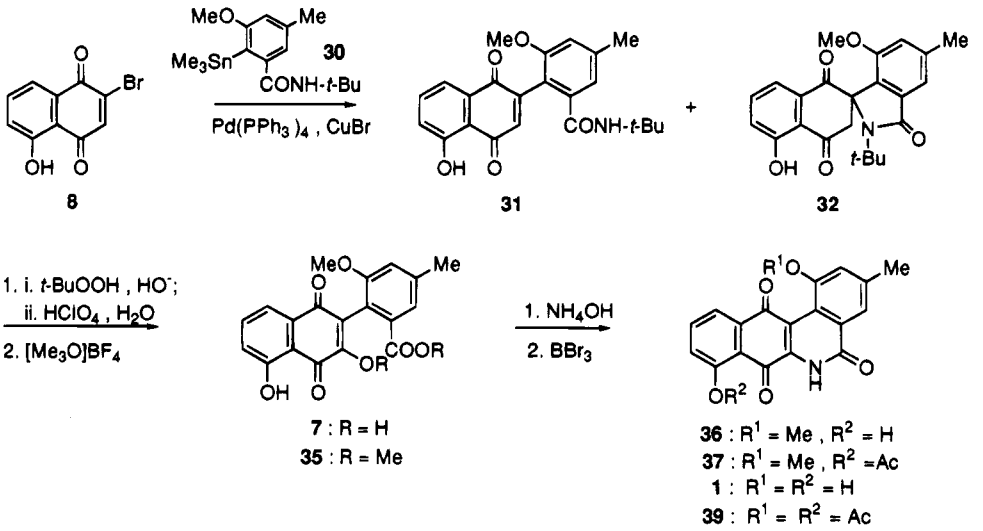
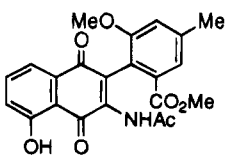
(26) Perni, R. B.; Gribble, G. W. *Org. Prep. Proc. Int.* **1983**, *15*, 297.

(27) The coupling constant between H-1 and H-2 in naphtahlene is 8.5 Hz (8–9 Hz in derivatives), while the coupling constant between H-2 and H-3 is 7.5 Hz (5–7 Hz in derivatives): Pretsch, E.; Clerc, T.; Seibl, J.; Simon, W. *Tables of Spectral Data for Structure Determination of Organic Compound*; Springer: Berlin, 1983.

**Scheme 3**



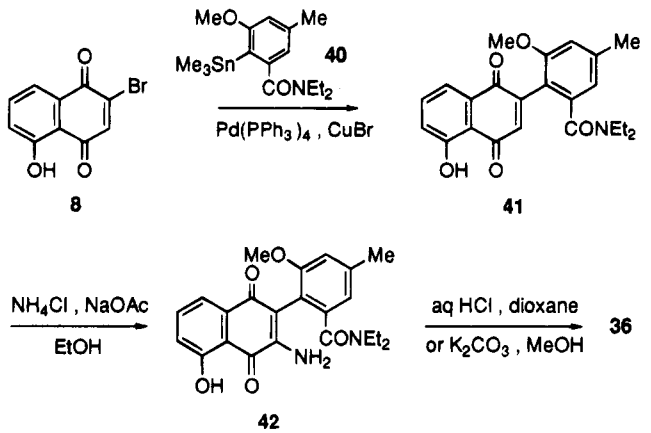

variable yields of **35** and formation of several byproducts.[28] Methylation with MeOH under reflux in the presence of $H_2SO_4$ as the catalyst led only to methylation of the carboxyl functionality yielding to the ester. On the other hand, reaction of **7** with trimethyloxonium tetrafluoroborate afforded cleanly **35** in 76% yield (Scheme 3). Heating **35** with $NH_4OH$ in MeOH under reflux conditions for 48 h gave **36** in 54% yield, after mild acid treatment of the crude reaction mixture. This acid treatment apparently allows for the hydrolysis of an intermediate purple quinone imine formed under the heterocyclization reaction conditions. Benzo[*b*]phenanthridinone **36** was purified by chromatography after acetylation with $Ac_2O$ and $H_2SO_4$ to give the monoacetate **37**, which after saponification gave pure **36** quantitatively. Presumably, the heterocyclization takes place by means of ammonia attack at C-3 of the naphthoquinone, followed by ring formation. In fact, when the reaction was allowed to proceed for shorter reactions times, acetamide **38** was isolated in low yield, after acetylation of the crude reaction mixture. The presence of a signal corresponding to the methyl ester at 52.26 ppm in the $^{13}C$ NMR spectrum and the absence of imide carbonyls support the assigned structure for **38**. Finally, demethylation of **36** was achieved after treatment with $BBr_3$ in $CH_2Cl_2$ to give **1** in 47%. Again, this polar compound was better purified by chromatography of its diacetate **39**, followed by quantitative methanolysis. The low yields obtained in the formation of **36** and **1** are a consequence of their very low solubility in organic solvents.




**38**

A more direct synthesis of **1** was accomplished by using stannane **40** with a tertiary carboxamide (Scheme 4). Coupling of **40** with bromoquinone **8** proceeded uneventfully to give **41**. Treatment of **41** with ammonium

**Scheme 4**




chloride and sodium acetate in ethanol under reflux led to the formation of bright red **42** by a Michael-type addition of ammonia and *in situ* air oxidation.[29] 3-Aminoquinone **42** could be converted into **36** by hydrolysis of the tertiary amide with aqueous HCl in 1,4-dioxane at 75 °C. Alternatively, heating of **42** with $K_2CO_3$ in methanol led also cleanly to **36**. Thus, the use of stannane **40** allows for the preparation of target **1** in four steps from quinone **8**.

## Conclusions

We have demonstrated that the synthesis of arylnaphthoquinones can be performed simply by using as the key reaction the Pd(0)- and Cu(I)-catalyzed coupling of arylstannanes with 2-bromonaphthoquinones as the electrophiles. The palladium-catalyzed coupling reaction is general[7a,30] and allows for the functionalization of the unprotected quinone nucleus with alkyl, alkenyl, and aryl substituents. The coupling process tolerates the presence of a chelated *peri* hydroxyl. The reaction is also rather insensitive to the steric crowding of a 2,6-disubstituted arylstannane, although the preparation of a 2,2′,6,6′-tetrasusbtituted biaryl by coupling of **27** as the electrophile with 2,6-disubstituted arylstannanes was unsuc-

(28) Diazomethane has been reported to form epoxides by reaction with the naphthoquinone carbonyl. See: Bergy, M. E. *J. Antibiot.* **1968**, *21*, 454.

(29) Amination of 1,4-quinones: Bayer, O. *Methoden der Organischen Chemie (Houben-Weyl)*; Thieme: Stuttgart, 1979; Vol. 7/3c, p 218.

(30) For the recently developed coupling of arylboronic acids with haloquinones, see: Fukuyama, Y.; Kiyama, Y.; Kodama, M. *Tetrahedron Lett.* **1993**, *34*, 7637.

cessful. Simple syntheses of antibiotics WS 5995 A and C and a hypothetical intermediate in the biosynthesis of benz[*b*]phenanthridine alkaloids have been completed by using this method as the key step.

## Experimental Section

Only the most significant IR absortions and the molecular ions and/or base peaks in the MS are given. 2-Bromo-5-hydroxy-1,4-naphthoquinone (**8**),[17] 2-bromo-1,4-naphthoquinone (**22**),[17b] 2,3-dibromo-5-hydroxy-1,4-naphthoquinone (**28**), 2-bromo-3,5-bis(acetyloxy)-1,4-naphthoquinone (**27**),[17] (2,3-dihydro-4*H*-pyran-6-yl)tri-*n*-butylstannane (**9**),[31] *N*-(*tert*-butoxycarbonyl)-2-(trimethylstannyl)aniline (**10**)[19] were prepared according to known procedures. "Usual workup" means extraction with EtOAc or $CH_2Cl_2$, drying with $Na_2SO_4$, filtration, and evaporation. Chromatography was performed with flash grade silica gel. All reactions, except for the hydrolysis and the formation of **42**, were carried out under an atmosphere of Ar.

**(2,6-Dimethoxy-4-methylphenyl)trimethylstannane (11).** This stannane was prepared by a modification of a described procedure:[32] A solution of 3,5-dimethoxytoluene (1.42 g, 9.3 mmol) in THF (20 mL) at −78 °C was treated with *t*-BuLi (7.8 mL, 1.3 M solution in pentane, 10.1 mmol). The mixture was warmed up to −20 °C over 1 h and stirred at this temperature for 2 h. A solution of $Me_3SnCl$ (2.01 g, 10.1 mmol) in THF (5 mL) was added and the mixture was stirred at −20 °C for 30 min. The resulting mixture was poured into an aqueous $NH_4Cl$ solution (saturated, pH 8) and extracted with EtOAc. After the usual workup and chromatography (25:1 hexane−EtOAc), **12** was obtained as a yellow oil (2.14 g, 73%). Its spectral data are in agreement with those reported.[31]

**[2-[(*tert*-Butoxycarbonyl)amino]-6-methoxy-4-methylphenyl]trimethylstannane (12).** (i) To a solution of 3-amino-5-methylphenol[33] (1.05 g, 8.5 mmol) in THF (15 mL) was added di-*tert*-butyl dicarbonate (2.05 g, 9.4 g) and the resulting mixture was heated under reflux conditions for 2 h. The solution was diluted with EtOAc and washed with aqueous tartaric acid, $H_2O$, and a saturated aqueous NaCl solution. After the usual workup and chromatography (5:1 hexane−EtOAc) 3-[(*tert*-butoxycarbonyl)amino]-5-methylphenol was obtained as a colorless oil (1.90 g, quantitative yield): IR (neat) 3340, 2980, 1700, 1600, 1160 $cm^{-1}$; $^1H$ NMR ($CDCl_3$, 300 MHz) $\delta$ 6.37 (br s, 1 H), 6.33 (br s, 1 H), 6.29 (br s, 1 H), 3.65 (br s, 2 H), 2.23 (s, 3 H), 1.54 (s, 9 H). Anal. Calcd for $C_{12}H_{17}NO_3$: C, 64.55; H, 7.67; N, 6.28. Found: 64.26; H, 8.01; N, 6.21. (ii) A mixture of the above phenol (1.30 g, 5.8 mmol), benzyltrimethylammonium chloride (190 mg, 0.8 mmol), and MeI (0.7 mL, 12.2 mmol) in $CH_2Cl_2$ (7 mL) and aqueous NaOH (13%, 6 mL) was stirred at 23 °C for 9 h. After the usual workup the crude product was chromatographed (12:1 hexane−EtOAc) to give 1-[(*tert*-butoxycarbonyl)amino]-3-methoxy-5-methylbenzene as an viscous oil that solidifies at room temperature (1.26 g, 91%): mp 69−70 °C; IR (KBr) 3320, 1700, 1605, 1550, 1280, 1160 $cm^{-1}$; $^1H$ NMR ($CDCl_3$, 200 MHz) $\delta$ 6.85 (br t, $J$ = 2.1 Hz, 1 H), 6.75 (br s, 1 H), 6.60 (br s, 1 H), 6.41 (br s, 1 H), 3.76 (s, 3 H), 2.27 (s, 3 H), 1.51 (s, 9 H); $^{13}C\{^1H\}$ NMR ($CDCl_3$, 50 MHz; DEPT) $\delta$ 160.02 (s), 152.61 (s), 139.78 (s), 139.29 (s), 111.40 (d), 109.65 (d), 80.30 (s), 55.09 (q), 28.24 (q, 3 C), 21.56 (q). Anal. Calcd for $C_{13}H_{19}NO_3$: C, 65.77; H, 8.07; N, 5.90. Found: 65.48; H, 8.18; N, 6.11. (iii) A solution of 1-[(*tert*-butoxycarbonyl)amino]-3-methoxy-5-methylbenzene (2.90 g, 12.3 mmol) in THF (25 mL) at −78 °C was added *t*-BuLi (24 mL, 1.2 M solution in pentane, 28.8 mmol). The mixture was warmed up to −20 °C over 1 h and stirred at this temperature for 2 h. A solution of $Me_3SnCl$ (5.14 g, 25.8 mmol) in THF (10 mL) was added and the mixture was stirred at −20 °C for 30 min. To the mixture cooled at −20 °C was added 0.5 mL of an aqueous $NH_4Cl$ solution (saturated, pH 8). After drying with $Na_2SO_4$ the mixture was evaporated. The residue was chromatographed (15:1 hexane−EtOAc; silica gel deactivated with 10:1 hexane−$Et_3N$) to give **12** as a colorless oil (3.68 g, 75%): IR (neat) 3440, 2950, 1740, 1230, 1160 $cm^{-1}$; $^1H$ NMR ($CDCl_3$, 300 MHz) $\delta$ 7.31 (s, 1 H), 6.54 (br s, 1 H), 6.41 (s, 1 H), 3.75 (s, 3 H), 2.32 (s, 3 H), 1.51 (s, 9 H), 0.32 [s, 9 H; $^2J(^{119}Sn-^1H)$ = 56 Hz, $^2J(^{117}Sn-^1H)$ = 54 Hz]; $^{13}C\{^1H\}$ NMR ($CDCl_3$, 50 MHz) $\delta$ 163.95, 153.24, 144.52, 141.21, 114.57, 106.26, 79.98, 55.36, 28.34 (3 C), 21.81, −7.19 [$^1J(^{119}Sn-^{13}C)$ = 365 Hz, $^1J(^{117}Sn-^{13}C)$ = 351 Hz] (one carbon resonance was not observed). Anal. Calcd for $C_{16}H_{27}NO_3Sn$: C, 48.03; H, 6.80; N, 3.50. Found: C, 48.31; H, 7.15; N, 3.28.

**[2-[(*tert*-Butoxycarbonyl)amino]-6-(methoxymethoxy)-4-methylphenyl]trimethylstannane (13).** (i) To a solution of 3-[(*tert*-butoxycarbonyl)amino]-5-methylphenol (1.80 g, 8.1 mmol) in $CH_2Cl_2$ (20 mL) was added tetra-*n*-butylammonium bromide (390 mg, 1.2 mmol), NaOH (488 mg, 12.2 mmol) in $H_2O$ (10 mL), and methoxymethyl chloride (0.93 mL, 12.2 mmol). The resulting mixture was stirred at 23 °C for 12 h. After the usual workup and chromatography (8:1 hexane−EtOAc) to give 1-[(*tert*-butoxycarbonyl)amino]-5-methyl-3-(methoxymethoxy)benzene as a colorless oil (1.80 g, 88%): IR (KBr) 3340, 2950, 1740, 1610, 1550, 1160, 1030 $cm^{-1}$; $^1H$ NMR ($CDCl_3$, 300 MHz) $\delta$ 6.88 (s, 1 H), 6.87 (s, 1 H), 6.53−6.52 (m, 2 H), 5.13 (s, 2 H), 3.46 (s, 3 H), 2.27 (s, 3 H), 1.50 (s, 9 H); $^{13}C\{^1H\}$ NMR ($CDCl_3$, 50 MHz) $\delta$ 157.67, 152.66, 139.94, 112.81, 111.60, 103.88, 94.33, 80.33, 55.88, 28.27, 21.56. (ii) To a solution of the above protected phenol (1.20 g, 4.70 mmol) in THF (20 mL) at −78 °C was added *t*-BuLi (8.6 mL, 1.2 M solution in pentane, 10.3 mmol). The mixture was warmed up to −20 °C over 1 h and stirred at this temperature for 2 h. A solution of $Me_3SnCl$ (1.97 g, 9.9 mmol) in THF (5 mL) was added and the mixture was stirred at −20 °C for 30 min. The resulting mixture was poured into an aqueous $NH_4Cl$ solution (saturated, pH 8) and extracted with EtOAc. After the usual workup and chromatography (15:1 hexane−EtOAc) to give **13** as a white solid (0.95 g, 47%): mp 91−92 °C; IR (KBr) 3320, 2990, 1690, 1510, 1280, 1250, 1160, 1050, 1030 $cm^{-1}$; $^1H$ NMR ($CDCl_3$, 300 MHz) $\delta$ 7.30 (s, 1 H), 6.65 (s, 1 H), 6.54 (br s, 1 H), 5.11 (s, 2 H), 3.44 (s, 3 H), 2.32 (s, 3 H), 1.50 (s, 9 H), 0.34 [s, 9 H; $^2J(^{119}Sn-^1H)$ = 56 Hz, $^2J(^{117}Sn-^1H)$ = 53 Hz]; $^1H$ NOEDIFF ($CDCl_3$, 300 MHz): irradiation at $\delta$ 5.11 (MOM $CH_2$) gives rise to enhancements of the signals at 6.65 (H-5, 5%), 3.34 (MOM MeO, 3%), and 0.34 ($SnMe_3$, 1%); irradiation at $\delta$ 2.32 (C-4 Me) gives rise to enhancements of the signals at 7.30 (H-3, 2%) and 6.65 (H-5, 2%); $^{13}C\{^1H\}$ NMR ($CDCl_3$, 50 MHz; DEPT) $\delta$ 161.88 (s), 153.28 (s), 144.46 (s), 141.31 (s), 115.74 (d), 109.08 (d), 94.24 (t), 80.00 (s), 55.94 (q), 28.31 (q, 3 C), 21.68 (q), −7.07 [q; $^1J(^{119}Sn-^{13}C)$ = 365 Hz, $^1J(^{117}Sn-^{13}C)$ = 349 Hz] (one carbon resonance was not observed). Anal. Calcd for $C_{17}H_{29}NO_4Sn$: C, 47.47; H, 6.80; N, 3.26. Found: C, 47.48; H, 6.82; N, 3.50.

**3-Methoxy-5-methyl-2-(trimethylstannyl)benzoic Acid *tert*-Butylamide (30).** (i) To a suspension of 3-hydroxy-5-methylbenzoic acid (540 mg, 3.6 mmol)[20] in aqueous NaOH (30%, 5 mL) at 23 °C was added dimethyl sulfate (1.70 mL, 18 mmol) and aqueous NaOH (30%, 5 mL). The mixture was heated under reflux conditions for 24 h. After being cooled to room temperature, the solvent was evaporated and the residue was extracted with $Et_2O$. The aqueous phase was acidified with 23% HCl (pH 1) and extracted with $Et_2O$. The solution was dried with $MgSO_4$ and evaporated to give 3-methoxy-5-methylbenzoic acid as a white solid (590 mg, quantitative yield): mp 132−134 °C, lit.[34] 133−137 °C. (ii) To a suspension of the above acid (1.90 g, 11.4 mmol) in $CH_2Cl_2$ (20 mL) was added $SOCl_2$ (2.50 mL, 34 mmol) and a catalytic amount of DMF. The mixture was stirred at 23 °C for 3 h. The solvent was evaporated and the viscous residue was dissolved in $CH_2Cl_2$ (10 mL), treated with *tert*-butylamine (2.40 mL, 23.0 mmol), and stirred at 23 °C for 3 h. The mixture was partitioned between $CH_2Cl_2$ and 10% aqueous HCl. After the usual workup, the *tert*-butyl amide was obtained as a white solid

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(32) Del Valle, L.; Stille, J. K.; Hegedus, L. S. *J. Org. Chem.* **1990**, *55*, 3019.
(33) Wessely, F.; Eibl, H.; Friedrich, G. *Monatsh. Chem.* **1952**, *83*, 24.
(34) Tamura, Y.; Fukata, F.; Sasho, M.; Tsugoshi, T.; Kita, Y. *J. Org. Chem.* **1985**, *50*, 2273.

(2.30 g, 96%): mp 104–106 °C; IR (KBr) 3290, 2980, 1640, 1590, 1540, 1450, 1330, 1220, 1060 $cm^{-1}$; $^1H$ NMR ($CDCl_3$, 200 MHz) $\delta$ 7.06 (br s, 1 H), 7.00 (br s, 1 H), 6.01 (br s, 1 H), 3.74 (s, 3 H), 2.28 (s, 3 H), 1.41 (s, 9 H). Anal. Calcd for $C_{13}H_{19}NO_2$: C, 70.55; H, 8.65; N, 6.33. Found: 70.46; H, 8.35; N, 6.15. (iii) To a solution of the above amide (489 mg, 2.2 mmol) in THF (10 mL) at −78 °C was added *t*-BuLi (5.30 mL, 1.05 M in pentane, 5.6 mmol). The mixture was warmed up to −20 °C over 1 h and stirred at this temperature for 2 h. A solution of $Me_3SnCl$ (916 mg, 4.6 mmol) in THF (4 mL) was added and the mixture was stirred at −20 °C for 30 min. The mixture was poured into an aqueous $NH_4Cl$ solution (saturated, pH 8). After the usual workup and chromatography (10:1 hexane–EtOAc), **30** was obtained as a white solid (781 mg, 92%): mp 62–63 °C; IR (KBr) 3360, 2965, 1630, 1530, 1455, 1320, 1080, 845 $cm^{-1}$; $^1H$ NMR ($CDCl_3$, 300 MHz) $\delta$ 6.87 (br s, 1 H), 6.70 (br s, 1 H), 5.77 (br s, 1 H), 3.75 (s, 3 H), 2.36 (s, 3 H), 1.45 (s, 9 H), 0.26 (s, 9 H); $^{13}C\{^1H\}$ NMR ($CDCl_3$, 50 MHz) $\delta$ 169.71, 165.28, 145.39, 139.97, 119.76, 112.46, 55.46, 51.55, 28.93 (3×), 21.48, −5.41 (3×) [$^1J(^{119}Sn-^{13}C)$ = 375 Hz, $^1J(^{117}Sn-^{13}C)$ = 358 Hz]. Anal. Calcd for $C_{16}H_{27}NO_2Sn$: C, 50.03; H, 7.09; N, 3.65. Found: 50.03; H, 7.01; N, 3.52.

**3-Methoxy-5-methyl-2-(trimethylstannyl)benzoic Acid Diethylamide (40).** (i) To a solution of 3-methoxy-5-methylbenzoyl chloride (prepared from 1.90 g, 11.4 mmol of acid) in $CH_2Cl_2$ (10 mL) was slowly added $Et_2NH$ (2.50 mL, 23.90 mmol) and the resulting mixture was stirred at 23 °C for 12 h. The mixture was diluted with $CH_2Cl_2$ (15 mL) and washed with aqueous HCl (5%) and aqueous $NaHCO_3$ (5%). After the usual workup and chromatography (4:3 hexane–EtOAc) the carboxamide was obtained as a colorless oil (2.30 g, 91%): IR (neat) 2975, 2940, 1635, 1595, 1330, 1060, 805 $cm^{-1}$; $^1H$ NMR ($CDCl_3$, 200 MHz) $\delta$ 6.71 (m, 3 H), 3.79 (s, 3 H), 3.52 (br m, 2 H), 3.27 (br m, 2 H), 2.33 (s, 3 H), 1.20 (br m, 6 H); $^{13}C\{^1H\}$ NMR ($CDCl_3$, 75 MHz) $\delta$ 171.05, 159.41, 139.65, 138.26, 119.09, 115.49, 108.51, 55.13, 43.13, 39.01, 21.35, 14.12, 12.79; MS *m/z* 221 ($M^+$, 43), 220 (38), 149 (100), 121 (38), 91 (22), 77 (16). Anal. Calcd for $C_{13}H_{19}NO_2$: C, 70.56; H, 8.65; N, 6.33. Found: C, 70.27; H, 8.88; N, 6.33. (ii) The carboxamide (2.00 g, 9.00 mmol) was lithiated and stannylated as described above for **30** to give stannane **40** as a crystalline white solid (2.36 g, 68%): mp 76–77 °C; IR (Nujol) 1630, 1315, 1070 $cm^{-1}$; $^1H$ NMR ($CDCl_3$, 200 MHz) $\delta$ 6.64 (m, 2 H), 3.77 (s, 3 H), 3.52 (q, $J$ = 7.2 Hz, 2 H), 3.26 (q, $J$ = 7.2 Hz, 2 H), 2.33 (s, 3 H), 1.25 (t, $J$ = 7.2 Hz, 3 H), 1.06 (t, $J$ = 7.2 Hz, 3 H), 0.22 [s, 9 H; $J(^{119}Sn-^1H$ = 57.0 Hz); $J(^{117}Sn-^1H$ = 54.6 Hz)]; $^{13}C\{^1H\}$ NMR ($CDCl_3$, 75 MHz) $\delta$ 171.17, 164.41, 145.57, 139.95, 124.28, 119.47 [$J(Sn-^{13}C)$ = 36.6 Hz], 110.33 [$J(Sn-^{13}C)$ = 21.3 Hz], 55.32, 43.29, 38.94, 21.50, 13.98, 12.98, −7.35 [$J(^{119}Sn-^{13}C)$ = 365.3 Hz; $J(^{117}Sn-^{13}C)$ = 349.0 Hz]; MS *m/z* 384 ($M^+$, 1), 370 (100). Anal. Calcd for $C_{16}H_{27}NO_2Sn$: C, 50.04; H, 7.09; N, 3.65. Found: C, 49.82; H, 6.91; N, 4.03.

**2-Bromo-8-hydroxy-6-methoxy-1,4-naphthoquinone (24).** To a solution of 2,6-dibromobenzoquinone (2.60 g, 9.80 mmol) in benzene (10 mL) was added (*Z*)-1-ethoxy-3-methoxy-1-[(trimethylsilyl)oxy]-1,3-butadiene[35] (2.30 g, 10.4 mmol) in benzene (5 mL) at 23 °C. The resulting mixture was stirred at this temperature for 10 min. Addition of MeOH (10 mL) led to the formation of an orange precipitate. The solid was filtered off to give **24** as an orange solid (1.23 g, 45%): mp 165–166 °C; IR (KBr) 2915, 1660, 1625, 1390, 1315, 1135, 1070, 1000 $cm^{-1}$; $^1H$ NMR ($CDCl_3$, 300 MHz) $\delta$ 11.94 (s, 1 H), 7.41 (s, 1 H), 7.17 (d, $J$ = 2.6 Hz, 1 H), 6.66 (d, $J$ = 2.6 Hz, 1 H), 3.92 (s, 3 H); $^{13}C\{^1H\}$ NMR ($CDCl_3$, 50 MHz) $\delta$ 181.52, 180.80, 166.63, 165.02, 140.40, 133.25, 119.22, 108.98, 108.42, 56.17; MS *m/z* 284 ($M^+$+ 2, 95), 282 ($M^+$, 100), 254 (12), 203 (46), 175 (99). Anal. Calcd for $C_{11}H_7BrO_4$: C, 46.67; H, 2.49. Found: C, 46.28; H, 2.18.

**Coupling of 2-Bromonaphthoquinones. General Procedure.** A solution of the bromoquinone, stannane (1.2 mmol), and the appropriate catalyst (0.05 mmol) [catalyst A: $Pd(PPh_3)_4$; catalysts B: $Pd(PPh_3)_4$–CuBr (0.05 mmol each); catalyst C: $Pd(dppf)Cl_2$] was heated in 1,4-dioxane. When the reaction was completed as judged by TLC, the mixture was washed with $H_2O$ and saturated aqueous NaCl, dried ($Na_2SO_4$), and evaporated and the residue chromatographed with the stated eluent.

**5-Hydroxy-2-methyl-1,4-naphthoquinone (plumbagin) (14).** This quinone was prepared according to the general procedure with catalyst B in quantitative yield after 15 h (chromatography: 5:1 hexane–EtOAc) as an orange solid: mp 73–74 °C, lit.[36] 76–77 °C. Quinone **14** showed spectral data in agreement with those reported.[36]

**2-Butyl-5-hydroxy-1,4-naphthoquinone (15).** This quinone was prepared according to the general procedure with catalyst C in 86% yield after 8.5 h and with catalyst B in 98% yield after 30 h (chromatography: 15:1 hexane–EtOAc) as an orange-yellow solid: mp 97–98 °C; IR (KBr) 2960, 2940, 1640, 1450, 1370, 1270, 1250, 1230 $cm^{-1}$; $^1H$ NMR ($CDCl_3$, 300 MHz) $\delta$ 11.97 (s, 1 H), 7.62–7.58 (m, 2 H), 7.24 (dd, $J$ = 7.5, 2.0 Hz, 1 H), 6.74 (t, $J$ = 1.4 Hz, 1 H), 2.56 (dt, $J$ = 6.9, 1.4 Hz, 2 H), 1.60–1.24 (m, 4 H), 0.95 (t, $J$ = 7.2 Hz, 3 H). Anal. Calcd for $C_{14}H_{14}O_3$: C, 73.02; H, 6.13. Found: C, 72.92; H, 6.05.

**5-Hydroxy-2-[2-(4,5-dihydropyranyl)]-1,4-naphthoquinone (16).** This quinone was prepared according to the general procedure with catalyst A in 82% yield after 1 h (chromatography: 10:1 hexane–EtOAc) as a red solid: mp 134–135 °C; IR (KBr) 2960, 1715, 1635, 1600, 1560, 1470, 1450, 1360, 1260 $cm^{-1}$; $^1H$ NMR ($CDCl_3$, 200 MHz) $\delta$ 12.04 (s, 1 H), 7.60–7.57 (m, 2 H), 7.26–7.18 (m, 1 H), 7.13 (d, $J$ = 0.7 Hz, 1 H), 6.49 (t, $J$ = 4.5 Hz, 1 H), 4.17–4.12 (m, 2 H), 2.37–2.28 (m, 2 H), 1.97–1.86 (m, 2 H); $^{13}C\{^1H\}$ NMR ($CDCl_3$, 50 MHz; DEPT) $\delta$ 190.73 (s), 183.38 (s), 160.78 (s), 145.46 (s), 144.80 (s), 140.93 (s), 136.01 (d), 135.30 (s), 130.74 (d), 123.78 (d), 119.41 (d), 114.92 (d), 66.37 (t), 21.86 (t, 2 C). Anal. Calcd for $C_{15}H_{12}O_4$: C, 70.30; H, 4.72. Found: C, 70.40; H, 4.52.

**5-Hydroxy-2-phenyl-1,4-naphthoquinone (17).** This quinone was prepared according to the general procedure with catalyst B in quantitative yield after 5 h (chromatography: 5:1 hexane–EtOAc) as an orange solid: mp 129–130 °C; IR (KBr) 1630, 1460, 1360, 1250, 1235, 900 $cm^{-1}$; $^1H$ NMR ($CDCl_3$, 200 MHz) $\delta$ 12.00 (s, 1 H), 7.72–7.45 (m, 7 H), 7.28 (dd, $J$ = 7.8, 1.8 Hz, 1 H), 7.02 (s, 1 H); $^{13}C\{^1H\}$ NMR ($CDCl_3$, 50 MHz; DEPT) $\delta$ 190.17 (s), 183.62 (s), 161.11 (s), 149.21 (s), 136.34 (d), 134.94 (d), 133.08 (s), 132.39 (s), 130.27 (d), 129.42 (d, 2 C), 128.48 (d, 2 C), 124.14 (d), 119.69 (d), 115.12 (s). Anal. Calcd for $C_{16}H_{10}O_3$: C, 76.79; H, 4.03. Found: C, 76.89; H, 4.01.

**2-[2-[(*tert*-Butoxycarbonyl)amino]phenyl]-5-hydroxy-1,4-naphthoquinone (18).** This quinone was prepared according to the general procedure with catalyst A in 70% yield after 20 h (chromatography: 10:1 hexane–EtOAc) as an orange solid: mp 120–121 °C; IR (KBr) 3360, 2950, 1730, 1640, 1455, 1250, 1160 $cm^{-1}$; $^1H$ NMR ($CDCl_3$, 300 MHz) $\delta$ 11.95 (s, 1 H), 7.73–7.63 (m, 3 H), 7.44 (dt, $J$ = 8.3, 4.4 Hz, 1 H), 7.31 (dd, $J$ = 8.1, 1.5 Hz, 1 H), 7.21 (d, $J$ = 4 Hz, 2 H), 6.97 (s, 1 H), 6.53 (br s, 1 H), 1.40 (s, 9 H); $^{13}C\{^1H\}$ NMR ($CDCl_3$, 50 MHz) $\delta$ 189.99, 183.84, 161.34, 153.25, 149.80, 137.42, 136.49, 135.80, 132.17, 130.36, 127.27, 124.82, 124.58, 124.47, 120.02, 115.05, 80.72, 28.18 (3 C). Anal. Calcd for $C_{21}H_{19}NO_5$: C, 69.03; H, 5.24; N, 3.84. Found: C, 69.30; H, 5.28; N, 3.75.

**2-(2,6-Dimethoxy-4-methylphenyl)-5-hydroxy-1,4-naphthoquinone (19).** This quinone was prepared according to the general procedure with catalyst A in 46 % yield after 18 h (chromatography: 15:1 hexane–EtOAc) as an orange solid: mp 177–179 °C; IR (KBr) 2920, 1670, 1645, 1620, 1600, 1260, 1240, 1130 $cm^{-1}$; $^1H$ NMR ($CDCl_3$, 300 MHz) $\delta$ 12.06 (s, 1 H), 7.65 (dd, $J$ = 7.5, 1.5 Hz, 1 H), 7.60 (t, $J$ = 7.9 Hz, 1 H), 7.25 (dd, $J$ = 8.1, 1.5 Hz, 1 H), 6.91 (s, 1 H), 6.45 (s, 2 H), 3.72 (s, 6 H), 2.39 (s, 3 H); $^{13}C\{^1H\}$ NMR ($CDCl_3$, 50 MHz) $\delta$ 190.61, 182.90, 161.10, 157.68, 146.48, 141.65, 138.46, 138.03, 135.98, 132.72, 123.58, 119.42, 115.34, 108.73, 104.95 (2 C), 55.82 (2 C), 22.36. Anal. Calcd for $C_{19}H_{16}O_5$: C, 70.36; H, 4.97. Found: C, 70.18; H, 5.22.

(35) Prepared by silylation of the dienolate of ethyl 3-methoxycrotonate by a procedure analogous to that described: Savard, J.; Brassard, P. *Tetrahedron* **1984**, *40*, 3455.

(36) Wurm, G.; Gurka, H. J. *Arch. Pharm. (Weinheim, Ger.)* **1986**, *319*, 190.

**2-[2-[(*tert*-Butoxycarbonyl)amino]-4-methyl-6-methoxyphenyl]-5-hydroxy-1,4-naphthoquinone (20).** This quinone was prepared according to the general procedure with catalyst B in 60% yield after 3 h (chromatography: 10:1 hexane–EtOAc) as an orange solid: mp 169–170 °C; IR (KBr) 3340, 1740, 1640, 1460, 1260, 1160 $cm^{-1}$; $^1H$ NMR ($CDCl_3$, 300 MHz) $\delta$ 11.97 (s, 1 H), 7.62–7.59 (m, 2 H), 7.33 (br s, 1 H), 7.26 (dd, $J$ = 8.2, 2.4 Hz, 1 H), 6.91 (s, 1 H), 6.55 (s, 1 H), 6.32 (br s, 1 H), 3.70 (s, 3 H), 2.38 (s, 3 H), 1.41 (s, 9 H); $^{13}C\{^1H\}$ NMR ($CDCl_3$, 50 MHz) $\delta$ 189.96, 182.89, 161.13, 157.07, 152.83, 146.65, 141.29, 138.47, 136.26, 136.20, 132.34, 123.97, 119.69, 115.41, 115.12, 111.92, 107.75, 80.70, 55.80, 28.12 (3C), 22.03. Anal. Calcd for $C_{23}H_{23}NO_6$: C, 67.47; H, 5.66; N, 3.42. Found: C, 67.15; H, 5.40; N, 3.25.

**2-[2-[(*tert*-Butoxycarbonyl)amino]-4-methyl-6-(methoxymethoxy)phenyl]-5-hydroxy-1,4-naphthoquinone (21).** This quinone was prepared according to the general procedure with catalyst B in quantitative yield after 3 h (chromatography: 8:1 hexane–EtOAc) as an orange-yellow solid: mp 153–154 °C; IR (KBr) 3100, 2990, 1740, 1640, 1450, 1250, 1160, 1060 $cm^{-1}$; $^1H$ NMR ($CDCl_3$, 300 MHz) $\delta$ 11.96 (s, 1 H), 7.67–7.63 (m, 2 H), 7.34 (br s, 1 H), 7.28 (dd, $J$ = 7.6, 1.9 Hz, 1 H), 6.93 (s, 1 H), 6.80 (br s, 1 H), 6.22 (br s, 1 H), 5.04 (q, $J$ = 6.7 Hz, 2 H), 3.36 (s, 3 H), 2.37 (s, 3 H), 1.40 (s, 9 H); $^{13}C\{^1H\}$ NMR ($CDCl_3$, 50 MHz; DEPT) $\delta$ 189.99 (s), 182.91 (s), 161.27 (s), 154.90 (s), 152.85 (s), 146.84 (s), 141.46 (s), 138.21 (s), 136.35 (d), 136.15 (s), 132.44 (s), 124.06 (d), 119.66 (d), 116.71 (d), 115.22 (s), 113.08 (s), 111.14 (d), 94.65 (t), 80.81 (s), 56.15 (q), 28.14 (q, 3 C), 21.95. Anal. Calcd for $C_{24}H_{25}NO_7$; C, 65.59; H, 5.73; N, 3.19. Found: C, 65.19; H, 5.62; N, 3.35.

**2-Phenyl-1,4-naphthoquinone (23).** This quinone was prepared according to the general procedure with catalyst B in 66% yield after 12 h (chromatography: 6:1 hexane–EtOAc) as a pale yellow solid: mp 110–111 °C, lit.[37] 110 °C; IR (KBr) 1680, 1650, 1610, 1590, 1570, 1310, 1250 $cm^{-1}$; $^1H$ NMR ($CDCl_3$, 200 MHz) $\delta$ 8.21–8.09 (m, 2 H), 7.81–7.75 (m, 2 H), 7.60–7.53 (m, 2 H), 7.49–7.45 (m, 2 H), 7.25–7.21 (m, 1 H), 7.07 (s, 1 H).

**2-Butyl-8-hydroxy-6-methoxy-1,4-naphthoquinone (25).** This quinone was prepared according to the general procedure with catalyst C in 74% yield after 18 h (chromatography: 7:1 hexane–EtOAc) as a yellow solid: mp 135–136 °C; IR (KBr) 2960, 1650, 1635, 1620, 1390, 1315, 1255 $cm^{-1}$; $^1H$ NMR ($CDCl_3$, 300 MHz) $\delta$ 12.34 (s, 1 H), 7.15 (d, $J$ = 2.4 Hz, 1 H), 6.69 (t, $J$ = 1.4 Hz, 1 H), 6.63 (d, $J$ = 2.5 Hz, 1 H), 3.90 (s, 3 H), 2.55 (dt, $J$ = 7.7, 1.4 Hz, 2 H), 1.60–1.41 (m, 4 H), 0.96 (t, $J$ = 7.2 Hz, 3 H); MS $m/z$ 260 ($M^+$, 73), 245 (26), 218 (100), 190 (20); HRMS calcd for $C_{15}H_{16}O_4$ 260.1049, found 260.1013.

**8-Hydroxy-6-methoxy-2-phenyl-1,4-naphthoquinone (26).** This quinone was prepared according to the general procedure with catalyst B in quantitative yield after 15 h (chromatography: 8:1 hexane–EtOAc) as an orange solid: mp 184–186 °C; IR (KBr) 1650, 1630, 1610, 1590, 1580, 1325, 1305, 1235 $cm^{-1}$; $^1H$ NMR ($CDCl_3$, 300 MHz) $\delta$ 12.39 (s, 1 H), 7.58–7.54 (m, 2 H), 7.50–7.45 (m, 3 H), 7.21 (d, $J$ = 2.6 Hz, 1 H), 6.96 (s, 1 H), 6.68 (d, $J$ = 2.6 Hz, 1 H), 3.92 (s, 3 H); $^{13}C\{^1H\}$ NMR ($CDCl_3$, 50 MHz) $\delta$ 187.87, 184.24, 166.21, 164.87, 148.64, 135.61, 133.79, 132.93, 130.08, 129.47 (2 C), 128.43 (2 C), 109.91, 107.32, 106.44, 56.05; MS $m/z$ 280 ($M^+$, 100), 251 (24), 209 (8), 152 (5), 150 (15), 122 (11); HRMS calcd for $C_{17}H_{12}O_4$ 280.0736, found 280.1013.

**2-[2-[(*tert*-Butoxycarbonyl)amino]phenyl]-3,5-bis(acetyloxy)-1,4-naphthoquinone (29).** A mixture of quinone **27** (70 mg, 0.2 mmol), stannane **10** (86 mg, 0.2 mmol), $Pd(PPh_3)_4$ (12 mg, 0.01 mmol), and CuBr (2 mg, 0.01 mmol) in 1,4-dioxane (3 mL) was heated under reflux conditions for 6 h. After 5 h, additional stannane **10** was added (14 mg, 0.04 mmol). After being cooled to room temperature, the mixture was partitioned between EtOAc and water. After the usual workup, the residue was chromatographed (10:1 hexane–EtOAc) to give **29** as an orange solid (56 mg, 60%) (decomposed on melting): $^1H$ NMR ($CDCl_3$, 300 MHz) $\delta$ 8.13 (dd, $J$ = 7.8, 1.3 Hz, 1 H), 7.86 (d, $J$ = 8.4 Hz, 1 H), 7.80 (t, $J$ = 7.9 Hz, 1 H), 7.43 (dd, $J$ = 8.1, 1.3 Hz, 1 H), 7.40 (d, $J$ = 1.7 Hz, 1 H), 7.18–7.07 (m, 2 H), 6.30 (br s, 1 H), 2.46 (s, 3 H), 2.17 (s, 3 H), 1.44 (s, 9 H); $^{13}C\{^1H\}$ NMR ($CDCl_3$, 50 MHz) $\delta$ 182.86, 176.38, 169.27, 167.75, 153.00, 151.65, 149.92, 136.26, 135.33, 135.04, 133.80, 130.19, 129.96, 129.77, 125.64, 123.72, 123.01, 122.40, 121.03, 80.64, 28.15 (3 C), 20.97, 20.16; HRMS calcd for $C_{25}H_{23}NO_8$ $m/z$ 465.1424, found $m/z$ 465.1454.

**5-Hydroxy-2-[2-[(*tert*-butylamino)carbonyl]-6-methoxy-4-methylphenyl]-1,4-naphthoquinone (31).** A mixture of quinone **8** (120 mg, 0.5 mmol), stannane **30** (230 mg, 1.6 mmol), $Pd(PPh_3)_4$ (29 mg, 0.02 mmol), and CuBr (4 mg, 0.02 mmol) in 1,4-dioxane (5 mL) was heated under reflux conditions for 3 h. After being cooled to room temperature, the mixture was partitioned between EtOAc and water. After the usual workup, the residue was chromatographed (5:1 hexane–EtOAc) to give **31** as an orange solid (153 mg, 82%): mp 81–82 °C; IR (KBr) 3370, 2960, 1690, 1640, 1605, 1450, 1330, 1250 $cm^{-1}$; $^1H$ NMR ($CDCl_3$, 300 MHz) $\delta$ 12.04 (s, 1 H), 7.74–7.69 (m, 2 H), 7.59–7.57 (m, 1 H), 7.26–7.22 (m, 2 H), 6.94–6.92 (m, 1 H), 6.85 (br s, 1 H), 5.72 (br s, 1 H), 3.76 (s, 3 H), 2.40 (s, 3 H), 1.27 (s, 9 H). Anal. Calcd for $C_{23}H_{23}NO_5$: C, 70.21; H, 5.89; N, 3.56. Found: 70.45; H, 6.01; N, 3.31. As a byproduct ***N*-tert-butyl-4-methoxy-6-methylisoindol-3-spiro-2′-(2′,3′-dihydro-5′-hydroxynaphthalene)-1,1′,4′-trione (32)** was obtained in *ca.* 5% yield as a pale yellow solid: mp 180–182 °C; IR (KBr) 1700, 1655, 1460, 1350, 1300, 1250 $cm^{-1}$; $^1H$ NMR ($CDCl_3$, 300 MHz) $\delta$ 12.12 (s, 1 H), 7.70–7.67 (m, 2 H), 7.35 (dd, $J$ = 7.9, 1.0 Hz, 1 H), 7.22 (s, 1 H), 6.65 (s, 1 H), 3.96 (d, $J$ = 18.8 Hz, 1 H), 3.37 (s, 3 H), 3.26 (d, $J$ = 18.8 Hz, 1 H), 2.37 (s, 3 H), 1.59 (s, 9 H). $^1H$ NOEDIFF ($CDCl_3$, 300 MHz): irradiation at $\delta$ 3.96 gives rise to enhancements of the signals at 3.26 (31%) and $\delta$ 1.59 (9%); irradiation at $\delta$ 1.59 gives rise to enhancements of the signals at 3.96 (16%); $^{13}C\{^1H\}$ NMR ($CDCl_3$, 50 MHz; DEPT) $\delta$ 199.79 (s), 192.39 (s), 169.23 (s), 160.94 (s), 152.10 (s), 141.66 (s), 136.43 (d), 134.07 (s), 133.62 (s), 131.74 (s), 124.00 (d), 119.66 (d), 118.80 (d), 116.38 (d), 114.76 (d), 70.69 (s), 56.91 (s), 54.71 (q), 47.82 (t), 29.11 (q), 21.68 (q); MS $m/z$ 393 ($M^+$ + 1, 12), 378 (15), 337 (100).

**2-(1,4-Dihydro-3,5-dihydroxy-1,4-dioxo-2-naphthalenyl)-3-methoxy-5-methylbenzoic acid (Antibiotic WS-5995 C) (7).** A solution of **31** (440 mg, 1.1 mmol), benzyltrimethylammonium hydroxide (1.41 mL, 40% aqueous solution, 8.96 mmol), and *tert*-butyl hydroperoxide (1.42 mL, 80% solution in di-*tert*-butyl peroxide, 14.0 mmol) in THF (20 mL) was stirred at 23 °C for 1 h. The mixture was partitioned between EtOAc and a saturated aqueous $NH_4Cl$ solution. After the usual workup the dark red residue was dissolved in 1,4-dioxane (10 mL) and treated with $HClO_4$ (10 mL, 30% aqueous solution). The resulting mixture was heated under reflux conditions for 8 h. After being cooled to room temperature, the mixture was partitioned between 10% aqueous NaOH solution and $Et_2O$. The aqueous phase was washed several times with $Et_2O$, acidified with 10% HCl, and extracted with $CH_2Cl_2$. After the usual workup, **7** was obtained as a bright red solid (390 mg, 98%): mp 290–292 °C, lit.[24b] 288–290 °C; TLC (4:1 benzene–MeOH) $R_f$ 0.26; lit.[24b] $R_f$ 0.21; IR (KBr) 3375, 2920, 1690, 1630, 1605, 1460, 1300, 1150, 1090 $cm^{-1}$; $^1H$ NMR (DMSO-$d_6$, 300 MHz) $\delta$ 11.44 (br s, 1 H), 10.81 (br s, 1 H), 7.72 (t, $J$ = 7.7 Hz, 1 H), 7.50 (dd, $J$ = 7.4, 1.0 Hz, 1 H), 7.39–7.38 (m, 1 H), 7.30 (dd, $J$ = 8.4, 0.6 Hz, 1 H), 7.12 (br s, 1 H), 3.69 (s, 3 H), 2.39 (s, 3 H); $^{13}C$ NMR (DMSO-$d_6$, 50 MHz) $\delta$ 184.85 (s), 182.45 (d, $J$ = 3 Hz), 167.43 (t, $J$ = 2 Hz), 160.16 (d, $J$ = 9 Hz), 156.95 (s), 153.45 (s), 138.88 (d, $J$ = 6 Hz), 137.31 (d, $J$ = 176 Hz), 132.52 (d, $J$ = 8 Hz), 131.98 (s), 122.96 (br d, $J$ = 167 Hz), 122.46 (s), 122.39 (br d, $J$ = 163 Hz), 118.84 (br s), 118.48 (dd, $J$ = 168, 8 Hz), 115.61 (d, $J$ = 159 Hz), 113.68 (br s), 55.98 (q, $J$ = 144 Hz), 21.07 (q, $J$ = 127 Hz); UV-vis (EtOH) $\lambda_{max}$ ($\epsilon$) 287 (8000), 408 (2650) nm; MS $m/z$ 354 ($M^+$, 65), 336 (47), 326 (31), 308 (100), 290 (24), 278 (28).

**8-Hydroxy-3-methyl-1-methoxy-5*H*-benzo[*d*]naphtho-[2,3-*b*]pyran-5,7,12-trione (Antibiotic WS-5995A) (5).** To a solution of **7** (70 mg, 0.20 mmol) in THF (7 mL) was added trifluoroacetic anhydride (2.5 mL). The mixture was stirred at 23 °C for 12 and evaporated to give the trifluoroacetate of **5**: $^1H$ NMR ($CDCl_3$, 300 MHz) $\delta$ 8.12 (d, $J$ = 7.7 Hz, 1 H), 7.87 (t, $J$ = 7.9 Hz, 1 H), 7.81 (br s, 1 H), 7.49 (d, $J$ = 8.1 Hz,

(37) Kvalnes, D. E. *J. Am. Chem. Soc.* **1934**, *56*, 2478.

1 H), 7.21 (br s, 1 H), 3.97 (s, 3 H), 2.53 (s, 3 H). The trifluoroacetate was treated with MeOH (5 mL) for *ca.* 30 min, and the mixture was evaporated to give **5** as an orange solid (65 mg, quantitative yield): mp 288–290 °C, lit.[24b] 288–290 °C; TLC (4:1 benzene-MeOH) $R_f$ 0.80; lit.[24b] $R_f$ 0.88; (5:1 benzene-EtOAc) $R_f$ 0.60; lit.[22b] $R_f$ 0.60; IR (KBr) 2915, 1760, 1640, 1450, 1325, 1280 $cm^{-1}$; $^1H$ NMR ($CDCl_3$, 300 MHz) $\delta$ 11.62 (s, 1 H), 7.82 (m, 1 H), 7.66 (t, $J$ = 7.8 Hz, 1 H), 7.58 (dd, $J$ = 7.5, 1.3 Hz, 1 H), 7.26 (dd, $J$ = 8.3, 1.3 Hz, 1 H), 7.21 (br s, 1 H), 3.93 (s, 3 H), 2.54 (s, 3 H); UV-vis (THF) $\lambda_{max}$ ($\epsilon$) 241 (30 100), 302 (11 200), 431 (8500) nm.

**Methyl 2-(1,4-Dihydro-5-hydroxy-3-methoxy-1,4-dioxo-2-naphthalenyl)-3-methoxy-5-methylbenzoate (35).** A solution of **7** (270 mg, 0.8 mmol), trimethyloxonium tetrafluoroborate (280 mg, 1.9 mmol), and diisopropylethylamine (0.33 mL, 1.90 mmol) in $CH_2Cl_2$ (40 mL) was stirred at 23 °C for 2 h. The mixture was acidified with 10% aqueous HCl and extracted with $CH_2Cl_2$. After the usual workup, the residue was chromatographed (2:1 hexane–EtOAc) to give **35** as a yellow solid (222 mg, 76%): mp 161–163 °C, lit.[24b] 164–166 °C; IR (KBr) 2960, 1725, 1640, 1620, 1380, 1285, 1215, 1070 $cm^{-1}$; $^1H$ NMR ($CDCl_3$, 300 MHz) $\delta$ 12.94 (s, 1 H), 7.64–7.58 (m, 2 H), 7.51 (br s, 1 H), 7.22 (dd, $J$ = 7.1, 2.5 Hz, 1 H), 6.96 (br s, 1 H), 3.77 (s, 3 H), 3.76 (s, 3 H), 3.74 (s, 3 H), 2.45 (s, 3 H); $^{13}C\{^1H\}$ NMR ($CDCl_3$, 50 MHz; DEPT) $\delta$ 184.54 (s), 183.70 (s), 166.76 (s), 161.60 (s), 157.05 (s), 155.71 (s), 140.23 (s), 136.41 (d), 132.42 (s), 131.13 (s), 129.97 (s), 123.54 (d), 123.19 (d), 120.26 (s), 119.19 (d), 115.56 (d), 114.82 (s), 60.34 (q), 56.01 (q), 52.14 (q), 21.70 (q).

**1-(Acetyloxy)-6-bromo-2-[2-[(*tert*-butylcarbonyl)amino]-6-methoxy-4-methyl)phenyl]-4,5-dihydroxynaphthalene (33).** A solution of **31** (14 mg, 0.04 mmol) in HBr–HOAc (33%, 4 mL) was stirred at 23 °C for 2 h. The mixture was poured into ice–water and the suspension was filtered off. The crude solid was chromatographed (EtOAc) to give **33** as a greenish yellow solid (11 mg, 52%): decomposed without melting; IR (KBr) 3320, 2920, 1750, 1710, 1460, 1220 $cm^{-1}$; $^1H$ NMR ($CDCl_3$, 200 MHz) $\delta$ 12.85 (br, 1 H), 11.10 (br, 1 H), 7.55 (d, $J$ = 9.0 Hz, 1 H), 7.11 (d, $J$ = 9.0 Hz, 1 H), 7.10 (s, 1 H), 7.06 (br s, 1 H), 6.78 (br s, 1 H), 6.48 (br s, 1 H), 3.70 (s, 3 H), 2.36 (s, 3 H), 2.09 (s, 3 H), 0.96 (s, 9 H); $^1H$ NOEDIFF ($CDCl_3$, 300 MHz) irradiation at $\delta$ 3.70 gives rise to enhancements of the signal at $\delta$ 6.78 (7%); irradiation at $\delta$ 2.09 gives rise to enhancements of the signal at $\delta$ 7.11 (7%); $^{13}C\{^1H\}$ NMR ($CDCl_3$, 50 MHz; DEPT) $\delta$ 170.86 (s), 169.51 (s), 155.96 (s), 151.86 (s), 151.44 (s), 140.19, 137.81 (s), 137.00 (s), 132.02 (d), 128.44 (s), 126.24 (s), 121.82 (d), 120.36 (s), 115.20 (s), 113.62 (d), 112.68 (d), 110.82 (d), 103.84 (s), 56.16 (q), 52.03 (q), 27.86 (q, 3×), 21.67 (q), 20.48 (q); MS $m/z$ 517 ($M^+$, 3), 515 (3), 475 (12), 473 (13), 402 (100), 400 (99).

**5-Hydroxy-2-[6-methoxy-4-methyl-2-[(diethylamino)-carbonyl]phenyl]-1,4-naphthoquinone (41).** A mixture of quinone **8** (70 mg, 0.28 mmol), stannane **23** (200 mg, 0.52 mmol), $Pd(PPh_3)_4$ (16 mg, 0.01 mmol), and CuBr (6 mg, 0.04 mmol) in 1,4-dioxane (3 mL) was heated under reflux conditions for 15 h. After being cooled to room temperature, the mixture was diluted with $CH_2Cl_2$ (20 mL) and extracted with aqueous NaOH (5%) (60 mL, 3×). The aqueous extract was washed with $Et_2O$ (30 mL, 3×), acidified with aqueous HCl (10%) and extracted with EtOAc (20 mL, 2×). After the usual workup and chromatography (2:1 hexane–EtOAc) **41** was obtained as a brown solid (59 mg, 54%): mp 126–128 °C: IR (KBr) 2980, 1640, 1630, 1460, 1325, 1255, 1065 $cm^{-1}$; $^1H$ NMR ($CDCl_3$, 200 MHz) $\delta$ 12.03 (s, 3 H), 7.61 (d, $J$ = 4.8 Hz, 2 H), 7.26 (m, 1 H), 7.01 (s, 1 H), 6.80 (d, $J$ = 5.2 Hz, 2 H), 3.76 (s, 3 H), 3.64 (m, 1 H), 3.21 (m, 3 H), 2.42 (s, 3 H), 1.05 (t, $J$ = 7.1 Hz, 3 H), 0.95 (t, $J$ = 7.1 Hz, 3 H); $^{13}C\{^1H\}$ NMR ($CDCl_3$, 75 MHz) $\delta$ 190.00, 182.79, 169.14, 161.11, 157.17, 146.94, 141.23, 137.89, 137.49, 136.04, 132.21, 123.88, 119.31, 118.62, 117.37, 115.10, 112.34, 55.82, 42.73, 38.37, 21.74, 13.82, 12.18; MS $m/z$ 393 ($M^+$, 42), 322 (100), 293 (31), 250 (22), 165 (16), 72 (46).

**3-Amino-5-hydroxy-2-[6-methoxy-4-methyl-2-[(diethylamino)carbonyl]phenyl]-1,4-naphthoquinone (42).** A mixture of quinone **41** (57 mg, 0.14 mmol), $NH_4Cl$ (149 mg, 2.80 mmol), and NaOAc (230 mg, 2.80 mmol) in EtOH (4 mL) was heated under reflux conditions for 13 h. After being cooled to room temperature, the mixture was diluted with $CH_2Cl_2$ (50 mL) and extracted with aqueous NaOH (5%). The aqueous extract was washed with $Et_2O$ (20 mL, 3×), acidified with aqueous HCl (10%), and extracted with EtOAc. After the usual workup and chromatography (1:1 hexane–EtOAc) **42** was obtained as a bright red solid (39 mg, 68%): mp 152–154 °C; IR (KBr) 3440, 3340, 1620, 1590, 1455, 1320, 1220, 1070 $cm^{-1}$; $^1H$ NMR ($CDCl_3$, 200 MHz) $\delta$ 11.62 (s, 1 H), 7.58 (m, 2 H), 6.82 (br s, 1 H), 6.75 (br s, 1 H), 5.36 (br s, 2 H), 3.75 (s, 3 H), 3.67 (m, 1 H), 3.35 (m, 1 H), 3.04 (m, 1 H), 2.91 (m, 1 H), 2.41 (s, 3 H), 0.98 (t, $J$ = 7.1 Hz, 3 H), 0.91 (t, $J$ = 7.1 Hz, 3 H); $^{13}C\{^1H\}$ NMR ($CDCl_3$, 50 MHz) $\delta$ 185.77, 182.56, 170.19, 161.24, 157.44, 146.75, 140.64, 139.36, 137.01, 133.30, 122.12, 118.81, 115.14, 114.11, 112.36, 55.87, 42.70, 38.26, 13.77, 12.21 (one carbon signal was not observed); MS $m/z$ 408 ($M^+$, 29), 337 (100), 322 (37), 72 (61).

**8-Hydroxy-1-methoxy-3-methylbenzo[*b*]phenanthridine-5,7,12-trione (36). Method a:** A suspension of **35** (100 mg, 0.26 mmol) in MeOH (5 mL) with $NH_4OH$ (5 mL, 30% aqueous solution) was heated under reflux conditions for 48 h. After 24 h, more $NH_4OH$ (2 mL) was added. After being cooled to room temperature, the mixture was acidified with 10% aqueous HCl and extracted with $CH_2Cl_2$. After the usual workup, the dark red residue was acetylated with $Ac_2O$ (5 mL) and concd $H_2SO_4$ (cat.) at 23 °C for 3 h. The mixture was poured into ice–water and extracted with EtOAc. After the usual workup, the residue was chromatographed (2:1 hexane–EtOAc) to give the acetate **37** as an orange solid (54 mg, 55% yield): mp 232–234 °C; IR (KBr) 3060, 2920, 1770, 1680, 1650, 1610, 1490, 1330, 1290, 1200, 1125 $cm^{-1}$; $^1H$ NMR ($CDCl_3$, 200 MHz) $\delta$ 9.27 (br s, 1 H), 8.01 (dd, $J$ = 7.7, 1.2 Hz, 1 H), 7.87 (br s, 1 H), 7.77 (t, $J$ = 7.9 Hz, 1 H), 7.33 (dd, $J$ = 8.1, 1.2 Hz, 1 H), 7.12 (br s, 1 H), 3.96 (s, 3 H), 2.52 (s, 3 H), 2.45 (s, 3 H); $^{13}C\{^1H\}$ NMR ($CDCl_3$, 50 MHz) $\delta$ 180.22, 176.11, 169.21, 160.66, 157.76, 149.62, 142.87, 137.17, 135.90, 134.99, 130.15, 128.22, 125.09, 121.65, 120.17, 119.75, 118.73, 117.62, 56.43, 22.00, 21.01; UV-vis ($CHCl_3$) $\lambda_{max}$ ($\epsilon$) 262 (27 400), 288 (19 800), 334 (12 100), 456 (4000) nm. Additionally, in one experiment, acetamide **38** was obtained as a byproduct as a yellow solid (decomposed on melting): IR (KBr) 1780, 1775, 1725, 1680, 1600, 1325, 1200, 1175 $cm^{-1}$; $^1H$ NMR ($CDCl_3$, 200 MHz) $\delta$ 8.11 (dd, $J$ = 7.7, 2.1 Hz, 1 H), 7.75 (t, $J$ = 7.9 Hz, 1 H), 7.49 (br s, 1 H), 7.39 (dd, $J$ = 8.1, 1.3 Hz, 1 H), 6.96 (br s, 1 H), 3.74 (s, 3 H), 3.96 (s, 3 H), 2.44 (s, 6 H), 2.09 (s, 3 H); $^{13}C\{^1H\}$ NMR ($CDCl_3$, 50 MHz) $\delta$ 182.76, 176.49, 169.44, 167.16, 166.88, 156.38, 149.88, 149.78, 140.75, 134.77, 134.15, 130.87, 129.55, 125.44, 123.07, 122.23, 116.97, 115.69, 56.40, 52.27, 21.69, 21.07, 20.24; MS $m/z$ 453 ($M^+$ + 2, 2), 410 (38), 308 (100). Hydrolysis of the acetate of **37** was achieved with $NaHCO_3$ (90 mg, 1.07 mmol) in $H_2O$ (15 mL) at 23 °C for 12 h. Acidification with 10% aqueous HCl and extraction with $CH_2Cl_2$ followed by the usual workup gave **36** as a bright red solid (47 mg, quantitative yield): mp 311–313 °C; IR (KBr) 3295, 2930, 1680, 1640, 1465, 1320, 1260, 1170, 1150 $cm^{-1}$; $^1H$ NMR ($CDCl_3$, 200 MHz) $\delta$ 11.29 (s, 1 H), 9.30 (br s, 1 H), 7.71–7.58 (m, 2 H), 7.21 (dd, $J$ = 6.2, 1.6 Hz, 1 H), 7.15 (br s, 1 H), 3.97 (s, 3 H), 2.54 (s, 3 H); $^{13}C\{^1H\}$ NMR ($CDCl_3$, 75 MHz) $\delta$ 181.72, 180.57, 161.37, 160.64, 143.13, 137.71, 135.29, 134.59, 130.23, 122.87, 120.18, 119.37 119.29, 117.87, 113.54, 56.36, 22.06 (the resonances of 2 C were not observed); UV-vis ($CHCL_3$) $\lambda_{max}$ ($\epsilon$) 259 (14 500), 290 (11 300), 334 (5200), 454 (4000) nm; MS $m/z$ 335 ($M^+$, 100), 318 (99), 290 (11). Anal. Calcd for $C_{19}H_{13}NO_5$: C, 68.06; H, 3.91; N, 4.18. Found: C, 68.04; H, 3.80; N, 4.01.

**Method b:** Aminoquinone **42** (8 mg, 0.02 mmol) was heated at 75 °C in 1,4-dioxane (3 mL) containing aqueous HCl (0.5 mL, 6 M) for 15 h. After being cooled to room temperature the mixture was partitioned between EtOAc and $H_2O$. After the usual workup, the residue was filtered through silica gel eluting successively with 1:1 hexane–EtOAc and 3:1 EtOAc–MeOH to give **36** (4 mg, 61%). **(c)** A mixture of aminoquinone **42** (8 mg, 0.02 mmol) and $K_2CO_3$ (20 mg, 0.14 mmol) in MeOH (3 mL) was heated under reflux conditions for 3 days. After being cooled to room temperature, the mixture was partitioned between EtOAc and $H_2O$. After the usual workup, the residue was filtered through silica gel eluting successively with 1:1

hexane–EtOAc, EtOAc and 1:1 EtOAc–MeOH to give **36** (3 mg, 45%; 95% corrected for conversion).

**1,8-Dihydroxy-3-methylbenzo[*b*]phenanthridine-5,7,-12-trione (1).** To a solution of **36** (28 mg, 0.08 mmol) in $CH_2Cl_2$ (12 mL) at −78 °C was added $BBr_3$ (0.24 mL, 1 M solution in $CH_2Cl_2$, 0.24 mmol) and stirred at this temperature for 30 min. The resulting mixture was warmed up to 23 °C over 1 h. A 5% aqueous $NaHCO_3$ solution was added and the mixture was extracted with $CH_2Cl_2$. After the usual workup, the dark red residue was acetylated with $Ac_2O$ (3 mL) and concd $H_2SO_4$ (cat.) at 23 °C for 2 h. The mixture was poured into ice–water and extracted with EtOAc. After the usual workup, the residue was chromatographed (2:1 hexane–EtOAc) to give the diacetate **39** as a yellow solid (16 mg, 47% yield): mp 229–230 °C; IR (KBr) 2930, 1780, 1680, 1660, 1495, 1330, 1280, 1180 $cm^{-1}$; $^1H$ NMR ($CDCl_3$, 200 MHz) $\delta$ 9.39 (br s, 1 H), 8.23–8.21 (m, 1 H), 8.02 (dd, $J$ = 7.7, 1.3 Hz, 1 H), 7.83 (t, $J$ = 8.0, 1 H), 7.45–7.44 (m, 1 H), 7.39 (dd, $J$ = 8.1, 1.3 Hz, 1 H), 2.55 (s, 3 H), 2.47 (s, 3 H), 2.34 (s, 3 H); $^{13}C\{^1H\}$ NMR ($CDCl_3$, 75 MHz) $\delta$ 180.30, 176.01, 169.10, 168.82, 160.05, 149.87, 147.69, 142.23, 136.31, 136.28, 136.20, 130.69, 130.08, 128.75, 126.01, 125.08, 122.63, 121.55, 116.55, 21.42, 21.09, 20.99; UV-vis ($CHCl_3$) $\lambda_{max}$ ($\epsilon$) 282 (27 650), 340 (8100), 433 (3850) nm. Cleavage of the above acetate was achieved with $Na_2CO_3$ (210 mg, 2.0 mmol) in MeOH (3 mL) at 23 °C for 12 h. Acidification with 10% aqueous HCl and extraction with $CH_2Cl_2$ followed by the usual workup gave **1** as a dark red solid (12 mg, quantitative yield): mp > 340 °C; IR (KBr) 3260, 2910, 1685, 1630, 1460, 1315, 1265, 1240 $cm^{-1}$; $^1H$ NMR (DMSO-$d_6$, 200 MHz) $\delta$ 11.96 (s, 1 H), 11.64 (br s, 1 H), 9.68 (br s, 1 H), 7.76 (dd, $J$ = 7.8, 1.2 Hz, 1H), 7.71 (dq, $J$ = 2.0, 0.8 Hz, 1 H), 7.53 (t, $J$ = 8.0 Hz, 1 H), 2.38 (br s, 3 H); UV-vis ($CHCl_3$) $\lambda_{max}$ ($\epsilon$) 255 (16 300), 325 (7700), 420 (2600) nm; MS $m/z$ 322 ($M^+$ + 1, 23), 321 ($M^+$, 100), 296 (16); HRMS calcd for $C_{18}H_{11}NO_5$ $m/z$ 321.0637, found $m/z$ 321.0633.

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**Supplementary Material Available:** Copies of NMR spectra for compounds **25**, **26**, **29**, **32**, **33**, **35**, **39**, **1**, **41**, and **42** (21 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 ACS; see any current masthead page for ordering information.