Pergamon

Tetrahedron 55 (1999) 6039–6050

TETRAHEDRON

Studies on Quinones. Part 32.[1] Regioselective Synthesis of Benz[*b*]phenantridines Related to Phenantroviridone

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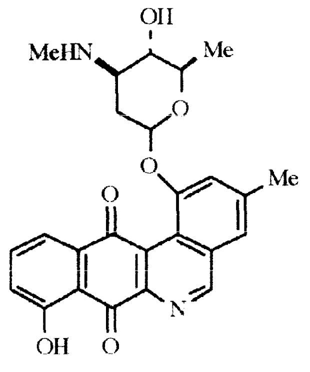
Received 13 November 1998; accepted 25 March 1999

Abstract: The Diels-Alder reaction of juglone (**4**) and bromojuglone **18** with 1-cyclohexenecarboxaldehyde dimethylhydrazone (**3**) is described. Through these cycloaddition reactions 8-hydroxy-1,2,3,4-tetrahydrobenz[*b*]phenantridin-7,12-dione (**5**) was obtained in 55 and 78% yield, respectively. Oxidation of **5** to 8-hydroxybenz[*b*]phenantridin-7,12-dione (**6**) and 8-hydroxy-1,2,3,4-tetrahydrobenz[*b*]phenantridin-1,7,12-trione (**15**) is also reported.

Keywords: *Phenantroviridone; Diels-Alder reactions; angular quinones; azadienes*

INTRODUCTION

We have earlier described two approaches to construct tetracyclic angular quinones based on: a) Diels-Alder reaction of naphthoquinones with a vinylcyclohexene[2] and b) dienone-phenol rearrangement of spironaphthalentriones.[3,4] The biological relevance attributed to the coplanar 2-phenylnaphthalene-type ring system, found in many biological active compounds from synthetic and natural origin,[5] has renewed our interest in the synthesis of tetracyclic angular quinones. We have recently focused our attention on the benz[*b*]phenantridine framework of the cytotoxic naturally ocurring phenantroviridin (**1**) and its aglycone **2**[6] which contain the aforementioned 2-phenylnaphthalene fragment.



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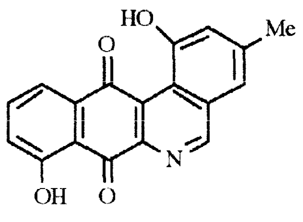

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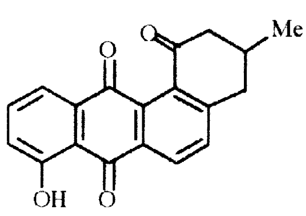
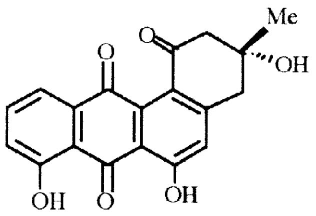
PII: S0040-4020(99)00278-1

Gould has reported the regioselective synthesis of phenantroviridone (**2**) from 2,5-dimethylphenol employing the coupling of a cyanophthalide with an appropriate cinnamate as the key step.[7,8] Recently Echavarren has described the synthesis of **2** by coupling reaction of aryl stannanes with 2-bromo-5-methoxy-1,4-naphthoquinone.[9] More recently Snieckus has reported the synthesis of **2** using a directed *ortho*-metalation-trimethylborate quench protocol.[10]

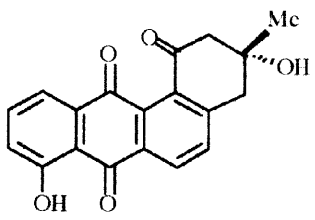
The Diels-Alder reactions between naphthoquinones and vinylcyclohexene derivatives have been used by several research groups to construct the angular tetracyclic skeleton of angucyclines antibiotics.[2,11-14] This approach has led to the total synthesis of ochromycinone,[11] rubiginone B1,[13] rabelomycin[15] and tetrangomycin[16] and appears to be the most successful one. Here we report an extension of this methodology to construct the benz[*b*]phenantridine skeleton of phenantroviridin (**2**) based on the cycloaddition of juglone (**4**) and 3-bromojuglone (**18**) with the inner-outer azadiene **3**.[17]



ochromicinone



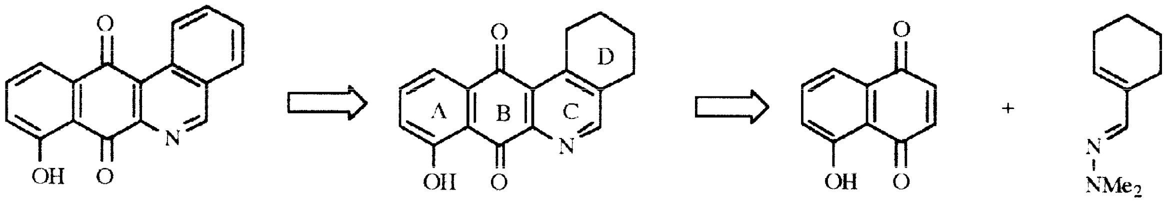
rabelomycin



tetrangomycin

RESULTS AND DISCUSSION

We envisioned that 8-hydroxybenz[*b*]phenanthridine **6**, a model compound containing the ring system of quinone **2**, could be constructed *via* an AB + D = ABCD strategy based on the disconnection across the pyridine ring of the aromatic tetracyclic system of 8-hydroxy-1,2,3,4-tetrahydrobenz[*b*]phenanthridine **5**. The retrosynthetic analysis of the target compound **5** requires a regiocontrolled Diels-Alder reaction between juglone (**4**) as an AB synthon and the corresponding azadiene **3** (Scheme 1).



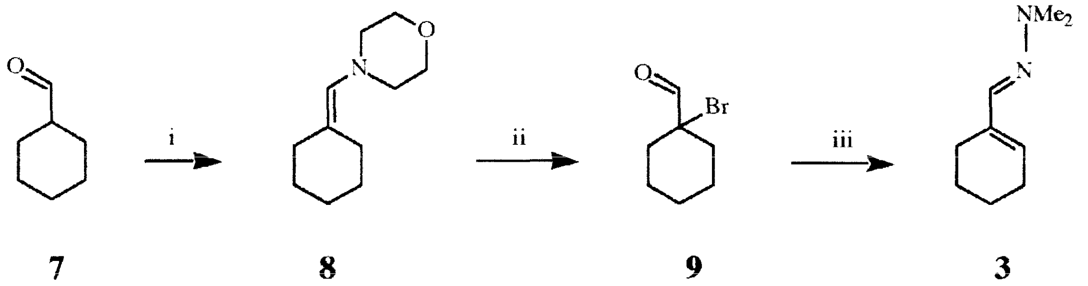
6 **5** **4** **3**

Scheme 1

We planned this strategy because the Diels-Alder reaction of 1-azabuta-1,3-dienes with quinones is a powerful method to obtain quinones fused to nitrogen six membered rings.[18-26] Furthermore the regiochemistry of the cycloaddition of juglone (**4**) with methacrolein *N,N*-dimethylhydrazone and crotonaldehyde *N,N*-dimethylhydrazone has been firmly established by Potts[19] and Fillion.[22] The high regiocontrol observed in these cycloadditions has been ascribed to the high polarization of the azadienes and to the directing effect of the 5-hydroxy group of the dienophile.

There are some reported methods to obtain 1-cyclohexenecarboxaldehyde,[27-30] a suitable precursor of dimethylhydrazone **3** however, we decided to attemp the synthesis of this azadiene from 1-cyclohexanecarboxaldehyde (**7**) as shown in Scheme 2. This route is based on the well established reactions of enamines with halogens that form α-haloimmonium salts, which on hydrolysis yield the corresponding α–halocarbonyl compounds.[31]

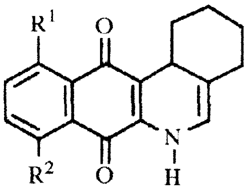
Enamine **8** was prepared in nearly quantitatively yield by condensation of aldehyde **7** with morpholine. Reaction of enamine **8** with bromine at low temperature followed by hydrolysis furnished 1-bromocyclohexanecarboxaldehyde (**9**)[32] in 70% yield. Dimethylhydrazone **3** was prepared in 79% yield from **9** and dimethylhydrazine following a reported procedure.[33] Hydrazone **3** was purified by column chromatography on silica gel and was stored at low temperature to avoid decomposition.



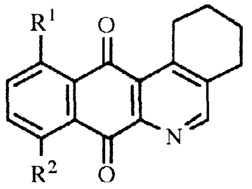
Scheme 2 *Reagents and conditions:* i, morpholine, benzene, reflux, 100%; ii, Br_2, CH_2Cl_2, -60°C, 70%; iii, *N,N*-dimethylhydrazine, CH_2Cl_2, reflux, 79%

The reaction of azadiene **3** with an excess of juglone (**4**) was carried out in acetonitrile with admission of air. The cycloaddition occurred slowly (5 days) at room temperature to afford a complex reaction mixture. The main product, that precipitated into the reaction mixture as a green solid, was isolated by filtration. The ^1H and ^{13}C NMR spectra displayed signals in agreement with heterocyclic angular quinone **10** (55% yield). Silica gel chromatography of the filtrate allowed the isolation of tetracyclic quinones **5** and **12** in 27 and 2% yield, respectively, along with a mixture of regioisomers **13** and **14**. No attempts were made in order to separate isomers **13** and **14**. These compounds have been reported by Fillion *et al* as secondary products from the reaction of juglone (**4**) and crotonaldehyde dimethylhydrazone.[22]

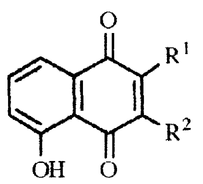
Assignment of structure **10** is in accord with the directing effect of the 5-hydroxy group in juglone (**4**) and related 1,4-naphthoquinones in cycloaddition reactions with 1-azadienes[19,22] and other electron rich dienes[2,34] where the cycloadditions are highly regioselective. Furthermore, FMO calculations of azadiene **3** shows that the primary orbital of the C-4 atom possesses a higher HOMO coefficient (0.3593) than the primary orbital of the N-1 atom (-0.1962), thus indicating a high polarization of the 1-azabuta-1,3-diene system .[35]



10. R^1=H, R^2=OH
11. R^1=OH, R^2=H



5. R^1=H, R^2=OH
12. R^1=OH, R^2=H



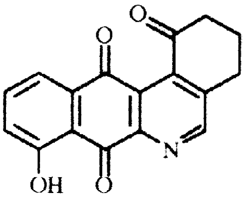
13. R^1= NMe_2, R^2=H
14. R^1 = H, R^2 = NMe_2

These results could be explained by considering that the Diels-Alder adducts generated by cycloaddition between compounds **3** and **4** are unstable and undergo 1,2-elimination of diethylamine followed by double bond rearrangement to give quinones **10** and **11**. Nucleophilic addition by the released amine on juglone (**4**) followed by aerial oxidation of the corresponding addition products yield quinones **13** and **14**.

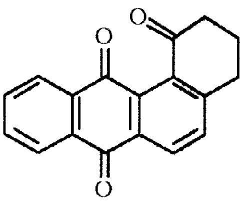
Aromatization of the heterocyclic ring of quinones **10** and **11** to the corresponding angular quinones **5** and **12** take place by aerial oxidation. This reaction was confirmed through purity control by tlc of compound **10** which showed convertion to compound **5** on the cromatographic support. Oxidation attempts directed to prepare quinone **5** from quinone **10** with silver (I) oxide and active manganese dioxide were unsuccessful. In view of the above results we attempted to improve the *in situ* formation of angular quinone **5** from **10** by carrying out the cycloaddition under oxygen atmosphere. The reaction was left for 10 days at room temperature providing a complex reaction mixture. Compounds **5**, **10**, **12** and **15** were isolated by column cromatography on silica gel in 47, 18, 1.25 and 2.1% yield, respectively. Isomers **13** and **14** were detected (tlc) in the reaction mixture and were not isolated.

The location of the carbonyl group at the 1-position in compound **15** was deduced by the unusual infrared absorption at 1720 cm^{-1}. Several members of the angucyclinone group antibiotics such as rabelomycin[36] and dioxamycin[37] display this spectral feature attributed to steric and electronic interactions between the C-1 and C-12 carbonyl groups.The structure of **15** was also supported by comparison of the δ ppm of the methylene protons (δ 2.25, 2.94 and 3.09 ppm) with those of the model substances: 1,2,3,4-tetrahydrobenz[*a*]anthracene-1,7,12-trione (**16**) {δ2.23 and 2.92 (4H) ppm} and 1,2,3,4-tetrahydrobenz[*a*]anthracene-4,7,12-trione (**17**) (δ 2.19, 2.75 and 3.65 ppm).[38]

The formation of **15** from **5** was not surprising since we have observed a similar selective aerial oxidation under basic conditions of 1,2,3,4-tetrahydrobenz[*a*]anthracene-7,12-diones to 1,2,3,4-tetrahydrobenz[*a*]anthracene-1,7,12-triones.[2] Furthermore, this selective oxidation under light-induced and neutral conditions has been successfully employed for the synthesis of some angucyclinones and related compounds.[15,16,39]



15



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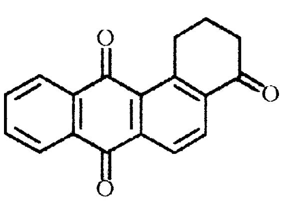


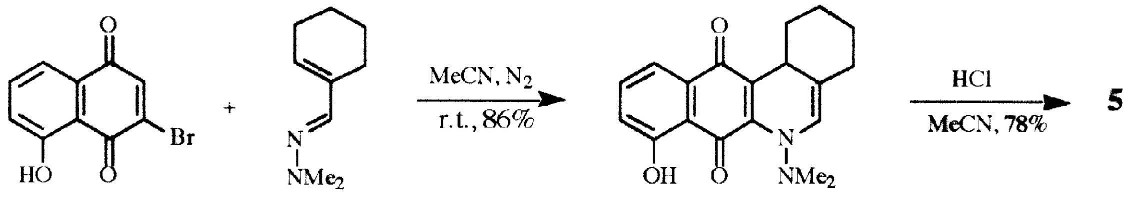
17

In order to improve the synthesis of benz[*b*]phenantridine **5** we explored its preparation through cycloaddition of 3-bromo-5-hydroxy-1,4-naphthoquinone (**18**) and azadiene **3**. This strategy takes into account reported reactions of bromonaphthoquinones and azadienes where the bromine atom provides high control on the stereochemistry of the cycloaddition **3**.[40-42] According with the directing effect of the bromine atom the cycloaddition should provide a sole cycloadduct resulting from the attack of the nucleophilic end of the azadiene **3** to the C-2 atom of the dienophile **18**.

Bromonaphthoquinone **18**, prepared by bromination of juglone (**4**) in glacial acetic acid,[43] was reacted with azadiene **3** in acetonitrile under nitrogen atmosphere at room temperature. The treatment was performed in the presence of sodium hydrogencarbonate to avoid the formation of by-products.[41] The reaction proceeded cleanly providing regiospecifically the angular quinone **19** in 86% yield. Indeed the absence of by-products arising from the addition of dimethylamine to the quinone precursor is due to the relative high stability of **19** to undergo 1,4-elimination of dimethylamine.

We attempted to induce the aromatization of the heterocyclic nucleus of **19** by heating in acetonitrile solution in the presence of hydrochloric acid. This provided tetrahydrophenantridine **5** that showed spectral properties in full agreement with those displayed by the benzophenantridine isolated from the reaction of juglone (**4**) with azadiene

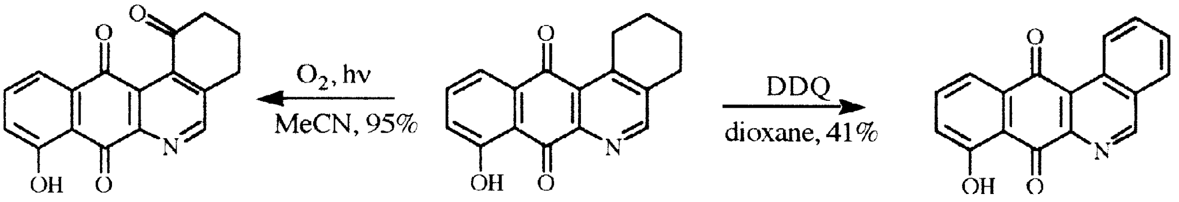
3. This result supports the proposed regiochemistry for the cycloaddition of juglone with azadiene **3** and the structure of products **10**, **5** and **12**. In order to confirm the structure of compound **15**, quinone **5** was submitted to photooxygenation in acetonitrile for three weeks.



18 **3** **19**

Scheme 3

The reaction cleanly provided compound **15** in 95% yield. The spectral properties of **15** were identical in all respect to those of the benzophenantridinetrione isolated from the reaction of **4** with azadiene **3**, thus confirming the previous assigned structure. We also attempted the aromatization of compound **5** with DDQ in dioxane solution which provided angular tetracyclic quinone **6** in 41% yield.



15 **5** **6**

Scheme 4

In summary, the inner-outer azadiene **3** is easily prepared in a three step sequence from cyclohexanecarboxaldehyde in 55% overall yield. The cycloaddition of diene **3** with juglone (**4**) and 3-bromojuglone (**18**) occurs with high regiocontrol to provide valuable benzophenantridines structurally related with the skeleton of phenantroviridone (**2**). The formation of angular tetracyclic quinone **15** which exhibits an oxygenation level similar to aglycon **2** supports further studies with **3** and structurally related azadienes directed towards the synthesis of analogues of naturally occurring antibiotic **2**.

EXPERIMENTAL

General. All reagents were of commercial quality, reagent grade, and were used without further purification. M.p.s were determined on a Kofler hot-stage apparatus and are uncorrected. The IR spectra were recorded on a FT Bruker spectrophotometer for KBr disc and the wave numbers are given in cm^{-1}. The ^{1}H and ^{13}C NMR spectra were acquired on Bruker AM-200 in deuteriochloroform. Chemical shifts are reported in δ ppm downfield to TMS, and J values are given in Hertz. Silica gel Merck 60 (70-230 mesh), and DC-Alufolien 60F$_{254}$ were used for preparative column and analytical TLC, respectively. Juglone (**4**) and 1-cyclohexancarboxaldehyde (**7**) were commercially available. Bromonaphthoquinone **18** was prepared by bromination of **4** following the reported method.[43]

N-(cyclohexylidenemethyl) morpholine (**8**)

A solution of 1-cyclohexanecarboxaldehyde (**7**) (1.0 g, 8.93 mmol) and morpholine (850 mg, 9.88 mmol) in benzene (25 mL) was heated at reflux in a Dean-Stark apparatus for 2 h. Evaporation of the solvent afforded enamine **8** as an oily liquid in nearly quantitatively yield. All attempts to purified enamine **8** were unsuccessful and no correct elemental analysis could be obtained. IR (neat): 1660; ^{1}H NMR: δ ppm 1.50 (m, 4H, 2$\times$CH$_2$), 1.97 (m, 2H, CH$_2$), 2.20 (m, 2H, CH$_2$), 2.54 (t, 4H, J= 4.7, CH$_2$-N) , 3.68 (t, 4H, J= 4.7, CH$_2$-O), 5.28 (m, 1H, =CH); ^{13}C NMR: δ ppm 26.8, 27.8, 28.0, 28.4, 33.4, 53.5, 66.4, 128.3, 132.5.

1-Bromocyclohexancarboxaldehyde (**9**)

To a solution of enamine **8** (4.85 g, 26.8 mmol) in dichloromethane (30 mL) was added a cooled solution (-60C) of bromine (4.28 g, 26.8 mmol) in dichloromethane (29 mL). The stirring mixture was heated at room temperature, water was added (50 mL) and the stirring was mantained for 1 h. The oganic layer was washed with 2% aqueous sodium bisulfite solution (60 mL) and dried over MgSO$_4$. The residue obtained by evaporation of the solvent was purified by column chromatography to afford bromoaldehyde **9** (3.56 g, 70%) as an pale yellow oily liquid;[32] IR (neat): 1720; ^{1}H NMR: δ ppm 1.38-2.13 (m, 10H, 5$\times$CH$_2$), 9.34 (s, 1H, CHO).

N'-(cyclohex-1-enylmethylene)-N,N-dimetylhydrazone (**3**)

A suspension of bromoaldehyde **9** (866 mg, 4.54 mmol), *N,N*-dimethylhydrazine (655 mg, 10.89 mmol) and anhydrous sodium sulfate (200 mg) in dichloromethane (10 mL) was heated to reflux for 2h. The mixture was filtered and the filtrate was evaporated. The residue was purified by column cromatography on silica gel (chloroform) to afford hydrazone **3** (543 mg, 79%) as an oily liquid.[33] Azadiene **3** was stored at -10°C under nitrogen; I.R.

(neat): 1580; ^{1}H NMR: δ ppm 1.56-1.70 (m, 4H, 2×CH_2); 2.15 (m, 2H, CH_2), 2.24 (m, 2H, CH_2), 2.79 (s, 6H, NMe_2), 5.82 (m, 1H, C=CH), 7.02 (s,1H, N=CH); ^{13}C NMR: δ ppm 22.3, 22.8, 23.9, 25.8, 43.1, 129.7, 136.4, 139.1.

Diels-Alder reaction of azadiene **3** *and juglone* (**4**)

Assay A

A solution of **4** (308 mg, 1.77 mmol) and *N,N*-dimetylhydrazone **3** (90 mg, 0.59 mmol) in acetonitrile (7 mL) was left for one day at room temperature. Filtration of the reaction mixture afforded 8-hydroxy-1,2,3,4,6,12b-hexahydrobenz[*b*]phenantridin-7,12-dione (**10**) (90.55 mg, 55%) as a green solid. Attempts to obtain an analytical sample of **10** by column cromatography were unsuccessful due to its partial air oxidation; for this reason microanalysis data are not satisfactory. I.R: 3260, 1640 and 1620; ^{1}H NMR: δ ppm 1.29-2.32 (m, 8H, 4×CH_2); 3.71 (dd, 1H, J=11.7 and 3.5, 12b-H), 5.87 (d, 1H, J= 4.1, 5-H), 6.54 (br s, 1H, NH), 7.11 (m, 1H, 9-H), 7.58 (m, 2H, 10-H and 11-H), 11.46 (s, 1H, OH).

The filtrate was left at r.t. for 5d and then evaporated in vacuo. The residue was succesively cromatographied in column (chloroform) and preparative t.l.c. (9:1 chloroform-petroleum ether). This procedure provided the following compounds:

8-hydroxy-1,2,3,4-tetrahydrobenz[*b*]phenantridin-7,12-dione (**5**) (43.85 mg, 27%) yellow solid m.p.183-185°C; Anal. Calcd. for $C_{17}H_{13}NO_3$: C, 73.09; H, 4.69; N, 5.02. Found: C, 72.98; H, 4.89; N, 4.72; I.R. : 3420, 1660, 1640; ^{1}H NMR: δ ppm 1.89 (m, 4H, 2-H and 3-H), 2.94 (m, 2H, 4-H), 3.42 (m, 2H, 1-H), 7.31 (dd, 1H, J= 7.8 and 1.8, 9-H), 7.69 (dd, 1H, J= 7.8 and 7.6, 10-H), 7.76 (dd, 1H, J= 7.6 and 1.8, 11-H), 8.74 (s, 1H, 5-H), 12.47 (s, 1H, OH); ^{13}C NMR: δ ppm 21.2 , 22.4, 28.0, 28.8, 115.5, 119.4, 123.9, 128.6, 134.1, 137.0, 139.8, 147.8, 150.4, 154.9, 162.3, 184.4, 187.0.

11-hydroxy-1,2,3,4-tetrahydrobenz[*b*]phenantridin-7,12-dione (**12**) (3.35 mg; 2%), yellow solid m.p. 151-154 °C; HRMS Calcd. for $C_{17}H_{13}NO_3$: 279.08954. Found: 279.08951; I.R: 3420, 1660, 1620; ^{1}H NMR: δ ppm 1.89 (m, 4H, 2-H and 3-H), 2.94 (m, 2H, 4-H), 3.46 (m, 2H, 1-H), 7.33 (dd, 1H, J= 8.3 and 1.2, 10-H), 7.67 (dd, 1H, J= 8.3 and 7.5, 9-H), 7.89 (dd, 1H, J= 7.5, 1.1, H-8), 8.75 (s, 1H, 5-H), 12.60 (s, 1H, OH); ^{13}C NMR: δ ppm 21.2 , 22.5, 28.0, 29.1, 116.6, 119.7, 124.9, 128.2, 132.6, 136.5, 139.4 ,148.4, 150.6, 155.4, 162.4, 181.5, 191.5.

1,4-Naphthoquinones **13** and **14** (25 mg, 20%).

Assay B

A solution of juglone (**4**) (300 mg, 1.72 mmol) and hydrazone **3** (87 mg, 0.575 mmol) in acetonitrile (10 mL) under oxygen atmosphere was stirred at room temperature for 10 d. The solvent was removed and the residue was column cromatographied using petroleum ether-ethyl acetate as the eluent. Each fraction was purified by preparative t.l.c. eluting with 9:1 chloroform- petroleum ether solution. This procedure afforded the following compounds: 8-hydroxy-1,2,3,4,6,12b-hexahydrobenz[*b*]phenantridin-7,12-dione (**10**) (29.45 mg, 18%), 8-hydroxy-1,2,3,4-tetrahydrobenz[*b*]phenantridin-7,12-dione (**5**) (76 mg, 47%), 11-hydroxy-1,2,3,4-tetrahydrobenz[*b*]phenantridin-7,12-dione (2 mg, 1.25%) and 8-hydroxy-1,2,3,4-

tetrahydrobenz[*b*]phenantridin-1,7,12-trione (**15**) (3.5 mg; 2.1%); yellow solid, m.p.180°C (d); HRMS Calcd. for $C_{17}H_{11}O_4N$: 293.06881. Found: 293.06857; I.R: 3446, 1720, 1660, 1640; ^1H NMR (DMSO-d_6): δ ppm 2.25 (q, 2H, *J* = 6.5, 3-H), 2.94 (t, 2H, *J* = 8.0, 2-H or 4-H), 3.09 (t, 2H, *J* = 6.0, 4-H or 2-H), 7.48 (d, 1H, *J* = 8.4, 9-H), 7.65 (d, 1H, *J* =7.4, 11-H), 7.90 (dd, 1H, *J* = 8.4 and 7.4, 10-H), 9.15 (s, 1H, 5-H), 12.24 (s, 1H, OH); ^{13}C NMR: δ ppm 22.9, 26.7, 39.1, 115.6, 119.7, 124.5, 130.6, 134.1, 137.5, 142.8, 143.9, 148.4, 155.0, 162.7, 174.8, 186.0, 197.5.

Diels-Alder reaction of 3-bromo-5-hydroxy-1,4-naphthoquinone (**18**) *with* **3**

A suspension of quinone **18** (110 mg, 0.43 mmol), diene **3** (70 mg, 0.46 mmol), and sodium hydrogencarbonate (50 mg, 0.43 mmol) in acetonitrile (5 mL) was heated to reflux under nitrogen atmosphere for 2 h. The mixture was partitioned between water-chloroform and the organic extract was dried over magnesium sulfate. Evaporation of the solvent afforded *N*-dimethyamino-8-hydroxy-1,2,3,4,6,12b-hexahydrobenz[*b*]phenantridin-7,12-dione (**17**) (120 mg, 86%) as dark green solid m.p. 112.5-113°C. Attempts to obtain an analytical sample of **19** by column cromatography or recrystallization were unsuccessful due to its partial air oxidation; for this reason microanalysis data are not satisfactory. IR: 3424, 1638; ^1H NMR: δ ppm 1.20-2.40 (m, 8H, $4\times CH_2$), 2.67 (br s, 6H, $2\times CH_3$), 2.89 (dd, 1H, *J* = 11.34 and 3.79, 12b-H), 5.95 (s, 1H, 5-H), 7.15 (dd, 1H, *J* = 5.8 and 3.7 , 9-H), 7.54 (m, 2H, 10- and 11-H), 11.71 (s, 1H, OH); ^{13}C NMR: δ ppm 26.9, 29.1, 32.7, 35.4, 36.2, 44.0, 114.4, 115.4, 117.8, 122.5, 122.7, 126.5, 132.4, 135.8, 145.5, 160.7, 182.7, 185.8 .

8-hydroxy-1,2,3,4-tetrahydrobenzo[b]phenantridin-7,12-dione (**5**)

A solution of compound **19** (120 mg, 0.37 mmol) in acetonitrile (10 mL) containing two drops of 16N hydrochloric acid was heated to reflux for 2 h. The mixture was diluted with water and the yellow solid precipitate was filtered and washed with water. This provided quinone **5** (80 mg, 78%) identical in all respect (tlc, IR and ^1H NMR) to compound **5** isolated from the reaction of azadiene **3** and juglone (**4**).

8-hydroxy-1,2,3,4-tetrahydrobenz[b]phenantridin-1,7,12-trione (**15**)

A solution of quinone **5** (8.60 mg; 0.0317 mmol) in acetonitrile was stirred under oxygen atmosphere for three weeks at room temperature. Removal of the solvent followed by preparative t.l.c. (9:1 chloroform-petroleum ether) afforded pure quinone **15** as a yellow solid (8.55 mg; 95%).

8-hydroxybenz[b]phenantridin-7,12-dione (**6**)

A solution of **5** (10 mg, 0.036 mmol) and DDQ (146.5 mg, 0.645 mmol) in dioxane (8 mL) was heated to reflux for 92 h. The mixture was poured into water and the solution was extracted with chloroform. The extract was dried over magnesium sulfate and evaporated to give crude quinone **6**. Preparative t.l.c. (9:1 chloroform-petroleum ether) afforded pure phenantridinequinone **6** (4 mg; 41%) as orange solid m.p. 229-231°C; HRMS Calcd. for $C_{17}H_9NO_3$: 275.05824. Found: 275.05835; I.R.: 3446, 1660, 1638; ^1H NMR: δ ppm 7.35 (dd, 1H, *J*= 8.0 and 1.2, H-9), 7.72 (dd, 1H, *J*= 8. 7 and 7.0, H-10), 7.83-7.91 (m, 2H, 3-H and 11-H), 8.03 (ddd, 1H, *J*= 9. 7, 5.0 and 1.5, 2-H), 8.15 (dd with fine coupling, 1H, *J* =7.7 and 0.9, 4-H), 9.61 (s, 1H, 5-H), 9.70 (dd with fine coupling, 1H, *J*= 9.0, 1-H), 12.43 (s, 1H, OH); ^{13}C NMR: δ ppm 115.3, 119.6, 124.3, 125.1, 128.0, 128.8, 130.5, 130.8, 132.8, 134.0, 134.3, 137.1, 145.3, 158.5, 162.3, 185.5, 187.3.

ACKNOWLEDGEMENTS

We thank Fondo Nacional de Ciencia y Tecnología, FONDECYT (Grant N° 92-603) for financial support. The authors are grateful to Prof. M. Carmen Maestro of Universidad Autónoma de Madrid, for kindly providing the high resolution mass spectra.

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