Synthesis of Novel Heterocycles Related to the Dynemicin A Ring Skeleton

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This paper is dedicated to the memory of the late Professor Nicholas Alexandrou who taught us much about humanity and science.

Studies directed towards the construction of the CDE ring framework of dynemycin A (**1**) are reported. A series of quinoline based dienophiles containing an activating group (*e.g.* **5**, Scheme 1), reacted with acyclic dienes (*e.g.* **4**, Scheme 1) in a Diels-Alder fashion under increased pressure to afford a variety of heterocyclic systems related to the CDE skeleton of dynemycin A. Reaction of dienophile **15** with cyclic diene **29** led to the novel hetereocycle **34** whereas attempted decarbonylation of **41** led to a novel rhodium-promoted intramolecular carbonylation of the terminal acetylene furnishing compound **43**.

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1. Introduction

Dynemicin A (**1**, Scheme 1) [1], a naturally occurring member of the class of enediyne antitumor antibiotics [2], represents a target of considerable synthetic challenge. Despite its relatively small size, this molecule, which contains an anthraquinone fused onto a more complex enediyne moiety has, until recently, eluded total synthesis [3]. Wide interest in dynemicin A has resulted in investigations concerned not only with its total synthesis and mechanism of action [4], but also with the design, synthesis and biological investigations of numerous biological mimics [5]. In this article we describe some of our recent studies [6] relating to the enediyne-containing region of dynemicin A.

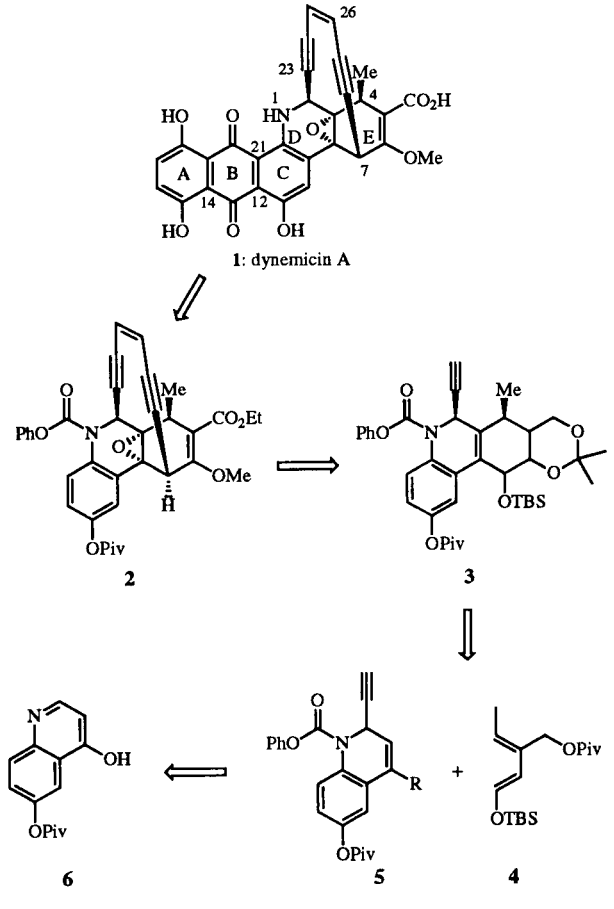
During our studies we considered a Diels-Alder approach for the construction of the right-hand side of dynemicin A (see retrosynthetic analysis, Scheme 1). Although several Diels-Alder disconnection pathways may be envisioned for the E-ring of dynemicin A it was felt that a disconnection between a quinoline based dienophile such as **5**, containing an activating group, and an acyclic diene such as **4** (Scheme 1) was most prudent, as structures of this type are readily available. It was hoped that the "handle" R on the dienophile (**5**) would not only serve for fine tuning the Diels-Alder reaction, but also to allow for further chemical modification of the anticipated cycloadduct [7].

2. Results and Discussion.

a. Synthesis of Dienophiles **13-15**.

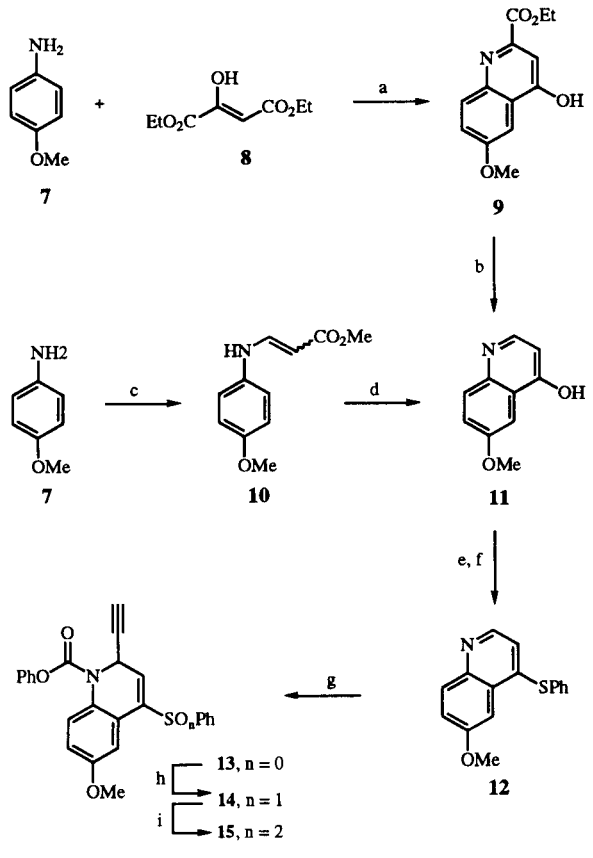
Utilizing the Conrad-Limpach reaction [8] for the construction of quinolines from β-anilinoacrylates, compounds of type **5** (*e.g.* **13-15**, Scheme 2) were synthesized by two separate pathways converging on 4-hydroxy-6-methoxyquinoline **11** [9] as shown in Scheme 2. Condensation of *p*-anisidine (**7**) and diethyl oxalacetate followed by thermal cyclization in Dowtherm A™ [10] provided the 2-carboethoxy-4-hydroxyquinoline derivative **9** in 75% yield.

Scheme 1
Retrosynthetic analysis of dynemicin A (1)



Scheme 2

Synthesis of activated quinoline dienophiles for the Diels-Alder reaction. Reagents and conditions: (a) cat. conc. H_2SO_4, $CHCl_3$, 65°C, 1 hour, then Dowtherm A™, 250°C, 1 hour, 75%; (b) 10% NaOH (aq), 110°C, 5 hours, then Ph_2O, 250°C, 5 minutes, 58%; (c) 1.0 equiv of methyl propiolate, MeOH, 25°C, 12 hours, 100%; (d) Dowtherm A™, 250°C, 30 minutes, 95%; (e) 10.0 equiv of $POCl_3$, DMF, 0°C, 1 hour, 78%; (f) 1.1 equiv of PhSH, PhH, 80°C, 12 hours, 92%; (g) 1.15 equiv of ethynyl magnesium bromide, THF, -78°C then 1.2 equiv of PhOCOCl, 25°C, 15 minutes, 95%; (h) 1.1 equiv of *m*-CPBA, CH_2Cl_2, 25°C, 10 minutes, 93%; (i) 2.1 equiv of *m*-CPBA, CH_2Cl_2, 25°C, 1 hour, 95%.



Saponification of the ester present in **9** with aqueous sodium hydroxide followed by decarboxylation at 250° gave **11** in 58% overall yield [11]. In a more direct manner, nucleophilic addition of *p*-anisidine (**7**) to methyl propiolate [9] provided acrylate **10** [12] (100% yield) and subsequent thermal cyclization led to the aforementioned quinoline **11** directly (95% yield). Reaction of **11** with the Vilsmeier salt derived from phosphorus oxychloride and *N*,*N*-dimethylformamide provided the corresponding 4-chloro-6-methoxyquinoline compound (78% yield), which upon treatment with thiophenol in refluxing benzene gave the 4-thiophenylquinoline derivative **12** (92% yield) [11]. Addition of ethynylmagnesium bromide to the imine double bond of **12** at -78°, followed by quenching the resultant anion with phenyl chloroformate afforded carbamate **13** [13] in 95% yield. Oxidation of **13** to either the phenylsulfoxide (93% yield) **14** or the phenylsulfone (95% yield) **15** was accomplished by treatment with the appropriate amount of *m*-chloroperoxybenzoic acid (*m*-CPBA), thus completing the construction of three dienophiles (**13-15**) of varying electrophilicity for the Diels-Alder reaction.

b. Diels-Alder Reaction of Dienophiles **13-15**.

Initial attempts at effecting the Diels-Alder reaction under standard conditions for cyclizations of this type (thermal, Lewis acid catalysis, solvophobic effects) were unsuccessful. However, under high pressure (13 kbar) [14], the reaction of these dienophiles with numerous acyclic dienes proceeded quite readily. Table 1 shows several examples of Diels-Alder reactions which serve to illustrate certain trends concerning these dienophiles.

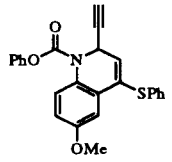
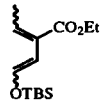
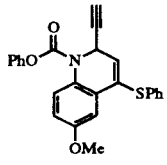
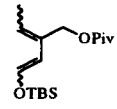
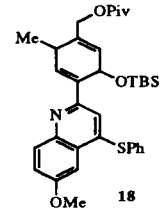
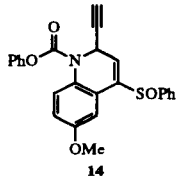
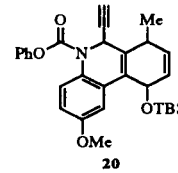
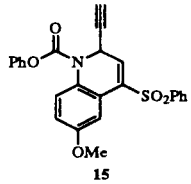
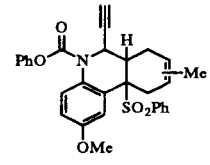
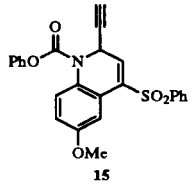
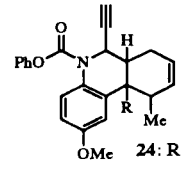
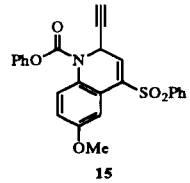
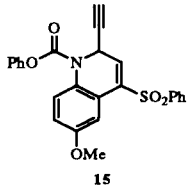
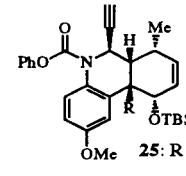
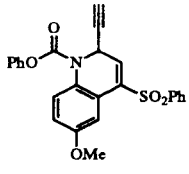
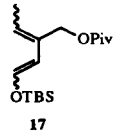
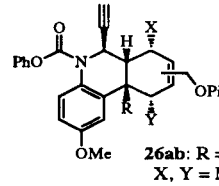
The dienophile **13** containing the thiophenyl group is predictably unreactive towards **16** and **17** (Table 1, entries 1 and 2). The ability of the sulfur to donate electron density into the double bond makes this dienophile electronically a poor match for the electron-rich dienes used in this study [15]. However, dienophile **13** undergoes cycloaddition with diene **17** across the triple bond (entry 2), demonstrating the higher propensity of the acetylene group to act as a dienophile in the Diels-Alder reaction within this system. Elimination of the phenyl carbamate moiety then provides cycloadduct **18** (15% yield).

With a sulfoxide group as an activator, dienophile **14** reacts with diene **19** to provide, after elimination of sulfenic acid, the phenanthroline derivative **20** as a single regioisomer in 20% yield (entry 3).

As matters expired, the phenylsulfone substituted olefin **15** proved to be the most suitable dienophile for the desired Diels-Alder reaction. Thus, compound **15** reacted smoothly under high pressure (13 kbar) with isoprene (**21**) (entry 4) to give a 70% yield of cycloadducts **22** in *ca* 1:1 ratio and 91% total yield. Cycloaddition of **15** with the two stereoisomers of piperylene (entries 5 and 6) resulted in very different outcomes. Thus, Diels-Alder reaction of **15** with *trans*-piperylene (**23a**) (entry 5) gave, in 80% yield, the expected cycloadduct (**24**) as a single regioisomer, whereas *cis*-piperylene (**23b**) exhibited no reactivity towards **15** under the same reaction conditions (entry 6). This can be explained by the inability of **23b** to adopt the reactive *s-cis* (cisoid) conformation required for the Diels-Alder reaction.

The last two entries in Table 1 (entries 7 and 8) represent examples of the striking diastereofacial selectivity encountered in this particular study. Thus, Diels-Alder reaction of **15** with diene **19** (entry 7) under high-pressure provided cycloadduct **25** as a single regioisomer in 96% yield. Unfortunately, however, the stereochemical outcome of this reaction was not as desired, the methyl group was subsequently found by X-ray crystallographic analysis to be *trans* to the acetylene group. Thus, deprotection of the silyl ether present in cycloadduct **25**, followed by

Table 1
Diels-Alder Reactions of Quinoline Dienophiles with Acyclic Dienes

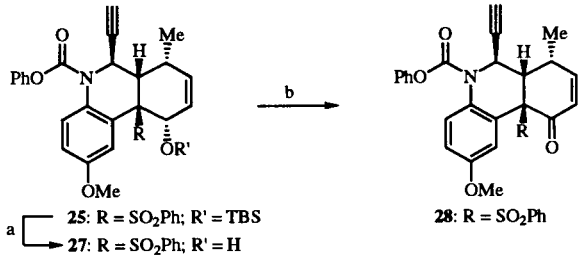
Entry	Dienophile	Diene	Conditions	Product	Yield (%) [a]
1	 **13**	 **16**	13 kbar, CH_2Cl_2, 25°C	no reaction	–
2	 **13**	 **17**	"	 **18**	15
3	 **14**	 **19**	"	 **20**	20 [b]
4	 **15**	 **21**	"	 **22**	91 [c]
5	 **15**	 **23a**	"	 **24**: R = SO_2Ph	83
6	 **15**	 **23b**	"	no reaction	–
7	 **15**	 **19**	"	 **25**: R = SO_2Ph	96
8	 **15**	 **17**	"	 **26ab**: R = SO_2Ph; X, Y = Me, OTBS	79 [c]

[a] isolated yield. [b] plus 37% recovered starting material. [c] 1:1 mixture of regioisomers.

oxidation, provided enone **28** (Scheme 3) as a crystalline compound whose X-ray crystallographic analysis provided the required stereochemical proof (see ORTEP drawing, Figure 1). Finally, Diels-Alder reaction of **15** with the more substituted diene **17** (entry 8) gave a 1:1 mixture of the regioisomeric cycloadducts **26ab** in a 79% total yield. The presence of two regioisomers indicates a possible secondary interaction of the hydroxymethyl group of the diene with the dienophile producing a counter effect to the expected regioselectivity. Again, X-ray crystallographic analysis of both cycloadducts **26a** and **26b** proved that the relative stereochemical relationship between the acetylene and the methyl group in these compounds was *trans* (see ORTEP drawings, Figure 1).

Scheme 3

Synthesis of enone **28** from Diels-Alder adduct **25**. Reagents and conditions: (a) excess HF (aq), MeCN, 25°C, 5 hours, 83%; (b) 1.2 equiv of Dess-Martin periodinane, CH_2Cl_2, 25°C, 1 hour, 92%.



c. Mechanistic Considerations of the Diels-Alder Reaction.

The diastereofacial selectivities observed in these Diels-Alder reactions allowed the formulation of a rational transition state model for the prediction of the outcome of this type of cycloaddition reaction (Scheme 4). The ability of the phenylsulfonyl group to direct an *exo* approach [15] of the diene to the dienophile limits the potential transition states available to the reacting partners. It is also clear that the allylic acetylene acts as a facial directing group for *anti* approach of the diene to the dienophile, narrowing even further the options of the reaction [7,16]. In addition, by virtue of the electronic nature of the diene/dienophile partners, one should ordinarily be able to predict the regiochemical outcome of the cycloaddition. However, internal substitution on the diene system (Table 1, entries 4 and 8) may reverse this inherent electronic preference as the result of an unfavorable steric interaction between the pivaloate ester and the phenyl carbamate (Table 1, entry 8). Finally, entries 5 and 6 confirm that the more reactive conformation for the diene methyl group is the *trans* isomer. Scheme 4 depicts the final two options for the Diels-Alder reaction of dienophile **15** and diene **17**.

d. The Cyclic Diene Approach.

The tendency of the phenylsulfonyl group on the dienophile to direct an *exo* approach of the diene and the reactivity of the stereoisomers for the diene methyl group

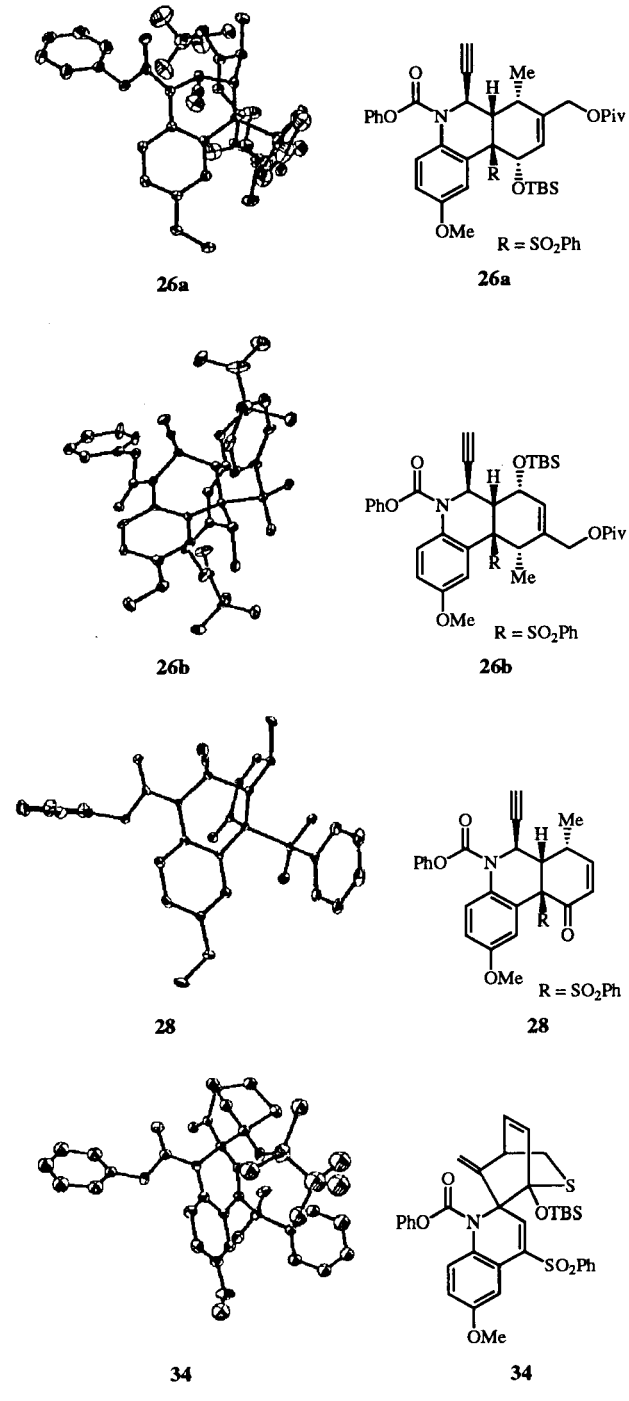
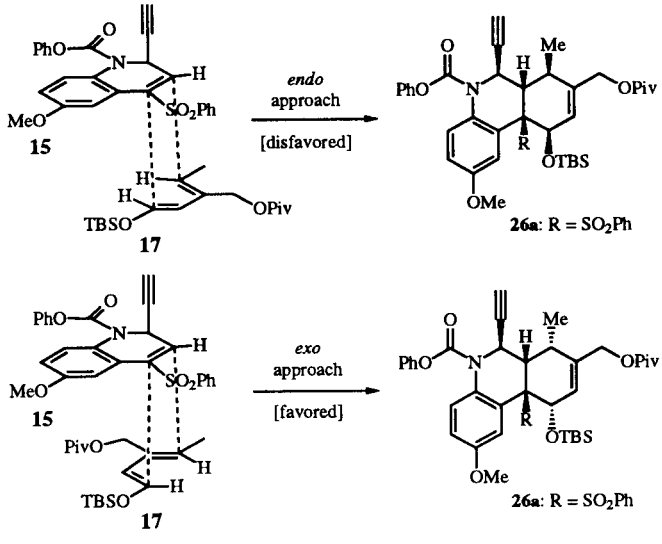


Figure 1. ORTEP drawings of compounds **26a**, **26b**, **28** and **34**.

(*vide supra*) gave rise to our first attempt at reversal of the stereochemical outcome for the Diels-Alder reaction (Scheme 5). Based on this model, the cyclic diene **29** was designed as part of a strategy to force the issue of stereochemistry. Specifically, it was reasoned that diene **29**, in which the diene methyl group equivalent is constrained in a *cis* conformation, would provide the opportunity to

Scheme 4

Transition state models for the Diels-Alder reaction of dienophile **16** with dienes.

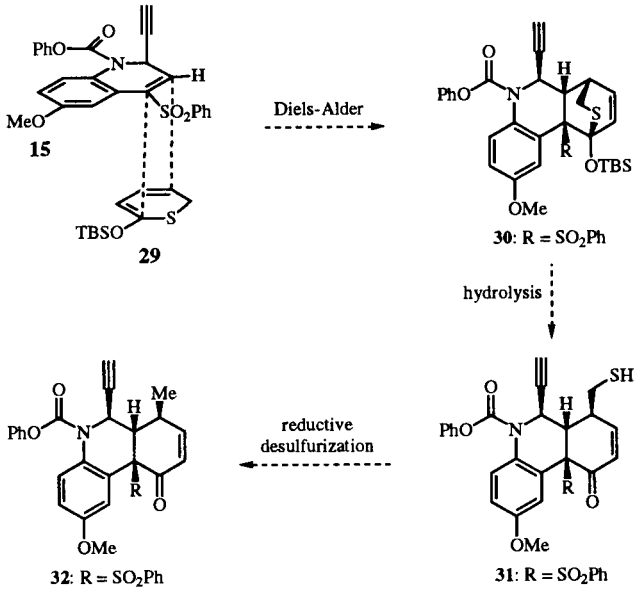


reverse the stereochemical outcome. In principle, this strategy could allow for the formation of the desired product *via* an indirect route involving initial Diels-Alder reaction followed by subsequent generation of the methyl and carbonyl groups (Scheme 5).

Preparation of the envisioned cyclic diene **29** (Scheme 6) proceeded smoothly from 3,6-dihydro-2*H*-thiopyran-2-one (**33**) [17] by exposure to *tert*-butyldimethylsilyl trifluoromethanesulfonate (TBSOTf) in the presence of triethylamine (89% yield). Reaction of diene **29** with dienophile **15** resulted in a 50% yield of what initially appeared to be,

Scheme 5

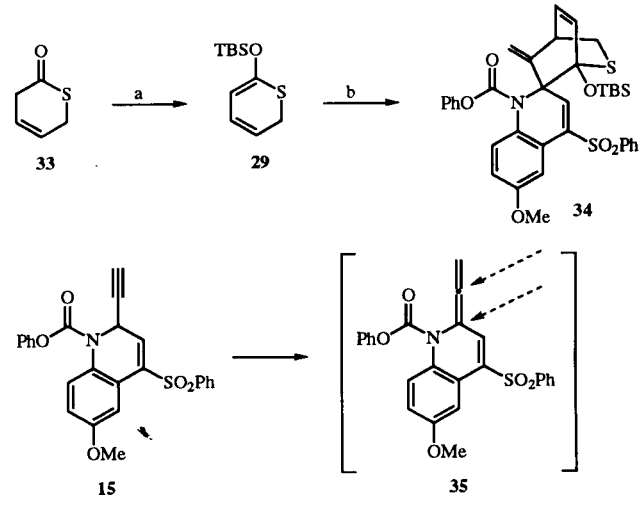
Strategy for the reversal of the C-4 methyl stereochemistry *via* a Diels-Alder reaction employing cyclic diene **29**.



by nmr spectroscopy, the desired cycloadduct, except for the clear absence of the acetylenic proton. Subsequent crystallization and X-ray crystallographic analysis of the product revealed its true structure **34** (see ORTEP drawing, Figure 1). Apparently, initial rearrangement of the acetylene group present in **15** to the allene **35** followed by Diels-Alder reaction with **29** (at the indicated double bond) led to the observed product **34** (Scheme 6). Despite the undesired outcome, this reaction resulted in the formation of a novel ring structure containing an exocyclic double bond [18].

Scheme 6

Novel cycloadduct from the Diels-Alder reaction of **15** with diene **29**. Reagents and conditions: (a) 1.2 equiv of Et_3N, CH_2Cl_2, 0°C; then 1.1 equiv of TBSOTf, 10 minutes, 89%; (b) 0.25 equiv of 15, CH_2Cl_2, sealed Teflon™ tube, 13 kbar, 25°C, 24 hours, 50%.



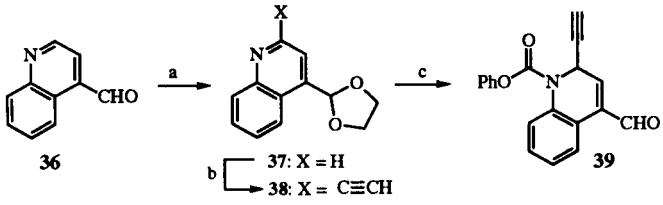
e. The Formyl-Substituted Dienophile Approach.

An alternative strategy for the reversal of the diastereoselectivity of the present cycloaddition reaction is to change the facial approach of the diene to the dienophile. To this end, the formyl-substituted compound **39** (Scheme 7) was chosen for synthesis as a prelude for testing this hypothesis. Thus, 4-quinolinecarboxaldehyde (**36**) was converted to its 1,3-dioxolane derivative **37** by treatment with ethylene glycol in the presence of catalytic amounts of *p*-toluenesulfonic acid (80% yield) and thence to acetylenic compound **38** by exposure to phenyl chloroformate and ethynylmagnesium bromide (89% yield), followed by dioxolane hydrolysis (aqueous hydrochloric acid, 78% yield) to provide dienophile **39**.

Dienophile **39** reacted with diene **17** under high pressure (13 kbar, dichloromethane) to afford, in 90% yield, a mixture of diastereoisomers (at the OTBS center) of a single regioisomer. The latter conclusion was supported by oxidation (Dess-Martin periodinane) of **40** following TBS removal (aqueous hydrogen fluoride-acetonitrile) to give a single enone, **42**, in high overall yield (92 x 96%). The assignment of relative stereochemistry in **40**

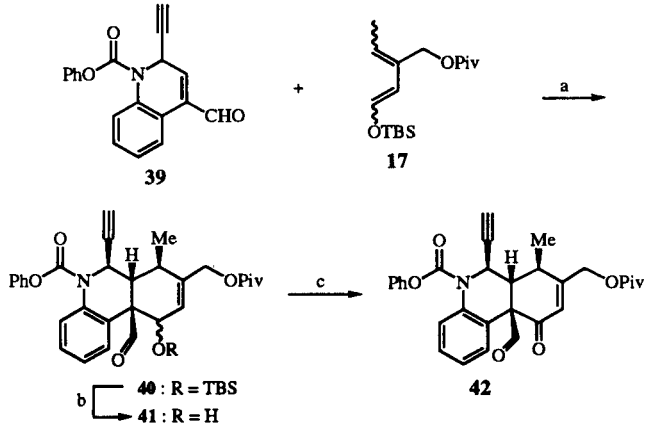
Scheme 7

Synthesis of the CHO activated dienophile **39**. Reagents and conditions: (a) 5.0 equiv of ethylene glycol, 0.1 equiv of TsOH, PhH, 90°C, 12 hours, 80%; (b) 1.15 equiv of ethynyl magnesium bromide, THF, -78°C; then 1.2 equiv of PhOCOCl, 25°C, 15 minutes, 89%; (c) excess of 1.0 *N* HCl (aq), THF, 55°C, 8 hours, 78%.



Scheme 8

Diels-Alder reaction of **39** with diene **17**. Reagents and conditions; (a) 4.0 equiv of 17, CH_2Cl_2, sealed Teflon™ tube, 13 kbar, 25°C, 24 hours, 90%; (b) excess HF (aq), MeCN, 25°C, 3 hours, 92%; (c) 1.1 equiv of Dess-Martin periodinane, CH_2Cl_2, 25°C, 30 minutes, 96%.

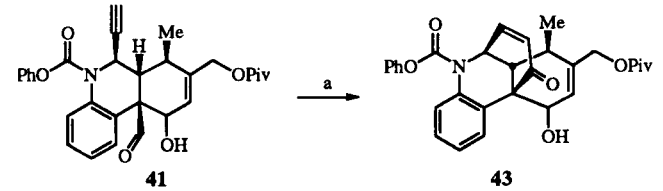


is tentative at present and is based on ^1H nmr comparisons with adducts **25** and **26ab** (Table 1).

While further investigations with compounds **40** and **41** are still ongoing, an interesting observation with allylic alcohol **41** is worth noting. Attempted decarbonylation [19] of **41** with Wilkinson's catalyst [$(PPh_3)_3RhCl$, stoichiometric amounts] resulted, not in the anticipated outcome, but instead in the formation of the 6-membered ring enone **43** (Scheme 9) in 78% yield based on a 50% conversion. Although the rhodium (I)-promoted intramolecular cyclization of unsaturated aldehydes [20] and of α,ω-alkynoic acids (to form alkylidene lactones) [21] is known, the present example represents a potentially powerful method for converting acetylenic aldehydes to cyclic frameworks. We suspect that the rigidity of the substrate is crucial for the success of this reaction. Scheme 10 shows a mechanistic rationale for this intriguing, rhodium-catalyzed process.

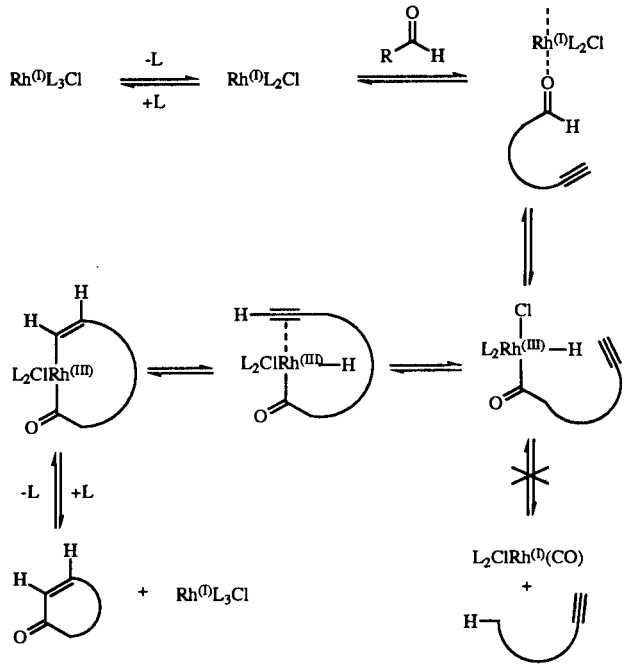
Scheme 9

A novel rhodium(I)-promoted intramolecular hydroacylation reaction. Reagents and conditions: (a) 1.0 equiv of $Rh(PPh_3)_3Cl$, MeCN, 25°C, 78% based on 50% conversion.



Scheme 10

A postulated mechanism for the intramolecular Rh(I)-promoted cyclization of acetylenic aldehyde **38** to enone **40**.



3. Conclusion.

This study was designed to investigate a Diels-Alder approach to the dynemicin A (**1**) CDE ring system and has resulted in the preparation of a number of interesting heterocycles and advanced intermediates for the target molecule. Furthermore a potentially useful cyclization reaction involving intramolecular carbonylation of terminal acetylenes induced by rhodium catalysis was discovered.

The reported Diels-Alder and cyclization reactions as well as the compounds described, are expected to find uses in both molecular design and chemical synthesis.

EXPERIMENTAL

General Techniques.

All non-aqueous reactions were carried out under an argon atmosphere with dry, freshly distilled solvents under anhydrous

conditions, unless otherwise noted. Tetrahydrofuran (THF) and diethyl ether (ether) were distilled from sodium/benzophenone, and dichloromethane and benzene from calcium hydride. All high-pressure reactions were carried out in a Leco™ hydraulically pressurized apparatus containing a castor oil medium using teflon vessels sealed at both ends with brass clamps. Yields refer to chromatographically and spectroscopically (^{1}H nmr) homogeneous materials, unless otherwise stated. All aqueous solutions used in workup procedures were saturated unless otherwise noted. Most reagents were purchased at the highest available commercial quality and were used without further purification unless otherwise stated.

All reactions were monitored by thin layer chromatography carried out on 0.25 mm E. Merck silica gel plates (60 F_{254}) using uv light as visualizing agent and ethanolic *p*-anisaldehyde solution (2.7%) and heat as developing agents. E. Merck silica gel (60, particle size 0.040-0.063 mm) was used for flash column chromatography. Preparative thin layer chromatography separations were carried out on E. Merck silica gel plates (60 F_{254}, 0.50 mm).

The nmr spectra were recorded at ambient temperature on a Bruker AMX-500 instrument calibrated with the residual undeuterated solvent as the internal reference. The following abbreviations were used to denote the multiplicities: s, singlet; d, doublet; t, triplet; q, quartet; m, multiplet; br, broad. The ir spectra were recorded on a Perkin-Elmer 1600 series FT-IR spectrometer. High-resolution mass spectra (hrms) were recorded on a VG ZAB-2SE mass spectrometer under fast atom bombardment (FAB) conditions or on a Hewlett-Packard GC-MS under electron ionization (EI) conditions. Nomenclature used to name intermediates was based on IUPAC guidelines.

Ethyl 4-Hydroxy-6-methoxy-2-quinolinecarboxylate (**9**).

Diethyl oxalacetate sodium salt (50.0 g, 0.238 mole) was suspended in ether (300 ml) and washed with aqueous hydrochloric acid (1.0 *M*, 2 x 100 ml). The organic layer was dried (magnesium sulfate) and the solvent was removed *in vacuo* to give a crude oil. The oil was redissolved in chloroform (300 ml) in a flask fitted with a Dean-Stark apparatus and *p*-anisidine (28.8 g, 0.234 mole) was added followed by concentrated sulfuric acid (several drops) and the reaction mixture was heated to reflux for one hour. The solvent was removed *in vacuo* and the residue was dissolved in Dowtherm A™ (400 ml) and the reaction mixture was heated to 250° until ethanol was no longer given off. The reaction mixture was cooled to room temperature and slowly poured into hexanes (2 l). The resulting precipitate was filtered off and washed with hexanes to give, after drying, 44.11 g (75%) of **9** as a tan powder; **9**: R_f = 0.65 (silica, methanol:ethyl acetate 1:9); ir (thin film): ν_{max} 3442, 3075, 2951, 1729, 1605, 1527, 1490, 1383, 1298, 1224, 1076, 1047, 1027, 990 cm^{-1}; ^{1}H nmr (500 MHz, methyl sulfoxide-d_6): δ 12.08 (br s, 1 H, N*H*), 7.90 (d, J = 9.2 Hz, 1 H, Ph), 7.45 (d, J = 2.8 Hz, 1 H, Ph), 7.36 (dd, J = 9.1, 2.7 Hz, 1 H, Ph), 6.60 (br s, 1 H, Ph), 4.40 (q, J = 7.1 Hz, 2 H, $CO_2CH_2CH_3$), 3.84 (s, 3 H, OCH_3), 1.35 (t, J = 7.1 Hz, 3 H, $CO_2CH_2CH_3$); ^{13}C nmr (125 MHz, methyl sulfoxide-d_6): δ 176.7, 162.3, 156.3, 136.8, 127.2, 123.4, 121.4, 108.7, 103.6, 62.5, 55.4, 39.8; hrms Calcd. for $C_{13}H_{14}NO_4$ $(M + H)^+$: 248.0923. Found m/z 248.0928.

Methyl 3-[(4-Methoxyphenyl)amino]-2-propenoate (**10**).

To a solution of *p*-anisidine (24.60 g, 0.200 mole) in methanol (500 ml) was added methyl propiolate (17.79 ml, 0.200 mole) and the reaction mixture was allowed to stir at room temperature for 16 hours. The now heterogeneous reaction mixture was concentrated *in vacuo* to give a crude solid which was redissolved in hot ethyl acetate (200 ml) and filtered through silica to give, after removal of the solvent, 41.44 g (100%) of **10** as a yellow crystalline solid (mixture of two stereoisomers); **10**: ir (thin film): ν_{max} 3311, 2954, 1667, 1624, 1515, 1481, 1204, 1030, 825, 785 cm^{-1}; ^{1}H nmr (500 MHz, deuteriochloroform) (multiple peaks due to mixture of stereoisomers): δ 9.78 (br d, J = 12.4 Hz, 1 H, *cis* compound N*H*), 7.82 (t, J = 13.0 Hz, 1 H, *trans* compound NHC*H*=CH), 7.15 (dd, J = 12.9, 8.2 Hz, 1 H, *cis* compound NHC*H*=CH), 6.92-6.83 (m, 4 H, Ph), 6.61 (br d, J = 13.0 Hz, 1 H, *trans* compound N*H*), 5.14 (d, J = 13.1 Hz, 1 H, *trans* compound CH=C*H*CO), 4.78 (d, J = 8.2 Hz, 1 H, *cis* compound CH=C*H*CO), 3.77 (s, 3 H, OCH_3), 3.70 (s, 3 H, *cis* compound CO_2CH_3), 3.69 (s, 3 H, *trans* compound CO_2CH_3); ^{13}C nmr (125 MHz, deuteriochloroform) (multiple peaks due to mixture of stereoisomers): δ 170.8, 169.5, 155.6, 155.5, 144.3, 144.2, 134.3, 133.9, 117.7, 117.0, 90.7, 85.6, 55.5, 50.8, 50.5; hrms Calcd. for $C_{11}H_{14}NO_3$ $(M + H)^+$: 208.0974. Found *m/z* 208.0980.

4-Hydroxy-6-methoxyquinoline (**11**).

Method A: from Ethyl 4-Hydroxy-6-methoxy-2-quinolinecarboxylate (**9**).

A suspension of compound **9** (26.00 g, 0.105 mole) in 5% aqueous sodium hydroxide (100 ml) was heated at reflux for five hours. After cooling to room temperature, the reaction mixture was diluted with water (200 ml), neutralized (concentrated hydrochloric acid) with cooling, and the resulting precipitate was filtered and washed with water. After drying, the solid was slowly added to a round-bottom flask containing biphenyl ether (300 ml) at 250°. After completion of the addition, the reaction mixture was heated at 250° for an additional 5 minutes, cooled to room temperature and poured into hexanes (2 l). The resulting precipitate was filtered and washed with hexanes to give, after drying, 10.68 g (58%) of **11** as a brown powder.

Method B: from Methyl 3-[(4-Methoxyphenyl)amino]-2-propenoate (**10**).

To boiling Dowtherm A™ (250°, 500 ml) was added acrylate **10** (40.00 g, 0.193 mole). After completion of the addition, the reaction mixture was heated at 250° for an additional 30 minutes. After cooling, the reaction mixture was poured into hexanes (2 l) and the resulting precipitate was filtered and washed with hexanes to give, after drying, 32.12 g (95%) of **11** as a white powder; **11**: R_f = 0.38 (methanol:ethyl acetate 1:9); ir (thin film): ν_{max} 3441, 3255, 3069, 3004, 1600, 1523, 1490, 1377, 1311, 1227, 992 cm^{-1}; ^{1}H nmr (500 MHz, deuteriochloroform): δ 1.76 (br s, 1 H, N*H*), 7.84 (d, J = 7.3 Hz, 1 H, Ph), 7.50-7.48 (m, 2 H, Ph), 7.27 (dd, J = 9.0, 3.0 Hz, 1 H, Ph), 5.99 (d, J = 7.2 Hz, 1 H, Ph), 3.81 (s, 3 H, OCH_3); ^{13}C nmr (125 MHz, deuteriochloroform): δ 176.2, 155.4, 138.4, 134.6, 126.8, 122.1, 120.0, 107.5, 104.1, 55.3; hrms Calcd. for $C_{10}H_{10}NO_2$ $(M + H)^+$: 176.0712. Found *m/z* 176.0707.

6-Methoxy-4-(phenylthio)quinoline (**12**).

To a solution of 6-methoxy-4-chloroquinoline (15.00 g, 0.078 mole) in benzene (300 ml) was added thiophenol (8.75 ml, 0.085 mole) and the reaction mixture was heated at reflux for 16 hours. The reaction mixture was concentrated *in vacuo* to give a crude oil. Purification by flash column chromatography (silica, ethyl acetate:dichloromethane 1:9) gave 19.06 g (92%) of **12** as a

viscous yellow oil which crystallized upon standing. R_f = 0.55 (silica, ethyl acetate:dichloromethane 1:9); ir (thin film): ν_{max} 1620, 1564, 1501, 1462, 1428, 1358, 1264, 1233, 1162, 1029, 840 cm^{-1}; ^1H nmr (500 MHz, deuteriochloroform): δ 8.45 (d, J = 4.8 Hz, 1 H, Ph), 7.98 (d, J = 9.1 Hz, 1 H, Ph), 7.55-7.54 (m, 2 H, Ph), 7.44-7.36 (m, 5 H, Ph), 6.80 (d, J = 4.8 Hz, 1 H, Ph), 3.92 (s, 3 H, OCH_3); ^{13}C nmr (125 MHz, deuteriochloroform): δ 157.8, 146.9, 145.9, 143.6, 134.7, 134.7, 131.3, 130.1, 129.9, 129.3, 129.3, 127.0, 122.4, 118.8, 101.5, 55.5; FAB hrms Calcd. for $C_{16}H_{14}NOS$ $(M + H)^+$: 268.0796. Found m/z 268.0785.

Phenyl 2-Ethynyl-6-methoxy-4-(phenylthio)-1,2-dihydroquinoline-1-carboxylate (**13**).

To a solution of compound **12** (15.00 g, 0.056 mole) in THF (250 ml) cooled to -78° was added ethynylmagnesium bromide (0.5 *M* in THF, 129 ml, 0.064 mole) and the reaction mixture was slowly allowed to warm to 25°. After re-cooling to -78°, phenyl chloroformate (8.45 ml, 0.067 mole) was added and the reaction mixture was again allowed to warm to 25° and stir for 15 minutes. Aqueous ammonium chloride (25 ml) was added and the reaction mixture was poured into aqueous sodium hydrogen carbonate (200 ml). The aqueous layer was extracted with ether (2 x 200 ml) and the combined organic layers were dried (magnesium sulfate), and concentrated *in vacuo* to give a crude oil, which after purification by flash column chromatography (silica, ether:hexanes 4:6), gave 21.98 g (95%) of **13** as a white crystalline solid; **13**: R_f = 0.51 (silica, ether:hexanes 4:6); ir (thin film): ν_{max} 3288, 3065, 2950, 1720, 1577, 1489, 1381, 1295, 1261, 1201, 1161, 1120, 1044, 937, 909 cm^{-1}; ^1H nmr (500 MHz, deuteriochloroform): δ 7.60 (br s, 1 H, Ph), 7.42-7.18 (m, 11 H, Ph), 6.88 (dd, J = 9.0, 2.9 Hz, 1 H, Ph), 6.13 (d, J = 6.7 Hz, 1 H, C=C*H*), 6.00 (dd, J = 6.7, 2.2 Hz, 1 H, NC*H*), 3.75 (s, 3 H, OCH_3), 2.27 (s, 1 H, CC*H*); ^{13}C nmr (125 MHz, deuteriochloroform): δ 156.8, 150.8, 132.9, 131.2, 129.4, 127.6, 127.1, 125.8, 121.5, 114.6, 110.2, 79.1, 72.4, 55.4, 44.8; FAB hrms Calcd. for $C_{25}H_{20}NO_3S$ $(M + H)^+$: 414.1164. Found *m/z* 414.1150.

Phenyl 2-Ethynyl-6-methoxy-4-(phenylsulfinyl)-1,2-dihydroquinoline-1-carboxylate (**14**).

To a solution of sulphide **13** (2.50 g, 5.821 mmole) in dichloromethane (50 ml) cooled to 0° was added portionwise *m*-chloroperoxybenzoic acid (*m*-CPBA) (1.10 g, 6.364 mmole) and the reaction mixture was allowed to stir at 25° for 20 minutes. The reaction mixture was diluted with dichloromethane (100 ml), washed with aqueous sodium thiosulfate (10%, 2 x 50 ml), aqueous sodium hydrogen carbonate (2 x 100 ml), aqueous sodium chloride (100 ml), dried (magnesium sulfate), and the solvent removed *in vacuo*. Purification by flash column chromatography (silica, ether:hexanes 4:1) gave 1.848 g (93%) of **14** as a white foam (mixture of diastereoisomers); **14**: R_f = 0.54 (silica, ether:hexanes 4:1); ir (thin film): ν_{max} 3291, 3060, 2954, 1721, 1603, 1492, 1380, 1294, 1259, 1200, 1162, 1118, 1045, 911 cm^{-1}; ^1H nmr (500 MHz, deuteriochloroform) (multiple peaks due to mixture of diastereoisomers): δ 7.79-7.71 (m, 2 H, Ph), 7.54-7.36 (m, 6 H, Ph), 7.25-6.95 (m, 5 H, Ph, C=C*H*), 6.86-6.83 (m, 1 H, Ph), 6.29 (dd, J = 6.6, 2.2 Hz, 1 H, NC*H*), 6.23 (dd, J = 6.6, 2.4 Hz, 1 H, NC*H*), 3.77 (s, 3 H, OCH_3), 3.66 (s, 3 H, OCH_3), 2.35 (br s, 1 H, CC*H*); ^{13}C nmr (125 MHz, deuteriochloroform) (multiple peaks due to mixture of diastereoisomers): δ 156.5, 150.6, 142.6, 141.7, 140.1, 131.9, 129.7, 129.6, 129.5, 129.4, 126.8, 126.2, 126.0, 125.6, 123.3, 121.5, 115.2, 114.5, 108.8, 108.5, 77.9, 73.6, 65.8, 55.5, 55.4, 45.0, 44.4; FAB hrms Calcd. for $C_{25}H_{19}NO_4SCs$ $(M + Cs)^+$: 562.0089. Found m/z 562.0076.

Phenyl 2-Ethynyl-6-methoxy-4-(phenylsulfonyl)-1,2-dihydroquinoline-1-carboxylate (**15**).

Following the same procedure as that described for **14** using 2.10 molar equivalents of *m*-CPBA gave, after purification by flash column chromatography (silica, ether:hexanes 4:1) 2.461 g (95%) of **15** as a white foam; **15**: R_f = 0.68 (silica, ether:hexanes 4:1); ir (thin film): ν_{max} 3290, 3071, 2956, 1723, 1601, 1492, 1382, 1297, 1261, 1200, 1152, 1085, 1044, 910 cm^{-1}; ^1H nmr (500 MHz, deuteriochloroform): δ 7.97-7.96 (m, 2 H, Ph), 7.64-7.54 (m, 5 H, Ph), 7.40-7.32 (m, 3 H, Ph), 7.26-7.23 (m, 1 H, Ph), 7.12 (br s, 2 H, Ph, C=C*H*), 6.89 (dd, J = 9.1, 2.9 Hz, 1 H, Ph), 6.25 (dd, J = 6.9, 2.4 Hz, 1 H, NC*H*), 3.77 (s, 3 H, OCH_3), 2.33 (s, 1 H, CC*H*); ^{13}C nmr (125 MHz, deuteriochloroform): δ 162.7, 156.7, 150.6, 139.4, 138.4, 133.9, 133.8, 129.6, 129.5, 129.4, 127.9, 127.8, 127.7, 121.4, 115.8, 110.1, 110.0, 74.2, 55.5, 43.9; FAB hrms Calcd. for $C_{25}H_{19}NO_5SCs$ $(M + Cs)^+$: 578.0038. Found *m/z* 578.0024.

General Procedure for the High-Pressure Diels-Alder Reactions.

Phenyl 10-[[(1,1-Dimethylethyl)dimethylsilyl]oxy]-6-ethynyl-2-methoxy-7-methyl-5,6,7,10-tetrahydrophenanthridine-5-carboxylate (**20**).

The dienophile **14** (0.500 g, 1.164 mmole) was placed in a length (~15 cm) of Teflon™ tubing sealed at one end with a brass clamp. Next was added diene **19** (0.924 g, 4.657 mmole), followed by dichloromethane (2 ml). The tube was sealed with a second brass clamp and placed in a Leco™ hydraulically pressurized reactor (13 kbar) for 24 hours. Concentration of the reaction mixture *in vacuo* followed by purification by flash column chromatography (silica, ethyl acetate:hexanes 1:9) gave 0.117 g (20%) of compound **20** as a yellow oil; **20**: R_f = 0.44 (silica, ethyl acetate:hexanes 1:9); ir (thin film): ν_{max} 3305, 2957, 2930, 2856, 1728, 1715, 1609, 1495, 1471, 1386, 1326, 1303, 1249, 1203, 1164, 1073, 1050, 956 cm^{-1}; ^1H nmr (500 MHz, deuteriochloroform): δ 7.54 (br s, 1 H, Ph), 7.39-7.33 (m, 2 H, Ph), 7.25-7.22 (m, 1 H, Ph), 7.15-7.09 (m, 3 H, Ph), 6.85 (dd, J = 8.9, 2.8 Hz, 1 H, Ph), 6.02 (d, J = 2.4 Hz, 1 H, NC*H*), 5.96 (ddd, J = 10.0, 3.5, 1.1 Hz, 1 H, C*H*=CHCHOSi), 5.89 (dd, J = 9.6, 1.8 Hz, 1 H, CH=C*H*CHOSi), 5.49 (br s, 1 H, C*H*OSi), 3.84 (s, 3 H, OCH_3), 3.07-3.04 (m, 1 H, C*H*CH_3), 2.15 (s, 1 H, CC*H*), 1.37 (d, J = 6.5 Hz, 3 H, CHCH_3), 0.75 (s, 9 H, SiC(CH_3)$_3$), 0.03 (s, 3 H, SiCH_3), -0.20 (br s, 3 H, SiCH_3); ^{13}C nmr (125 MHz, deuteriochloroform): δ 151.0, 135.4, 131.6, 131.5, 129.4, 129.3, 128.2, 126.9, 126.2, 125.7, 121.5, 113.2, 109.7, 79.7, 71.6, 63.4, 60.4, 55.5, 45.3, 31.3, 29.7, 25.7, 19.4, 18.1, 14.2, -2.7, -3.3; FAB hrms Calcd. for $C_{30}H_{35}NO_4SiCs$ $(M + Cs)^+$: 634.1390. Found m/z 634.1375.

The following compounds were prepared in a similar manner:

Phenyl 6-Ethynyl-5,6,6a,7,10,10a-hexahydro-2-methoxy-8(9)-methyl-10a-(phenylsulfonyl)phenanthridine-5-carboxylate (**22**).

Compound **22** was prepared according to the procedure given for **20** and was purified by flash column chromatography (silica, ethyl acetate:hexanes 3:7) (91%) as a white foam (mixture of regioisomers); **22**: R_f = 0.41 (silica, ethyl acetate:hexanes 3:7); ir (thin film): ν_{max} 3301, 2964, 1733, 1587, 1498, 1446, 1392, 1302, 1234, 1202, 1143, 1081, 1047, 911 cm^{-1}; ^1H nmr (500

MHz, deuteriochloroform) (multiple peaks due to mixture of regioisomers) δ 7.61-7.55 (m, 6 H, Ph), 7.50-7.47 (m, 2 H, Ph), 7.43-7.39 (m, 4 H, Ph), 7.36-7.32 (m, 4 H, Ph), 7.27-7.23 (m, 4 H, Ph), 7.19-7.16 (m, 2 H, Ph), 6.89-6.85 (m, 3 H, Ph), 6.68 (d, J = 2.8 Hz, 1 H, Ph), 5.66-5.63 (m, 1 H, NC*H*), 5.46-5.43 (m, 1 H, NC*H*), 4.34 (dd, J = 8.2, 2.5 Hz, 1 H, C=C*H*), 4.10 (dd, J = 9.6, 2.6 Hz, 1 H, C=C*H*), 3.76-3.72 (m, 1 H, C*H*CH_2), 3.69-3.63 (m, 1 H, C*H*CH_2), 3.68 (s, 3 H, OCH_3), 3.66 (s, 3 H, OCH_3), 3.04 (d, J = 14.7 Hz, 1 H, CHCH_2), 2.99 (br d, J = 15.0 Hz, 1 H, CHCH_2), 2.73 (dd, J = 15.0, 6.2 Hz, 1 H, CHCH_2), 2.67 (d, J = 14.6 Hz, 1 H, CHCH_2), 2.50 (d, J = 2.6 Hz, 1 H, CC*H*), 2.26 (d, J = 2.6 Hz, 1 H, CC*H*), 1.71 (s, 3 H, CCH_3), 1.69 (s, 3 H, CCH_3); ^{13}C nmr (125 MHz, deuteriochloroform) (multiple peaks due to mixture of regioisomers) δ 156.8, 156.7, 152.3, 152.2, 151.1, 138.3, 135.7, 135.6, 135.4, 134.0, 133.7, 131.0, 130.9, 129.4, 129.2, 129.1, 128.6, 128.5, 128.3, 128.0, 127.4, 127.2, 125.4, 125.3, 121.9, 121.8, 117.7, 114.5, 114.4, 114.0, 113.2, 79.1, 78.8, 75.5, 74.7, 70.2, 60.4, 55.4, 52.5, 52.3, 41.5, 41.2, 36.5, 32.4, 31.2, 28.3, 23.0, 22.8, 14.2; FAB hrms Calcd. for $C_{30}H_{27}NO_5SCs$ (*M* + Cs)$^+$: 646.0664. Found *m/z* 646.0648.

Phenyl 6-Ethynyl-5,6,6a,7,10,10a-hexahydro-2-methoxy-10-methyl-10a-(phenylsulfonyl)phenanthridine-5-carboxylate (**24**).

Compound **24** was obtained as described above for **20** and was purified by flash column chromatography (silica, ethyl acetate:hexanes 3:7) as a white foam (83%); **24**: R_f = 0.38 (silica, ethyl acetate:hexanes 3:7); ir (thin film): ν_{max} 3301, 2939, 1721, 1610, 1585, 1497, 1392, 1293, 1202, 1141, 1078, 1047, 911 cm^{-1}; ^{1}H nmr (500 MHz, deuteriochloroform): δ 7.82-7.78 (m, 3 H, Ph), 7.55-7.51 (m, 1 H, Ph), 7.45-7.40 (m, 3 H, Ph), 7.36-7.32 (m, 2 H, Ph), 7.21-7.18 (m, 1 H, Ph), 7.14-7.11 (m, 2 H, Ph), 6.90 (dd, J = 8.9, 2.9 Hz, 1 H, Ph), 5.86-5.84 (m, 2 H, C*H*=C*H*), 4.86 (dd, J = 4.8, 2.5 Hz, 1 H, NC*H*), 3.86 (s, 3 H, OCH_3), 3.63-3.58 (m, 1 H, C*H*CH_3), 3.48 (dt, J = 6.7, 4.9 Hz, 1 H, C*H*CH_2), 2.63-2.58 (m, 1 H, CHCH_2), 2.36-2.31 (m, 1 H, CHCH_2), 1.80 (d, J = 2.5 Hz, 1 H, CC*H*), 1.05 (d, J = 7.1 Hz, 3 H, CCH_3); ^{13}C nmr (125 MHz, deuteriochloroform): δ 156.5, 150.9, 137.6, 133.5, 132.9, 131.6, 131.5, 130.1, 129.3, 129.2, 128.8, 128.7, 127.9, 127.3, 126.4, 125.6, 121.6, 115.0, 114.3, 79.3, 74.2, 73.1, 55.6, 52.0, 42.0, 34.9, 28.5, 17.5; FAB hrms Calcd. for $C_{30}H_{27}NO_5SCs$ (*M* + Cs)$^+$: 646.0664. Found m/z 646.0648.

Phenyl 10-[[(1,1-Dimethylethyl)dimethylsilyl]oxy]-6-ethynyl-5,6,6a,7,10,10a-hexahydro-2-methoxy-7-methyl-10a-(phenylsulfonyl)phenanthridine-5-carboxylate (**25**).

Compound **25** was obtained as described above for **20** and was purified by flash column chromatography (silica, ethyl acetate:hexanes 3:7) as a white foam (96%); **25**: R_f = 0.61 (silica, ethyl acetate:hexanes 3:7); ir (thin film): ν_{max} 3307, 2956, 2932, 2857, 1716, 1612, 1590, 1499, 1467, 1393, 1291, 1261, 1204, 1146, 1079, 1029, 910 cm^{-1}; ^{1}H nmr (500 MHz, deuteriochloroform): δ 8.52 (d, J = 2.3 Hz, 1 H, Ph), 7.89 (d, J = 7.4 Hz, 2 H, Ph), 7.51 (t, J = 7.4 Hz, 1 H, Ph), 7.42 (t, J = 7.8 Hz, 2 H, Ph), 7.38-7.32 (m, 3 H, Ph), 7.21 (t, J = 7.5 Hz, 1 H, Ph), 7.05 (br s, 2 H, Ph), 6.87 (dd, J = 8.9, 2.9 Hz, 1 H, Ph), 5.68-5.65 (m, 1 H, CH=C*H*CHOSi), 5.55 (br s, 1 H, NC*H*), 5.51 (d, J = 2 Hz, 1 H, C*H*OSi), 5.52-5.49 (m, 1 H, CHC*H*=CH), 3.93 (s, 3 H, OCH_3), 3.06 (br d, J = 4.9 Hz, 1 H, CHC*H*CH), 2.94 (br s, 1 H, C*H*CH_3), 1.40 (d, J = 7 Hz, 3 H, CHCH_3), 1.25 (d, J = 2 Hz, 1 H, CC*H*), 0.89 (s, 9 H, SiC(CH_3)$_3$), 0.31 (s, 3 H, SiCH_3), 0.14 (s, 3 H, SiCH_3); ^{13}C nmr (125 MHz, deuteriochloroform): δ 155.6, 150.8, 138.1, 133.3, 132.9, 131.5, 129.4, 129.1, 128.8, 128.4, 126.2, 125.7, 121.5, 118.3, 114.0, 80.2, 70.7, 70.3, 55.6, 51.4, 43.0, 31.9, 25.9, 18.1, 16.8, -4.4, -4.5; FAB hrms Calcd. for $C_{36}H_{41}NO_6SSiCs$ (*M* + Cs)$^+$: 776.1478. Found m/z 776.1498.

Diels-Alder Adducts **26a** and **26b**.

Compounds **26a** and **26b** were obtained as described above for **20** and were purified by flash column chromatography (silica, ether:hexanes 1:1) in 79% total yield as white foams.

Phenyl 10-[[(1,1-Dimethylethyl)dimethylsilyl]oxy]-8-[2,2-dimethyl-1-(oxopropoxy)methyl]-6-ethynyl-5,6,6a,7,10,10a-hexahydro-2-methoxy-7-methyl-10a-(phenylsulfonyl)phenanthridine-5-carboxylate (**26a**).

This compound had R_f = 0.42 (silica, ether:hexanes 1:1); ir (thin film): ν_{max} 3306, 2957, 2857, 1728, 1504, 1393, 1281, 1201, 1145, 1079, 1045, 911 cm^{-1}; ^{1}H nmr (500 MHz, deuteriochloroform): δ 7.91 (d, J = 7.8 Hz, 2 H, Ph), 7.57-7.49 (m, 3 H, Ph), 7.44-7.34 (m, 4 H, Ph), 7.24-7.11 (m, 3 H, Ph), 6.85 (dd, J = 9.1, 2.9 Hz, 1 H, Ph), 5.90-5.89 (m, 1 H, C=C*H*), 5.45 (br s, 1 H, NC*H*), 4.68 (br s, 1 H, C*H*OSi), 4.40 (d, J = 13.9 Hz, 1 H, CCH_2O), 4.29 (d, J = 13.9 Hz, 1 H, CCH_2O), 3.84 (s, 3 H, OCH_3), 3.29 (br d, J = 6.7 Hz, 1 H, CHC*H*CH), 2.22 (m, 1 H, C*H*CH_3), 2.14 (d, J = 1.7 Hz, 1 H, CC*H*), 1.36 (d, J = 7.0 Hz, 3 H, CHCH_3), 1.17 (s, 9 H, COC(CH_3)$_3$), 0.90 (s, 9 H, SiC(CH_3)$_3$), -0.10 (s, 3 H, SiCH_3), -0.13 (br s, 3 H, SiCH_3); ^{13}C nmr (125 MHz, deuteriochloroform): δ 177.7, 155.8, 152.2, 150.7, 133.5, 133.2, 131.5, 129.4, 129.3, 128.8, 128.1, 125.8, 121.5, 121.2, 117.9, 114.0, 73.9, 64.4, 55.6, 55.5, 49.3, 38.7, 33.0, 31.6, 27.2, 25.9, 25.8, 18.2, 17.9, 14.1, -4.6, -5.2; FAB hrms Calcd. for $C_{42}H_{51}NO_8SSiCs$ (*M* + Cs)$^+$: 890.2159. Found m/z 890.2168.

Phenyl 7-[[(1,1-Dimethylethyl)dimethylsilyl]oxy]-9-[2,2-dimethyl-1-(oxopropoxy)methyl]-6-ethynyl-5,6,6a,7,10,10a-hexahydro-2-methoxy-10-methyl-10a-(phenylsulfonyl)phenanthridine-5-carboxylate (**26b**).

This compound had R_f = 0.46 (silica, ether:hexanes 1:1); ir (thin film): ν_{max} 2956, 2857, 1727, 1494, 1397, 1288, 1262, 1203, 1142, 1102, 1079 cm^{-1}; ^{1}H nmr (500 MHz, deuteriochloroform): δ 8.00 (br s, 1 H, Ph), 7.82 (d, J = 7.4 Hz, 2 H, Ph), 7.56-7.53 (m, 1 H, Ph), 7.44-7.32 (m, 5 H, Ph), 7.19-7.16 (m, 3 H, Ph), 6.87 (dd, J = 9.0, 2.9 Hz, 1 H, Ph), 5.99 (br s, 1 H, C=C*H*), 5.76 (br s, 1 H, NC*H*), 4.91-4.89 (m, 1 H, C*H*OSi), 4.40 (d, J = 13.5 Hz, 1 H, CCH_2O), 4.30 (d, J = 13.5 Hz, 1 H, CCH_2O), 3.85 (s, 3 H, OCH_3), 3.67 (br s, 1 H, C*H*CH_3), 3.37 (br s, 1 H, CHC*H*CH), 1.43 (d, J = 7.0 Hz, 3 H, CHCH_3), 1.41 (br s, 1 H, CC*H*), 1.08 (s, 9 H, COC(CH_3)$_3$), 0.92 (s, 9 H, SiC(CH_3)$_3$), 0.21 (s, 3 H, SiCH_3), 0.16 (s, 3 H, SiCH_3); ^{13}C nmr (125 MHz, deuteriochloroform): δ 177.9, 155.7, 151.0, 150.9, 136.9, 133.6, 131.3, 129.3, 128.8, 127.3, 126.6, 125.4, 125.3, 121.3, 15.8, 114.3, 80.4, 72.6, 71.2, 67.3, 64.5, 55.5, 51.9, 43.8, 38.6, 36.3, 27.0, 25.8, 18.0, 14.8, -4.5, -4.9; FAB hrms Calcd. for $C_{42}H_{51}NO_8SSiCs$ (*M* + Cs)$^+$: 890.2159. Found m/z 890.2172.

Phenyl 6-Ethynyl-5,6,6a,7,10,10a-hexahydro-10-hydroxy-2-methoxy-7-methyl-10a-(phenylsulfonyl)phenanthridine-5-carboxylate (**27**).

To a solution of compound **25** (0.150 g, 0.233 mmole) in acetonitrile (10 ml) was added an excess of 48% aqueous hydrogen fluoride and the reaction mixture was stirred at 25° for 12 hours.

The reaction mixture was diluted with dichloromethane (50 ml), washed with aqueous sodium hydrogen carbonate (20 ml), aqueous sodium chloride (20 ml), dried (magnesium sulfate), and the solvent removed *in vacuo*. Purification by flash column chromatography (silica, ethyl acetate:hexanes 4:6) gave 0.101 g (83%) of **27** as a white foam; **27**: R_f = 0.49 (silica, ethyl acetate:hexanes 4:6); ir (thin film): ν_{max} 3543, 3304, 2964, 2933, 1714, 1501, 1393, 1322, 1269, 1204, 1140, 1077, 1028, 911 cm^{-1}; ^1H nmr (500 MHz, deuteriochloroform): δ 8.25 (d, J = 2.1 Hz, 1 H, Ph), 7.99 (d, J = 7.5 Hz, 2 H, Ph), 7.59 (t, J = 7.5 Hz, 1 H, Ph), 7.49 (t, J = 7.8 Hz, 2 H, Ph), 7.36-7.29 (m, 3 H, Ph), 7.21 (br t, J = 7.3 Hz, 1 H, Ph), 7.01 (d, J = 7.5 Hz, 2 H, Ph), 6.89 (dd, J = 8.9, 2.8 Hz, 1 H, Ph), 5.66 (br s, 1 H, CH=C*H*CHOH), 5.62 (t, J = 2.6 Hz, 1 H, NC*H*), 5.60-5.58 (m, 2 H, C*H*=CHC*H*OH), 3.91 (s, 3 H, OCH_3), 3.57 (br s, 1 H, CHO*H*), 3.12 (br d, J = 4.8 Hz, 1 H, CHC*H*CH), 2.75 (br s, 1 H, C*H*CH_3), 1.40 (d, J = 7 Hz, 3 H, $CHCH_3$), 1.18 (d, J = 1.6 Hz, 1 H, CC*H*); ^{13}C nmr (125 MHz, deuteriochloroform) δ 155.8, 150.7, 136.4, 134.0, 133.4, 131.7, 129.6, 129.4, 129.2, 129.0, 127.1, 125.8, 121.4, 116.9, 113.9, 80.4, 74.6, 71.5, 70.6, 60.4, 55.5, 51.0, 42.9, 32.0, 29.7, 21.0, 16.6, 14.2; FAB hrms Calcd. for $C_{30}H_{27}NO_6SCs$ (M + Cs)$^+$: 662.0613. Found m/z 662.0626.

Phenyl 6-Ethynyl-5,6,6a,7,10,10a-hexahydro-2-methoxy-7-methyl-10-oxo-10a-(phenylsulfonyl)phenanthridine-5-carboxylate (**28**).

To a solution of compound **27** (0.100 g, 0.189 mmole) in dichloromethane (10 ml) was added Dess-Martin periodinane (0.096 g, 0.226 mmole) and the reaction mixture was stirred at 25° for 0.5 hours. The reaction mixture was diluted with dichloromethane (30 ml), washed with 20% aqueous sodium thiosulfate (2 x 20 ml), aqueous sodium hydrogen carbonate (2 x 20 ml), aqueous sodium chloride (25 ml), dried (magnesium sulfate) and the solvent removed *in vacuo*. Purification by flash column chromatography (silica, ethyl acetate:hexanes 4:6) gave 0.091 g (92%) of **28** as a white foam; **28**: R_f = 0.54 (silica, ethyl acetate:hexanes 4:6); ir (thin film): ν_{max} 3273, 2966, 2935, 1724, 1677, 1587, 1499, 1394, 1321, 1306, 1207, 1144, 911 cm^{-1}; ^1H nmr (500 MHz, deuteriochloroform): δ 7.98 (d, J = 7.7 Hz, 2 H, Ph), 7.66 (t, J = 7.4 Hz, 1 H, Ph), 7.58-7.54 (m, 3 H, Ph), 7.36-7.31 (m, 3 H, Ph), 7.18 (t, J = 7.4 Hz, 1 H, Ph), 7.05 (d, J = 7.9 Hz, 2 H, Ph), 6.87 (dd, J = 8.8, 2.6 Hz, 1 H, Ph), 6.82 (d, J = 10.2 Hz, 1 H, CH=C*H*CO), 6.31 (dd, J = 10.2, 2.5 Hz, 1 H, CHC*H*=CH), 5.39 (dd, J = 4.3, 2.4 Hz, 1 H, NC*H*), 3.93-3.91 (m, 1 H, C*H*CH_3), 3.67 (s, 3 H, OCH_3), 3.38 (br s, 1 H, CHC*H*CH), 2.21 (d, J = 2.1 Hz, 1 H, CC*H*), 1.41 (d, J = 7.4 Hz, 3 H, $CHCH_3$); ^{13}C nmr (125 MHz, deuteriochloroform): δ 189.8, 157.4, 154.1, 150.7, 140.7, 134.3, 130.3, 129.6, 129.3, 129.1, 128.4, 127.6, 121.6, 114.6, 113.6, 82.0, 77.8, 72.9, 60.4, 56.1, 55.5, 48.0, 33.3, 29.7, 21.0, 17.4, 14.2; FAB hrms Calcd. for $C_{30}H_{25}NO_6SCs$ (M + Cs)$^+$: 660.0457. Found m/z 660.0460.

[(1,1-Dimethylethyl)dimethyl]-(2*H*-thiopyran-6-yloxy)silane (**29**).

To a solution of thiopyranone **33** (0.500 g, 4.380 mmole) in dichloromethane (100 ml) cooled to 0° was added triethylamine (0.532 g, 5.256 mmole) followed by *tert*-butyldimethylsilyl trifluoromethanesulfonate (TBSOTf) (1.274 g, 4.818 mmole) and the reaction mixture was allowed to stir at 0° for 10 minutes. The reaction mixture was diluted with hexanes (500 ml), filtered through a silica gel plug (3 x 5 cm), and the solvent was removed *in vacuo* to give 0.883 g (89%) of **29** as a colorless oil; **29**: R_f = 0.85 (silica, ether:hexanes 2:18); ir (thin film): ν_{max} 2956, 2929, 2858, 1562, 1252, 1212, 1176, 1150, 841 cm^{-1}; ^1H nmr (500 MHz, deuteriochloroform): δ 5.95 (ddt, J = 9.6, 6.4, 1.2 Hz, 1 H, C*H*=CHCH$_2$), 5.46 (d, J = 6.4 Hz, 1 H, C*H*=CS), 5.29 (dt, J = 9.6, 5.2 Hz, 1 H, CH=C*H*CH$_2$), 3.41 (dd, J = 5.2, 1.2 Hz, 2 H, SC*H*$_2$CH), 0.95 (s, 9 H, SiC(C*H*$_3$)$_3$), 0.23 (s, 6 H, Si(C*H*$_3$)$_2$); ^{13}C nmr (125 MHz, deuteriochloroform): δ 151.5, 127.7, 109.2, 103.7, 27.9, 25.5, 18.1, -4.5.

Phenyl Spiro-2(1*H*), 6'-[2]thiabicyclo[2.2.2]oct[7]ene-1'-[[(1,1-dimethylethyl)dimethylsilyl]oxy]-6-methoxy-5'-methylene-4-(phenylsulfonyl)quinoline-1-carboxylate (**34**).

Compound **34** was prepared as described for **20** and was purified by flash column chromatography (silica, ether:hexanes 6:4) (50%) as a white solid; **34**: R_f = 0.50 (silica, ether:hexanes 6:4); ir (thin film): ν_{max} 2928, 2856, 1737, 1493, 1318, 1251, 1198, 1151, 1086, 910 cm^{-1}; ^1H nmr (500 MHz, deuteriochloroform): δ 8.09-8.07 (m, 2 H, Ph), 7.67-7.55 (m, 4 H, Ph), 7.33-7.28 (m, 3 H, Ph), 7.15 (t, J = 7.4 Hz, 1 H, Ph), 7.09 (d, J = 8.9 Hz, 1 H, Ph), 6.96 (dd, J = 7.6, 1.2 Hz, 2 H, Ph), 6.73 (dd, J = 9.0, 2.9 Hz, 1 H, Ph), 6.51 (dd, J = 8.8, 7.0 Hz, 1 H, CHC*H*=CH), 6.30 (dd, J = 8.8 Hz, 1 H, CHCH=C*H*), 5.25 (s, 1 H, C=C*H*$_2$), 5.21 (s, 1 H, C=C*H*$_2$), 3.75-3.72 (m, 1 H, CH$_2$C*H*CH=CH), 3.71 (s, 3 H, OCH_3), 3.15-3.10 (m, 1 H, SC*H*$_2$CH), 2.73 (dd, J = 8.9, 1.9 Hz, 1 H, SC*H*$_2$CH), 0.42 (s, 9 H, SiC(C*H*$_3$)$_3$), 0.07 (s, 3 H, SiC*H*$_3$), -0.19 (s, 3 H, SiC*H*$_3$); ^{13}C nmr (125 MHz, deuteriochloroform): δ 156.0, 152.2, 151.7, 150.9, 144.3, 140.8, 137.7, 134.6, 133.5, 132.1, 130.8, 129.4, 129.3, 127.8, 126.4, 125.4, 121.5, 121.1, 114.9, 112.7, 109.2, 87.7, 71.1, 55.5, 40.9, 38.6, 25.3, 17.4, -2.4, -2.6; FAB hrms Calcd. for $C_{36}H_{39}NO_6S_2SiCs$ (M + Cs)$^+$: 806.1042. Found m/z 806.1030.

4-(1,3-Dioxolan-2-yl)quinoline (**37**).

In a flask fitted with a Dean-Stark apparatus, containing 4-quinolinecarboxaldehyde (**36**) (10.00 g, 0.064 mole) in benzene (100 ml) was added *p*-toluenesulfonic acid (1.21 g, 6.363 mmole) followed by ethylene glycol (19.75 g, 0.318 mole) and the reaction mixture was heated at reflux for 12 hours. The reaction mixture was diluted with dichloromethane (300 ml) and the organic layer was washed with aqueous sodium hydrogen carbonate (2 x 100 ml), aqueous sodium chloride (100 ml), dried (magnesium sulfate) and the solvent was removed *in vacuo* to give a crude oil. Purification by flash column chromatography (silica, ethyl acetate:dichloromethane 2:8) gave 10.24 g (80%) of **37** as a yellow oil; **37**: R_f = 0.49 (silica, ethyl acetate:dichloromethane 2:8); ir (thin film): ν_{max} 2888, 1598, 1510, 1371, 1357, 1242, 1116, 1072, 1031, 974, 942 cm^{-1}; ^1H nmr (500 MHz, deuteriochloroform): δ 8.93 (d, J = 4.4 Hz, 1 H, Ph), 8.18 (dd, J = 8.5, 0.9 Hz, 1 H, Ph), 8.14 (d, J = 8.4 Hz, 1 H, Ph), 7.72 (m, 1 H, Ph), 7.59 (m, 2 H, Ph), 6.45 (s, 1 H, C*H*-O(CH$_2$)$_2$O-), 4.14 (s, 4 H, -O(C*H*$_2$)$_2$O-); ^{13}C nmr (125 MHz, deuteriochloroform): δ 150.1, 148.3, 142.5, 129.9, 129.2, 126.8, 125.8, 124.1, 117.3, 100.6, 65.4; FAB hrms Calcd. for $C_{12}H_{12}NO_2$ (M + H)$^+$: 202.0868. Found m/z 202.0870.

Phenyl 4-(1,3-Dioxolan-2-yl)-1,2-dihydro-2-ethynylquinoline-1-carboxylate (**38**).

Compound **38** was prepared according to the procedure described for **13** and was purified by recrystallization (dichloromethane:hexanes) of the crude reaction mixture; **38**: (89% yield); white solid; R_f = 0.54 (silica, ether:hexanes 6:4); ir (thin film): ν_{max} 3305, 3154, 2984, 2895, 1793, 1717, 1492,

1381, 1329, 1304, 1264, 1202, 1113, 1030, 902 cm^{-1}; ^1H nmr (500 MHz, deuteriochloroform): δ 7.78 (br s, 1 H, Ph), 7.62 (d, J = 7.8 Hz, 1 H, Ph), 7.41 (t, J = 7.9 Hz, 2 H, Ph), 7.34 (dt, J = 7.4, 1.3 Hz, 1 H, Ph), 7.28-7.20 (m, 6 H, Ph), 6.44 (d, J = 6.6 Hz, 1 H, C=C*H*), 6.09 (dd, J = 6.6, 2.1 Hz, 1 H, NC*H*), 5.88 (s, 1 H, C*H*(-O(CH_2)$_2$O-)), 4.16-4.04 (m, 4 H, O(CH_2)$_2$O), 2.27 (d, J = 2.1 Hz, 1 H, CC*H*); ^{13}C nmr (125 MHz, deuteriochloroform): δ 150.8, 133.8, 132.5, 129.4, 128.2, 125.8, 125.2, 125.1, 124.7, 124.3, 121.5, 100.9, 79.2, 72.4, 65.1, 43.8.

Phenyl 4-Formyl-1,2-dihydro-2-ethynylquinoline-1-carboxylate (**39**).

To a solution of compound **38** (10.00 g, 0.029 mole) in THF (200 ml) was added aqueous hydrochloric acid (1.0 *N*, 100 ml) and the reaction mixture was heated to 55° for 8 hours. The reaction mixture was allowed to cool to room temperature and diluted with ether (300 ml), the organic layer was washed with aqueous sodium hydrogen carbonate (2 x 200 ml), aqueous sodium chloride (200 ml), dried (magnesium sulfate) and the solvent was removed *in vacuo* to give a crude oil. Purification by flash column chromatography (silica, ether:hexanes 6:4) gave 6.81 g (78%) of **39** as a red foam; **39**: R_f = 0.62 (ether:hexanes 6:4); ir (thin film): ν_{max} 3154, 1816, 1793, 1719, 1703, 1642, 1602, 1561, 1470, 1380, 1326, 1299, 1264, 1201, 1164, 1095, 912 cm^{-1}; ^1H nmr (500 MHz, deuteriochloroform): δ 9.80 (s, 1 H, C*H*O), 8.26 (dd, J = 7.9, 1.4 Hz, 1 H, Ph), 7.76 (br s, 1 H, Ph), 7.43-7.38 (m, 3 H, Ph), 7.31-7.24 (m, 2 H, Ph), 7.18 (d, J = 7.9 Hz, 2 H, Ph), 6.93 (d, J = 6.6 Hz, 1 H, C=C*H*), 6.30 (dd, J = 6.6, 2.4 Hz, 1 H, NC*H*), 2.33 (d, J = 2.3 Hz, 1 H, CC*H*); ^{13}H nmr (125 MHz, deuteriochloroform): δ 190.7, 150.6, 134.8, 129.5, 129.4, 129.3, 126.2, 126.1, 126.0, 125.6, 121.4, 73.9, 43.9, 29.7; FAB hrms Calcd. for $C_{19}H_{14}NO_3$ (M + H)$^+$: 304.0974. Found m/z 304.0963.

Phenyl 10-[[(1,1-Dimethylethyl)dimethylsilyl]oxy]-8-[2,2-dimethyl-1-(oxopropoxy)methyl]-6-ethynyl-10a-formyl-5,6,6a,7,10,10a-hexahydro-7-phenanthridinyl-5-carboxylate (**40**).

Compound **40** was prepared according to the procedure given for **20** and was purified by flash column chromatography (silica, ether:hexanes 3:7) (90%) as a white foam; **40**: R_f = 0.41 (silica, ether:hexanes 3:7); ir (thin film): ν_{max} 2956, 2930, 2957, 1727, 1492, 1380, 1326, 1280, 1261, 1200, 1148, 1077, 1034 cm^{-1}; ^1H nmr (500 MHz, deuteriochloroform): δ 10.19 (s, 1 H, C*H*O), 7.73 (br d, J = 6.7 Hz, 1 H, Ph), 7.41-7.38 (m, 2 H, Ph), 7.30-7.22 (m, 3 H, Ph), 7.18-7.15 (m, 3 H, Ph), 5.87-5.86 (m, 1 H, C=C*H*), 5.08 (br s, 1 H, NC*H*), 4.67 (d, J = 3.1 Hz, 1 H, C*H*OSi), 4.53 (s, 2 H, CCH_2O), 2.94-2.92 (m, 1 H, CHC*H*CH), 2.36-2.31 (m, 1 H, C*H*CH_3), 2.28 (d, J = 2.3 Hz, 1 H, CC*H*), 1.29 (d, J = 7.3 Hz, 3 H, CHCH_3), 1.18 (s, 9 H, COC(CH_3)$_3$), 0.85 (s, 9 H, SiC(CH_3)$_3$), -0.04 (s, 3 H, SiCH_3), -0.23 (s, 3 H, SiCH_3); ^{13}C nmr (125 MHz, deuteriochloroform): δ 204.9, 177.9, 152.4, 150.7, 139.9, 134.7, 129.4, 129.3, 128.6, 127.6, 126.1, 125.9, 124.9, 121.4, 81.7, 72.7, 69.5, 65.0, 49.4, 33.9, 27.1, 26.0, 25.7, 20.3, 17.9, -4.5, -5.6; FAB hrms Calcd. for $C_{36}H_{45}NO_6SiCs$ (M + Cs)$^+$: 748.2071. Found m/z 748.2051.

Phenyl 8-[2,2-Dimethyl-1-(oxopropoxy)methyl]-6-ethynyl-10a-formyl-5,6,6a,7,10,10a-hexahydro-10-hydroxy-7-phenanthridinyl-5-carboxylate (**41a**) and (**41b**).

Compounds **41a** and **41b** were prepared by desilylation as described above for **27** and were purified by flash column chromatography (silica, ethyl acetate:hexanes 3:7) (95% total yield) as white foams; **41a** (less polar diastereoisomer): R_f = 0.44 (silica, ethyl acetate:hexanes 3:7); ir (thin film): ν_{max} 3486, 2972, 2930, 1726, 1493, 1455, 1380, 1331, 1201, 1160, 1034, 755 cm^{-1}; ^1H nmr (500 MHz, deuteriochloroform): δ 9.60 (s, 1 H, C*H*O), 7.80 (dd, J = 8.1, 0.8 Hz, 1 H, Ph), 7.40-7.33 (m, 3 H, Ph), 7.22-7.14 (m, 4 H, Ph), 7.04 (dd, J = 7.8, 1.4 Hz, 1 H, Ph), 5.96 (d, J = 4.4 Hz, 1 H, C=C*H*), 5.00 (dd, J = 9.7, 2.1 Hz, 1 H, NC*H*), 4.82 (d, J = 4.4 Hz, 1 H, C*H*OH), 4.65 (d, J = 13.2 Hz, 1 H, CCH_2O), 4.50 (d, J = 13.1 Hz, 1 H, CCH_2O), 2.71 (q, J = 7.5 Hz, 1 H, C*H*CH_3), 2.65 (d, J = 9.7 Hz, 1 H, CHC*H*CH), 2.35 (d, J = 2.1 Hz, 1 H, CC*H*), 1.19 (s, 9 H, COC(CH_3)$_3$), 1.18 (d, J = 7.5 Hz, 3 H, CHCH_3); ^{13}C nmr (125 MHz, deuteriochloroform): δ 200.0, 178.1, 153.3, 150.9, 137.2, 129.5, 129.4, 129.3, 128.6, 127.3, 127.0, 126.1, 126.0, 125.8, 125.7, 125.0, 121.6, 83.6, 71.2, 65.8, 65.3, 56.4, 49.7, 33.4, 27.1, 19.4; FAB hrms Calcd. for $C_{30}H_{31}NO_6Cs$ (M + Cs)$^+$: 634.1206. Found m/z 634.1179.

41b (more polar diastereoisomer): R_f = 0.40 (silica, ethyl acetate:hexanes 3:7); ir (thin film): ν_{max} 3496, 3289, 2974, 1727, 1492, 1382, 1330, 1283, 1201, 1161, 1031, 911 cm^{-1}; ^1H nmr (500 MHz, deuteriochloroform): δ 9.79 (d, J = 2.0 Hz, 1 H, C*H*O), 7.84 (d, J = 8.2 Hz, 1 H, Ph), 7.41-7.36 (m, 3 H, Ph), 7.26-7.18 (m, 4 H, Ph), 7.03 (dd, J = 7.7, 1.4 Hz, 1 H, Ph), 6.04-6.02 (m, 1 H, C=C*H*), 4.85 (dd, J = 9.4, 2.2 Hz, 1 H, NC*H*), 4.64 (d, J = 13.4 Hz, 1 H, CCH_2O), 4.49 (d, J = 13.0 Hz, 1 H, CCH_2O), 4.49 (br s, 1 H, C*H*OH), 2.75 (dd, J = 9.4, 1.8 Hz, 1 H, CHC*H*CH), 2.55-2.51 (m, 1 H, C*H*CH_3), 2.37 (d, J = 2.2 Hz, 1 H, CC*H*), 1.25 (d, J = 7.0 Hz, 3 H, CHCH_3), 1.20 (s, 9 H, COC(CH_3)$_3$); ^{13}C nmr (125 MHz, deuteriochloroform): δ 203.1, 178.0, 152.3, 150.7, 137.1, 134.7, 132.1, 129.4, 129.3, 128.5, 128.0, 127.6, 127.3, 126.2, 126.1, 125.9, 125.2, 121.5, 82.5, 71.8, 67.9, 65.1, 54.9, 49.2, 48.6, 33.4, 27.2, 19.0; FAB hrms Calcd. for $C_{30}H_{31}NO_6Cs$ (M + Cs)$^+$: 634.1206. Found m/z 634.1227.

Phenyl 8-[2,2-Dimethyl-1-(oxopropoxy)methyl]-6-ethynyl-10a-formyl-5,6,6a,7,10,10a-hexahydro-10-oxo-7-phenanthridinyl-5-carboxylate (**42**).

Compound **42** was prepared using Dess-Martin periodinane as described for **28** and was purified by flash column chromatography (silica, ether:hexanes 1:1) (96%) as a white foam; **42**: R_f = 0.60 (silica, ether:hexanes 6:4); ir (thin film): ν_{max} 3284, 2975, 2933, 1731, 1660, 1594, 1491, 1456, 1378, 1327, 1199, 1163, 1147, 1034 cm^{-1}; ^1H nmr (500 MHz, deuteriochloroform): δ 9.94 (s, 1 H, C*H*O), 7.94 (br d, J = 8 Hz, 1 H, Ph), 7.80 (dd, J = 8.0, 1.4 Hz, 1 H, Ph), 7.44-7.16 (m, 7 H, Ph), 6.05 (d, J = 1.8 Hz, 1 H, C=C*H*), 5.79 (t, J = 2.8 Hz, 1 H, NC*H*), 4.80 (d, J = 16.5 Hz, 1 H, CCH_2O), 4.62 (d, J = 16.5 Hz, 1 H, CCH_2O), 3.45 (dd, J = 8.8, 3.3 Hz, 1 H, CHC*H*CH), 2.65-2.61 (m, 1 H, C*H*CH_3), 2.29 (d, J = 2.4 Hz, 1 H, CC*H*), 1.46 (d, J = 7.0 Hz, 3 H, CHCH_3), 1.20 (s, 9 H, COC(CH_3)$_3$); ^{13}C nmr (125 MHz, deuteriochloroform): δ 200.4, 195.0, 177.5, 159.8, 150.5, 134.8, 129.6, 129.3, 128.9, 128.2, 126.2, 125.6, 124.8, 123.1, 121.6, 121.4, 80.5, 76.4, 63.5, 46.6, 45.7, 31.8, 27.2, 27.1, 17.8; FAB hrms Calcd. for $C_{30}H_{29}NO_6Cs$ (M + Cs)$^+$: 632.1049. Found m/z 632.1022.

Phenyl 8-[2,2-dimethyl-1-(oxopropoxy)methyl]-5,6,6a,7,10,10a-hexahydro-10-hydroxy-7-methyl-11-oxo-6,10a-propenophenanthridine-5-carboxylate (**43**).

To a solution of a mixture of alcohols **41ab** (0.250 g, 0.498 mmole) in acetonitrile (5 ml) was added $Rh(PPh_3)_3Cl$ (Wilkinsons catalyst) (0.461 g, 0.498 mmole) and the reaction mixture was allowed to stir at 25° for 2 hours. The now orange suspension was concentrated *in vacuo* and the residue was

purified by flash column chromatography (silica, ethyl acetate:hexanes 6:4) to give 0.098 g (78%, based on 50% conversion) of **43** as a white foam and 0.119 g of unreacted starting material **41** (one diastereoisomer only); **43**: R_f = 0.88 (silica, ethyl acetate:hexanes 6:4); ir (thin film): ν_{max} 3494, 2974, 2930, 2873, 1730, 1690, 1486, 1456, 1373, 1325, 1283, 1263, 1196, 1158, 1069, 1026, 989 cm^{-1}; ^1H nmr (500 MHz, deuteriochloroform): δ 8.22 (dd, J = 8.8, 0.8 Hz, 1 H, Ph), 7.43-7.38 (m, 2 H, Ph), 7.27-7.27 (m, 4 H, Ph), 7.11 (dd, J = 7.9, 1.4 Hz, 1H, Ph), 7.05 (dt, J = 7.9, 1.0 Hz, 1 H, Ph), 6.95 (d, J = 9.9 Hz, 1 H, CH=C*H*CO), 6.19 (dd, J = 9.9, 0.9 Hz, 1 H, C*H*=CHCO), 6.06 (d, J = 4.9 Hz, 1 H, NC*H*), 5.23 (s, 1 H, C=C*H*), 4.95 (d, J = 5.5 Hz, 1 H, C*H*OH), 4.47 (d, J = 13.2 Hz, 1 H, CCH_2O), 4.38 (d, J = 13.1 Hz, 1 H, CCH_2O), 2.60 (dd, J = 10.2, 2.1 Hz, 1 H, CHC*H*CH), 1.91-1.85 (m, 1 H, C*H*CH_3), 1.20 (d, J = 7.0 Hz, 3 H, CHCH_3), 1.04 (s, 9 H, COC(CH_3)$_3$); ^{13}C nmr (125 MHz, deuteriochloroform): δ 194.3, 177.2, 154.4, 150.6, 141.1, 135.8, 129.5, 129.4, 127.9, 126.8, 126.6, 126.0, 124.8, 124.2, 123.8, 122.4, 121.8, 65.8, 64.9, 58.6, 42.3, 38.9, 31.2, 29.7, 27.1, 15.4; FAB hrms Calcd. for $C_{30}H_{31}NO_6Cs$ (M + Cs)$^+$: 634.1203. Found m/z 634.1233.

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