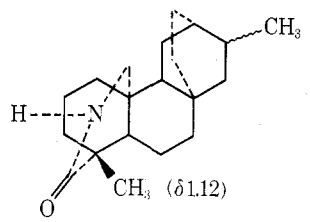
through a study of their ^1H NMR spectra (Table I). The absorption at δ 2.13 in these alkaloids in comparison with that of compounds **3–6** is assigned to the *N*-methyl group in the B unit of the molecule. This result establishes the presence of a lactam ring in the A unit of the molecule. These data also indicate that the exceptionally low field absorptions at δ 2.98 and 2.92 in staphigine and staphirine, respectively, are accommodated by the *N*-methyl group of the lactam ring. The downfield methyl singlet at δ 1.12 is also in perfect agreement with the value for the methyl singlet of the atisine lactam derivative **7**.[5]



7

The comparison of carbon-13 chemical shifts of these two new staphisine-type bisditerpene alkaloids was made with known alkaloids **3–6** to establish the presence of a lactam ring and their complete structures **1** and **2** (Table II). Assignment of the resonances to individual carbon atoms was achieved by using conventional techniques, chemical shift theory, and direct analysis of nonprotonated carbon centers.[6]

The pattern of carbon-13 chemical shifts in these new alkaloids is very similar to that of the known alkaloids **3–6.** The chemical shifts of C-4′, C-5′, C-8′, C-9′, C-10′, C-11′, C-15′, C-16′, C-19′, C-20′, and N-CH_3′ carbons in staphigine and staphirine are similar to those of compounds **3–6,** suggesting that the B unit is staphigine and staphirine is identical with that in compounds **3–6.**

The presence of the carbonyl group (singlets at 175.1 and 175.0 ppm),[7] and the lack of the *N*-methylene carbon resonance at 60.7 and 60.4 ppm in staphigine and staphirine when compared to **3** and **4**, indicate that the carbonyl carbon is present as a part of the lactam moiety in staphigine and staphirine. The downfield shifts (10.4 and 10.5 ppm) of the C-4 carbon and the upfield shift (1.5 ppm) of the C-20 carbon in **1** and **2** relative to **3** and **4**, respectively, are due to the presence of the lactam ring in the A unit. The lactam moiety in unit A was also confirmed on the basis of an *N*-methyl singlet at δ 2.13 in the ^1H NMR spectrum and the constant carbon-13 chemical shifts shown by C-19′, C-20′, and N-CH_3′ carbons of staphigine and staphirine in comparison with the known alkaloids **3–6** (Tables I and II). Based on the arguments presented here, we assign structures **1** and **2** for staphigine and staphirine, respectively.[8]

Staphigine and staphirine occur in extremely small amounts in the seeds of *D. staphisagria* in comparison with staphisine (**3**) and staphidine (**4**). These lactam alkaloids do not appear to be artifacts which arise by oxidation of compounds **3** and **4**, respectively, during isolation. All of these alkaloids (**1–6**) are closely related in structure and occur as methoxyl and demethoxyl pairs in *D. staphisagria.*

Experimental Section

Carbon-13 spectra were determined at 25.03 MHz in the Fourier mode using a JEOL-PFT-100 spectrometer in conjunction with an EC-100-20K memory computer. The spectrometer features a deuterium lock system, a JNM-SD-HC random noise (2500 Hz bandwidth) proton decoupler, and JNM-DP-1 digital pulse programmer. Spectra of the compounds were determined in deuteriochloroform solutions (which also provided the lock signal) with 5% Me_4Si added as internal reference. All samples were contained in precision ground 10-mm o.d. tubes. The spectrometer was used in the crosscoil configuration. On the average, a 12-μs pulse, corresponding to an approximate tilt angle of 45°, was employed. For the average spectral width of 5000 Hz the delay between pulses was 3 s. Acquisition times averaged 2–8 over 8K data points for concentrations of the order of 0.1–0.5 M. For of-resonance spectra this time was 8–32 h.

Acknowledgment. We thank Mr. Courtney Pape for providing the carbon-13 NMR spectra needed for this investigation. We acknowledge with pleasure a National Science Foundation matching grant to the department for purchase of the ^{13}C NMR spectrometer. We are grateful to the late Dr. Lyman C. Craig and to Dr. William C. Agosta of the Rockefeller University for generous supplies of the mother liquors of *D. staphisagria.*

Registry No.—**1,** 59588-13-5; **2,** 59588-14-6; **3,** 36575-56-4; **4,** 59588-15-7; **5,** 59588-19-1; **6,** 59588-18-0.

References and Notes

(1) S. W. Pelletier, A. H. Kapadi, L. H. Wright, S. W. Page, and M. Gary Newton, *J. Am. Chem. Soc.*, **94,** 1754 (1972).
(2) W. A. Jacobs and L. C. Craig, *J. Biol. Chem.*, **141,** 67 (1941).
(3) S. W. Pelletier, N. V. Mody, Z. Djarmati, I. V. Mićović, and J. K. Thakkar, *Tetrahedron Lett.*, 1055 (1976).
(4) Elemental analyses for C, H, and N showed satisfactory agreement with the stated empirical formulas. The melting points are corrected and were taken on a hot-stage microscope equipped with a polarizer.
(5) S. W. Pelletier and T. N. Oeltmann, *Tetrahedron*, **24,** 2019 (1968).
(6) E. Wenkert, A. O. Clouse, D. W. Cochran, and D. Doddrell, *J. Am. Chem. Soc.*, **91,** 6879 (1969).
(7) The carbonyl resonances of amides were found in the region between 160 and 180 ppm. See G. C. Levy and G. L. Nelson in "Carbon-13 Nuclear Magnetic Resonance for Organic Chemists", Wiley-Interscience, New York, N.Y., 1972, Chapter 5, p 120.
(8) We were unable to carry out any transformation of compounds **1** and **2** to **3** and **4**, respectively, owing to the unstability of **1** and **2** toward various reagents (e.g., $LiAlH_4$, $NaBH_4$, etc.).

2*H*-Benzo[*b*]thiete 1,1-Dioxide

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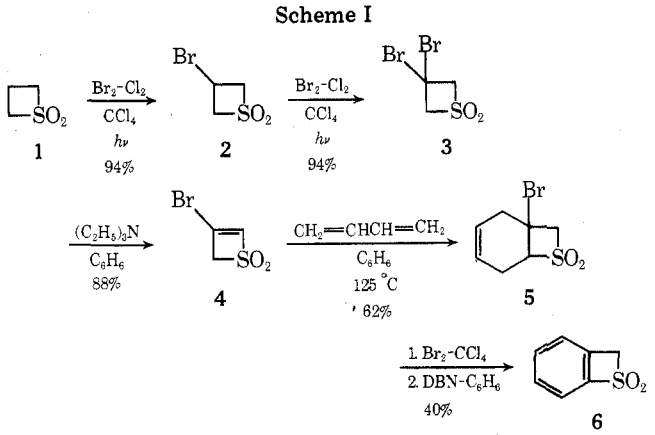
In 1967 the synthesis of 2*H*-benzo[*b*]thiete 1,1-dioxide (benzothiete sulfone) was reported in very low yield from 7-thiabicyclo[4.2.0]-1(6)-octene 7,7-dioxide.[1] Recently, the method described in our earlier report has been improved to provide benzothiete sulfone in a higher overall yield.[2] This report describes a different synthesis of the sulfone (in still higher yield) and some of its chemical properties. Scheme I illustrates this new synthesis.

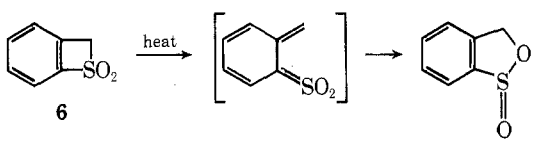
Scheme I



The yields in the bromination steps are generally good if a correction is made for the recovery of unreacted sulfone. Attempts to obtain the dibromide in one step were not successful. The bromination may involve chlorine bromide, and the selective halogenation of the 3 position may be a consequence of hydrogen atom abstraction by a chlorine atom produced by homolysis of chlorine bromide.[3] The abstraction of hydrogen atoms by chlorine atoms is influenced in other cases by electronic effects, hydrogen-atom abstraction occurring mainly at a site remote from an electron-withdrawing substituent.[4] A steric effect of the oxygen atoms of the sulfone group also could cause halogen atoms to attack the more remote 3 position. Bromination of diethyl sulfone with chlorine bromide gave the β-bromo derivative.[5] However, bromination of tetrahydrothiophene 1,1-dioxide by chlorine bromide is reported to yield the 2-bromosulfone although chlorination yields the 3-chlorosulfone.[6] Some chloride is produced as a by-product of the bromination, but its presence does not affect the synthesis of benzothiete sulfone. We have tried preformed chlorine bromide in the halogenation, but its use gave no better yield of the 3-bromosulfone, **2**.

The remaining steps are straightforward and require no comment except that the tribromide obtained from **5** is unstable and should be dehydrohalogenated at once.[7]

Thermolysis of benzothiete sulfone, either neat or dissolved in benzene, gave the sultine, 3*H*-2,1-benzoxathiole 1-oxide, in good yield. This sultine also has been obtained by thermolysis of 2*H*-1,2,3-benzothiadiazine 1,1-dioxide at 500 °C (1 mm), possibly via a vinyl sulfene intermediate.[8] Attempts to trap a vinyl sulfene intermediate with *N*-phenylmaleimide or maleic anhydride were unsuccessful, although *N*-phenylmaleimide was used to successfully trap an α,β-unsaturated thioketone intermediate in the photolysis of a thiolactone.[9] Thermolysis of a naphthothiete sulfone[10] or of thiete sulfone itself[11] yields cyclic sulfinate esters or sultines.[12] Possible intermediates are vinyl sulfenes. Vinyl sulfene, a presumed intermediate in the thermolysis of thiete sulfone, has been trapped by reaction with phenol[11] and by reaction with the strained, olefinic bond of norbornene.[13] Perhaps a more electron-rich dienophile would react better with the vinyl sulfene. A benzothiazete sulfone apparently decomposes via a nitrogen analogue of vinyl sulfene.[14]



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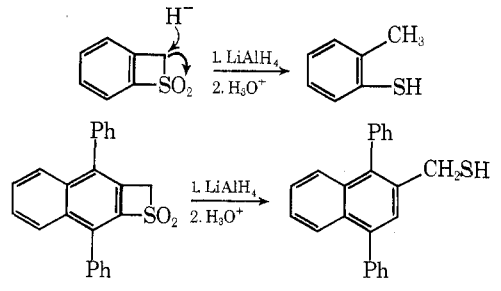
Reduction of benzothiete sulfone with lithium aluminum hydride gives *o*-toluenethiol. This result is surprising in view



7

of the course of reduction of the naphthothiete sulfone, **7**, which yields a benzyl mercaptan.[15] Thiete sulfone, itself, is reduced to propanethiol.[16] Hydride attack at the methylene group in **7** may be hindered by the neighboring phenyl ring so that attack on the sulfone group occurs with cleavage of the aryl–sulfonyl bond. Cathodic cleavage of benzothiete sulfone also occurs principally at the aryl–sulfonyl bond and only to a minor extent between the sulfonyl group and the methylene group.[2]

Experimental Section[17]

3-Bromothietane 1,1-Dioxide (2). Thietane 1,1-dioxide[18] (1, 7.4 g, 70 mmol) was dissolved in 75 ml of warm carbon tetrachloride. The solution was brought to reflux and irradiated with a 250-W sun lamp. Bromine (6.4 g, 40 mmol) in 50 ml of carbon tetrachloride and chlorine (3.6 g, 50 mmol) in 100 ml of carbon tetrachloride were added dropwise and simultaneously to the stirring solution.[19] 3-Bromothietane 1,1-dioxide (12.2 g, 66 mmol, 94%) was removed by filtration: mp 153–155 °C (sealed capillary);[20] ir (KBr) 1300 (s), 1210 cm^{-1} (s); NMR (Me_2SO-d_6) δ 4.1–5.0 (complex m). Anal. Calcd for $C_3H_5BrO_2S$: C, 19.46; H, 2.70. Found: C, 19.70, H 3.02.

3,3-Dibromothietane 1,1-Dioxide (3). 3-Bromothietane 1,1-dioxide (9.2 g, 50 mmol) was dissolved in 250 ml of hot carbon tetrachloride and brominated as described above with a mixture of bromine (8.0 g, 50 mmol) and chlorine (3.6 g, 50 mmol). After the reaction mixture was cooled, 3,3-dibromothietane 1,1-dioxide was removed by filtration (12.4 g, 4.7 mmol, 94%): mp 165–166 °C (sublimes); ir (KBr) 1310 (s), 1210 (s), 1130 cm^{-1} (s); NMR (Me_2SO-d_6) δ 5.5 (s). An analytically pure sample, free of what is thought to be the bromo chloro compound, was obtained after three recrystallizations from carbon tetrachloride. Anal. Calcd for $C_3H_4Br_2O_2S$: C, 13.64; H, 1.52; S, 12.12. Found: C, 13.8; H, 1.41; S, 11.83.

3-Bromothiete 1,1-Dioxide (4). 3,3-Dibromothietane 1,1-dioxide (7.8 g, 29.5 mmol) was dissolved in warm benzene. To this was added triethylamine (5 ml) and the mixture was stirred for 2 h at 50 °C. The amine salt was removed by filtration and the solvent was removed in vacuo. The off-white solid residue was recrystallized from chloroform–hexane to give 3-bromothiete 1,1-dioxide (4.8 g, 26 mmol, 88%): mp 139–141 °C; ir (KBr) 1540 (s), 1310 (s), 1210 (s), 1120 cm^{-1} (s); NMR ($CDCl_3$) δ 7.05 (s, 1 H) 4.76 (s, 2 H). An analytically pure sample, free of what is thought to be the chloro compound, was obtained by five recrystallizations from chloroform–hexane. Anal. Calcd for $C_3H_3BrO_2S$: C, 19.67; H, 1.64; S, 17.49. Found: C, 19.43; H, 1.68; S, 17.80.

1-Bromo-7-thiabicyclo[4.2.0]-3-octene 7,7-Dioxide (5). 3-Bromothiete 1,1-dioxide (1.83 g, 10 mmol) was placed in a Carius tube, and butadiene (3 ml) was distilled into the tube. Benzene (5 ml) and hydroquinone (50 mg) were added and the tube sealed under vacuum at −196 °C. The tube was heated for 72 h at 125 °C and opened. The solvent was removed and the residue digested with methanol (50 ml). The methanol was removed in vacuo and the residue was recrystallized from chloroform–hexane to give the adduct (1.475 g, 6.2 mmol, 62%): mp 88–92 °C; ir (KBr) 1525 (w), 1340 (s), 1180 cm^{-1} (s); NMR ($CDCl_3$) δ 6.1 (m, 2 H), 5.0–4.15 (m, 3 H), 3.0–2.5 (m, 4 H); mass spectrum (70 eV) *m/e* 238, 236.

2*H*-Benzo[*b*]thiete 1,1-Dioxide (6). The adduct **5** (1.68 g, 7 mmol) was dissolved in carbon tetrachloride (25 ml). Bromine (1.6 g, 10 mmol) was added. The solution was refluxed for 1 h. The solvent and excess bromine were removed in vacuo. The resulting oil was then dissolved in benzene (50 ml) and 1,5-diazabicyclo[4.3.0]nonene (2.65 g, 21 mmol) was added. This mixture was refluxed for 1 h. The solution was washed twice with 10 ml of 10% HCl and dried over magnesium sulfate. The residue after removal of solvent was submitted to dry column chromatography (silica gel, chloroform eluent) and benzothiete 1,1-dioxide (0.44 g, 2.9 mmol, 41%) was obtained: mp 126–128 °C (lit.[1] mp 126–128 °C); ir 1300 (s), 1195 (s), 1120 (s), 720 (s), 710 cm^{-1} (s); NMR ($CDCl_3$) δ 7.55 (s, 4 H), 5.10 (s, 2 H). Admixture with an authentic sample[1] gave no melting point depression.

Thermolysis of Benzothiete 1,1-Dioxide in Solution. Benzothiete 1,1-dioxide (51 mg, 3 mmol) was dissolved in benzene (1 ml) and placed in a Carius tube. The tube was sealed under vacuum at −78 °C and then heated (sand bath) to 280 °C for 0.5 h. The tube was cooled and opened. The contents were rinsed into a flask with benzene and the solvent removed in vacuo. The residue was submitted to dry column chromatography (silica gel, chloroform eluent). Starting material (20 mg, 0.12 mmol, 40%) was recovered and 3*H*-2,1-benzoxathiole 1-oxide (20 mg 0.12 mmol, 40%) was also obtained as an oil which slowly crystallized on standing: mp 38–40 °C (lit.[21] mp 40–41 °C); ir (film) 1305 (m), 1120 (s), 945 cm^{-1} (s); NMR ($CDCl_3$) δ 7.8–7.4 (m, 4 H), 5.40, 5.76 (AB quartet, J = 13.5 Hz, 2 H).

Thermolysis of Benzothiete 1,1-Dioxide Neat. Benzothiete 1,1-dioxide (154 mg, 1 mmol) was placed in a test tube and heated to

210° (sand bath) under nitrogen for 2 h. At the end of this time an oil was observed above the sand level. The tube was cut below this level and the oil was washed into a flask with chloroform which was removed in vacuo leaving 3*H*-2,1-benzoxathiole 1-oxide (138 mg, 0.9 mmol, 90%) whose properties were identical with those reported above.

Reduction of Benzothiete 1,1-Dioxide with Lithium Aluminum Hydride. Benzothiete 1,1-dioxide (154 mg, 1 mmol) was dissolved in 10 ml of dry tetrahydrofuran (THF). This solution was added dropwise to a stirred suspension of lithium aluminum hydride (156 mg, 4 mmol) in THF (5 ml) at 0 °C. The mixture was quenched with H_2O (0.2 ml) and 3 N NaOH (0.2 ml). To this was added 3 N NaOH (3 ml) and diethyl ether (25 ml). The solid was removed by filtration and the layers were separated. The aqueous layer and solid were acidified with 10% hydrochloric acid and extracted twice with 10 ml of chloroform. The extracts were dried and the solvent removed in vacuo. The residue was submitted to dry column chromatography (silica gel, chloroform eluent). *o*-Toluenethiol (70 mg, 0.56 mmol, 56%) was obtained as a pale yellow oil: ir (film) 2600 (w), 1460 (s), 745 cm^{-1} (s); NMR ($CDCl_3$) δ 7.08 (m, 4 H), 3.32 (s, 1 H), 2.25 (s, 3 H). The ir and NMR spectra were identical with those reported for an authentic sample of *o*-toluenethiol.[22]

Acknowledgment. The authors are grateful to the National Cancer Institute (Grant CA 08250) for support of this work.

Registry No.—**1**, 5687-92-3; **2**, 59463-72-8; **3**, 59463-73-9; **4**, 59463-74-0; **5**, 59463-75-1; **6**, 16065-50-2; butadiene, 106-99-0; 3*H*-2,1-benzoxathiole 1-oxide, 31910-65-3; *o*-toluenethiol, 137-06-4.

References and Notes

(1) D. C. Dittmer and F. A. Davis, *J. Org. Chem.*, **32**, 3872 (1967).
(2) B. Lamm and J. Simonet, *Acta. Chem. Scand., Ser. B*, **28**, 147 (1974).
(3) The free-radical chain reaction may be propagated by attack of the 3-thietanyl 1,1-dioxide radical on the bromine atom of chlorine bromide: C. Walling, "Free Radicals in Solution", Wiley, New York, N.Y., 1957, p 379.
(4) W. A. Pryor, "Introduction to Free Radical Chemistry", Prentice-Hall, Englewood Cliffs, N.J., 1966, p 56.
(5) V. I. Dronov and V. A. Snegotskaya, *J. Org. Chem. USSR (Engl. Transl.)*, **6**, 2038 (1970).
(6) V. I. Dronov and V. A. Snegotskaya, *Khim. Seraorg. Soedin., Soderzh. Nefyakh. Nefteprod.*, **8**, 133, (1968); *Chem. Abstr.*, **71**, 81066 (1969).
(7) We are indebted to Mr. Barry Van Gemert and Professor William E. Truce for checking the synthesis. They report that it is a viable scheme, although somewhat lower yields were obtained in several steps. They suggest using a larger excess of butadiene than we did.
(8) J. F. King, B. L. Huston, A. Hawson, J. Komery, D. M. Deaken, and D. R. K. Harding, *Can. J. Chem.*, **49**, 936 (1971).
(9) G. Jacqmin, J. Nasielski, G. Billy, and M. Remy, *Tetrahedron Lett.*, 3655 (1973).
(10) D. C. Dittmer, R. S. Henion, and N. Takashina, *J. Org. Chem.*, **34**, 1310 (1969).
(11) J. F. King, P. de Mayo, C. L. McIntosh, K. Piers, and D. J. H. Smith, *Can. J. Chem.*, **48**, 3704 (1970).
(12) R. S. Henion, "Eastman Organic Chemical Bulletin", Vol. 41, No. 3, 1969.
(13) D. C. Dittmer, J. E. Babiarz, and J. E. McCaskie, Abstracts of Papers, First Chemical Congress of the North American Continent, Mexico City, 1975, No. ORGA 110.
(14) M. A. Ao and E. M. Burgess, *J. Am. Chem. Soc.*, **93**, 5298 (1971).
(15) D. C. Dittmer and N. Takashina, *Tetrahedron Lett.*, 3809 (1964); L. A. Paquette, *J. Org. Chem.*, **30**, 629 (1965).
(16) D. C. Dittmer and M. E. Christy, *J. Am. Chem. Soc.*, **84**, 399 (1962).
(17) Infrared spectra were recorded on a Perkin-Elmer 137 spectrophotometer. Proton magnetic resonance spectra were recorded on a Varian Associates A-60 spectrometer and mass spectra were obtained on a Hitachi-Perkin Elmer RMU 6E spectrometer. Melting points are uncorrected.
(18) E. Grishkevich-Trokhimovskii, *J. Russ. Phys.-Chem. Soc.*, **48**, 880 (1916); *Chem. Zentralbl.*, **94**, 773 (1923). It is recommended that a tungstate catalyst be used in the oxidation of thietane by hydrogen peroxide: H. L. Schultz, H. B. Freyermuth, and S. R. Buck, *J. Org. Chem.*, **28**, 1140 (1963).
(19) Instead of adding a solution of chlorine, one may add the gas via a gas bubbler tube. The rate of bromine and chlorine addition is adjusted so that the color of the solution remains a light red-orange throughout the addition.
(20) Another crystalline form of the bromide with an observed melting point of 135–136 °C has been obtained by sublimation.
(21) J. F. King, A. Hawson, B. L. Huston, L. J. Danks, and J. Komery, *Can. J. Chem.*, **49**, 943 (1971).
(22) "Sadtler Standard Spectra. Infrared", Vol. 21, Midget ed, The Sadtler Research Laboratories, Philadelphia, Pa., No. 21 700; "Sadtler Standard Spectra. Nuclear Magnetic Resonance", The Sadtler Research Laboratories, Philadelphia, Pa., No. 9803.

A Thiophene Analogue of 7,12-Dihydropleiadene

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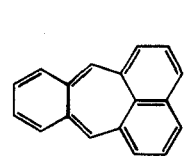
Replacement of the benzene ring in pleiadene (**1**) by a *b*-fused thiophene ring gives rise to the analogue naphtho[1,2-*b*]thiophene[1] (**2a**) as shown. Pleiadene itself has been gener-



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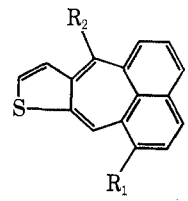
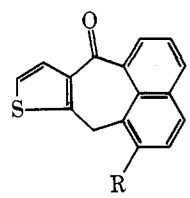
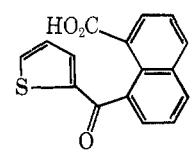


2a, $R_1 = R_2 = H$
b, $R_1 = OCH_3$; $R_2 = OCOCH_3$
c, $R_1 = OCH_3$; $R_2 = OK$



3a, R = H
b, $R = OCH_3$



4

ated in solution by Cava and co-workers[2] and has been shown to undergo an addition reaction with *N*-phenylmaleimide and also to dimerize. The present work reports an attempt to ascertain if any quinodimethane character can be detected in a keto analogue of **2**, viz., **3b**. Attempts to utilize 8-(2-thenoyl)-1-naphthoic acid (**4**) (as a precursor for **3a**) were abandoned owing to difficulty in reducing the ketone group and the scheme outlined below was followed.

Reaction of 2-methoxy-1-naphthaldehyde with 3-bromo-2-thienyllithium at −70 °C afforded 1-(2-methoxynaphthyl)-3′-bromo-2-thienylmethanol (**5**) in 62% yield. Reduction of the alcohol function by means of lithium aluminum hydride–aluminum chloride[3] gave 1-(3′-bromo-2′-thenyl)-2-methoxynaphthalene (**6**) in 52% yield. The bromo derivative **6** was converted to the corresponding carboxylic acid **7** in 91% yield by treatment with *n*-butyllithium at −70 °C followed by carbonation. Cyclization of the resulting 1-(3′-carboxy-2′-thenyl)-2-methoxynaphthalene (**7**) by means of phosphorus pentachloride followed by stannic chloride gave the cyclic ketone 6-methoxynaphtho[1′,8′:4,5,6]cyclohepta[1,2-*b*]thiophen-11(7*H*)-one (**3b**) in 68% yield.

An attempt to form the pleiadene analogue 11-acetoxy-6-methoxynaphtho[1′,8′:4,5,6]cyclohepta[1,2-*b*]thiophene (**2b**) by treatment of the acid **7** with acetic anhydride and zinc chloride under conditions where acetoxyanthracenes were produced[4] afforded a product whose spectra and elemental analysis indicated it to be 2-(?)-acetylmethoxynaphtho-[1′,8′:4,5,6]cyclohepta[1,2-*b*]thiophen-11(7*H*)-one (**8**), together with unreacted starting material. When the above reaction was carried out in the presence of *N*-phenylmaleimide in an attempt to trap **2b**, only unchanged starting material was recovered.

An attempt was made to ascertain whether base-catalyzed enolization of **3b** could be induced by treatment of the ketone with freshly sublimed potassium *tert*-butoxide.[6] Upon mixing these reagents in THF solution no change in color was observed. Quenching of the mixture with deuterium oxide re-