$C(CH_3)_3$], 1.64 (s, 6, CH_3); IR (CCl_4) 2956 (s), 2919 (s), 1477 (m), 1444 (m), 1394 (m), 1363 (m), 1192 (m), 1141 (m), 1073 (m); MS *m/e* 168 (M^+), 111, 97, 84, 69, 57, 41 (base).

(*E*)-2,2,3,4,5,5-Hexamethyl-3-hexene from above showed spectral properties comparable to those already reported.[5]

Pyrolysis. Samples of a solution containing 5 μL of 1, 5 μL of tridecane, and 0.5 mL of tetradecane (prefiltered through a small column of basic alumina) were sealed in washed (1% ammonia water) and dried melting point capillaries. Samples were heated in a stirred, constant-temperature bath filled with silicone oil, heated with a quartz heater, and controlled (cycled, ± 0.4 °C, about an accurately (±0.02 °C) measured temperature) with an Omega 2001 regulator. After pyrolysis, each sample was removed from the bath, immediately quenched in ice water, and analyzed by GLC. Peak areas were determined by triangulation. Integration against tridecane showed the total amount of 1 and 2 remained essentially constant throughout the pyrolysis period. Correction was made for the small impurity by subtracting a constant amount from each area for 1. In order to minimize the significance of this 4.7% correction, data points beyond 90% conversion to 2 were excluded from the analysis.

Data Treatment. Rate constants and Arrhenius parameters were determined by using the least-squares procedure available with Mintab.[12] The Arrhenius parameters were calculated by using a weighted regression that took into consideration the errors in the rate constants.[13] All error limits are statistical standard deviations calculated during the data treatment.

Effect of Free Radical Trap. Varying concentrations, up to a saturated solution, of 3-*tert*-butyl-4-hydroxy-5-methylphenyl sulfide[7b] were added to the reaction solution, and the samples were heated for 40 min at 220 °C. GLC analysis showed no detectable difference in results between the samples.

Reversibility of Isomerization. A sample of 2 containing 98.7% 2 and 1.7% 1 in tetradecane was heated at the highest temperature available, 225 °C, for 90 min. This lead to no further conversion to 1. This result, which was limited by the purity of 2, showed no further formation of 1 from 2. At one extreme they could be at equilibrium. At the other extreme, 1 could be slowly going to 2. This sets a limit on the value of $\Delta G > -3.7$ kcal/mol at 225 °C.

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Registry No. 1, 54429-93-5; 2, 54290-40-3; 3, 75245-22-6; 4, 75245-13-5; 5, 105903-60-4; (*E*)-$(CH_3)_3CCH{=}C(CH_3)_3$, 692-48-8; (*Z*)-$(CH_3)_3CCH{=}CHC(CH_3)_3$, 692-47-7; (*Z*)-$CH_3CH_2{=}CH_2CH_3$, 590-18-1; (*E*)-$CH_3CH_2{=}CH_2CH_3$, 624-64-6; $CH_2{=}CH_2$, 74-85-1; pinacolone, 75-97-8.

(12) Ryan, T. A., Jr.; Joiner, B. L.; Ryan, B. F. *Mintab Student* Handbook; Duxbury: North Scituate, Massachusetts, 1976; pp 148-193.

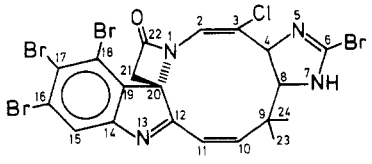
(13) Young, H. D. *Statistical Treatment of Experimental* Data, McGraw: New York, 1962; p 108.

Communications

Chartellamide A and B, Halogenated β-Lactam Indole-Imidazole Alkaloids from the Marine Bryozoan *Chartella papyracea*[1a]

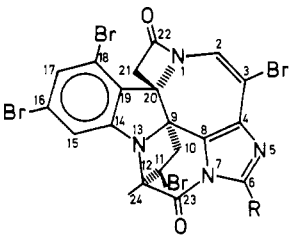
Summary: Two structurally unusual β-lactam indole-imidazole alkaloids have been isolated from the marine bryozoan *Chartella papyracea*.

Sir: Investigations of the marine bryozoan *Chartella papyracea* (Ellis and Solander) (also known as *Flustra papyracea*) have resulted in the identification of unique alkaloids[1a,2] exemplified by (*S*)-chartelline A (1).[3] These



1

alkaloids possess the β-lactam ring and may equally well be classified as indole or imidazole alkaloids. This report deals with the isolation and structure elucidation of two novel alkaloids, chartellamide A (2) and B (3), originating with the same organism.



2 R = H
3 R = Br

The bryozoans collected from Roscoff Marine Biological Station in the autumn of 1985 were lyophilized to give 801 g of dry material. After the material was defatted with petroleum ether, extraction with twice-distilled ethyl acetate gave 5.7 g of soluble material. Cellulose column chromatography served, after elution with hexane, to yield a raw alkaloid mixture (4.1 g) on elution with methylene chloride. Recrystallization of this fraction from methylene chloride gave almost pure chartelline A (1).[1a] Evaporation of the mother liquor followed by silica chromatography (Merck, kiesel gel, ethyl acetate) gave the chartellamides. Preparative HPLC (RP-8 Merck; MeOH/H_2O, 80/20) gave pure chartellamide A (2) (28 mg, 3.5×10^{-3}% of dry weight) and chartellamide B (3) (36 mg, 4.5×10^{-3}% of dry weight).

The elemental compositions were determined from MS (2, calcd for $C_{20}H_{12}N_4{}^{79}Br_4O_2$, 655.76, found 655.81 with

(1) (a) Contribution 13 of the series "Marine Alkaloids". For part 12, see: Anthoni, U.; Chevolot, L.; Larsen, C.; Nielsen, P. H.; Christophersen, C. *J. Org. Chem.* in press. (b) Department of Organic Chemistry, The Technical University of Denmark, DK-2800 Lyngby, Denmark. (c) UA CNRS 322, Université de Bretagne Occidentale, 29287 Brest, France.

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0022-3263/87/1952-5638$01.50/0

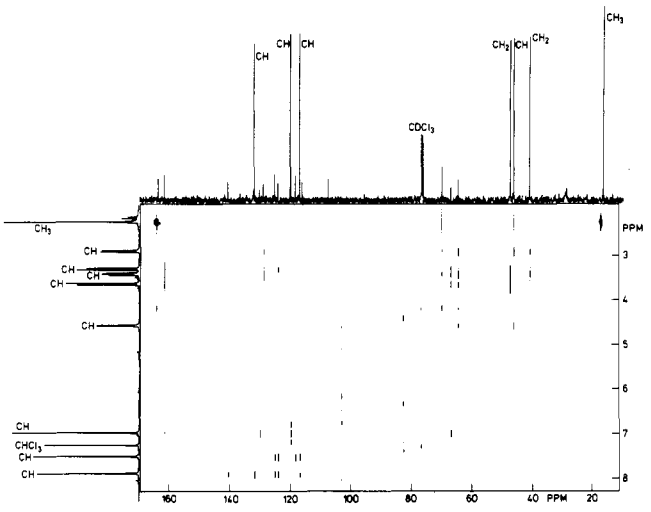

Figure 1. 2D COLOC experiment on chartellamide B (**3**). Due to the small amount of **3** available (33 mg in 700 ±L of $CDCl_3$) the acquisition time was 72 h. The resulting signal to noise ratio gives rise to spurious peaks in the 2D diagram. These peaks were discarded in all cases since they appear in regions which lack either proton signals, carbon signals, or both.

Br_4 isotopic pattern; **3**, calcd for $C_{20}H_{11}N_4{}^{79}Br_5O_2$, 733.67, found 733.63 with Br_5 isotopic pattern). The striking similarity of all spectroscopic data, including identical fragmentation patterns[4] and almost superimposable IR[5] and UV spectra,[6] served to identify **3** as a bromo derivative of **2**.

Both compounds have a β-lactam moiety as evidenced by loss of ketene in the mass spectrum, strong IR aborption around 1780 cm^{-1}, and two doublets in the ^1H NMR spectra at δ 3.63 and 3.33 in **2** and 3.63 and 3.31 (J = 16 Hz) in **3**, respectively. Signals at δ 7.52 (d, J = 1.5 Hz) and 7.91 (d, J = 1.5 Hz), in **3**, assigned to two meta-situated aromatic protons, appear at δ 7.51 and 7.88 in **2**. Furthermore, an ABX system in **2** at δ 2.89 (dd, J = 2.5, 14 Hz), 3.44 (dd, J = 9.5, 14 Hz), and 4.64 (dd, J = 2.5, 9.5 Hz) appear analogously in **3** at δ 2.89 (dd, J = 2.5, 14 Hz), 3.40 (dd, J = 9.5, 14 Hz), and 4.56 (dd, J = 2.5, 9.5 Hz). The proposed coupling patterns were verified by a COSY experiment in the case of **2**. Both alkaloids have a methyl group (δ 2.03 (s) in **2**; δ 2.25 (s) in **3**) and a deshielded proton (δ 7.02 in **2**; δ 6.99 in **3**), while **2** has in addition a strongly deshielded proton at δ 7.66 (s). C,H-Correlation experiments[7] in **2** revealed the identity of the carbon resonances originating from proton-bearing carbons, while the multiplicities of the carbon resonances in **3** were identified by a DEPT sequence. These data alone did not allow the skeletal structure to be unambiguously identified. Therefore **3** was subjected to a 2D COLOC experiment[8] (Figure 1). From the resulting connectivity data[9] the skeleton of **3** could be unambiguously defined with the following assignment of the carbon resonances (in ppm): C2, 120.6; C3, 108.1; C4, 130.8; C6, 116.6; C8, 129.5; C9, 65.2; C10, 41.6; C11, 46.8; C12, 70.5; C14, 141.1; C15, 117.6; C16, 126.0; C17, 132.5; C18, 119.4; C19, 124.7; C20, 67.6; C21, 48.0; C22, 162.1; C23, 164.1; C24, 17.1. The ^{13}C NMR signals of **2** were assigned in analogy with these findings.[10]

Molecular models show that the β-lactam ring and the bromo-substituted pyrrolidine ring are almost perpendicular to the plane defined by the condensed indoline–dihydroazepine–imidazole–piperazinone ring systems. In order to distinguish between the two structural possibilities having either the rings on the same side of the plane (cis) or on opposite side (trans) a NOE difference experiment was performed. Enhancement could not be detected for the C21 proton signals on irradiation at the frequency of the C10 proton signals and vice versa strongly indicating that the two rings are trans with respect to the plane. Other enhancements were as expected from the model of the structure. For example, in **3** irradiation with the frequency corresponding to the signal of the C24 methyl group protons produced enhancements of 5%, 6%, and 3% of the signals originating from the C11, C15, and C17 protons, respectively.

The two alkaloids must have the same absolute configuration since their CD curves are nearly superimposable.[11] From a NOE experiment of **3** (enhancements of 5% for C15-H and 2% for C17-H on irradiation at the frequency corresponding to the signal of C11-H) it was concluded that the proton of C11 faces the protons of C15 and C17. Provided the absolute configuration around C20 is the same as in chartelline A, i.e., *S*, then C9 must be *S*, C11, *R*, and C12 *R*. This assumption is presumably justified since the reaction sequence where the butyrolactam ring closure occurs is undoubtedly enzyme mediated and seems to occur early in the biosynthetic sequence.

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Registry No. 1, 96845-55-5; 2, 111268-63-4; 3, 111268-64-5.

(4) **2**: m/z 660 (M^+), 579 (M^+ – Br), 537 (579 – CH_2CO), 500 (579 – Br), 458 (537 – Br and 500 – CH_2CO), all fragmentation pathways supported by metastable ions. **3**: m/z 740 (M^+), 659 (M^+ – Br), 617 (M^+ – Br – CH_2CO), 580 (M^+ – 2Br).

(5) **2**: IR (KBr) 3100, 2930, 2858, 1782 vs, 1719 vs, 1620, 1586, 1569, 1460, 1450, 1416 s, 1378, 1336, 1290, 1255, 1216, 1169, 1141, 1109, 1072, 1055, 1028, 983, 919, 860, 813, 789, 589 cm^{-1}. **3**: IR (KBr) 3100, 3080, 2928, 2858, 1784 vs, 1720 vs, 1646, 1586, 1570, 1450, 1417 s, 1370, 1330, 1318, 1294, 1254, 1210, 1146, 1111, 1074, 1055, 1031, 985, 919, 861, 810, 786 cm^{-1}.

(6) **2**: UV (EtOH) λ_{max} (log ε) 212 nm (4.28), 230 (4.41), 258 (4.03), 294 (3.76), 303 (3.74), 318 (3.53). **3**: UV (EtOH) λ_{max} (log ε) 213 nm (3.70), 231 (3.81), 260 (3.46), 293 (3.19), 303 (3.15), 318 (2.85).

(7) C,H-Correlation in **2**: δ_H (correlates with δ_C) 2.03 (15.4), 2.89 and 3.44 (41.6), 3.33 and 3.63 (47.8), 4.64 (45.8), 7.50 (132.5), 7.88 (117.6), 702 (120.4), 7.66 (133.2).

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(9) CH_3 (δ_H 2.25, δ_C 17.1) connects with δ_C 46.8 (CH), 70.5 (C), and 164.1 (C); CH (2.89, 41.6) 46.8 (CH), 65.2 (C), 70.5 (C), 129.5 (C); CH (3.40, 41.6) 65.2 (C), 67.6 (C), 70.5 (C), 129.5 (C); CH (4.56, 46.8) 65.2 (C); CH (3.31, 48.0) 67.6 (C), 124.7 (C), 162.1 (C); CH (3.63, 48.0) 65.2 (C), 67.6 (C), 162.1 (C); CH (6.99, 120.6) 67.6 (C), 130.8 (C), 162.1 (C); CH (7.52, 117.6) 119.4 (C), 124.7 (C), 126.0 (C); CH (7.91, 132.5) 117.6 (C), 124.7 (C), 126.0 (C), 141.1 (C).

(10) δ: C2, 120.4; C3, 109.5; C4, 130.5; C6, 133.2; C8, 126.6; C9, 65.9; C10, 41.6; C11, 45.9; C12, 67.9; C14, 141.5; C15, 117.6; C16, 125.9; C17, 132.5; C18, 119.4; C19, 124.8; C20, 67.4; C21, 47.8; C22, 162.5; C23, 164.9; C24, 15.4.

(11) **2**: CD (c 0.055; EtOH) λ_{max} (Δε) 313 nm (7.39, sh), 286 (18.2), 268 (0), 251 (–23.6), 209 (–16.7). **3**: CD (c 0.038; EtOH λ_{max} (Δε) 316 nm (8.5, sh), 300 (22.4, sh), 285 (34.8), 267 (0), 249 (–49.6), 212 (–31.1).

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