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TWO NEW POLYHALOGENATED MONOTERPENES FROM THE RED ALGA *PLOCAMIUM CARTILAGINEUM**

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Key Word Index—*Plocamium cartilagineum;* red alga; marine natural products; polyhalogenated alicyclic monoterpenes.

Abstract—The structures and absolute configurations of two new halogenated alicyclic monoterpenes isolated from the ether extract of the red alga *Plocamium cartilagineum* (Linn) Dixon were determined as: 1*R*,2*S*,4*S*,5*R*-5-chloro-2-*E*-chlorovinyl-1,4-dibromo-1,5-dimethylcyclohexane and 1*S*,2*S*,4*R*,5*S*-2-bromo-1-*E*-bromovinyl-4,5-dichloro-1,5-dimethylcyclohexane, respectively.

INTRODUCTION

Red algae of the genus *Plocamium* have been shown to be a source of polyhalogenated aliphatic [1, 2] and alicyclic [3, 4] monoterpenes. This paper describes two polyhalogenated alicyclic monoterpenes featuring novel halogenation patterns.

RESULTS

For compound **1**, the MS data were compatible with the molecular formula $C_{10}H_{14}Br_2Cl_2$. The presence of two vinyl carbons supported by signals at 131.2 and 120.9 ppm in the CMR spectrum and by a 4-signal pattern at δ 6.1 (2H) in the PMR (90 MHz, $CDCl_3$) spectrum, together with the molecular formula, suggested a monocyclic structure. The remaining signals in the CMR spectrum were 28.0 and 33.6 ppm (*q*); 36.3 and 57.1 ppm (*t*); 53.5 and 57.1 (*d*); 67.4 and 71.1 ppm (s).

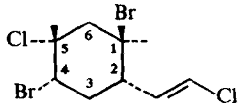
In addition to the vinyl protons the PMR spectrum showed the presence of two Me singlets at δ 1.69 and 1.97; and AB quartet [δ 2.7 and 3.0 (J_{AB} = 16 Hz)] partially overlapping a complex pattern of signals (δ2–3; 3H) assigned to a methylene and to an allylic proton. The methylene protons were coupled to each other and to the allylic proton. The methylene was further coupled to a methine bearing a halogen atom [*dd*, δ 4.01 (J = 4, 12 Hz)]. Double resonance experiments showed that the 4-signal pattern corresponding to the olefinic protons arises from a *trans* AB vinylic system (J_{AB} = 14 Hz) coupled to the allylic proton at δ 2.85. The above structural data are consistent with the structure proposed for **1**.

For compound **2** the MS data are in agreement with the molecular formula $C_{10}H_{14}Br_2Cl_2$. Two vinyl carbons were present, as shown by the signals at 108.0 and 139.4 ppm in the CMR spectrum and the appearance of an AB quartet at δ6.43 and 6.64 ppm (J_{AB} = 16 Hz) in the PMR spectrum.

The remaining signals in the CMR and PMR spectra were in accordance with the structure ascribed to **2**. CMR: 26.1 and 29.8 ppm (*q*); 41.1 and 55.0 ppm (*t*); 56.4 and 66.8 ppm (*d*); 44.8 and 70.5 (*s*). PMR: δ 1.30 and 1.70, two methyl singlets; δ 2.57 and 2.70, an AB quartet (J_{AB} = 12 Hz) partially overlapping the signals (δ 2.1–2.9) corresponding to the methylene protons of a —CH*X*—CH_2—CH*X*— system. The methine protons of this system appear at δ 3.9 [*dd*, (J = 4, 12 Hz)] and 4.2 [*dd*, (J = 4, 12 Hz)].

In order to establish the absolute configuration of **1** and **2** and the relative location of the halogen atoms, *X*-ray diffraction experiments were performed. Compound **1** crystallizes as irregular octahedra in the orthorhombic system, space group $P2_12_12_1$. There are 4 molecules in the cell a = 11.665(6), b = 11.240(2), c = 10.082(1) Å. All independent Friedel-pair reflections for θ = 30° were recorded on an automatic diffractometer with graphite monochromated MoKα radiation. Considerable crystal damage was observed (50 % decay in 10 hr exposure) and consequently 11 crystals were needed during the data collection process (Cu-radiation or crystal isolation in capillary tubes did not prevent decomposition). Of the 2183 independent reflections collected, 902 were accepted as observed [I 20(I)] after correction for Lorentz and polarization effects. No absorption effects were taken into account.

Compound **2** crystallizes as needles in the monoclinic system, space group $P2_1$, with four molecules in a cell,



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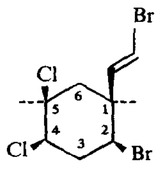

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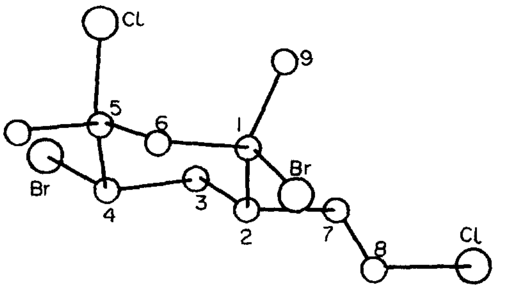
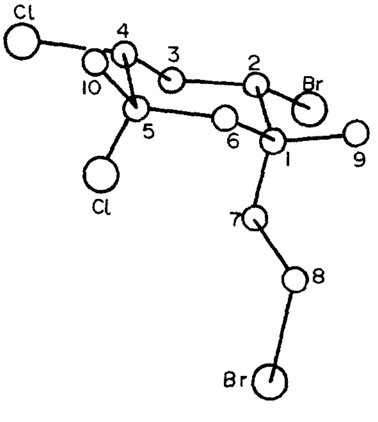
* Part 16 in the series 'Marine Natural Products from the Atlantic Zone'. For Part 15, see González, A. G., Darias, J., Martin, J. D., Díaz, A., Fourneron, J. D. and Pérez, C. (1976) *Tetrahedron Letters* 3051.



dimensions: $a = 12.907(1)$, $b = 8.390(1)$, $c = 12.238(1)$ Å, $\beta = 91.48(1)°$. All independent Friedel-pair reflections for $\theta = 25°$ were measured in the same way as those of compound **1** ($\lambda = 0.7107$ Å). Of the 2504 independent reflections taken, 1834 were considered observed [I 20(I)] after correction for polarization, Lorentz, absorption and crystal damage (18% intensity decay in 52 hr of data collection).

Both structures were solved by the standard heavy atom method and refined using full matrix weighted least squares. The anisotropic temperature factors for Cl and Br atoms were hypothesized [5]. Final agreement factors were 9.2% for **2** and 8.6% for **1**. The absolute configurations for both compounds are shown in **1a** and **2a**. These were determined using the anomalous dispersion effect with more than 99.5% accuracy [6]. For **2** no significant differences were found between both crystallographic independent molecules. The rings of both compounds present a flattened chair conformation, the average torsional angle within the ring being 55(2)° (60° for the theoretical chair). In both compounds the —CH=CH—*X* groups are *trans*, the torsional angle at the double bond being 180 (2)°. The orientation of the above-mentioned groups with regard to the rings is defined by the torsional angles 7-1-8-9 = 32(2)° (**2**) and H(2)-2-8-9(2)°, (**1**). This is the first time that an alicyclic polyhalogenated monoterpene featuring a bromovinyl group has been isolated from a natural source. The compound **1** is a bromine analog of an identical chloro-compound isolated from *Plocamium violaceum* [4].



EXPERIMENTAL

Mps were determined on a Kofler block and are uncorr.

Extraction and isolation of **1** *and* **2**. The plant was collected at Playa de la Victoria, Cadiz (Spain) in June 1976 and was identified as *P. cartilagineum* by Dr J. Seoane, Faculty of Pharmacy, University of Barcelona. The air-dried plant was extracted with Et_2O which was then evapd, leaving a dark residue to be chromatographed over Si gel (0.05–0.2 mm) with petrol and petrol–EtOAc mixtures as eluents. Repeated chromatography of the petrol eluates over Si gel with *n*-hexane as eluent yielded two pure compounds, GLC (UC-W-98 10%-Chromosorb W, 2 m × 1.5 mm). Compound **1** was crystallized from *n*-hexane: mp 121–122°, $[\alpha]_D$ −88° ($CHCl_3$); MS (GC–MS) 15 eV *m/e*, 362, 364, 366. 368 $[M^+]$, 282, 284, 286 $[M^+\text{-Br}]$, 247, 249, 251 $[M^+\text{-(Br, Cl)}]$, 203, 205, 207 $[M^+\text{-2Br}]$, 167 (base peak), 169, 131; TMS as int. stand.; PMR and CMR as described in the text. Compound **2** was crystallized from *n*-hexane: mp 72–73°, $[\alpha]_D$ −18° ($CHCl_3$); MS (GC–MS) 15 eV *m/e*, 362, 364, 366, 368 $[M^+]$, 282, 284, 286 $[M^+\text{-Br}]$, 247, 249, 251 $[M^+\text{-(Br, Cl)}]$, 212, 214 $[M^+\text{-(Br, 2Cl)}]$, 203, 205, 207 $[M^+\text{-(2Br)}]$, 167, 169, 105, 107, 92 (base peak); PMR (90 MHz) CCl_4; TMS as int. stand.; other spectra as described in the text

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REFERENCES

1. Crews, P. and Kho, E. (1974) *J. Org. Chem.* **39**, 3303.
2. Mynderse, J. S. and Faulkner, D. J (1975) *Tetrahedron* **31**, 1963.
3. Crews, P. and Kho, E. (1975) *J. Org. Chem.* **40**, 2568.
4. Mynderse, J. S., Faulkner, D. J., Finer, J. and Clardy, J. (1975) *Tetrahedron Letters* 2175 and references quoted therein.
5. The following crystallographic programmes were consulted: Stewart, J. M., Kundell, F. A. and Baldwin, J. C. (1970) *The X Ray 70 System*. Computer Science Center, University of Maryland; Martínez-Ripolls, M. and Cano, F. H. *Pesos* and Foces-Foces, C., Cano, F. H. and Martínez-Ripolls, M. *Torsión*. Instituto Rocasolano, CSIC, Serrano 117, Madrid, Spain.
6. Hamilton, W. C. (1965) *Acta Crystallogr.* **18**, 502.