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NEW SESQUITERPENES FROM LIVERWORTS AND FROM THE REARRANGEMENT OF β-BAZZANENE

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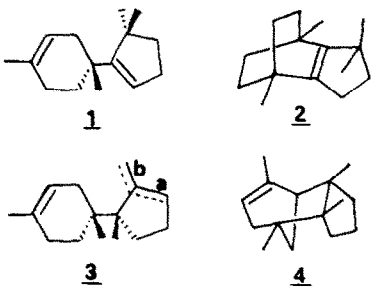
Abstract - By spectral properties and chemical correlation, the structures of two related new sesquiterpenes, isobazzanene and isocyclobazzanene, were proposed to be 1 and 2, respectively.

In this paper, we report on the evidence concerning the structure assignments of two new sesquiterpenes, named isobazzanene (1) and isocyclobazzanene (2), respectively. 2 was one of the five acid rearranged products derived from β-bazzanene (3b),[1,2] and 1 was produced both from liverworts Bazzania sp. and from the rearrangement of 3b. Since their structures were closely related, we decided to report on them together.

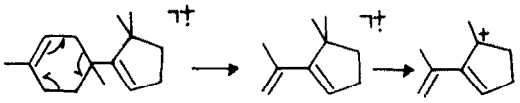


Isobazzanene (1) was present in amounts of ca. 3-7% in the sesquiterpene hydrocarbon fraction of two Bazzania sp. (B. fauriana,[3] and B. angustifolia). Its MS spectrum (M^+, 204) showed strong fragments at m/z (rel. int.) 121 (100) and 136 (50-90), and the rest of the peaks were of very weak intensities. Its PMR data indicated three tertiary methyls (δ 1.08, 1.15 and 1.18), one vinyl methyl (1.63) and two trisubstituted olefinic protons (5.26 and 5.36). The corresponding compound from the acid rearrangement of β-bazzanene (3b) (Table 1) exhibited spectral properties identical to those of the liverwort component. The same experiment on acid treatment of 3b was reported by Andersen et al. in 1977.[2]

In this report a tricyclic structure (4) was proposed for this compound based on the PMR and CD data of an impure (85% purity) sample. The PMR spectrum obtained in the present work was in accordance with the published data except that the signals at δ 5.26 and 5.36 were integrated clearly to two protons instead of that at 5.3-5.45 for one or two protons as described in Andersen's report. Consequently, the previously proposed tricyclic structure 4 for isobazzanene must be revised.

Catalytic hydrogenation of 1 in HOAc produced four tetrahydro isomers. Their MS spectra revealed fragmentation pattern quite similar to that from hydrogenated bazzanenes (Table 2). However, the Kovats' indices[4] of these

four isobazzananes were definitely different from those of the four bazzananes. Based on the above data, a bicyclic structure similar to the bazzanane skeleton was considered feasible for isobazzanene (1). Since this compound was also fourd to be a rearranged product from 3b, structure 1, derived from 3b with a methyl rearrangement, was proposed for isobazzanene. Its major MS fragment of m/z 136 could be explained as arising from a retro-Diels-Alder cleavage of the cyclohexene ring (Scheme 1). Obviously, the formation of a conjugated double bond in species 5 is the main driving force for this cleavage since the same type of cleavage does not occur to any significant degree in cases of α- and β-bazzanenes (3a,3b),[3] where such conjugation would not occur.



1 5 6

Scheme 1

When treated with acid, 3b afforded five products (Table 1). Cuparene (9) and α-bazzanene (3a) were easily recognized on the basis of GC and GC/MS data. Isobazzanene (1) was identified as the third rearranged product as mentioned above. In 1977, Matsuo et al.[5] also reported an experiment on HCO_2H treatment of 3b. The only product isolated by them was cyclobazzanene (7), whose structure was elucidated by x-ray analysis of its derivative 8. From a comparison of the PMR spectra of our rearranged products with that of 7, we found that the product with a Kovats' index of 1445, on SF-96 phase, was indeed cyclobazzanene (7).

Now, the only unknown structure of the five rearranged products from 3b was isocyclobazzanene (2). 2 was well characterized by its particularly short GC retention time and its unique MS spectrum. It had the smallest Kovats' indices on all three stationary phases used as compared with other known sesquiterpenes. Its MS spectrum displayed an M^+ of 204 (23), a base peak at m/z 176 and major fragments at 189 and 161 (both ~50). The PMR spectrum of 2 also appeared interesting, i.e., besides registering three singlets (1.07, 3H; 1.1, 6H and 1.23, 3H) corresponding to four tertiary methyls, no absorption from olefinic proton was observed.

Table 1. Results of acid treatment on β-bazzanene (3b)

Product, % \ Run*	1#	2	3	4	5	6
2	5	13	15	29	14	21
7	3	7	17	13	66	37
1	18	24	18	18	10	15
9	6	10	10	7	6	11
3a	62	43	37	30	2	17

*Condition for each run

Condition** \ Run	1	2	3	4	5	6
HCO_2H(ml)	1	1	1	0.1	0	1
$MeSO_3H$(ml)	0	0	0.1	0.1	1	1
Temp.(°C)	RT	80	RT	80	RT	80
Rxn time (h)	24	5	24	24	1	5

#Results from Andersen et al.[2]
**All rxns were carried out with 1-5 mg of β-bazzanene in 1 ml of heptane.

Although hydrogenation of 2 in EtOAc (stirred at RT 4h) resulted in 90% recovery of the starting material, hydrogenation in HOAc (stirred at RT 4h) afforded two products. From GC/MS analysis, the minor of the two products had an M^+ of 206 and the major showed an M^+ of 208 (Table 2). As the decoupled ^{13}C-NMR of this compound was taken, it was clear that two absorptions, corresponding to one double bond, at δ 142.6 and 148.5 were shown. Furthermore, this ^{13}C-NMR spectrum only revealed a total of 12 lines for a compound of 15 carbons, which indicated

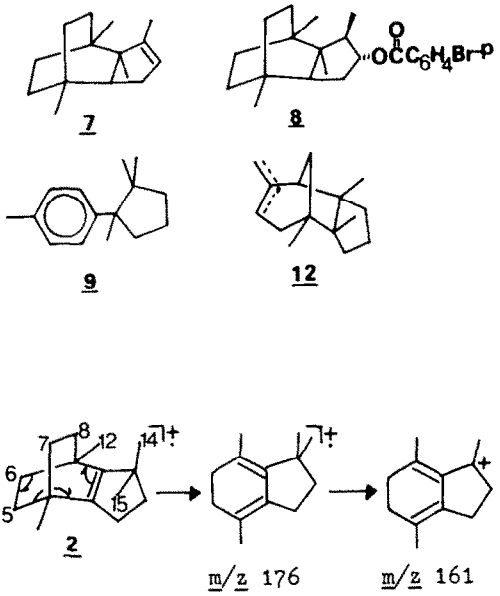
that either the other three absorptions were too weak to be observed or there might be symmetry elements in the molecule.

At this stage, we were quite positive that 2 possessed a tricyclic skeleton and a tetrasubstituted double bond. As for the tetrahydro product, it was likely formed through the hydrogenolysis of one of the ring linkages, just as what was observed in the case of 7 upon hydrogenation (Table 2).

From the yields of rearranged products obtained from acid treatment of 3b under various conditions, we noticed that 3a and 1 were easily formed under mild conditions (runs 1,2 in Table 1), whereas the total percentage of 7 and 2 increased only under more ionizing conditions (runs 5,6 in Table 1). Therefore we suspected that the latter two compounds might have a close structural relationship. This assumption was subsequently verified by the conversion of 2 to 7 when treated with CF_3CO_2H.

Based on the afore-mentioned observations and spectaral data, structure 2 was proposed for isocyclobazzanene. Its typical MS fragment of m/z 176 could again be well explained by this structure through a retro-Diels-Alder reaction (Scheme 2).

Structure 2 also happens to have



Scheme 2

Table 2. Hydrogenation results from compounds 1, 2, 3b and 7

Reactant \ Prod.	I_B^{170*}	%	M^+	GC/MS data
2	1439	38	206	81(100),95(78),135(66),41(65),136(62),107(58),150(56),121(47)
	1533	62	208	55(100),69(97),96(87),81(78),41(65),97(50),111(44),95(40)
7	1486	7	206	96(100),55(89),41(88),95(71),81(67),43(64),69(52)
	1493	5		(not detected)
	1502	21	208	55(100),124(90),95(81),81(69),41(67),69(67)
	1515	55	208	55(100),41(84),95(58),124(52),81(39),69(34)
1	1483	35	208	69(100),111(46),55(45),110(44),95(42),81(39),41(37)
	1508	35	208	69(100),111(95),55(60),110(50),95(47),81(37),41(28)
	1539	7	208	69(100),111(93),55(55),110(50),95(36),81(30),41(26)
	1550	20	208	69(100),96(99),55(94),81(73),111(59),97(58),41(40)
3b	1441	3	206	96(100),81(89),55(87),41(86),69(81),95(65),44(60),43(54)
	1517	7	208	69(100),55(99),96(94),81(86),97(54),41(54),111(51),95(43)
	1542	52	208	96(100),69(98),81(83),55(83),97(54),111(51),95(41),41(39)
	1554	32	208	69(100),55(75),96(71),81(67),111(58),97(54),95(42),41(33)
	1576	6	208	69(100),55(94),41(60),81(58),96(45),97(42),111(42),95(36)

*GC Kovats' indices: the superscript is the temperature, the subscript is the liquid phase used (see the Experimental).

a plane of symmetry cutting through the bicyclo[2,2,2]octane rings, which make the chemical shifts of C_5, C_6 and C_{15} equivalent to those of C_7, C_8 and C_{14} in the ^{13}C-NMR decoupled spectrum, just as what had been observed for 2. Moreover, in view of the structural relationship of 2,7 and 1, we propose the following pathways for the formation of these rearranged products from 3b (Scheme 3). In other words, both 7 and 2 could arise from 1 and shared the common tricyclic intermediates 10 and 11. Cation 10 suffered serious steric interferences between C_{14}- and C_{12}-Me groups as well as C_{14}-Me and syn-H_8. Such van der waals interactions, however, were much relieved in cation 11 and in either of the end products, cyclobazzanene (7) and isocyclobazzanene (2). The reason for the unusual formation of tetrahydro products from both 7 and 2 (Table 2) now became quite clear, since their dihydro products would again be subject to similar steric interactions as cation 10. Also note that 7 gave two dihydro and two tetrahydro products, whereas 2 gave only one of each due to its symmetric skeleton.

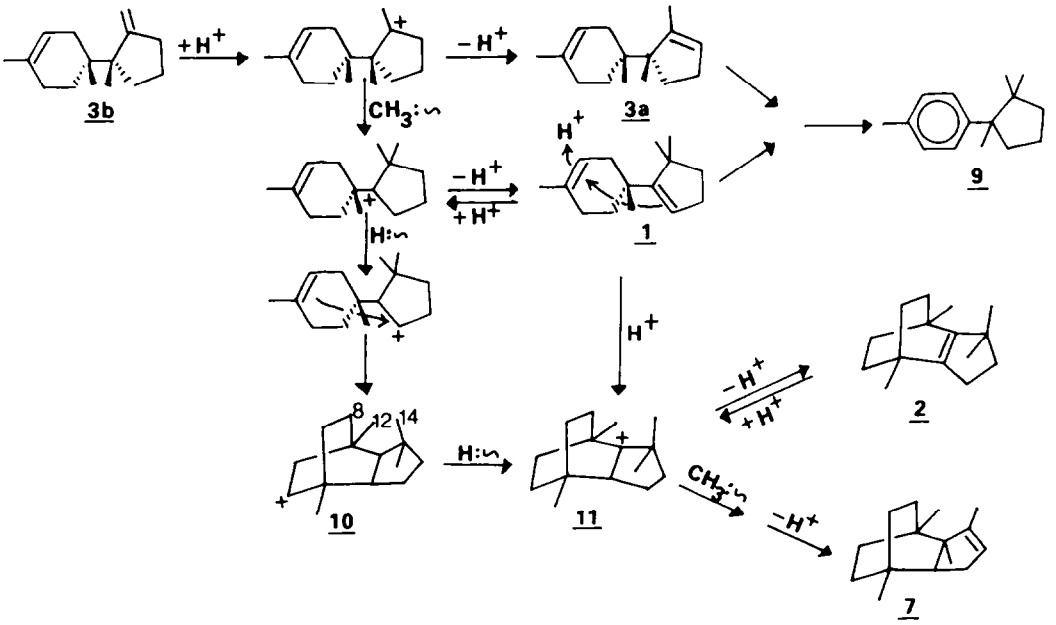
Both 1 and 2 (or 7) represent new types of sesquiterpene skeleton. Of particular interest is the bicyclo[2,2,2]octane system. It does not have any more energy strain than the bicyclo[3,2,1]octane system, nevertheless, sesquiterpenes with the former skeleton have not been found occurring naturally, while the latter does, such as α- and β-barbatenes (12), which has been considered biogenetically derived from β-bazzanene (3b).[2,9]

EXPERIMENTAL

General Methods. Procedures for GC analyses, acid-catalyzed rearrangements, hydrogenations and preparative GC collections are as in ref. 6. For GC analyses longifolene and β-bazzanene were used as standards. GC phases employed in present work were: A, Apiezon L; B, SF-96; C, Carbowax-20M as described in ref. 7. The PMR and ^{13}C-NMR spectra were recorded on a Jeol NM-60HL or Jeol FX-100 spectrometer in $CDCl_3$ solution. GC/MS analyses were carried out at 70 ev on Hitachi M-52 spectrometer. The optical rotations were measured in a $CHCl_3$ solution.

Plant Materials. Liverworts were collected at Yuenyang Lake, Taiwan. Samples identified by Dr.M.C.Lai were deposited in the National Museum of Natural Science, Taiwan.

Isolation of 1 from B. angustifolia oil. A sample oil of 6 g was chromatographed over Si gel (70-230 mesh).



Scheme 3

The hexane eluent afforded 0.9 g of pure β-bazzanene (3b) and 1 g of hydrocarbon oil. The hydrocarbon oil was then repeatedly chromatographed on $AgNO_3/SiO_2$ column to separate each component. Further purification of 1 was accomplished on preparative GC collections. The identified sesquiterpene constituents of B. angustifolia and their percentage (in parentheses) in the hydrocarbon fraction were as follows: α-barbatene(5), thujopsene(1), isobazzanene(7), β-barbatene(14), β-chamigrene(5), cuparene(5), α-bazzanene (5), β-bazzanene(42) and angustifolene (5). Among these, thujopsene and cuparene were identified by GC and GC/MS, the rest were by GC, GC/MS and PMR. Angustifolene is another new compound, its structure will be reported elsewhere.

Acid treatment of β-bazzanene (3b) (preparative scale). Appropriate condition (Table 1) was employed each time in order to prepare more of 1, 2 or 7, respectively. The products were extracted into hexane, washed with H_2O and $NaHCO_3$, and dried. $AgNO_3/SiO_2$ column chromatography and preparative GC were used to isolate and purify each product.

The GC Kovats' indices[4] of these new sesquiterpenes were listed in Table 3. Their spectral properties were described below:

Isobazzanene (1); PMR, δ 1.08(3H,s), 1.15(3H,s), 1.18(3H,s), 1.63(3H,bs), 5.26(1H,bs) and 5.36(1H,s); MS, m/z(rel. int.) 204(M^+,18), 121(100), 136(57), 93 (45), 189(18) and 107(17).

Isocyclobazzanene (2); $[\alpha]_D$ 0°(c,0.2); PMR, δ 1.07(3H,s), 1.1(6H,s), 1.23(3H, s), 1.58(4H,m) and 2.3(2H,bt); ^{13}C-NMR, δ 22.8, 23.0, 27.7, 28.0, 29.7,35.0, 36.6, 37.1, 41.9, 47.3, 142.6 and 148.5; MS, m/z 204(M^+,18), 176(100), 161(44), 119(43), 189(31) and 105(23). When treated with CF_3CO_2H, 2 was converted to cyclobazzanene (7) in 80% yield based on GC/MS analysis.

Cyclobazzanene (7); $[\alpha]_D$ 0°(c,0.55); PMR,[5] δ 0.7(3H,s), 0.82(3H,s), 1.03(3H,s), 1.67(3H,bs) and 5.25(1H,bs); ^{13}C-NMR, δ 16.3, 23.2, 23.7, 26.3, 28.4, 31.7, 32.06, 32.16, 32.6, 35.5, 38.7, 53.4, 54.9, 125.6 and 144.6; MS, m/z 204(M^+, 10), 95(100), 94(58), 109(44), 108(34), 93(32) and 107(25).

Table 3. GC Kovats' indices of new sesquiterpenes

Compound	I_A^{190}*	I_B^{170}	I_C^{150}
isobazzanene(1)	1498	1460	1641
isocyclobazzanene(2)	1391	1350	1449
cyclobazzanene(7)	1498	1445	1641

*GC Kovats' indices, see Table 2.

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REFERENCES

1. A. Matsuo and S. Hayashi, J. C. S. Chem. Comm. 566 (1977).
2. N. H. Andersen, P. Bissonette, C. B. Liu, B. Shunk, Y. Ohta, C. L. W. Tseng, A. Moore and S. Huneck, Phytochemistry 16, 1731 (1977).
3. C. L. Wu, R. S. Tsai and C. M. Wu, Tamkang Journal 19, 487 (1982).
4. N. H. Andersen and M. S. Falcone, J. Chromatogr. 44, 52 (1969).
5. A. Matsuo, H. Nozaki, T. Maeda, M. Nakayama, Y. Kushi and S. Hayashi, J. C. S. Chem. Comm. 568 (1977).
6. Y. Ohta, N. H. Andersen and C. B. Liu, Tetrahedron 33, 617 (1977).
7. C. L. Wu, F. F. Wey and S. J. Hsu, Phytochemistry 21, 2659 (1982).
8. C. L. Wu, A. C. Chen and C. C. Hsieh, Tamkang Journal 20, 293 (1983).
9. J. D. Connolly, A. E. Harding and Ian M. S. Thornton, J. C. S. Perkin trans. 1(21), 2487 (1974).