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ALKALOIDS OF *DELPHINIUM BARBEYI*

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Key Word Index—*Delphinium barbeyi*; Ranunculaceae; diterpenoid alkaloids; 14-acetyldictyocarpine; barbinine; barbinidine.

Abstract—Chemical investigation of the aerial parts of *Delphinium barbeyi* resulted in the isolation of three new alkaloids, 14-acetyldictyocarpine, barbinine and barbinidine, as well as 13 known alkaloids. Structures and stereochemistry were deduced by spectroscopic methods. The structures of 14-acetyldictyocarpine and barbinidine were confirmed by chemical correlation with dictyocarpine.

INTRODUCTION

Tall larkspur [*Delphinium barbeyi* (Huth) Huth] is found in abundance in the Rocky Mountains region of North America and has been shown to be a serious poison for grazing cattle [1, 2]. Among the commonly growing species, *D. barbeyi*, *D. glaucescens* and *D. occidentale*, *D. barbeyi* is by far the most toxic and causes more financial loss than all other poisonous plants growing on the Wasatch Plateau of Central Utah [3]. Because the relative toxicity of a species can be correlated with the content of certain alkaloids, we have carried out a careful examination of the alkaloids present in *D. barbeyi*.

Previous chemical studies of *D. barbeyi* have shown the presence of anthranoyllycoctonine (**1**) [4], lycoctonine (**2**) [4, 5], deltaline (**3**) [5], delpheline (**4**) [5], 6-dehydrodeltamine (**5**) [6], deltamine (**6**) [6], dictyocarpine (**7**) [6] and delcosine (**8**) [6]. Recent reports [7–9] from our laboratory described the isolation of an unusual alkaloid barbeline (**9**), as well as lycoctonine (**2**), deltaline (**3**), delpheline (**4**), dictyocarpine (**7**), delcosine (**8**), 6-acetyldelpheline (**10**), glaucenine (**11**), browniine (**12**), delphatine (**13**) and occidentaline (6-deoxydelpheline, **14**) from a hybrid population of *Delphinium occidentale* and *D. barbeyi*. In the present article, we report the isolation and structure elucidation of three new and 13 known diterpenoid alkaloids from authentic *Delphinium barbeyi* collected from the Wasatch Plateau, west of Ferron, Utah.

RESULTS AND DISCUSSION

Extraction and pH gradient fractionation [10] of the aerial parts of *D. barbeyi* gave a mixture of alkaloids in *ca* 2.34% yield. Chromatographic separations, which include vacuum liquid chromatography (vlc) [11] and centrifugally accelerated, radial, thin-layer chromatography (Chromatotron) [12, 13], of pH 6 fraction furnished deltaline (**3**) [5, 14, 15], delpheline (**4**) [14, 16], dictyocarpine (**7**) [17, 18], delcosine (**8**) [19], barbeline (**9**) [8], glaucenine (**11**) [20], browniine (**12**) [18, 21], 14-dehydrobrowniine (**15**) [14, 22], glaucerine (**16**) [20], methyllycaconitine (**17**) [20], 14-deacetylnudicauline (**18**) [23], delelatine (**19**) [24] and two new alkaloids, 14-acetyldictyocarpine (**20**) and barbinine (**21**). From the pH 13 extract 6-dehydrodeltamine (**5**) [25, 26] and a new alkaloid barbinidine (**22**) were isolated. The structures of the known alkaloids were established spectroscopically and by direct comparison with authentic samples.

14-Acetyldictyocarpine (**20**), $C_{28}H_{41}NO_9$, contained two acetate groups (IR: 1740 cm^{-1} and ^1H NMR: δ1.99, 6 protons). The signals at δ5.34 (1H, *s*) and δ5.20 (1H, *t*, J = 4.5 Hz) could be readily assigned to the 6α and 14β-protons, respectively, adjacent to the acetate groups. The ^{13}C NMR data of **20** are in good agreement with those of a synthetic material prepared by the acetylation of dictyocarpine [20], except for the chemical shifts of C(5) and methylene of the *N*-ethyl group. The literature [20] reported identical shifts (50.4 ppm) contrary to two different shifts [C(5) at 49.8 and *N*–CH_2–Me at 50.2 ppm] observed in the present work. We attribute these difference in shifts due to difference in the field strengths (15.03 and 22.49 MHz) at which the spectra were recorded, as the present isolate also showed a single frequency for both the carbons when measured at 15.03 MHz. Acetylation of dictyocarpine, gave **20**, identical in all respects with the natural product. 14-Acetyldictyocarpine has been prepared previously from dictyocarpine [20], but never to our knowledge has it been isolated as a natural product.

Barbinine (**21**), $C_{36}H_{46}N_2O_{10}$, shows the presence of a cyclopentanone group (IR band at 1750 cm^{-1}, ^{13}C NMR at 215.3 ppm). The ^1H NMR spectrum showed the presence of an *N*-ethyl (δ1.08, *t*, J = 7 Hz), three methoxyls (δ3.34, 3.33 and 3.29) and resonances (see Experimental) characteristic of an ester function as in methyllycaconitine (**17**) and related alkaloids [27]. A plausible structure incorporating these features is **21**, i.e. a dehydro derivative of 14-deacetylnudicauline (**18**). That the carbonyl group is at C(14) was evident from the comparison of the ^{13}C NMR shifts of C(8), C(9), C(12), C(13), C(14) and C(16) (Table 1) of barbinine with those of 14-deacetylnu-

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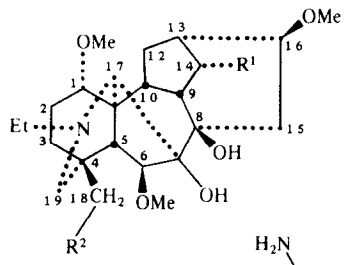

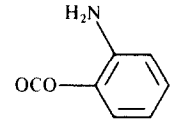

1 R^1 = OMe, R^2 = OCO–

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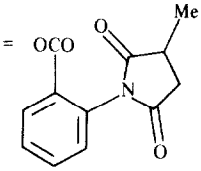
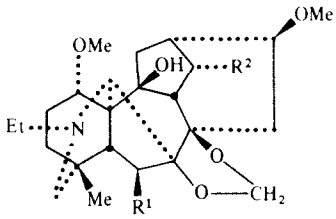
12 R^1 = OH, R^2 = OMe
13 R^1 = R^2 = OMe
15 R^1 = O, R^2 = OMe

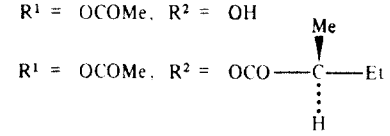


17 R^1 = OMe, R^2 = OCO

18 R^1 = OH, R^2 = as in **17**
21 R^1 = O, R^2 = as in **17**

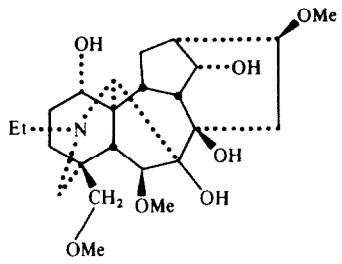


3 R^1 = OCOMe, R^2 = OMe
5 R^1 = O, R^2 = OMe
6 R^1 = OH, R^2 = OMe
7 R^1 = OCOMe, R^2 = OH



11 R^1 = OCOMe, R^2 = OCO–C(Me)(H)–Et

16 R^1 = OCOMe, R^2 = $OCOCH(Me)_2$
20 R^1 = R^2 = OCOMe
22 R^1 = O, R^2 = OCOMe
24 R^1 = R^2 = OH
25 R^1 = R^2 = O
26 R^1 = OH, R^2 = O
27 R^1 = O, R^2 = OH



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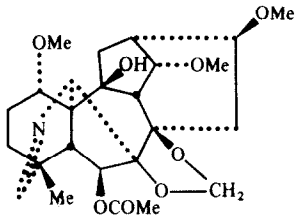

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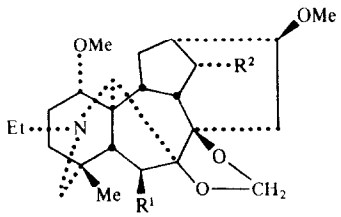


4 R^1 = OH, R^2 = OMe
10 R^1 = OCOMe, R^2 = OMe
14 R^1 = H, R^2 = OMe
19 R^1 = R^2 = OH
23 R^1 = R^2 = OCOMe

dicauline (**18**) [23]. These changes in chemical shifts parallel those of the pair 14-dehydrobrowniine (**15**) [28] and browniine (**12**) [29]. An attempt to correlate barbinine with **18** by oxidation of the latter with pyridinium chlorochromate resulted in the decomposition of the starting material.

The third new alkaloid, $C_{26}H_{37}NO_8$, designated barbinidine, was isolated in a small amount and its structure (**22**) is proposed on the basis of IR and ^1H NMR spectral data. The ^1H NMR spectrum demonstrated the presence of a methylenedioxy (δ5.58 and 5.10), two methoxyls (δ3.32 and 3.28), an acetate (δ2.06) an *N*-ethyl (δ1.08, *t*, $J=7$ Hz) and a quaternary methyl (δ0.95) group. The presence of a keto function (IR, 1710 cm^{-1}) at C(6) was discerned by the large difference in the chemical shifts between the methylenedioxy protons (Δ0.48 ppm), as well as by the significant paramagnetic shifts of these protons when compared with alkaloids containing a methylenedioxy group, but lacking a keto function [27]. The signal at δ5.25 which appeared as a triplet ($J=5$ Hz) was assigned to H(14β) bearing the acetate. Comparison of the chemical shift of H(14) with those of 14-acetyldictyocarpine (δ5.20) and 14-acetyl-10-deoxydictyocarpine (**23**) (δ4.77) [30] revealed the presence of a hydroxyl group at C(10). To verify the conclusions drawn from the spectral data barbinidine was synthesized from dictyocarpine (**7**). Alkaline hydrolysis of **7** gave dictyocarpinine (**24**) and oxidation of the latter with pyridinium chlorochromate furnished 6,14-didehydrodictyocarpinine (**25**) [31], 14-

Table 1. ^{13}C NMR data of compounds **12**, **15**, **18** and **21** (δppm $CDCl_3$)

C	12	15	18	21
8	76.3	85.5	76.3	85.2
9	49.6	53.8	50.3	53.7
12	27.5	25.3	27.5	25.3
13	36.4	49.5	36.5	50.2
14	75.3	216.3	75.3	215.3
16	81.7	85.5	81.8	84.8

dehydrodictyocarpinine (**26**) [32] and 6-dehydrodictyocarpinine (**27**) [33]. Acetylation of **27** gave a substance which showed identical IR and ^1H NMR spectral data with those of natural barbinidine.

EXPERIMENTAL

General. Mps: corr. For vacuum liquid chromatographic (vlc) [11] separations silica gel HF-254 + 366 (EM 7744) and alumina H-basic, type E (EM 1085) were used. For chromatographic separations on a Chromatotron [12, 13] silica gel HF-254 + 366 (EM 7744), basic alumina PF-254, type E (EM 1103) and basic alumina PF-254 + 366, type E (EM 1104-3) were used. TLC was carried out on silica gel 60 H (EM 7736).

Plant material. Above-ground parts of plant were collected on 4 and 5 August, 1975. The stage of growth varied from plants having no conspicuous flower buds to those having well-formed buds and occasionally flowers, with the bud stage being predominant. The collection site was a predominantly east-facing slope about mid-way (2926–3200 m altitude) between Ferron Reservoir and the summit of the skyline divide of the Wasatch Plateau, in the Manti-Lasal National Forest, west of Ferron, Utah. Plants were identified as *Delphinium barbeyi* (Huth) Huth by Dr Leila McReynolds Shultz (Curator, Intermountain Herbarium, Department of Biology, Utah State University, Logan, UT 84321-5500). The large collection of plants was air-dried in direct sunlight. The entire collection was ground and mixed thoroughly in a commercial feed grinder. The total yield of 328 lbs was stored in sealed plastic bags in a walk-in cooler (5°) until analysed or used in other experiments.

Extraction and isolation of alkaloids. Above ground parts of dried *Delphinium barbeyi* (1.4 kg) were extracted twice with 80% EtOH at room temp. Evapn of the combined extract at 40° *in vacuo* gave a residue (231.4 g) which when treated with ice-cold toluene (5 l) gave toluene-soluble and insoluble fractions. Gradient pH fractionation [10] of the toluene fraction gave the alkaloidal fractions A (pH 6, 8.28 g), B (pH 9, 0.62 g) and C (pH 13, 0.066 g). The toluene insoluble fraction was partitioned between a 1:1 mixture of $CHCl_3$ and 1.5% H_2SO_4 (3 l). Gradient pH extraction of the acidic solution gave the alkaloidal fractions D (pH 6, 21.84 g), E (pH 9, 1.3 g) and F (pH 13, 0.685 g).

Fraction A (8.28 g) was adsorbed on Al_2O_3 (15 g) and chromatographed (vlc) over Al_2O_3 (100 g) to afford fractions 2–3 (hexane–ether 4:1, 200 ml and hexane-Et_2O 3:1, 100 ml, 0.53 g), 4 (hexane–Et_2O 3:1, 100 ml, 0.44 g), 5–7 (hexane–Et_2O 3:1, 400 ml and hexane–Et_2O, 2:1, 200 ml, 1.938 g), 8–9 (hexane–Et_2O 1:1, 400 ml, 0.942 g), 10 (hexane–Et_2O 1:1, 200 ml, 0.183 g), 11 (hexane–Et_2O 1:2, 200 ml, 0.034 g), 12–14 (hexane–Et_2O 1:2, 200 ml and hexane–Et_2O 1:3, 400 ml, 0.38 g), 15 (hexane–Et_2O 1:6, 200 ml, 0.41 g), 16 (hexane–Et_2O 1:6, 200 ml, 0.61 g), 17 (ether, 200 ml, 0.34 g), 18–19 (ether, 200 ml and ether-EtOH 19:1, 200 ml, 0.21 g), 20–21 (Et_2O–EtOH 9:1, 200 ml and Et_2O–EtOH 4:1, 200 ml, 0.189 g), 22–23 (Et_2O–EtOH 4:1, 400 ml, 0.065 g) and 24–25 (Et_2O–EtOH 1:1, 200 ml and MeOH, 500 ml, 0.611 g).

Isolation of deltaline (**3**) *and 14-acetyldictyocarpine* (**20**). Purification of fraction A (4) on a Chromatotron (silica) gave 117 mg of 14-acetyldictyocarpine (**20**) and 280 mg of deltaline (**3**), mp 184–186°. Compound **20**: amorphous, $[\alpha]^{19} - 50.9°$ ($CHCl_3$; *c* 0.369); IR ν^{nujol}: 3500, 1740 and 1710 cm^{-1}; MS: *m/z* 535 (M^+, $C_{28}H_{41}NO_9$), 520 $[M-15]^+$, 504 $[M-31]^+$ and 476 $[M-59]^+$; ^1H NMR ($CDCl_3$): δ5.34 (*br*, H-6α), 5.20 (*t*, $J = 4.5$ Hz, H-14β), 4.88 and 4.80 (each, *s*, OCH_2O), 3.23 and 3.20 (each *s*, OMe), 1.99 (*s*, 6H, OAc), 0.99 (*t*, $J = 7$ Hz, N–CH_2–Me) and 0.80 (*s*, Me-18).

Fractions A (5–7), (8–9) and (10) were crystallized from acetone–hexane to give 1.554 g (mp 182–185°), 0.485 g (mp 184–186°) and 0.115 g (mp 180–182°) of **3**, respectively. The mother liquors from the above fractions were combined (0.741 g) and chromatographed (vlc) on 50 g of alumina to afford fractions AA (6–8) (hexane–Et_2O 3:1, 300 ml, 14 mg), AA (9–11) (hexane–Et_2O 7:3, 200 ml and hexane–Et_2O 2:3, 100 ml, 0.33 g), AA (12–15) (hexane–Et_2O 2:1, 300 ml and hexane–Et_2O 1:3, 100 ml, 0.286 g). Crystallization of fractions AA (9–15) from Me_2CO–hexane gave 0.231 g of **3**, mp 183–185°. The mother liquor upon purification on a Chromatotron (silica) gave 0.131 g of **20** and 0.110 g of **3**.

Isolation of glaucerine (**16**), *glaucenine* (**11**), *14-dehydrobrowniine* (**15**) *and browniine* (**12**). Purification of fractions A (2–3) (0.53 g) on silica and alumina rotors of a Chromatotron gave 5 mg of glaucerine (**16**), 48 mg of glaucenine (**11**), 171 mg of 14-acetyldictyocarpine (**20**) and 29 mg of deltaline (**3**). Fractions A (12–14) were purified on a Chromatotron (silica) to yield 85 mg of 14-dehydrobrowniine (**15**) and 82 mg of slightly impure browniine (**12**). Crystallization of **15** from EtOAc–hexane gave a substance with mp 173–175°. Repurification of impure **12** on a Chromatotron (alumina) gave 39 mg of a spectroscopically pure compound.

Isolation of methyllycaconitine (**17**) *and dictyocarpine* (**7**). Fractions A (15–19) (1.57 g) were further chromatographed (VLC) on aluminia (45 g) to yield fractions 2–3 (hexane–Et_2O 2:3, 300 ml, 98 mg), 4–7 (hexane–Et_2O 2:3, 400 ml, 263 mg), 8–9 (hexane–Et_2O 2:3, 100 ml and hexane–Et_2O 1:3, 100 ml, 300 mg), 10 (hexane–Et_2O 1:3, 100 ml, 241 mg), 11–12 (hexane–Et_2O 1:8, 200 ml, 374 mg) and 13–14 (hexane–Et_2O 1:8, 200 ml, 122 mg). Purification of fractions 4–7 on a Chromatotron (silica) gave 213 mg of methyllycaconitine (**17**). Fractions 8–12 (915 mg) contained mainly **17**. Purification of fractions 13–14 on a Chromatotron (alumina) gave 47 mg of **17** and 35 mg of dictyocarpine (**7**), mp 210–212°.

Isolation of deltaline (**3**), *delpheline* (**4**), *14-acetyldictyocarpine* (**20**), *glaucenine* (**11**), *and glaucerine* (**16**). A part (14.2 g) of fraction D was chromatographed as detailed for fraction A to afford fractions 2–3 (hexane–Et_2O 7:1, 400 ml and hexane–Et_2O 4:1, 200 ml, 0.74 g), 4 (hexane–Et_2O 4:1, 200 ml, 0.94 g), 5–6 (hexane–Et_2O 3:1, 300 ml, 1.9 g), 7 (hexane–Et_2O 3:1, 100 ml, 0.938 g), 8–9 (hexane–Et_2O 3:1, 200 ml and hexane–Et_2O 2:1, 200 ml, 2.02 g), 10 (hexane–Et_2O 2:1, 200 ml, 0.59 g), 11 (hexane–Et_2O 1:1, 200 ml, 0.233 g), 12–13 (hexane–Et_2O 1:1, 200 ml and hexane–Et_2O 1:2, 200 ml, 0.282 g), 14–16 (hexane–Et_2O 1:2, 200 ml and hexane–Et_2O 1:3, 400 ml, 1.11 g), 17–19 (hexane–Et_2O 1:9, 200 ml, Et_2O 200 ml and Et_2O–EtOH 19:1, 200 ml, 2.45 g) 20 (Et_2O–EtOH 9:1, 200 ml, 0.438 g) and 21–22 (Et_2O–EtOH 4:1, 200 ml and Et_2O–EtOH 7:3, 200 ml, 0.268 g).

Crystallization of fractions D (5–6), D (7), D (8–9) and D (10) from Me_2CO–hexane furnished 1.128 g (mp 182–185°), 0.710 g) (mp 182–185°), 1.466 g (mp 183–185°) and 0.354 g (mp 182–184°)

of deltaline (**3**), respectively. The mother liquors of the above fractions and fractions D (2–4) from the VLC were combined (3.21 g) and chromatographed (VLC) on silica (50 g) to yield fractions DD (5–6) (hexane–Et_2O 3:1, 400 ml, 5 mg), DD (7–8) (hexane–Et_2O 2:1, 400 ml, **4** mg), DD (9) (hexane–Et_2O 2:1, 26 mg), DD (10) (hexane–Et_2O 3:2, 200 ml, 61 mg), DD (11–12) (hexane–Et_2O 1:1, 710 mg), DD (13) (hexane–Et_2O 1:1, 200 ml, 211 mg), DD (14–15) (hexane–Et_2O 2:3, 400 ml, 1.11 g), DD (16–18) (hexane–Et_2O 2:3, 200 ml and hexane–Et_2O 1:3, 400 ml, 832 mg) and DD (19–21) (hexane–Et_2O 1:9, 400 ml and Et_2O–EtOH, 19:1, 200 ml, 138 mg). Crystallization of fractions DD (14–18) from Me_2CO–hexane gave 1.316 g of deltaline (**3**), mp 183–185°. Fraction DD (10) upon standing in Me_2CO gave a material with mp 210–216° (26 mg) which upon purification on a Chromatotron (alumina) gave 20 mg of delpheline (**4**), mp 214–216°. Purification of fraction DD (9), the mother liquor of DD (10) and a portion of DD (11–12) (total wt 647 mg) on a Chromatotron (silica) furnished 403 mg of *ca* 95% pure 14-acetyldictyocarpine (**20**) and an impure fraction (33 mg). Purification of the latter on alumina (Chromatotron) gave 21 mg of glaucenine (**11**) and 5 mg of glaucerine (**16**).

Isolation of dehydrobrowniine (**15**), *browniine* (**12**), *methyllycaconitine* (**17**). Purification of fractions D (12–13) (282 mg) on a Chromatotron (silica) gave 110 mg of slightly impure dehydrobrowniine (**15**). Crystallization from EtOAc–hexane gave a pure compound, mp 172–174°. Purification of a portion (0.939 g) of fractions D (14–16) on a Chromatotron (silica) furnished 89 mg of browniine (**12**) and 282 mg of methyllycaconitine (**17**).

Isolation of dictyocarpine (**17**), *methyllycaconitine* (**17**) *and deleletine* (**19**). Crystallization of fractions D (17–19) from Me_2CO–hexane afforded 501 mg of dictyocarpine (**7**), mp 212–214°. The mother liquor (1.69 g) was chromatographed (VLC) on alumina (50 g) to yield fractions 3–4 (hexane–Et_2O 1:1, 200 ml, hexane–Et_2O 2:3, 200 ml, 74 mg), 5–7 (hexane–Et_2O 2:3, 200 ml and hexane–Et_2O 1:3, 200 ml, 841 mg), 8–10 (hexane–Et_2O 1:3, 200 ml, hexane–Et_2O 1:9, 200 ml, and Et_2O– EtOH 49:1, 200 ml, 0.616 g), 11–13 (Et_2O–EtOH 19:1, 200 ml, Et_2O–EtOH 9:1, 200 ml and Et_2O–EtOH 4:1, 129 mg). Fractions 5–7 were mainly methyllycaconitine (**17**). Purification of fractions 8–10 on a Chromatotron (alumina) gave 437 mg of methyllycaconitine (**17**), 48 mg of dictyocarpine (**7**), mp 213–215° and 49 mg of an impure fraction. Repurification of this fraction on a silica rotor of a Chromatotron gave 33 mg of delelatine (**19**), mp 84–86° [24].

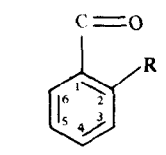
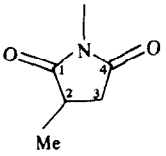
Isolation of barbeline (**9**), *barbinine* (**21**), *14-deacetylnudicauline* (**18**) *and delcosine* (**8**). Fractions 11–13 from D (17–19) (129 mg) upon purification on a Chromatotron (alumina) gave two fractions in yields of 12 and 103 mg. Crystallization of the former with Me_2CO–hexane yielded 6 mg of barbeline (**9**), mp 264–267° [8]. The latter fraction was repurified on a Chromatotron (silica) to give 13 mg of barbinine (**21**) and 71 mg of 14-deacetylnudicauline (**18**). Barbinine (**21**): amorphous; $[\alpha]^{26}+35.9°$ ($CHCl_3$; *c* 0.388); IR ν^{nujol}: 3470, 1750, 1715 and 1600 cm^{-1}; MS: *m/z* 666 (M^+, $C_{36}H_{46}N_2O_{10}$), 651 $[M-15]^+$ and 635 $[M-31]^+$; ^1H NMR ($CDCl_3$): δ8.00 (*dd*, $J=7.6$, 2.2 Hz), 7.70 (*dt*, $J=2$, 7.6 Hz), 7.54 (*dt*, $J=2$, 7.6 Hz), 7.27 (*dd*, $J=7.6$, 2 Hz) (aromatic protons); 4.07 (*br*, H-18a and 18b), 3.34, 3.33 and 3.29 (each *s*, OMe), 1.44 (*d*, $J=6$ Hz, CH–Me), 1.08 (*t*, $J=7$ Hz, *N*–CH_2–Me). For ^{13}C NMR data see Table 2.

Purification of fraction D (20) (0.438 g) on a Chromatotron (silica) gave a fraction (221 mg) containing two compounds. Repurification as above on alumina gave 140 mg of 14-deacetylnudicauline (**18**) and impure barbinine (**21**) (51 mg). Repurification of the latter by prep. TLC (silica, $CHCl_3$–EtOH, 9:1) gave 36 mg of spectroscopically pure **21**.

Purification of fractions D (21–22) (268 mg) on a Chromatotron (alumina, then silica gel) gave 99 mg of a fraction containing mostly one component. Repurification by prep. TLC (silica, $CHCl_3$–MeOH, 9:1) gave 64 mg of pure delcosine (**8**), mp 201–202°.

Isolation of barbinidine (**22**) *and 6-dehydrodeltamine* (**5**). Alkaloidal fractions C and F were combined and chromatographed (VLC) on alumina (60 g) to yield fractions CF (4–6) (hexane–Et_2O 3:7, 400 ml and hexane–Et_2O 2:1, 200 ml, 9 mg),

Table 2. ^{13}C NMR data of barbinine (**21**) and barbinidine (**22**) (δ ppm $CDCl_3$)

C	21	22	C	21	22
1	85.2	76.9	1′	55.9	55.7
2	25.3	26.6	6′	58.5	—
3	32.0	37.5	OCH_2O	—	95.3
4	37.9	35.0	16′	56.1	56.1
5	46.0	56.1	C=O	—	172.0
6	90.1	216.1	Me	—	21.3
7	88.8	90.3		164.1	—
8	85.2	81.6		1 127.1	—
9	53.7	51.4		2 133.1	—
10	43.9	79.9		3 129.4	—
11	49.0	51.2		4 133.6	—
12	25.3	38.2		5 130.9	—
13	50.2	34.8		6 133.0	—
14	215.3	73.6		1 179.7	—
15	33.0	34.1		2 35.3	—
16	84.8	80.4		3 37.0	—
17	65.3	62.8		4 175.7	—
18	69.2	24.7		5 16.4	—
19	52.3	57.0			
N-CH_2	51.1	50.0			
CH_3	14.3	13.7			

CF (7) (hexane–Et_2O 1:1, 200 ml, 16 mg), CF (8–9) (hexane–Et_2O 1:1, 400 ml, 4 mg), CF (10) (hexane–Et_2O 1:2, 200 ml, 82 mg), CF (11) (hexane–Et_2O 1:2, 200 ml, 15 mg), CF (12–13) (hexane–Et_2O 1:3, 200 ml and hexane–Et_2O 1:4, 200 ml, 69 mg), CF (14–15) (hexane–Et_2O 1:6, 200 ml and Et_2O, 200 ml, 138 mg). Purification of fraction CF (10) (82 mg) on a silica rotor of a Chromatotron gave 4 mg of barbinidine (**22**) and 62 mg of 6-dehydrodeltamine (**5**). Barbinidine (**22**): mp 215–216° (Me_2CO–hexane); IR ν^{KBr}: 3430, 1740 and 1710 cm^{-1}; MS: *m/z* 491 (M^+, $C_{26}H_{37}NO_8$), 476 $[M-15]^+$ and 460 $[M-31]^+$ and ^1H NMR ($CDCl_3$): δ5.58 and 5.10 (each *br*, OCH_2O), 5.25 (*t*, $J=5$ Hz, H-14β), 3.32 and 3.28 (each *s*, OMe), 2.06 (*s*, OAc), 1.08 (*t*, $J=7$ Hz, *N*–CH_2–Me), 0.95 (*s*, Me-18). 6-Dehydrodeltamine (**5**): mp 154–157° (Me_2CO–hexane) (lit. [25] 120–122°) and $[\alpha]^{26}$ −57° ($CHCl_3$; *c* 0.245). The ^1H and ^{13}C NMR data of **5** were in good agreement with those reported [26]. However, the literature assignments for C (5) and C (19) should be interchanged as a result of a DEPT experiment. The mother liquor upon standing in the above solvent mixture gave a substance which melted in parts at 93, 145 and 157°. The ^1H NMR spectrum of this sample, however, was identical with that of the original sample. To clarify this controversy, deltamine (**6**) was oxidized with pyridinium chlorochromate in the usual manner to give 6-dehydrodeltamine (**5**), $[\alpha]^{26}$ −56.6° (*c* 0.3365, $CHCl_3$); the IR, ^1H and ^{13}C NMR spectral data were identical with those of the natural product. However, the synthetic sample melted at 94–95°. A synthetic sample prepared earlier in our laboratory as detailed above also melted at 95–96°. We are unable to explain this phenomenon.

Correlation of 14-*acetyldictyocarpine* (**20**) *with dictyocarpine* (**7**). Dictyocarpine (49 mg) was acetylated with Ac_2O–pyridine in the customary fashion to yield 52 mg of **20**. The synthetic compound was identical in every respect ($[\alpha]_D$, IR, ^1H and ^{13}C NMR) with the natural substance.

Correlation of barbinidine (**22**) *with dictyocarpine* (**7**): *hydrolysis of dictyocarpine.* A mixture of dictyocarpine (79 mg), 5 ml of MeOH and 2 ml of 7% NaOH was stirred at room temperature for 16 hr. Usual work-up followed by crystallization from Me_2CO gave 62 mg of dictyocarpinine (**24**), mp 204–205° (lit. [17] 204–205°).

Oxidation of dictyocarpinine (**24**). A solution of **24** (60 mg) in 6 ml of CH_2Cl_2 was stirred with 4 mg of NaOAc and 34 mg of pyridinium chlorochromate at 30° for 18 hr. Usual work-up and subsequent purification on a Chromatotron (silica) furnished 5 mg of 6,14-didehydrodictyocarpinine (**25**) [31], 7 mg of 14-dehydrodictyocarpinine (**26**) [32] and 32 mg of 6-dehydrodictyocarpinine (**27**), mp 205–206° (lit. [33] 201–203.5°).

Acetylation of 6-*dehydrodictyocarpinine* (**27**). A mixture of **27** (24 mg), 1 ml of pyridine and 1 ml of Ac_2O was stirred at room temp. for 60 hr. Usual work-up and purification on a silica rotor gave 22 mg of barbinidine (**22**) and 2.5 mg of the starting material. The synthetic sample, mp 214–215.5° and $[\alpha]^{21}$ −31.6° ($CHCl_3$; *c* 0.152), had identical IR and ^1H NMR spectral data with those of the natural product. For ^{13}C NMR data see Table 2.

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