NEW SESQUITERPENE-COUMARIN ETHERS FROM *ACHILLEA* AND *ARTEMISIA* SPECIES

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ABSTRACT.—The isolation and identification of five new sesquiterpene-isofraxidin ethers from the roots of several *Artemisia* and *Achillea* species is reported. They are: farnochrol (farnesyl-isofraxidin) (**1**), drimartol B (hydroxydrimenyl-isofraxidin) (**3**), **4**: acetyl derivative of **3**, pectachol (exo-methylene isomer of **3**) (**6**), and **7**: acetyl derivative of **6**. The compounds were characterized by nmr, EI- and FD-ms, uv and ir data. Additionally, drimartol B (**3**) was correlated with the known drimartol A (**2**) by CrO_3-oxidation to the corresponding oxo-compounds **5**: (−)-**5** from **3**, and (+)-**5** from **2**. The ^{1}H-nmr spectra, including lanthanide induced shifts and the ms data, are discussed in detail.

Ethers with open-chain, mono- or bicyclic sesquiterpenes linked to a coumarin skeleton have nearly exclusively been found in the gum resins of *Ferula* and some closely related umbelliferous genera (1). Since these resins, widely known as asafoetida, galbanum and ammoniacum, are used for medicinal purposes and as spices, many investigations have been carried out to determine their chemical composition (2). The coumarin moiety of all sesquiterpene ethers isolated from these plants has proved to be uniformly umbelliferone (7-hydroxycoumarin). With regard to the restricted distribution of these compounds in the plant kingdom, the detection of isofraxidin-derived (7-hydroxy-6,8-dimethoxycoumarin) sesquiterpene ethers in *Artemisia pontica* L. and *A. abrotanum* L. (3) as well as in subspecies of *Anthemis cretica* L. and *A. aciphylla* Boiss. (*Asteraceae-Anthemideae*) (4) is of special chemosystematic interest.

Now, in continuation of current comparative investigations on *Artemisia* and *Achillea* root constituents (5–8), a series of new sesquiterpene ethers has been isolated, all of which are linked to isofraxidin. The sesquiterpene moieties have proved to be either farnesyl (**1**) or bicyclic drimenyl derivatives (**2–4**, **6**, **7**). All structures were confirmed by nmr and mass spectroscopy by the field desorption technique (fd). The relative stereochemistry of the compounds was determined by ^{1}H-nmr in connection with lanthanide-induced shifts (lis).

Since in both genera the accumulation of the derivatives is confined to closely related species, this chemical trend obviously represents a valuable criterion for an infrageneric classification. A more detailed comparative analysis will be presented elsewhere (9).

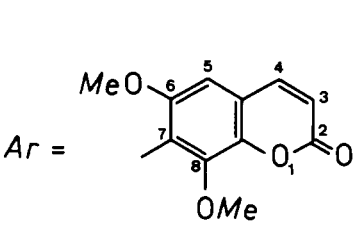
DISCUSSION

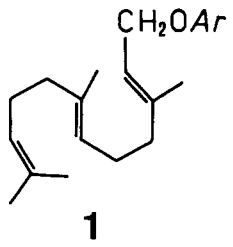
From the roots of two *Achillea* species (*A. ochroleuca* Ehrh., *A. pseudopectinata* Janka) and five *Artemisia* species (*A. pontica* L., *A. persica* Boiss., *A. abrotanum* L., *A. gmelinii* Web. ex Stechm., *A. vestita* Wall. ex DC.) six different isofraxidin sesquiterpene ethers have been isolated to date. Compounds **1**, **3**, **4**, **6** and **7** have proved to be new, whereas the structure and relative stereochemistry of **2** has already been elucidated in a previous communication (3).

The farnesyl isofraxidin ether **1**, designated as farnochrol, was found to some extent in all species investigated. With regard to its acyclic sesquiterpene moiety this suggests that **1** may be the biogenetic precursor of all derivatives belonging to that class of compounds (10). Ms and nmr data are in agreement with the proposed structure.

The other five compounds are derivatives with *trans* fused bicyclic sesquiterpene

moieties of the drimenol type, with the $-CH_2OAr$ substituent in pseudoaxial position. In accord with Bohlmann (3) we isolated **2** (with OH axial) from *Artemisia pontica* and *A. abrotanum* and, additionally, as the main component from *A. persica* and *A. gmelinii* (=*A. iwayomogi* Kitam.). In smaller quantities, **2** was also found in *A. vestita* and *Achillea pseudopectinata*.





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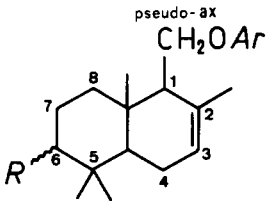

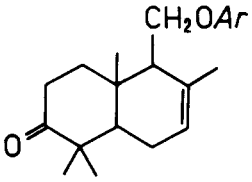

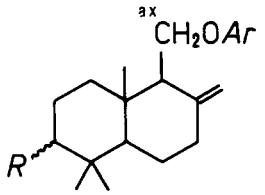

2 *R* = OH ax
3 OH eq
4 OAc eq

5

6 *R* = OH ax
7 OAc ax

Achillea ochroleuca afforded large amounts of the corresponding stereoisomer **3** (with OH equatorial) and, as a minor constituent, its acetyl derivative **4**. The mass spectra of **3** (EI–70 eV and FD) were almost identical with those of **2**. However, in the nmr spectrum, the broad C*H*(OH) signal at 3.36 ppm differs significantly from the one in **2**. Interestingly enough, oxidation of **2** and **3** gave the two *enantiomeric* 6-oxo derivatives (+)-**5** and (−)-**5**. The nmr and ms spectra were identical, the optical rotations, however, were of opposite sign (see Exp.). The *relative* stereochemistry at C–1, C–4a and C–8a is therefore the same for compounds (+)-**2** and (−)-**3**; the *absolute* configurations are obviously opposite.

A synthetic sample of **4** was prepared by acetylation of **3** and has proved to be identical with the natural product ($[\alpha]_D$, nmr and tlc comparison). The two stereoisomers **2** and **3**, named drimartol A[1] and B, crystallized easily even from the crude column fractions, whereas the remaining constituents could only be obtained by repeated preparative tlc.

The exo-methylene isomer **6**, designated as pectachol, and the corresponding acetyl derivative **7** dominate in the roots of *Achillea pseudopectinata*. The mass spectra of **6** (ei- and fd-ms) differ only slightly from those of **2** or **3** and high resolution ms confirms an identical elementary composition for **2**, **3** and **6** ($C_{26}H_{34}O_6$). However, the nmr spectrum of **6** clearly showed an exo-methylene arrangement by the lack of a fourth Me signal and the additional olefinic H. The chemical shifts of $-O-CH_2-$ and H(olefinic) were different from those of **2** and **3** (see table 1a). The relative stereochemistry was derived from the coupling constants (C–6, OH ax) and lis evidence (see the following discussion). In the case of compound **6**,

[1]Named in accordance with Prof. Dr. F. Bohlmann, Institute of Organic Chemistry, Technical University of Berlin.

the lis data are very close to those for **2** (table 1b). The structure of **7** was confirmed by ms, nmr and chemical (synthetic) evidence.

Extensive chromatographic comparisons of the petrol/ether extracts showed a further series of probably new isofraxidin-sesquiterpene ethers. The isolation and structure elucidation of these compounds is under way in our laboratories.

MASS SPECTROMETRY.—In the EI mass spectra at 70 eV, the molecular ions were of low intensity (no M^+ for **1** and 1–2% for all other compounds); even at 11 eV no increase of intensity was observed (3). For the relatively unstable ethers of this type, the field desorption technique has proved to be very valuable for molecular mass determinations; the base peak was M^+ in all cases at 2–4 ma ehc.

The EI mass spectra (70 eV) of the bicyclic sesquiterpene-isofraxidin ethers **2–4**, **6** and **7** were dominated by the base peak at *m/z* 222 ($C_{11}H_{10}O_5$)[2] which represented the isofraxidin moiety. Information on the terpenic part of the molecule was given mainly by the fragment *m/z* 203 ($C_{15}H_{23}$)[2] (3). Therefore, in all cases of bicyclic sesquiterpene-isofraxidin ethers, the main cleavage between the terpenic and aromatic part takes place obviously at the ether-O–C(terpene) bond.

This is different from the EI behaviour of the open chain compound **1** where the ether-O–C(aryl) bond is cleaved, resulting in the base peak *m/z* 205 ($C_{14}H_{21}O$)[2], which is in turn the product of $CH_3\cdot$ loss from *m/z* 220 ($C_{15}H_{24}O$, 25%)[2]. In the EI-ms of **1** no fragment 220 (isofraxidin) is found.

^{1}H-NMR AND LIS.—Evaluation of the ^{1}H-nmr spectra (together with ms data) revealed the structure of **1** (open chain sesquiterpene component) and the bicyclic nature of the sesquiterpene structures in **2–4**, **6** and **7**.

In the nmr spectrum of **1** the four methyl group signals were at 1.68, 1.66, 1.59 and 1.58 ppm, all other aliphatic protons ranged from 2.1 to 1.95 ppm indicating that all Me and CH_2 were attached to an olefinic carbon (C=C–Me, C=C–CH_2–). The chemical shifts for the olefinic methyl groups are in excellent agreement with the values expected for trans-trans farnesyl derivatives: 2 Me at δ 1.66 and 2 Me at 1.59 ppm (11, 12).

In the bicyclic drimenol derivatives, two stereochemical questions arose: the relative configurations at C–6 and C–1.

The stereochemistry at C–6 (OH axial or equatorial) can be derived easily from the coupling patterns of the corresponding C–6 proton. For OH ax and therefor H eq, one has to expect vicinal coupling constants for eq-ax and eq-eq resulting in a relatively narrow multiplet for the C–6 H ($w_{1/2}$ 9 Hz for the carbinols **2** and **6** and $w_{1/2}$ 7 Hz for acetyl derivative **7**). In case of OH eq the corresponding axial H should exhibit ax-ax and ax-eq coupling constants leading to a broad multiplet for carbinol **3** ($w_{1/2}$ 19 Hz) and to a dd type signal in the acetyl derivative **4** (corresponding to $w_{1/2}$ ca. 17 Hz) (see table 1a).

This assignment of C–6 OH is confirmed by the lis data for **2**, **3** and **6** (see table 1b, Me signals): for OH ax, only one C–5 methyl exhibits a markedly higher lis value than all other methyl signals (3.61 resp. 3.96 ppm for **2** resp. **6**), for OH eq, both C–5 methyl signals are shifted considerably more than the remaining ones (5.46, 6.15 ppm, compound **3**). In the former case the C–5 Me trans to the axial OH is too far from the coordinated lanthanide ion (or the coordinating OH function) and only the cis Me suffers a high lanthanide-induced shift. In the latter case, both C–5 Me are necessarily cis (and therefore close) to the equatorial OH.

The problem of the stereochemistry at C–1 is more complicated. In the case of **2**, the –CH_2OAr moiety was determined to be in a pseudoaxial configuration; the argument was that the chemical shift of the axial C–8 proton (ddd at 2.50 ppm) suffered additional deshielding from the oxygen of the axial –CH_2OAr arrangement (3). Unfortunately, in **3** and **6** the corresponding C–8 proton cannot be identified and utilized in a similar manner.

[2]Proved by exact mass determination within ±5 ppm limits (peak matching at 10 000 resolution, 10% valley).

TABLE 1. ^{1}H-nmr data for natural products **1–4**, **6** and **7**. a. Chemical shifts: δ/ppm ($CDCl_3$, TMS)[a]. b. Lanthanide induced shifts: ppm [$CDCl_3$, Eu(dpm)$_3$], extrapolated to a concentration ratio S_o:L_o = 1:1.

No.	3-H (d)[b]	4-H (d)[b]	5-H	6-OMe 8-OMe (s)	7-O-CH_2-	CH-OR[c]	H (olefinic)	Me(olefin.) (s)	Me(aliph.) (s)
a. Chemical shifts									
1	6.34	7.60	6.60	3.88 4.04	4.68(d, 2H)[d]	—	5.56(t,1H)[d,e] 5.09(m,2H)[e]	1.68 1.66 1.59 1.58	–
2	6.35	7.60	6.66	3.90 4.01	4.32(dd,1H)[f] 3.96(dd,1H)[g]	3.46 (m, w½ 9 Hz)	5.53(m,1H)[e]	1.81[e]	1.01 0.98 0.96
3	6.34	7.59	6.65	3.87 4.00	4.15(dd,1H)[h] 3.90(dd,1H)[i]	3.36 (m, w½ 19 Hz)	5.48(m,1H)[e]	1.80[e]	1.04 1.00 0.92
4	6.34	7.60	6.67	3.93 4.03	4.20(dd,1H)[h] 3.90(dd,1H)[i]	4.65(dd)[k]	5.49(m,1H)[e]	1.80[e]	1.00 0.98 0.90
6	6.33	7.60	6.64	3.87 3.98	4.39(dd,1H)[l] 4.16(dd,1H)[m]	3.44 (m, w½ 9 Hz)	4.78(d,1H)[n] 4.84(d,1H)[n]	—	1.02 0.97 0.86
7	6.32	7.59	6.64	3.85 3.95	4.36(dd,1H)[l] 4.13(dd,1H)[m]	4.65 (m, w½ 7 Hz)	4.77(d,1H)[n] 4.82(d,1H)[n]	—	1.01 0.89 0.85
b. LIS									
1	0.92	0.48	0.91	0.32 0.21	1.11	—	1.00 0.15 0.03	0.03 0.03 0.07 0.52	—
2	0.39	−0.22	−0.45	0.31 −0.25	1.82 1.34	9.4	0.81	0.62	1.85 1.54 3.61
3	0.25	±0.00	0.10	0.55 −0.05	1.36 1.00	13.4	1.07	0.69	5.46 2.31 6.15
6	0.18	−0.19	−0.25	0.21 −0.25	1.26 1.05	9.1	0.44 0.48	—	1.86 1.49 3.96

[a]Further ring protons (m) of the sesquiterpene moiety in the region of 2.50–1.07 ppm; **1**: 2.10–2.00(6H), 2.00–1.95(2H); **2**: 2.50(1H), 2.15–1.90(3H), 1.80–1.70(3H), 1.23(1H); **3**: 2.15(1H), 2.00(1H), 1.85(1H), 1.75–1.65(2H), 1.55–1.30(3H); **4**: 2.32(1H), 2.10–1.95(2H), 1.80–1.60(3H), 1.50(1H), 1.35(1H); **6**: 2.35–2.25(3H), 2.15–2.00(2H), 1.75(1H), 1.65–1.55(2H), 1.43(1H), 1.07(1H); **7**: 2.35–2.25(3H), 2.00–1.90(2H), 1.75–1.55(3H), 1.40(1H), 1.07(1H); [b]J=9.5 Hz; [c]R=H (**2** δ OH 1.90 ppm, **3** 1.75, **6** 1.60) or $COCH_3$ (**4** δ COMe 2.09 ppm, **7** 2.01); [d]J=7 Hz; [e]broad; [f]J=10/5 Hz; [g]J=10/2 Hz; [h]J=10/6 Hz; [i]covered by OMe; [k]slightly broadened pseudotriplet with J=7.5 Hz (corresponds to w½ ca. 17 Hz); [l]J=9.5/5.5 Hz; [m]J=9.5/8 Hz (appears as a broadened pseudotriplet); [n]small J, appears as a broad pseudosinglet.

Comparing the nmr spectra of **2–4**, **6** and **7** with the corresponding data for coladonin and farnesiferol A (13), the coupling pattern of $>CH-CH_2-OAr$ (AB part of an ABX system, see table 1a) is in favor of an axial $-CH_2OAr$ arrangement.

The axial configuration of $-CH_2OAr$ at C-1 could be confirmed unambiguously by means of the lis technique. In all carbinols (**2**, **3** and **6**), there appear negative (upfield) Eu(dpm)$_3$ induced shifts[3] for protons within the isofraxidin rest. This is only possible if the supplement to the angle Eu(III)—coordination center (carbinol O)—particular proton H_i is more than 54.7° (14–16). Negative lis values always indicate therefore a "bent" ("U" or at least "L") arrangement between the coordinating group and the proton exhibiting negative lis. In the "linear" arrangement the angle Eu–O–H_i is necessarily always close to 180°, therefore, supplement close to 0° and by no means >54.7° where the McConnell-Robertson relationship would reverse its sign. In this "linear" case, the lis are always positive (downfield) for Eu(III). For an equatorial configuration of $-CH_2OAr$ ("linear" case) inspection of Dreiding models[4] shows that negative Eu(III) shifts are virtually impossible; no such lanthanide position can exist for any possible conformation of the substrate in the Eu(dpm)$_3$-substrate complex (18).

Remarkable negative Eu(III) shifts are observed for the arrangement OH ax/CH_2OAr ax in **2** and **6** ("U" arrangement), less impressive but still observable for the arrangement OH eq/CH_2OAr ax in **3** ("L" arrangement, see table 1b).

Thus, for all bicyclic carbinols **2**, **3** and **6** an axial configuration of $-CH_2OAr$ could be proved, the acetyl derivatives **4** and **7** were correlated with the corresponding carbinols by acetylation.

EXPERIMENTAL[5]

ISOLATION.—Fresh, air-dried roots (35–110 g) of five *Artemisia* and two *Achillea* species[6] (see Discussion) were separately cut into small pieces and extracted at room temperature in turn with petroleum ether (bp 60–80°)/ether (2:1) and ether for several days. Ether and petroleum ether were removed under reduced pressure and the combined, concentrated extract was roughly fractionated on a silica gel column eluted with petroleum ether/ether mixtures, with ether increasing from 0 to 100% and finally with 3–10% (v/v) methanol in ether. The coumarin derivative containing fractions (100% ether–10% methanol in ether) were detected by uv spectroscopy and separated by tlc on 1 mm thick layers of silica gel GF 254 (Merck) with ether/petroleum ether (4:1) or methylene chloride/ethanol (98.5:1.5) as solvent. Rf values in ether/petroleum ether (9:1), silica gel 60 F 254 (Merck): (**1**) 0.60, (**4**) 0.44, (**7**) 0.40, (**2**) 0.32, (**6**) 0.25, (**3**) 0.20.

LANTHANIDE INDUCED SHIFTS.—To determine the lis-values, increasing amounts of Eu(dpm)$_3$ [tris-(dipivalo-methanato)-europium, Merck] were added to a solution of 2–5 mg of substrate in 0.5 ml $CDCl_3$. The spectra were recorded at 4–6 different reagent concentrations up to a molar concentration ratio of reagent:substrate = 0.7:1.0; the lis for the 1:1 complex were obtained by extrapolation.

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[3]Eu(dpm)$_3$ is the reagent of choice for semiquantitative or quantitative considerations concerning polyfunctional or conformationally mobile compounds of this type since it is not too strongly coordinating: in carbinols **2**, **3** and **6**, the only (or highly dominant) coordination site at small reagent concentrations is the OH function. Complexation at the lactone carbonyl or at the $-OCH_3$ and $-CH_2-O-Ar$ ether oxygens may be neglected. So, in compound **1**, lacking the strongly coordinating carbinol oxygen, the observed lis are smaller and indicate about equal coordination at the lactone carbonyl and at the $-CH_2O-Ar$ ether oxygen (table 1b). For Eu(fod)$_3$, which is stronger but less selective in its complexing behaviour, no negative lis were observed for carbinol **2** (3) because, obviously, complexation at other possible coordination centers takes place.

[4]A detailed computational approach to the conformational analysis of these compounds is in progress (17).

[5]Melting points (uncorr.) were determined on a Kofler micro-hotstage. For determination of optical rotations a Perkin Elmer 141 polarimeter was used. Uv spectra were obtained with a Cary-15 spectrometer. For ir spectra, a Perkin Elmer 273 spectrometer was used. The 70 eV-EI-direct inlet mass spectra were recorded on a Varian MAT CH-7, the high resolution and FD-ms using the double focussing mass spectrometer MAT 311 A, both instruments being combined with a Varian 166 Spectra System. Nmr spectra were recorded on a Bruker WM 250-NMR spectrometer.

[6]Plant material was either cultivated under field conditions in the Botanical Garden of the University of Vienna (e.g. A-1604) or received from wild collections (W). Voucher specimens are deposited at the herbarium of the Institute of Botany, University of Vienna (WU).

FARNOCHROL (**1**), 6,8-DIMETHOXY-7-(3,7,11-TRIMETHYL-DODECA-2,6,10-TRIENOXY)-2H-1-BENZOPYRAN-2-ONE.—Roots (100 g) of *Artemisia vestita* (W) afforded 10 mg of **1**; 35 g roots of *Achillea ochroleuca* (A–1604) afforded 8 mg. It had the following properties: a colorless oil; ir (CCl_4): 2940, 1750, 1565, 1465, 1430, 1410, 1295, 1155, 1130, 1050, 985, 845 cm^{-1}; uv (λ max, EtOH): 340 (6 300), 295 (9 800), 228 (24 600 sh), 206 (57 000 sh); ms (70 eV, 50°, direct inlet): 426 (M^+, 0%), 220 (25), 206 (15), 205 (100), 177 (8), 145 (11), 105 (8), 95 (8), 91 (8); ms (FD): 426 (M^+, 100%), 222 (15), 221 (20), 220 (20), 202 (28), 200 (30); high resolution ms: calc. for $C_{26}H_{34}O_5$ 426.2305, found 426.231±0.002; ^{1}H-nmr and lis: see table 1.

DRIMARTOL A (**2**), (1α,4aα,6α,8aβ)-6,8-DIMETHOXY-7[(1,4,4a,5,6,7,8,8a-OCTAHYDRO-6-HYDROXY-2,5,5,8a-TETRAMETHYL-1-NAPHTHALENYL)METHOXY]-2H-1-BENZOPYRAN-2-ONE.—Roots (180 g) of *Artemisia pontica* (W) afforded 140 mg of **2**; 57 g roots of *Artemisia persica* (AR–929) afforded 45 mg; 110 g roots of *Artemisia gmelinii* (AR–807) afforded 25 mg; 135 g roots of *Artemisia abrotanum* (AR–561) gave 20 mg; 100 g roots of *Achillea pseudopectinata* (A–1074) yielded 12 mg; and 100 g roots of *Artemisia vestita* (W) afforded 8 mg. It exhibited the following properties: colorless crystals from ether; mp. 128–129° (Ref.(3) 129.5°); $[\alpha]^{21}_D$+185, $[\alpha]^{21}_{436}$+415 (c=0.6, acetone); ms (FD): 442 (M^+, 100%), 222 (4); ^{1}H-nmr and lis: see table 1.

DRIMARTOL B (**3**), (1α,4aα,6β,8aβ)-6,8-DIMETHOXY-7[(1,4,4a,5,6,7,8,8a-OCTAHYDRO-6-HYDROXY-2,5,5,8a-TETRAMETHYL-1-NAPHTHALENYL)METHOXY]-2H-1-BENZOPYRAN-2-ONE.—Roots (35 g) of *Achillea ochroleuca* (A–1604) afforded 220 mg of **3**. It had the following properties: Colorless crystals from ether, mp. 145–146°; $[\alpha]^{21}_D$−140, $[\alpha]^{21}_{436}$−330 (c=0.3, acetone); ir (CCl_4): 3630, 2930, 1740, 1555, 1455, 1430, 1410, 1290, 1150, 1130, 1040, 980, 840 cm^{-1}; uv (λ max, EtOH): 338 (7 000), 297 (9 900), 227 (17 500), 207 (36 600); ms (70 eV, 110°): 442 (M^+, 1%), 223 (25), 222 (100), 221 (6), 204 (11), 203 (66), 161 (11), 147 (20), 135 (11), 133 (23), 121 (19), 119 (29), 109 (25), 107 (28), 105 (21), 95 (39), 93 (21), 91 (17); ms (FD): 442 (M^+, 100%), 222 (6); high resolution ms: calc. for $C_{26}H_{34}O_6$ 442.2356, found 442.235±0.002; ^{1}H-nmr and lis: see table 1.

ACETYLDRIMARTOL B (**4**), (1α,4aα,6β,8aβ)-7-[(6-ACETYLOXY-1,4,4a,5,6,7,8,8a-OCTAHYDRO-2,5,5,8a-TETRAMETHYL-1-NAPHTHALENYL)METHOXY]-6,8-DIMETHOXY-2H-1-BENZOPYRAN-2-ONE.—Roots (35 g) of *Achillea ochroleuca* (A–1604) afforded 4 mg of **4**. It exhibited the following properties: Colorless crystals from petrol/ether; mp. 103–106°; $[\alpha]^{21}_D$−145, $[\alpha]^{22}_{436}$−365 (c=0.2, acetone); ir (CCl_4): 2925, 1745, 1560, 1455, 1425, 1405, 1290, 1145, 1125, 1040, 840 cm^{-1}; uv (λ max, EtOH): 339 (7 200), 297 (10 400), 227 (17 000), 206 (34 500); ms (70 eV, 110°): 484 (M^+, 2%), 223 (27), 222 (100), 221 (7), 204 (14), 203 (78), 202 (11), 161 (14), 147 (20), 135 (10), 133 (22), 121 (13), 119 (25), 109 (20), 107 (20), 105 (16), 95 (27), 93 (12), 91 (9); ^{1}H-nmr: see table 1.

The structure of **4** was confirmed by acetylation of **3**: To 1 mg of **3** was added 0.2 ml of acetic anhydride and the solution kept at 60° for 5 h. Evaporation of excess anhydride and prep. tlc yielded **4** which was compared by nmr, tlc and optical rotation with the natural product.

OXO-DERIVATIVES OF **2** AND **3** (**5**), (1α,4aα,8aβ)-6,8-DIMETHOXY-7[(1,4,4a,5,6,7,8,8a-OCTAHYDRO-2,5,5,8a-TETRAMETHYL-6-OXO-1-NAPHTHALENYL)METHOXY]-2H-1-BENZOPYRAN-2-ONE.—A mixture of 10 mg **2**, resp. **3**, and 50 mg CrO_3 in 2 ml of dry pyridine was stirred for 10 h at room temperature. Then 50 ml of ether and a sufficient amount of 2n-HCl was added to obtain an acidic aqueous layer. The ether layer was washed neutral, dried over $MgSO_4$, and the ether evaporated, and the oxo-product **5** was purified by tlc.

(+)-**5**: from **2**, yield 7 mg (70%); $[\alpha]^{21}_D$+140 (Ref. (3) +156.3), $[\alpha]^{21}_{436}$+390 (Ref. (3) +405) (c=0.5, $CHCl_3$); ^{1}H-nmr and ms in agreement with the data reported in (3).

(−)-**5**: from **3**, yield 8.5 mg (85%); $[\alpha]^{21}_D$−135, $[\alpha]^{21}_{436}$−375 (c=0.5, $CHCl_3$); ^{1}H-nmr and ms in agreement with the data reported in (3) and identical with the data for (+)-**5**.

PECTACHOL (**6**), (1α,4aα,6α,8aβ)-6,8-DIMETHOXY-7[(6-HYDROXY-DECAHYDRO-5,5,8a-TRIMETHYL-2-METHYLENE-1-NAPHTHALENYL)METHOXY]-2H-1-BENZOPYRAN-2-ONE.—Roots (100 g) of *Achillea pseudopectinata* (A–1074) afforded 18 mg of **6**. It had the following properties: Colorless crystals from ether; mp. 113–115°; $[\alpha]^{21}_D$−18, $[\alpha]^{21}_{436}$−47 (c=0.7, acetone); ir (CCl_4): 3640, 2920, 1740, 1555, 1455, 1420, 1405, 1285, 1145, 1120, 1040, 980, 840 cm^{-1}; uv (λ max, EtOH): 340 (7 300), 298 (10 000), 226 (20 400), 207 (42 000); ms (70 eV, 100°): 442 (M^+, 1%), 223 (23), 222 (100), 203 (31), 161 (8), 147 (13), 133 (11), 121 (10), 119 (11), 109 (13), 107 (17), 105 (11), 95 (21), 93 (16), 91 (21); ms (FD): 443 (37%), 442 (M^+, 100), 249 (11), 222 (5); high resolution ms: calc. for $C_{26}H_{34}O_6$ 442.2356, found 442.236±0.002; ^{1}H-nmr and lis: see table 1.

ACETYLPECTACHOL (**7**), (1α,4aα,6α,8aβ)-7-[(6-ACETYLOXY-DECAHYDRO-5,5,8a-TRIMETHYL-2-METHYLENE-1-NAPHTHALENYL)METHOXY]-6,8-DIMETHOXY-2H-1-BENZOPYRAN-2-ONE.—Roots (100 g) of *Achillea pseudopectinata* (A–1074) afforded 25 mg of **7**. It had the following properties: Colorless crystals from petroleum/ether; mp. 139–141°; $[\alpha]^{21}_D$−7, $[\alpha]^{21}_{436}$−24 (c=0.8, acetone); ir (CCl_4): 2930, 1750, 1560, 1460, 1420, 1405, 1290, 1240, 1150, 1125, 1040, 840 cm^{-1}; uv (λ max, EtOH): 338 (7 600), 296 (10 400), 227 (18 800), 206 (35 600); ms (70 eV, 100°): 484 (M^+, 2%), 223 (23), 222 (100), 203 (51), 202 (15), 161 (11), 147 (21), 133 (19), 121 (14), 119 (21), 109 (21), 107 (23), 105 (20), 95 (33), 93 (18), 91 (27); ms (FD): 485 (30%), 484 (M^+, 100), 222 (2); high resolution ms: calc for $C_{28}H_{36}O_7$ 484.2461, found 484.246±0.002; ^{1}H-nmr: see table 1a.

Acetylation of **6** (Ac_2O, 60°, 5 h, prep. tlc) yielded a product which was identical with natural **7** (nmr, $[\alpha]^{21}_D$).

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