Phytochemistry, 1970, Vol. 9, pp. 1615 to 1621. Pergamon Press. Printed in England

CONSTITUENTS OF *ARTEMISIA* AND *CHRYSANTHEMUM* SPECIES—THE STRUCTURES OF CHRYSARTEMINS A AND B*

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(*Received* 21 *October* 1969)

Abstract—The guaianolides matricarin (Ib) and desacetylmatricarin (Ia) have been found as constituents of *Artemisia klotzchiana*. The eudesmanolides arglanin (VIII) and douglanin (IXa) were isolated from *A. mexicana*. The new guaianolides chrysartemin A (II) and B (XIV) are constituents of *Chrysanthemum parthenium*. Chrysartemin A (II) was also found in *A. mexicana* and *A. klotzchiana*.

FOLLOWING our studies of sesquiterpenes found in the Compositae, we have examined the bitter herb *Artemisia klotzchiana*, which is widely distributed in the arid regions of the high plateau of Mexico. Chromatography of the extract of the plant yielded in the less polar fractions a product, m.p. 191–192°, identified by its spectral properties as matricarin (Ib)[1–3] (see Experimental). The polar fractions gave desacetylmatricarin (Ia),[4] m.p. 128°, identified by its transformation into matricarin (Ia) by acetylation.

A new lactone which we propose to name chrysartemin A was obtained from the more polar fractions of the chromatography. Chrysartemin A (II) has the composition $C_{15}H_{18}O_5$, m.p. 250°, $(\alpha)_D + 51°$. Its i.r. spectrum shows absorption at 3520 cm^{-1} (hydroxyl) and at 1770 and 1680 cm^{-1} (α-methylene-γ-lactone). The hydroxyl group of chrysartemin A (II) could not be acetylated with acetic anhydride–pyridine and was resistant to chromic acid oxidation. Three oxygen atoms of chrysartemin A (II) are located in a tertiary hydroxy group and the γ-lactone; the other two appear to be involved in heterocyclic rings. The u.v. spectrum of II exhibits a single maximum at 205 nm (ϵ, 9700), corresponding to the exocyclic methylene group conjugated with the γ-lactone. The NMR spectrum (in DMSO-d_6)‡ of chrysartemin A (II) shows signals for two protons of the exocyclic methylene group (doublets $J = 3$ Hz) at 5·96 and 5·50. The CH—O proton of the lactone grouping appears as a doublet of doublets centered at 4·47 ($J = 11·5$, 9·5) which in the guaianolide series is characteristic of a lactone closed at C-6. This proton is coupled with the C-5 hydrogen, the latter being responsible for a doublet ($J = 11$ Hz) centered at 2·24. Singlets at 1·38 and 0·90 are attributed to

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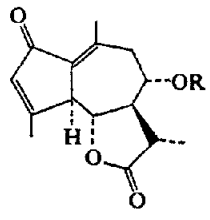
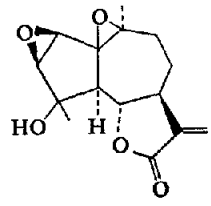
‡ NMR spectra were determined on Varian A-60A and HA-100 spectrometers in $CDCl_3$ solution (unless stated otherwise) using tetramethylsilane as internal standard. All chemical shifts are reported in ppm as δ values.

[1] Z. CEKAN, V. PROCHAZKA, V. HEROUT and F. SORM, *Collection Czech. Chem. Commun.* **24**, 1554 (1969).
[2] E. H. WHITE and E. K. WINTER, *Tetrahedron Letters* 137 (1963).
[3] E. H. WHITE and J. N. MARX, *J. Am. Chem. Soc.* **89**, 5511 (1967).
[4] W. H. HERZ Y K. UEDA, *J. Am. Chem. Soc.* **83**, 1139 (1961). See also F. SORM and L. DOLEJS, *Guaianolides and Germacranolides*, Chimie de Substances Naturelles, (edited by E. LEDERER), Herman, Paris (1966).

methyl groups attached to carbon atoms bearing an ethereal oxygen and a hydroxyl group, respectively, and doublets (1 H each, $J = 1$ Hz) at 3·42 and 3·25 are ascribed to protons attached to carbon atoms having an epoxide function. In the NMR spectrum of II (in $CDCl_3$) a signal at 4·77 corresponding to the hydroxyl proton disappeared after equilibration with deuterium oxide. Hydrogenation of chrysartemin A (II) in the presence of palladium on charcoal catalyst saturated the exocyclic methylene. The NMR spectrum of the resulting dihydroderivative (III) exhibited in the methyl region a doublet ($J = 7$ Hz) attributed to a secondary methyl group.



(I) *a*. R = H
b. R = Ac



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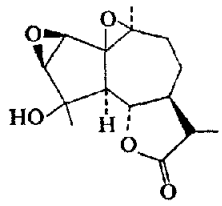
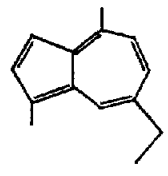
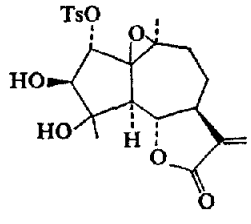


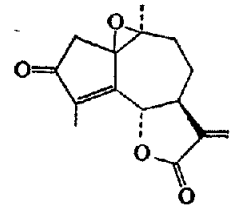
(III)



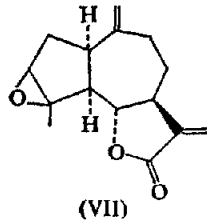
(IV)



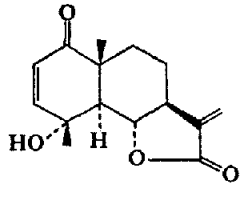
(V)



(VI)



(VII)



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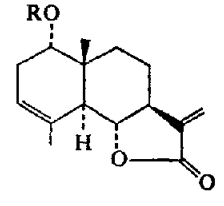
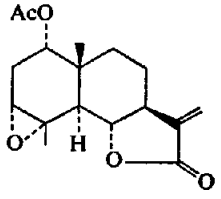


(IX) *a*. R = H
b. R = Ac

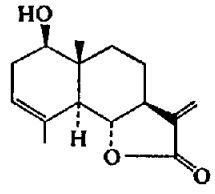
Aromatization of chrysartemin A (II) with palladium on charcoal afforded chamazulene (IV), characterized as its trinitrobenzene adduct. The properties of chrysartemin A (II) were therefore interpreted on the basis of a guaiane structure. Several attempts to prove the presence of epoxide groupings in chrysartemin A (II) were unsuccessful, until a mild treatment of a chloroformic solution of II with *p*-toluenesulfonic acid gave the *p*-toluenesulfonate V. Although this product was not analyzed, its NMR spectrum indicates that only 1 M of *p*-toluenesulfonic acid caused openings to an epoxide grouping, whose oxygen atom was attached to secondary carbons. The NMR spectrum of the derivative V showed the following signals: A pair of low field doublets (2 H each, $J = 9$ Hz) at 7·78 and at 7·32 (aromatic protons), three singlets at 2·42, at 1·12 and at 1·72 (aromatic, C-4 and C-10 methyl groups), two

doublets ($J = 2{\cdot}5$ Hz) at 6·20 and at 5·52 (exocyclic methylene) and two doublets ($J = 3$ Hz) at 4·78 and at 3·92 (C-2 and C-3 protons). A doublet of doublets ($J = 11$ Hz) centred at 4·31 and a doublet ($J = 11$ Hz) at 2·43, coupled between them (C-6 and C-5 hydrogens, respectively) and a sharp signal (2 H) at 4·07 which disappeared on equilibration with deuterium oxide (hydroxyl protons).

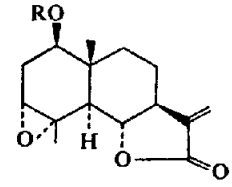
A pinacolic rearrangement took place by treatment of the *p*-toluenesulfonate V with formic acid. The structure VI of the resulting ketone was deduced from its spectral properties. The u.v. maximum at 243 nm (ϵ 10,800) is a composite of two chromophores: the cyclopentenone and the exocyclic methylene conjugated with the γ-lactone. The i.r. spectrum of the ketone VI showed a band at 1705 cm^{-1} corresponding to a cyclopentenone. The NMR



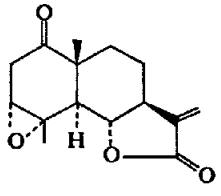
(X)



(XI)



(XII) *a*. R = H
b. R = Ac



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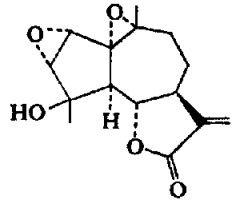
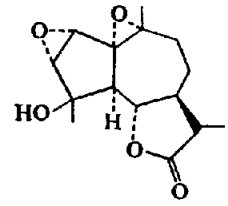
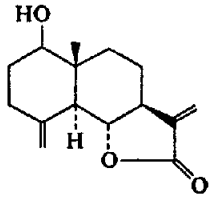


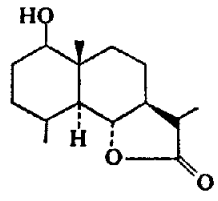
(XIV)



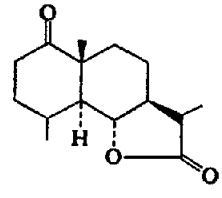
(XV)



(XVI)



(XVII)



(XVIII)

spectrum of VI exhibited a doublet ($J = 11$ Hz) centered at 4·46 assigned to the C-6 proton. Additional splitting of this signal ($J = 0{\cdot}5$ Hz) indicates long-range coupling with the vinyl methyl group, located at 1·98. A singlet at 1·44 is ascribed to the C-10 methyl group whereas the C-7 allylic proton is responsible for a multiplet centered at 3·08. Doublets ($J = 3$ Hz) at 6·29 and 5·57 correspond to the exocyclic methylene protons.

In a previous study of *A. mexicana* Willd, the guaianolide estafiatin (VII) was isolated.[1-3] Now we have found chrysartemin A (II) and the eudesmanolides arglanin (VIII)[4] and douglanin (IXa)[7,*] as minor constituents of this species. The latter was characterized by its acetate

* We are grateful to Dr. T. A. Geissman for samples of arglanin and douglanin acetate.

[5] F. Sánchez-Viesca and J. Romo, *Tetrahedron* **19**, 1285 (1963).
[6] S. Matsueda and T. A. Geissman, *Tetrahedron Letters* 2013 (1967).
[7] S. Matsueda and T. A. Geissman, *Tetrahedron Letters* 2159 (1967).

(IXb) and the epoxide X. It has been established before that douglanin (IXa)[7] differs from santamarin (XI)[8] in the stereochemistry of the hydroxyl group.[7] We have now carried out a correlation of santamarin (XI) with arglanin (VIII) in the following way: The previously described[8] epoxide XIIa derived from santamarine (XI), afforded the acetate XIIb. Chromium trioxide oxidation of the epoxide XIIa gave the dehydroderivative XIII whose i.r. spectrum showed two carbonyl bands at 1770 and at 1715 cm^{-1} corresponding to the γ-lactone and the cyclohexanone. The NMR spectrum of XIII exhibited a pair of low field doublets ($J = 3$ Hz) at 6·13 and at 5·48 (exocyclic methylene), a triplet ($J = 11$ Hz) centered at 4·03 (C-6 proton) coupled to a doublet ($J = 11$ Hz) at 2·18 (C-5 hydrogen), a multiplet at 3·26 (C-3 proton) and singlets at 1·60 and at 1·26 (C-4 and C-10 methyl groups).

Efforts to rearrange the ketoepoxide XIII under different acid conditions failed; the conversion of XIII into the unsaturated ketone was, however, achieved by treatment of a pyridine solution with *p*-toluenesulfonic acid. The resulting product (λ_{max} 212 nm; ϵ 10,800) showed in the i.r. spectrum a hydroxyl band at 3570 cm^{-1} and carbonyl bands at 1775 cm^{-1} (γ-lactone) and at 1680 cm^{-1} (cyclohexenone). The NMR spectrum showed a pair of doublets ($J = 10$ Hz) at 6·67 and at 5·90 (C-2 and C-3 vinylic protons), two doublets ($J = 3$ Hz) at 6·16 and at 5·52 (exocyclic methylene), a triplet centered at 4·18 (C-6 proton), a signal at 2·97 disappearing on equilibration with deuterium oxide (hydroxyl groups) and two singlets at 1·57 and 1·20 (C-4 and C-10 methyl groups). This product was identified as arglanin (VIII)[6] by direct comparison with an authentic specimen.

Chromatography of the extract of *Chrysanthemum parthenium* gave in the less polar fractions the known constituent santamarine (XI)[8] followed by chrysartemin A (II). From the more polar fractions of the chromatogram we isolated a lactone ($C_{15}H_{18}O_5$), m.p. 262–263°; $(\alpha)_D + 37°$; (λ_{max} 206 nm; ϵ 11,000), stereoisomeric with chrysartemin A (II), which we propose to name chrysartemin B. The structure (XIV) of this guaianolide was deduced from the close similarity of its spectral properties with those exhibited by chrysartemin A (II). The i.r. spectrum of XIV had a hydroxyl band at 3440 cm^{-1} and bands at 1750 and at 1670 cm^{-1} corresponding to an exocyclic methylene conjugated with a γ-lactone. Hydrogenation of XIV afforded the dihydro derivative XV.

The mass spectra* of chrysartemins A (II) and B (XIV) are very similar. Both gave the molecular ion at 278 *m/e*, the 100 per cent peak at 43 *m/e* and have identical fragmentation patterns, differing only in the intensity of peaks. The NMR spectrum of chrysartemin B (XIV) exhibits the same signals observed in the spectrum of chrysartemin A (II). When determined in DMSO-d_6, it showed a pair of low field doublets ($J = 3$ Hz) at 6·04 and 5·58 corresponding to the exocyclic methylene protons. The C-10 and C-4 methyl groups are responsible for two singlets at 1·42 and 0·94, respectively. A pair of doublets ($J = 1$ Hz) at 3·63 and at 3·40 are assigned to the C-2 and C-3 protons, a doublet of doublets ($J = 11$ Hz) centered at 3·93 is ascribed to the C-6 proton and a doublet ($J = 11$ Hz) centered at 2·91 corresponds to the C-5 proton. The large coupling constant exhibited by the signals corresponding to the C-5and C-6 protons in the NMR spectra of chrysartemins A (II) and B (XIV) indicates that in the two compounds the C-6 proton bears a *trans* relationship with both the C-5 and C-7 hydrogens. Assuming that the C-7 side-chain is *beta* oriented as happens in all the guaianolides of known configuration, both chrysartemins must possess the same stereochemistry at C-5 and C-6 as shown in the formulas II and XIV. Another interesting observa-

* The mass spectra were determined by Mr. E. Cortés on a Hitachi–Perkin–Elmer RMU-6D spectrometer at 70 eV.

[8] A. ROMO DE VIVAR and H. JIMÉNEZ, *Tetrahedron* **21**, 1741 (1965).

tion in respect to the signals corresponding to the C-5 and C-6 protons in the NMR spectra of both chrysartemins is the difference in chemical shifts. The signal assigned to the C-6 proton of chrysartemin A (II) is deshielded in respect to the same signal of chrysartemin B (XIV), suggesting that the epoxide group attached at C-1, C-10 is *beta* oriented in compound II. The chemical shift of the doublet ascribed to the C-5 proton indicates that the epoxide bonded to C-2, C-3 has also a *beta* configuration, since this signal shows similar chemical shifts as the same proton of many guaianolides. Whereas the chemical shifts of the C-5 and C-6 protons in the NMR spectrum of chrysartemin B (XIV) suggests that both epoxide groupings are *alpha* oriented, since now the C-6 proton signal appears at usual fields and the proton at C-5 is deshielded respect to the same signal of chrysartemin A (II). The validity of the epoxide deshielding effects are well known.[9] Irradiation experiments with chrysartemin A (II) indicate a 4 σ bond coupling between the C-3 and the C-4 methyl protons. The stereochemical requirements ("M" arrangement) of this type of coupling indicate that chrysartemin A (II) possesses a C-4 methyl group with a *beta* orientation.

From the mother liquors left after the crystallization of santamarine (XI), there was isolated a minor constituent. Chemical and spectroscopic evidence suggests that this sesquiterpene possesses the structure (XVI)* It analyzed for $C_{15}H_{20}O_3$, m.p. 146° (λ_{max} 208 nm; ϵ 12,000), and showed i.r. hydroxyl bands at 3520 and at 3610 cm^{-1}, γ-lactone at 1770 cm^{-1} and olefinic double bond at 1680 cm^{-1}. The NMR spectrum of this lactone had the following signals: a pair of doublets ($J = 3$ Hz) at 6·10 and at 5·46 (exocyclic methylene conjugated with the γ-lactone), two broad singlets with long-range coupling at 5·01 and at 4·89 (C-4 exocyclic methylene), a triplet ($J = 11$ Hz) centered at 4·06 (C-6 proton), a doublet of doublets centered at 3·53 (C-1 proton), a sharp signal at 2·04 which disappears upon addition of deuterium oxide (hydroxyl proton) and a singlet at 0·85 (tertiary methyl group)*. Chromium trioxide oxidation of the tetrahydro derivative of the above product gave a ketone. Its i.r. spectrum showed a band at 1705 cm^{-1} corresponding to a cyclohexanone.

EXPERIMENTAL

Melting points are uncorrected, u.v. spectra were measured in 95% ethanol solution and rotations were run in $CHCl_3$ unless noted otherwise. Analysis by Dr. F. Pascher, Bonn, Germany. The alumina used was Alcoa F-20 washed with EtOAc.

Extraction and Isolation of the Constituents of Artemisia klotzchiana†

A collection of 14 kg of the dried aerial parts of *A. klotzchiana*, collected in the vicinity of Actopan (estado de Hidalgo) in October 1967, was extracted with ethanol (24 l.) under reflux for 8 hr. The extract was concentrated to 3 l., treated with a solution of lead acetate (100 g) in water (3 l.), left at room temperature for 2 hr, filtered, diluted with water (3:1) and extracted with $CHCl_3$. The organic extract was evaporated to dryness and the residue dissolved in benzene–hexane (1:1) and chromatographed on alumina. The fractions eluted with benzene–hexane, 1:1, were combined and recrystallized from acetone–ether. This yielded 1·2 g of matricarin (Ib), m.p. 191–192°, $(\alpha)_D$ +16°; λ_{max} 255 nm; ϵ 15,900; ν_{max}: 1780 (γ-lactone), 1740 (acetate), 1690 (cyclopentenone), and 1645 and 1623 cm^{-1} (olefinic double bonds); NMR spectrum:[10] triplet at 6·15 (broad, 1 H, $J = 1$ Hz) vinylic proton, triplet of doublets centered at 4·90 (1 H, C-8 proton), triplet centered at 3·8 (1 H, $J = 10$ Hz, C-6 hydrogen), two singlets (3 H each) at 2·48 (broad, C-10 vinylic methyl group) and at 2·17 (acetate) and two doublets (3 H each) at 2·35 ($J = 1$ Hz) and at 1·37 ($J = 7$ Hz) C-7 vinylic methyl group and secondary methyl group respectively. (Found: C, 67·20; H, 6·65; O, 26·08. Calc. for $C_{17}H_{20}O_5$: C, 67·09; H, 6·62; O, 26·29%.)

* The scarcity of material precluded further study of this lactone.

† We are indebted to Dr. A. Gómez Pompa of the Instituto de Biología (UNAM) for the identification of the plants.

[9] K. Tori, K. Kitahouoki, Y. Takano, H. Tanida and T. Tsuji, *Tetrahedron Letters* 559 (1964).
[10] E. Díaz, P. Joseph-Nathan, A. Romo de Vivar and J. Romo, *Bol. Inst. Quím. Univ. Natl. Auton. Méx.* **17**, 122 (1965).

The crystalline fractions eluted with benzene were combined and recrystallized from acetone–hexane. This yielded desacetylmatricarin (Ia) (3·6 g), m.p. 128° (it resolidified and melted again at 145–146°); $(\alpha)_D$ +28°; λ_{max} 255 nm; ϵ 14,200; ν_{max}: 3400 (hydroxyl), 1780 (γ-lactone), 1690 (cyclopentenone), and 1645 and 1625 cm^{-1} (olefinic double bonds). (Found: C, 68·45; H, 6·99; O, 24·70. Calc. for $C_{15}H_{18}O_4$: C, 68·68; H, 6·92; O, 24·40%.) Acetylation of the above product with pyridine–acetic anhydride for 1 hr on the steam bath gave matricarin (Ib), m.p. 190–191°. Mixed m.p. with the product obtained in the less polar fractions of the chromatogram was undepressed and the i.r. spectra were superimposable.

The crystalline fractions eluted with benzene and increasing proportions of EtOAc afforded chrysartemin A (II) (740 mg), m.p. 250°; $(\alpha)_D$ +51°; λ_{max} 206 nm; ϵ 9700, ν_{max}: 3520 (hydroxyl), 1770 (γ-lactone) and 1680 cm^{-1} (olefinic double bond). (Found: C, 64·83; H, 6·45; O, 28·68. $C_{15}H_{18}O_5$ required: C, 64·73; H, 6·52; O, 28·75%.)

Dihydrochrysartemin A (III)

A solution of chrysartemin A (II) (300 mg) in EtOAc (60 ml) was hydrogenated with 5% Pd—C (70 mg) until the uptake of H_2 ceased. The solution was filtered and evaporated to dryness. Crystallization of acetone–ether afforded prisms, m.p. 225°; $(\alpha)_D$ +53°; ν_{max}: 3550 (hydroxyl), and 1775 cm^{-1} (γ-lactone). (Found: C, 64·49; H, 7·21; O, 28·11. $C_{15}H_{20}O_5$ required: C, 64·27; H, 7·19; O, 28·54%.)

Aromatization of Chrysartemin A (II)

A mixture of chrysartemin A (II) (360 mg) and 5% Pd—C (700 mg) in nujol (2 ml) was heated for 10 min at 300–305°, cooled, diluted with hexane, filtered and extracted with 85% H_3PO_4. The complex was decomposed with ice-water and extracted with hexane. The organic solution was washed with water, dried and chromatographed on alumina. The blue fraction was evaporated to dryness and converted into the TNB adduct. Repeated crystallizations from methanol afforded 15 mg of the adduct of chamazulene with TNB, m.p. 128–129°, identified by the standard methods with an authentic sample.

Ketone (VI)

Chrysartemin A (II) (570 mg) and *p*-toluenesulfonic acid (500 mg) in $CHCl_3$ were heated under reflux for 10 min (the suspended solid went into solution during the first minutes of reflux). The solution was washed with aq. $NaHCO_3$ and water, dried and evaporated to dryness *in vacuo*. The crude product (V) showed in the i.r. spectrum hydroxyl bands at 3550 and 3440 cm^{-1}, γ-lactone at 1760 cm,$^{-1}$ olefinic double bond at 1665 cm^{-1} and aromatic double bonds at 1600 cm^{-1}. It was dissolved in HCO_2H (20 ml), heated under reflux for 30 min and evaporated to dryness *in vacuo*. The residue dissolved in benzene–hexane (1 : 1) was chromatographed on alumina (10 g). The less polar fractions crystallized. Recrystallization from acetone–ether gave prisms (70 mg), m.p. 195–197°; $(\alpha)_D$ −247°; λ_{max} 212, 243 nm: ϵ 13,000, 10,800; ν_{max}: 1780 (γ-lactone), 1705 (cyclopentenone), and 1650 and 1620 cm^{-1} (olefinic double bonds). (Found: C, 69·02; H, 6·16; O, 24·53. $C_{15}H_{16}O_4$ required: C, 69·21; H, 6·20; O, 24·59%.)

Isolation of the Constituents of Artemisia mexicana

The plant (3·8 kg) was collected in August 1968 in the neighborhood of Mexico City and extracted as described for the previous case. Chromatography on alumina of the $CHCl_3$ extract afforded arglanin (VIII) (1·735 g), m.p. 202–204°; λ_{max} 212 nm; ϵ 11,500; ν_{max}: 3565 (hydroxyl), 1780 (γ-lactone), 1680 (α-β unsaturated cyclohexanone) and 1620 cm^{-1} (olefinic double bond). NMR spectrum: two doublets (J = 10 Hz) at 6·67 and 5·90 (AB system, vinylic protons at C-2 and C-3), two doublets (J = 3 Hz) at 6·16 and 5·52 (exocyclic methylene protons), a triplet (J = 11 Hz) centered at 4·18 (C-6 proton) and two singlets at 1·57 and 1·20 (C-4 and C-10 methyl groups, respectively). (Found: C, 68·73; H, 6·79; O, 24·50. Calc. for $C_{15}H_{18}O_4$: C, 68·68; H, 6·92; O, 24·40%.) Undepressed on admixture with an authentic specimen.[6,*] The i.r. spectra were superimposable.

The mother liquors left from the crystallization of arglanin (VIII) were combined, acetylated and chromatographed on alumina. The crystalline fractions were combined and recrystallized from acetone–hexane. This yielded douglanin acetate (IXb) (560 mg), m.p. 137°; $(\alpha)_D$ +26°; λ_{max} 208 nm; ϵ 10,600, ν_{max}: 1765 (γ-lactone), 1727 (acetate) and 1674 and 1620 cm^{-1} (olefinic double bonds). NMR spectrum: two doublets (J = 3 Hz) at 6·07 and 5·41 (2 H, exocyclic methylene protons) broad signals (1 H each), at 5·31 and 4·66 (C-1 and C-3 protons), two singlets at 2·07 and 0·92 (3 H each, acetate and C-10 methyl group) and a broad signal at 1·90 (3 H, vinylic methyl group). Undepressed on admixture with an authentic specimen.[1–3] The i.r. spectra were superimposable.

From another collection (September 1967) of *A. mexicana* (1·1 kg), estafiatin (VII)[1–3] (130 mg), m.p. 99–100°, and chrysartemin A (II), m.p. 245–247°, were obtained and identified with authentic specimens by the standard methods.

Isolation of the Constituents of Chrysanthemum parthenium

The plant (2 kg) was collected in February 1968 in Xochimilco, D. F., extracted with ethanol and processed as in the previous case. Chromatography of the $CHCl_3$ extract on alumina afforded in the less polar fractions santamarine (XI)[8] (2·76 g), m.p. 129–131°.

The mother liquors of the crystallization of santamarine (XI) were combined and repeated crystallization from acetone–isopropyl ether yielded the lactone XVI (150 mg), m.p. 146°; λ_{max} 208 nm; ϵ 12,000; ν_{max}: 3610 and 3520 (hydroxyl), 1770 (γ-lactone) and 1680 cm^{-1} (olefinic double bond). (Found: C, 72·48; H, 8·13; O, 19·51. $C_{15}H_{20}O_3$ required: C, 72·55; H, 8·12; O, 19·33%.)

Hydrogenation of Lactone (XVI)

A solution of XVI (250 mg) in EtOAc (15 ml) was hydrogenated in the presence of 5% Pd—C (60 mg) until the absorption of H_2 ceased. After work-up as usual, repeated crystallization from acetone–pentane gave the tetrahydroderivative (XVII), m.p. 158–160°; ν_{max} 3620 and 3510 (hydroxyl) and 1770 cm^{-1} (γ-lactone). (Found: C, 71·44; H, 9·73; O, 19·23. $C_{15}H_{24}O_3$ required: C, 71·39; H, 9·59; O, 19·02%.)

Chromium Trioxide Oxidation of XVII

A solution of XVII (150 mg) dissolved in acetone was oxidized with Jones' reagent until an orange colour persisted. The solution was diluted with EtOAc, washed with water, dried and evaporated to dryness. Crystallization from acetone–isopropyl ether gave the ketone XVIII, m.p. 162°, ν_{max}: 1760 (γ-lactone) and 1705 cm^{-1} (cyclohexanone). (Found: C, 71·81; H, 8·75; O, 19·30. $C_{15}H_{22}O_3$ required: C, 71·97; H, 8·86; O, 19·17%.)

Chrysartemin A (II) (180 mg) was obtained from the polar fractions of the chromatography of *C. partenium*. Crystallization from methanol–ether gave prisms, m.p. 248–249°, undepressed on admixture with an authentic specimen. The i.r. spectra were superimposable.

Chrysartemin B (XIV) (240 mg) was eluted from the most polar fraction of this chromatogram. Crystallization from methanol–ether gave prisms, m.p. 262–263°; $(\alpha)_D$ +37°; λ_{max} 206 nm; ϵ 11,000, ν_{max}; 3440 (hydroxyl), 1750 (γ-lactone) and 1670 cm^{-1} (olefinic double bond). (Found: C, 64·98; H, 6·52; O, 28·59. $C_{15}H_{18}O_5$ required: C, 64·73; H, 6·52; O, 28·75%.)

Dihydrochrysartemin B (XV)

A solution of the lactone XIII (200 mg) in methanol (20 ml) was hydrogenated in the presence of 5% Pd—C overnight. The solution was filtered and concentrated. Upon addition of ether, there crystallized the dihydroderivative XV (130 mg), m.p. 224–225°; $(\alpha)_D$ +38°; ν_{max}: 3600 and at 3475 cm^{-1} (hydroxyl) and 1760 cm^{-1} (γ-lactone). (Found: C, 64·29; H, 6·96; O, 28·47. $C_{15}H_{20}O_5$ required: C, 64·27; H, 7·19; O, 28·54%.)

Epoxide of Douglanin Acetate (X)

A solution of douglanin acetate (IXb) (200 mg) in $CHCl_3$ was treated with *m*-chloroperbenzoic acid (200 mg), heated under reflux for 2 hr, washed with aq. $NaHCO_3$ and water, dried and evaporated to dryness. Crystallization of the residue from acetone–ether yielded prisms (130 mg), m.p. 170–172°; $(\alpha)_D$ +16°; λ_{max} 209 nm; ϵ 7100; ν_{max}: 1765 (γ-lactone), 1725 (acetate) and 1670 cm^{-1} (olefinic double bond). (Found: C, 66·42; H, 7·27; O, 26·31. $C_{17}H_{22}O_5$ required: C, 66·55; H, 7·25; O, 26·11%.)

Epoxide of Santamarine Acetate (XIIb)

Acetylation of XIIa in Ac_2O–pyridine, afforded the acetate (XIIb), m.p. 178–179° (small prisms from acetone–ether); $(\alpha)_D$ +14°; λ_{max} 210 nm; ϵ 6400; ν_{max}: 1765 (γ-lactone), 1725 (acetate) and 1670 cm^{-1} (olefinic double bond). (Found: C, 66·46; H, 7·14; O, 25·95. $C_{17}H_{22}O_5$ required: C, 66·55; H, 7·24; O, 26·11%.)

Dehydrosantamarine Epoxide (XIII)

A solution of santamarine epoxide (XIIa) (1 g) in acetone (25 ml) was oxidized at 5° with Jones' reagent as above. Crystallization of the residue from acetone–isopropyl ether gave the ketoepoxide (XIII) (735 mg), m.p. 169°. Several crystallizations from acetone–hexane raised the m.p. to 180–182°; $(\alpha)_D$ +96°; λ_{max} 211 nm; ϵ 9200; ν_{max}: 1770 (γ-lactone), 1715 (cyclohexanone) and 1670 cm^{-1} (olefinic double bond). (Found: C, 68·55; H, 7·00; O, 24·25. $C_{15}H_{18}O_4$ required: C, 68·68; H, 6·92; O, 24·40%.)

Rearrangement of the Epoxiketone (XIII) into Arglanin (VIII)

A solution of the epoxiketone (XIII) (100 mg) in pyridine (4 ml) was treated with *p*-toluenesulfonic acid (30 mg), heated under reflux for 30 min and diluted with EtOAc. The organic solution was washed with dil. HCl, aq. $NaHCO_3$ and water, dried and evaporated to dryness. Crystallization of the residue from acetone–ether afforded arglanin (VIII) (50 mg), m.p. 199–202°; λ_{max} 212 nm; ϵ 10,800; ν_{max}; 3570 (hydroxyl), 1775 (γ-lactone), 1680 (cyclohexenone) and 1620 cm^{-1} (olefinic double bond). Identified with an authentic specimen[4,*] by standard methods.