Studies on the Constituents of Artemisia annua
Part II

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Abstract
The present paper is a continuation of our study on the Chinese traditional herb Artemisia annua L. [1—5], describing several additional constituents: quinghaosu IV and V (V, VII), quinghao acid (VIII) [6], chrysosplenol (VIa) [7] and a paraffinic alcohol; V, VII and VIII are compounds with unreported structures.

Introduction
A number of our earlier papers have been devoted to studies of chemical constituents isolated from Artemisia annua L. (Compositae), the most notable constituent being the antimalarial quinghaosu (I) [1—4], a peroxidic lactone with unique structure. Other constituents include quinghaosu-I-III (II-IV), a flavonol (VI), scopoletin and a few terpenes from the essential oil [5].

This paper deals with the isolation and characterization of V, VIa, VII, VIII and a paraffinic alcohol.

It is pertinent here to point out the close stereochemical kinship among the previously established structures I-IV. They all belong to the amorphane series (IX) [9], which has a cis decalin skeleton with the isopropyl group trans to the hydrogen on the ring juncture. Compounds I and IV are further distinguished by the presence of a modified seven-membered A-ring as the result of insertion of an extra ether oxygen.

1 For Part I, see ref. 5.
Results and Discussion

Qinghaosu-IV (V) is a colourless crystalline compound with m.p. 172–173°. MS molecular weight 282 (M+) agreed with C15H22O3. Hydroxy and lactonic carbonyl groups can be inferred from its IR spectrum (3450, 1728 cm⁻¹). The ¹H NMR spectrum displayed the following features: δ 0.95 (d, J = 6 Hz, 10-CH₃), 1.20 (d, J = 6, 11-CH₃), 1.65 (s, 4-CH₃), 3.20 (m, H-C-11), 3.60 (br, H-C-3), 5.60 (s, H-C-5) and an exchangeable OH group at 1.88. Except for the two signals at δ 1.88 and 3.60, the NMR spectra of IV and V are almost superposable, thus leading to the conclusion that the extra oxygen of V is in the form of a hydroxyl group with only four possible places (C-2, 3, 8 and 9) for its accommodation. Eu(fod)₃ was used for its allocation. Addition of successive aliquots of the shift reagent gave rise to linear changes of chemical shifts. In the case of qinghaosu III (IV), we have for 10-CH₃, δ 0.95 → 0.96 → 1.16 → 1.16; for 11-CH₃, 2.60 → 2.60 → 2.60; for 3-CH₅, 1.27 → 1.27 → 1.27; for 4-CH₃, 1.65 → 1.65 → 1.65; for H-C-3, 5.75 → 5.75 → 5.75; for H-C-5, 5.70 → 5.70 → 5.70; for 10-CH₃, 1.60 → 1.60 → 1.60. The marked shifts for 4-CH₃ and H-C-5 in compound V are compatible only with an OH group at position-3, and the W½ 6 Hz of the H-C-3 multiplet (hence equatorial) indicates an ω-orientation for the OH group (axial). The structure of IV has been firmly established by its preparation from qinghaosu (I) by catalytic hydrogenation [5].

Chrysosplenol (6a) has very similar UV and ¹H NMR spectra to eupatin (3, 5, 3′-triOH, 6, 7, 4′-triOMe) [7]. However, large discrepancies in m.p. of the acetates (155–157°, 219–221° for eupatin acetate) led us to a direct comparison of their IR spectra which also displayed conspicuous differences. The structure of chrysosplenol (VIa) was confirmed by the following facts. Methylation gave the hexamethyl ether, identical with an authentic specimen. The 5-OH showed a characteristic chelated NMR shift at δ 12.60. Methylation with CD₂N₂ in CH₃OH gave three partially deuterated methyl groups onto the original phenolic hydroxyls, and solvent shifts (benzene vs. chloroform [10]) revealed 5, 3′ and 4′ as the labelled positions. Further confirmation came from alkaline fusion of the ethylated derivative, whereby 3,4-diethoxybenzoic acid (m.p. and MS) was obtained.

Qinghaosu acid (VIII) forms colourless cubes with m.p. 131°, [α]D +36° (0.01, CHCl₃) and MS m/e 234 (M⁺), compatible with C₁₅H₂₂O₂. IR peaks at 3480–2590 (s, br), 1690 (s) and 1625 (m) are indicative of an α, β-unsaturated acid. These are borne out by ¹H NMR data, δ 0.83 (d, J = 6, 10-CH₃), 1.60 (m, CH₂), 4.94 (br, H-C-3), 5.54, 6.46 (br, 11 = CH₂)

and 11.56 (br, CO₂H). Irradiation of 4-CH₃ caused an NOE increase of H-C-5 by 40%. No NOE was found between H-C-5 and the endocyclic methylene hydrogens, presumably due to free rotation of the C₇ - C₁₁ bond.

Comparison with II or its LAH reduction product (IIa) showed that the olefinic signal of qinghao acid at 4.94 (W½ = 5.6 Hz) is much sharper (for 2 and 2a, we have δ 5.60 and 5.50, respectively, with W½ = 11 Hz, due to the coupling with two neighboring protons). Hence the endocyclic double bond of qinghao acid should be placed at C₄ and not C₃₄. Biogenetic considerations led to the proposal of VIII as the structure of qinghao acid.

Qinghaosu V (VII) has m.p. 125–126°, and a formula of C₁₅H₂₂O₃ from MS data. IR data (3420, 1700, 1630 cm⁻¹) showed the presence of OH and α, β-unsaturated lactone functionalities. The ¹H NMR spectrum showed two methyl groups at δ 0.85 (d) and 1.36 (s), and terminal methane protons at 5.56 (s) and 16.16 (s). The carboxylic hydrogen at C-5 (δ 3.82) is a doublet with J = 3, hence should be in cis relationship with the hydrogen on the ring juncture (C-6). Further studies have been thwarted by scantly supply of material, and the structure as shown by VII is thus tentatively proposed, leaning heavily on biogenetic considerations.

We also isolated a straight chain fatty alcohol, m.p. 74–76°, characterized by its IR and ¹H NMR spectra. The MS peak at m/e 392 (M-18) [11] showed it to be octacosanol (C₂₈H₅₇OH), probably contaminated by some C₃₀ alcohol (ca. 5%) as evidenced by a tiny peak at m/e 420. Further fragmentations of interest involved successive losses of 28 units from m/e 392, giving peaks at m/e 364 and 336. The last mentioned peak however was stronger than usual [11], indicating the possible contamination by a C₂₆ alcohol. ULBEBLEN et al. [12] reported the isolation of a C₂₆ alcohol from the same species, using elemental analysis as the main evidence. Since C₂₆ and C₂₈ alcohols cannot be adequately differentiated by elemental analysis, there is room for the possibility of their sample being also octacosanol.

Experimental

Melting points were not corrected. IR spectra were taken with KBr discs on an IR-S spectrometer. ¹H NMR spectra were taken with CDCl₃ solutions on WH-90, with TMS as the internal standard. MS were recorded with MM70–70H spectrometer.

Plant Material

Artemisia annua L. is a regular commodity, available in practically all warehouses for Chinese herbs. However, there might well be variations in chemical constituents with different localities, which were therefore specified below.

Silica gel columns and plates were used and eluted with the mixed solvent of petroleum ether and ethyl acetate in individually specified proportions.
Constituents of Artemisia annua

Qinghaosu-IV

Plant material from Sichuan Province was extracted with petroleum ether and the solvent removed. The crude extract was chromatographed. Qinghaosu-IV composed of only a single spot on TLC (1:1 mixed solvent, 2% phosphomolybdic acid spray). It was purified by recrystallization from ethanol. MS, m/e (%): 232 (M*, 5), 231 (1), 222 (75), 209 (1), 194 (11), 178 (14), 166 (18), 150 (23), 142 (9), 117 (1), 101 (1), 77 (2), 55 (39). IR (cm⁻¹): 3400 (s), 2985 (m), 1725 (s), 1465 (s), 1360 (m), 1220 (s). The mass spectrum showed only one peak of m/e 232, identical with those of other samples. After purification, the yield of Qinghaosu-IV was 9:1 proportion.

Qinghaosu acid

The crude acid was dissolved in a single spot on TLC (9:1 mixed solvent, 2% vanillin-H₂SO₄ spray). It was purified by recrystallization from petroleum ether. MS, m/e (%): 250 (M*, 24), 235 (7), 233 (6), 232 (15), 217 (7), 208 (18), 192 (18), 180 (15), 177 (10), 174 (8), 161 (11), 147 (15), 135 (16), 134 (12), 133 (13), 121 (15), 119 (15), 107 (26), 105 (19), 95 (27), 93 (27), 91 (31), 84 (13), 82 (23), 81 (28), 79 (28), 77 (20), 71 (35), 67 (25), 65 (10), 55 (32), 53 (30), 43 (100).

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References


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