Terpenoids from Roots of *Chloranthus spicatus*

by **Zhi-Yong Xiao**[a]), **Xia-Chang Wang**[a]), **Gui-Ping Zhang**[a]), **Zhong-Liang Huang**[b]), and **Li-Hong Hu***[a])

[a]) Shanghai Research Center for Modernization of Traditional Chinese Medicine, Shanghai Institute of Materia Medica, Chinese Academy of Sciences, 199 Guo Shou Jing Road, Shanghai 201203, P. R. China (phone: +86-21-50272221; fax: +86-21-50272221, e-mail: simmhulh@mail.shcnc.ac.cn)

[b]) Dinghushan Station, South China Botanical Garden, Chinese Academy of Sciences, Dinghushan, Zhaoqing 526070, Guangdong, P. R. China

Five new terpenoids, including four eudesmane-type sesquiterpenoids, **1**–**4**, and one labdane-type diterpenoid, **6**, together with ten known compounds, were isolated from the roots of *Chloranthus spicatus*. The structures and their relative configurations were mainly established by 1D- and 2D-NMR spectra, and MS experiments.

Introduction. – *Chloranthus spicatus* (THUNB.) MAKINO (Chloranthaceae) is a Chinese herbal medicine used in the treatment of numerous disorders such as ache, trauma, bone fracture, bleeding, and swellings [1]. In the course of searching for biologically active substances from traditional Chinese medicines, a series of sesquiterpenoids, dimeric sesquiterpenoids, and diterpenoids have been isolated from the genus *Chloranthus* [2–17]. The mono- and dimeric sesquiterpenoids were reported to show antifungal and tumor growth-inhibitory activities [2–6][13][16]. The present phytochemical investigation of the root extract of *C. spicatus* resulted in the isolation of four new eudesmane-type sesquiterpenoids, namely 4α-hydroxy-5α,8β(*H*)-eudesm-7(11)-en-8,12-olide (**1**), 4α-hydroxy-5α,8α(*H*)-eudesm-7(11)-en-8,12-olide (**2**), 4α,8β-dihydroxy-5α(*H*)-eudesm-7(11)-en-8,12-olide (**3**), and 4α-hydroxy-5α(*H*)-8β-methoxy-eudesm-7(11)-en-8,12-olide (**4**), and one new labdane-type diterpenoid, (12*S**,13*E*)-12-hydroxy-15-methoxylabda-8(17),13-dien-18-oic acid (**5**), together with ten known compounds **6**–**15** (*Fig.*). The new structures and their relative configurations were established mainly by 1D-, and 2D-NMR spectra, and MS experiments. The structures of the known compounds were confirmed by comparison with reported data.

Results and Discussion. – Compound **1** was obtained as a white, optically active powder. Its HR-ESI-MS indicated a molecular formula of $C_{15}H_{22}O_3$ from the peak at *m*/*z* 251.1651 ([*M* + H]$^+$, $C_{15}H_{23}O_3^+$, calc. 251.1647). The IR absorptions at 3448 and 1733 cm^{-1} revealed the presence of OH and C=O groups, respectively. The ^{13}C-NMR spectrum of **1** (*Table 1*) showed signals for three Me groups (δ(C) 22.5, 18.8, and 8.4), five CH_2 groups (δ(C) 50.8, 43.3, 40.3, 22.8, and 19.8), two CH groups (δ(C) 78.2 and 55.1), two quaternary C-atoms (δ(C) 72.1 and 35.8), one CO group (δ(C) 175.2), and a tetrasubstituted C=C bond (δ(C) 163.3 and 120.0). The NMR data of **1** were very similar to those of the known compound 1β,4α-dihydroxy-5α,8β(*H*)-eudesm-7(11)-en-

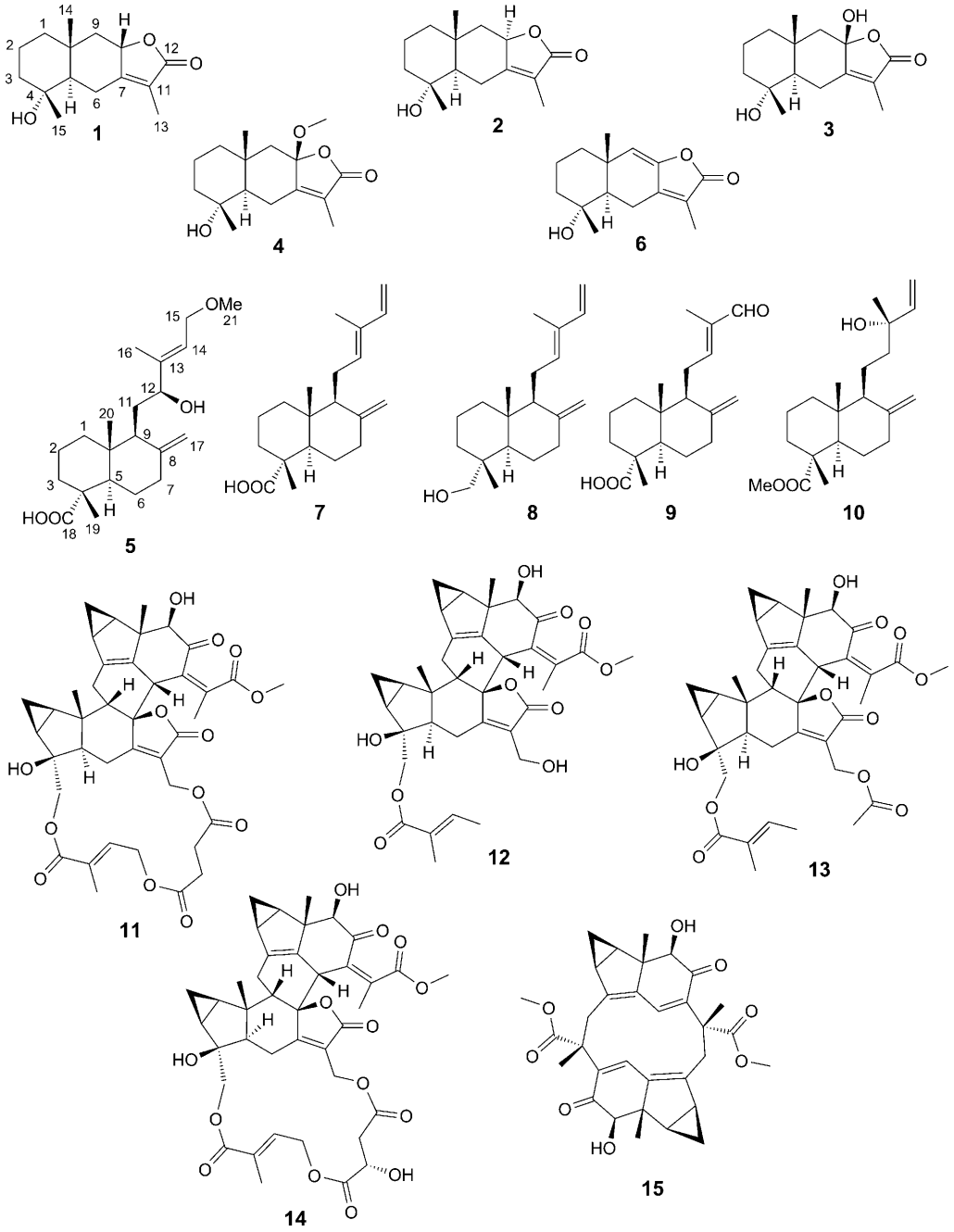

Figure. *The structures of compounds* **1**–**15**

8,12-olide, which was previously isolated from the same plant [18]. The difference between them emerged at C(1), showing up as CH_2 group in **1**, instead of the CH–OH group in the known compound. The structure of **1** was confirmed by the HMQC, HMBC, and ROESY spectra. In the HMBC spectrum, the long-range correlations from CH_2(2) (δ(H) 1.58–1.64 (*m*, 2 H)), CH_2(3) (δ(H) 1.34–1.38 and 1.84–1.88 (*m*, 2 H)), H–C(5) (δ(H) 1.29 (*dd*, J = 3.6, 13.5, 1 H)), and Me(15) (δ(H) 1.22 (*s*, 3 H)) to C(4) (δ(C) 72.1) led to the assignment of HO–C(4). The assignment of a C(7)=C(11) bond was supported by the presence of the corresponding correlations of CH_2(6) to C(7) and C(11). The CO group (δ(C) 175.2) is located at C(12) due to the correlation between Me(13) (δ(H) 1.83 (br. *s*, 3 H)) to C(12). The linkage of C(8) and C(12) *via* an O-atom to form a five-membered γ-lactone was confirmed through the severe downfield chemical shift of H–C(8) at δ(H) 4.80 [18]. The relative configuration of **1** was determined on the basis of its ROESY spectrum. The observation of the ROESY correlations Me(14)/Me(15), Me(14)/H_β–C(6), Me(14)/H_β–C(8), Me(15)/H_β–C(6), and H_β–C(8)/H_β–C(6) indicated that Me(14), Me(15), and H–C(8) are all in the axial position, and were assigned β-configuration as shown in the *Figure*. Compound **1** was, therefore, elucidated as 4α-hydroxy-5α,8β(*H*)-eudesm-7(11)-en-8,12-olide.

Table 1. *^{1}H- and ^{13}C-NMR Data of* **1** *and* **2**. At 300 and 75 MHz, resp., in $CDCl_3$; δ in ppm, J in Hz.

Position	**1**		**2**	
	δ(H)	δ(C)[a])	δ(H)	δ(C)[a])
CH_2(1)	1.15–1.19 (*m*), 1.50–1.56 (*m*)	40.3 (*t*)	1.16–1.18 (*m*), 1.58–1.62 (*m*)	42.7 (*t*)
CH_2(2)	1.58–1.64 (*m*)	19.8 (*t*)	1.59–1.66 (*m*)	20.6 (*t*)
CH_2(3)	1.34–1.38 (*m*), 1.84–1.88 (*m*)	43.3 (*t*)	1.36–1.40 (*m*), 1.81–1.87 (*m*)	43.5 (*t*)
C(4)		72.1 (*s*)		72.6 (*s*)
H–C(5)	1.29 (*dd*, J=3.6, 13.5, H_α)	55.1 (*d*)	1.38 (overlapped, H_α)	48.3 (*d*)
CH_2(6)	3.10 (*dd*, J=3.6, 13.8, H_α), 2.15 (br. *t*, J=13.5, H_β)	22.8 (*t*)	2.86 (*m*, H_α), 2.56 (*m*, H_β)	22.5 (*t*)
C(7)		163.3 (*s*)		162.8 (*s*)
H–C(8)	4.80 (*dd*, J=6.3, 10.8, H_β)	78.2 (*d*)	4.98 (*m*, H_α)	77.5 (*d*)
CH_2(9)	1.37 (overlapped, H_α), 2.19 (*dd*, J=6.3, 11.7, H_β)	50.8 (*t*)	1.42 (overlapped, H_α), 2.20 (*m*, H_β)	47.3 (*t*)
C(10)		35.8 (*s*)		35.3 (*s*)
C(11)		120.0 (*s*)		121.4 (*s*)
C(12)		175.2 (*s*)		175.5 (*s*)
Me(13)	1.83 (br. *s*)	8.4 (*q*)	1.83 (br. *s*)	8.6 (*q*)
Me(14)	1.06 (*s*)	18.8 (*q*)	0.76 (*s*)	22.8 (*q*)
Me(15)	1.22 (*s*)	22.5 (*q*)	1.26 (*s*)	23.6 (*q*)

[a]) Multiplicities from DEPT experiments.

Compound **2** was obtained as a white, optically active powder. Its HR-ESI-MS indicated a molecular formula of $C_{15}H_{22}O_3$ from a peak at *m*/*z* 251.1650 ($[M+H]^+$, $C_{15}H_{23}O_3^+$; calc. 251.1647), which was same as that of compound **1**. The ^{1}H- and ^{13}C-NMR spectra of **2** (*Table 1*) exhibited similar chemical shifts and the same

multiplicities of all C-atoms as in **1**, with minor differences, suggesting that compound **2** has an eudesmane-type backbone with the same substitution pattern as compound **1**. In the ROESY spectrum, the correlations Me(14)/Me(15), Me(14)/H_β–C(6), and Me(15)/H_β–C(6) indicated that Me(14) and Me(15) are in β-configuration, while H–C(8) is α-configurated. Compound **2** was thus elucidated as 4α-hydroxy-5α,8α(*H*)-eudesm-7(11)-en-8,12-olide.

Compound **3** was obtained as a white, optically active powder. Its HR-ESI-MS indicated a molecular formula of $C_{15}H_{22}O_4$ from a peak at *m*/*z* 289.1419 ($[M + Na]^+$, for $C_{15}H_{22}NaO_4^+$; calc. 289.1416). The IR spectrum revealed the presence of OH and C=O groups, characterized by absorptions at 3561, 3378, and 1726 cm^{-1}. Comparison of the ^{1}H- and ^{13}C-NMR data of **3** (*Table 2*) with those of **1** and **2**, and those of other eudesmane-type sesquiterpenoids established the presence of the same backbone, but with two OH groups in compound **3** [4][12][18]. The structure of **3** was confirmed by the HMQC, HMBC, and ROESY spectra. In the HMBC spectrum, the long-range correlations from HO–C(4) (δ(H) 4.22 (*s*, 1 H)) to C(3) (δ(C) 42.4), C(4) (δ(C) 70.3), C(5) (δ(C) 56.6), and C(15) (δ(C) 22.4) led to the assignment of HO–C(4); the long-range correlations from HO–C(8) (δ(H) 6.99 (*s*, 1 H)) to C(7) (δ(C) 162.6), C(8) (δ(C) 103.9), and C(9) (δ(C) 54.3) led to the assignment of HO–C(8). The relative configuration of **3** was determined on the basis of its ROESY spectrum. The observation of ROESY correlations Me(14)/H_β–C(6), Me(14)/HO_β–C(8), H_β-C(6)/HO_β–C(8), HO_α–C(4)/H_α–C(5), HO_α–C(4)/H_α–C(6), and H_α–C(5)/H_α–C(6)

Table 2. *^{1}H- and ^{13}C-NMR Data of* **3** *and* **4**. At 300 and 75 MHz, resp., in (D_6)DMSO; δ in ppm, *J* in Hz.

Position	**3**		**4**	
	δ(H)	δ(C)[a]	δ(H)	δ(C)[a]
CH_2(1)	0.99–1.01 (*m*), 1.36–1.41 (*m*)	40.4 (*t*)	0.99–1.01 (*m*), 1.38–1.42 (*m*)	40.1 (*t*)
CH_2(2)	1.46–1.47 (*m*), 1.48–1.50 (*m*)	19.2 (*t*)	1.46–1.48 (*m*), 1.49–1.54 (*m*)	19.2 (*t*)
CH_2(3)	1.20–1.26 (*m*), 1.63–1.67 (*m*)	42.4 (*t*)	1.24–1.28 (*m*), 1.63–1.67 (*m*)	42.3 (*t*)
C(4)		70.3 (*s*)		70.2 (*s*)
H–C(5)	1.17 (*dd*, *J* = 2.4, 12.9, H_α)	56.6 (*d*)	1.18 (br. *d*, *J* = 12.9, H_α)	56.5 (*d*)
CH_2(6)	2.93 (*dd*, *J* = 2.4, 12.9, H_α), 2.06 (br. *t*, *J* = 12.9, H_β)	21.2 (*t*)	2.97 (br. *d*, *J* = 12.9, H_α), 1.99 (br. *t*, *J* = 12.9, H_β)	21.5 (*t*)
C(7)		162.6 (*s*)		160.6 (*s*)
C(8)		103.9 (*s*)		106.2 (*s*)
CH_2(9)	1.28 (*d*, *J* = 12.9, H_α), 2.06 (*d*, *J* = 12.9, H_β)	54.3 (*t*)	1.30 (*d*, *J* = 13.2, H_α), 2.11 (*d*, *J* = 13.2, H_β)	53.2 (*t*)
C(10)		35.0 (*s*)		35.0 (*s*)
C(11)		119.5 (*s*)		122.6 (*s*)
C(12)		171.8 (*s*)		171.1 (*s*)
Me(13)	1.70 (*s*)	8.0 (*q*)	1.76 (*s*)	8.0 (*q*)
Me(14)	1.06 (*s*)	19.1 (*q*)	1.01 (*s*)	18.9 (*q*)
Me(15)	1.06 (*s*)	22.4 (*q*)	1.06 (*s*)	22.5 (*q*)
HO–C(4)	4.22 (*s*)		4.33 (*s*)	
HO–C(8)	6.99 (*s*)			
MeO–C(8)			3.03 (*s*)	49.8 (*q*)

[a]) Multiplicities from DEPT experiments.

revealed that Me(14), Me(15), and HO–C(8) are on the same face of the molecule, and were assigned β-configuration as shown in the *Figure*. Compound **3** was, therefore, elucidated as 4α,8β-dihydroxy-5α(*H*)-eudesm-7(11)-en-8,12-olide.

Compound **4** was obtained as a white, optically active powder. Its HR-ESI-MS indicated a molecular formula of $C_{16}H_{24}O_4$ from the signal at *m/z* 303.1576 ($[M + Na]^+$, $C_{16}H_{24}NaO_4^+$; calc. 303.1572). Besides, there was a MeO signal in **4**, and the ^{1}H- and ^{13}C-NMR spectra of **4** (*Table 2*) showed similar chemical shifts and the same multiplicities for most of the H- and C-atoms as for **3**, indicating that **4** is the *O*-methylated derivative of **3**. This was confirmed by HMBC experiments. Compound **4** was thus elucidated as 4α-hydroxy-5α(*H*)-8β-methoxy-eudesm-7(11)-en-8,12-olide.

Compound **5** was obtained as colorless, optically active oil. Its HR-ESI-MS indicated a molecular formula of $C_{21}H_{34}O_4$ from the signal at *m/z* 373.2387 ($[M + Na]^+$, $C_{21}H_{34}NaO_4^+$; calc. 373.2355). The ^{1}H-NMR spectrum of **5** (*Table 3*) showed signals for an allylic alcohol moiety, $R_2C{=}CHCH_2OH$, as characterized by the olefinic H-atom signal at δ(H) 5.45 (*t*, $J = 6.9$, 1 H), the secondary alcohol resonances appearing at δ(H) 3.98 (br. *d*, $J = 6.9$, 2 H), an exocyclic C=C bond at δ(H) 4.69 (*s*) and 4.81 (*s*), and three *singlet* Me groups at δ(H) 0.72, 1.13, and 1.65. By analysis of the ^{13}C-NMR spectrum of **5** and comparison with the literature [19], **5** was assigned as (13*E*)-12-hydroxy-15-methoxylabda-8(17),13-dien-18-oic acid, which was further con-

Table 3. *^{1}H- and ^{13}C-NMR Data of* **5**. At 400 and 100 MHz, resp., in $CDCl_3$; δ in ppm, *J* in Hz.

	δ(H)	δ(C)[a])	HMBC[b])	NOE correlations from ROESY[c])
CH_2(1)	1.03 (*m*), 1.76 (*m*)	38.0 (*t*)	2, 3, 5, 9, 10, 20	2, 3, 5, 9, 20
CH_2(2)	1.60 (*m*)	18.6 (*t*)	1, 3, 4, 10	1, 3, 19, 20
CH_2(3)	1.60 (*m*), 1.74 (*m*)	37.2 (*t*)	1, 2, 4, 5, 18, 19	1, 5, 19
C(4)		47.7 (*s*)		
H–C(5)	1.89 (*dd*, J = 3.3, 12.3)	49.7 (*d*)	1, 3, 4, 6, 7, 9, 10, 18, 19, 20	1, 3, 6, 7, 9
CH_2(6)	1.33 (*m*), 1.45 (*m*)	26.9 (*t*)	4, 5, 7, 8, 10	5, 7, 19, 20
CH_2(7)	1.96 (br. *d*, J = 14.2), 2.31 (br. *d*, J = 14.2)	38.0 (*t*)	5, 6, 8, 9, 17	5, 6, 9, 17
C(8)		148.2 (*s*)		
H–C(9)	1.52 (*m*)	53.1 (*d*)	1, 5, 7, 8, 10, 11, 12, 17, 20	1, 5, 7, 11, 12, 17
C(10)		38.9 (*s*)		
CH_2(11)		28.2 (*t*)		9, 12, 17, 20
H–C(12)	4.15 (*t*, J = 6.9)	77.2 (*d*)	9, 11, 13, 14, 16	9, 11, 14, 16, 17
C(13)		140.7 (*s*)		
H–C(14)	5.45 (*t*, J = 6.9)	124.9 (*d*)	12, 13, 15, 16	12, 14, 21
CH_2(15)	3.98 (br. *d*, J = 6.9)	68.8 (*t*)	13, 14, 21	14, 16, 21
Me(16)	1.65 (*s*)	10.8 (*q*)	12, 13, 14	12, 15
CH_2(17)	4.69 (*s*), 4.81 (*s*)	107.6 (*t*)	7, 8, 9	7, 9, 11, 12
C(18)		184.8 (*s*)		
Me(19)	1.13 (*s*)	16.5 (*q*)	3, 4, 5, 18	2, 3, 6, 20
Me(20)	0.72 (*s*)	15.0 (*q*)	1, 5, 9, 10	1, 2, 6, 11, 19
Me(21)	3.35 (*s*)	58.3 (*q*)	15	14, 15

[a]) Multiplicities from DEPT and HMBC experiments. [b]) The H-atom showing long-range correlation with indicated C-atoms. [c]) The H-atom showing correlation with indicated H-atom.

firmed by HMQC, HMBC, and ROESY experiments. The MeO group (δ(C) 58.3) was located at C(15) due to the long-range correlations from the H-atom signal at δ(H) 3.35 (*s*, Me(21)) to the C-atom signal at δ(C) 124.9 (C(14)) and 68.8 (C(15)) in the HMBC spectrum. The observation of ROESY correlations Me(19)/Me(20) and Me(20)/CH_2(11) revealed that Me(19), Me(20), and CH_2(11) are on the same face of the molecule, and were assigned β-configuration as shown in the *Figure*. The signal correlations observed between H–C(12), and H–C(14), H–C(15), and Me(16) in the ROESY spectrum were indicative of a (13*E*) configuration for **5**. Compound **5**, exhibiting signals for CH_2(17) at δ(H) 4.69 and 4.81, is suggested to have (12*S*)-configuration, which was confirmed in the literature [19][20]. Thus, the structure of compound **5** was determined as (12*S*, 13*E*)-12-hydroxy-15-methoxylabda-8(17),13-dien-8-oic acid.

Furthermore, a known eudesmane-type sesquiterpene, shizukalidol (**5**) [2], four known labdane-type diterpenes, *i.e.*, labdan-8(17),12,14-trien-18-oic acid (**7**) [21], labdan-8(17),12,14-trien-18-ol (**8**) [21], (12*E*)-15-nor-14-oxolabda-8(17),12-diene-18-oic acid (**9**) [22], and 13β-hydroxylabda-8(17),14-dien-18-oic acid methyl ester (**10**) [23], and five known lindenane sesquiterpene dimers, *i.e.*, shizukaol B (**11**) [15], shizukaol C (**12**) [15], chlorahololide D (**13**) [8][24], shizukaol G (**14**) [25], and cycloshizukaol A (**15**) [14] were identified by comparison of their spectroscopic data with literature values.

Experimental Part

General. All solvents used were of anal. grade and purchased from the *Shanghai Chemical Plant*, Shanghai, P. R. China. *Sephadex LH-20* (25–100 μm) was purchased from *Pharmacia*. *MCI* gel *CHP 20P* (75–150 μm) was purchased from *Mitsubishi Chemical Ind.*, Tokyo, Japan. *RP-18* (20–45 μm) was purchased from *Fuji Silysia Chemical Ltd.* SiO_2 (200–300 mesh) for column chromatography (CC) was purchased from *Qingdao Marine Chemical Ltd.*, Qingdao, P. R. China. SiO_2 Plates (*GF-254*) for TLC were purchased from *Yantai Huiyou Inc.*, Yantai, P. R. China. HPLC: *Waters 2695 SeparationModule* equipped with a *Waters 2996* photodiode array detector and a *Kromacil* C18 column (4.6 × 150 mm, 0.5 μm). Optical rotations: *Perkin-Elmer 341* polarimeter. IR Spectra: *Nicolet* FTIR 750 spectrophotometer; in cm^{-1}. ^1H- and ^{13}C- NMR, ^1H,^1H-COSY, DEPT, HMQC, HMBC, and ROESY spectra: at 300 MHz for ^1H, at 100 MHz for ^{13}C, and at 600 MHz for ROESY with *Bruker* AMX-300/400/600 instruments in $CDCl_3$ or (D_6)DMSO soln. HR-ESI-MS: *Micromass Q-Tof Global* mass spectrometers. ESI-MS: *Bruker Esquire 3000^{plus}* spectrometer.

Plant Material. The roots of *C. spicatus* were collected from Dinhushan Mount, Zhaoqing City, Guangdong Province, P. R. China, in November 2007, and identified by Prof. *Zhong-Liang Huang* (South China Botanical Garden, Chinese Academy of Sciences). A voucher sample (20071130) was deposited with the South China Botanical Garden, Chinese Academy of Sciences, Zhaoqing, Guangdong, China.

Extraction and Isolation. Dried and powdered roots of *C. spicatus* (2.9 kg) were extracted with MeOH (3 × 10 l) at 70° and afforded 212 g of extract after evaporation under vacuum at 45°. The extract was suspended in H_2O and then partitioned with AcOEt to afford the AcOEt solubles (67 g). The AcOEt solubles were then subjected to a column of *MCI* gel eluted with 30, 50, 70, and 90% aq. MeOH, and 25 g of the 70% aq. MeOH fraction was separated on a SiO_2 column eluted with petroleum ether (PE)/AcOEt 9:1–3:7 to yield nine fractions, *Frs. I–IX*. *Fr. I* (5.8 g) was chromatographed on an *RP-18* column, using 80% aq. MeOH, to yield compound **7** (990 mg). *Fr. II* (2 g) was subjected to *RP-18* (80% aq. MeOH) column to yield compounds **8** (30 mg) and **10** (17 mg). *Fr. V* (1.6 g) was first subjected to a SiO_2 column with PE/acetone 9:1, then separated further on *RP-18* (68% aq. MeOH) column to yield compound **9** (70 mg). *Fr. VI* (0.7 g) was recrystallized from acetone to give **6** (138 mg). *Fr. VII* (3.7 g) was first subjected to a SiO_2 column with PE/acetone 8:2, then separated further on *RP-18* (45% aq. MeOH)

column to yield compounds **1** (26 mg), **2** (10 mg), **3** (45 mg), **4** (165 mg), **5** (16 mg), **13** (45 mg), and **15** (30 mg). *Fr. VIII* (2.5 g) was subjected to SiO_2 column with PE/acetone 7:3 to afford compounds **11** (300 mg), **12** (190 mg), and **14** (33 mg).

*4α-Hydroxy-5α,8β(*H*)-eudesm-7(11)-en-8,12-olide* (*=(4a*R**,5*R**,8a*R**,9a*S**)-4a,5,6,7,8,8a,9,9a-Octahydro-5-hydroxy-3,5,8a-trimethylnaphtho[2,3-*b*]furan-2(4*H*)-one*; **1**). White powder. $[\alpha]_D^{20} = -34$ ($c = 0.3$, MeOH). IR: 3448, 2923, 1733, 1677, 1382, 1326, 1101, 1029. ^{1}H- and ^{13}C-NMR: *Table 1*. ESI-MS: 251.1 ($[M + H]^+$). HR-ESI-MS: 251.1651 ($[M + H]^+$, $C_{15}H_{23}O_3^+$; calc. 251.1647).

*4α-Hydroxy-5α,8α(*H*)-eudesm-7(11)-en-8,12-olide* (*=(4a*R**,5*R**,8a*R**,9a*R**)-4a,5,6,7,8,8a,9,9a-Octahydro-5-hydroxy-3,5,8a-trimethylnaphtho[2,3-*b*]furan-2(4*H*)-one*; **2**). White powder. $[\alpha]_D^{20} = +76.3$ ($c = 0.35$, MeOH). IR: 3430, 2931, 2869, 1735, 1679, 1448, 1386, 1330, 1105, 1027. ^{1}H- and ^{13}C-NMR: *Table 1*. ESI-MS: 251.1 ($[M+H]^+$). HR-ESI-MS: 251.1650 ($[M+H]^+$, $C_{15}H_{23}O_3^+$; calc. 251.1647).

*4α,8β-Dihydroxy-5α(*H*)-eudesm-7(11)-en-8,12-olide* (*=(4a*R**,5*R**,8a*R**,9a*S**)-4a,5,6,7,8,8a,9,9a-Octahydro-5,9a-dihydroxy-3,5,8a-trimethylnaphtho[2,3-*b*]furan-2(4*H*)-one*; **3**). White powder. $[\alpha]_D^{20} = -48$ ($c = 0.3$, MeOH). IR: 3561, 3378, 2935, 1726, 1685, 1430, 1326, 1126. ^{1}H- and ^{13}C-NMR: *Table 2*. ESI-MS: 289.2 ($[M + Na]^+$). HR-ESI-MS: 289.1419 ($[M + Na]^+$, $C_{15}H_{22}NaO_4^+$; calc. 289.1416).

*4α-Hydroxy-5α(*H*)-8β-methoxyeudesm-7(11)-en-8,12-olide* (*=(4a*R**,5*R**,8a*R**,9a*S**)-4a,5,6,7,8,8a,9,9a-Octahydro-5-hydroxy-9a-methoxy-3,5,8a-trimethylnaphtho[2,3-*b*]furan-2(4*H*)-one*; **4**). White powder. $[\alpha]_D^{20} = -74$ ($c = 0.3$, MeOH). IR: 3482, 2939, 2856, 1747, 1689, 1448, 1319, 1188, 1155, 1103. ^{1}H- and ^{13}C-NMR: *Table 2*. ESI-MS: 583.3 ($[2M + Na]^+$). HR-ESI-MS: 303.1576 ($[M + Na]^+$, $C_{16}H_{24}NaO_4^+$; calc. 303.1572).

*(12*S*,13*E*)-12-Hydroxy-15-methoxylabda-8(17),13-dien-18-oic acid* (*=(1*R**,4a*R**,5*S**,8a*R**)-5-[(2*S*,3*E*)-Decahydro-2-hydroxy-5-methoxy-3-methylpent-3-en-1-yl]-1,4a-dimethyl-6-methylidenenaphthalene-1-carboxylic acid*; **5**). Colorless oil. $[\alpha]_D^{20} = +14$ ($c = 0.2$, $CHCl_3$). IR: 3426, 2921, 2850, 1699, 1639, 1461, 1384, 1168, 1078. ^{1}H- and ^{13}C-NMR: *Table 3*. ESI-MS: 373.3 ($[M + Na]^+$). HR-ESI-MS: 373.2387 ($[M + Na]^+$, $C_{21}H_{34}NaO_4^+$; calc. 373.2355).

REFERENCES

[1] Editorial Committee of the Administration Bureau of Traditional Chinese Medicine, *Zhonghua Benchao* **1998**, *3*, 451.
[2] B. Wu, S. He, Y.-J. Pan, *Tetrahedron Lett.* **2006**, *48*, 453.
[3] B. Wu, S. He, X.-D. Wu, D.-K. Wu, Y.-J. Pan, *Helv. Chim. Acta* **2007**, *90*, 1586.
[4] B. Wu, S. He, X.-D. Wu, D.-K. Wu, Y.-J. Pan, *Planta Med.* **2006**, *72*, 1334.
[5] B. Wu, S. He, X.-D. Wu, D.-K. Wu, Y.-J. Pan, *Chem. Biodiversity* **2008**, *5*, 1298.
[6] Y.-J. Xu, C.-P. Tang, C.-Q. Ke, J.-B. Zhang, H.-C. Weiss, E.-R. Gesing, Y. Ye, *J. Nat. Prod.* **2007**, *70*, 1987.
[7] S.-P. Yang, Z.-B. Gao, F.-D. Wang, S.-G. Liao, H.-D. Chen, C.-R. Zhang, G.-Y. Hu, J.-M. Yue, *Org. Lett.* **2007**, *9*, 903.
[8] S.-P. Yang, Z.-B. Gao, Y. Wu, G.-Y. Hu, J.-M. Yue, *Tetrahedron* **2008**, *64*, 2027.
[9] S.-P. Yang, J.-M. Yue, *Tetrahedron Lett.* **2006**, *47*, 1129.
[10] J. Kawabata, E. Fukushi, J. Mizutani, *Phytochemistry* **1998**, *47*, 231.
[11] J. Kawabata, Y. Fukushi, S. Tahara, J. Mizutani, *Phytochemistry* **1990**, *29*, 2332.
[12] B. Wu, H.-B. Qu, Y.-Y. Cheng, *Helv. Chim. Acta* **2008**, *91*, 725.
[13] H. Kuang, Y.-G. Xia, B.-Y. Yang, Q.-H. Wang, S.-W. Lii, *Chem. Biodiversity* **2008**, *5*, 1736.
[14] J. Kawabata, Y. Fukushi, J. Mizutani, *Phytochemistry* **1993**, *32*, 1347.
[15] J. Kawabata, J. Mizutani, *Phytochemistry* **1992**, *31*, 1293.
[16] B. Wu, J. Chen, H.-B. Qu, Y.-Y. Cheng, *J. Nat. Prod.* **2008**, *71*, 877.
[17] X.-C. Wang, Y.-N. Zhang, L.-L. Wang, S.-P. Ma, J.-H. Liu, L.-H. Hu, *J. Nat. Prod.* **2008**, *71*, 674.
[18] S.-P. Yang, C.-R. Zhang, H.-D. Chen, S.-G. Liao, J.-M. Yue, *Chin. J. Chem.* **2007**, *25*, 1892.
[19] J.-M. Fang, Y.-C. Sou, Y.-H. Chiu, Y.-S. Cheng, *Phytochemistry* **1993**, *34*, 1581.
[20] Y.-Z. Wang, C.-P. Tang, C.-Q. Ke, H.-C. Weiss, E.-R. Gesing, Y. Ye, *Phytochemistry* **2008**, *69*, 518.
[21] J. Du, M.-L. Wang, R.-Y. Chen, D.-Q. Yu, *Planta Med.* **2001**, *67*, 542.

[22] M.-Z. Sultan, Y.-M. Jeon, S.-S. Moon, *Planta Med.* **2008**, *74*, 449.
[23] T. Hieda, Y. Mikami, Y. Obi, *Agric. Biol. Chem.* **1983**, *47*, 787.
[24] C.-J. Li, D.-M. Zhang, Y.-M. Luo, S.-S. Yu, Y. Li, Y. Lu, *Phytochemistry* **2008**, *69*, 2867.
[25] J. Kawabata, E. Fukushi, J. Mizutani, *Phytochemistry* **1995**, *39*, 121.

Received August 19, 2009