Chinese Journal of Natural Medicines

Abietane diterpenoids and iridoids from *Caryopteris mongolica*

Shanshan ZHANG, Xudong MAO, Hongtao XU, Xiaohui WEI, Guixin CHOU

Citation: Shanshan ZHANG, Xudong MAO, Hongtao XU, Xiaohui WEI, Guixin CHOU, Abietane diterpenoids and iridoids from *Caryopteris mongolica*, Chinese Journal of Natural Medicines, 2023, 21(12), 927−937. doi: 10.1016/S1875−5364(23)60409−1.

View online: https://doi.org/10.1016/S1875−5364(23)60409−1

Available online at www.sciencedirect.com
ScienceDirect
Chinese Journal of Natural Medicines 2023, **21**(12): 927-937
doi: 10.1016/S1875-5364(23)60409-1
Chinese Journal of Natural Medicines

•Original article•

Abietane diterpenoids and iridoids from *Caryopteris mongolica*

ZHANG Shanshan[1Δ], MAO Xudong[3Δ], XU Hongtao[2], WEI Xiaohui[1*], CHOU Guixin[1, 2*]

[1] *Institute of Chinese Materia Medica, Shanghai University of Traditional Chinese Medicine, Shanghai 201203, China;*
[2] *Shanghai R&D Center for Standardization of Chinese Medicines, Shanghai 201203, China;*
[3] *State Key Lab of New Drug and Pharmaceutical Process, Shanghai Institute of Pharmaceutical Industry, China State Institute of Pharmaceutical Industry, Shanghai 201203, China*

Available online 20 Dec., 2023

[ABSTRACT] Six new abietane diterpenoids (**1**−**6**) and five undescribed iridoids (**7**−**11**) have been isolated from the aerial parts of *Caryopteris mongolica*. The intricate structural characterization of these compounds was meticulously undertaken using an array of advanced spectroscopic techniques. This process was further enhanced by the application of DP4+ probability analyses and electronic circular dichroism (ECD) calculations. Following isolation and structural elucidation, the cytotoxicity of these compounds was evaluated. Among them, compound **3** stood out, displaying significant cytotoxic activity against HeLa cells with an IC_{50} value of 7.83 ± 1.28 μmol·L^{-1}. Additionally, compounds **1**, **2**, **4**, **9**, and **10** manifested moderate cytotoxic effects on specific cell lines, with IC_{50} values ranging from 11.7 to 20.9 μmol·L^{-1}.

[KEY WORDS] *Caryopteris mongolica*; Abietane diterpenoids; Spectroscopic analysis; Cytotoxicity
[CLC Number] R284.1 **[Document code]** A **[Article ID]** 2095-6975(2023)12-0927-11

Introduction

Caryopteris mongolica Bunge. (*C. mongolica*), a distinguished member of the Lamiaceae family, is deeply rooted in the traditional medicinal practices of northern China. It is recognized for its therapeutic benefits, notably in the treatment of rheumatic pain, dyspepsia, edema, and bronchitis. This plant enjoys a wide distribution across provinces like Inner Mongolia, Gansu, Hebei, and Shanxi [1]. Several different types of compounds, including iridoid glycosides, alkaloids, diterpenoids, and flavone glycosides, have been isolated from the aerial parts of this plant [2-6]. In addition, phytochemical investigations on the root of *C. mongolica* resulted in a variety of *abeo*-abietanes, including 12-*O*-demethylcryptojaponol and 6*α*-hydroxydemethylcryptojaponol, which were found to exert preventive effects against neurodegenerative diseases by evaluating their inhibitory activities against AChE and BChE [5]. Furthermore, a rare diterpenoid bearing an *ortho*-quinone and spiro three-membered ring system was identified in the roots of *C. mongolica*, which showed potent antibacter [7]. In the ongoing quest to identify cytotoxic agents from traditional Chinese medicine for cytotoxic natural products [8-11]—a rich source of potential antitumor agents [12]—a systematic study was undertaken on the aerial parts of *C. mongolica*.

In this study, six undescribed diterpenoids caryopterons E–J (**1–6**) and five undescribed iridoids caryopteridoids A–E (**7–11**) (Fig. 1), together with four known diterpenoids, (3*R*,5*R*,10*S*,16*R*)-3,11,12,16-tetrahydroxy-17(15→16), 18(4→3)-*diabeo*-abieta-4(19),8,11,13-tetraen-7-one (**12**) [7], (5*R*,10*S*,16*R*)-11,12,16-trihydroxy-17(15→16)-*abeo*-abieta-8,11,13-trien-3,7-dione (**13**) [7], (5*R*,10*S*,16*R*)-11,16-dihydroxy-12-methoxy-17(15→16)-*abeo*-abieta-8,11,13-trien-3,7-dione (**14**) [7], and sugiol (**15**) [13] (Fig. 1), were isolated and identified from the *C. mongolica*. Their structures were determined through spectroscopic analysis, DP4+ probability analysis, and electronic circular dichroism (ECD) data. When evaluating the cytotoxicity of all isolates against three kinds of human tumor cell lines, caryopteron G (**3**) showed significant cytotoxic activities against HeLa cells with an IC_{50} value of 7.83 μmol·L^{-1}. Herein, the isolation, structural elucidation, and biological assay evaluation of these compounds are presented.

Results and Discussion

Caryopteron E (**1**) was isolated as a yellow, amorphous powder with a molecular formula of $C_{21}H_{26}O_5$, as deduced

[Received on] 02-Mar.-2023
[Research funding] This work was supported by the National Nature Science Foundation of China (No. 21672152).
[*Corresponding author] E-mails: xhweixh@163.com (WEI Xiao-Hui); chouguixin@shutcm.edu.cn (CHOU Gui-Xin)
[Δ]These authors contributed equally to this work.
These authors have no conflict of interest to declare.

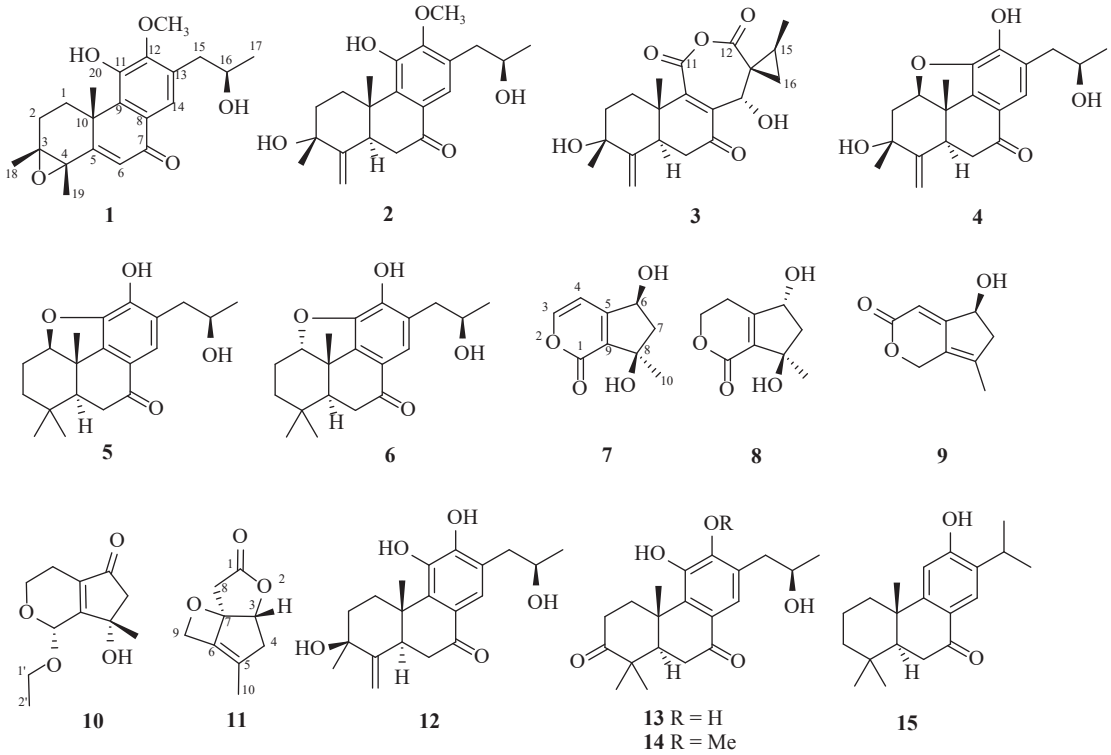


Fig. 1 Structures of compounds 1–15 isolated from the *C. mongholica*.

from carbon nuclear magnetic resonance (^{13}C NMR) data and high-resolution electrospray ionization mass spectrometry (HR-ESI-MS) data, producing an ion at *m/z* 359.1866 [M + H]$^+$ (Calcd. for $C_{21}H_{27}O_5$, 359.1853). The one-dimensional (1D) NMR spectra (Tables 1 and 2) exhibited chemical shifts corresponding to four methyl groups (δ_H 1.17, 1.47, 1.62, and 1.56), one methoxy group (δ_H 3.79), three isolated methylenes (δ_H 2.97 and 1.14, 2.18 and 2.05, and 2.87 and 2.75), one methine (δ_H 4.07), one aromatic proton (δ_H 7.60), and one olefinic proton (δ_H 6.65). The ^{1}H-^{1}H correlation spectroscopy (COSY) identified an oxygen-substituted propyl group through cross-peaks of H_2-15/H-16 and H-16/Me-17 (Fig. 2). The 1D and two-dimensional (2D) NMR spectra revealed that compound **1** was similar to 3,4-epoxy-11,12,16-trihydroxy-17(15→16),18(4→3)-*diabeo*-abieta-5,8,11,13-tetraen-7-one [7] except for the extra methoxy group. The heteronuclear multiple bond correlation (HMBC) cross-peak (Fig. 2) of the methoxy proton (δ_H 3.79) with C-12 (δ_C 152.6) indicated that the methoxy group was linked to C-12. Thus, the structure of compound **1** was confirmed to be 3,4-epoxy-11,16-dihydroxy-12-methoxy-17(15→16),18(4→3)-*diabeo*-abieta-5,8,11,13-tetraen-7-one. The nuclear Overhauser effect spectroscopy (NOESY) showed proximal correlations for methyl groups Me-19, Me-18, and Me-20, suggesting co-orientation (Fig. 3). The relative configuration of C-16 was elucidated using density functional theory (DFT) NMR calculations for two diastereoisomers, 16*R**-**1** and 16*S**-**1** (Fig. 4). The ^{13}C NMR chemical shifts of the two epimers were measured at the mPW1PW91/6-311 + G(d,p) level in polarizable continuum model (PCM) methanol [14]. The calculated results for 16*R**-**1** exhibited a high correlation coefficient (R^2 = 0.9986) compared with 16*S**-**1** (R^2 = 0.9981) and a DP4+ probability of 99.99% (Fig. 4 and Supporting information, Table C1), in agreement with the experimental data, confirming its predominance. Further validation of the absolute configuration was achieved through electronic circular dichroism (ECD) calculations at the PBE0/def2-TZVP level in methanol [15]. The result showed that the theoretical configuration of (3*R*,4*S*,10*S*,16*R*)-**1** matched well with the experimental configuration (Fig. 5). The absolute configuration of compound **1** was thus established as (3*R*,4*S*,10*S*,16*R*)-3,4-epoxy-11,16-dihydroxy-12-methoxy-17(15→16),18(4→3)-*diabeo*-abieta-5,8,11,13-tetraen-7-one (Fig. 1).

Caryopteron F (**2**) was obtained as a light-yellow, amorphous powder. Its molecular formula, deduced from the HR-ESI-MS spectra ion at *m/z* 361.2010 [M + H]$^+$ (Calcd. for $C_{21}H_{29}O_5$, 361.2023), was determined as $C_{21}H_{28}O_5$ with two more hydrogen atoms than compound **1**. A comparative analysis of their 1D NMR spectra (Tables 1 and 2) revealed structural similarities, pointing both compounds towards the 17(15→16),18(4→3)-*diabeo*-abietane class. However, unique characteristics set them apart. Compound **2** presented an exocyclic double bond at δ_H 4.75 (1H, d, *J* = 1.3 Hz) and 5.21 (1H, d, *J* = 1.3 Hz) and lacked a methyl group, a distinction further supported by the HMBCs (Fig. 2) of the olefinic protons H_2-19 with C-3, C-4, and C-5, H_2-6 with C-7, and Me-18 with C-2, C-3, and C-4. The HMBC between the methoxyl proton (δ_H 3.77) and C-12 (δ_C 153.1) suggested that compound **2** was the 12-*O*-methyl derivative of 3,11,12,16-tetrahydroxy-17(15→16),18(4→3)-*diabeo*-abieta-4(19),

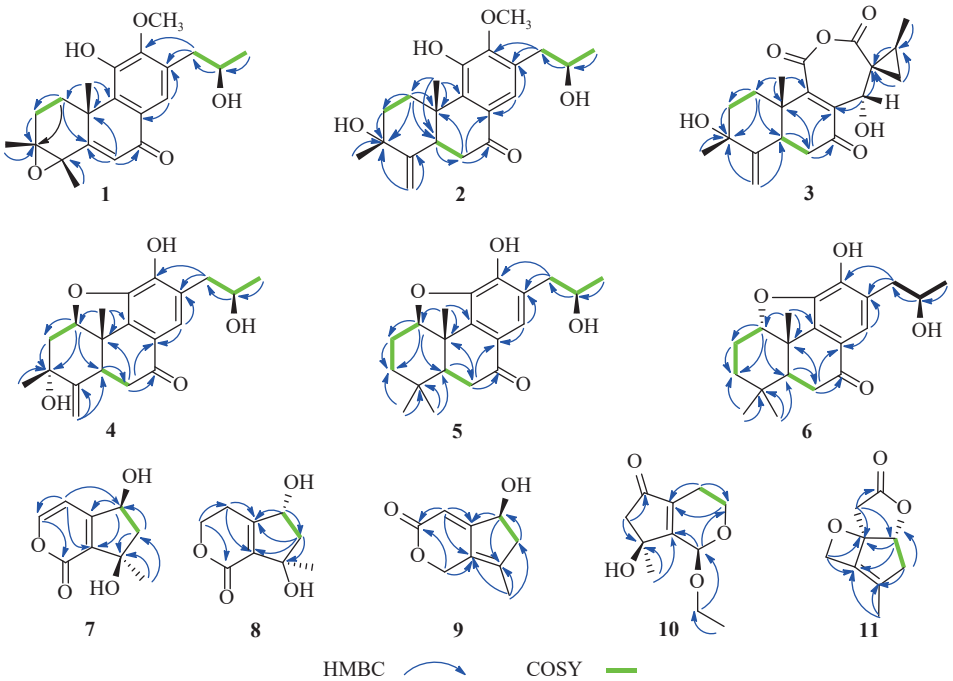


Fig. 2 Key HMBC and ^{1}H–^{1}H COSY correlations for compounds 1–11.

8,11,13-tetraen-7-one [7]. In the NOESY experiment (Fig. 3) of compound **2**, the key correlations of Me-18/H-2*β* and Me-20/H-2*β* confirmed the configuration of a 3*β*-methyl group. The DP4+ probability (Supporting Information, Table C2) and common biosynthesis suggested that C-16 in compound **2** shared the same relative configuration as that in compound **1**. In addition, the calculated ECD spectrum for the (3*R*,5*R*,10*S*,16*R*) isomer of compound **2** is in good agreement with the experimental data (Fig. 5). Accordingly, the structure of compound **2** was corroborated as (3*R*,5*R*,

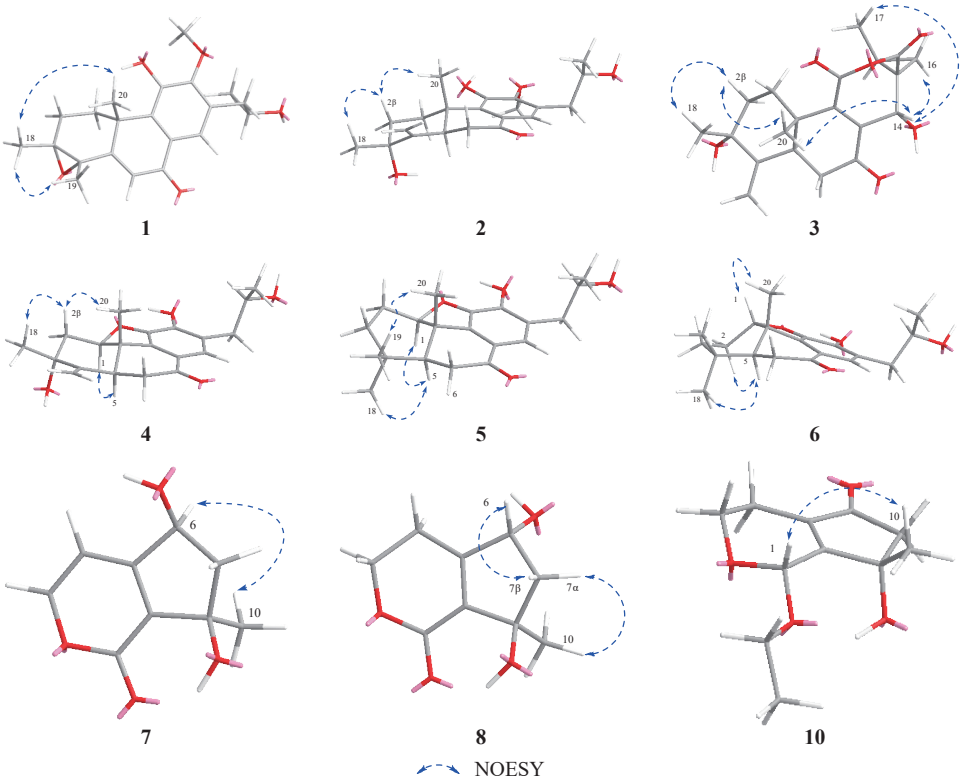
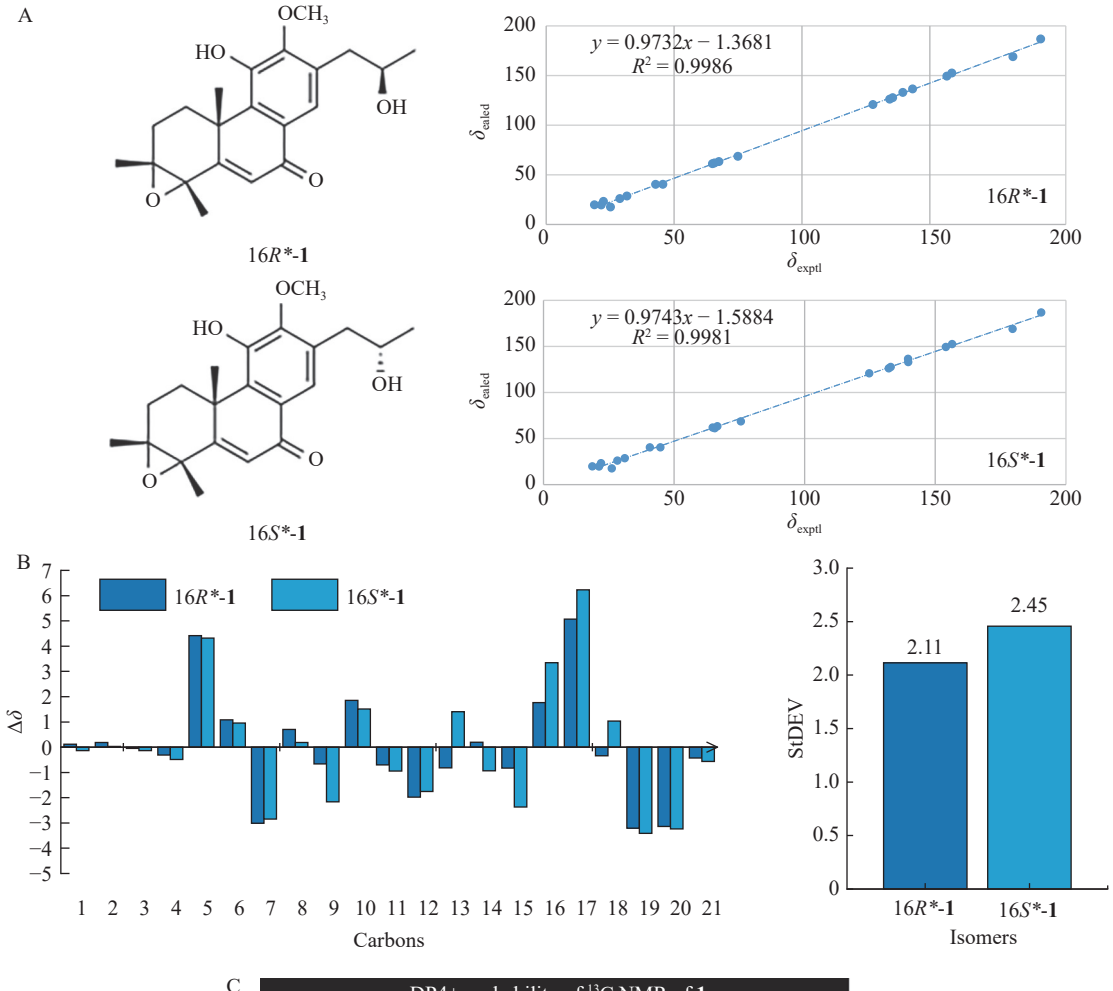


Fig. 3 Key NOESY correlations for compounds 1–8 and 10.



C

DP4+ probability of ^{13}C NMR of **1**		
Possible isomer	16*R**-**1**	16*S**-**1**
sDP4+	99.63%	0.37%
uDP4+	96.36%	3.64%
DP4+	99.99%	0.01%

Fig. 4 ^{13}C NMR calculation results of two possible isomers of 1. (A) Linear correlation plots of calculated versus experimental ^{13}C NMR data; (B) Relative errors and standard derivations between the calculated and experimental ^{13}C NMR data; (C) DP4+ probability of ^{13}C NMR chemical shifts.

10*S*,16*R*)-3,11,16-trihydroxy-12-methoxy-17(15→16), 18(4→3)-*diabeo*-abieta-4(19),8,11,13-tetraen-7-one (Fig. 1).

Caryopteron G (**3**) was determined to have the molecular formula $C_{20}H_{24}O_6$ based on its HR-ESI-MS ion at *m/z* 359.1492 $[M - H]^-$ (Calcd. for $C_{20}H_{23}O_6$, 359.1478). The proton (^{1}H) NMR spectrum (Table 1) of compound **3** revealed that it also contained an exocyclic double bond at δ_H 4.77 (1H, d, *J* = 1.5 Hz) and 5.23 (1H, d, *J* = 1.5 Hz), and two tertiary methyl groups at δ_H 1.42 (3H, s) and 1.09 (3H, s). A comparison between the 1D NMR spectra of compound **3** (Tables 1 and 2) and those of compound **2** revealed that they shared similar rings A and B, with the main differences being that the chemical shifts of C-8 and C-9 showed a downfield shift and the aromatic ring C was highly oxidized in **3**. However, ring C of compound **3** was the same as that of the known compound caryopteron B[5]. This inference was confirmed using ^{13}C NMR at δ_C 172.7 (C-11) and 175.4 (C-12), supported by the HMBC cross-peaks (Fig. 2) of H-15/C-12 and H-14/C-8 and C-9. In addition, the existence of the spiro-methylcyclopropane moiety was supported by the HMBC correlations of Me-17/C-15 and C-13, H-15/C-13, and H-16/C-13 and C-15. Thus, the structure of compound **3** was established as 18(4→3)-*abeo*-caryopteron B [5]. The relative configuration of compound **3** was established by analyzing its NOESY spectrum (Fig. 3). The NOE correlations of H-2*β* with Me-18 and Me-20 indicated that Me-18 and Me-20 were *β*-oriented, and correlations from Me-20 to H-14, H-14 to H-16, and Me-17 indicated that H-14, H-16, and Me-17 were also *β*-oriented. The absolute configuration of compound **3** was established by comparing the calculated ECD spectrum

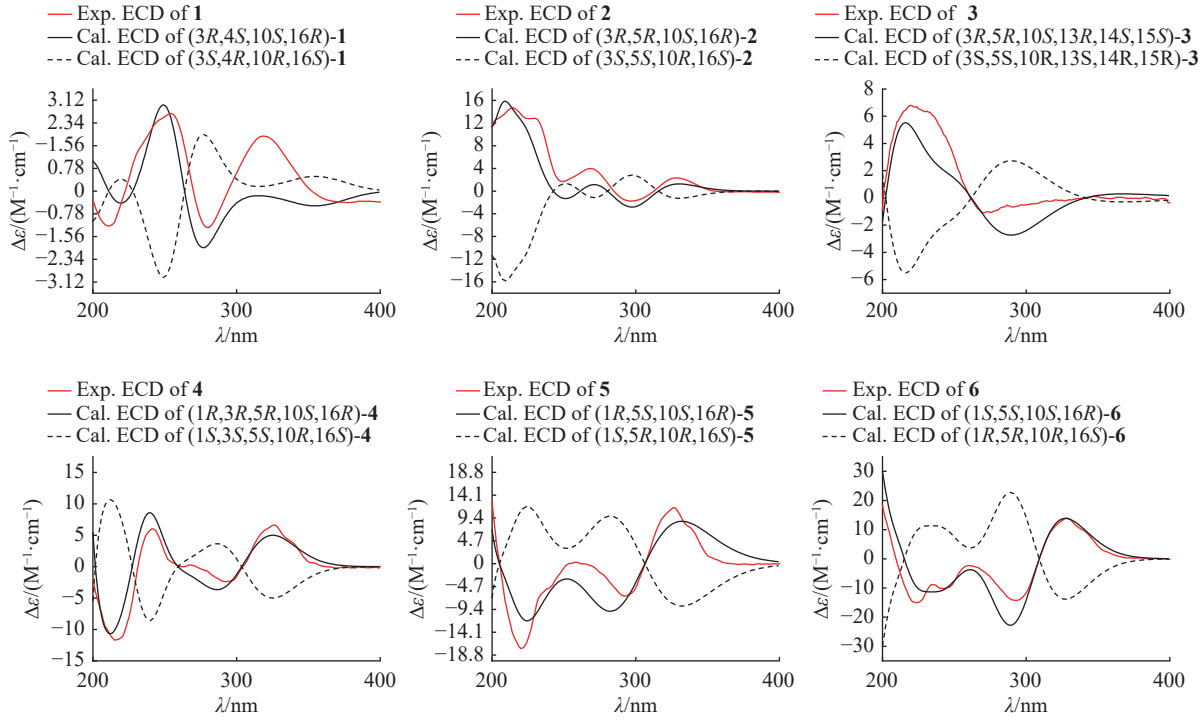


Fig. 5 Experimental and calculated ECD spectra of compounds 1–6.

Table 1 ^{1}H NMR spectroscopic data for compounds 1–6 (δ in ppm, *J* in Hz)

No.	1[a]	2[a]	3[a]	4[b]	5[b]	6[b]
1	2.97 ddd (13.5, 6.2, 1.7) 1.14 dd (13.5, 5.6)	3.20 m 1.79 ov	1.98 td (13.4, 4.7) 2.42 ov	4.63 dd (12.8, 4.6)	4.00 dd (12.8, 3.5)	4.71 dd (11.3, 6.4)
2	2.18 dd (12.8, 6.2) 2.05 dd (12.8, 5.6)	1.76 ov	1.78 ov	2.31 d (12.7) 2.39 dd (12.7, 4.6)	2.09 m 2.32 dd (12.2, 4.1)	1.68 d (13.0) 1.94 m
3					1.48 td (14.7, 4.8) 1.83 m	1.26 ov 1.60 m
5		3.33 ov	3.48 d (14.6)	3.18 m	2.03 dd (13.3, 4.6)	2.03 dd (13.1, 4.1)
6	6.65 s	2.69 ov 2.36 dd (16.0, 2.7)	2.73 dd (17.1, 14.7) 2.38 dd (17.1, 3.3)	2.67 s 2.65 s	2.52 dd (17.2, 4.6) 2.59 dd (17.2, 13.3)	2.42 dd (18.4, 4.2) 2.66 dd (18.4,13.1)
14	7.60 s	7.50 s	4.80 s	7.14 s	7.09 s	7.01 s
15	2.87 dd (13.6, 7.1) 2.75 dd (13.6, 6.2)	2.82 dd (13.6, 7.0) 2.72 ov	1.80 ov	2.78 dd (14.7, 7.0) 2.95 dd (14.7, 2.6)	2.76 dd (14.7, 7.0) 2.93 dd (14.7, 2.5)	2.77 dd (14.7, 7.1) 2.89 dd (14.7, 2.6)
16	4.07 m	4.04 m	1.56 dd (9.0, 5.0) 1.20 dd (7.4, 5.0)	4.26 m	4.25 m	4.25 m
17	1.17 d (6.2)	1.16 d (6.2)	1.36 d (6.4)	1.25 d (6.2)	1.24 d (6.2)	1.26 d (6.3)
18	1.47 s	1.42 s	1.42 s	1.58 s	0.95 s	0.91 s
19	1.62 s	5.21 d (1.3) 4.75 d (1.3)	5.23 d (1.5) 4.77 d (1.5)	5.31 d (1.5) 4.78 d (1.5)	1.07 s	1.00 s
20	1.56 s	1.22 s	1.09 s	0.94 s	1.20 s	1.40 s
OCH_3	3.79 s	3.77 s				

[a] 400 MHz in CD_3OD; [b] 400 MHz in $CDCl_3$; ov: Overlapped signal

for the (3*R*,5*R*,10*S*,13*R*,14*R*,15*S*) isomer with the experimental spectra, which showed good agreement (Fig. 5). Therefore, the structure of compound **3** was determined to be a derivative of caryopteron B, as shown (Fig. 1).

Caryopteron H (**4**) was isolated as a yellow, amorphous powder. The molecular formula of $C_{20}H_{24}O_5$ was determined from the HR-ESI-MS ion at *m/z* 367.1523 $[M + Na]^+$ (Calcd. for $C_{20}H_{24}O_5Na$, 367.1516) and ^{13}C NMR. The ^1H and ^{13}C NMR spectra of compound **4** (Tables 1 and 2) were similar to those of compound **2**, with the main differences being the absence of a methoxyl group and the presence of an oxymethine group at δ_C 93.9 (C-1) in compound **4**, as supported

Table 2 ^{13}C NMR spectroscopic data for compounds 1–6 (δ in ppm)

No.	1[a]	2[a]	3[a]	4[b]	5[b]	6[b]
1	26.1	31.9	30.0	93.9	99.1	94.0
2	28.7	37.9	37.1	40.3	24.7	24.3
3	63.4	71.5	71.4	74.9	41.9	35.3
4	62.0	153.7	152.3	151.1	34.7	31.0
5	169.1	44.0	44.8	43.9	51.0	48.3
6	126.2	38.6	39.2	38.4	37.3	36.2
7	186.9	200.9	196.2	196.3	197.8	198.6
8	127.7	129.1	152.4	120.0	119.7	121.3
9	136.5	139.5	153.1	147.1	149.5	144.8
10	40.5	41.9	38.8	41.4	41.3	44.1
11	149.4	150.0	172.7	145.3	144.3	144.2
12	152.6	153.1	175.4	146.5	146.6	145.0
13	133.0	131.8	28.2	127.9	127.5	126.8
14	120.8	121.8	81.4	122.8	122.4	122.2
15	40.4	40.4	24.2	40.8	40.9	40.5
16	68.7	68.6	23.9	70.1	70.0	70.2
17	23.3	23.2	14.0	23.0	23.0	23.1
18	19.8	27.8	108.6	28.8	32.6	30.0
19	17.6	108.1	27.8	109.9	23.7	26.0
20	19.7	14.3	15.2	12.7	14.6	24.0
OCH_3	61.3	61.1				

[a] 100 MHz in CD_3OD; [b] 100 MHz in $CDCl_3$.

by the HMBCs (Fig. 2) of δ_H 4.63 (H-1) with δ_C 40.3 (C-2), 43.9 (C-5), 147.1 (C-9), and 41.4 (C-10), and δ_H 0.94 (H-20) with 93.9 (C-1). A proposed epoxidation between C-1 and C-11, leading to furan ring formation, aligns with the observed oxygenation at these positions and matches the molecular structure of epoxyhinokiol [16]. In the NOESY spectrum (Fig. 3) of compound **4**, correlations between H-1 and H-5 and between H-2*β* and Me-18/Me-20 confirmed the *α*-configuration at H-1 and H-5 and the *β*-configuration at Me-18 and Me-20. The absolute configuration was established as 1*R*,3*R*,5*R*,10*S*,16*R*, which was supported by common biosynthesis and comparison of the overlaid experimental and calculated ECD data (Fig. 5). Therefore, the structure of compound **4** was determined to be (1*R*,3*R*,5*R*,10*S*,16*R*)-1,11-epoxy-3,12,16-trihydroxy-17(15→16),18(4→3)-*diabeo*-abieta-4(19),8,11,13-tetraen-7-one (Fig. 1).

Caryopteron I (**5**) was obtained as a yellow, amorphous powder. Its molecular formula was deduced as $C_{20}H_{26}O_4$ according to the sodium adduct (+)-HR-ESI-MS ion at *m/z* 353.1731 $[M + Na]^+$ (Calcd. for $C_{20}H_{26}O_4Na$, 353.1723). The ^{1}H and ^{13}C NMR spectra of compound **5** (Tables 1 and 2) exhibited striking similarities to those of compound **4**, yet the distinguishing feature of compound **5** was the *gem*-dimethyl group at C-4. This difference was supported by the HMBCs (Fig. 2) of δ_H 0.95 (Me-18) with δ_C 41.9 (C-3), 34.7 (C-4), 51.0 (C-5), and 23.7 (C-19), and of δ_H 1.07 (Me-19) with δ_C 41.9 (C-3), 34.7 (C-4), 51.0 (C-5), and 32.6 (C-18). Detailed analysis of its NOESY spectrum (Fig. 3) showed that the cross-peaks of H-5 to H-1 and Me-18 and of Me-19 to Me-20 indicated that Me-19 and Me-20 were *β*-oriented and H-1, H-5, and Me-18 were *α*-oriented. Furthermore, the calculated ECD spectrum of (1*R*,5*S*,10*S*,16*R*)-**5** was in good accordance with the experimental ECD spectrum (Fig. 5), indicating the absolute configuration of compound **5**. Consequently, the structure of compound **5** was determined to be (1*R*,5*S*,10*S*,16*R*)-1,11-epoxy-12,16-dihydroxy-17(15→16)-*abeo*-abieta-8,11,13-triene-7-one (Fig. 1).

Caryopteron J (**6**) was isolated as a yellow, amorphous powder, and it shared the same molecular formula of $C_{20}H_{26}O_4$ as compound **5** based on the HR-ESI-MS ion peak at *m/z* 329.1765 $[M - H]^-$ (Calcd. for $C_{20}H_{25}O_4$, 329.1758). The ^{1}H and ^{13}C NMR spectra of compound **6** (Tables 1 and 2) closely mirrored those of compound **5**, with notable shielding observed at C-1, C-3, C-4, and C-9 and deshielding at C-10, C-19, and C-20. Detailed analysis of the HMBC and ^{1}H-^{1}H COSY correlations (Fig. 2) suggested that compound **6**

possessed the same planar structure as compound **5**. The key NOE correlation (Fig. 3) between H-1 and Me-20 confirmed that compound **6** was a C-1 epimer of compound **5**. Based on the matched experimental and calculated ECD spectra (Fig. 5), the 1*S* configuration was deduced accurately. Therefore, the structure of compound **6** was determined to be (1*S*,5*S*,10*S*,16*R*)-1,11-epoxy-12,16-dihydroxy-17(15→16)-*abeo*-abieta-8,11,13-triene-7-one (Fig. 1).

Caryopteridoid A (**7**) was isolated as a yellow, amorphous powder and determined to have the molecular formula of $C_9H_{10}O_4$ by HR-ESI-MS at *m/z* 205.0471 $[M + Na]^+$ (Calcd. for $C_9H_{10}O_4Na$, 205.0476). 1D NMR spectroscopic data (Tables 3 and 4) showed the presence of an ester group, two pairs of double bonds, two oxygenated sp^3 carbons, a methylene, and a methyl, suggesting that compound **7** is a structural derivative of the known iridoid 5,7-dihydroxy-7-methyl-4,5,6,7-tetrahydrocyclopenta[*c*]pyran-1(3*H*)-one [17]. However, an additional double bond was conjugated with *α*,*β*-unsaturated lactone to form *α*-pyrone, resulting in a subtle difference. This deduction was confirmed using HMBC correlations (Fig. 2) from δ_H 7.55 (H-3) to δ_C 161.2 (C-1) and 159.1 (C-5) and from δ_H 6.48 (H-4) to δ_C 71.7 (C-6) and 130.7 (C-9). In the NOESY experiment (Fig. 3) on compound **7**, the key cross-peak of H-6 with Me-10 revealed that 6-OH was *β*-oriented and Me-10 was *α*-oriented. The absolute configuration was deduced to be 6*S*,8*R*, which was supported by compatible experimental and calculated ECD curves (Fig. 6). Therefore, the structure of compound **7** was determined (Fig. 1).

Caryopteridoid B (**8**) was obtained as a light-yellow oil. Its molecular formula was determined to be $C_9H_{12}O_4$ based on the HR-ESI-MS ion at *m/z* 207.0629 $[M + Na]^+$ (Calcd. for $C_9H_{12}O_4Na$, 207.0633). The ^1H and ^{13}C NMR spectra of compound **8** (Tables 3 and 4) were similar to those of compound **7**, except for the absence of a double bond between C-3 and C-4. Further evidence to this structure came from the HMBCs (Fig. 2) of H-3 with C-1 and C-4 and of H-4 with C-5, and C-9 and ^1H–^1H COSY correlations (Fig. 2) of H_2-3/H_2-4. Additionally, the NOESY correlations (Fig. 3) of H-7*α*/H-10 and H-6/H-7*β* indicated an *α*-configuration for the hydroxyl group at C-6 and the methyl group at C-8. The absolute configuration of compound **8** was determined to be 6*R*,8*R*, backed by a comparison of experimental and calculated ECD data (Fig. 6). Therefore, the structure of compound **8** was assigned (Fig. 1).

Caryopteridoid C (**9**) was isolated as a light-brown amorphous powder, and its molecular formula was determined to be $C_9H_{10}O_3$ by the HR-ESI-MS ion at *m/z* 167.0704 $[M + H]^+$ (Calcd. for $C_9H_{11}O_3$, 167.0703) and ^{13}C NMR. Its ^{13}C NMR and DEPT spectra (Table 4) revealed nine carbon signals, including one ester carbonyl group at δ_C 165.5, three quaternary carbons at δ_C 167.8, 147.1, and 126.3, two methylenes at δ_C 65.8 and 46.5, two methenyls at δ_C 105.8 and 70.2, and a methyl at δ_C 15.3. The iridoid skeleton was deduced by analysis of the HMBCs (Fig. 2) of Me-10 with C-7, C-8, and C-9; of H-6 with C-4, C-5, C-7, and C-9; of H-4 with C-3, C-6, and C-9; and of H-1 with C-3, C-5, C-8, and C-9. These NMR characteristics closely resembled those of cyclopentanepyrone A [18], with the primary differences being the presence of a double bond between C-8 and C-9 and the absence of a methyl group at C-8 in compound **9**. Therefore, a planar structure was deduced. Furthermore, the absolute configuration at C-6 was determined as *S*, as evidenced by matching the experimental and calculated ECD data (Fig. 6). Thus, the structure of compound **9** was assigned (Fig. 1).

Caryopteridoid D (**10**) was isolated as a light-yellow oil, which had a molecular formula of $C_{11}H_{16}O_4$ with four degrees of unsaturation based on the HR-ESI-MS peak at *m/z* 235.0946 $[M + Na]^+$ (Calcd. for $C_{11}H_{16}O_4Na$, 235.0914). Its

Table 3 ^1H NMR spectroscopic data of compounds 7–11 (δ in ppm, *J* in Hz)

No.	7[a]	8[a]	9[c]	10[c]	11[b]
1			5.10 qd (15.0, 1.4)	5.46 s	
3	7.55 d (5.2)	4.50 m 4.38 m		3.87 dd (8.9, 2.3)	4.70 d (6.3)
4	6.48 d (5.2)	2.60 m	5.69 s	2.31 m 2.18 m	2.38 d (18.1) 2.88 dd (18.2, 6.4)
6	4.78 t (6.9)	4.92 t (5.8)	4.91 ddd (6.8, 2.5, 1.6)		
7	2.60 dd (13.5, 7.5) 2.01 dd (13.5, 6.5)	2.44 dd (13.8, 7.2) 1.81 dd (13.8, 5.7)	2.88 dt (18.6,7.9) 2.51 d (18.0)	2.62 s	
8					2.77 d (18.2) 3.17 d (18.2)
9					4.28 d (12.4) 4.18 d (12.5)
10	1.51 s	1.61 s	1.83 s	1.60 s	1.80 s
1′				3.92 m 3.67 m	
2′				1.28 t (7.1)	

[a] 400 MHz in CD_3OD; [b] 600 MHz in CD_3OD; [c] 400 MHz in $CDCl_3$.

Table 4 ^{13}C NMR spectroscopic data of compounds 7–11 (δ in ppm)

No.	7[a]	8[a]	9[c]	10[c]	11[b]
1	161.2	165.0	65.8	92.5	177.9
2					
3	153.4	68.4	165.5	56.5	89.4
4	104.9	23.8	105.8	20.5	42.8
5	159.1	164.6	167.8	138.5	140.2
6	71.7	74.9	70.2	204.1	136.2
7	50.9	51.2	46.5	52.8	89.5
8	78.2	80.2	147.1	75.8	40.8
9	130.7	134.0	126.3	166.9	55.7
10	26.0	27.3	15.3	27.3	14.1
1’				64.3	
2’				15.4	

[a] 100 MHz in CD_3OD; [b] 150 MHz in CD_3OD; [c] 100 MHz in $CDCl_3$

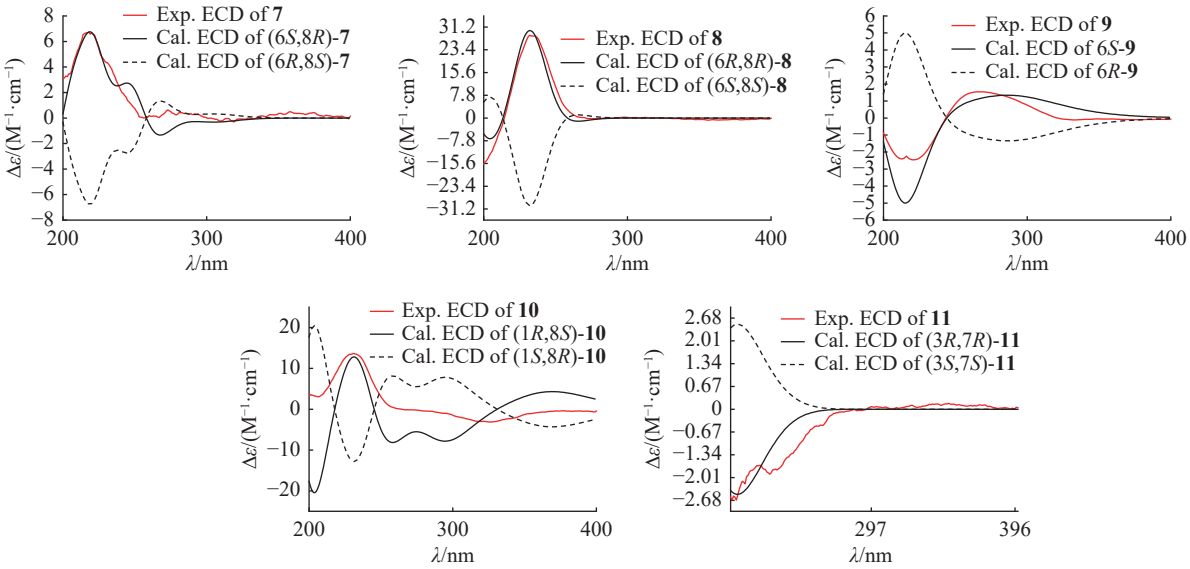


Fig. 6 Experimental and calculated ECD spectra of compounds 7–11.

^{1}H NMR and ^{13}C NMR spectra (Tables 3 and 4) showed the signal for an ethoxy group at δ_H 1.28 (3H, t, Me-2′), 3.92 (1H, m, H-1′a), and 3.67 (1H, m, H-1′b); δ_C 15.4 (C-2'), 64.3 (C-1'). Apart from the ethoxy group, the ^{13}C NMR and DEPT spectra of compound **10** revealed nine carbon signals, including one carbonyl group at δ_C 204.1, one tetra-substituted double bond at δ_C 138.5 and 166.9, three methylenes at δ_C 56.5, 52.8, and 20.5, one methine at δ_C 92.5 and a methyl at δ_C 27.3. Detailed analysis of the HMBC spectrum (Fig. 2) of compound **10** revealed correlations of H-7 with C-5, C-6, C-8, and C-9, which indicated that the ketone carbonyl group was located at C-6. All of the above spectral analyses revealed that compound **10** bore a resemblance to pediverticillatasin A [19], with the only difference being the location of the carbonyl group. The relative configuration of compound **10** was deduced by the NOESY correlations (Fig. 3) between H-1 and Me-10, indicating that H-1 should have the same orientation as Me-10, and DP4+ probability analyses (Supporting Information, Table C3) also proved this inference. A comparison of the experimental ECD data for compound **10** with the calculated data cemented its configuration as 1*R*,8*S* (Fig. 6). Thus, the structure of compound **10** was identified (Fig. 1).

Caryopteridoid E (**11**) was obtained as a colorless, amorphous powder, and its molecular formula of $C_9H_{10}O_2$ was deduced from an $[M + H]^+$ ion at *m/z* 167.0705 (calculated for $C_9H_{11}O_2$, 167.0703), indicating five degrees of unsaturation. ^{13}C NMR and DEPT spectra (Table 4) of compound **11** revealed nine carbon signals, including one ester group at δ_C 177.9, and one tetra-substituted double bond at δ_C

140.2 and 136.2. The remaining three indices of hydrogen deficiency suggest the presence of a tricyclic system. The HMBCs of H-4*α* and H-4*β* with C-3, C-5, C-6, and C-7, and of H-10 with C-5 indicated that cyclopentene and the methyl group were located at C-5. Subsequently, the unusual downfield-shifted signals of C-7 (δ_C 89.5) and C-9 (δ_C 55.7), as well as the HMBCs of H-9*α*/H-9*β* with C-5, C-6, and C-7, indicated that C-6, C-7, and C-9 were composed of an oxygen-containing four-membered ring. Furthermore, lactone was formed through the C-1 carboxyl group and C-3 hydroxyl group, which was elucidated according to the HMBC correlations (Fig. 2) from H-3 to C-1 and from H-8 to C-3, C-7, and C-1. The 3*R*,7*R* configuration was defined based on the comparison between experimental and calculated ECD data (Fig. 6). Therefore, the structure of compound **11** was established (Fig. 1).

The isolated compounds were screened for cytotoxicity against the A549, HeLa, and HepG2 cell lines using the Cell-Counting Kit (CCK)-8 method [20]. The results showed that compound **3** exhibited significant cytotoxic activity against HeLa cells, registering an IC_{50} value of 7.83 ± 1.28 μmol·L^{-1}, and compounds **1**, **2**, **4**, **9**, and **10** also exhibited cytotoxic effects, with their IC_{50} values falling within the range of 11.7–20.9 μmol·L^{-1} (Table 5). These results suggest that the presence of allyl alcohol on ring A is essential for the cytotoxic effects, while isopropyl alcohol on ring C is non-essential, as indicated by compounds **4** and **5**.

Experimental

General experimental procedures

Infrared (IR) spectra of the compounds were obtained using a PerkinElmer FT-IR spectrometer. Bruker AV-400 and Bruker AV-600 instruments were used for NMR spectroscopy with tetramethylsilane (TMS) as the internal standard. HR-ESI-MS data were recorded using a Waters Ultra-Performance Liquid Chromatography (UPLC) Premier QTOF instrument. Column chromatography (CC) was performed using silica gel (100–200 and 200–300 mesh; Qingdao Marine Chemical Factory, China), ODS C_{18} (45–60 μm, YMC Co., Ltd., Kyoto, Japan), and Sephadex LH-20 (Amer-sham Pharmacia Biotech) columns. Semi-preparative high-performance liquid chromatography (HPLC) was conducted using an Agilent 1200 liquid chromatograph equipped with a Shiseido Capcellpak Prep C_{18} ODS column (250 mm × 20 mm, 5 μm). Medium pressure liquid chromatography (MPLC) was conducted using a GRACE system. Preparative thin layer chromatography (PTLC) was performed using pre-coated silica gel GF_{254} plates (Qingdao Marine Chemical Factory, China). Spots were visualized under ultraviolet (UV) light (254 nm) or by spraying with 10% H_2SO_4-EtOH, followed by heating.

Plant material

Caryopteris mongholica (Lamiaceae) was the focal plant material for this study. It was collected from Inner Mongolia, China, in October 2020 and authenticated by Prof. WU Li-hong (Shanghai University of Traditional Chinese Medicine). For archival purposes and to foster transparency in scientific endeavors, a voucher specimen (MGY201116) was deposited in the herbarium of the Institute of Chinese Materia Medica at Shanghai University of Traditional Chinese Medicine.

Extraction and isolation

The dried and powdered samples of *C. mongholica* (20.0 kg) were extracted with 95% aqueous EtOH (4 × 100 L, 7 d each) at room temperature. The evaporation of the solvent under reduced pressure yielded a crude residue (1.18 kg). This residue was then partitioned using CH_2Cl_2 (3 × 10 L), producing a CH_2Cl_2 extract (92 g). This extract was subjected to CC using silica gel (200–300 mesh, 1.0 kg) and eluted with petroleum ether–EtOAc (100 ∶ 1 to 1 ∶ 1, *V*/*V*) to obtain 12 fractions (Frs. A–L): Fr. A (1.35 g), B (0.52 g), C (0.54 g), D (5.59 g), E (4.49 g), F (10.6 g), G (6.7 g), H (5.82 g), I (16.5 g), J (7.01 g), K (11.2 g), and L (21.2 g). Fr. G (6.7 g) underwent further separation *via* MPLC on an ODS-AQ column (MeOH–H_2O, 30 ∶ 70–100 ∶ 0, *V*/*V*), yielding 25 sub-fractions (Frs. G1–G25). Further purification of the G sub-fractions using PTLC (CH_2Cl_2–MeOH, 40 ∶ 1; 20 ∶ 1; 20 ∶ 1, *V*/*V*) resulted in the isolation of compounds 10 (5.0 mg), 5 (18.0 mg), and 6 (9.6 mg) from Fr. G4 (32.0 mg), Fr. G6 (42.0 mg), and Fr. G5 (40.0 mg), respectively. Fr. H (5.82 g)

Table 5 Cytotoxicity of compounds 1–4, 9, and 10 against cancer cell lines (mean ± SD, *n* = 3)

compounds	IC_{50} (μmol·L^{-1})		
	HeLa	HepG2	A549
1	20.9 ± 2.80	15.6 ± 2.24	15.9 ± 0.84
2	-[a]	-	13.7 ± 0.95
3	7.83 ± 1.28	19.1 ± 1.36	-
4	13.9 ± 3.79	17.4 ± 2.49	-
9	12.1 ± 0.85	15.1 ± 2.43	11.7 ± 0.92
10	19.0 ± 3.10	13.6 ± 2.39	19.4 ± 0.50
taxol	4.14 ± 0.12	5.68 ± 0.94	5.38 ± 0.36

[a] Compounds did not exhibit cytotoxicity

was separated into 21 fractions (Frs. H1–H21) using MPLC on an ODS-AQ column (MeOH–H_2O, 20 ∶ 80–100 ∶ 0, *V*/*V*). Fr. H14 (122.0 mg) was subjected to Sephadex LH-20 in (PE–CH_2Cl_2–MeOH, 3 ∶ 3 ∶ 1, *V*/*V*) to obtain three sub-fractions (Frs. H14.1–H14.3). Fr. H14.1 (50.0 mg) was further purified by PTLC (CH_2Cl_2–MeOH, 20 ∶ 1, *V*/*V*) to obtain compounds **1** (8.1 mg) and **3** (6.3 mg). Fr. H19 (54.0 mg) was purified by PTLC (CH_2Cl_2–MeOH, 20 ∶ 1, *V*/*V*) to obtain compound **2** (2.3 mg). Fr. J (7.01 g) was separated into 9 fractions (Frs. J1–J9) using MPLC on an ODS-AQ column (MeOH–H_2O, 30 ∶ 70–100 ∶ 0). Fr. J8 (128.0 mg) was subjected to Sephadex LH-20 in (PE–CH_2Cl_2–MeOH, 3 ∶ 3 ∶ 1, *V*/*V*) to obtain three sub-fractions (Frs. J8.1–J8.3). Fr. J8.1 (26.0 mg) was further purified by PTLC (CH_2Cl_2–MeOH, 20 ∶ 1, *V*/*V*) to obtain compound **4** (5.0 mg). Fr. L (21.2 g) was subjected to MPLC on an ODS-AQ column (MeOH–H2O, 30 ∶ 70–100 ∶ 0, *V*/*V*) to obtain 22 fractions (Frs. L1–L22). Fr. L3 (520 mg) was separated using Sephadex LH-20 in (PE–CH_2Cl_2–MeOH, 3 ∶ 3 ∶ 1, *V*/*V*) to obtain 11 sub-fractions (Frs. L3.1–11). Fr. L3.8 (110 mg) was separated using Sephadex LH-20 in (PE–CH_2Cl_2–MeOH, 5 ∶ 5 ∶ 1, *V*/*V*) to obtain three subfractions (Frs. L3.8.1–3). Fr. L3.8.2 (48.0 mg) was further purified using PTLC (CH_2Cl_2–MeOH, 10 ∶ 1, *V*/*V*) to obtain compounds **7** (7.2 mg) and **8** (10.5 mg). Fr. L6 (172 mg) was separated using Sephadex LH-20 in (PE–CH_2Cl_2–MeOH, 3 ∶ 3 ∶ 1, *V*/*V*) to obtain five subfractions (Frs. L6.1–6). Fr. L6.2 (15.0 mg) was further purified using preparative HPLC, with CH_3CN–H_2O (20 ∶ 80, *V*/*V*) to obtain compound **9** (3.0 mg). Fr. L6.3 (11.0 mg) was purified using preparative HPLC with CH_3CN–H_2O (20 ∶ 80, *V*/*V*) to obtain compound **11** (1.1 mg).

Caryopteron E (**1**): yellow, amorphous powder; $[\alpha]_D^{20}$ +29 (*c* 0.01, MeOH); ECD (MeOH) λ ($\Delta\varepsilon$) 212 (−1.19), 254 (2.66), 280 (−1.25), 319 (1.89), and 377 (3.92) nm; IR ν_{max} 3340, 1709, 1258, 1604, 1083, 1038, 1012, and 795 cm^{-1}; ^1H and ^{13}C NMR spectroscopic data (Tables 1 and 2); HR-ESI-MS *m/z* 359.1866 $[M + H]^+$ (Calcd. for $C_{21}H_{27}O_5$, 359.1853).

Caryopteron F (**2**): pale yellow, amorphous powder; $[\alpha]_D^{20}$ +86 (*c* 0.01, MeOH); ECD (MeOH) λ ($\Delta\varepsilon$) 215 (14.64), 249 (1.68), 268 (3.98), 296 (−1.75), and 328 (2.33) nm; IR ν_{max} 3340, 2928, 1670, 1599, 1316, 1231, 1079, 1038, 1027, and 903 cm^{-1}; ^1H and ^{13}C NMR spectroscopic data (Tables 1 and 2); HR-ESI-MS *m/z* 361.2010 $[M + H]^+$ (Calcd. for $C_{21}H_{29}O_5$, 361.2023).

Caryopteron G (**3**): pale yellow, amorphous powder; $[\alpha]_D^{20}$ +86 (*c* 0.01, MeOH); ECD (MeOH) λ ($\Delta\varepsilon$) 220 (6.81), and 271 (−1.10); IR ν_{max} 2963, 1713, 1412, 1258, 1082, 1012, and 791 cm^{-1}; ^1H and ^{13}C NMR spectroscopic data (Tables 1 and 2); HR-ESI-MS *m/z* 359.1492 $[M - H]^-$ (Calcd. for $C_{20}H_{23}O_6$, 359.1478).

Caryopteron H (**4**): yellow, amorphous powder; $[\alpha]_D^{20}$ +93 (*c* 0.01, MeOH); ECD (MeOH) λ ($\Delta\varepsilon$) 215 (−11.69), 241 (6.02), 293 (−2.38), and 326 (6.60) nm; IR ν_{max} 2923, 1655, 1597, 1364, 1258, 1156, 1033, and 798 cm^{-1}; ^1H and ^{13}C NMR spectroscopic data (Tables 1 and 2); HR-ESI-MS *m/z* 367.1523 $[M + Na]^+$ (Calcd. for $C_{20}H_{24}O_5Na$, 367.1516).

Caryopteron I (**5**): yellow, amorphous powder; $[\alpha]_D^{20}$ +91 (*c* 0.01, MeOH); ECD (MeOH) λ ($\Delta\varepsilon$) 220 (−17.44), 258 (0.29), 292 (−6.70), and 326 (11.52) nm; IR ν_{max} 2961, 1659, 1600, 1463, 1262, 1062, 949, and 750 cm^{-1}; ^1H and ^{13}C NMR spectroscopic data (Tables 1 and 2); HR-ESI-MS *m/z* 353.1731 $[M + Na]^+$ (Calcd. for $C_{20}H_{26}O_4Na$, 353.1723).

Caryopteron J (**6**): yellow, amorphous powder; $[\alpha]_D^{20}$ +30 (*c* 0.01, MeOH); ECD (MeOH) λ ($\Delta\varepsilon$) 224 (−15.02), 235 (−8.83), 243 (−10.15), 260 (−2.34), 293 (−14.24), and 328 (13.95) nm; IR ν_{max} 2961, 1659, 1600, 1463, 1262, 1062, 949, and 750 cm^{-1}; ^1H and ^{13}C NMR spectroscopic data (Tables 1 and 2); HR-ESI-MS peak at *m/z* 329.1765 $[M - H]^-$ (Calcd. for 329.1758).

Caryopteridoid A (**7**): yellow, amorphous powder; $[\alpha]_D^{20}$ +10 (*c* 0.01, MeOH); ECD (MeOH) λ ($\Delta\varepsilon$) 218 (6.74), 256 (0.00), 273 (0.63), and 319 (−0.31) nm; IR ν_{max} 2924, 1703, 1560, and 1059 cm^{-1}; ^1H and ^{13}C NMR spectroscopic data (Tables 3 and 4); HR-ESI-MS *m/z* 205.0471 $[M + Na]^+$ (Calcd. for $C_9H_{10}O_4Na$, 205.0476).

Caryopteridoid B (**8**): light-yellow oil; $[\alpha]_D^{20}$ +26 (*c* 0.01, MeOH); ECD (MeOH) λ ($\Delta\varepsilon$) 232 (28.39), and 277 (−0.22) nm; IR ν_{max} 3349, 1699, 1403, 1068, 992, and 791 cm^{-1}; ^1H and ^{13}C NMR spectroscopic data (Tables 3 and 4); HR-ESI-MS *m/z* 207.0633 $[M + Na]^+$ (Calcd. for $C_9H_{12}O_4Na$, 207.0628).

Caryopteridoid C (**9**): light brown amorphous powder; $[\alpha]_D^{20}$ +4 (*c* 0.01, MeOH); ECD (MeOH) λ ($\Delta\varepsilon$) 220 (−2.46), 267 (1.54), 333 (−0.108) nm; IR ν_{max} 3382, 1708, 1215, 1084, 1026, and 836 cm^{-1}; ^1H and ^{13}C NMR spectroscopic data (Tables 3 and 4); HR-ESI-MS *m/z* 167.0704 $[M + H]^+$ (Calcd. for $C_9H_{11}O_3$, 167.0703).

Caryopteridoid D (**10**): light-yellow oil; $[\alpha]_D^{20}$ −5 (*c* 0.01, MeOH); ECD (MeOH) λ ($\Delta\varepsilon$) 206 (3.07), 231 (13.66), and 326 (−3.16) nm; IR ν_{max} 2962, 1258, 1012, 864, 791, and 701 cm^{-1}; ^1H and ^{13}C NMR spectroscopic data (Tables 3 and 4); HR-ESI-MS *m/z* 235.0946 $[M + Na]^+$ (Calcd. for $C_{11}H_{16}O_4Na$, 235.0914).

Caryopteridoid E (**11**): colorless, amorphous powder; $[\alpha]_D^{20}$ −5 (*c* 0.01, MeOH); ECD (MeOH) λ ($\Delta\varepsilon$) 220 (−1.65), 227 (−1.91), and 350 (0.17) nm; IR ν_{max} 2962, 1258, 1012, 864, 791, and 701 cm^{-1}; ^1H and ^{13}C NMR spectroscopic data (Tables 3 and 4); HR-ESI-MS *m/z* 167.0705 $[M + H]^+$ (Calcd. for $C_9H_{11}O_2$, 167.0703).

Cytotoxicity assays

A549 cells were cultured in Roswell Park Memorial Institute (RPMI) 1640 medium, while HeLa and HepG2 cells were cultured in Dulbecco's modified Eagle's medium (DMEM). The culture conditions were unified by using a complete medium supplemented with 10% (*V*/*V*) fetal bovine serum (FBS) and penicillin (100 $U \cdot mL^{-1}$)–streptomycin (100 $\mu g \cdot mL^{-1}$) solution. All cells were incubated at 37 °C in a humidified incubator containing 5% CO_2. The cell viability was quantified using the CCK-8 assay. For this purpose, the cells

were seeded in 96-well plates (1×10^4 cells/well) and treated with the test compounds at several concentrations (0.1, 0.5, 1, 5, 25, and 50 μmol·L^{-1}) for 24 h. Taxol was used as the positive control. Post-treatment, the media were replaced with 100 μL of the CCK-8 solution per well, followed by a 30-minute incubation at 37 °C. Cell viability was measured at 450 nm wavelength using a microplate reader (BioTek, USA). Data from the assays were analyzed using GraphPad Prism 8.0 (GraphPad Software Inc.). Assays were performed in triplicate to ensure the reliability of the results, with IC_{50} values presented as mean ± SD.

Supplementary Information

^{1}H NMR, ^{13}C NMR, 2D NMR, HR-ESI-MS, IR, and ECD spectra for all new compounds, and DP4+ analysis results of compounds **1**, **2**, and **10** are available in the Supporting Information and can be requested by sending an e-mail to the corresponding author.

References

[1] Editorial Committee of Flora of China. *Flora of China* [M]. Beijing: Science Press, 1982: 196.

[2] Mishig D, Gruner M, Lubken T, *et al*. Isolation and structure elucidation of pyridine alkaloids from the aerial parts of the Mongolian medicinal plant *Caryopteris mongolica* Bunge [J]. *Sci Rep*, 2021, **11**(1): 13740.

[3] Murata T, Selenge E, Oikawa S, *et al*. Cholinesterase-inhibitory diterpenoids and chemical constituents from aerial parts of *Caryopteris mongolica* [J]. *J Nat Med*, 2015, **69**(4): 471-478.

[4] Zhang YH, Yang L, Cheng DL. Iridoid glucosides from *Caryopteris mongholica* [J]. *Pharmazie*, 2000, **55**(11): 845-847.

[5] Saruul E, Murata T, Selenge E, *et al*. An antibacterial orthoquinone diterpenoid and its derivatives from *Caryopteris mongolica* [J]. *Bioorg Med Chem Lett*, 2015, **25**(12): 2555-2558.

[6] Dai NYT, Wang QH, Bai MR, *et al*. A new abietane diterpene tuurgan a from *caryopteris mongholica* [J]. *Nat Prod Res*, 2023, **37**(21): 3663-3667.

[7] Murata T, Ishikawa Y, Saruul E, *et al*. Abietane-type diterpenoids from the roots of *Caryopteris mongolica* and their cholinesterase inhibitory activities [J]. *Phytochemistry*, 2016, **130**: 152-158.

[8] Zhang CG, Chou GX, Mao XD, *et al*. Nepetaefolins A−J, cytotoxic chinane and abietane diterpenoids from *Caryopteris nepetaefolia* [J]. *J Nat Prod*, 2017, **80**(6): 1742-1749.

[9] Zhao SM, Chou GX, Yang QS, *et al*. Abietane diterpenoids from *Caryopteris incana* (Thunb.) Miq [J]. *Org Biomol Chem*, 2016, **14**(14): 3510-3520.

[10] Zhang CG, Chen T, Yang JJ, *et al*. Two pairs of epimers and three undescribed diterpenoids from *Pseudocaryopteris paniculata* [J]. *Nat Prod Res*, 2023, 1074-1081.

[11] Mao XD, Zhang CG, Chen T, *et al*. Cytotoxic diterpenoids from *Caryopteris aureoglandulosa* [J]. *J Nat Prod*, 2020, **83**(7): 2093-2101.

[12] Aldrich LN, Burdette JE, Carcache de Blanco E, *et al*. Discovery of anticancer agents of diverse natural origin [J]. *J Nat Prod*, 2022, **85**(3): 702-719.

[13] Jiang CY, Yang MY, Zhao CX, *et al*. Abietane diterpenes from the twigs and leaves of *Cephalotaxus oliveri* Mast. with antitumor activity [J]. *Phytochemistry*, 2022, **199**: 113187.

[14] Grimblat N, Zanardi MM, Sarotti AM. Beyond DP4: an improved probability for the stereochemical assignment of isomeric compounds using quantum chemical calculations of nmr shifts [J]. *J Org Chem*, 2015, **80**(24): 12526-12534.

[15] Stephens PJ, Harada N. ECD cotton effect approximated by the Gaussian curve and other methods [J]. *Chirality*, 2010, **22**(2): 229-233.

[16] Zhao SS, Ling JH, Li ZL, *et al*. Nine new diterpenes from the leaves of plantation-grown *Cunninghamia lanceolata* [J]. *Bioorg Med Chem Lett*, 2015, **25**(7): 1483-1489.

[17] Lichti H, von Wartburg A. Iridoids. II. Structure of harpagoside [J]. *Helv Chim Acta*, 1966, **49**(5): 1552-1580.

[18] Yu SF, Huang XJ, Fu SN, *et al*. New monoterpenoids from fruits of *Gardenia jasminoides* var. *radicans* [J]. *Helv Chim Acta*, 2015, **98**(9): 1267-1272.

[19] Shao MH, Dai W, Yuan SW, *et al*. Iridoids from *Pedicularis verticillata* and their anti-complementary activity [J]. *Chem Biodivers*, 2018, **15**(6): e1800033.

[20] Tominaga H, Ishiyama M, Ohseto F, *et al*. A water-soluble tetrazolium salt useful for colorimetric cell viability assay [J]. *Anal Commun*, 1999, **36**(2): 47-50.

Cite this article as: ZHANG Shanshan, MAO Xudong, XU Hongtao, WEI Xiaohui, CHOU Guixin. Abietane diterpenoids and iridoids from *Caryopteris mongolica* [J]. *Chin J Nat Med*, 2023, **21**(12): 927-937.