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TETRAHEDRON

Absolute Configuration and Total Synthesis of (-)-Cabenegrin A-I

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Abstract: The total synthesis of (-)-cabenegrin A-I [(-)-**1**] in five steps was achieved from (-)-6a*R*,11a*R*-maackiain [(-)-**5**], which in turn was prepared by the optical resolution of racemic (±)-**5** using *S*-(-)-α-methylbenzyl isocyanate as the the chiral auxiliary. The homochirality of (-)-maackiain [(-)-**5**] and (-)-cabenegrin A-I [(-)-**1**] was proved by CD measurements. Synthesis of (±)-maackiain [(±)-**5**] is also presented, starting from the readily available phenol derivatives resorcinol and sesamol, which demonstrates the synthetic utility of the Heck-type oxyarylation process for obtaining pterocarpane derivatives on a multigram scale. A new ring-opening reaction of pterocarpanes (**7** → **28**) is described.

Keywords: Benzopyrans, biologically active compounds, flavanoids, resolution

Pterocarpanes are naturally occurring plant products carrying a *cis*-fused benzofuranyl-benzopyran ring system.[1] Many of them are phytoalexins possessing high antifungal and antibacterial activity,[2,3] and several of them have been reported to inhibit HIV-1 reverse transcriptase and the cytopathic effect of HIV-1 in cell cultures.[4,5] Furthermore, one of us has demonstrated that two representatives of these natural products, cabenegrin A-I [(-)-**1**] and A-II [(-)-**2**] are the active components of a Brazilian folk medicine used against snake venoms.[6] Thus, both compounds have been found to be active in male beagle dogs (1 mg/kg i.v.) against the venom of *Bothrops atrrox*.[7] These potent antidotes have been isolated by Nakanishi and co-workers[6] from the aqueous alcoholic extract of the root of a South American plant called "Cabeca de Negra", and their structures have been elucidated by spectroscopic methods (UV, ^{1}H and ^{13}C NMR, CD, MS) and

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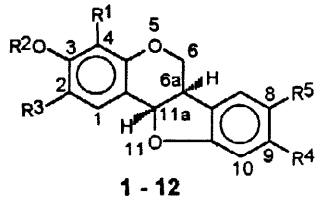
substantiated by the synthesis of their racemates.[8] The CD spectra of (-)-cabenegrin A-I [(-)-**1**], showing a large negative Cotton-effect ($\Delta\varepsilon$ = -9.84) at 238 nm, allowed us to conclude that it is homochiral with (-)-6a*R*,11a*R*-



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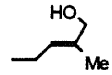
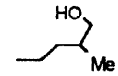
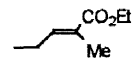
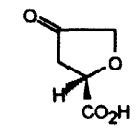
	R1	R2	R3	R4	R5
1		H	H	—OCH_2O—	
2	H	H		—OCH_2O—	
3	H	Me	H	OMe	H
4	H	β-D-Glup	H	OMe	H
5	H	H	H	—OCH_2O—	
6	H	Bn	H	—OCH_2O—	
7	H	CH_2=CH-CH_2—	H	—OCH_2O—	
8	CH_2=CH-CH_2—	H	H	—OCH_2O—	
9	H	H	CH_2=CH-CH_2—	—OCH_2O—	
10	—CH_2—CHO	H	H	—OCH_2O—	
11	—CH_2—CHO	H	I	—OCH_2O—	
12		H	H	—OCH_2O—	



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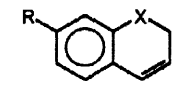


	R	X
14	BnO	O
15	H	NH

homopterocarpin [(-)-**3**] isolated by Rall *et al.*[9] from *Neorautanenia edulis*. However, it is to be noted that the CD-spectra of (-)-**3** were not reported in that publication, but on the basis of the large negative optical rotation of (-)-**3** at the sodium-D line ($[\alpha]_D$ = -277.7) Rall and co-workers supposed its homochirality with (-)-trifolirhizin [(-)-**4**], the 6a*R*,11a*R* absolute configuration of which had been established[10] by chemical correlation with (-)-paraconic acid [(-)-**13**] of known absolute configuration. Moreover, further doubt is presented by fact that the optical rotation value for (-)-**1** at the sodium-D line was not published by Nakanishi et al.[6]

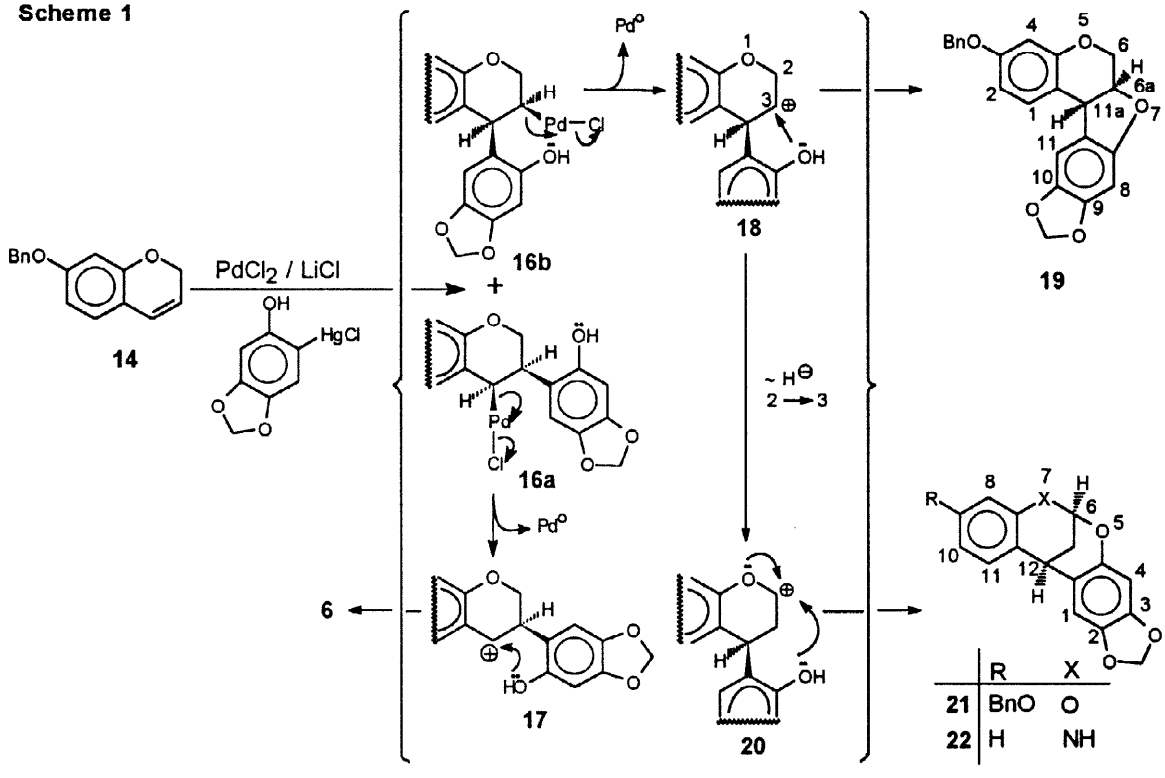
In order to unambiguously determine the absolute configuration of (-)-cabenegrin A-I [(-)-**1**], and to examine its biological activity in comparison with that of its racemate, we set our sights on its total synthesis *via* (-)-maackiain [(-)-**5**], the 6a*R*,11a*R* absolute configuration of which had been deduced from chemical correlation with (-)-6a*R*,11a*R*-trifolirhizin [(-)-**4**].[11]

The strategy of our synthesis was based on the well-documented synthetic availability of racemic maackiain [(±)-**5**].[12-15] Its functionalizable hydroxyl group at C-3 offers a good chance to prepare diastereoisomers with a suitable chiral auxiliary, separable by chromatography or crystallization. Among the known syntheses of (±)-**5**, the one reported by Breytenbach and Rall[12] seemed to be useful to obtain (±)-**5** on a multigram scale, from the commercially available starting materials resorcinol and sesamol (3,4-methylenedioxyphenol). Indeed, 7-benzyloxy-*2H*-1-benzopyran (**14**) could be obtained from resorcinol in four steps in an 18% overall yield, and reacted with 2-chloromercurio-3,4-methylenedioxyphenol (prepared from sesamol by a simple mercuration) under the conditions of the Heck oxyarylation procedure, to afford the required 3-benzylmaackiain [(±)-**6**] in an acceptable yield (53%). However, it is to be noted that - in contrast to the reports of Breytenbach[12] and Harano[15] - our TLC examination showed that the oxyarylation reaction produced not only

(±)-**6** in 66% yield, but also additional coupled products. Moreover, the m.p. of our product [(±)-**6**, m.p. 143-144°C] was found to be characteristically different from that of Breytebach's compound (m.p. 173-174°C).

After isolation of (±)-**6** the side-products were separated by preparative TLC and their structures were elucidated by spectroscopic methods. On the basis of the comparison of the ^{1}H-NMR and MS data of the less polar component of m.p. 199-200°C with those of the oxazocine derivative **22**, prepared by two of us[16] by the Heck-type coupling of 1,2-dihydroquinoline (**15**) with 2-chloromercurio-3,4-methylenedioxyphenol, a 6,12-methano-6H-dibenzo [d,g][1,3]dioxacine structure **21** has been unambiguously assigned. The HRMS and ^{1}H-NMR spectra of the other unexpected compound clearly show that it is an isomer of (±)-**6** bearing the 3,4-methylendioxyphenyl group at C-4 of the 7-benzyloxychromane skeleton. Comparison of these data with our previous observations[16] suggests that (i) the Heck-type oxyarylation of 3-chromene derivatives did not take

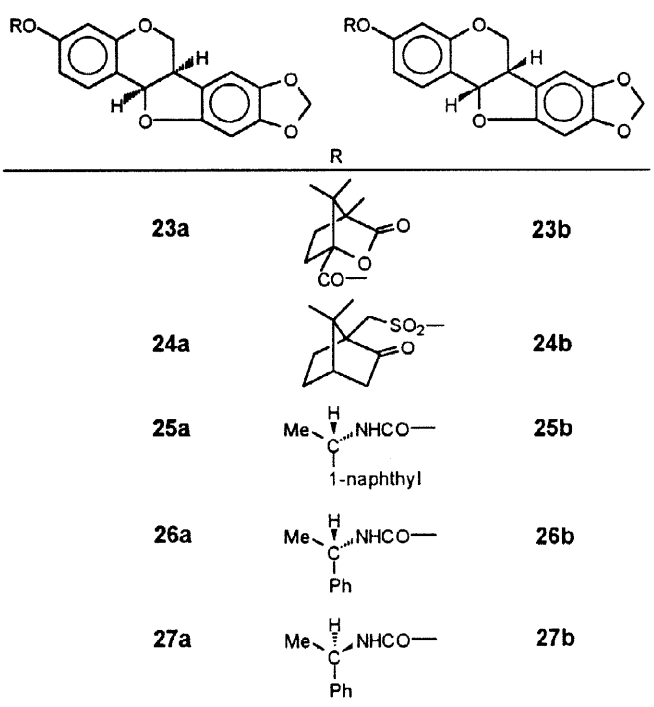
Scheme 1



place with completo regioselectivity (**14** → **16a** → **17** → **6**) as published Breytenbach and others,[12,15] (**ii**) the ring closure of the corresponding organo-palladium intermediate **16b**, leading to the side products **19** and **21**, took place *via* a carbocation intermediate (**18**). This carbocation readily accepts not only an electron pair of the nucleophilic hydroxyl group to form the C-O bond of **19**, but it rearranges *via* a hydride shift to the more stable **20** which, upon reaction with the phenolic hydroxyl group, affords the dioxacine derivative **21** as depicted in Scheme 1.

Since our target molecule [(±)-**6**] could be separated from the side-products **19** and **21** by a very simple treatment with diethyl ether at room temperature, we developed this method for the multigram-scale preparation of (±)-**6** to be used as the starting material for the synthesis of (-)-cabenegrin A-I [(-)-**1**].

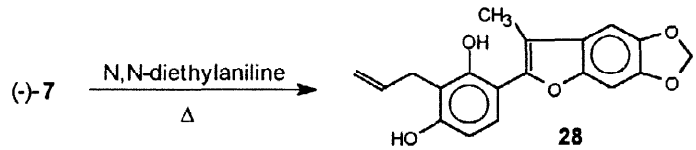
In the first step the benzyl protecting group of (±)-**6** was cleaved by catalytic hydrogenation over 10% palladium charcoal without cleavage of the C-11a—O-bond,[17] to give racemic maackiain [(±)-**5**] in 92% yield. In order to resolve (±)-**5**, the hydroxyl group at C-3 was acylated with both 1*S*-(-)-camphanic chloride and D-(+)-camphor-10-sulphonyl chloride under the conditions described by Lampe *et al.*[18] to give the diastereomeric mixtures **23a,b** and **24a,b**, respectively, in good yield. Although these were stable and crystalline compounds, their resolution by chromatography or crystallization, using various solvents was unsuccessful. Similar attempts with the carbonates **25a,b**, prepared with *R*(-)-1-(1-naphthyl)ethyl isocyanate,[19] also failed. Finally, racemic maackiain [(±)-**5**] was treated with an equimolar amount of *R*-(+)-α-methylbenzyl isocyanate in dry benzene at 80°C in the presence of N,N-dimethylethanolamine. The reaction was monitored by TLC, which clearly showed that a large amount of the starting material [(±)-**5**] was present after 13 h. Since addition of the isocyanate to the hydroxyl group of (±)-**5** proceeded very slowly, a possibility of a kinetic resolution[20] could not be ruled out. Therefore, the reaction mixture was slowly cooled and a colourless crystalline product of m.p. 151-152°C was collected in 22% yield. Although this crystalline compound of sharp melting point seemed to be diastereomerically pure (**26a** or **26b**) on the basis of its ^{1}H NMR data at 400 MHz, the cleavage of its carbamoyl function under the reported conditions[21,22] resulted in the racemic maackiain [(±)-**5**]. Therefore, the crystalline product of m.p. 151-152°C proved to be a 1:1 diastereomeric mixture of **26a** and **26b**, but its repeated crystallization from methanol yielded (+)-**26b** of m.p. 209-210°C, whose diastereomeric purity was found to be 95.3% by HPLC analysis. From the combined mother liquors evaporation and repeated crystallization also gave (-)-**26a** of m.p. 199-200°C, whose HPLC analysis showed a 93% **26a** and 7% **26b** content. The establishment of the configuration of (-)-**26a** and (+)-**26b** at the pterocarpane nucleus was performed by chemical correlation with the maackiain enantiomers [(-)-**5** and (+)-**5**], prepared by cleavage of the carbamoyl group of the diastereomers [(-)-**26a** → (-)-**5**, (+)-**26b** → (+)-**5**].



Since (-)-6a*R*,11a*R*-maackiain [(-)-5] has been found to be homochiral with (-)-cabenegrin A-I [(-)-1] on the basis of comparison of their CD-spectra, and its carbamoyl derivative [(-)-**26a**] was isolated from the mother liquors of the fractional crystallization of the 1:1 mixture of (-)-**26a** and (+)-**26b**, it seemed to be more expedient to repeat and optimize the resolution of (±)-**5** with the enantiomeric chiral reagent *S*-(-)-α-methylbenzyl isocyanate. Thus, (±)-**5** was treated with *S*-(-)-α-methylbenzyl isocyanate and a 1:1 diastereomeric mixture of the carbamates **27a** + **27b** (m.p. 147-149°C, $[\alpha]_D$ = -80) was isolated in 50% yield. The process of the fractional crystallization is given in the Experimental. It is to be noted that very modest yields [**27a** (5%), **27b** (2%)] could be achieved due to very small differences in their solubilities. Such small differences both in the chemical shift values in their ^{1}H NMR spectra, and in their chromatographic behaviour on TLC (they were inseparable) also clearly indicated the absence of high second-order interactions, such as hydrogen bonds, *etc.*, between the molecules, which would be necessary to achieve a higher yield of separation of **27a** and **27b** by crystallization. Removal of the chiral auxiliary of (-)-**27a** by reduction with $LiAlH_4$ in a mixture of dry benzene and diethyl ether at r.t. gave the crude (-)-**5**, which was purified by chromatography to afford enantiomerically almost pure (-)-6a*R*,11a*R*-maackiain [(-)-**5**, ee = 99.5% by HPLC analysis]. It is noteworthy that the cleavage of the carbamoyl group of **27a** or **26b** with $SiHCl_3$ according to the methods reported by Messe[21] and Pirkle[22] resulted in a significantly lower yield.

The regioselective introduction of the hydroxyisoprene unit at C-4 of (-)-**5** was developed according to the method of Ishiguro *et al.*[8] In the first step (-)-maackiain [(-)-**5**] was alkylated with allyl bromide in the presence of potassium carbonate to give (-)-**7** in 77% yield, whose thermal Claisen rearrangement in N,N-diethylaniline at 208°C (in contrast to Ishiguro's result) did not give regioselectively the corresponding 4-allyl-derivative [(-)-**8**], but was followed by cleavage of the C-O bond of the benzopyrane moiety and loss of hydrogens at C-6a and C-11a to result in 42% of **28** as depicted in Scheme 2. This unexpected transformation of the pterocarpane skeleton could be avoided when the reaction was executed in a sealed tube in xylene at 192°C. At this temperature the Claisen rearrangement takes place rather slowly, but without considerable side-reaction. Although the reaction mixture still contained the starting material [(-)-**7**] in a considerable amount (20%) after 24 h, the desired product [(-)-**8**] could be isolated by preparative TLC in 68%

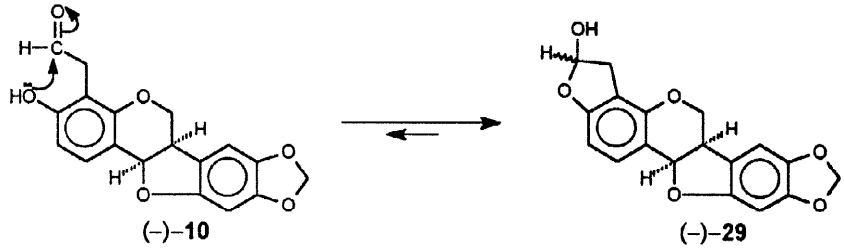
Scheme 2



yield, beside the isomeric C-allyl derivative [(-)-**9**], characterised by ^{1}H NMR measurements. In the next step of the synthesis we observed a rather different transformation of (-)-**8** than in case of its racemic form. Thus, treatment of (-)-**8** with osmium tetroxide, followed by oxidation with sodium metaperiodate in dioxan at room temperature resulted in a mixture of (-)-**10** and (-)-**11**, which could be readily separated by preparative TLC. This side-reaction occurred due to the good solubility of (-)-**10**, which did not precipitate from the solution in

contrast to the racemic aldehyde [(±)-**10**], and therefore its iodo derivative [(-)-**11**] was also produced. It is noteworthy, that on the basis of the ^{1}H NMR measurements of (-)-**10**, it exists in $CDCl_3$ in its hemiacetal form [(-)-**29**], due to a rapid intramolecular cyclization as shown in Scheme 3.

Scheme 3



The *E*-olefinic side-chain of (-)-**1** was stereoselectively introduced by the Wittig reaction of (-)-**10** with α-ethoxycarbonylethyltriphenylphosphonium bromide[23] in ethanol at room temperature in the presence of potassium ethoxide to give 48% of (-)-**12**, whose enantiomeric purity (ee% = 99.1%) was determined by HPLC on a Chiracel-OD column using a mixture of hexane and ethanol (82:18) as eluent. In the last step of the synthesis, the *E*-ester [(-)-**12**] was reduced with lithium aluminium hydride in diethyl ether at room temperature to afford (-)-**1** in 31% yield. The UV, NMR and CD-data of this *levo*-rotatory enantiomer were identical with those reported for cabenegrin-AI,[6] and therefore this allows the assignment of the 6a*R*,11a*R* configuration for (-)-cabenegrin-AI [(-)-**1**].

Furthermore, it is to be noted that in our hands reduction of the ester (-)-**12** or its racemate [(±)-**12**] did not result in the corresponding allyl alcohol (-)-**1** or (±)-**1**, respectively, under the conditions ($LiAlH_4$, THF, -40°C) reported by Ishiguro et al.[8] Instead, no transformation of these compounds could be detected.

In summary, we accomplished the total synthesis of (-)-6a*R*,11a*R*-cabenegrin-AI [(-)-**1**] *via* (-)-6a*R*, 11a*R*-maackiain [(-)-**5**], which was prepared by the optical resolution its racemic form [(±)-**5**] using *S*-(-)-α-methylbenzyl isocyanate as the chiral auxiliary. We showed that the Heck-type oxyarylation of 7-benzyloxy-*2H*-1-benzopyran (**14**) with 2-chloromercurio-3,4-methylenedioxyphenol offers a suitable, direct route to racemic maackiain [(±)-**5**] on a multigram scale. A notable feature of this strategy is that in contrast to previous observations[12,15] the palladium chloride-catalysed coupling reaction did not proceed with full regioselectivity to give the pterocarpane ring system, but it also furnished other O-heterocycles as side-products. A new thermal ring opening reaction of pterocarpanes (**7** → **28**) was also observed.

Experimental

Melting points were determined on a Kofler hot-stage apparatus and are uncorrected. 200-MHz ^{1}H-NMR spectra were recorded with a Bruker WP 200 SY (marked by an asterisk*) and XLAA 400 Varian instrument in $CDCl_3$ with TMS as internal standard. MS spectra were obtained with a VG-7035 GC/MS/DS spectrometer (ion current 0.1 mA, direct insertion technique). IR spectra were recorded on a Perkin Elmer FT IR spectrometer. Elemental analyses were carried out with a Carlo Erba 1106 analyser. Optical rotation was

measured with Perkin-Elmer 241 polarimeter at the sodium-D line. CD spectra were recorded with a Jobin-Yvon Mark VI dichrograph at toom temerature. (1*S*)-(-)-Campanic chloride, (1*S*)-(+)-camphorsulfonyl chloride, (R)-(-)-1-(1-naphthyl)ethyl isocyanate, (*S*)-(+)-α-methylbenzyl isocyanate, (*S*)-(-)-α-methylbenzyl isocyanate and osmium tetroxide were purchased from Sigma-Aldrich, 7-benzyloxy-2*H*-1-benzopyran (**14**), 2-chloromercury-4,5-methylenedioxy-phenol and triphenyl-(1-ethoxycarbonyl)ethyl-phosphonium bromide were prepared by known methods.[12,13] Pre-coated silica gel plates (Kieselgel 60 F254, 0.25 mm, Merck) were used for analytical and preparative TLC. For workup the solutions were dried ($MgSO_4$) and concentrated in vacuo.

(±)-3-Benzyloxy-8,9-methylenedioxypterocarpan [(±)-6], (±)-6,11-methano-2,3-methylendioxy-6*H*-dibenzo[d,g][1,3]dioxacin (21) and (±)-6a,12b-dihydro-6*H*-benzo[4,5]furo[2,3-c]chromene (19). Palladium chloride (17.1 g, 9.6 mmol) and lithium chloride (8.52 g, 20.2 mmol) were stirred in dry acetone (300 ml) for 15 min and 5-benzyloxy-2*H*-1-benzopyran (**14**)[12] (22.85 g, 9.6 mmol) was added, stirred again for 15 min, followed by dilution of the mixture with dry acetone (300 ml) and addition of 2-chloromercury-4,5-methylenedioxyphenol[12] (38 g, 10.1 mmol). Stirring was continued for 150 min, and then the reaction mixture was poured into brine (1500 ml), extracted with benzene, washed with brine, dried and concentrated in vacuo to a viscous crude product (60g), which became a gray to white solid on addition of a small quantity of methanol. After filtration the crude product was purified by stirring with diethyl ether (200 ml) at room temperature to give rac. **6** of m.p. 143-144°C (19 g, 53%). ν_{max} (KBr): 1620, 1584, 1506, 1474, 1462, 1180, 1166, 1144, 1036 cm^{-1}. ^1H NMR*: 7.50-7.30 (m, 6H, C1-H), 6.72 (s, 1H, C10-H), 6.70 (d, J = 2.5 Hz, C2-H), 6.56 (d, J = 2.5 Hz, C4-H), 6.42 (s, 1H, C7-H), 5.90 (d, 1H, O-CH_2-O), 5.50 (d, J = 7.5 Hz, 1H, C11a-H), 5.08 (s, 2H, benzyl-CH_2), 4.23 (dd, J = 3 and 12 Hz, 1H, $C6_{eq}$-H), 3.64 (t, J = 12 Hz, 1H, $C6_{ax}$-H), 3.50 (m, 1H, $C6_a$-H); Anal. Calcd. for $C_{23}H_{18}O_5$ (374.39): C, 73.78; H, 4.84; found C, 73.52; H, 4.81. Evaporation of the mother liquor gave a thick oil (27 g). A small quantity (100 mg) of this oil was purified on preparative TLC using benzene as eluent to result in **21** (10 mg) and **19** (4 mg). **21**: colourless needles from acetone, m.p. 199-200°C; ν_{max} (KBr): 1624, 1580, 1500, 1480, 1442, 1240, 1172, 1144, 1088 cm^{-1}. ^1H NMR*: 2.20 (t, J = 2 Hz, 2H, C13-H_2), 3.68 (s, 1H, C6-H), 4.99 (s, 2H, benzyl-CH_2), 5.82 (d, 2H, O-CH_2-O), 6.05 (s, 1H, C12-H), 6.42 (s, 1H, C4-H), 6.55-6.49 (m, 2H, C8,10-H), 6.60 (s, 1H, C12-H), 7.03 (d, J = 8 Hz, 1H, C11-H), 7.25-7.41 (m, 5H, Ph); Anal. Calcd. for $C_{23}H_{18}O_5$ (374.39): C, 73.78; H, 4.84; found C, 73.49; H, 4.90; **19**: colourless oil; ν_{max} (KBr): 1620, 1580, 1502, 1482, 1460, 1198, 1180, 1146, 932 cm^{-1}. ^1H NMR*: 4.10-4.25 (m, 2H, C6-H_2), 4.28 (t, J = 3.5 Hz, 1H, C6a-H), 5.01 (s, 2H, benzyl-CH_2), 5.22 (d, J = 3.5 Hz, 1H, C11a-H), 5.38 (s, 2H, O-CH_2-O), 5.82 (d, J = 3 Hz, 1H, C4-H), 6.47 and 6.49 (s, 2H, C8,11-H), 6.50-6.60 (m, 2H, C2,4-H), 6.82 (d, J = 7.5 Hz, 1H, C1-H), 7.32-7.50 (m, 5H, Ph); HRMS: Calcd. for $C_{23}H_{18}O_5$ (374.1154), found m/z: 374.1147 (M^+).

(±)-3-Hydroxy-8,9-methylenedioxypterocarpan [rac.-maackiain, (±)-5]. (±)-**6** (9.6 g, 26.2 mmol) was dissolved in a mixture of acetone-tetrahydrofuran (3:1, 480 ml) and hydrogenated in the presence of 10% palladium-charcoal (2.5 g) until the uptake of 680 ml of hydrogen. Usual workup resulted in rac. maackiain (6.8 g, 92%) of m.p. 194-196°C. Lit.[24] m.p. 195-196°C; Anal. Calcd. for $C_{16}H_{12}O_5$ (284.26): C, 67.60; H, 4.25; found C, 67.50; H, 4.49.

(-)-3(1*S*-Camphanic)-maackiain (23a,b). (±)-**5** (500 mg, 1.75 mmol) was dissolved in dry pyridine (10 ml) and (1*S*)-(-)-camphanic chloride (605 mg, 2.8 mmol) was added at room temperature. After stirring for 24 hrs the reaction mixture was poured into ice-water, when the colourless solid product was precipitated (625 mg, 77 %), and it was crystallized from methanol yielding 527 mg (50%) of **23a,b** (diastereomeric mixture), m.p. 190-191°C, $[\alpha]_D^{24}$ = -5 (c = 0.9 in chloroform). ν_{max} (KBr): 1788, 1754, 1618, 1474, 1460, 1260, 1116, 1046, 992 cm^{-1}. ^1H NMR: 1.09, 1.15 and 1.17 (s, 3x3H, C4'-H_3, C8'-H_3, C9'-H_3), 1.77 and 1.99 (m, 2H, C5'-H_2), 2.20 and 2.56 (m, 2H, C6'-H_2), 3.53 (m, *J* = 10.3, 7.0 and 4.8 Hz, 1H, C6a-H), 3.66 and 3.67 (2xt, *J* = 10.3 Hz, 1H, C6-H_{ax}), 4.28 (d, *J* = 10.3 and 4.5 Hz, 1H, C6-H_{eq}), 5.51 (d, *J* = 7.0 Hz, 1H, C11a-H), 5.91 and 5.93 (*J* = 1.5 Hz, 2H, O-CH_2-O), 6.73 and 6.75 (2xd, *J* = 2.2 Hz, 1H, C4-H), 6.83 (dd, *J* = 8.1 and 2.2 Hz, 1H, C2-H), 7.54 (d, *J* = 8.1 Hz, 1H, C1-H); Anal. Calcd. for $C_{26}H_{24}O_8$ (464.45): C, 67.23; H, 5.20; found C, 67.21; H 5.27.

(+)-3(1-*S*-Camphor-10-sulfonyl)-maackiain (24a,b). 500 mg (1.76 mmol) of [(±)-**5**], abs. pyridine (10 ml) and 700 mg (2.8 mmol) of (1*S*)-(+)-10-camphorsulfonyl chloride was stirred at room temperature for 24 h. The reaction mixture was poured into ice-water. The product precipitated was filtered off and washed with water. 680 mg 75 % of colourless solid was obtained, m.p. 136°C, which was crystallized from methanol, yielding 400 mg (44 %) of **24a,b** (diastereomeric mixture), m.p. 142-143°C, $[\alpha]_D^{24}$ = +21 (c = 1 in acetone). ν_{max} (KBr): 1746, 1614, 1494, 1474, 1460, 1374, 1180, 1146, 1110 cm^{-1}. ^1H NMR: 0.92 and 1.18 (s, 2x3H, C8'-H_3, C9'-H_3), 1.47 and 1.72 (m, 2H, C5'-H_2), 1.98 (d, *J* = 18.3 Hz, 1H, C3'-H_A), 2.09 (m, *J* = 18.3, 4.3 and 3.5 Hz, 1H, C3'-H_B), 2.14 (dd, *J* = 4.5 and 4.3 Hz, 1H, C4'-H), 2.42 and 2.55 (m,2H, C6'-H_2), 3.53 and 3.54 (m, *J* = 10.5, 7.0 and 4.9 Hz, 1H, C6a-H), 3.64 and 3.66 (2xt, *J* = 10.5 Hz, 1H, C6-H_{ax}), 4.29 (dd, *J* = 10.5 and 4.9 Hz, 1H, C6-H_{eq}), 5.50 (d *J* = 7.0 Hz, 1H, C11a-H), 5.90 and 5.93 (*J* = 1.4 Hz, 2H, O-CH_2-O), 6.43 (s, 1H, C10-H), 6.72 (s, 1H, C7-H), 6.92 and 6.94 (2xd, *J* = 2.2 Hz, 1H, C4-H), 7.03 (dd, *J* = 8.2 and 2.2 Hz, 1H, C2-H), 7.55 (d, *J* = 8.2 Hz, 1H, C1-H); Anal. Calcd. for $C_{26}H_{26}O_8S$ (498.56): C, 62.63; H, 5.25; S, 6.43; found C, 62.75; H, 5.10; S, 6.35.

(+)-3[1-*S*-N-(1-Naphthyl)ethylcarbamoyl]-maackiain (25a,b). A stirred solution of 100 mg (0.35 mmol) of (±)-**5**, 69 mg (0.35 mmol) of (*R*)-(-)-1-(1-naphthyl)ethyl isocyanate 20 ml of dry benzene, and 1 drop of N,N-dimethylethanolamine catalyst was heated under reflux for 9.5 h. The solvent was removed in vacuo and the crude diastereomeric carbamates were crystallized from methanol. A total of 75 mg (45 %) of colourless crystalline product was collected, m.p. 152-153°C, $[\alpha]_D^{24}$ = +25 (c = 0.8 in acetone) (diastereomeric mixture). ν_{max} (KBr): 1736, 1728,

1618, 1494, 1474, 1460, 1256, 1180, 1144 cm^{-1}. ^1H NMR: 1.73 (d, J = 7.2 Hz, 3H, CH_3), 3.48 and 3.50 (m, 1H, C6a-H), 3.62 and 3.65 (2xt, J = 10.6 Hz, 1H, C6-H_{ax}), 4.22 (dd, J = 10.6 and 5.0 Hz, 1H, C6-H_{eq}), 5.33 (d, J = 8 Hz, 1H, NH), 5.48 (d, J = 7.0 Hz, 1H, C11a-H), 5.73 (m, 1H, CH), 5.89 and 5.93 (J = 1.5 Hz, 2H, O-CH_2-O), 6.42 (s, 1H, C10-H), 6.71 (s, 1H, C7-H), 6.73 and 6.75 (2xd, J = 2.2 Hz, 1H, C4-H), 6.84 and 6.88 (dd, J = 7.0 and 2.1 Hz, 1H, C2-H), 7.40 and 7.60 (m, 5H, C3'-H, C6'-H, C7'-H, C1-H, C2'-H), 7.82 and 7.88 (dd, J = 7.0 and 1.5 Hz, 2H, C4'-H, C5'-H), 8.12 (dd, J = 7.4 and 1.3 Hz, 1H, C8'-H); Anal. Calcd. for $C_{29}H_{23}NO_6$ (481.49): C, 72.34; H, 4.81; N, 2.90; found C, 72.51; H, 4.79; N, 2.89.

(-)-3[1-*R*-N(1-Methyl)benzylcarbamoyl]-6a*R*,11a*R*-maackiain (26a) and (+)-3[1'-*R*-N(1'-methyl)benzyl-carbamoyl]-6a*S*,11a*S*-maackiain (26b). A mixture of (±)-**5** (2.5 g, 8.75 mmol), (*R*)-(+)-α-methylbenzyl isocyanate (1.4 g, 1.75 mmol), N,N-dimethylethanolamine (3 drop), and dry benzene (225 ml) was heated at 80°C for 18 h. After cooling 875 mg (22 %) of colourless crystalline product was obtained; m.p. 151-152°C; $[\alpha]_D^{24}$ = +67 (c = 1, chloroform), (1:1 mixture of diastereomeric carbamates); ^1H NMR: 1.52 (d, J = 7.2 Hz, 3H, CH_3), 3.47 and 3.49 (m, 1H, C6a-H), 3.64 and 3.66 (2xt, J = 10 Hz, 1H, C6-H_{ax}), 4.22 (dd, J = 10.6 and 5.0 Hz, 1H, C6-H_{eq}), 4.92 (m, 1H, CH), 5.28 (d, J = 7.8 Hz, 1H, NH), 5.48 (d, J = 7.0 Hz, 1H, C11a-H), 5.88 and 5.93 (J = 1.4 Hz, 2H, O-CH_2-O), 6.43 (s, 1H, C10-H), 6.71 (s, 1H, C7-H), 6.72 and 6.73 (2xd, J = 2.1 Hz, 1H, C4-H), 6.81 and 6.83 (2xdd, J = 7.8 and 2.1 Hz, 1H, C2-H), 7.26 and 7.35 (m, 5H, C2'-H, C6'-H), 7.44 (d, J = 7.8 Hz, 1H, C1-H); MS (70 eV) m/z %: 431 [M^+] (100), 413, 386, 368; HPLC (Chiracel-OD; eluent; n-hexane:ethanol = 82:18): R_t = 16.54 and 21.30 min. Fractional crystallization of the diastereomeric carbamates from methanol yielded (+)-**26b** (120 mg, 6%); m.p. 209-210°C, $[\alpha]_D^{24}$ = +243 (c = 1 in acetone); HPLC: R_t = 16.52 min; ν_{max} (KBr): 1708, 1618, 1546, 1530, 1496, 1460, 1454, 1180, 1146 cm^{-1}. Anal. Calcd. for $C_{25}H_{21}NO_6$ (431.42) C, 69.60; H, 4.90; N, 3.24; found C, 69.51; H, 4.87; N, 3.15. Fractional crystallization of the product obtained by evaporation of the combined mother liquors of the above mentioned crystallization resulted in (-)-**26a** (45 mg, 3%), m.p. 199-200°C, $[\alpha]_D^{24}$ = -45 (c = 1 in acetone); HPLC: R_t = 21.30 min; ν_{max} (KBr): 1702, 1618, 1562, 1530, 1498, 1474, 1456, 1160, 1146 cm^{-1}. Anal. Calcd. for $C_{25}H_{21}NO_6$ (431.42) C, 69.60; H, 4.90; N, 3.24; found C, 69.15; H, 4.88; N, 3.40.

(-)-3[1-*S*-N(1-Methyl)benzylcarbamoyl]-6a*R*,11a*R*-maackiain (27a) and (+)-3[1-*S*-N(1-methyl)benzyl-carbamoyl]-6a*S*,11a*S*-maackiain (27b). 5 g (17.5 mmol) of (±)-**5** and *S*-(-)-α-methylbenzyl isocyanate (5 ml, 34 mmol), in dry benzene (300 ml) in presence of 5 drops of N,N-dimethylethanolamine was boiled for 15 h. After cooling to room temperature 3.8 g (50 %) **27a,b** (1:1 mixture of diastereomeric carbamates) was obtained, m.p. 147-149°C, $[\alpha]_D^{24}$ = -80 (c = 0.9 in acetone); HPLC: R_t = 16.88 and 18.62 min. The diastereomeric mixture was dissolved in ethanol (150 ml) under reflux and cooled slowly to room temperature to give a colourless precipitate (840 mg), whose crystallization from ethanol (100 ml) resulted in a crystalline product (420 mg, $[\alpha]_D$ = -178). Its crystallization from ethanol afforded (-)-**27a** of m.p. 209-210°C (210 mg, $[\alpha]_D$ = -240), whose melting point increased to 214-215°C (190 mg, 5%), $[\alpha]_D$ = -262, c = 1 in acetone) by a repeated crystallization from ethanol; HPLC: R_t = 18.62

min. ν_{max} (KBr): 1708, 1618, 1592, 1528, 1496, 1474, 1456, 1232, 1146 cm^{-1}. Anal. Calcd. for $C_{25}H_{21}NO_6$ (431.45): C, 69.62; H, 4.92; N, 3.24; found C, 69.84; H, 4.91; N, 3.24.

Fractional crystallization of the product (1920 mg, $[\alpha]_D$ = -67) obtained from the methanol liquors of the first crystallization of the diastereomeric carbamates of m.p. 147-149°C resulted in (+)-**27b** (75 mg, 2%), $[\alpha]_D^{24}$ = +79 (c = 0.9 in acetone), m.p. 203-204°C; HPLC: R_t = 16.88 min. ν_{max} (KBr): 1706, 1618, 1592, 1526, 1494, 1474, 1454, 1158, 1144 cm^{-1}. Anal. Calcd. for $C_{25}H_{21}NO_6$ (431.45): C, 69.62; H, 4.92; N, 3.24; found C, 69.92; H, 4.94; N, 3.25.

(+)-6a*S*,11a*S*-Maackiain [(+)-5]. a) To a stirred solution of **26b** (43 mg, 0.1 mmol) and 1 drop of triethylamine in 7 ml of dry benzene was added 0.15 ml (0.12 mmol) of $SiHCl_3$ in 5 ml of dry benzene over a 10-min period. The reaction mixture was heated at reflux under argon for 4 h. For completion of the decomposition of the diastereomer carbamate a further 0.5 ml (0.4 mmol) of $SiHCl_3$ was added in dry benzene (5 ml) and boiled for 2 hrs. After being cooled, the reaction mixture was poured with stirring into 50 ml of saturated aqueous NH_4Cl. The insoluble silicon-containing solid was removed by filtration and washed with benzene. The organic phase was washed with water, dried over $MgSO_4$ and concentrated. The residue was purified on preparative TLC yielding 10 mg (35 %) of (+)-**5**. M.p. 181-182°C, $[\alpha]_D^{24}$ = +179 (c = 0.1 in acetone), its enantiomeric purity was 83.5 % as checked by HPLC analysis. b) Starting from **27b** ($[\alpha]_D^{24}$ = +79) (+)-**5** was obtained, with $LiAlH_4$ as described below, m.p. 179-181°C, $[\alpha]_D^{24}$ = +258 (c = 0.1 in acetone). CD(CH_3CN) λnm (Δε): 211 (28.60), 237 (11.02), 313 (-2.23); ee=99% (HPLC: Chiralpak OT(+), methanol, R_t = 9.43 min); Anal. Calcd. for $C_{16}H_{12}O_5$ (284.26): C, 67.60; H, 4.25; found C, 67.65; H, 4.25.

(-)-6a*R*,11a*R*-Maackiain [(-)-5]. To a stirred solution of **27a** (340 mg, 0.8 mmol), ($[\alpha]_D$ = -262) in a mixture of dry ether (100 ml) and dry benzene (100 ml) 150 mg (4 mmol) of $LiAlH_4$ was added. After 20 min the excess of $LiAlH_4$ was decomposed with water. The organic phase was separated and washed with water (2x50 ml). The aqueous phase was acidified with 5 % of HCl to pH = 6 and extracted with benzene. Drying over $MgSO_4$ and concentration of the combined organic phase afforded crude (-)-**5** which was purified by column chromatography on silica gel (toluene:acetone = 4:1) yielding 200 mg (90 %) of (-)-**5** as colourless prisms. M.p. 181-187°C, $[\alpha]_D^{24}$ = -267 (c = 0.1 in acetone). CD(CH_3CN) λnm (Δε): 208 (-28.51), 238 (-10.06), 309 (+2.66), ee = 99.5 % (HPLC: Chiralpak OT(+), methanol, R_t = 11.37 min). ν_{max} (KBr): 3428, 1620, 1598, 1510, 1476, 1312, 1286, 1180, 1146 cm^{-1}. ^1H NMR*: 7.40 (d, J = 10 Hz, 1H, C1-H), 6.70 (s, 1H, C10-H), 6.55 (dd, J = 10 Hz, 4 Hz, 1H, C2-H), 6.45 (s, 1H, C7-H), 6.40 (d, J = 4 Hz, 1H, C4-H), 5.90 (d, 2H, O-CH_2-O), 5.50 (d, J = 10 Hz, 1H, C11a-H), 5.0 (br.s, 1H, C3-OH), 4.20 (dd, J = 5 Hz and 10 Hz, 1H, $C6_{eq}$-H), 3.60 (t, J = 10 Hz, 1H, $C6_a$-H), 3.45 (m, 1H, $C6_{ax}$-H); Anal. Calcd. for $C_{16}H_{12}O_5$ (284.26): C, 67.60; H, 4.25; found C, 67.61; H, 4.24. Starting from **27a** ($[\alpha]_D^{24}$ = -262) (-)-**5** was obtained with $SiHCl_3$ only in 40% yield.

(-)-3-Allyloxy-8,9-methylenedioxypterocarpan [(-)-7]. To a solution of (-)-**5** (250 mg, 0.88 mmol) in acetone (30 ml), K_2CO_3 (500 mg) and allyl bromide (0.2 ml) were added and the mixture was stirred at 50°C for 10 h. After filtration of the salt the filtrate was evaporated to give a colourless oil (261 mg), whose crystallization from n-hexane afforded 193 mg (77 %) of (-)-7 as colourless needles of m.p. 138-139°C, $[\alpha]_D^{24}$ = -224 (c = 0.1 in acetone), CD(CH_3CN) λnm (Δε): 312 (3.35), 239 (-14.79), 212 (-32.53); ν_{max} (KBr): 1620, 1614, 1586, 1504, 1478, 1330, 1288, 1266, 1242 cm^{-1}. ^1H NMR: 3.40 (m, *J* = 11.0, 6.8 and 5.1 Hz, 1H, C6a-H), 3.57 (t, *J* = 11.0 Hz, 1H, C6-H_{ax}), 4.15 (dd, *J* = 11 and 5.1 Hz, 1H, C6-H_{eq}), 4.45 (m, *J* = 5.2, 1.3 and 1.3 Hz, 2H, C1'-H_2), 5.20 (m, *J* = 10.8, 1.5, 1.3 and 1.3 Hz, 1H, C3'-H_A), 5.32 (m, *J* = 17.0, 1.5, 1.3 and 1.3 Hz, 1H, C3'-H_B), 5.40 (d, *J* = 6.8 Hz, 1H, C11a-H), 5.82 and 5.84 (*J* = 1.5 Hz, 2H, O-CH_2-O), 5.96 (m, 1H, C2'-H), 6.37 (s, 1H, C10-H), 6.41 (d, *J* = 2.5 Hz, 1H, C4-H), 6.57 (dd, *J* = 8.5 and 2.5 Hz, 1H, C2-H), 6.63 (s, 1H, C7-H), 7.33 (d, *J* = 8.5 Hz, 1H, C1-H). Anal. Calcd. For $C_{19}H_{16}O_5$ (324.32): C, 70.36; H, 4.97; found C, 70.43; H, 5.01.

(-)-4-Allyl-8,9-methylendioxypterocarpan [(-)-8], (-)-2-allyl-8,9-methylendioxypterocarpan [(-)-9] and 2-(2',4'-dihydroxy-3'-allyl)phenyl-3-methyl-5,6-methylendioxybenzo[b]furan (28). 600 mg (1.4 mmol) of (-)-7 was dissolved in dry xylene (10 ml) and kept in a sealed tube at 192°C for 24 h. After cooling the solvent was evaporated in vacuo and the residue was purified by preparative TLC on silica gel to result in (-)-**8**, (-)-**9**, **27** and unchanged (-)-7 (120 mg, 20%); (-)-**8**: 413 mg (68%), colourless prisms of m.p. 122-123°C, $[\alpha]_D^{24}$ = -223 (c = 0.17 in acetone); ν_{max} (KBr): 3358, 1620, 1602, 1496, 1474, 1188, 1144, 1220, 1036 cm^{-1}. ^1H NMR: 3.38 (m, 2 H, C1'-H_2), 3.41 (m, *J* = 11.0, 6.6 and 5 Hz, 1H, C6a-H), 3.54 (t, *J* = 11.0 Hz, 1H, C6-H_{ax}), 4.20 (dd, *J* = 11 and 5.0 Hz, 1H, C6-H_{eq}), 5.02 (m, *J* = 10.3, 1.6 and 1.4 Hz, 1H, C3'-H_A), 5.02 (s, 1H, OH), 5.04 (m, *J* = 17.2, 1.8 and 1.4 Hz, 1H, C3'-H_B), 5.41 (d, *J* = 6.6 Hz, 1H, C11a-H), 5.82 and 5.84 (*J* = 1.4 Hz, 2H, O-CH_2-O), 5.90 (m, 1H, C2'-H), 6.37 (s, 1H, C10-H), 6.48 (d, *J* = 8.3 Hz, 1H, C2-H), 6.63 (s, 1H, C7-H), 7.21 (d, *J* = 8.3 Hz, 1H, C1-H); Anal. Calcd. for $C_{19}H_{16}O_5$ (324.32) C, 70.36; H,4.97; found C, 70.61; H, 4.62; (-)-**9**: 20 mg (3 %) colourless prisms, m.p. 174-175°C, $[\alpha]_D^{24}$ = -249 (c = 0.2 in acetone); ν_{max} (KBr): 3358, 1620, 1602, 1496, 1472, 1216, 1144, 1120, 936 cm^{-1}. ^1H NMR: 3.29 (m, *J* = 5.9, 1.4 and 1.5, 2 H, C1'-H_2), 3.37 (m, *J* = 10.9, 5.0 and 7.0 Hz, 1H, C6a-H), 3.53 (t, *J* = 10.9 Hz, 1H, C6-H_{ax}), 4.12 (dd, *J* = 10.9 and 5.0 Hz, 1H, C6-H_{eq}), 5.02 (s, 1H, OH), 5.08 (m, *J* = 10.0, 1.4 and 1.7 Hz, 1H, C3'-H_A), 5.11 (m, *J* = 17.1, 1.5 and 1.7 Hz, 1H, C3'-H_B), 5.38 (d, *J* = 7.0 Hz, 1H, C11a-H), 5.80 and 5.82 (*J* = 1.4 Hz, 2H, O-CH_2-O), 5.93 (m, 1H, C2'-H), 6.36 (s, 1H, C10-H), 6.38 (s, 1H, C4-H), 6.61 (s, 1H, C7-H), 7.14 (s, 1H, C1-H). **28**: 3 mg (0.5 %), colourless rhombic prisms of m.p. 90-92°C; ν_{max} (KBr): 3434, 3346, 1626, 1606, 1496, 1462, 1376, 1310, 1170 cm^{-1}. ^1H NMR*: 7.18 (d, *J* = 7 Hz, 6'-H), 7.00 and 6.95 (s, 2H, 4,7-H), 6.51 (d, *J* = 7 Hz, 4'-H), 6.01 (s, 2H, 5,6-OCH_2O-), 6.10-5.90 (m, 1H, -CH=), 5.19 (m, 2H, =CH_2), 3.55 (d, *J* = 5.5 Hz, 2H, 3'-allyl-CH_2), 2.30 (s, 3H, 3-Me); Anal. calcd. for $C_{19}H_{16}O_5$ (324.32) C, 70.36; H, 4.97; found C, 70.10; H, 4.81. This compound as a sole product was also obtained in 42% yield, when (-)-7 was heated in N,N-diethylaniline at 208°C.

(-)-3-Hydroxy-4-(2-oxo)ethyl-8,9-methylendioxypterocarpan [(-)-10] and 3-hydroxy-2-iodo-4-(2-oxo) ethyl-8,9-methylendioxy-pterocarpan [(-)-11]. To a stirred solution of (-)-**8** (305 mg, 0.94 mmol) in dioxane (19.2 ml) OsO_4 (43 mg, 0.15 mmol) was added at room temperature. After 30 min a solution of $NaIO_4$ (450 mg) in water (50 ml) was added dropwise and stirred overnight. After addition of water the product was extracted with $CHCl_3$. The organic phase was washed with aqueous $NaHSO_3$, dried over $MgSO_4$ and evaporated in vacuo. The syrupy residue was purified on preparative TLC with toluene:ethyl acetate (4:1) as the eluent, yielding 104 mg (34 %) of (-)-**10** as colourless needles, m.p. 150-151°C, $[\alpha]_D^{24}$ = -175 (c = 0.1 in acetone). R_f = 0.54; ν_{max} (KBr): 3470, 1716, 1624, 1496, 1474, 1144, 1072, 1038, 1008 cm^{-1}. ^1H NMR: 2.93 (dd, *J* = 16.6 and 2.1 Hz, 1H, C1'-H_A), 3.04 and 3.05 (2xd, *J* = 6.0 and 5.7 Hz, 1H, 2xOH), 3.23 (dd, *J* = 16.6, and 6.4, 1 H, C1'-H_B), 3.39 and 3.41 (m, 1H, C6a-H), 3.63 and 3.64 (2xt, *J* = 10.8 Hz, 1H, C6-H_{ax}), 4.17 and 4.18 (2xdd, *J* = 10.8 and 5.0 Hz, 1H, C6-H_{eq}), 5.42 and 5.43 (2xd, *J* = 6.9 Hz, 1H, C11a-H), 5.80 and 5.82 (d, *J* = 1.4 Hz, 2H, O-CH_2-O), 6.02 and 6.04 (m, 1H, C2'-H), 6.37 (s, 1H, C10-H), 6.52 (d, *J* = 8.4 Hz, 1H, C2-H), 6.61 (s, 1H, C7-H), 7.22 (d, *J* = 8.4 Hz, 1H, C1-H); Anal. Calcd. for $C_{18}H_{14}O_6$ (326.30): C, 66.25; H, 4.32; found C, 66.10; H, 4.28; (-)-**11** was also isolated (29 mg, 7 %); R_f = 0.85; m.p. 175°C, $[\alpha]_D^{24}$ = -180 (c = 0.1 in acetone); ν_{max} (KBr): 3428, 1722, 1642, 1618, 1474, 1460, 1254, 1234, 1200 cm^{-1}. ^1H NMR: 2.90 (dd, *J* = 16.6 and 2.1 Hz, 1H, C1'-H_A), 3.06 and 3.07 (2xd, *J* = 6.0 and 5.7 Hz, 1H, 2xOH), 3.25 (dd, *J* = 16.6, and 6.4, 1 H, C1'-H_B), 3.40 and 3.41 (m, 1H, C6a-H), 3.63 and 3.65 (2xt, *J* = 10.8 Hz, 1H, C6-H_{ax}), 4.17 and 4.18 (2xdd, *J* = 10.8 and 5.0 Hz, 1H, C6-H_{eq}), 5.42 and 5.44 (2xd, *J* = 6.9 Hz, 1H, C11a-H), 5.80 and 5.82 (d, *J* = 1.4 Hz, 2H, O-CH_2-O), 6.02 and 6.04 (m, 1H, C2'-H), 6.38 (s, 1H, C10-H), 6.40 (s, 1H, C4-H), 6.62 (s, 1H, C7-H), 7.24 (s, 1H, C1-H). Anal. Calcd. for $C_{18}H_{13}IO_6$ (452.19): C, 47.81; H, 2,89; I, 28,06; found C, 47.55; H, 2.79; I, 28.51.

(-)-3-Hydroxy-4-[(E)-2-ethoxycarbonyl-2-buten-4-yl]-8,9-methylendioxypterocarpan [(-)-12]. To a solution of (-)-**10** (120 mg, 0.37 mmol) and triphenyl-(1-ethoxycarbonyl)ethylphosphonium bromide (200 mg, 0.45 mmol) in abs. ethanol (5 ml) 0.91 ml of 1N $NaOC_2H_5$ was added at room temperature. After 3 h the reaction mixture was partially evaporated, acidified slightly with 10% HCl and diluted with water. The product was extracted with dichloromethane, washed with water, dried and evaporated to give the crude product which was purified by preparative TLC (toluene:acetone = 20:1) affording 72 mg (48 %) of (-)-**12** as rhombic prisms, m.p. 175-176°C, $[\alpha]_D^{24}$ = -73 (c = 0.1 in chloroform); ν_{max} (KBr): 3386, 1704, 1640, 1614, 1474, 1292, 1260, 1144, 1074 cm^{-1}. ^1H NMR: 1.17 (t, *J* = 6.8 Hz, 3H, CH_3), 1.91 (s, 3H, C5'-H_3), 3.39 (m, *J* = 11.0, 7.0 and 5.0 Hz, 1H, C6a-H), 3.46 (d, *J* = 7.4 Hz, 2H, C1'-H_2), 3.54 (d, *J* = 11.0 Hz, 1H, C6-H_{ax}), 4.08 (q, *J* = 8 Hz, 2H, OCH_2), 4.21 (dd, *J* = 11.0 and 5.0 Hz, 1H, C6-H_{eq}), 5.08 (s, 1H, OH), 5.41 (d, *J* = 7.0 Hz, 1H, C11a-H), 5.82 and 5.85 (*J* = 1.5 Hz, 2H, O-CH_2-O), 6.35 (s, 1H, C10-H), 6.42 (d, *J* = 8.3 Hz, 1H, C2-H), 6.62 (s, 1H, C7-H), 6.68 (t, *J* = 7.4 Hz, 1H, C2'-H), 7.14 (d, *J* = 8.3 Hz, 1H, C1-H); HPLC (Chiracel-OD, n-hexane:ethanol=82:18); R_t = 13.51 and 11.17 min for (-)-**12** and (+)-**12** resp., ee = 99.1%; Anal. Calcd. for $C_{23}H_{22}O_7$ (410.41): C, 67.31; H, 5.40; found C, 67.17; H, 5.52.

(-)-3-Hydroxy-4[(*E*)-2-hydroxymethyl-2-buten-4-yl]-8,9-methylendioxypterocarpan; (-)-cabenegrin-AI [(-)-1]. 36 mg (0.99 mmol) (-)-**12** was dissolved in diethyl ether, cooled to 0°C and $LiAlH_4$ (20 mg) was added in four portions. After stirring for 2 hrs the reaction mixture was pured into NH_4Cl solution. The product was extracted with ethyl acetate, dried and evaporated to give an amorpheus powder (30 mg) which was purified by means of preparative TLC (toluene:ethyl acetate=4:1) resulting in (-)-**1** (11 mg, 31 %) as colourless prisms, m.p. 165-167°C, $[\alpha]_D^{24}$ = -127 (c=0.1 in chloroform); CD(EtOH) λnm (Δε): 214 (-30.53), 240 (-13.31), 309 (+3.54); ν_{max} (KBr): 3550, 1614, 1500, 1474, 1144, 1094, 1074, 1016, 940 cm^{-1}. ^1H NMR: 1.22 (t, *J* = 4.4 Hz, 1H, OH), 1.76 (s, 3H, C5'-H_3), 3.33 (d, *J* = 7.3 Hz, 2H, C1'-H_2), 3.41 (m, *J* = 11.0, 6.5 and 5.0 Hz, 1H, C6a-H), 3.55 (dd, *J* = 11.0 and 10.9 Hz, 1H, C6-H_{ax}), 3.92 (d, *J* = 4.4 Hz, 2H, C4'-H_2), 4.22 (dd, *J* = 10.9 and 5.0 Hz, 1H, C6-H_{eq}), 5.41 (d, *J* = 6.5 Hz, 1H, C11a-H), 4.95 (s, 1H, OH), 5.42 (t, *J* = 7.3 Hz, 1H, C2'-H), 5.82 and 5.85 (*J* = 1.4 Hz, 2H, O-CH_2-O), 6.36 (s, 1H, C10-H), 6.46 (d, *J* = 8.4 Hz, 1H, C2-H), 6.64 (s, 1H, C7-H), 7.17 (d, *J* = 8.4 Hz, 1H, C1-H); ^{13}C NMR: 13.77 ((C5'), 21.84 (C1'), 40.14 (C6a), 66.71 (C6), 68.68 (C4'), 79.07 (C11a), 93.78 (C10), 101.26 (OCH_2O), 104.73 (C-7), 109.60 (C2), 112.63 (C4), 115.02 (C1a), 118.03 (C7a), 123.31 (C2'), 129.15 (C1), 136.09 (C3'), 141.65 (C8), 148.06 (C9), 154.20 (C4a,10a), 155.06 (C3); MS (70eV) m/z, %: 368 [M^+] (100), 350 (80), 335 (95), 295 (18), 175 (27). Anal. Calcd. for $C_{21}H_{20}O_6$ (368.36): C, 68.47; H, 5.47; found C, 68.27; H, 5.31.

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