Synthesis of *rac*-(*E*)-Opposita-4(15),7(11)-dien-12-al

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Dedicated to Professor Hans Bock on the occasion of his 70th birthday

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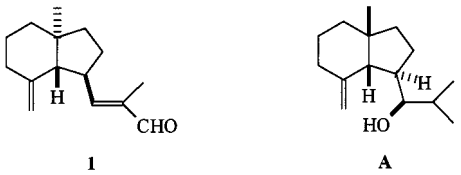
rac-(*E*)-Opposita-4(15),7(11)-dien-12-al (**1**) was synthesized in 12 steps via the aldehyde **11** as the key compound. The spectroscopic data of *rac*-**1** are identical with those of the corresponding natural product, previously isolated from Vetiver oil. Synthetic *rac*-**1** has a strong, green woody odor with soft-floral undertones, which confirms that **1** is an olfactorily important constituent of Vetiver oil.

The commercial Haitian Vetiver oil [ex *Vetiveria zizanioides* (L.) Nash], highly appreciated in perfumery due to its woody, heavy sweet, earthy, green notes is one of the most complex essential oils. Although there are several publications within the last twenty years,[1] many of the olfactorily important constituents seem to be unknown. We analyzed a Haitian Vetiver oil and isolated more than 170 constituents, many of which were hitherto unknown.[2–6] Remarkably, some of them possess the rare oppositane (axane) skeleton, e.g. *epi*-dracunculifoliol (**A**), previously synthesized by us.[7] One of the most interesting minor constituents (ca. 2%) was the new aldehyde (*E*)-opposita-4(15),7(11)-dien-12-al (**1**).[4] The isolated sample (GC: 65%) had a strong odor with a green, rhubarb-like note, typical for Vetiver oil. Since a further purification of this sample was not possible, due to its sensitivity to oxygen, we were interested to synthesize *rac*-oppositadienal **1**[8] to confirm the stereochemistry and the olfactory properties.

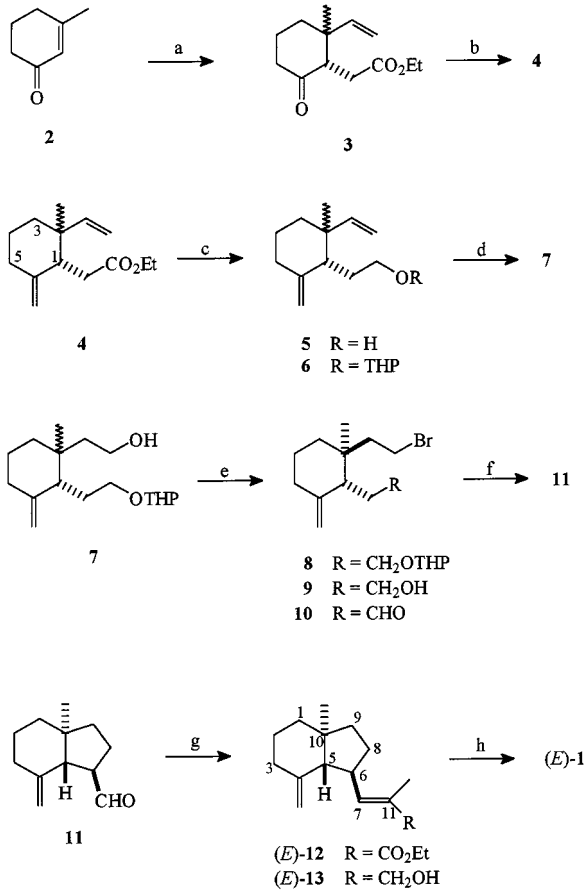


1 **A**

Scheme 1. Only relative configurations are shown

Synthesis

The key compound for the synthesis of the sesquiterpene aldehyde **1** is the *trans*-hydrindane aldehyde **11** possessing the correct stereochemistry at C-5, C-6 and C-10. We prepared **11** some years ago in 16 steps on the way to the oppositadienol dracunculifoliol.[7] This lengthy route can be improved, and therefore, the *trans* stereochemistry of C-5 and C-10[9] should be established at a very early stage.



Scheme 2. Only relative configurations are shown:
a: 1. $BrMgCH{=}CH_2$, CuI_2, 2. $BrCH_2CO_2Et$; b: $Ph_3P^+CH_3Br^-$, KO*t*Bu; c: 1. $LiAlH_4$, 2. DHP; d: 1. 9-BBN, 2. H_2O_2, NaOH; e: 1. NBS, Ph_3P; 2. TsOH; 3. PDC; f: KO*t*Bu; g: 1. $(EtO)_2P(O)CH(Me)$-CO_2Et, K_2CO_3, 2. $LiAlH_4$, $AlCl_3$; h: MnO_2

Tandem alkylation of 3-methylcyclohexenone (**2**) with vinylmagnesium bromide in the presence of Cu_2I_2, followed by trapping of the enolate with ethyl bromoacetate according to a similar procedure of Fétizon[10] gave an isomeric mixture (3:1) of the esters *trans*- and *cis*-**3**, not separable by flash chromatography (FC). The stereochemistry can be

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assigned unambiguously from the very different chemical shifts of the axial (δ_H = 0.85, δ_C = 16.4, *trans*-**3**) and equatorial (δ_H = 1.17, δ_C = 25.7, *cis*-**3**) 2-methyl groups in the ^{1}H- and ^{13}C-NMR spectrum.[11] The methylene derivatives *trans*- and *cis*-**4** (2:1) were formed by usual Wittig olefination. A direct selective hydroboration of the vinyl group of **4** could not be effected. Apparently, the ester function prohibits such a reaction. Therefore, **4** was converted into the THP ether **6** in almost quantitative yield. After some preliminary experiments, 9-BBN was found to be the most convenient selective hydroboration reagent affording the easily separable alcohols *trans*- and *cis*-**7**. Bromination of *trans*-**7** with NBS/Ph_3P in presence of pyridine (→ *trans*-**8**) and deprotection led to the bromo alcohol *trans*-**9**. Oxidation with PDC on Celite® gave aldehyde *trans*-**10** in high yield, and the final ring closure to furnish key compound **11** occurred almost quantitatively. For the correct stereochemistry at C-6 the less hindered spatial arrangement of the enolate with respect to the methyl group seems to be responsible (see also ref.[7]). Thus, aldehyde **11**, identical in all spectral data with the compound obtained previously,[7] was now synthesized in 9 steps with an overall yield of 9%.

Wittig−Horner olefination with triethyl phosphonopropionate in the presence of K_2CO_3 gave the α,β-unsaturated ester **12** in a 12:1 (*E*)/(*Z*) ratio. The (*E*) configuration of the main isomer follows from the downfield-shifted olefinic proton signal (7-H, δ = 6.64) relative to that of (*Z*)-**12** (δ = 5.79) and from the NOED spectra. Reduction of the (*E*)-ester **12** with $LiAlH_4/AlCl_3$ afforded (*E*)-oppositadienol (**13**), which showed NMR data identical to those of the product obtained by $NaBH_4$ reduction of natural oppositadienal.[4] Finally, MnO_2 oxidation of (*E*)-**13** provided *rac*-(*E*)-oppositadienal (**1**), also identical in all spectral data with the natural compound isolated from Vetiver oil.[4] The odor was evaluated as strong, green with soft-floral undertones of mimosa and orris, and a woody tonality. This result shows that the sesquiterpene aldehyde **1** is an olfactorily important constituent of Vetiver oil, although the rhubarb tonality of the isolated sample containing 65% of **1** should be due to the trace constituents.

Experimental Section

^{1}H NMR ($CDCl_3$): Bruker AM 400. − ^{13}C NMR ($CDCl_3$): Bruker AH 270 with DEPT program. − HR MS: MAT 95 SC (direct inlet, 70 eV). − GC MS: MAT 95 SC, 30-m DB 5 column (Fa. J & W), carrier gas He. − GC: Packard 439 with a 25-m CP Sil 5 CB column (0.39 μm), carrier gas N_2, RRI: relative retention index. − Flash chromatography (FC): ICN Biomedicals silica 32−63; elution with light petroleum ether (PE, boiling range 40−60°C) and increasing amounts of diethyl ether. − TLC: Silica gel 60 F254 (Merck no. 5554). − IR (CCl_4): Perkin-Elmer 881. − Kugelrohr distillation (KRD): B.p. means the temp. of the air bath. − Usual workup: The aqueous layer was extracted several times with diethyl ether; the combined organic phases were washed with dild. hydrochloric acid, $NaHCO_3$ and satd. NaCl solution, dried with $MgSO_4$, and concentrated in a rotatory evaporator. For reactions in which water had to be excluded, the vessels were flame-dried under N_2. The solvents were dried as usual and stored over molecular sieves. All compounds are racemic. For numbering see Scheme 2.

Ethyl (1*SR*,2*SR*)-2-(2-Ethenyl-2-methyl-6-oxocyclohexyl)ethanoate (3): By analogy to ref.[10] 105 mL (105 mmol) of a 1 M solution of vinylmagnesium bromide in THF was stirred with 2.2 g of Cu_2I_2 for 30 min at −5°C. Then 7.7 g (70 mmol) of 3-methylcyclohex-2-enone (**2**) was added dropwise and stirring was continued for 1 h. This solution was added dropwise to a solution of 24 g (145 mmol) of ethyl bromoacetate in 80 mL of HMPA at room temp. and the mixture then stirred for 1 h. An excess of 5% HCl was added and stirred for 1 h. Usual workup and FC gave 7.85 g (50%) of an oily mixture (3:1) of *trans*- and *cis*-**3**[11]. − IR: $\tilde{\nu}$ = 1735 (CO_2R), 1715 cm^{-1} (CO). − ^{1}H NMR (typical signals from the mixture): *trans*-**3**: δ = 0.85 (s, 2-Me), 2.11 (dd, *J* = 17, 2.5 Hz) and 2.61 (dd, *J* = 17, 11 Hz, 1-CH_2), 2.95 (dd, *J* = 11, 2.5 Hz, 1-H), 5.00 (d, *J* = 17.5), 5.05 (d, *J* = 11), 5.80 (dd, *J* = 17.5, 11 Hz, 2-CH_2=CH); CO_2Et: δ = 4.06, 4.12 (ABq, *J* = 11, 7 Hz), 1.24 (t, *J* = 7 Hz); *cis*-**3**: δ = 1.17 (s, 2-Me), 2.15 (dd, *J* = 17, 3.5 Hz) and 2.71 (dd, *J* = 17, 9 Hz, 1-CH_2), 2.90 (dd, *J* = 9, 3.5 Hz, 1-H), 4.97 (d, *J* = 17.5), 5.07 (d, *J* = 11), 5.62 (dd, *J* = 17.5, 11 Hz, 2-CH_2=CH); CO_2Et: δ = 4.06, 4.12 (ABq, *J* = 11, 7 Hz), 1.24 (t, *J* = 7 Hz). − ^{13}C NMR (from the mixture): *trans*/*cis*-**3**: δ = 16.4/25.7 (q, 2-Me), 22.6/22.1 (t, C-4), 29.0 (t, 1-CH_2), 38.5/39.2 (t, C-3), 40.9/40.7 (t, C-5), 44.7 (s, C-2), 53.8/55.4 (d, C-1), 112.4/114.7 (t), 145.7/140.0 (d, 2-CH_2=CH), 209.9 (s, C-6); CO_2Et: δ = 172.7 (s), 60.1 (t), 13.9 (q). − GC MS (*cis*- + *trans*-**3**); *m*/*z* (%): 224 (22) [M^+], 209 (6), 196 (10), 179 (37), 178 (40), 163 (41), 150 (38), 137 (23), 135 (40), 122 (20), 107 (20), 95 (28), 93 (28), 81 (100), 79 (88), 67 (50), 55 (69). − $C_{13}H_{20}O_3$ (224.3): calcd. C 69.61, H 8.99; found C 69.82, H 8.87.

Ethyl (1*RS*,2*SR*)-2-(2-Ethenyl-2-methyl-6-methylenecyclohexyl)-ethanoate (4): 16.1 g (45 mmol) of methyltriphenyl phosphonium bromide in 80 mL of DME was treated with 4.75 g (42 mmol) of KO*t*Bu and refluxed for 30 min. To this stirred solution 7.85 g (35 mmol) of **3** in 20 mL of DME was added dropwise and the mixture was heated at 85°C for 1 h. Then it was quenched with satd. NH_4Cl solution and worked up. The residue was treated with cold PE and filtered through silica gel to eliminate triphenylphosphane oxide. FC yielded 5.8 g (75%) of an oily 2:1 mixture of *trans*- and *cis*-**4**. − IR: $\tilde{\nu}$ = 1740 (CO_2R) cm^{-1}. − ^{1}H NMR (typical signals from the mixture): *trans*-**4**: δ = 0.85 (s, 2-Me), 2.57 (dd, br., *J* = 10, 3 Hz, 1-H), 4.56, 4.83 (2 m_c, CH_2=), 5.00 (d, *J* = 17), 5.02 (d, *J* = 11), 5.81 (dd, *J* = 17, 11 Hz, 2-CH_2=CH); CO_2Et: δ = 4.06, 4.12 (ABq, *J* = 11, 7 Hz), 1.20 (t, *J* = 7 Hz); *cis*-**4**: δ = 1.05 (s, 2-Me), 4.63, 4.79 (2 m_c, CH_2=), 4.95 (d, *J* = 17), 5.01 (d, *J* = 11), 5.83 (dd, *J* = 17, 11 Hz, 2-CH_2=CH); CO_2Et: δ = 4.06, 4.12 (ABq, *J* = 11, 7 Hz), 1.24 (t, *J* = 7 Hz). − ^{13}C NMR (from the mixture): *trans*/*cis*-**4**: δ = 16.6/25.4 (q, 2-Me), 23.5/22.9 (t, C-4), 32.9/32.7 (t, 1-CH_2), 36.1 (t, C-5), 39.2 (t, C-3), 41.8/40.5 (s, C-2), 47.0/49.2 (d, C-1), 107.8/109.6 (t), 147.9 (s, 6-CH_2=C), 112.0/112.1 (t), 148.1/145.0 (d, 2-CH_2=CH); CO_2Et: δ = 173.3 (s), 60.1 (t), 14.1 (q). − GC MS: *trans*-**4**; *m*/*z* (%): 222 (16) [M^+], 207 (22), 194 (12), 177 (14), 176 (11), 161 (13), 149 (16), 148 (24), 135 (34), 134 (90), 133 (55), 121 (72), 119 (60), 105 (28), 93 (50), 81 (100), 79 (45), 67 (20); *cis*-**4**: nearly identical with that of *trans*-**4**. − $C_{14}H_{22}O_2$ (222.3): calcd. C 75.63, H 9.97; found C 75.48, H 9.85.

(1*RS*,2*SR*)-2-(2-Ethenyl-2-methyl-6-methylenecyclohexyl)ethanol (5): A solution of 4.4 g (20 mmol) of ester **4** in 10 mL of Et_2O was added dropwise to a stirred suspension of 0.50 g (13 mmol) of $LiAlH_4$ in 25 mL of Et_2O. Stirring was continued for 20 h, then water and dild. HCl (10%) were added until the deposit was dissolved. Usual workup gave 3.5 g (97%) of an oily 2:1 mixture of *trans*- and *cis*-**5**. − IR: $\tilde{\nu}$ = 3450 (OH) cm^{-1}. − ^{1}H NMR (typical signals from the mixture, *trans*/*cis*-**5**): δ = 0.90/1.00 (s, 2-Me), 3.5−3.7 (m, CH_2OH), 4.63, 4.86/4.69, 4.81 (2 m_c, CH_2=), 4.97/

4.93 (d, J = 17), 5.00/4.98 (d, J = 11), 5.82/5.76 (dd, J = 17, 11 Hz, 2-CH_2=CH). − ^{13}C NMR (typical signals from the mixture, *trans*/*cis*-**5**): δ = 19.4/25.3 (q, 2-Me), 23.7/22.7 (t, C-4), 29.5 (t, 1-CH_2), 34.9 (t, C-5), 37.5 (t, C-3), 40.4/41.9 (s, C-2), 50.1/47.9 (d, C-1), 61.8 (t, CH_2O), 108.4/110.0 (t), 148.9 (s, 6-CH_2=C), 111.5/111.1 (t), 148.4/147.3 (d, 2-CH_2=CH). − GC MS: (*trans*-**5**); *m*/*z* (%): 180 (1) [M^+], 165 (10), 152 (15), 147 (10), 136 (15), 121 (53), 108 (20), 107 (33), 105 (24), 93 (50), 91 (42), 81 (88), 79 (100), 77 (26), 67 (48), 55 (26), 53 (37); *cis*-**5**: nearly identical with that of *trans*-**5**.

(1*RS*,2*SR*)-2-[2-(2-Ethenyl-2-methyl-6-methylenecyclohexyl)-ethoxy]tetrahydropyrane (6): A mixture of 2.7 g (15 mmol) of crude **5**, 2.5 g (30 mmol) of dihydropyrane, 0.2 g of amberlyst-15® and of 20 mL of PE was stirred for 2 d. After filtration and workup, 3.85 g (97%) of crude **6** (mixture of 4 diastereomers) was obtained and used as such for the next step.

(1*RS*,2*SR*)-2-{1-Methyl-3-methylene-2-[2-(tetrahydropyran-2-yloxy)ethyl]cyclohexyl}ethanol (7): 66 mL (33 mmol) of 0.5 M 9-BBN in THF was added within 15 min at 0°C to a stirred solution of 3.17 g (12 mmol) of crude **6** in 40 mL of THF. Stirring was continued for 7 h at room temp., then 11 mL of 3 M NaOH and 11 mL of 30% H_2O_2 were added at 0°C to the mixture. The mixture was allowed to warm to room temp. and stirred overnight. Usual workup and FC gave as first fraction 0.2 g of a mixture of unidentified compounds. 1.52 g (45%) of *trans*-**7** (2 diastereomers) was obtained as second fraction. − IR: $\tilde{\nu}$ = 3440 (OH) cm^{-1}. − ^{1}H NMR (typical signals): δ = 0.84 (s, 1-Me), 3.66 (t, J = 7 Hz, CH_2OH), 4.49/4.53 (dd, J = 5, 3 Hz OCHO). − ^{13}C NMR (typical signals): δ = 23.8 (q, 1-Me), 48.3 (d, C-2), 59.0 (t, CH_2OH). − 0.34 g (10%) of *cis*-**7** (2 diastereomers) was isolated as third fraction. − IR: $\tilde{\nu}$ = 3440 (OH) cm^{-1}. − ^{1}H NMR (typical signals): δ = 0.86 (s, 1-Me), 3.60 (t, J = 7 Hz, CH_2OH), 4.43 (dd, J = 5, 3 Hz OCHO). − ^{13}C NMR (typical signals): δ = 26.8 (q, 1-Me), 49.3 (d, C-2), 58.5 (t, CH_2OH).

(1*RS*,2*SR*)-2-{2-[2-(2-Bromoethyl)-2-methyl-6-methylenecyclohexyl]ethoxy}tetrahydropyrane (*trans*-8): A solution of 4.98 g (19 mmol) of triphenylphosphane in 15 mL of CH_2Cl_2 was added dropwise to a stirred suspension of 3.56 g (20 mmol) of NBS in 30 mL of CH_2Cl_2. After 5 min, 0.6 mL of pyridine and then 1.41 g (5.0 mmol) of *trans*-**7** in 15 mL of CH_2Cl_2 was added. Stirring was continued overnight; then the mixture was concentrated. The residue was treated with 25 mL of PE/MTB (4:1) and filtered through silica gel. After washing several times with this solvent mixture, the filtrate was concentrated to give 1.21 g (70%) of crude *trans*-**8** (2 diastereomers). − ^{1}H NMR (typical signals): δ = 0.87 (s, 2-Me), 4.51, 4.55 (dd, J = 5, 3 Hz OCHO). − ^{13}C NMR (typical signals): δ = 23.3 (q, 2-Me), 38.6 (s, C-2), 48.0/48.3 (d, C-1), 98.7/99.3 (d, OCHO), 110.1 (t), 147.7 (s, 6-CH_2=C).

(1*RS*,2*SR*)-[2-(2-Bromoethyl)-2-methyl-6-methylenecyclohexyl]ethanol (*trans*-9): 0.69 g (2.0 mmol) of crude *trans*-**8** and 15 mg of *p*-toluenesulfonic acid hydrate were stirred for 2 h in 20 mL of methanol. Then, a spatula tip of $NaHCO_3$ was added and the solvent evaporated. Usual workup and FC yielded 0.52 g (99%) of *trans*-**9**. − IR: $\tilde{\nu}$ = 3330 (OH) cm^{-1}. − ^{1}H NMR: δ = 0.87 (s, 2-Me), 1.25−1.7 (m, 5 H), 1.91, 1.99 (ABdd, J = 14, 12, 5.5 Hz, 2-CH_2), 2.0−2.1 (m, 3 H), 3.34, 3.39 (Abdd, J = 10, 12, 5.5 Hz, CH_2Br), 3.5−3.6 (m, CH_2OH), 4.68, 4.83 (2 m_c, CH_2=). − ^{13}C NMR: δ = 22.7 (t, C-4), 23.4 (q, 2-Me), 28.8, 28.9 (2 t, 1-CH_2, CH_2Br), 31.2 (t, C-5), 32.7 (t, 2-CH_2), 38.4 (s, C-2), 42.6 (t, C-3), 48.4 (d, C-1), 61.4 (t, CH_2O), 110.1 (t), 148.3 (s, 6-CH_2=C). − $C_{12}H_{21}BrO$ (261.3): calcd. C 55.16, H 8.10; found C 55.03, H 8.01.

(1*RS*,2*SR*)-[2-(2-Bromoethyl)-2-methyl-6-methylenecyclohexyl]ethanal (*trans*-10): 0.62 g (2.8 mmol) of PDC was added to a stirred suspension of 0.50 g (1.9 mmol) of *trans*-**9** and 0.37 g of Celite® in 25 mL of CH_2Cl_2. After 1 h, the mixture was diluted with 25 mL of MTB and filtered through Celite®. Concentration yielded 0.42 g (86%) of crude *trans*-**10** which was immediately used for the next step. − IR: $\tilde{\nu}$ = 1730 (CHO) cm^{-1}. − ^{1}H NMR: δ = 0.83 (s, 2-Me), 1.4−1.6 (m, 3-,4-H_2), 1.94, 1.99 (ABdd, J = 14, 10, 6.5 Hz, 2-CH_2), 2.08, 2.16 (ABdd, br., J = 14, 7, 7 Hz, 5-H_2), 2.44 (m_c, 1-H), 2.50, 2.56 (AB, J = 8.5 Hz, B part d, J = 4 Hz, 1-CH_2), 3.36, 3.41 (ABdd, J = 11, 10, 6.5 Hz, CH_2Br), 4.61, 4.85 (2 m_c, CH_2=), 9.64 (d, J = 4 Hz, CHO). − ^{13}C NMR: δ = 21.9 (q, 2-Me), 22.7 (t, C-4), 28.3 (t, CH_2Br), 32.9, 34.0 (2 t, C-3,-5), 38.5 (s, C-2), 41.1, 43.2 (2 t, 1-,2-CH_2), 45.9 (d, C-1), 110.5 (t), 147.2 (s, 6-CH_2=C), 202.0 (d, CHO). − GC MS; *m*/*z* (%): 260/258 (0.1) [M^+], 161 (8), 151 (66), 133 (21), 123 (16), 109 (88), 91 (16), 81 (100), 67 (21), 55 (24).

(1*RS*,3a*SR*,7a*RS*)-(3a-Methyl-7-methyleneoctahydroindene-1-yl)carbaldehyde (11): 0.28 g (2.5 mmol) of KO*t*Bu was added to a solution of 415 mg (1.6 mmol) of *trans*-**10** in 45 mL of *t*BuOH at 30°C. After stirring at 30°C for 1 h, 45 mL of dild. HCl was added. Usual workup gave 276 mg (97%) of **11**. All spectral data were identical with those given for **11** in ref.[7]

***rac*-Ethyl (*E*)-Opposita-4(15),7(11)-dien-12-oate [Ethyl (1*SR*,3a*S-R*,7a*RS*)-2-Methyl-3-(3a-methyl-7-methyleneoctahydroindene-1-yl)propenoate, 12]:** A suspension of 0.52 g (2.2 mmol) of triethyl phosphonopropionate and 2.0 g of K_2CO_3 in 2 mL of water was stirred for 12 h. Then 267 mg (1.5 mmol) of **11** was added. After stirring overnight and usual workup, 0.35 g of crude (*Z*)- and (*E*)-**12** (GC: 1:12) was obtained. Separation by FC gave as first fraction 10 mg (2.5%) of (*Z*)-**12** (GC: 95%) and as second fraction 247 mg (63%) of (*E*)-**12** (GC: 97%). − IR: $\tilde{\nu}$ = 1710, 1650 (C=CCO_2R) cm^{-1}. − (*Z*)-**12**: ^{1}H NMR: δ = 0.69 (s, 10-Me), 1.25−1.65 (m, 5 H), 1.70 (d, br., J = 11 Hz, 5-H_{ax}), 1.72 (m_c, 1-H_{eq}), 1.8−1.9 (m, 1 H), 1.88 (d, J = 1 Hz, 11-Me), 1.91 (ddd, br., J = 13, 13, 6 Hz, 3-H_{ax}), 2.05−2.15 (m, 8-H), 2.26 (dd, br., J = 13, 4 Hz, 3-H_{eq}), 3.59 (dddd, J = 11, 11, 10, 6 Hz, 6-H_{ax}), 4.48, 4.72 (2 ddd, J = 2, 2, 2 Hz, 4-CH_2=), 5.79 (dq, J = 9.5, 1 Hz, 7-H); CO_2Et: δ = 1.31 (t, J = 7 Hz), 4.19, 4.24 (ABq, J = 11, 7 Hz). − GC MS: nearly identical with that of (*E*)-**12**. − (*E*)-**12**: ^{1}H NMR: δ = 0.71 (s, 10-Me), 1.33 (ddd, br., J = 13, 13, 5 Hz, 1-H_{ax}), 1.4−1.7 (m, 5 H), 1.74 (d, br., J = 13 Hz, 1-H_{eq}), 1.87 (d, br., J = 11 Hz, 5-H_{ax}), 1.90 (d, J = 1.5 Hz, 11-Me), 1.92 (ddd, br., J = 13, 13, 6 Hz, 3-H_{ax}), 2.0−2.1 (m, 8-H), 2.26 (dd, br., J = 13, 4 Hz, 3-H_{eq}), 2.88 (dddd, J = 11, 10, 10, 6 Hz, 6-H_{ax}), 4.31, 4.72 (2 ddd, J = 1.5, 1.5, 1.5 Hz, 4-CH_2=), 6.64 (dq, J = 10, 1.5 Hz, 7-H); CO_2Et: δ = 1.29 (t, J = 7 Hz), 4.15, 4.18 (ABq, J = 11, 7 Hz). − ^{13}C NMR: see Table 1. − GC MS; *m*/*z* (%): 262 (10) [M^+], 247 (48), 216 (17), 217 (20), 201 (20), 193 (15), 189 (55), 188 (38), 173 (82), 148 (36), 147 (31), 145 (33), 133 (82), 119 (40), 107 (78), 105 (54), 93 (71), 91 (100), 79 (95), 77 (46), 67 (52), 65 (32), 55 (30). − $C_{17}H_{26}O_2$ (262.4): calcd. C 77.82, H 9.99; found C 78.04, H 9.78.

***rac*-(*E*)-Opposita-4(15),7(11)-dien-12-ol [(*E*)-(1*SR*,3a*SR*,7a*RS*)-2-Methyl-3-(3a-methyl-7-methyleneoctahydroindene-1-yl)prop-2-ene-1-ol, 13]:** A suspension of 63 mg (1.65 mmol) of $LiAlH_4$ and 72 mg (0.54 mmol) of $AlCl_3$ in 5 mL of Et_2O was stirred for 20 min at room temp., then cooled to −30°C and treated with 215 mg (0.82 mmol) of (*E*)-**12** in 2 mL of Et_2O. After 4 h, it was quenched with 2 M HCl. Usual workup and FC gave 154 mg (85%) of (*E*)-**13** (GC: 99%, RRI 1687, b.p. 90°C/0.05 Torr (KRD). − IR: $\tilde{\nu}$ = 3610 cm^{-1} (OH). − ^{1}H NMR (C_6D_6 [$CDCl_3$]): δ = 0.78 [0.70] (s, br., 10-Me), 1.24 (ddd, br., J = 12, 12, 5.5 Hz, 1-H_{ax}), 1.36 (dm, J = 11 Hz, 9-

Table 1. ^{13}C-NMR data ($CDCl_3$) of the oppositanes **1,** (*E*)-**12**, and (*E*)-**13**[a]

C		**1**[b,c]	(*E*)-**13**[c]	(*E*)-**12**
1	t	39.4	39.6	39.5
2	t	23.4	23.6	23.5
3	t	35.5	35.8	35.7
4	s	147.3	148.2	147.7
5	d	60.2	59.9	60.0
6	d	37.2	35.7	36.9
7	d	159.8	131.8	147.2
8	t	28.1	28.7	28.0
9	t	39.2	39.0	39.2
10	s	44.5	44.2	44.4
10-Me	q	18.3	18.4	18.4
11-Me	q	9.6	14.1	12.8
11-R[d]		195.4 (s)	68.9 (t)	168.4 (s)
4-CH_2	t	105.8	105.4	

[a] For numbering see Scheme 2. − [b] With NOED and ^{1}H,^{13}C correlation. − [c] In complete agreement with the values reported in refs.[4,5] − [d] **1**: R = CHO; (*E*)-**13**: R = CH_2OH; (*E*)-**12**: R = CO_2Et [δ = 60.3 (t), 14.3 (q)].

H), 1.38 (m_c, 8-H), 1.54 (dm, *J* = 11 Hz, 9′-H), 1.56 (m_c, 2-H_2), 1.68 [1.74] (d, *J* = 1.5 Hz, 11-Me), 1.68 (dm, *J* = 12 Hz, 1-H_{eq}), 1.73 (d, br., *J* = 11 Hz, 5-H_{ax}), 1.92 [2.02] (ddd, br., *J* = 13, 13, 7 Hz, 3-H_{ax}), 2.05 (dm, *J* = 9 Hz, 8′-H), 2.29 [2.26] (dd, br., *J* = 14, 4 Hz, 3-H_{eq}), 2.91 [2.80] (dddd, *J* = 11, 10, 10, 6 Hz, 6-H_{ax}), 3.83 [3.98] (s, br., 11-CH_2OH), 4.67, 4.93 [4.36, 4.72] (2 ddd, *J* = 1.5, 1.5, 1.5 Hz, 4-CH_2=), 5.33 [5.28] (dq, *J* = 9, 1.5 Hz, 7-H). − ^{13}C NMR: see Table 1. − GC MS; *m/z* (%): 220 (1) [M^+], 205 (13), 202 (12), 189 (100), 187 (63), 161 (16), 148 (19), 147 (20), 135 (20), 133 (68), 119 (28), 109 (28), 107 (52), 105 (48), 95 (28), 93 (76), 91 (87), 81 (47), 79 (85), 77 (54), 69 (27), 67 (54), 65 (25), 55 (50), 53 (33). − $C_{15}H_{24}O$ (220.4): calcd. C 81.76, H 10.98, found C 81.91, H 10.93. − ^{1}H- and ^{13}C-NMR data are identical, GC-MS data are in agreement with those given for the product obtained by $NaBH_4$ reduction of natural oppositadienal (**1**).[4]

***rac*-(*E*)-Opposita-4(15),7(11)-dien-12-al [(*E*)-(1*SR*,3a*SR*,7a*RS*)-2-Methyl-3-(3a-methyl-7-methyleneoctahydroindene-1-yl)prop-2-ene-1-al, 1]:** A suspension of 154 mg (0.70 mmol) of (*E*)-**13** and 1.0g of MnO_2 in 12 mL of CH_2Cl_2 was stirred overnight. After filtration through Celite® and evaporation of the solvent, column chromatography on Al_2O_3 (neutral, act. III) gave 116 mg (76%) of **1** (GC: 98%, RRI 1684). − IR: $\tilde{\nu}$ = 1690, 1640 cm^{-1} (C=C−CHO). − ^{1}H NMR (C_6D_6 [$CDCl_3$]): δ = 0.68 [0.75] (s, br., 10-Me), 1.16 [1.47] (ddd, br., *J* = 11, 7, 2 Hz, 8-H), 1.18 [1.36] (ddd, br., *J* = 13, 12, 5 Hz, 1-H_{ax}), 1.25 [1.48] (ddd, br., *J* = 11, 11, 7 Hz, 9-H), 1.45 [1.65] (ddd, *J* = 11, 9, 2 Hz, 9′-H), 1.52 [1.57] (dddd, *J* = 13, 13, 13, 4, 4 Hz, 2-H_{ax}), 1.52 [1.65] (d, br., *J* = 13 Hz, 2-H_{eq}), 1.62 [1.92] (d, br., *J* = 11 Hz, 5-H_{ax}), 1.64 [1.77] (d, br., *J* = 13 Hz, 1-H_{eq}), 1.79 [1.81] (d, *J* = 1.5 Hz, 11-Me), 1.84 [2.12] (dddd, *J* = 11, 11, 10, 9 Hz, 8′-H), 1.84 [1.93] (ddd, br., *J* = 13, 13, 6 Hz, 3-H_{ax}), 2.22 [2.29] (ddd, br., *J* = 13, 4, 2 Hz, 3-H_{eq}), 2.90 [3.07] (dddd, *J* = 11, 10, 10, 6 Hz, 6-H_{ax}), 4.38, 4.79 [4.28, 4.73] (2 ddd, *J* = 1.5, 1.5, 1.5 Hz, 4-CH_2=), 5.91 [6.37] (dq, *J* = 10, 1 Hz, 7-H), 9.39 [9.38] (s, 11-CHO). − ^{13}C NMR: see Table 1. − GC MS; *m/z* (%): 218 (21) [M^+], 203 (43), 189 (22), 185 (28), 175 (30), 161 (28), 147 (29), 133 (52), 119 (33), 107 (67), 105 (53), 95 (46), 93 (74), 91 (100), 79 (97), 77 (58), 67 (50), 65 (34), 55 (33), 53 (36). − ^{1}H- and ^{13}C-NMR data are identical, GC-MS data are in agreement with those given for the natural product.[4]

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