Organic Chemistry

Electrophilic cyclization of α- and β-geranyl acetates by mercury(II) trifluoroacetate

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Electrophilic cyclization of β-geranyl acetate promoted by mercury(II) trifluoroacetate leads to mixtures of α- and γ-5α*H*-cyclogeranyl acetate derivatives and 6α-hydroxy-5α*H*- and 6α-hydroxy-5β*H*-cyclogeranyl acetate derivatives mercurated at the C-3 atom. The ratio of the unsaturated and hydroxymercurated products depends on the reaction conditions. α-Geranyl acetate reacts with mercury(II) trifluoroacetate to give a mixture of 6α-hydroxy-5α*H*- and 6α-hydroxy-5β*H*-geranyl acetates, mercurated at C-9, with an equatorial mercurated methylene group at C-4. The mercury-containing groups in mercurated cyclogeranyl derivatives can easily be reduced or replaced by an oxygen-containing functional group; this constitutes a convenient route to polyfunctional cyclogeranyl derivatives that are difficult to obtain.

Key words: electrophilic cyclization, α- and β-geranyl acetates, mercury(II) trifluoroacetate, cyclogeranyl derivatives.

Electrophilic cyclization of α- (**1**) and β-geranyl acetates (**2**) promoted by mercury salts is of certain synthetic interest, because, owing to the possibility of easy replacement of the mercury-containing residue by an oxygen-containing functional group,[1] it opens a way to difficultly accessible cyclogeranyl derivatives with functional groups in the *gem*-dimethyl position or at the C-3 atom (from here on, the steroid numbering of atoms is used). The alternative pathway to cyclogeranyl derivatives hydroxylated at the above-mentioned positions, which involves cyclization of the corresponding aliphatic epoximonoterpenoids with a terminal epoxide ring is of low efficiency.[2–5]

In this paper, we report the results of a study of the cyclization of α- and β-geranyl acetates **1** and **2** promoted by $Hg(OCOCF_3)_2$. It should be noted that cyclization of β-geranyl acetate **2** in the presence of this reagent has been carried out earlier;[6] α- (**3a**) and γ- (**4a**) cyclogeranyl acetates mercurated at the C-3 atom were isolated in an overall yield of 24%.

By the reaction of β-geranyl acetate **2** with $Hg(OCOCF_3)_2$ at room temperature in 1-nitropropane followed by treatment of the reaction mixture with a solution of NaCl, we obtained a mixture of compounds, which was separated by chromatography on a column with silica gel. The least polar fraction contained unreacted geranyl acetate **2**. The next fraction in order of polarity consisted of a mixture (1 : 7) of mercurated cyclic compounds **3b** and **4b** (overall yield 45.7%) (Scheme 1), whose structures are confirmed by the fact that the mixture of **3b** and **4b** was reduced by $NaBH_4$ under standard conditions[7] to give a mixture (1 : 7,

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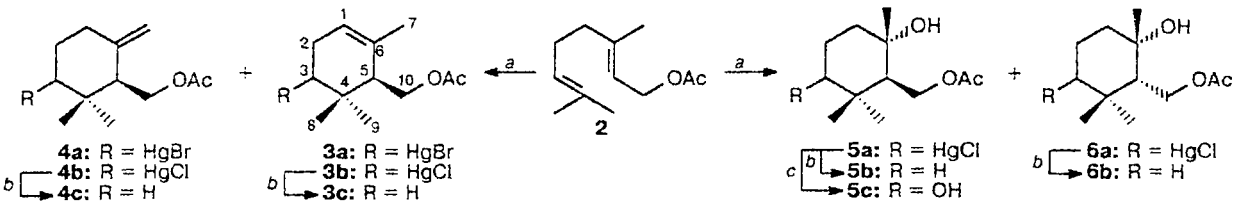
Scheme 1



Reagents: *a*. $Hg(OCOCF_3)_2$—$C_3H_7NO_2$, NaCl—H_2O; *b*. $NaBH_4$, NaOH/H_2O/ EtOH—CH_2Cl_2; *c*. $NaBH_4/O_2$—DMF.

according to GLC) of α- (**3c**) and γ-cyclogeranyl acetates (**4c**) identified by IR and ^1H NMR spectroscopy. We were not able to separate this mixture into individual isomers.

Later, a crystalline fraction consisting of mercurated hydroxyacetates **5a** and **6a** was eluted from the column (yield 15.2%). Its crystallization from Et_2O gave predominantly compound **5a**, which was reduced by $NaBH_4$ to the known hydroxyacetate **5b**[8] identified by comparison with an authentic sample.[9] We were not able to isolate mercurohydroxyacetate **6a** in a pure state. However, reduction of a mixture of **5a** and **6a** by $NaBH_4$ afforded a mixture (3 : 1) of hydroxyacetates **5b** and **6b** identified by comparing their chromatographic behavior (TLC, GLC) with that of authentic samples (Scheme 1).[9]

When cyclization of **2** is carried out under milder conditions (at −20 °C), the yield of the mixture of mercurated hydroxyacetates **5a** and **6a** increases to 57.3%, while the yield of the mixture of unsaturated mercurated acetates **3b** and **4b** decreases to 26.1%, which may be due to the fact that at a lower temperature, the carbocations formed are stabilized giving carboxonium ions. This assumption is also supported by the fact that cyclization of the same compounds by a superacid afforded no dehydration products.[10]

Compound **5a** reacts smoothly with $NaBH_4$ and oxygen[1] to give dihydroxyacetate **5c** (yield 83%). The structure of the latter was confirmed by spectral data, which are in agreement with the data reported previously for optically active compound **5c**.[5]

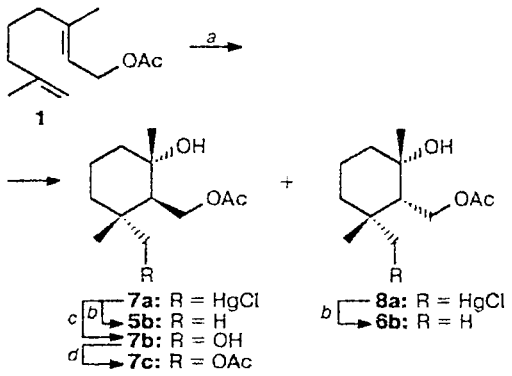
Thus, the transformations **2** → **5a** → **5c** described above constitute a fairly efficient pathway to cyclogeranyl derivatives with functional groups at C-3.

α-Geranyl acetate **1** reacts with $Hg(OCOCF_3)_2$ to give a mixture of mercurated hydroxyacetates **7a** and **8a**. The total yield of **7a** and **8a** is 75%. It is noteworthy that in this case, no unsaturated mercurated cyclogeranyl derivatives similar to **3b** and **4b** are formed. The reduction of a mixture of **7a** and **8a** by $NaBH_4$ affords a mixture of hydroxyacetates **5b** and **6b** (Scheme 2).

The predominant reaction product **7a** can be isolated in a pure state by crystallization from Et_2O. The reduction of this compound by $NaBH_4$ yields hydroxyacetate **5b**.

The configuration of the asymmetric center C-4 in compounds **7a** and **8a** was established from their subsequent transformations. The replacement of the mercury-containing group in compound **7a** by a hydroxyl group

Scheme 2

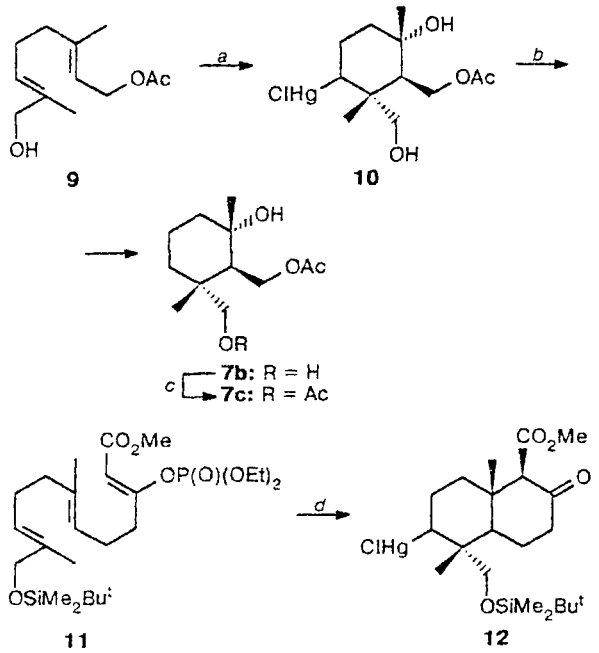


Reagents: *a*. $Hg(OCOCF_3)_2$—$C_3H_7NO_2$, NaCl—H_2O; *b*. $NaBH_4$, NaOH/H_2O/ EtOH—CH_2Cl_2; *c*. $NaBH_4/O_2$—DMF; *d*. Ac_2O/Py.

by a known procedure[1] followed by acetylation of the reaction product (**7b**) by an Ac_2O/Py mixture afforded hydroxydiacetate (**7c**), whose structure was confirmed by spectral data and by an alternative synthesis from 8-hydroxygeranyl acetate (**9**)[4,11] (Scheme 3). The latter undergoes cyclization promoted by $Hg(OCOCF_3)_2$; subsequent treatment of the reaction mixture with a solution of NaCl gives mercury-containing dihydroxyacetate (**10**) (yield 37%), whose reduction by $NaBH_4$ followed by acetylation by an Ac_2O/Py mixture gives rise to hydroxydiacetate **7c** identical with the product prepared from α-geranyl acetate **1**.

According to Corey *et al.*,[12] after treatment of the reaction mixture with a solution of NaCl, cyclization of ester **11** promoted by mercury trifluoroacetate in nitromethane leads to one product (**12**) with an equatorial $Bu^tMe_2SiOCH_2$ group. Judging from spectral characteristics, cyclization of 8-hydroxygeranyl acetate (**9**) in the presence of the same reagent occurs in a similar way and yields product **10** in which the hydroxymethylene group at the C-4 atom is equatorial. This conclusion is supported by the fact that the position of the corresponding signal in the ^1H NMR spectrum (δ 3.36) is in full agreement with the published data[13] on terpene derivatives with an equatorial hydroxymethylene group in ring A.

Scheme 3



Reagents: *a*. $Hg(OCOCF_3)_2$—$C_3H_7NO_2$, NaCl—H_2O; *b*. $NaBH_4$, NaOH/H_2O/ EtOH—CH_2Cl_2; *c*. Ac_2O/Py; *d*. $Hg(OCOCF_3)_2$—CH_3NO_2, NaCl—H_2O.

In conclusion, it should be noted that, despite our efforts, cyclization of compounds **1**, **2**, and **9** in the presence of mercury trifluoroacetate did not proceed to completion. The data presented above indicate that the sequence of transformations **1** → **7a** → **7b** is a convenient route for the synthesis of cyclogeranyl compounds with an equatorial hydroxymethylene group at C-4.

Experimental

Melting points were determined on a Boetius hot-stage apparatus. IR spectra were recorded on a Specord 74 IR instrument in $CHCl_3$, and ^1H NMR spectra were obtained on Tesla BS-476 (60 MHz) and Bruker AC-80 (80 MHz) spectrometers in $CDCl_3$. GLC analysis was carried out on a Chrom-5 chromatograph with a flame ionization detector and a 1500×3 mm glass column using 5% SE-30 on Chromaton N-AW-DCMS as the stationary phase. Column chromatography was carried out using silica gel (below referred to as SiO_2) L 100/400 mm, and TLC was performed using SiO_2 LS 5/40 mm. Solutions of substances in organic solvents were dried with sodium sulfate.

Preparation of a mixture of α- (3b) and γ-3β-chloromercurocyclogeranyl acetates (4b), 3β-chloromercuro-6α-hydroxy-5α*H*-cyclogeranyl acetates (5a) and 3β-chloromercuro-6α-hydroxy-5β*H*-cyclogeranyl acetates (6a). *A.* At ~22 °C, a solution of β-geranyl acetate (**2**) (1.35 g) in 10 mL of $C_3H_7NO_2$ was added to a suspension of $Hg(OCOCF_3)_2$ (3.27 g) in 15 mL of 1-nitropropane; the mixture was stirred for 1 h at ~22 °C, and 60 mL of saturated aqueous NaCl was added. Then the mixture was stirred for 12 h and extracted with ether (3×30 mL). The extract was washed with H_2O, a saturated solution of $NaHCO_3$, and again with H_2O, and dried, and the solvent was evaporated. The residue (2.6 g) was chromatographed on a column with 50 g of SiO_2. Elution with petroleum ether gave 345 mg (25%) of the initial β-geranyl acetate **2**, and elution with a mixture of petroleum ether with AcOEt (97 : 3) gave 1.01 g of a 1 : 7 mixture of mercury-containing compounds **3b** and **4b** (yield 45.7%; from here on, the yields are presented with allowance for the recovered initial compounds). Elution with chloroform gave 350 mg (15%) of a 5 : 1 crystalline mixture of compounds **5a** and **6a**.

B. At −20 °C, a solution of β-geranyl acetate (**2**) (0.73 g) in 4 mL of $C_3H_7NO_2$ was added to a suspension of $Hg(OCOCF_3)_2$ (1.75 g) in 6 mL of $C_3H_7NO_2$; the mixture was stirred for 1 h, 30 mL of a saturated aqueous solution of NaCl was added, then the mixture was stirred for 10 h, and worked up as described above (*A*). The residue (1.2 g) was chromatographed on a column with 22 g of SiO_2. Elution with petroleum ether afforded 525 mg of a mixture of compounds **2**, **3b**, and **4b**, and elution with $CHCl_3$ gave 682 mg (57.3%) of a 5 : 1 crystalline mixture of mercury-containing compounds **5a** and **6a**. The first fraction (525 mg) was chromatographed once again on a column with 12 g of SiO_2. Elution with petroleum ether yielded 210 mg of β-geranyl acetate (**2**), and elution with a mixture of petroleum ether and ethyl acetate (97 : 3) afforded 298 mg (26.1%) of a 1 : 7 mixture of compounds **3b** and **4b**.

A mixture of α- (3c) and γ-cyclogeranyl acetates (4c). A solution of $NaBH_4$ (476 mg) and NaOH (1 g) in 3 mL of H_2O was added at ~22 °C with stirring to a solution of a mixture (536 mg) of compounds **3b** and **4b**, prepared as described above, (*A*) in a 1 : 1 mixture of CH_2Cl_2 and EtOH (15 mL). The reaction mixture was stirred for 30 min, diluted with 10 mL of H_2O, and extracted with Et_2O (3×15 mL). The extract was washed with 10% H_2SO_4, H_2O, a solution of $NaHCO_3$, and again H_2O, and dried, and the solvent was evaporated. The residue (208 mg) was dissolved in 5 mL of dry pyridine, Ac_2O (2 mL) was added, and the mixture was allowed to stand for 8 h and extracted with ether. The ethereal extract was washed successively with water, 10% H_2SO_4, water, a saturated solution of $NaHCO_3$, and water, dried, and filtered, and the ether was evaporated in the vacuum of a water jet pump. The reaction product (240 mg) was chromatographed on a column with 5 g of SiO_2. Elution with a mixture of petroleum ether and AcOEt (97 : 3) afforded 210 mg (86.1%) of a mixture (1 : 7, GLC data) of α- (**3c**) and γ-cyclogeranyl acetates (**4c**). IR (CCl_4), ν/cm^{-1}: 1230, 1730 (OAc), 1358, 1377 ($C(CH_3)_2$), 890, 1647 (>C=CH_2), 855 (>C=C<$_H$). ^1H NMR, δ: 0.96, 1.02 (both s, 2×3 H, $C(CH_3)_2$), 1.70 (d, 0.3 H, CH_3—C(6)=, J = 1.5 Hz), 2.08 (s, 3 H, $OCOCH_3$), 2.70 (t, 1 H, HC(5), J = 7 Hz), 4.25 (d, 2 H, CH_2—O, J = 7 Hz), 4.61 (br.s, 1.6 H, >C=CH_2), 5.47 (m, 0.12 H, >C=C<$_H$).

3β-Chloromercuro-6α-hydroxy-5α*H*-cyclogeranyl acetate (5a). The crystalline chromatographic fraction (350 mg) obtained as described above (*A*) was recrystallized from Et_2O to give 210 mg of compound **5a**, m.p. 118—120 °C. Found (%): C, 31.95; H, 4.67. $C_{12}H_{21}ClHgO_3$. Calculated (%): C, 32.08; H, 4.71. IR, ν/cm^{-1}: 1132, 3450, 3575 (OH), 1233, 1725 (OAc), 1356, 1377 ($C(CH_3)_2$). ^1H NMR, δ: 1.08 and 1.17 (both s, 2×3 H, $C(CH_3)_2$), 1.22 (s, 3 H, CH_3—C(6)=), 2.06 (s, 3 H, $OCOCH_3$), 2.46 (br.s, 1 H, OH), 2.76 (br.s, 1 H, HC(5)).

A mixture of 6α-hydroxy-5α*H*- (5b) and 6α-hydroxy-5β*H*-cyclogeranyl acetates (6b). $NaBH_4$ (76 mg) and a solution of NaOH (160 mg) in H_2O (0.2 mL) were added with stirring to a solution of 85 mg of the mother liquors obtained after crystallization of compound **5a** in a 1 : 1 mixture of $CHCl_3$ and EtOH (2.5 mL). The mixture was stirred for 1 h and worked up as described above. The product (42 mg) was acetylated by a mixture of dry Py (2 mL) and Ac_2O (0.1 mL) (~20 °C, 12 h). The reaction product (44 mg) obtained after the usual workup was chromatographed on a column with 1.1 g of SiO_2. Elution with a mixture of petroleum ether and AcOEt (9 : 1) gave 35 mg of a 3 : 1 mixture of hydroxyacetates **5b** and **6b**, which were identified by comparison of their chromatographic behavior with that of authentic samples.[9]

6α-Hydroxy-5α*H*-cyclogeranyl acetate (5b). ***A*. From compound 5a.** A solution of $NaBH_4$ (90 mg) and NaOH (200 mg) in H_2O (0.8 mL) was added with stirring at ~22 °C to a solution of mercurated hydroxyacetate **5a** (100 mg) in a 1 : 1 mixture of CH_2Cl_2 and EtOH (5 mL). The reaction mixture was stirred for 30 min and worked up as described above. The residue (43 mg) was dissolved in a mixture of dry Py (1.5 mL) and Ac_2O (0.2 mL) and kept at ~22°C for 5 h. Then the mixture was extracted with ether, and the ethereal extract was washed successively with water, 10% H_2SO_4, water, a saturated solution of $NaHCO_3$, and again with water, dried, and filtered, and the ether was evaporated in the vacuum of a water jet pump. The reaction product (49 mg) was chromatographed on a column with 1.3 g of SiO_2. Elution with a mixture of petroleum ether and AcOEt (9 : 1) gave 42 mg (88%) of hydroxyacetate **5b**, which was identified by comparing its chromatographic and spectral behavior with those of an authentic sample.[9]

***B*. From compound 7a.** A solution of $NaBH_4$ (100 mg) and NaOH (200 mg) in H_2O (0.8 mL) was added with stirring at ~22 °C to a solution of chloromercurohydroxyacetate **7a** (110 mg) in 5 mL of a 1 : 1 mixture of CH_2Cl_2 and EtOH. The mixture was stirred for 30 min and worked up as described above, and the residue (41 mg) was acetylated (0.2 mL of Ac_2O and 1.5 mL of Py, 5 h). The reaction product (49 mg) was chromatographed on a column with 1.3 g of SiO_2. Elution with a mixture of petroleum ether and AcOEt (9 : 1) afforded 47 mg (89.6%) of hydroxyacetate **5b**.

3β,6α-Dihydroxy-5α*H*-cyclogeranyl acetate (5c). A solution of mercury-containing hydroxyacetate **5a** (321 mg) in 10 mL of DMF was added dropwise over a period of 10 min with stirring at 22 °C to a suspension of $NaBH_4$ (59 mg) in DMF (4 mL); during this period, oxygen was constantly bubbled through the solution. The reaction mixture was stirred for 5 min, 1*N* H_2SO_4 was added to it, and the mixture was extracted with Et_2O (3×10 mL). The extract was washed successively with H_2O, a solution of $NaHCO_3$, and with H_2O, dried, and the solvent was evaporated. The residue (156 mg) was chromatographed on a column with 1.1 g of SiO_2. Elution with a mixture of petroleum ether and ethyl acetate (17 : 3) gave 12 mg of a mixture of low-polarity substances, which was not studied, whereas elution with a 4 : 1 mixture of the same solvent gave 136 mg (82.7%) of dihydroxyacetate **5c**. IR (CCl_4), ν/cm^{-1}: 1356, 1373 ($C(CH_3)_2$), 1124, 3455, 3600 (OH), 1230, 1730 (OAc). ^1H NMR, δ: 0.90 and 1.08 (both s, 2×3 H, $C(CH_3)_2$), 2.05 (s, 3 H, $OCOCH_3$), 2.87 (s, 1 H, OH), 2.94 (s, 1 H, OH), 3.40 (m, 1 H, HC(3)), 4.37 (d, 2 H, CH_2O, J = 7 Hz). The spectral characteristics of compound **5c** were identical with those presented in Ref. 5.

9-Chloromercuro-6α-hydroxy-5α*H*-cyclogeranyl acetate (7a). A solution of α-geranyl acetate (**1**) (734 mg) in $C_3H_7NO_2$ 10 mL was added at −20 °C to a suspension of $Hg(OCOCF_3)_2$ (2 g) in $C_3H_7NO_2$ (8 mL). The mixture was stirred at the same temperature for 1 h. Then a saturated aqueous solution of NaCl (40 mL) was added to it, and the mixture was stirred for 10 h at 22 °C and worked up as described for the preparation of compounds **3b**, **4b**, **5a**, and **6a**. The reaction product (1.21 g) was purified by crystallization from Et_2O to give 490 mg (72%) of chloromercurohydroxyacetate **7a**, m.p. 127.5—130 °C. Found (%): C, 32.15; H, 4.65. $C_{12}H_{21}ClHgO_3$. Calculated (%): C, 32.08; H, 4.71. IR, ν/cm^{-1}: 1130, 3456, 3570 (OH), 1230, 1724 (OAc). ^1H NMR, δ: 1.08 (s, 3 H, CH_3—C(4)), 1.22 (s, 5 H, CH_3—C(6) and C(4)—CH_2HgCl), 2.63 (br.s, 1 H, OH), 4.63 (t, 2 H, CH_2—O, J = 5 Hz).

Preparation of a mixture of 6α-hydroxy-5α*H*- and 6α-hydroxy-5β*H*-cyclogeranyl acetates (5b and 6b) from a mixture of mercurated compounds 7a and 8a. A solution of $NaBH_4$ (700 mg) and NaOH (1.5 g) in H_2O (2 mL) was added with stirring to the mother liquors (880 mg) obtained after crystallization of compound **7a** in 25 mL of a mixture of CH_2Cl_2 and EtOH (1 : 1). The reaction mixture was stirred for 30 min and worked up as described above; the product (475 mg) was acetylated with a mixture of Ac_2O (1 mL) and dry Py (3 mL) (~22 °C, 12 h); the standard workup yielded 465 mg of a product that was chromatographed on a column with 12 g of SiO_2. Elution with a mixture of petroleum ether and AcOEt (19 : 1) afforded 346 mg of the starting α-geranyl acetate (**1**); elution with a 9 : 1 mixture of the same solvents gave 40 mg of hydroxyacetate **6b**, while a 5 : 1 mixture of the solvents eluted 30 mg of hydroxyacetate **5b**. Compounds **5b** and **6b** were identified by chromatographic comparison (TLC, GLC) with authentic samples.

Preparation of 9-acetoxy-6α-hydroxy-5α*H*-cyclogeranyl acetate (7c). *A*. From 9-chloromercuro-6α-hydroxy-5α*H*-cyclogeranyl acetate (7a). A solution of compound **7a** (276 mg) in 8.3 mL of DMF was added dropwise over a period of 10 min with stirring at ~22 °C to a suspension of $NaBH_4$ (45 mg) in 3 mL of DMF; during this period, oxygen was constantly bubbled through the solution. The mixture was stirred for 5 min, 10 mL of 1 *N* H_2SO_4 was added, and the mixture was worked up as described above. The reaction product (127 mg) was chromatographed on a column with 2.1 g of SiO_2. Elution with a mixture of petroleum ether and AcOEt (4 : 1) gave 118 mg (83.4%) of dihydroxyacetate **7b** (a colorless viscous liquid). Found (%): C, 62.64; H, 9.55. $C_{12}H_{22}O_4$. Calculated (%): C, 62.58; H, 9.63. IR (CCl_4) ν/cm^{-1}: 1025, 1125, 3445, 3590 (OH), 1230, 1732 (OAc). ^1H NMR (CCl_4), δ: 0.93 (s, 3 H, 4-CH_3), 1.20 (s, 3 H, 6-CH_3), 2.05 (s, 3 H, $OCOCH_3$), 2.75 (m, 2 H, 2 OH), 3.36 (m, 2 H, CH_2OH), 4.28 (m, 2 H, CH_2OAc).

Ac_2O (0.1 mL) was added to a solution of dihydroxyacetate **7b** (70 mg) in dry Py (1.8 mL), and the mixture was allowed to stand for 14 h at ~22 °C. Then the product was extracted with ether, and the ethereal extract was washed successively with water, 10% H_2SO_4, water, a saturated solution of $NaHCO_3$, and water, dried, and filtered. The ether was evaporated in the vacuum of a water-jet pump. The reaction product (73 mg) was chromatographed on a column with 1.7 g of SiO_2. Elution with a mixture of petroleum ether and AcOEt (9 : 1) gave 71 mg (91%) of hydroxydiacetate **7c** (a colorless viscous liquid). Found (%): C, 61.81; H, 8.75. $C_{14}H_{24}O_5$. Calculated (%): C, 61.74; H, 8.88. IR, ν/cm^{-1}: 1134, 3443, 3578 (OH),

1236, 1722 (OAc). ^{1}H NMR (CCl_4), δ: 0.95 (s, 3 H, 4-CH_3), 1.17 (s, 3 H, 6-CH_3), 1.98 (s, 3 H, $OCOCH_3$), 2.02 (s, 3 H, $OCOCH_3$), 3.22 (br.s, 1 H, OH), 3.58—4.53 (m, 4 H, 2 CH_2OAc).

***B.* From 8-hydroxygeranyl acetate (9).** A solution of 8-hydroxygeranyl acetate **9** (750 mg) in 5 mL of $C_3H_7NO_2$ was added at −10 °C to a suspension of $Hg(OCOCF_3)_2$ (1.8 g) in $C_3H_7NO_2$ (8 mL). The mixture was stirred for 1 h at the same temperature, 30 mL of a saturated aqueous solution was added to it, and the mixture was stirred for an additional 12 h. Then it was worked up as described above, and the reaction product (1.1 g) was chromatographed on a column with 20 g of SiO_2. Elution with a mixture of petroleum ether and AcOEt (9 : 1) gave 410 mg of a mixture of the starting 8-hydroxygeranyl acetate **9** and a more polar compound, and elution with $CHCl_3$ afforded 330 mg (37.6%) of dihydroxymercuroacetate **10**. Found (%): C, 30.89; H, 4.64. $C_{12}H_{21}ClHgO_4$. Calculated (%): C, 30.98; H, 4.55. IR, ν/cm^{-1}: 1233, 1730 (OAc), 3443, 3600 (OH). ^{1}H NMR, δ: 1.01 (s, 3 H, 4-CH_3), 1.26 (s, 3 H, 6-CH_3), 2.17 (s, 3 H, $OCOCH_3$), 3.28 (br.s, 2 H, 2 OH), 4.04 (m, 2 H, CH_2OH), 4.26 (m, 2 H, CH_2OAc).

A solution of $NaBH_4$ (273 mg) and NaOH (570 mg) in H_2O (0.7 mL) was added with stirring at ~22 °C to a solution of compound **10** (330 mg) in a 1 : 1 mixture of CH_2Cl_2 and EtOH (8 mL). The mixture was stirred for 30 min and worked up as described for compounds **3c** and **4c**. The reaction product (126 mg) was acetylated by a mixture of Ac_2O (0.1 mL) and Py (3 mL) (~22°C, 16 h). The product resulting from the usual workup (185 mg) was chromatographed on a column with 3 g of SiO_2. Elution with a mixture of petroleum ether and AcOEt (5 : 1) gave 145 mg (75.1%) of hydroxydiacetate **7c** identical with that prepared by method *A*.

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