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Prostanoids: XC.* Extension to the Synthesis of Enprostil of the *o*-Nitrophenylsulfonylhydrazine Method for Transformation of 2-Propynyl Alcohols into Allenes

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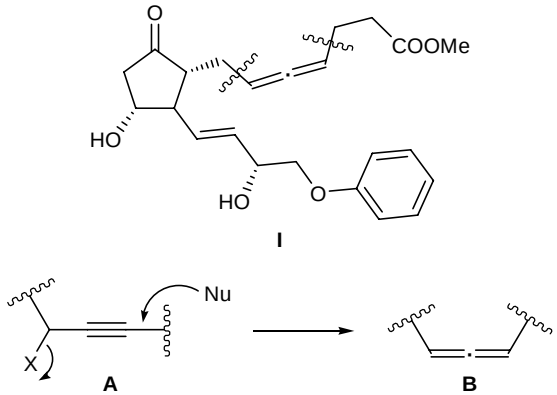
Abstract—A potential precursor of enprostil, (±)-9-acetoxy-11,15-di-*O*-(*tert*-butyldimethylsilyl)-2-decarboxy-6-hydroxy-16-phenoxy-2-triphenylmethyloxymethyl-4,4,5,5-tetradehydro-17,18,19,20-tetranorprostaglandin F1α, was synthesized. This compound remained unchanged under the conditions for generation of allenes from 2-propynyl alcohols by the action of the system diisopropyl azodicarboxylate–triphenylphosphine–*o*-nitrophenylsulfonylhydrazine.

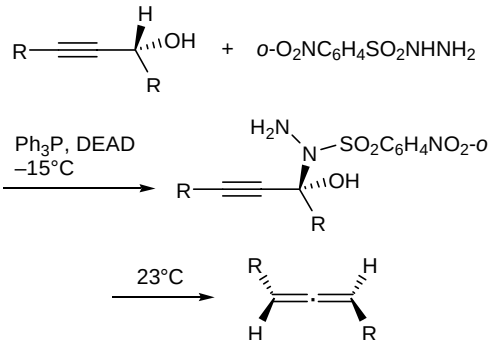
In the synthesis of a highly effective analog of prostaglandin E2, enprostil (**I**) (racemate, a ~1:1 mixture of diastereoisomers at the allene center) which exhibits antiulcer activity, the most difficult is transformation of the acetylenic fragment in precursors into allene moiety (**A** → **B**, X = OH or Hlg) [2–6]. As a rule, allene fragment is introduced into acetylenic enprostil precursors like **A** with the aid of Me_2CuLi (X = OAc) [2, 3] or Zn (X = Cl) [4] (Scheme 1); this procedure ensures moderate yields of the corresponding allenes. Myers and Zheng [7] described a new one-step synthesis of allenes from acetylenic alcohols via transformation of the latter into *o*-nitrobenzenesulfonohydrazides according to Mitsunobu [8] and subsequent easy fragmentation of the hydrazides at room temperature with formation of allenes (Scheme 2).

Scheme 1.



X is a departing group.

Scheme 2.



DEAD is diethyl azodicarboxylate (EtOCON=NCOOEt).

We tried to extend this approach to the key stages in the formation of allene fragment in the synthesis of enprostil from bis-silyl ether **II** [1]. In order to obtain a precursor of compound **I** with a 2-propynyl alcohol moiety in the α-chain, diastereoisomerically pure lactone **II** was brought into condensation with lithium derivative **III** of 5-triphenylmethoxy-1-pentyne under appropriate conditions [9]. The reaction smoothly afforded 70% of the expected acetylenic ketone **IV** (Scheme 3). Under the same conditions, semiacetal **V** gave rise to diol **VI** in a moderate yield, despite the use of excess lithium derivative **III** (more than 3 equiv).

* For preceding communication, see [1].

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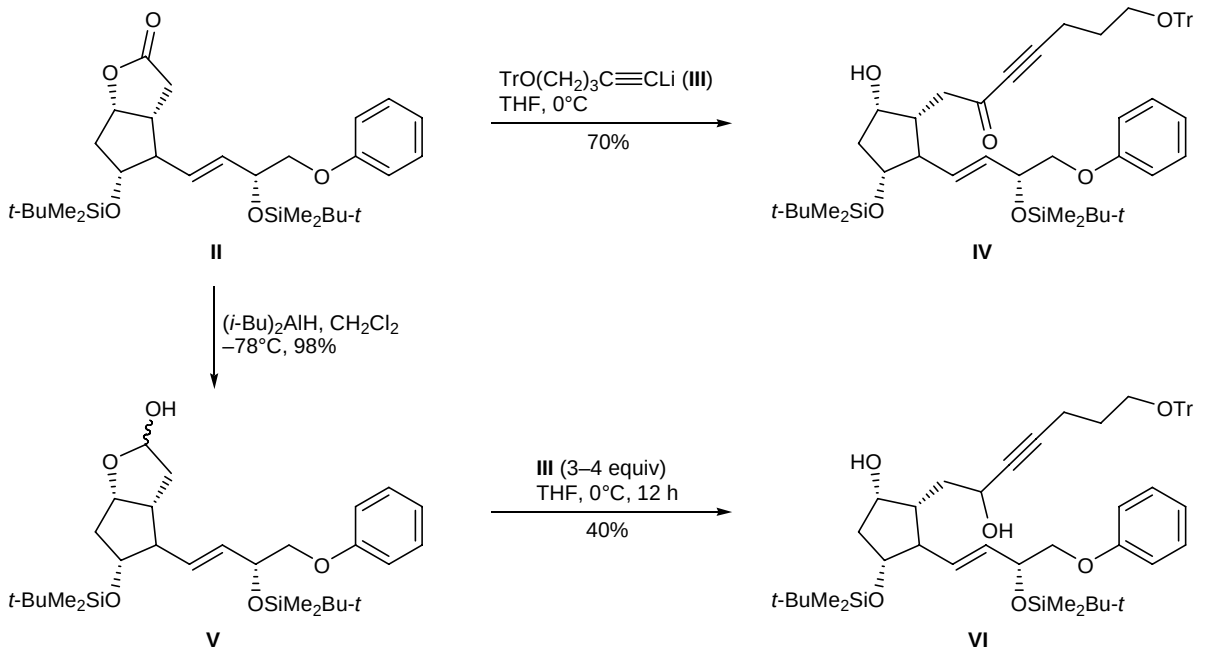
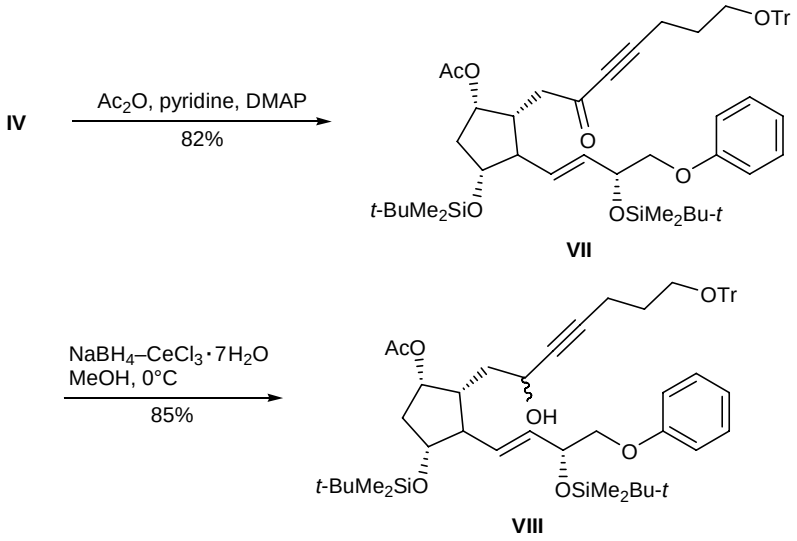
Scheme 3.



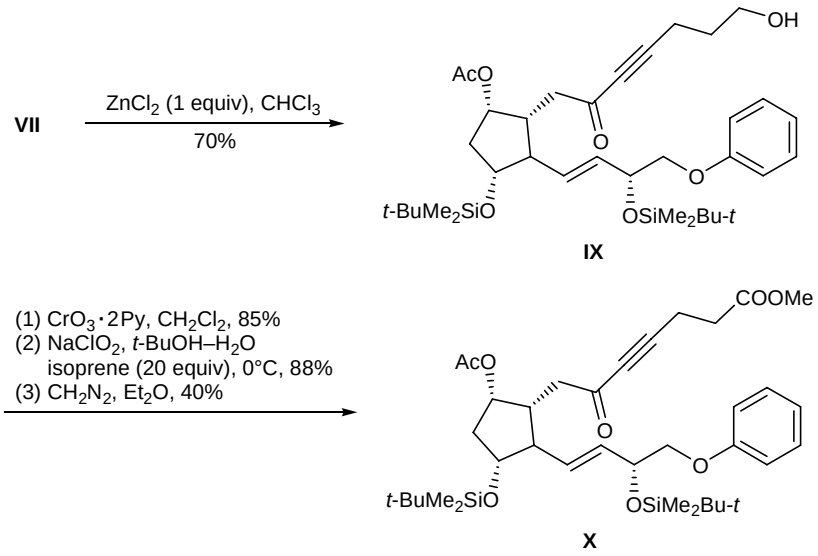
These results were rationalized by possible replacement of the labile semiacetal hydroxy proton by the metal in the reaction with acetylide **III**, which deactivated compound **V** toward further reaction with **III**.

It seemed convenient to use keto alcohol **IV** to obtain selectively protected derivatives of diol **VI**. For this purpose, it was necessary to introduce an appropriate protecting group to the hydroxy group on C^9 and reduce the C^6=O carbonyl group. Initially, by acetylation of hydroxy ketone **IV** with acetic anhydride in pyridine we obtained 82% of acetate **VII** (Scheme 4). However, the reduction of enone **VII** with $NaBH_4$ in methanol at –20°C was accompanied by hydrolysis of the acetoxy group on C^9 to give diol **VI**. We succeeded in effectively reducing enone **VII** with the system $NaBH_4$–$CeCl_3 \cdot 7H_2O$ in MeOH [10], and the desired epimeric (~1:1) acetoxy alcohols **VIII** were obtained in 85% yield. The CH_2OTr fragment in the α-chain can be transformed into ester group (CO_2Me) by standard methods, as we demonstrated by the conversion of ether **VII** into ester **X** (Scheme 5). We have encountered with considerable difficulties at the stage of selective removal of the triphenylmethyl protecting group from compound **VII**. A number of procedures

Scheme 4.



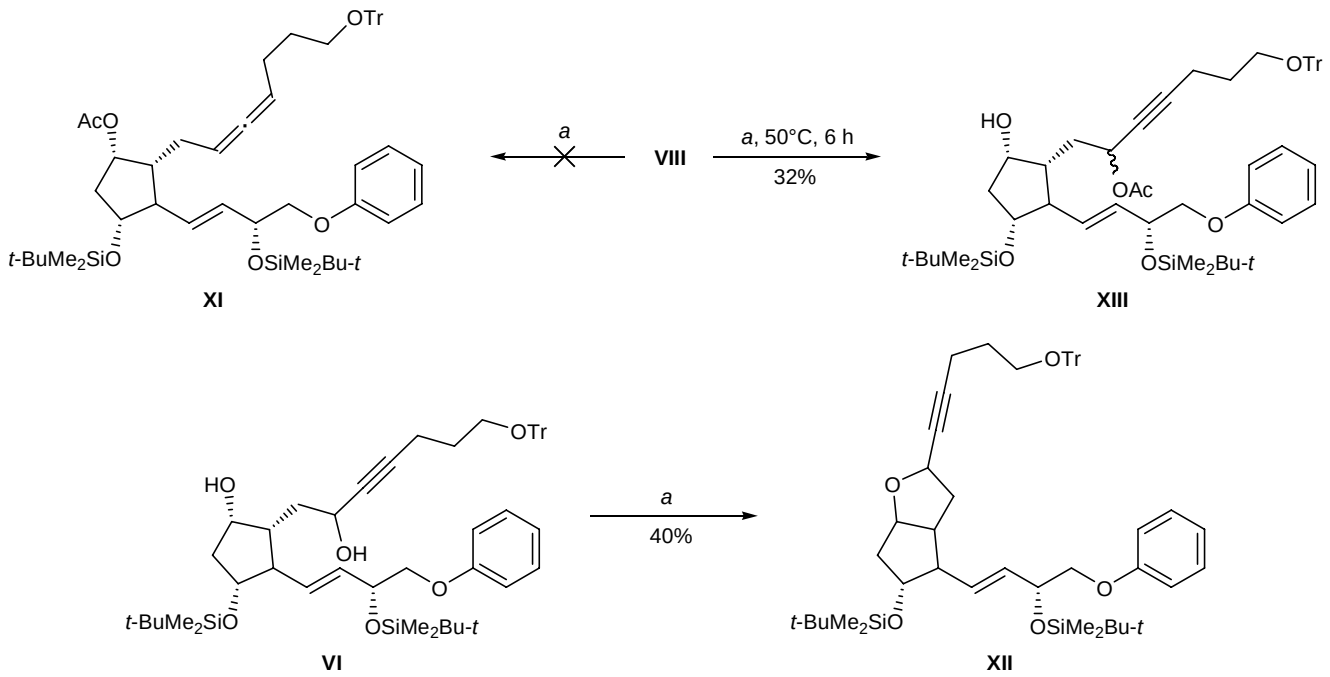
Scheme 5.



recommended for this purpose [11–13] turned out to be inappropriate, for they led to partial removal of the silyl protecting groups. Hydrolysis of the triphenylmethyl ether moiety in compound **VII** was accomplished with a good selectivity using an equimolar amount of $ZnCl_2$ in $CHCl_3$. We thus obtained alcohol **IX** in 70% yield.

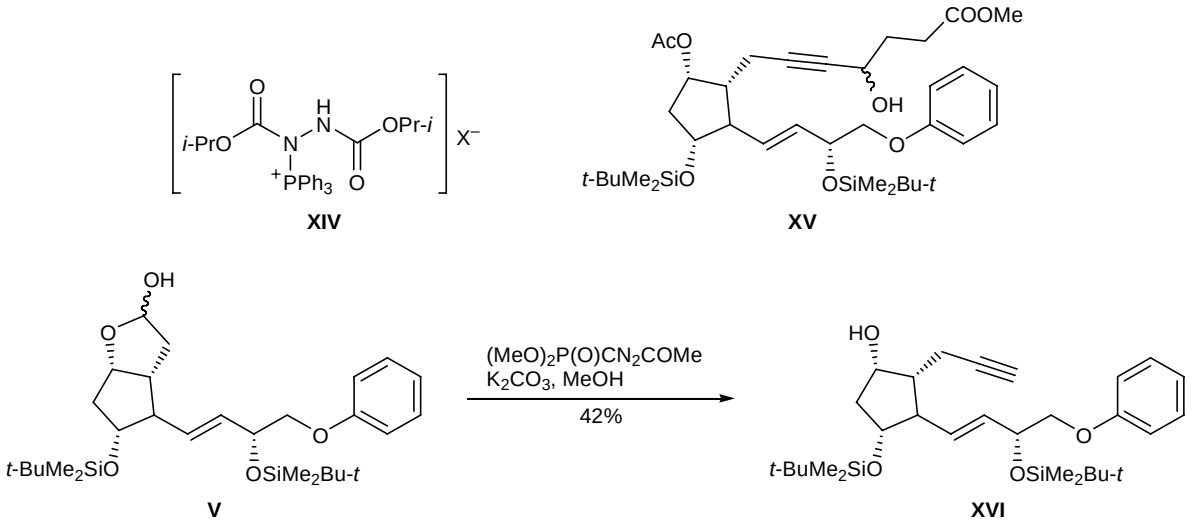
Using acetylenic alcohol **VIII** we tried to effect its transformation according to Myers [7]. It was also reasonable to involve in the same reaction diol **VI**, taking into account that higher reactivity of the hydroxy group at the triple bond, as compared to 9-OH, should give rise to higher chemoselectivity of the process. However, alcohol **VIII** remained almost unchanged in the Mitsunobu reaction with *o*-nitrophenylsulfonylhydrazine, and no desired allene **XI** was formed. An analogous reaction with diol **VI** gave 40% of intramolecular cyclization product **XII** (Scheme 6).

Scheme 6.



a: Ph_3P, *i*-PrOCON=NCOOPr-*i*, *o*-$O_2NC_6H_4SO_2NHNH_2$, THF, –15°C.

Scheme 7.



According to the ^{13}C NMR data, compound **XII** was a single stereoisomer (the stereochemistry of the C^{6*} chiral center was not determined). Under more severe conditions, namely on heating alcohol **VIII** with *o*-nitrophenylsulfonylhydrazine for 6 h at 50°C, migration of the acetyl group from C^9 to C^6 occurred to give acetoxy derivative **XIII**.

The formation of less polar cyclization product **XII** from diol **VI** may be rationalized assuming slow intramolecular dehydration under the Mitsunobu conditions [14]. Presumably, acetylenic alcohol **VIII** failed to react for steric reasons. Bulky Mitsunobu intermediate **XIV** [8] is likely to be incapable of attacking sterically crowded C^6–OH center in **VIII**. We believe that the reaction may be successful with less sterically hindered equivalents of alcohol **VIII**, e.g., compound **XV**. Acetylenic compound **XVI** necessary for the synthesis of **XV** is available through the reaction of compound **V** with dimethyl diazomethylphosphonate generated *in situ* from dimethyl 1-diazo-2-oxopropylphosphonate $(MeO)_2P(O)CN_2COMe$ [15] (Scheme 7).

EXPERIMENTAL

The IR spectra were recorded on a UR 20 spectrophotometer from samples prepared as thin films. The ^1H and ^{13}C NMR spectra were measured on a Bruker AM-300 spectrometer (300 and 75.47 MHz, respectively) from solutions in $CDCl_3$ using tetramethylsilane as internal reference. Thin-layer chromatography was performed using Silufol plates.

(±)-11,15-Bis(*tert*-butyldimethylsiloxy)-2-decarboxy-6-oxo-16-phenoxy-2-triphenylmethyloxy-methyl-4,4,5,5-tetradehydro-17,18,19,20-tetranorprostaglandin F1α (IV). A 1.95 N solution of butyllithium in hexane, 1.44 ml (2.82 mmol), was added over a period of 5 min to a solution of 0.919 g (2.82 mmol) of triphenylmethyl ether **III** in 10 ml of anhydrous tetrahydrofuran on stirring at –10°C under argon. The mixture was stirred for 5 min at that temperature and was then added dropwise at –10°C over a period of 10 min to a solution of 1.00 g (1.88 mmol) of ether **II** in 25 ml of anhydrous THF. The mixture was stirred for 1 h, 10 ml of a saturated solution of ammonium chloride was added, and the mixture was extracted with ethyl acetate (3×20 ml). The extract was dried over Na_2SO_4 and evaporated under reduced pressure, and the residue was subjected to column chromatography on silica gel to isolate 1.13 g (70%) of hydroxy ketone **IV** as an oily substance. IR spectrum, ν, cm^{-1}: 1600, 1680, 3500. ^1H NMR spectrum, δ, ppm: 0.05 s (6H, $SiMe_2$), 0.10 s (6H, $SiMe_2$), 0.88 s (9H, SiBu-*t*), 0.94 s (9H, SiBu-*t*), 1.80–1.90 m (3H), 2.05–2.20 m (2H), 2.30 (OH), 2.40–2.60 m (5H), 2.92 d.d (1H, 7-H, J = 10, 17 Hz), 3.20 t (2H, CH_2O, J = 6 Hz) 3.85 d (2H, $C^{16}H_2$, J = 5.3 Hz), 4.00 m (1H, 15-H), 4.25 m (1H, 11-H), 4.63 m (1H, 9-H), 5.60 m (2H, CH=CH), 6.90 m (3H, H_{arom}), 7.20–7.40 m (12H, H_{arom}), 7.48 m (5H, H_{arom}). ^{13}C NMR spectrum, δ_C, ppm: –4.61 ($SiMe_2$); 16.14 (C^3); 17.89 and 18.28 ($SiCMe_3$); 25.76 and 25.81 ($SiCMe_3$); 28.39 (C^2); 43.23 (C^{10}); 44.10 (C^7); 45.50 (C^8); 55.61 (C^{12}); 61.68 (C^1); 71.39 (C^{15}); 72.11 (C^{16}); 72.90 (C^9); 78.43 (C^{11}); 81.15 (C^5); 86.42 ($OCPh_3$); 93.70 (C^4); 114.36, 120.63, 129.39, 158.70 (OPh); 126.94, 127.75, 128.28, 144.05 (CPh_3); 131.56 and 132.17 (C^{13}, C^{14}); 187.66 (CO).

(±)-11,15-Bis(*tert*-butyldimethylsiloxy)-2-decarboxy-6-hydroxy-16-phenoxy-2-triphenylmethyloxymethyl-4,4,5,5-tetradehydro-17,18,19,20-tetranorprostaglandin F1α (VI). Compound **II**, 0.200 g (0.38 mmol), was dissolved in 4 ml of dry methylene chloride, the solution was cooled to –78°C, and 0.24 ml (0.95 mmol) of 73% (*i*-Bu)$_2$AlH was added over a period of 5 min under argon. The mixture was stirred for 2 h at –78°C, and excess (*i*-Bu)$_2$AlH was decomposed by adding 0.2 ml of water. The solvent was evaporated, the residue was extracted with MeOH (5×10 ml), and the extract was dried over Na_2SO_4 and evaporated to obtain 0.196 g (98%) of semiacetal **V**. The product was dissolved in 5 ml of THF, and a solution of 1.13 mmol of lithium derivative **III** (prepared from 0.367 g of the corresponding acetylene derivative and 0.58 ml of 1.95 N butyllithium) in 5 ml of THF was added dropwise at 10°C. The mixture was stirred for 12 h at 20°C, treated with 5 ml of a saturated solution of ammonium chloride, and extracted with ethyl acetate (3×10 ml). The extract was dried over Na_2SO_4 and evaporated under reduced pressure, and the residue was subjected to column chromatography on silica gel to isolate 0.145 g (40%) of diol **VI** (a ~1:1 mixture of epimers with respect to C^6) as an oily substance. ^{1}H NMR spectrum, δ, ppm: 0.05 s (6H, $SiMe_2$), 0.10 s (6H, $SiMe_2$), 0.90 s (9H, SiBu-*t*), 0.95 s (9H, SiBu-*t*), 1.60–2.40 m (10H), 3.15 t (2H, CH_2O, J = 6 Hz), 3.85 m (2H $C^{16}H_2$), 4.00 m (15-H), 4.20 m (1H, 11-H), 4.40 m (1H, 6-H), 4.50 m (1H, 9-H), 5.60 m (2H, CH=CH), 6.90 m (3H, H_{arom}), 7.20–7.45 m (17H, H_{arom}). ^{13}C NMR spectrum, δ, ppm: –4.65 ($SiMe_2$); 15.88 (C^3), 17.92 and 18.30 (Si**C**Me_3); 25.79 and 25.83 (SiC**Me**$_3$); 29.26 and 29.67 (C^2); 35.00 and 36.91 (C^7); 42.50 and 42.81 (C^{10}); 42.15 and 48.17 (C^8); 55.94 and 56.33 (C^{12}); 60.80 and 61.16 (C^6); 62.16 (C^1); 71.42 (C^{15}); 72.24 (C^{16}); 73.03 and 73.50 (C^{11}); 78.70 (C^9); 80.92 and 81.61 (C^4); 84.60 and 85.21 (C^5); 86.33 (O**C**Ph_3); 114.39, 120.62, 129.38, 158.62 (OPh); 126.88 127.70, 128.66, 144.23 (C**Ph**$_3$); 131.09 and 132.93 (C^{13}, C^{14}).

(±)-9-Acetoxy-11,15-bis(*tert*-butyldimethylsiloxy)-2-decarboxy-6-oxo-16-phenoxy-2-triphenylmethyloxymethyl-4,4,5,5-tetradehydro-17,18,19,20-tetranorprostaglandin F1α (VII). To a solution of 1.05 g (1.22 mmol) of hydroxy ketone **IV** in 5 ml of anhydrous pyridine we added 0.25 g (2.44 mmol) of acetic anhydride and 0.001 g of 4-dimethylaminopyridine. The mixture was stirred for 2 h at 20°C, 10 ml of a saturated solution of sodium chloride was added, and the mixture was extracted with chloroform (3×20 ml). The extract was dried over Na_2SO_4 and evaporated under reduced pressure, and the residue was purified by column chromatography on silica gel to isolate 0.90 g (82%) of compound **VII** as an oily substance. IR spectrum, ν, cm^{-1}: 1600, 1680, 1740, 3400. ^{1}H NMR spectrum, δ, ppm: 0.05 s (6H, $SiMe_2$), 0.10 s (6H, $SiMe_2$), 0.85 s (9H, SiBu-*t*), 0.90 s (9H, SiBu-*t*), 1.60 m (1H), 1.85 m (2H), 2.00 s (3H, $COCH_3$), 2.20–2.60 m (2H), 2.70 d.d (1H, 7-H, J = 10, 18 Hz), 3.18 t (2H, CH_2O, J = 6 Hz), 3.85 d (2H, $C^{16}H_2$, J = 5.3 Hz), 4.53 m (1H, 11-H), 5.10 m (1H, 9-H), 5.55–5.75 m (2H, CH=CH), 6.90 m (3H, H_{arom}), 7.20–7.45 m (17H, H_{arom}). ^{13}C NMR spectrum, δ_C, ppm: –4.60 ($SiMe_2$); 16.14 (C^3); 18.02 and 18.26 (Si**C**Me_3); 21.05 (CH_3); 25.81 (SiC**Me**$_3$); 29.44 (C^2); 41.40 (C^8); 42.16 (C^{10}); 43.32 (C^7); 54.99 (C^{12}); 61.72 (C^1); 71.12 (C^{15}); 72.05 (C^{16}); 73.33 (C^{11}); 76.37 (C^9); 80.81 (C^5); 86.47 (O**C**Ph_3); 93.63 (C^4); 114.29, 120.64, 129.39, 158.65 (OPh); 126.96 127.77, 128.57, 144.04 (C**Ph**$_3$); 131.41 and 133.35 (C^{13}, C^{14}), 170.35 (CO_2); 186.25 (CO).

(±)-9-Acetoxy-11,15-bis(*tert*-butyldimethylsiloxy)-2-decarboxy-6αβ-hydroxy-16-phenoxy-2-triphenylmethyloxymethyl)-4,4,5,5-tetradehydro-17,18,19,20-tetranorprostaglandin F1α (VIII). To a suspension of 0.034 g (0.88 mmol) of $NaBH_4$ in 4 ml of anhydrous methanol we added at –30°C 0.110 g (0.44 mmol) of $CeCl_3$, the mixture was stirred for 10 min, a solution of 0.200 g (0.22 mmol) of acetate **VII** in 2 ml of anhydrous methanol was added, and the mixture was stirred for 1 h. Excess $NaBH_4$ was decomposed by adding 3 ml of a saturated solution of sodium chloride, the mixture was extracted with chloroform (3×10 ml), the extract was dried over Na_2SO_4 and evaporated under reduced pressure, and the residue was purified by column chromatography on silica gel to isolate 0.170 g (85%) of compound **VIII** (a ~1:1 mixture of epimers with respect to C^6) as an oily substance. ^{1}H NMR spectrum, δ, ppm: 0.05 s (6H, $SiMe_2$), 0.10 s (6H, $SiMe_2$), 0.90 s (9H, SiBu-*t*), 0.95 s (9H, SiBu-*t*), 2.05 s and 2.06 s (3H, CH_3), 3.20 m (2H, CH_2O), 4.80–4.00 m (3H, $C^{16}H_2$, 15-H), 4.30 m (1H, 6-H), 4.55 m (1H, 11-H), 5.15 m (1H, 9-H), 5.70 m (2H, CH=CH), 6.90 m (3H, H_{arom}), 7.20–7.45 m (17H, H_{arom}). ^{13}C NMR spectrum, δ_C, ppm: –4.63 ($SiMe_2$); 15.82 (C^3); 18.01 and 18.26 (Si**C**Me_3); 21.21 (CH_3); 25.79 and 25.85 (SiC**Me**$_3$); 29.22 and 29.65 (C^2); 35 (C^7); 42.25 and 42.15 (C^{10}); 42.76 and 42.90 (C^8); 55.46 (C^{12}); 60.89 and 60.94 (C^6); 61.95 (C^1); 71.19 (C^{15}); 72.22 (C^{16}); 74.52 and 74.60 (C^{11}); the C^9 signals were obscured by the solvent ($CDCl_3$); 81.16 and 81.43 (C^4); 84.96 and 85.18 (C^5); 86.33 (O**C**Ph_3); 114.35, 120.63, 129.39,

158.70 (OPh); 126.82, 127.69, 128.68, 144.23 (C**Ph**$_3$); 132.14 and 132.76 (C^{13}, C^{14}); 170.81 (CO_2).

(±)-9-Acetoxy-11,15-bis(*tert*-butyldimethylsiloxy)-2-decarboxy-6-hydroxy-2-hydroxymethyl-16-phenoxy-4,4,5,5-tetradehydro-17,18,19,20-tetranorprostaglandin F1α (IX). To a solution of 0.200 g (0.22 mmol) of acetate **VII** in 4 ml of chloroform we added 0.030 g (0.22 mmol) of $ZnCl_2$, and the mixture was stirred for 3 h. The mixture was then treated with 2 ml of a saturated solution of sodium chloride and extracted with chloroform, the extract was dried over Na_2SO_4 and evaporated under reduced pressure, and the residue was purified by column chromatography on silica gel to obtain 0.096 g (70%) of alcohol **IX** as an oily substance. ^{1}H NMR spectrum, δ, ppm: 0.01 s and 0.10 s (6H each, $SiMe_2$), 0.85 s and 0.90 s (9H each, SiBu-*t*), 2.03 s (3H, CH_3), 3.70 m (2H, CH_2O), 3.80 d (2H, $C^{16}H_2$, J = 6 Hz), 4.90 m (1H, 15-H), 4.50 m (1H, 11-H), 5.10 m (1H, 9-H), 5.50–5.70 m (2H, C=H), 6.80–7.00 m (3H, H_{arom}), 7.30 m (2H, H_{arom}).

9-Acetoxy-11,15-bis(*tert*-butyldimethylsiloxy)-6-oxo-16-phenoxy-4,4,5,5-tetradehydro-17,18,19,20-tetranorprostaglandin F1α methyl ester (X). To a solution of 0.146 g (1.85 mmol) of anhydrous pyridine in 5 ml of methylene chloride we added at 0°C 0.092 g (0.92 mmol) of CrO_3, and the mixture was stirred for 15 min. To the dark red solution of Collins' reagent thus obtained we added at 20°C in a dropwise fashion a solution of 0.096 g (0.154 mmol) of alcohol **IX** in 2 ml of methylene chloride. The mixture was stirred for 20 min and filtered through a layer of silica gel, and the filtrate was evaporated under reduced pressure to obtain 0.082 g (85%) of the corresponding aldehyde. In a separate flask, 2 ml of a 2.6 M solution of isoprene in THF was added at 0°C to a solution of 0.037 g (0.35 mmol) of $NaClO_2$ and 0.032 g (0.18 mmol) of NaH_2PO_4 in a mixture of 2 ml of *tert*-butyl alcohol and 1 ml of water. The mixture was stirred for 10 min, a solution of 0.082 g (0.13 mmol) of the above aldehyde in 1 ml of THF was added, and the mixture was stirred for 3 h at room temperature. It was then evaporated under reduced pressure, 3 ml of a saturated solution of sodium chloride was added to the residue, and the mixture was extracted with chloroform (3×10 ml). The extracts were combined, dried over Na_2SO_4, and evaporated under reduced pressure. The residue was purified by column chromatography on silica gel to isolate 0.074 g (88%) of the corresponding acid which was treated with a solution of diazomethane in diethyl ether. By column chromatography on silica gel we isolated 0.030 g (40%) of ester **X** as an oily substance. ^{1}H NMR spectrum, δ, ppm: 0.05 s (6H, $SiMe_2$), 0.10 s (6H, $SiMe_2$), 0.85 s (9H, SiBu-*t*), 0.90 s (9H, SiBu-*t*), 1.60 m (1H), 2.00 s (3H, CH_3), 2.30 m (1H), 2.50–1.75 m (9H), 3.70 s (3H, OCH_3), 3.80 d (2H, $C^{16}H_2$, J = 6 Hz), 3.90 d (1H, 15-H), 4.50 m (1H, 11-H), 5.10 m (1H, 9-H), 5.55 d.d (1H, 13-H , J = 1.8, 15 Hz), 5.70 d.d (1H, 14-H, J = 4, 15 Hz). ^{13}C NMR spectrum, δ_C, ppm: –4.60 ($SiMe_2$); 14.71 (C^2); 18.02 and 18.28 (Si**C**Me$_3$); 21.07 (CH_3); 25.76 and 25.81 (SiC**Me**$_3$); 32.08 (C^3); 41.41 (C^8); 42.14 (C^{10}); 43.29 (C^6); 51.96 (OCH_3); 54.96 (C^{12}); 71.13 (C^{13}); 72.05 (C^{16}); 73.65 (C^9); 76.36 (C^{11}); 80.87 (C^5); 91.44 (C^4); 114.31, 120.64, 129.42, 158.68 (OPh); 131.35 and 133,44 (C^{13}, C^{14}); 170.36 (CO_2); 171.53 (CO_2); 186.18 (CO).

(±)-11,15-Bis(*tert*-butyldimethylsiloxy)-2-decarboxy-16-phenoxy-2-triphenylmethyloxymethyl-4,4,5,5-tetradehydro-17,18,19,20-tetranorprostaglandin I1 (XII). A solution of 0.043 ml (0.29 mmol) of diisopropyl azodicarboxylate and 0.074 g (0.29 mmol) of triphenylphosphine in 3 ml of anhydrous THF was stirred for 10 min at –15°C under argon. To the resulting light yellow solution we added first a solution of 0.200 g (0.22 mmol) of diol **VI** in 3 ml of anhydrous THF and, after 10 min, a solution of 0.036 g (0.29 mmol) of *o*-nitrophenylsulfonylhydrazine in 3 ml of anhydrous THF. The mixture was stirred for 1 h at –15°C and for 8 h at 20°C, the solvent was distilled off, and the residue was subjected to column chromatography on silica gel to isolate 0.081 g (40%) of bicyclic ether **XI** as an oily liquid. ^{1}H NMR spectrum, δ, ppm: 0.03 s and 0.1 s (6H each, $SiMe_2$), 0.85 s and 0.93 s (9H each, SiBu-*t*), 3.15 t (2H, CH_2O, J = 6 Hz), 3.70–3.90 m (3H), 4.40–4.75 m (3H), 5.70 m (2H, CH=CH), 6.80–6.95 m (3H, H_{arom}), 7.20–7.50 m (17H, H_{arom}). ^{13}C NMR spectrum, δ_C, ppm: –4.60 ($SiMe_2$); 15.30 (C^3); 18.07 and 18,34 (Si**C**Me$_3$); 25.86 (SiC**Me**$_3$); 38.49 (C^7); 41.51 (C^{10}); 46.12 (C^8); 55.62 (C^{12}); 62.09 (C^1); 67.58 (C^6); 71.30 (C^{15}); 72.30 (C^{16}); 76.99 (C^{11}); 79.16 (C^6); 80.00 (C^{10}); 85.12 (C^5); 86.33 (**C**Ph$_3$); 114.36, 120.61, 129.39, 158.77 (OPh); 126.82, 127.69, 128.07, 144.29 (C**Ph**$_3$).

(±)-6-Acetoxy-11,15-bis(*tert*-butyldimethylsiloxy)-2-decarboxy-16-phenoxy-2-triphenylmethyloxymethyl-4,4,5,5-tetradehydro-17,18,19,20-tetranorprostaglandin F1α (XIII) (a mixture of epimers at C^6**).** By reaction of 0.021 ml (0.14 mmol) of diisopropyl azodicarboxylate, 0.035 g (0.14 mmol) of triphenylphosphine, 0.100 g (0.12 mmol) of alcohol

VIII, and 0.018 g (0.14 mmol) of *o*-nitrophenylsulfonylhydrazine in THF according to the procedure described above for the synthesis of compound **XII**, followed by heating for 6 h at 50°C, we obtained 0.032 g (32%) of C^6-acetate **XIII** as an oily substance. IR spectrum, ν, cm^{-1}: 1600, 1740, 3500. ^1H NMR spectrum, δ, ppm: 0.01 s, 0.08 s, and 0.12 s (1:1:2; $SiMe_2$); 0.83 s, 0.84 s, and 0.90 s (1:1:2, 2SiBu-*t*); 1.95 s and 2.05 s (1:1, OAc); 3.10 m (2H, CH_2O); 3.80 m (2H, $C^{16}H_2$); 5.65 m (2H, CH=CH); 6.90–7.50 m (H_{arom}). ^{13}C NMR spectrum, δ_C, ppm: –4.21 ($SiMe_2$); 15.93 (C^3); 17.90, 18.02, and 18.30 (Si**C**Me_3); 21.13 and 21.92 (CH_3); 29.27, 29.68, and 30.04 (C^2); 33.96 and 34.23 (C^7); 42.36 and 43.18 (C^{10}); 42.56 and 46.93 (C^8); 55.40 and 56.36 (C^{12}); 63.65 and 65.43 (C^6); 71.31 and 71.54 (C^{15}); 72.32 (C^{16}); 73.85 and 74.31 (C^9); 79.20 (C^{11}); 77.97 (C^6); 85.75 (C^5); 86.41 and 86.53 (**C**Ph_3); 114.43, 120.64, 129.34, 158.81 (OPh); 126.89, 127.71, 128.65, 158.81 (C**Ph**$_3$); 169.84 and 170.61 (OCO).

4α-(*tert*-Butyldimethylsiloxy)-3β-[(1*E*)-3α-*tert*-butyldimethylsiloxy-4-phenoxy-1-butenyl]-2α-(2-propynyl)cyclopentan-1α-ol (XVI). To a solution of 0.200 g (0.36 mmol) of compound **V** in 4 ml of anhydrous methanol we added under stirring in succession 0.149 g (1.08 mmol) of anhydrous K_2CO_3 and 0.100 g (0.45 mmol) of dimethyl 1-diazo-2-oxopropylphosphonate, and the mixture was stirred for 8 h at 20°C. The solvent was distilled off under reduced pressure, the residue was treated with 3 ml of a saturated solution of sodium chloride, the mixture was extracted with chloroform (3×5 ml), and the extract was dried over Na_2SO_4 and evaporated. The residue was purified by column chromatography on silica gel to obtain 0.120 g (61%) of compound **XIV**. ^1H NMR spectrum, δ, ppm: 0.05 s and 0.10 s (6H each, $SiMe_2$), 0.85 s and 0.90 s (9H each, SiBu-*t*), 1.70–1.90 m (2H), 1.95 t (1H, ≡CH, *J* = 2.5 Hz), 2.05–2.10 m (1H), 2.30–2.60 m (3H), 4.85 m (2H, CH_2O), 4.10 m (1H, 3'-H), 4.30 m (1H, 1-H), 4.50 m (1H, 4-H), 5.60 m (2H, CH=CH), 6.35–6.95 m (3H, H_{arom}), 7.35 m (2H, H_{arom}). ^{13}C NMR spectrum, δ_C, ppm: –4.60 ($SiMe_2$); 17.70 and 17.90 (Si**C**Me_3); 18.32 (**C**H_2C≡); 25.76 and 25.82 (SiC**Me**$_3$); 42.86 (C^5); 49.53 (C^3); 55.62 (C^2); 71.50 ($C^{3'}$); 72.16 ($C^{4'}$); 73.79 (C^1); 77.22 (C^4); 79.22 (C≡); 83.47 (C≡); 114.40, 120.67, 129.39, 158.47 (OPh); 131.21 and 132.39 (CH=CH).

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