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Coupling reactions of diterpenoid η^2-tetracarbonylmanganese complexes with alkynes

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Abstract

A number of tetracarbonylmanganese complexes derived from podocarpic acid (**1**) have been coupled with acetylene or diphenylacetylene to give steroidal analogues in high yield. Several modes of activating these manganese complexes towards coupling reactions were investigated, including oxidative decarbonylation at room temperature and thermal promotion.

Introduction

We have reported the synthesis and subsequent coupling reactions of the pentacarbonylcarbenechromium complex of the diterpenoid methyl 12-methoxypodocarpa-8,11,13-trien-19-oate with some alkynes as a possible route to ring C aromatic steroidal derivatives [1]. More recently we have reported a one-pot sequence *via* reaction of cyclometallated acetophenone-related [2] and benzaldehyde-related [3] tetracarbonylmanganese(I) complexes with Me_3NO and then with an alkyne to give the cyclopentaannulated adducts in high yields. Coupling reactions of organometallic complexes with alkynes have been reported extensively in the literature. For example, aryl complexes of η^5-cyclopentadienyl(dicarbonyl)iron react thermally with diphenylacetylene to give indenone products [4,5]. More recently, this work has been extended to 1-naphthyl and 2-naphthyl complexes [6] which under photochemical or thermal activation in the presence of diphenylacetylene form 1,2-diphenyl-3*H*-benz[*e*]inden-3-one and 2,3-diphenyl-1*H*-benz[*e*]inden-1-one, respectively, in high yields. Co-condensation of iron atoms with cyclopentadiene and an alkyne at 77 K [7] resulted in incorporation of the alkyne skeleton into a cyclopentadienyl ring, leading to ferrocenes substituted on one of the cyclopentadienyl rings as well as to the expected [8] unsubstituted ferrocene. Chemical activation of (2-acetylphenyl)tetracarbonylmanganese (**4**) with trimeth-

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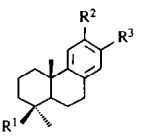
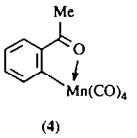
ylamine N-oxide and coupling of the resulting tricarbonyl intermediate with a number of unsymmetrical alkynes has been reported [9]. Yields of the isolated indenols were in the range 31–82%. These workers found that the coupling reactions were general, proceeding with terminal, internal, electron-rich, and electron-deficient alkynes, and that they exhibited a surprising degree of regiochemical control; in most cases only a single indenol was isolated.

We now report an extension of that work including an investigation of several methods for activating the tetracarbonyl complexes.



(1: $R^1 = CO_2H$, $R^2 = OH$, $R^3 = H$
2: $R^1 = CO_2Me$, $R^2 = OMe$, $R^3 = COMe$
3: $R^1 = CO_2Me$, $R^2 = OMe$, $R^3 = CHO$)



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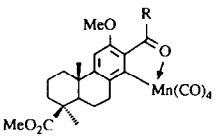
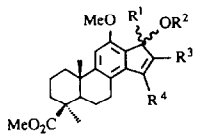


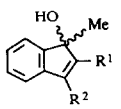
(5: R = Me
6: R = H)

Results and discussion

Reaction of the 13-acetyltetracarbonylmanganese complex **5** [10] with Me_3NO and then diphenylacetylene in acetonitrile for 48 h afforded the free ketone **2** (46%), and the epimers of methyl 17ζ-hydroxy-12-methoxy-4α-methyl-15,16-diphenyl-18-nor-5α-androsta-8,11,13,15-tetraene-4β-carboxylate (**7**) (14, 26%). The absolute stereochemistry of these epimers could not be assigned owing to the extreme similarity of their spectral and physical data. Both compounds were obtained as crystalline solids decomposing at 238–285°C and 248–280°C. Notwithstanding the high melting points, both isomers gave molecular ions (m/z 522) as the base peak in their mass spectrum. As expected, the fragment due to ($M^+ - H_2O$) was also very intense for each isomer. The combined isolated yield of the two cyclised adducts of 40% compares well with that of the coupled adduct **13** reported [9] from the tetracarbonylmanganese complex of acetophenone.

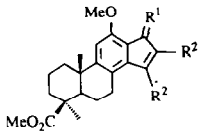


(7: $R^1 = Me$, $R^2 = H$, $R^3 = R^4 = Ph$
9: $R^1 = R^2 = Me$, $R^3 = R^4 = H$
11: $R^1 = Me$, $R^2 = H$, $R^3 = SiMe_3$, $R^4 = Ph$
12: $R^1 = Me$, $R^2 = H$, $R^3 = Ph$, $R^4 = SiMe_3$)

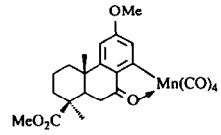


(13: $R^1 = R^2 = Ph$
14: $R^1 = R^2 = H$
15: $R^1 = CO_2Et$, $R^2 = Me$
16: $R^1 = R^2 = SiMe_3$
17: $R^1 = SiMe_3$, $R^2 = H$)

Acid-catalysed elimination of water from a mixture of the epimers **7** gave the exocyclic alkene **18** (90%) which showed two doublets (J 1.6 Hz) at 5.71 and 6.69 ppm in the ^1H NMR spectrum which were assigned to the 17=CH_2 hydrogens, while H(11) was observed as a singlet at 6.83 ppm. The resonances due to the phenyl hydrogens appeared as a ten-proton multiplet between 7.06 and 7.32 ppm, while the exocyclic methylene resonance was observed at 119.4 ppm in the ^{13}C NMR spectrum.



(18: $R^1 = CH_2$, R^2 = Ph
19: $R^1 = CH_2$, R^2 = H
20: R^1 = O, R^2 = H)



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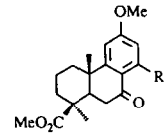


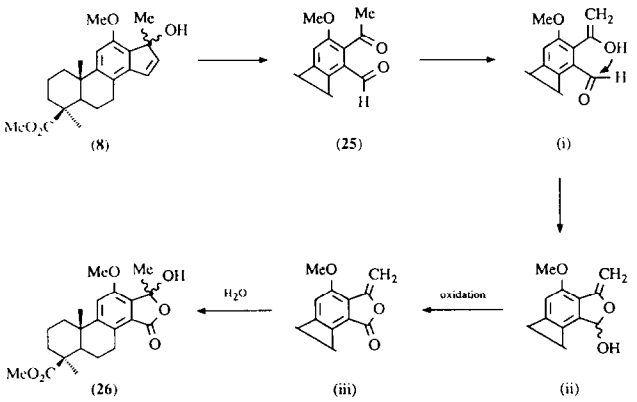
(22: R = H
23: R = C(Ph)=CHPh
24: R = COPh)

Reaction of the 7-oxo complex **21** with Me_3NO/diphenylacetylene in acetonitrile at room temperature for 27.5 h afforded the parent ketone **22** (53%) together with the two adducts **23** (5%) and **24** (12%) and a number of unidentified smaller fractions. 1,2-Diphenyl-1-[14-(methyl 12-methoxy-7-oxopodocarpa-8,11,13-trien-19-oate)]ethene (**23**) was assigned tentatively as the (*E*) stereoisomer. Accurate mass measurement of its molecular ion at *m/z* 494 gave a formula $C_{33}H_{34}O_4$, and two carbonyl absorptions were present in the IR spectrum at 1723 (ester) and 1674 cm^{-1} (ketone). Two *meta* coupled doublets (*J* 2.5 Hz) at 6.81 and 6.87 ppm in the ^1H NMR spectrum were assigned to H(11) and H(13), respectively. Also observed were a broad multiplet between 7.11–8.22 ppm and a singlet at 6.52 ppm, with relative integrals of 10:1. The IR spectrum of methyl 14-benzoyl-12-methoxy-7-oxopodocarpa-8,11,13-trien-19-oate (**24**) showed carbonyl absorptions at 1720 (ester) and 1669 cm^{-1} (intense, two ketones) and the presence of the two ketone carbonyl groups was confirmed by resonances at 196.3 and 197.8 ppm in the ^{13}C NMR spectrum. Substitution at C(14) was established by the presence of two *meta* coupled doublets (*J* 2.2 Hz) at 6.68 and 6.99 ppm, which were assigned to H(11) and H(13), respectively. The presence of a two-proton triplet at 7.40 (*J* 7.8 Hz), a one-proton triplet at 7.51 (*J* 7.5 Hz), and a two-proton doublet at 7.74 ppm (*J* 7.7 Hz) was consistent with a phenyl ketone, in which the *ortho* hydrogens were the most deshielded.

Attempted coupling reactions of either of the tetracarbonylmanganese complexes **5** and **21** with Me_3NO/bis(trimethylsilyl)acetylene in acetonitrile at room temperature were unsuccessful. This result was not unexpected because the trimethylsilyl groups are even bulkier than the phenyl groups, making incorporation of this alkyne into the carbon–manganese bond more difficult due to steric interactions.

Halogenated aromatic derivatives have been coupled with trimethylsilylacetylene in the presence of a catalytic amount of palladium(II) acetate and triphenylphosphine to form the (trimethylsilyl)ethynyl products, which were subsequently cleaved to form the ethynylated aromatic derivatives in high overall yield [11,12]. This sequence is equivalent to the direct insertion of an ethyne unit onto an aromatic ring. In their study of the coupling of oxidatively activated tetracarbonylmanganese complexes with alkynes Liebeskind *et al.* [9] did not investigate the use of ethyne, nor has anyone else reported such an attempt. However, acetylene has been coupled with (2-acetylphenyl-*C,O*)tetracarbonylmanganese (**4**) under thermal promotion to give the indenol **14** (60%) [13].

In the present work, coupling of the activated complex derived from **5** with ethyne (200 kPa, Fischer–Porter pressure bottle) in acetonitrile for 22 h afforded the parent ketone **2** (5%) and a mixture of the two epimers of **8** (Scheme 1) (92%) which were separated by repetitive PLC. The less polar isomer (34%) gave an



Scheme 1.

accurate mass measurement of its molecular ion corresponding to the formula $C_{23}H_{30}O_4$. The more polar isomer (63%) crystallized from hexanes/Et_2O as micro-rods and analysed correctly for its molecular formula. Although ^1H NMR and ^{13}C NMR spectral data were obtained for both isomers the chemical shift values as well as the coupling constants were so similar that they could not be used to assign the absolute stereochemistry.

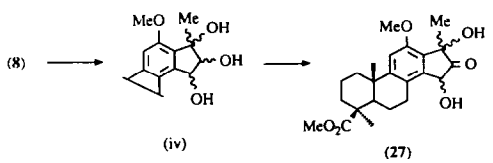
Acid-catalysed elimination of water from a diastereoisomeric mixture of **8** afforded the desired pentaene **19** (6%) and the 17-methoxy epimers **9** (12, 14%). The pentaene **19** was characterised fully by ^1H NMR and ^{13}C NMR spectroscopy, and accurate mass measurement of its molecular ion was correct for $C_{23}H_{28}O_3$. Each 17-methoxy epimer **9** also gave an accurate mass measurement consistent with its molecular formula. As was observed for their 17-hydroxy analogues **8**, the spectral data of these two isomers were very similar and could not be used to assign the absolute stereochemistry about C(17). Formation of these two methoxy-substituted products is explained either by acid-catalysed addition of methanol across the exocyclic alkene at C(17) or by interception of the stabilised cation arising from loss of water from **8**. When the dehydration reaction was carried out using a trace of pyridinium *p*-toluenesulfonate as catalyst in refluxing acetone for 9 h the pentaene derivative **19** was isolated in 80% yield.

The indenol derivative **15** has been oxidized [9] with $NaIO_4/RuCl_3$ [14–16] to afford 1,2-diacetylbenzene (30%). Similar treatment of the mixture of epimers **8** should give the keto-aldehyde **25** which should be amenable to base-catalysed aldol cyclisation to form the 17-oxo steroidal analogue **20**. In the event, treatment of a mixture of the epimers **8** with ruthenium trichloride hydrate (2.2 mol%) and sodium periodate (1.5 molar equiv.) in $H_2O/MeCN/CCl_4$ (3:2:2), at room temperature for 4 h gave a mixture (1:1) of the epimeric lactones **26** (28%) and a single diastereoisomer of the dihydroxy-2-indanone **27** (5%). The mixture of lactones **26** was isolated as a clear oil whose molecular ions had an accurate mass measurement that was correct for $C_{22}H_{28}O_6$. The IR spectrum showed broad absorption (OH) at 3423 and two carbonyl maxima at 1758 (lactone) and 1727 cm^{-1} (ester). The base peak was observed at m/z 370 ($M^+ - H_2O$) as expected for the proposed structure. The two lactone carbonyl resonances were observed at

168.20 and 168.24 ppm in the ^{13}C NMR spectrum, with the two ester carbonyl resonances appearing as a coincident singlet at 177.7 ppm. A mechanism leading to **26** is proposed in Scheme 1. The expected product of this oxidation reaction is the keto-aldehyde **25** which can cyclise *via* its enol (i) to form the hemiacetal (ii). Oxidation of this intermediate leads to the lactone (iii) which forms the observed products **26** by addition of H_2O across the exocyclic double bond [17,18].

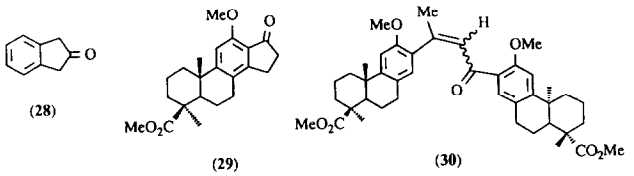
Formation of a single diastereoisomer of the dihydroxy-2-indanone **27** was unexpected. This compound gave a molecular ion which had an accurate mass measurement that was correct for $C_{23}H_{30}O_6$. The IR spectrum showed broad absorption (OH) at 3444 as well as two carbonyl peaks at 1758 (ketone) and 1722 cm^{-1} (ester). The ^1H NMR spectrum showed two downfield hydrogen resonances at 4.50 [bs, H(15)] and 7.07 ppm [s, H(11)]. The DEPT-135 ^{13}C NMR spectrum showed the compound to contain five methylene carbons whose chemical shift values were consistent with an intact diterpenoid carbon skeleton. Furthermore, it showed three methyl, two methoxy, and three methine carbon resonances. Two of the methine carbon signals had chemical shifts that were in agreement with those expected for C(5) and C(11); the third was observed at 83.7 ppm which is further downfield than expected for an oxygenated methine carbon resonance. This signal was therefore assigned to C(16), which is not only oxygenated but also benzylic and adjacent to a carbonyl carbon. The regiochemistries of the substituents at C(15) and C(16) were assigned on the basis of the ketone carbonyl absorption (1758 cm^{-1}) in the IR spectrum which is consistent for a non-conjugated five-membered ring ketone carbonyl [2-indanone (**28**)] [19], but not for a carbonyl group at the benzylic C(16) site. The dihydroxy-2-indanone **27** is envisaged to have formed *via* the triol intermediate (iv) which leads also to cleavage and loss of CO_2, and subsequently to the formation of **26**. If this triol is selectively oxidized at C(16) compound **27** forms instead (Scheme 2).

Reaction of the chemically activated complex derived from **6** with ethyne (310 kPa) in dry acetonitrile for 20 h gave the parent aldehyde **3** (5%) and a mixture of the epimeric allylic alcohols **10** (95%). A portion of the cyclopentenols **10** was separated further by repetitive PLC to give each alcohol, the less polar isomer being obtained in 29% yield and the more polar isomer in 62% yield. Also isolated were methyl 12-methoxy-4α-methyl-17-oxo-18-nor-5α-androsta-8,11,13,15-tetraene-4β-carboxylate (**20**) (2%) and its reduced analogue **29** (6%). Accurate mass measurement of the molecular ion from each of the epimeric alcohols **10** was correct for the expected molecular formula and full spectral characterisation of each compound was carried out. Unfortunately, the chemical shift values of the



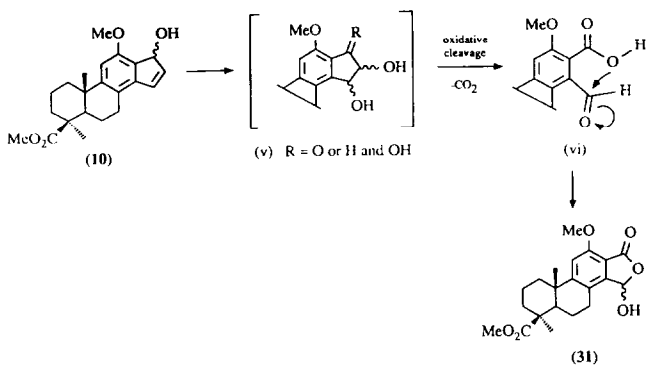
Scheme 2.

hydrogen and carbon resonances of the five-membered ring were very similar and therefore could not be used to assign the absolute stereochemistry of these isomers. The indanone **29** is envisaged to have formed *via* isomerisation of the allylic double bond to form the enol, which then tautomerizes to the observed ketone **29**.



(28) (29) (30)

The indenone derivative **20** clearly arises from oxidation of the cyclopentenols **10**. The structure of **10** was confirmed by oxidation with pyridinium chlorochromate [20] which gave not only the expected indenone **20** (21%) as an unstable oil, but also a mixture (1:1) of two diastereoisomeric lactones **31** (24%). The IR spectrum of **20** showed carbonyl maxima at 1723 (ester) and 1704 cm^{-1} (conjugated ketone). Although the mixture of diastereoisomeric lactones **31** was unstable, accurate mass measurement of the molecular ion was correct for $C_{21}H_{26}O_6$. This mixture showed carbonyl peaks in the IR spectrum at 1768 and 1749 (lactone, Fermi splitting), and 1724 cm^{-1} (ester), as well as an absorption band due to hydroxyl at 3418 cm^{-1}. The ^{13}C NMR spectrum was consistent with an intact diterpenoid skeleton substituted at both C(13) and C(14), and showed one additional methine carbon resonance at 95.9 ppm, which is consistent with the chemical shift expected for a doubly oxygenated benzylic carbon. The mixture of lactones **31** is proposed to have formed *via* the mechanism shown in Scheme 3. Thus, oxidative cleavage of the diol intermediate (v) and subsequent loss of CO_2 generates an *ortho* carboxybenzaldehyde (vi), which subsequently lactonizes to give **31**. Although formation of a diol such as (v) from reaction of an allylic alcohol with PCC/CH_2Cl_2 is unprecedented, analogous γ-hydroxybutenolides have been synthesized by oxidation of bromofurans with this reagent [21].



(10) (v) R = O or H and OH (vi) (31)

Scheme 3.

Reaction of the tetracarbonylmanganese complex **21** with Me_3NO and then ethyne (320 kPa) for 23 h at room temperature did not lead to any identifiable compounds after flash chromatography on silica gel and repetitive PLC.

Attempted thermal or photolytic promotion of coupling reactions of (2-acetylphenyl)tetracarbonylmanganese (**4**) with a number of substituted alkynes were unsuccessful, although no experimental details were provided [9]. However, the same complex has been coupled with diphenylacetylene in refluxing benzene to form the indenol **13** (97%). Similar coupling of **4** with acetylene or bis(trimethylsilyl)acetylene afforded the corresponding indenol derivatives **14** or **16** in 60 and 8% yield, respectively. More recently, thermally-promoted coupling of aliphatic isocyanates and *p*-tolyl isocyanate with tetracarbonylmanganese complexes has been reported [22]. In the present work reaction of the 13-acetyltetracarbonyl manganese complex **5** with diphenylacetylene in refluxing benzene for 16 h afforded a mixture of the epimers of indenol **7** in 97% yield. This represents an increase of 57% over the yield of the cyclised adduct isolated from the trimethylamine N-oxide mediated reaction. Similar treatment of **5** with bis(trimethylsilyl)acetylene afforded the parent ketone **2** (14%), the unexpected condensation products [(*E*) and (*Z*) isomers] **30** (22%), and the cyclopentaannulated derivatives **11** (2 diastereoisomers) (21%). The less polar stereoisomer of **30** was isolated in 6% yield, and the more polar in 16% yield. IR analysis showed two carbonyl absorptions at 1725 (very intense, two esters) and 1650 cm^{-1} (conjugated ketone). In the ^1H NMR spectrum of the less polar isomer the olefinic methyl resonance was observed as a doublet (*J* 1.3 Hz) at 2.17 ppm while the olefinic hydrogen resonance was a quartet at 6.53 ppm sharing the same allylic coupling constant. The ^1H NMR spectrum of the more polar isomer showed these resonances at 2.50 and 6.87 ppm, respectively. The presence of a conjugated ketone was confirmed by the signal observed at 192.8 ppm in the ^{13}C NMR spectrum. The mass spectrum of each isomer showed only a weak molecular ion peak at *m/z* 670 but gave an intense peak at *m/z* 640 ($M^+ - CH_2O$), accurate mass measurements of which corresponded with the formula $C_{41}H_{52}O_6$.

The two isomers of **11** represent incorporation of the bissilyl alkyne with subsequent displacement of one trimethylsilyl group and insertion of a molecule of benzene from the solvent. Each compound gave an accurate mass measurement for its molecular ion that was correct for $C_{32}H_{42}O_4Si$. The more polar isomer was purified further by Kugelrohr distillation and gave correct microanalytical data. The ^1H NMR spectrum of each isomer indicated the presence of one trimethylsilyl group, which was confirmed by signals at 0.82 and 0.76 ppm in the ^{13}C NMR spectrum of the less polar and more polar isomer, respectively. These chemical shifts compare well with those reported [9] for 1-methyl-2-trimethylsilyl-1*H*-inden-1-ol (**17**). Spectral evidence also confirmed the presence of the additional phenyl group. Thus, for each isomer, the ^1H NMR spectrum contained a five proton multiplet between 7.1–7.4 ppm, and five additional methine resonances were observed between 120–130 ppm in each ^{13}C NMR spectrum. The IR spectrum showed broad bands (OH) at 3580 cm^{-1} for both isomers. Together with the presence of a methyl resonance at 1.77 (less polar) and 1.80 ppm (more polar) these data indicate the regioisomeric structures **11**, in which the phenyl group is bonded to C(15), and **12**, in which it is bonded to C(16). The chemical shift of the 17-Me resonances could not be used to assign the regiochemistry of these trimeth-

ylsilyl derivatives owing to the similarity of these values. The chemical shifts of $H(7)_2$ were, however, affected significantly by the phenyl substitution at C(15) in the steroidal analogues. The epimeric cyclopentanols **8** obtained earlier showed signals due to H(7ax) and H(7eq) near 2.6 and 2.9 ppm, respectively. In the 15,16-diphenyl analogues **7**, however, these resonances were observed at 1.8 and 2.3 ppm, corresponding to an upfield shift of 0.8 ppm for H(7ax) and 0.6 ppm for H(7eq). In the indenols **7**, the *cis* phenyl groups bonded to C(15) and C(16) are perpendicular to the plane of ring C in order to minimise vicinal steric interactions. The chemical shift values of H(7ax) and H(7eq) in the more polar isomer of **11** clearly reflect significant shielding when compared with those of the free ketone **2** or of the ethene adducts **8**. The molar polar compound was therefore assigned as a single C(17) epimer of the 15-phenyl-16-trimethylsilyl regiosomer **11**. The $H(7)_2$ resonances of the less polar isomer were obscured by overlapping multiplets from other hydrogens, but nevertheless, were upfield relative to **8**; the less polar compound was therefore assigned as the other C(17) epimer of regioisomer **11**.

Formation of these phenyl-trimethylsilyl adducts from reaction of a tetracarbonylmanganese complex with bis(trimethylsilyl)acetylene is unprecedented, the closest analogy being the isolation of 2,3-bis(trimethylsilyl)-1-methyl-1*H*-inden-1-ol (**16**) (8%) from the tetracarbonylmanganese complex of acetophenone via thermal activation in benzene [**13**]. The mechanism by which the two epimers **11** have formed is unknown.

In summary, a number of tetracarbonylmanganese complexes have been coupled with acetylene or diphenylacetylene to give steroidal analogues in very high yields. For non-gaseous alkynes the yields are superior when the reactions are promoted thermally in refluxing benzene, relative to comparable reactions initiated at room temperature by decarbonylation of the tetracarbonylmanganese complex in acetonitrile. The reverse is true for ethyne, which was incorporated in 92 and 95% yield for R = H and Me, respectively, by chemical activation of the tetracarbonylmanganese complex in acetonitrile at room temperature.

Experimental

For general experimental details see refs. 1 and 23. High field ^1H NMR spectra were determined at 400.134 MHz on a Bruker AM400 instrument operating at 9.2 Tesla. Multiplicities were determined from DEPT spectra.

General procedure for activation of tetracarbonylmanganese complexes with Me_3NO in MeCN followed by coupling with alkynes

A solution of the tetracarbonylmanganese complex (0.1–0.5 mmol) in dry acetonitrile (5–10 mL) was treated with anhydrous trimethylamine N-oxide (1.5 molar equiv.) under argon (causing an immediate colour change) and the mixture was stirred for 5 min at room temperature. At the end of this time the deep orange or red solution was treated with the appropriate alkyne (1.0–8.0 molar equiv.) and the mixture was stirred at room temperature for 6–48 h, during which the colour faded. The mixture was then filtered through a small column of alumina or silica gel and the eluate concentrated *in vacuo*. The residue was purified by either PLC or flash chromatography (silica gel) using hexanes/Et_2O as eluent; components are reported in order of increasing polarity.

Reaction of tetracarbonyl(methyl 13-acetyl-12-methoxypodocarpa-8,11,13-trien-19-oate-C^{14},O^{13})manganese (5)

(i) with diphenylacetylene in MeCN. Reaction of **5** (0.20 g, 0.39 mmol) with Me_3NO (44 mg, 0.59 mmol), and diphenylacetylene (0.14 g, 0.78 mmol) for 48 h gave (i) diphenylacetylene (0.11 g); (ii) methyl 13-acetyl-12-methoxypodocarpa-8,11,13-trien-19-oate (**2**) (62 mg, 46%); (iii) one diastereoisomer of methyl 17ζ-hydroxy-12-methoxy-4α,17ζ-dimethyl-15,16-diphenyl-18-nor-5α-androsta-8,11,13,15-tetraene-4β-carboxylate (**7**) (29 mg, 14%) which crystallized (isopiestic) from Et_2O-$CHCl_3$/hexanes as rods, m.p. 238–285°C (dec) (Found: $M^{+\cdot}$, 522.2785. $C_{35}H_{38}O_4$ calcd. M, 522.2770). ν_{max} 3575 (OH), 1719 cm^{-1} (ester CO). δ(H) (ppm) 1.02, txd, J 13.5, 4.1 Hz, H(3ax); 1.06, s, $H(19)_3$; 1.15, s, (4-Me); 1.35, bd, J 12.2 Hz, H(5); 1.39, txd, J 13.2, 4.0 Hz, H(1ax); 1.60–1.69, 1.83–1.89, m, H(2eq), H(6ax), H(6eq), H(7ax); 1.72, s, (17-Me); 1.95, qxt, J 13.9, 5.4 Hz, H(2ax); 2.20–2.29, m, H(1eq), H(3eq); 2.41, dxd, J 16.3, 4.1 Hz, H(7eq); 2.67, s, (17-OH); 3.61, s, (4-CO_2Me); 3.90, s, (12-OMe); 6.76, s, H(11); 7.10–7.35, 10H, *aromatic*-H. δ(C) (ppm) 20.1, C(2); 20.9, C(6); 23.0, C(19); 23.4, (17-Me); 28.4, (4-Me); 29.4, C(7); 37.4, C(3); 39.4, C(10); 40.3, C(1); 43.8, C(4); 51.2, 4-CO_2*Me*; 52.1, C(5); 55.3, (12-OMe); 82.5, C(17); 107.3, C(11); 123.6, C(13); 126.8, 126.9, 27.5 (3C), 128.3, 129.3, 129.6 (2C), 130.1, *aromatic* C-H; 132.8, 134.7, 138.2, 140.3, 140.8, 149.6, (*ipso*-C)$_2$, C(8), C(14), C(15), C(16); 150.7, C(9); 153.1, C(12); 177.9, 4-*C*O_2Me. m/z 522 (100, M^+), 507 (52, M – Me), 504 (23, $M - H_2O$), 433 (10), 178 (15), 105 (13), 43 (15); and (iv) the other diastereoisomer of methyl 17ζ-hydroxy-12-methoxy-4α,17ζ-dimethyl-15,16-diphenyl-18-nor-5α-androsta-8,11,13,15-tetraene-4β-carboxylate (**7**) (54 mg, 26%) which crystallized (isopiestic) from Et_2O/hexanes as sheets, m.p. 248–280°C (dec) (Found: $M^{+\cdot}$, 522.2782. $C_{35}H_{38}O_4$ calcd. M, 522.2770). ν_{max} 3579 (OH), 1719 cm^{-1} (ester CO). δ(H) (ppm) 1.03, s, $H(19)_3$; 1.05, txd, J 13.6, 4.2 Hz, H(3ax); 1.19, s, (4-Me); 1.46, txd, J 12.9, 4.1 Hz, H(1ax); 1.51–1.63, 1.84–1.89, 2.13–2.26, m, H(2eq), H(6ax), H(6eq), H(7ax), H(7eq); 1.63, s, (17-Me); 1.99, qxt, J 13.7, 3.6 Hz, H(2ax); 2.21–2.26, m, H(1eq), H(3eq); 2.82, s, (17-OH); 3.59, s, (4-CO_2Me); 3.90, s, (12-OMe); 6.75, s, H(11); 7.03–7.39, 10H, *aromatic*-H. δ(C) (ppm) 20.1, C(2); 21.0, C(6); 23.0, C(19); 23.5, (17-Me); 28.4, (4-Me); 30.4, C(7); 37.5, C(3); 39.5, C(10); 40.3, C(1); 43.8, C(4); 51.2, 4-CO_2*Me*; 52.3, C(5); 55.3, (12-OMe); 82.6, C(17); 107.5, C(11); 123.8, C(13); 126.8, 127.0, 127.5 (2C), 127.7, 128.4, 129.4, 129.6 (2C), 129.8, *aromatic* C-H; 133.0, 134.9, 138.1, 140.4, 140.7, 148.7, (*ipso*-C)$_2$, C(8), C(14), C(15), C(16); 150.7, C(9); 153.0, C(12); 177.9, 4-*C*O_2Me. m/z 522 (100, M^+), 507 (59, M – Me), 504 (32, $M - H_2O$), 178 (22), 129 (11), 73 (17), 69 (23), 57 (35).

A solution of the diastereoisomeric alcohols **7** (70 mg, 0.13 mmol) in MeOH/$CHCl_3$ (20 mL, 1:1) was treated with dilute aqueous HCl (1 drop) at room temperature for 40 min. The solution was then filtered through a plug of sodium hydrogencarbonate, concentrated *in vacuo*, and purified by PLC to give methyl 12-methoxy-4α-methyl-17-methylene-15,16-diphenyl-18-nor-5α-androsta-8,11,13,15,17-pentaene-4β-carboxylate (**18**) (61 mg, 90%) which crystallized from hexanes/Et_2O as yellow rods, m.p. 205–207°C (Found: C, 83.5; H, 7.2. $C_{35}H_{36}O_3$ calcd.: C, 83.3; H, 7.2%). ν_{max} 1720 (ester CO), 1590, 1470 cm^{-1} (C=C). δ(H) (ppm) 1.07, txd, J 13.3, 4.3 Hz, H(3ax); 1.07, s, $H(19)_3$; 1.19, s, (4-Me); 1.45, txd, J 13.4, 4.1 Hz, H(1ax); 1.46, dxd, J 12.0, 1.2 Hz, H(5); 1.58–1.70, m, H(2eq), H(6ax); 1.90, bd, J 13.7, 6.2 Hz, H(6eq); 2.01, qxt, J 13.9, 3.7 Hz, H(2ax); 2.15, dxdxd, J 17.1,

12.7, 6.2 Hz, H(7ax); 2.24–2.29, m, H(1eq), H(3eq); 2.37, dxdxd, *J* 17.1, 5.2, 1.7 Hz, H(7eq); 3.60, s, (4-CO_2Me); 3.97, s, (12-OMe); 5.71, 6.69, d, *J* 1.6 Hz, 17=CH_2; 6.83, s, H(11); 7.06–7.32, m, 10H, *aromatic*-H. δ(C) (ppm) 20.1, C(2); 21.1, C(6); 22.9, C(19); 28.4, 4-Me; 30.2, C(7); 37.5, C(3); 39.6, C(10); 40.4, C(1); 43.9, C(4); 51.2, 4-CO_2*Me*; 52.3, C(5); 55.2, (12-OMe); 107.0, C(11); 119.4, C(17); 123.2, C(13); 126.4, 126.7, 127.4 (2C), 127.6, 127.7, 129.8, 130.8 (2C), *aromatic* C-H; 134.6, 138.4, 140.1, 141.4, 143.0, 146.0, (*ipso*-C)$_2$, C(8), C(14), C(15), C(16); 150.4, C(9); 154.4, C(12); 178.0, 4-*C*O_2Me. *m/z* 504 (100, $M^{+\cdot}$), 489 (1, *M* − Me), 446 (4), 429 (17), 125 (9), 55 (10), 43 (15).

(ii) with diphenylacetylene in benzene. Reaction of **5** (0.28 g, 0.55 mmol) and diphenylacetylene (0.20 g, 1.09 mm) in benzene (10 mL) (16 h) gave diphenylacetylene (81 mg) and a mixture of two diastereoisomers of **7** (0.28 g, 97%).

(iii) with bis(trimethylsilyl)acetylene in MeCN. Reaction of **5** (0.20 g, 0.39 mmol) with Me_3NO (44 mg, 0.55 mmol) and bis(trimethylsilyl)acetylene (0.18 mL, 0.78 mmol) (54 h) gave **2** (0.12 g, 92%).

(iv) with bis(trimethylsilyl)acetylene in benzene. Reaction of **5** and bis(trimethylsilyl)acetylene (0.19 g, 1.09 mmol) in benzene (10 mL) (15 h) gave (i) a single isomer of 1,3-bis[13-(methyl 12-methoxypodocarpa-8,11,13-trien-19-oate)]but-2-en-1-one (**30**) (11 mg, 6%) as a clear oil (Found: $M^{+\cdot}$ − CH_2O, 640.3711. $C_{41}H_{52}O_6$ calcd. *M* − CH_2O, 640.3764). ν_{max} 1725 (ester CO), 1650 (ketone CO), 1608, 1497, 1464 cm^{-1} (C=C). δ(H) (ppm) 0.950, 0.954, s, H(20)$_3$, H(20)′$_3$; 1.25, 1.26, s, H(18)$_3$, H(18)′$_3$; 2.17, d, *J* 1.3 Hz, −C(*Me*)=C(CO)H−; 3.65, s, (19-OMe), (19-OMe′); 3.66, 3.74, s, (12-OMe), 12-OMe′; 6.50, 6.56, s, H(11), H(11)′; 6.53, q, *J* 1.3 Hz, −C(Me)=C(CO)*H*−; 6.60, 6.99, s, H(14), H(14)′. *m/e* 670 (⩽, M^+), 640 (40, *M* − CH_2O), 639 (100, *M* − OMe), 503 (10), 487 (9), 344 (40), 329 (52), 269 (47); (ii) the other isomer of 1,3-bis[13-(methyl 12-methoxypodocarpa-8,11,13-trien-19-oate)]but-2-en-1-one (**30**) (29 mg, 16%) as a clear oil (Found: $M^{+\cdot}$ − CH_2O, 640.3717. $C_{41}H_{52}O_6$ calcd.: *M* − CH_2O, 640.3764). ν_{max} 1725 (ester CO), 1650 (ketone CO), 1609, 1496, 1463, 1403 cm^{-1} (C=C). δ(H) (ppm) 1.05, 1.06, s, H(20)$_3$, H(20)′$_3$; 1.28, s, H(18)$_3$, H(18)′$_3$; 2.50, d, *J* 1.1 Hz, −C(*Me*) = C(CO)H−; 3.67, s, (19-OMe), (19-OMe′); 3.79, 3.83, s, (12-OMe), (12-OMe′); 6.78, 6.83, s, H(11), H(11)′; 6.87, q, *J* 1.1 Hz, −C(Me)=C(CO)*H*−; 6.91, 7.23, s, H(14), H(14)′. δ(C) (ppm) 19.90, 19.93, C(2), C(2)′; 20.7, −C(*Me*)=C(CO)H−; 20.96, 21.03, C(6), C(6)′; 22.7, 22.8, C(20), C(20)′; 28.46, 28.50, C(18), C(18)′; 31.0, 31.1, C(7), C(7)′; 37.5, 37.6, C(3), C(3)′; 38.7, 39.0, C(10), C(10)′; 39.36, 39.44, C(1), C(1)′; 44.0, C(4), C(4)′; 51.3, 4-CO_2*Me*, 4-CO_2*Me*′; 52.6, 52.7, C(5), C(5)′; 55.7, 55.8, (12-OMe), (12-OMe′); 108.4, 108.7, C(11), C(11)′; 127.3, 127.8, C(8), C(8)′; 129.0, 131.7, C(13), C(13)′; 127.9, 129.6, 131.1, C(14), C(14)′, −C(Me)=*C*(CO)H−; 149.2, −*C*(Me)=C(CO)H−; 152.9, 153.8, C(9), C(9)′; 155.1, 156.2, C(12), C(12)′; 177.8, C(19), C(19)′; 192.8, −C(Me)=C(*C*O)H−. *m/z* 670 (⩽ 1, M^+), 640 (9, *M* − CH_2O), 639 (100, *M* − OMe), 346 (52), 331 (98), 271 (34), 227 (20), 121 (20), 91 (72); (iii) a mixture of a single diastereoisomer of methyl 17ζ-hydroxy-12-methoxy-4α,17ζ-dimethyl-16-trimethylsilyl-15-phenyl-18-nor-5α-androsta-8,11,13,15-tetraene-4β-carboxylate (**11**), an unidentified tetracarbonylmanganese complex, and a number of minor components (23 mg) as a bright yellow oil (Found: $M^{+\cdot}$, 518.2849. $C_{32}H_{42}O_4Si$ calcd. *M*, 518.2852). ν_{max} 3547 (OH), 2024, 1951, 1929 (br) (Mn−C≡O), 1728 (ester CO), 1610, 1563, 1498, 1464 cm^{-1} (C=C). *m/z* 518 (10, M^+), 503 (51, *M* − Me), 487 (64, *M* − $SiMe_3$), 428 (100), 369 (41), 353 (50), 293 (17); (iv) a single

diastereoisomer of methyl 17ζ-hydroxy-12-methoxy-4α,17ζ-dimethyl-16-trimethylsilyl-15-phenyl-18-nor-5α-androsta-8,11,13,15-tetraene-4β-carboxylate (**11**) (16 mg, 6%) as a clear oil (Found: $M^{+\cdot}$, 518.2856. $C_{32}H_{42}O_4Si$ calcd.: M, 518.2852). ν_{max} 3584 (OH), 1727 (ester CO), 1598, 1552, 1488, 1463, 1455, 1441 cm^{-1} (C=C). δ(H) (ppm) −0.06, s, (16-$SiMe_3$); 1.01, s, $H(19)_3$; 1.14, s, (4-Me); 1.77, s, (17-Me); 2.58, s, (17-OH); 3.60, s, (4-CO_2Me); 3.87, s, (12-OMe); 6.70, s, H(11); 7.16–7.33, m, 5H, *phenyl*-H. δ(C) (ppm) (DEPT-135) 0.82, (16-$SiMe_3$); 20.1, C(2); 20.8, C(6); 22.9, C(19); 2.42, (17-Me); 28.4, (4-Me); 28.6, C(7); 37.5, C(3); 40.2, C(1); 51.1, 4-CO_2*Me*; 51.8, C(5); 55.2 (12-OMe); 107.4, C(11); 127.1, 127.7, 127.8 (2C), 129.0, 129.7, *phenyl* C-H. *m/z* 518 (25, M^+), 503 (100, M − Me), 487 (87, $M - H_2O$), 445 (21, $M - SiMe_3$), 408 (19), 345 (12), 73 (42, $^+SiMe_3$); (v) **4** (27 mg, 14%); and (vi) the other diastereoisomer of methyl 17ζ-hydroxy-12-methoxy-4α,17ζ-dimethyl-16-trimethylsilyl-15-phenyl-18-nor-5α-androsta-8,11,13,15-tetraene-4β-carboxylate (**11**) (43 mg, 15%) as a clear oil (Kugelrohr, 220°C/0.05 mmHg) (Found: C, 74.0; H, 8.0. $C_{32}H_{42}O_4Si$ calcd.: C, 74.1; H, 8.2%) (Found: $M^{+\cdot}$, 518.2866. $C_{32}H_{42}O_4Si$ calcd. M, 518.2852). ν_{max} 3583 (OH), 1725 (ester CO), 1598, 1553, 1489, 1464 cm^{-1} (C=C). δ(C) (ppm) −0.06, s, (16-$SiMe_3$); 1.02, s, $H(19)_3$; 0.97–1.08, m, H(3ax); 1.16, s, (4-Me); 1.25–1.32, m, H(2eq); 1.34, bd, *J* 12.0 Hz, H(5); 1.36, txd, *J* 13.4, 3.7 Hz, H(1ax); 1.56, qxd, *J* 12.7, 5.0 Hz, H(6ax); 1.58–1.72, m, H(7ax); 1.80, s, (17-Me); 1.88–2.04, m, H(2ax), H(6eq); 2.12, bdxd, *J* 17.5, 4.0 Hz, H(7eq); 2.18–2.26, m, H(1eq), H(3eq); 2.54 (s, (17-OH); 3.59, s, (4-CO_2Me); 3.86, s, (12-OMe); 6.69, s, H(11); 7.16–7.37, m, 5H, *phenyl*-H. δ(C) (ppm) 0.76, (16-$SiMe_3$); 20.1, C(2); 21.0, C(6); 22.9, C(19); 24.2, (17-Me); 28.4, (4-Me); 29.6, C(7); 37.4, C(3); 39.4, C(10); 40.4, C(1); 43.8, C(4); 51.1, 4-CO_2*Me*; 52.3, C(5); 55.2, (12-OMe); 86.2, C(17); 107.4, C(11); 123.3, 128.3, C(8), C(13); 127.1, 127.7, 127.9, 129.2, 129.5, *phenyl* C-H; 136.2, *ipso*-C; 140.2, 140.9, C(14), C(16); 150.4, 152.8, C(9), C(15); 153.6, C(12); 177.9, 4-CO_2Me. *m/z* 518 (19, M^+), 503 (100, M − Me), 487 (93, $M - H_2O$), 445 (21, $M - SiMe_3$), 343 (17), 73 (43, $SiMe_3$).

(v) with ethyne in MeCN. Reaction of **5** (0.75 g, 1.47 mmol) with Me_3NO (0.17 g, 2.21 mmol) (5 min) and then ethyne (200 kPa) for 22 h gave (i) **2** (24 mg, 5%); and (ii) a mixture of the two diastereoisomers of methyl 17ζ-hydroxy-12-methoxy-4α,17-dimethyl-18-nor-5α-androsta-8,11,13,15-tetraene-4β-carboxylate (**8**) (0.50 g, 92%), a portion (0.10 g) of which on PLC gave (i) one diastereoisomer of methyl 17ζ-hydroxy-12-methoxy-4α,17ζ-dimethyl-18-nor-5α-androsta-8,11,13,15-tetraene-4β-carboxylate (**8**) (34 mg, 34%) as a clear oil (Found: $M^{+\cdot}$, 370.2156. $C_{23}H_{30}O_4$ calcd. M, 370.2144). ν_{max} 3490 (OH), 1725 (ester CO), 1610, 1596, 1568, 1465 cm^{-1} (C=C). δ(H) (ppm) 1.06, s, $H(19)_3$; 1.08, txd, *J* 13.5, 4.2 Hz, H(3ax); 1.28, s, (4-Me); 1.40, txd, *J* 13.2, 4.0 Hz, H(1ax); 1.51, dxd, *J* 12.3, 1.5 Hz, H(5); 1.63, dxp, *J* 14.2, 2.9 Hz, H(2eq); 1.69, s, (17-Me); 1.94, qxd, *J* 13.6, 5.5 Hz, H(6ax); 2.00, qxt, *J* 13.9, 3.7 Hz, H(2ax); 2.19–2.29, m, H(1eq), H(3eq), H(6eq); 2.31, s, (17-OH); 2.65, dxdxd, *J* 16.5, 12.8, 6.3 Hz, H(7ax); 2.91, dxdxd, *J* 16.5, 5.5, 1.5 Hz, H(7eq); 3.66, s, (4-CO_2Me); 3.84, s, (12-OMe); 6.26, d, *J* 5.6 Hz, H(16); 6.58, d, *J* 5.6 Hz, H(15); 6.64, s, H(11). δ(C) (ppm) 20.0, C(2); 20.6, C(6); 22.8, (17-Me); 22.9, C(19); 28.1, C(7); 28.5, (4-Me); 37.5, C(3); 39.0, C(10); 39.9, C(1); 44.0, C(4); 51.2, 4-CO_2*Me*; 52.7, C(5); 55.2, (12-OMe); 82.9, C(17); 106.6, C(11); 121.5, C(13); 128.0, C(16); 132.0, C(8); 141.2, C(14); 142.9, C(15); 150.4, C(9); 153.3, C(12); 177.8, 4-*C*O_2Me. *m/z* 370 (100, M^+), 355 (80, M − Me), 352 (26, $M - H_2O$), 295 (57, 355 − HCO_2Me), 277 (29, 295 − H_2O), 188 (30), 83 (23), 57 (22), 43 (23); and (ii) the

other diastereoisomer of methyl 17ζ-hydroxy-12-methoxy-4α,17ζ-dimethyl-18-nor-5α-androsta-8,11,13,15-tetraene-4β-carboxylate (**8**) (63 mg, 63%) which crystallized from hexanes/Et_2O as micro-rods, m.p. 159–168°C (dec) (Found: C, 74.6; H, 8.2. $C_{23}H_{30}H_4$ calcd.: C, 74.6; H, 8.2%). ν_{max} 3478 (OH), 1724 (ester CO), 1609, 1595, 1567, 1464 cm^{-1} (C=C). δ(H) (ppm) 1.05, s, $H(19)_3$; 1.08, txd, *J* 13.5, 4.2 Hz, H(3ax); 1.27, s, (4-Me); 1.43, txd, *J* 13.4, 4.0 Hz, H(1ax); 1.53, dxd, *J* 12.3, 1.6 Hz, H(5); 1.63, dxp, *J* 14.2, 2.9 Hz, H(2eq); 1.68, s, (17-Me); 1.93, qxd, *J* 13.7, 5.5 Hz, H(6ax); 2.00, qxt, *J* 14.0, 3.6 Hz, H(2ax); 2.19–2.29, m, H(1eq), H(3eq), H(6eq); 2.41, s, (17-OH); 2.61, dxdxd, *J* 16.4, 12.8, 6.4 Hz, H(7ax); 2.93, dxdxd, *J* 16.4, 5.4, 1.4 Hz, H(7eq); 3.66, s, (4-CO_2Me); 3.84, s, (12-OMe); 6.23, d, *J* 5.6 Hz, H(16); 6.59, d, *J* 5.6 Hz, H(15); 6.64, s, H(11). δ(C) (ppm) 20.0, C(2); 20.6, C(6); 22.8, (17-Me); 22.9, C(19); 27.7, C(7); 28.5, (4-Me); 37.5, C(3); 38.9, C(10); 39.8, C(1); 43.9, C(4); 51.2, 4-CO_2*Me*; 52.5, C(5); 55.2 (12-OMe); 82.8, C(17); 106.6, C(11); 121.4, C(13); 128.0, C(16); 132.0, C(8); 141.1, C(14); 142.9, C(15); 150.4, C(9); 153.3, C(12); 177.8, 4-*C*O_2Me. *m/z* 370 (100, M^+), 355 (82, *M* − Me), 352 (26, *M* − H_2O), 295 (61, 355 − HCO_2Me), 277 (29, 295 − H_2O), 188 (29).

A solution of a mixture of the diastereoisomeric alcohols **8** (50 mg, 0.14 mmol) in methanol was treated with dilute aqueous HCl (1 drop) at room temperature for 3 h, filtered through a plug of $NaHCO_3$ and concentrated *in vacuo*. PLC gave (i) methyl 12-methoxy-4α-methyl-17-methylene-18-nor-5α-androsta-8,11,13,15,17-pentaene-4β-carboxylate (**19**) (3 mg, 6%) as a clear oil (Found: $M^{+\cdot}$, 352.2054. $C_{23}H_{28}O_3$ calc.: *M*, 352.2038). ν_{max} 1725 (ester CO), 1592, 1463 cm^{-1} (C=C). δ(H) (ppm) 1.08, s, $H(19)_3$; 1.10, txd, *J* 13.5, 4.2 Hz, H(3ax); 1.29, s, (4-Me); 1.44, txd, *J* 13.2, 3.9 Hz, H(1ax); 1.57, dxd, *J* 12.4, 1.5 Hz, H(5); 1.64, dxp, *J* 14.2, 3.2 Hz, H(2eq); 1.97, qxd, *J* 13.3, 5.5 Hz, H(6ax); 2.02, qxt, *J* 13.9, 3.7 Hz, H(2ax); 2.20–2.30, m, H(1eq), H(3eq), H(6eq); 2.72, dxdxd, *J* 16.5, 12.8, 6.3 Hz, H(7ax); 3.02, dxdxd, *J* 16.5, 5.5, 1.5 Hz, H(7eq); 3.67, s, (4-CO_2Me); 3.90, s, (12-OMe); 5.81, d, *J* 1.8 Hz, 17=CH_2; 6.42–6.43, 6.86–6.88, m, H(15), H(16), 17=CH_2; 6.71, s, H(11). δ(C) (ppm) 20.1, C(2); 20.7, C(6); 22.9, C(19); 28.1, C(7); 28.6, (4-Me); 37.6, C(3); 39.1, C(10); 40.0, C(1); 44.1, C(4); 51.3, (4-CO_2*Me*); 52.8, C(5); 55.1, (12-OMe); 106.0, C(11); 119.1, 17=CH_2; 121.1, C(13); 130.0, 130.3, C(15), C(16); 138.6, C(8); 143.7, C(14); 146.9, C(17); 149.8, C(9); 154.5, C(12); 177.9, 4-*C*O_2Me. *m/z* 352 (8, M^+), 288 (26), 260 (28), 189 (34), 149 (100), 57 (70); (ii) one diastereoisomer of methyl 12,17ζ-dimethoxy-4α,17ζ-dimethyl-18-nor-5α-androsta-8,11,13,15-tetraene-4β-carboxylate (**9**) (6 mg, 12%) as a clear oil (Found: $M^{+\cdot}$, 384.2303. $C_{24}H_{32}O_4$ calcd.: *M*, 384.2301). ν_{max} 1726 (ester CO), 1592, 1567, 1467 cm^{-1} (C=C). δ(H) (ppm) 1.07, s, $H(19)_3$; 1.10, txd, *J* 13.5, 4.2 Hz, H(3ax); 1.29, s, (4-Me); 1.44, txd, *J* 13.3, 3.9 Hz, H(1ax); 1.58, dxd, *J* 12.2, 1.5 Hz, H(5); 1.62, dxp, *J* 14.3, 3.9 Hz, H(2eq); 1.63, s, (17-Me); 1.94, qxd, *J* 12.8, 5.5 Hz, H(6ax); 2.01, qxt, *J* 14.5, 3.6 Hz, H(2ax); 2.20–2.30, m, (H1eq), H(3eq), H(6eq); 2.68, dxdxd, *J* 16.5, 12.7, 6.3 Hz, H(7ax); 2.93, dxdxd, *J* 16.5, 5.4, 1.3 Hz, H(7eq); 2.99, s, (17-OMe); 3.67, s, (4-CO_2Me); 3.83, s, (12-OMe); 6.11, d, *J* 5.7 Hz, H(16); 6.64, s, H(11); 6.68, d, *J* 5.6 Hz, H(15). δ(C) (ppm) 20.1, C(2); 20.7, C(6); 21.4, (17-Me); 22.9, C(19); 28.1, C(7); 28.6, (4-Me); 37.6, C(3); 39.0, C(10); 39.9, C(1); 44.0, C(4); 51.2, 4-CO_2*Me*; 51.9, (17-OMe); 52.6, C(5); 55.4, (12-OMe); 88.1, C(17); 106.7, C(11); 121.2, C(13); 128.4, C(8); 129.2, C(16); 141.5, C(15); 142.3, C(14); 150.6, C(9); 154.2, C(12); 177.9, 4-*C*O_2Me. *m/z* 384 (100, M^+), 369 (81, *M* − Me), 354 (11, *M* − CH_2O), 309 (34, 369 − HCO_2Me), 203 (21), 57 (34); and (iii) the other diastereoisomer of methyl

12,17ζ-dimethoxy-4α,17ζ-dimethyl-18-nor-5α-androsta-8,11,13,15-tetraene-4β-carboxylate (**9**) (7 mg, 14%) as a clear oil (Found: $M^{+\cdot}$, 384.2309. $C_{24}H_{32}O_4$ calcd.: M, 384.2301). ν_{max} 1726 (ester CO), 1592, 1567, 1467 cm^{-1} (C=C). δ(H) (ppm) 1.07, s, $H(19)_3$; 1.09, txd, J 13.5, 4.1 Hz, H(3ax); 1.28, s, (4-Me); 1.44, txd, J 13.3, 3.2 Hz, H(1ax); 1.55, dxd, J 12.3, 1.3 Hz, H(5); 1.59–1.63, m, H(2eq); 1.62, s, (17-Me); 1.98, qxd, J 13.5, 4.4 Hz, H(6ax); 2.01, qxt, J 13.2, 3.1 Hz, H(2ax); 2.17–2.30, m, H(1eq), H(3eq), H(6eq); 2.63, dxdxd, J 16.3, 12.9, 6.4 Hz, H(7ax); 2.96, dxdxd, J 16.3, 4.1, 1.3 Hz, H(7eq); 3.01, s, (17-OMe); 3.67, s, (4-CO_2Me); 3.83, s, (12-OMe); 6.11, d, J 5.7 Hz, H(16); 6.65, s, H(11); 6.68, d, J 5.6 Hz, H(15). m/z 384 (100, M^+), 369 (67, M − Me), 353 (11, M − OMe), 309 (25, 369 − HCO_2Me), 203 (17), 57 (14).

Treatment of a mixture of the alcohols **8** (51 mg, 0.14 mmol) with pyridinium *p*-toluenesulfonate (trace) in refluxing acetone for 9 h gave **19** (39 mg, 80%) as an unstable yellow oil.

Treatment of 8 with $RuCl_3/NaIO_4$

A mixture of diastereoisomers of **8** (0.14 g, 0.36 mmol), ruthenium trichloride (1.7 mg, 8.0 μmol), and sodium periodate (0.32 g, 1.50 mmol) in a mixture (2:2:3, 7 mL) of CCl_4/MeCN/H_2O was stirred vigorously at room temperature for 4 h. Workup and PLC gave (i) a mixture (1:1) of two diastereoisomers of methyl [5aR-(1ζ,5aα,6β,9aβ)]-1-hydroxy-11-methoxy-1,6,9a-trimethyl-4,5,5a,6,7,8,9,9a-octahydrophenanthrol[1,2-*c*]-furan-3(1*H*)-one-6-carboxylate (**26**) (39 mg, 28%) as a clear oil (Found: $M^{+\cdot}$, 388.1887. $C_{22}H_{28}O_6$ calcd.: M, 388.1886). ν_{max} 4323 (OH), 1758 (lactone CO), 1727 cm^{-1} (ester CO). δ(H) (ppm) 1.03, 1.05, s, (9a-Me), (9a-Me′); 1.06–1.11, m, H(7ax), H(7ax)′; 1.27, s, (6-Me), (6-Me′); 1.32–1.44, m, H(9ax), H(9ax)′; 1.49, 1.51, bd, J 10.5 Hz, H(5a), H(5a)′; 1.60–1.69, m, H(8eq), H(8eq)′; 1.80–1.95, m, H(5ax), H(5ax)′; 1.90, 1.91, s, (1-Me), (1-Me′); 2.00, qxt, J 13.9, 3.5 Hz, H(8ax), H(8ax)′; 2.20–2.28, m, H(5eq), H(5eq)′, H(7eq), H(7eq)′, H(9eq), H(9eq)′; 2.71–2.82, m, H(4ax), H(4ax)′; 3.48, bdxd, J 18.2, 4.9 Hz, H(7eq), H(7eq)′; 3.65, s, (6-CO_2Me), (6-CO_2Me′); 3.80–3.85, bs, (1-OH), (1-OH′); 3.89, s, (11-OMe), (11-OMe′); 7.04, s, H(10), H(10)′. δ(C) (ppm) 19.85, C(8), C(8)′; 19.93. C(5), C(5)′; 22.8, (9a-Me), (9a-Me)′; 24.7, (1-Me), (1-Me)′; 22.1, 22.2, C(4), C(4)′; 28.4, (6-Me), (6-Me′); 37.3, C(7), C(7)′; 39.3, C(9a), C(9a)′; 39.8, C(9), C(9)′; 43.9, C(6), C(6)′; 51.4, 6-CO_2*Me*, 6-CO_2*Me*′; 52.1, C(5a), C(5a)′; 55.7, (11-OMe), (11-OMe′); 103.5, C(1), C(1)′; 114.0, C(10), C(10)′; 124.7, C(11a), C(11a)′; 128.5, C(3b), C(3b)′; 134.9, C(3a), C(3a)′; 152.4, C(9b), C(9b)′; 153.2, C(11), C(11)′; 168.20, 168.24, C(3), C(3)′; 177.7, 6-CO_2Me, 6-CO_2Me′. m/z 388 (17, M^+), 370 (100, M − H_2O), 355 (19, 370 − Me), 310 (40, 370 − HCO_2Me), 295 (42, 310 − Me), 241 (35), 83 (81); and (ii) a mixture consisting of several components (50 mg) which was further purified by PLC to give a single diastereoisomer of methyl 15ζ,17ζ-dihydroxy-12-methoxy-4α,17ζ-dimethyl-16-oxo-18-nor-5α-androsta-8,11,13-triene-4β-carboxylate (**27**) (8 mg, 5%) as a clear oil (Found: $M^{+\cdot}$, 402.2042. $C_{23}H_{30}O_6$ calcd.: M, 402.2042). ν_{max} 3444 (OH), 1758 (ketone CO), 1722 cm^{-1} (ester CO). δ(H) (ppm) 1.05, s, $H(19)_3$; 1.09, txd, J 13.5, 4.3 Hz, H(3ax); 1.28, s, (4-Me); 1.42, txd, J 13.2, 3.9 Hz, H(1ax); 1.50, s, (17-Me); 1.53, dxd, J 12.2, 1.3 Hz, H(5); 1.67 (dxp, J 14.3, 3.4 Hz, H(2eq); 1.88, qxd, J 13.0, 5.3 Hz, H(6ax); 2.02, qxt, J 13.9, 3.6 Hz, H(2ax); 2.22–2.32, m, H(1eq), H(3eq), H(6eq); 2.90, dxdxd, J 18.4, 12.5, 6.2 Hz, H(7ax); 2.93, s, OH; 3.24, dxd, J 18.4, 1.3 Hz, H(7eq); 3.40, s, OH; 3.67, s, (4-CO_2Me); 3.93, s, (12-OMe); 4.50, bs, H(15); 7.07, s, H(11). δ(C) (DEPT-135)

(ppm) 19.9, C(2); 20.2, C(6); 22.8, (10-Me); 23.6, (17-Me); 28.4, (4-Me); 28.5, C(7); 37.4, C(3); 39.6, C(1); 51.3, 4-CO_2*Me*; 52.2, C(5); 55.5, (12-OMe); 83.7, C(15); 114.4, C(11). *m/z* 402 (50, $M^{+\cdot}$), 384 (100, $M - H_2O$), 369 (19, 384 − Me), 356 (65, M − OMe − Me), 324 (37), 309 (35), 253 (29).

Reaction of tetracarbonyl(methyl 13-formyl-12-methoxypodocarpa-8,11,13-trien-19-oate-C^{14}, O^{13}*)manganese (6) with ethyne in MeCN*

Reaction of **6** (0.60 g, 1.21 mmol) with Me_3NO (0.14 g, 1.81 mmol) and ethyne (310 kPa) (20 h) gave (i) methyl 13-formyl-12-methoxypodocarpa-8,11,13-trien-19-oate (**3**) (19 mg, 5%); and (ii) a mixture of two diastereoisomers of methyl 17ζ-hydroxy-12-methoxy-4α-methyl-18-nor-5α-androsta-8,11,13,15-tetraene-4β-carboxylate (**10**) (0.41 g, 95%) a portion (0.10 g) of which was purified by PLC to give (a) methyl 12-methoxy-4α-methyl-17-oxo-18-nor-5α-androsta-8,11,13,15-tetraene-4β-carboxylate (**20**) (2 mg, 2%); (b) one diastereoisomer of methyl 17ζ-hydroxy-12-methoxy-4α-methyl-18-nor-5α-androsta-8,11,13,15-tetraene-4β-carboxylate (**10**) (29 mg, 29%) as a clear oil (Found: $M^{+\cdot}$, 356.1973. $C_{22}H_{28}O_4$ calcd.: *M*, 356.1988). ν_{max} 3489 (OH), 1724 (ester CO), 1601, 1562, 1467 cm^{-1} (C=C). δ(H) (ppm) 1.06, s, $H(19)_3$; 1.09, txd, *J* 13.5, 4.2 Hz, H(3ax); 1.29 (s, (4-Me); 1.41, txd, *J* 13.3, 4.0 Hz, H(1ax); 1.54, dxd, *J* 14.2, 3.1 Hz, H(2eq); 1.95, qxd, *J* 13.1, 5.5 Hz, H(6ax); 2.01, qxt, *J* 14.0, 3.6 Hz, H(2ax); 2.20–2.39, m H(1eq), H(3eq), H(6eq); 2.35, s, (17-OH); 2.70, dxdxd, *J* 16.4, 12.8, 6.3 Hz, H(7ax); 2.94, dxdxd, *J* 16.5, 4.8, 1.0 Hz, H(7eq); 3.67, s, (4-CO_2Me); 3.86, s, (12-OMe); 5.35, bs, H(17); 6.39, dxd, *J* 5.6, 1.7 Hz, H(16); 6.68, s, H(11); 6.75, bd, *J* 5.6 Hz, H(15). δ(C) (ppm) 20.0, C(2); 20.6, C(6); 22.9, C(19): 28.1, C(7); 28.5, (4-Me); 37.5, C(3); 39.0, C(10); 39.9, C(1); 44.0, C(4); 51.2, 4-CO_2*Me*; 52.7, C(5); 55.2, (12-OMe); 76.2, C(17); 106.4, C(11); 121.7, C(8); 128.7, C(13); 130.5, C(15); 137.0, C(16); 142.4, C(14); 150.8, C(9); 153.8, C(12); 177.8, 4-*C*O_2Me. *m/z* 356 (100, M^+), 341 (11, M − Me), 281 (53, 341 − HCO_2Me), 215 (11), 174 (54); (c) the other diastereoisomer of methyl 17ζ-hydroxy-12-methoxy-4α-methyl-18-nor-5α-androsta-8,11,13,15-tetraene-4β-carboxylate (**10**) (62 mg, 62%) as a clear oil (Found: $M^{+\cdot}$, 356.1979. $C_{22}H_{28}O_4$ calcd.: *M*, 356.1988). ν_{max} 3480 (OH), 1723 (ester CO), 1601, 1652, 1467 cm^{-1} (C=C). δ(H) (ppm) 1.06, s, $H(19)_3$; 1.08, txd, *J* 13.5, 4.2 Hz, H(3ax); 1.28, s, (4-Me); 1.41, txd, *J* 13.4, 4.0 Hz, H(1ax); 1.52, dxd, *J* 12.3, 1.1 Hz, H(5); 1.63, dxp, *J* 14.2, 3.0 Hz, H(2eq); 1.96, qxd, *J* 13.2, 5.5 Hz, H(6ax); 2.01, qxt, *J* 13.9, 3.6 Hz, H(2ax); 2.20–2.30, m, H(1eq), H(3eq), H(6eq); 2.45, s, (17-OH); 2.61, dxdxd, *J* 16.4, 12.8, 6.3 Hz, H(7ax); 2.91, dxdxd, *J* 16.5, 4.2, 1.0 Hz, H(7eq); 3.67, s, (4-CO_2Me); 3.86, s, (12-OMe); 5.33, bs, H(17); 6.38, dxd, *J* 5.6, 1.7 Hz, H(16); 6.67, s, H(11); 6.75, bd, *J* 5.6 Hz, H(15). δ(C) (ppm) 20.0, C(2); 20.6, C(6); 22.9, C(19): 27.8, C(7); 28.5, (4-Me); 37.5, C(3); 39.0, C(10); 39.9, C(1); 44.0, C(4); 51.2, 4-CO_2*Me*; 52.6, C(5); 55.2, (12-OMe); 76.2, C(17); 106.3, C(11); 121.6, C(8); 128.7, C(13); 130.4, C(15); 137.0, C(16); 142.2, C(14); 150.7, C(9); 153.8, C(12); 177.8, 4-*C*O_2Me. *m/z* 356 (100, M^+), 341 (10, M − Me), 281 (54, 341 − HCO_2Me), 215 (10), 174 (58), 69 (23), 55 (25); and (d) methyl 12-methoxy-4α-methyl-17-oxo-18-nor-5α-androsta-8,11,13-triene-4β-carboxylate (**29**) (6 mg, 6%) which crystallized from Et_2O as globular crystals, m.p. 110–111°C (Found: C, 73.2; H, 8.2. $C_{22}H_{28}O_4 \cdot \frac{1}{2}C_5H_{10}O$ calcd.: C, 73.3; H, 8.5%) (Found: $M^{+\cdot}$, 356.1976. $C_{22}H_{28}O_4$ calcd.: *M*, 356.1988). ν_{max} 1722 (ester CO), 1704 (ketone CO), 1602, 1585, 1482, 1464 cm^{-1} (C=C). δ(H) (ppm) 1.07, s, $H(19)_3$; 1.08, txd, *J* 13.6, 4.2 Hz, H(3ax); 1.29, s, (4-Me); 1.40, txd, *J* 13.3, 4.0 Hz, H(1ax); 1.53,

dxd, *J* 12.3, 1.5 Hz, H(5); 1.65, dxp, *J* 14.2, 2.9 Hz, H(2eq); 1.97, qxd, *J* 12.8, 5.6 Hz, H(6ax); 2.01, qxt, *J* 13.9, 3.7 Hz, H(2ax); 2.22–2.30, m, H(1eq), H(3eq), H(6eq); 2.54, dxdxd, *J* 16.9, 12.6, 6.4 Hz, H(7ax); 2.62–2.65, m, $H(16)_2$; 2.77, bdxd, *J* 17.1, 4.6 Hz, H(7eq); 2.90, dxd, *J* 17.4, 6.0 Hz, H(15); 2.76–2.83, m, H(15); 3.67, s, (4-CO_2Me); 3.89, s, (12-OMe); 6.70, s, H(11). δ(C) (ppm) 19.9, C(2); 20.3, C(6); 22.5, C(19); 24.5, C(16); 28.3, C(7); 28.5, (4-Me); 36.9, C(15); 37.4, C(3); 39.5, C(10), C(1); 44.0, C(4); 51.3, 4-CO_2*Me*; 52.2, C(5); 55.0, (12-OMe); 106.3, C(11); 123.1, 124.9, C(8), C(13); 155.8, 156.8, 157.0, C(9), C(12), C(14); 177.6, (4-*C*O_2Me); 204.7, C(17). *m/z* 356 (100, M^+), 341 (4, M – Me), 327 (33, $M - CH_2CH_2 - H$), 281 (47, 341 – HCO_2Me), 263 (10), 215 (11), 55 (14).

A solution of a mixture of the diastereoisomeric alcohols **10** (0.18 g, 0.49 mmol) in dichloromethane (10 mL) was treated with a solution of pyridinium chlorochromate (0.21 g, 0.98 mmol) in dichloromethane (10 mL) at room temperature for 3.5 h. Work-up and PLC gave (i) methyl 12-methoxy-4α-methyl-17-oxo-18-nor-5α-androsta-8,11,13,15-tetraene-4β-carboxylate (**20**) (37 mg, 21%) as a yellow oil (Kugelrohr, 200–220°C/0.1 mmHg) (Found: M^+, 354.1835. $C_{22}H_{26}O_4$ calcd.: *M*, 354.1831). ν_{max} 1723 (ester CO), 1704 (ketone CO), 1585, 1464 cm^{-1} (C=C). δ(H) (ppm) 1.05, s, $H(19)_3$; 1.09, txd, *J* 13.5, 4.0 Hz, H(3ax); 1.29, s, (4-Me); 1.43, txd, *J* 13.3, 4.0 Hz, H(1ax); 1.51, dxd, *J* 12.3, 1.5 Hz, H(5); 1.65, dxp, *J* 14.2, 2.9 Hz, H(2eq); 1.94, qxd, *J* 13.0, 5.5 Hz, H(6ax); 2.00, qxt, *J* 13.9, 3.6 Hz, H(2ax); 2.17–2.30, m, H(1eq), H(3eq), H(6eq); 2.59, dxdxd, *J* 16.7, 12.8, 6.4 Hz, H(7ax); 2.93, dxdxd, *J* 16.6, 5.3, 1.4 Hz, H(7eq); 3.67, s, (4-CO_2Me); 3.90, s, (12-OMe); 5.79, d, *J* 6.0 Hz, H(16); 6.72, s, H(11); 7.50, d, *J* 6.0 Hz, H(15). δ(C) (ppm) 19.9, C(2); 20.3, C(6); 22.8, C(19); 26.9, C(7); 28.5, (4-Me); 37.4, C(3); 39.6, C(1), C(10); 44.0, C(4); 51.4, 4-CO_2*Me*; 52.1, C(5); 55.9, (12-OMe); 111.6, C(11); 113.0, C(13); 123.32, C(8); 127.3, C(16); 144.8, C(14); 145.2, C(15); 154.8, C(9); 158.2, C(12); 177.6, 4-*C*O_2Me; 196.9, C(17). *m/z* 354 (47, M^+), 279 (39, M – Me – HCO_2Me), 197 (22), 159 (44), 83 (60), 43 (100); and (ii) a mixture (1 : 1) which was tentatively assigned as the two diastereoisomers of methyl [5a*R*-(3ζ,5α,9aβ)]-3-hydroxy-11-methoxy-6,9a-dimethyl-4,5,5a,6,7,8,9,9a-octahydrophenanthro[1,2-*c*]furan-1(1*H*)-one-6-carboxylate (**31**) (42 mg, 24%) as a pale yellow oil which decomposed rapidly on standing (Found: M^+, 374.1736. $C_{21}H_{26}O_6$ calcd.: *M*, 374.1729). ν_{max} 3418 (OH), 1768, 1749 (lactone CO), 1724 (ester CO), 1620, 1598, 1488, 1462 cm^{-1} (C=C). δ(H) (ppm) 1.04, 1.07, s, (9a-Me), (9a-Me′); 1.29 (s, (6-Me), (6-Me′); 3.67, s, (6-CO_2Me), (6-CO_2Me′); 3.92, s, (11-OMe), (11-OMe′); 4.12, 4.19, bs, (3-OH), (3-OH′); 6.43, 6.47, bs, H(3), H(3)′; 6.89, s, H(10), H(10)′. δ(C) (DEPT-135) (ppm) 19.8, C(8), C(8)′; 20.1, C(5), C(5)′; 22.7, 22.8, (ga-Me), (9a-Me′); 25.7, 27.3, C(4), C(4)′; 28.4, (6-Me′); 37.3, C(7), C(7)′; 39.5, C(9), C(9)′; 51.37, 51.42, 6-CO_2*Me*, 6-CO_2*Me*′; 51.9, 52.1, C(5a), C(5a)′; 55.9, (11-OMe), (11-OMe′); 95.9, C(3), C(3)′; 110.3, C(10), C(10)′. *m/z* 374 (100, M^+), 356 (23, $M - H_2O$), 341 (33, 356 – Me), 299 (60, M – Me – HCO_2Me), 255 (20), 129 (27).

Reaction of tetracarbonyl(methyl 12-methoxy-7-oxopodocarpa-8,11,13-trien-19-oate-C^{14}, O^7*)manganese (21)*

(i) with diphenylacetylene in MeCN. Reaction of **21** (0.15 g, 0.31 mmol) with Me_3NO (35 mg, 0.47 mmol) and diphenylacetylene (0.11 g, 0.62 mmol) (27.5 h) gave (i) diphenylacetylene (55 mg); (ii) (*E*)-1,2-diphenyl-1-[14-(methyl 12-methoxy-7-oxopodocarpa-8,11,13-trien-19-oate)]ethene (**23**) (8 mg, 5%) as an oily white solid

which could not be recrystallized, m.p. 110–157°C (Found: $M^{+\cdot}$, 494.2447. $C_{33}H_{34}O_4$ calcd.: M, 494.2457). ν_{max} 1723 (ester CO), 1674 (ketone CO), 1590 cm^{-1} (C=C). δ(H) (ppm) 1.08, s, $H(20)_3$; 1.10, txd, J 13.4, 3.8 Hz, H(3ax); 1.17, s, $H(18)_3$; 1.56, txd, J 13.2, 3.9 Hz, H(1ax); 1.70, dxp, J 14.2, 3.1 Hz, H(2eq); 1.96, dxd, J 14.0, 4.0 Hz, H(5); 2.02, qxt, J 13.9, 3.5 Hz, H(2ax); 2.26–2.33, m, H(1eq), H(3eq); 2.65, dxd, J 18.0, 3.9 Hz, H(6eq); 3.07, dxd, J 18.0, 14.1 Hz, H(6ax); 3.65, s, (19-OMe); 3.87, s, (12-OMe); 6.52, s, 14-C(Ph)=C*H*Ph; 6.81, d, J 2.5 Hz, H(11); 6.87, d, J 2.5 Hz, H(13); 7.11–8.22, m, 10H, *aromatic*-H. m/z 494 (27, M^+), 476 (2, $M - H_2O$), 464 (2, $M - CH_2O$), 4.17 (62, M – Ph), 223 (46), 168 (54), 141 (58), 77 (100, Ph^+); (iii) methyl 14-benzoyl-12-methoxy-7-oxopodocarpa-8,11,13-trien-19-oate (**24**) (16 mg, 12%) as a clear oil (Kugelrohr, 195°C/0.1 mmHg) (Found: C, 74.3; H, 6.4. $C_{26}H_{28}O_5$ calcd.: C, 74.3; H, 6.7%). ν_{max} 1720 (ester CO), 1669 cm^{-1} (ketone CO). δ(H) (ppm) 1.14, s, $H(20)_3$; 1.15, txd, J 13.6, 4.0 Hz, H(3ax); 1.21, s, $H(18)_3$; 1.58, txd, J 13.4, 4.0 Hz, H(1ax); 1.74, dxp, J 14.4, 3.1 Hz, H(2eq); 2.03, qxt, J 13.9, 3.4 Hz, H(2ax); 2.06, dxd, J 14.3, 4.7 Hz, H(5); 2.32, bd, J 13.9 Hz, H(3eq); 2.36, bd, J 13.2 Hz, H(1eq); 2.82, dxd, J 18.1, 3.2 Hz, H(6eq); 3.12, dxd, J 18.1, 14.5 Hz, H(6ax); 3.68, s, (19-OMe); 3.85, s, (12-OMe); 6.68, d, J 2.2 Hz, H(11); 6.99, J 2.3 Hz, H(13); 7.40, t, J 7.8 Hz, (*meta*-$H)_2$; 7.51, t, J 7.5 Hz, *para*-H; 7.74, d, J 7.7 Hz, (*ortho*-$H)_2$. δ(C) (ppm) 19.6, C(2): 21.5, C(20); 27.8, C(18); 37.0, C(6); 37.3, C(3); 38.5, C(1); 39.0, C(10); 43.9, C(4); 49.7, C(5); 51.6, (19-OMe); 55.6, (12-OMe); 110.6, 111.3, C(11), C(13); 122.9, C(8); 128.4, (*meta*-$C)_2$; 128.8, (*ortho*-$C)_2$; 132.6, *para*-C; 137.0, *ipso*-C; 144.6, C(14); 157.7, C(9); 163.6, C(12); 176.9, C(19); 196.3, 197.8, C(7), 14-*C*OPh. m/z 420 (100, M^+), 405 (4, M – Me), 391 (66), 361 (10, $M - CO_2Me$), 343 (40), 283 (34), 252 (30), 227 (35), 105 (82, COPh); and (iv) methyl 12-methoxypodocarpa-8,11,13-trien-19-oate (**22**) (52 mg, 53%). Also isolated were a number of smaller unidentified fractions.

(ii) with bis(trimethylsilyl)acetylene in MeCN. Reaction of **21** (0.20 g, 0.42 mmol) with Me_3NO (47 mg, 0.62 mmol) and bis(trimethylsilyl)acetylene (0.19 ml, 0.83 mmol) gave **22** (0.11 g, 82%).

Reaction with ethyne gave no identifiable products.

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