Bioactive Compounds with Added Value Prepared from Terpenes Contained in Solid Wastes from the Olive Oil Industry

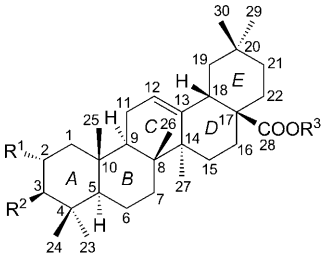
by **Andres Parra***, **Pilar E. Lopez**, and **Andres Garcia-Granados**

Departamento de Quimica Organica, Facultad de Ciencias, Universidad de Granada, ES-18071 Granada (phone: +34-958-240480; e-mail: aparra@ugr.es)

Starting from solid wastes from two-phase olive-oil extraction, the pentacyclic triterpenes oleanolic acid and maslinic acid were isolated. These natural compounds were transformed into methyl olean-12-en-28-oate (**5**), which then was transformed into several *seco-C*-ring triterpene compounds by chemical and photolytic modifications. The triene *seco*-products were fragmented through several oxidative procedures to produce, simultaneously, *cis*- and *trans*-decalin derivatives, both potential synthons for bioactive compounds. The chemical behavior of the isolated fragments was investigated, and a suitable approach to several low-molecular-weight terpenes was performed. These are interesting processes for the value-addition to solid waste from the olive-oil industry.

Introduction. – The olive-oil industry produces a large volume of wastes, both solid and liquid, which represents a disposal and potentially enviromental pollution problem. In fact, olive-oil waste has always been one of the biggest problems associated with this industry. However, these residues are promising sources in which potentially interesting compounds remain, such as phenolic compounds (tyrosol, hydroxytyrosol, and oleuropein), oligosaccharides, mannitol, and two known triterpene acids (oleanolic acid and maslinic acid), which can be converted into value-added products. Thus, in our case, the starting vegetal material was the waste product from a two-phase olive-oil industrial process containing both liquid and solid wastes. This natural starting material is a renewable source of available triterpenes that can serve to produce chiral intermediates and other compounds for flavors, fragrances, pharmaceutical products, and biocontrol agents. The isolated triterpene compounds are oleanolic acid (3β-hydroxyolean-12-en-28-oic acid; **1**) and maslinic acid (2α,3β-dihydroxyolean-12-en-28-oic acid; **2**) (*Fig.*), two natural pentacyclic triterpenoids widely distributed in nature [1]. Both acids and several closely related products exhibit a wide range of biological activities, and some may find application in medicine [2–4]. A method to obtain large quantities of both triterpene acids from olive-mill wastes has been reported by our group [5], and these compounds could be useful to semi-synthesize other biologically or chemically significant products. In fact, oleanenes possess a 4,4,10-trimethyl-substituted *trans*-decalin system with the H-atom at C(9) in an α-position (*A*- and *B*-rings), such as drimane sesquiterpenes or related compounds with remarkable biological, olfactory, and fixative properties [6–8]. Moreover, the bicyclic system formed by the *D*- and *E*-rings is related to naturally occurring tricyclic triterpenes such as camelliols A and B [9], and other bicyclic and tetracyclic triterpenes (preoleanate-traene and *seco-C*-oleanene, resp.) [10]. Therefore, this kind of products could be

useful as starting materials for affording simultaneously remarkable *cis*- and *trans*-decalin-type chiral synthons, vigorously sought by the scientific community [11][12]. On the other hand, the degradation of high-molecular-weight terpene compounds has frequently been regarded as an efficient way to access suitable molecular fragments for the synthesis of sesquiterpene compounds [13][14]. For example, *Ambrox*® has been synthesized by degradation from natural occurring labdanes such as labdanoic acid, sclareol, manool, manoyl oxide, and larixol.



	R^1	R^2	R^3
Oleanoic acid (**1**)	H	OH	H
Maslinic acid (**2**)	OH	OH	H
Methyl oleanoate (**3**)	H	OH	Me
Methyl maslinate (**4**)	OH	OH	Me
Methyl 12-oleanen-28-oate (**5**)	H	H	Me

Figure. *Structures of compounds* **1**–**5**

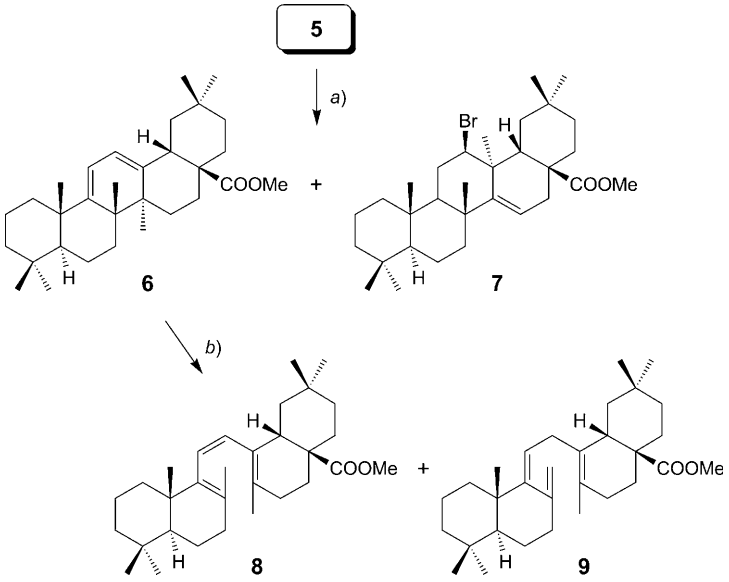
Recently, our research group has reported the solution- and solid-phase synthesis of several maslinic acid derivatives containing amino acids and peptides, which possess potent anti-HIV activity [15]. We have also described the remote hydroxylation of the Me(23) and Me(24) groups of these natural triterpene compounds by a regioselective cyclopalladation process yielding other natural compounds with potentially interesting biological activities [16]. In addition, we have reported an initial study of the formation of several derivatives from oleanolic acid and maslinic acid with a cleaved *C*-ring [17–19]. Moreover, deoxygenation of ring *A* of both acids through different methods has been described [20][21], and thus, starting from methyl oleanoate (**3**) or methyl maslinate (**4**), methyl olean-12-en-28-oate (**5**) was obtained.

Here, we report on the process of obtaining different trienes from methyl olean-12-en-28-oate (**5**) by an efficient reaction sequence including photochemical and chemical isomerization reactions. In addition, we present partial syntheses of several drimane-related fragments obtained from different oxidative cleavages of the C=C bonds situated in the opened *C* ring of the above-mentioned oleantrienes. In summary, triterpene compound **5**, deoxygenated in ring *A*, was used as a starting material to yield simultaneously *trans*- and *cis*-decalin compounds without OH substituents at the rings. Moreover, we describe the reactivity of the resulting *cis*- and *trans*-decalin fragments, as well as the decarboxylation of a monocyclic synthon originating from the ring *A* of the triterpene skeleton.

Results and Discussion. – 1. *Cleavage of the Original Triterpene Molecule at the C(8)–C(14) Bond.* The aim was to fragment the above-mentioned pentacyclic triterpenes through the *C*-ring. In a first step, a diene system was formed in this ring by treatment of product **5** with NBS/AIBN in CCl_4. Thus, by a one-step bromination/dehydrobromination process, compound **6**, with a conjugated C=C bond between C(9) and C(11), was obtained. Additionally, a minor product, **7**, was isolated, with a Me group migrated from C(14) to C(13) with retention of the orientation of the Me group,

with a C(14)=C(15) bond, and with a Br-substituent at C(12) (*Scheme 1*, path *a*). In the second step, the opening of the *C*-ring of homodiene **6** was achieved by irradiation with a high-pressure Hg street lamp in a borosilicate flask, yielding triene **8** by a conrotatory photochemical electrocyclic reaction which permitted the cleavage of the C(8)–C(14) bond (*Scheme 1*, path *b*). With an extra time of 20 min, the exocyclic triene **9** appeared, which has two conjugated C=C bonds between C(8) and C(26) and between C(9) and C(11), and additionally an isolated C=C bond between C(13) and C(14). These processes were based on previously known photochemical interconversions of provitamin D2, lumisterol, previtamin D2, tachysterol, and some derivatives, in addition to photochemical and thermal transformations of some pentacyclic triterpenoids, such as methyl dehydroursolate [22].

Scheme 1. *Synthesis of Trienes* **8** *and* **9**

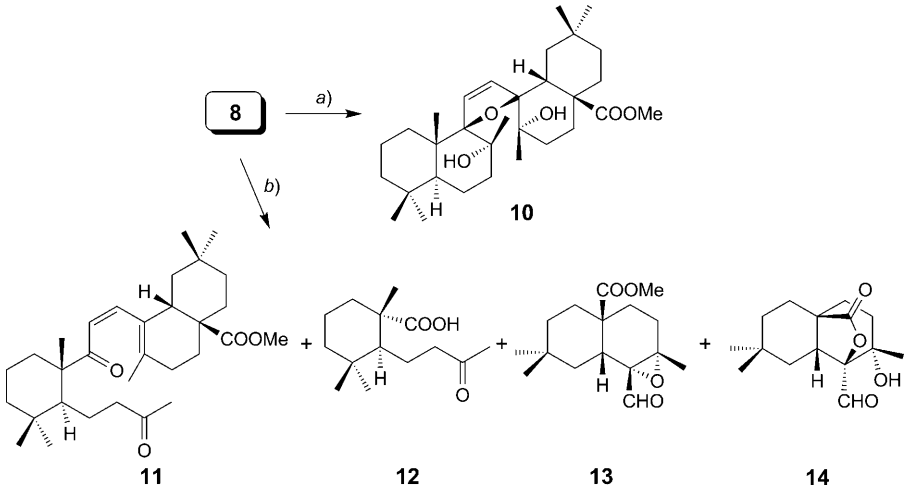


a) *N*-Bromosuccinimide (NBS), 2,2′-azobis(isobutyronitrile) (AIBN), CCl_4, reflux, 15 min; **6** (83%) and **7** (10%). *b*) *hν*, EtOH, r.t.

2. *Oxidative Treatment and Isomerization of* cis-*Triene* **8**. In an attempt to cleave the triterpene molecule at the *seco-C*-ring, triene **8** was treated with $NaIO_4/RuCl_3$ in acetone/H_2O, giving the cyclic ether **10** in a good yield (80%) (*Scheme 2*, path *a*); however, the C(11)=C(12) bond was not affected. With the same aim, ozonolysis of **8** was performed (*Scheme 2*, path *b*). A complex mixture of products was obtained from several breakups and oxidations of the different C=C bonds. Several low-molecular-weight products were obtained, indicating that the C(11)=C(12) bond had been cleaved. Compound **11** resulted from the reaction of the C(8)=C(9) bond with ozone, forming two CO groups at C(8) and C(9), while the other C=C bonds remained unaltered, yielding a triterpene molecule with open *B*- and *C*-rings. In compound **12**, ozonolysis cleaved the C(11)=C(12) bond, but in addition, also the C(8)=C(9) bond,

providing a monocyclic fragment, with only the *A*-ring unaffected. Compounds **13** and **14**, fragments containing the *D*- and *E*-rings of the former triterpene, were the result of the fragmentation at the C(11)=C(12) bond, which yielded the *cis*-decalin intermediates, which had been one of the aims of the fragmentation of the triterpene molecule. Compound **14** contains a γ-lactone ring and was formed from **13**. After ester hydrolysis, the oxirane was intramolecularily opened by the acid group.

Scheme 2. *Oxidation of* cis-*Triene* **8**



a) $RuCl_3$, $NaIO_4$, acetone, H_2O, r.t., 30 min, 80%. *b*) 1. O_3, AcOEt, $-78°$, 7 min; 2. Me_2S, r.t., 1 h; **11** (12%), **12** (22%), **13** (25%), and **14** (14%).

Therefore, to minimize undesirable oxidative cleavage, we protected triene **8** by previous epoxidation with *m*-chloroperbenzoic acid (MCPBA) under different reaction conditions (*Scheme 3*, *Table*). At low temperature ($-60°$), only product **15** was formed by epoxidation at the C(8)=C(9) bond on the α face. At $-40°$, the yield of epoxide **15** decreased, and compounds **16**–**19** were obtained in different yields depending on the reaction time. Compounds **16** and **17** had, as **15**, an epoxy group on the α face at C(8)–C(9); however, while **16** had a new oxirane group also on the α face at C(13)–C(14), in product **17**, this group had the opposite configuration. Product **18** was epoxidized at C(8)–C(9) on the α face, and a lactone system was formed between C(28) and C(13). This compound was the result of the attack of the hydrolized methoxycarbonyl group at C(28) at the C(13) position of the epoxide in compound **16**. This intramolecular reaction led to a compound with an α-OH group at C(14) and a lactone ring between C(13) and C(28). In turn, compound **19** had an epoxy group at C(8)–C(9) on the α face and two OH groups at C(13) and C(14). At room temperature, product **20** was obtained in addition to the other compounds. This compound had a structure similar to the cyclic ether **10**, but in **20**, the OH group at C(8) was eliminated, and a C(7)=C(8) bond was formed. Ozonolysis of the monoepoxy derivative **15** furnished products **19** and **20**, with the central C=C bond unaltered. Thus, although these epoxy and OH triterpene derivatives seemed to be suitable for the

cleavage at the *seco-C*-ring because they only had one central C=C bond, attempts to break up this ring under different conditions were unsuccessful, and the compounds were recovered unaltered after oxidative treatment.

Scheme 3. *Epoxidation of* cis-*Triene* **8**

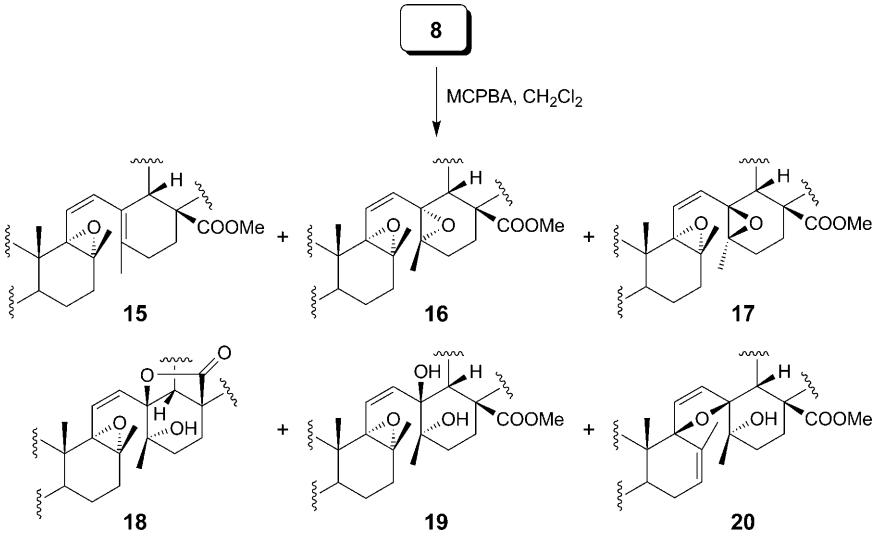
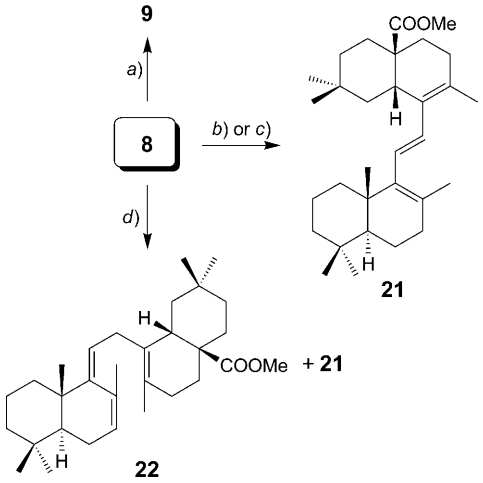


Table. *Epoxidation Yields of Triene* **8** *at Different Temperatures and Times*

Temp. [°]	Time [h]	Yield [%]						
		8	**15**	**16**	**17**	**18**	**19**	**20**
–60	24	40	55	–	–	–	–	–
–60	48	10	82	–	–	–	–	–
–40	3	–	60	16	8	6	–	–
–40	5	–	42	10	18	10	8	–
–40	12	–	31	8	20	15	4	–
r.t.	2	–	10	3	20	25	2	10

In addition, since oxidation reactions carried out using several compounds with the central C=C bond in (*Z*)-disposition did not allow the cleavage of the triterpene skeleton, triene **8** was subjected to several chemical and photolytic isomerizations (*Scheme 4*). First, irradiation of triene **8** in a quartz flask for 1 h yielded exocyclic triene **9** (*Scheme 4*, path *a*), already produced previously as a by-product in the formation of **8** (*Scheme 1*, path *b*). On the other hand, chemical isomerization of *cis*-triene **8** to *trans*-triene **21** was performed by treatment with I_2 in hexane (65%) or with TFA in toluene (95%). However, when *cis*-triene **8** was treated with TFA in CH_2Cl_2, a new triene, **22** with two conjugated C=C bonds between C(7) and C(8) and between C(9) and C(11) and another one in the original C(13)=C(14) position, was obtained in high yield (80%).

Scheme 4. *Isomerization of* cis-*Triene* **8**



a) *hv*, EtOH, r.t., quartz flask, 1 h, 95%. *b*) I_2, hexane, reflux, 5 h, 65%. *c*) CF_3COOH (TFA), toluene, reflux, 3.5 h, 95%. *d*) TFA, CH_2Cl_2, reflux, 5 h; **21** (15%) and **22** (80%).

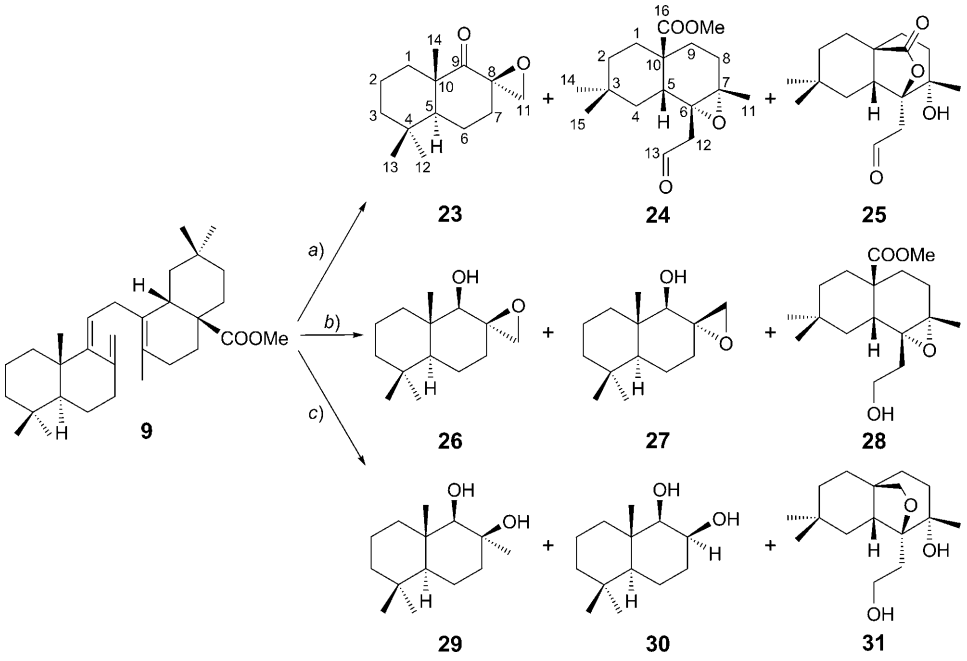
3. *Oxidative Treatment of* exo-*Triene* **9** *and* trans-*Triene* **21**. The *seco-C*-ring triterpene compounds **9** and **21** were independently treated with different oxidazing reagents. Thus, ozonolysis of triene **9** in AcOEt led to the cleavage of the C(9)=C(11) bond, resulting in a mixture of three fragments (*Scheme 5*, path *a*; products **23**–**25**). Compound **23**, a ketoepoxy synthon from the *A*- and *B*-rings, had a C_{14} skeleton and is an adequate precursor for the synthesis of drimane and related compounds. The other compounds obtained, **24** [18] and **25**, presented a C_{16} skeleton from the *D*- and *E*-rings of the triterpene skeleton.

When the ozonolysis was followed by reduction with $NaBH_4$, a complex mixture of products was formed (*Scheme 5*, path *b*; compounds **26**–**28**). Two of these, compounds **26** and **27**, had the *A*- and *B*-rings of the starting molecule and differed only in the configuration of the epoxy group between C(8) and C(11). On the other hand, compound **28** was similar to compound **24**, but the aldehyde at C(13) was reduced to an alcohol.

Finally, ozonolysis of compound **9** followed by reduction with $LiAlH_4$ (*Scheme 5*, path *c*), gave compounds **29**–**31**, thereof, **31** was the major product and a fragment from the *D*- and *E*-rings with a cyclic ether between C(16) and C(6). Compounds **29** and **30** were also obtained as a result of the C(9)=C(11) bond rupture and subsequent reduction of the formed keto and epoxy groups at C(9) and C(8), respectively.

On the other hand, ozonolysis of triene **21** gave better yields of compounds **12** and **13** (*Scheme 6*), products previously obtained by similar treatment of product **8** (*Scheme 2*). Treatment of compound **21** with $RuCl_3/NaIO_4$ in acetone/H_2O at room temperature for 30 min gave a mixture of two aldehyde sesquiterpenes (**32** and **33**, [18]), one of which, drim-8-en-11-al (**32**), has been used as an appropriate synthon to produce other remarkable drimane-related compounds [23][24].

Scheme 5. *Ozonolysis of* exo-*Triene* **9**

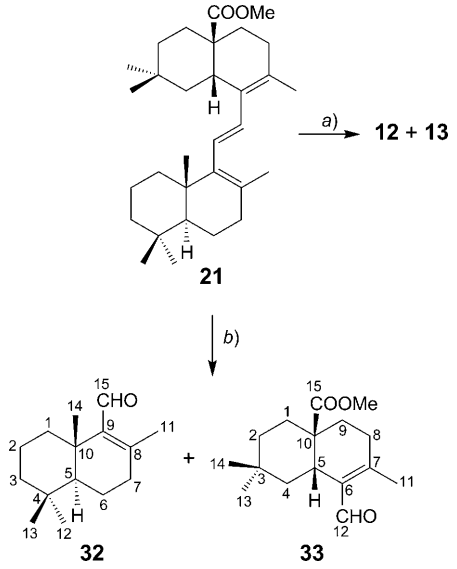


a) 1. O_3, AcOEt, −78°, 2 min; 2. Me_2S, r.t., 12 h; **23** (24%), **24** (32%), and **25** (16%). *b*) 1. O_3, AcOEt, −78°, 5 min; 2. $NaBH_4$, i-PrOH, r.t., 2 h; **26** (22%), **27** (9%), and **28** (36%). *c*) 1. O_3, AcOEt, −78°, 5 min; 2. $LiAlH_4$, THF, reflux, 1 h; **29** (20%), **30** (8%), and **31** (25%).

4. *Reactivity of Fragments* **12**, **32**, *and* **33**: *Partial Syntheses of* Ambrox® *and* cis-*Decalin Synthons.* Decarboxylation of compound **12**, originating from the *A*-ring of the original triterpene, was investigated using two methods, because some feasible products are interesting synthons related to mono- and tricyclic triterpenes such as elengasidiol [25], achilleols A and B [26], camelliol A [9], mokupalide [27], and other important compounds such as (+)-(4*R*)-manoalide [28], (−)-*Ambrox*® [29], and ambrinol [30]. Thus, treatment of compound **12** with $Pb(OAc)_4$ [31] gave a complex mixture of alkenes (**34**–**36**) [32] and the acetylated derivative **37** (14%) (*Scheme 7*, path *a*). When *Barton*'s decarboxylation protocol [33] was used on the previously synthesized acid chloride, only exocyclic alkene **34** and a thioether, **38**, were obtained. Oxidation and heating of compound **38** led to product **34** as the sole product.

The reactivity of the *trans*-decalin **32** was also studied (*Scheme 8*). Thus, reduction of compound **32** with $NaBH_4$ in i-PrOH for 2 h led to product **39**, which can be used to semisynthesize warburganal [34][35] and (−)-*Ambrox*® [36][37]. Therefore, compound **39** was treated with TsCl in pyridine to convert the OH group into a good leaving group, but under these reaction conditions, only the conjugated diene **40** [14] was obtained through elimination. Therefore, to carry out a S_N reaction on the OH group, the trifluoroacetate **41** was formed, but its treatment with KCN led to product **40** again. However, when trifluoroacetate **41** was treated with $Me_3SiCN/BF_3 \cdot Et_2O$ in CH_2Cl_2 at

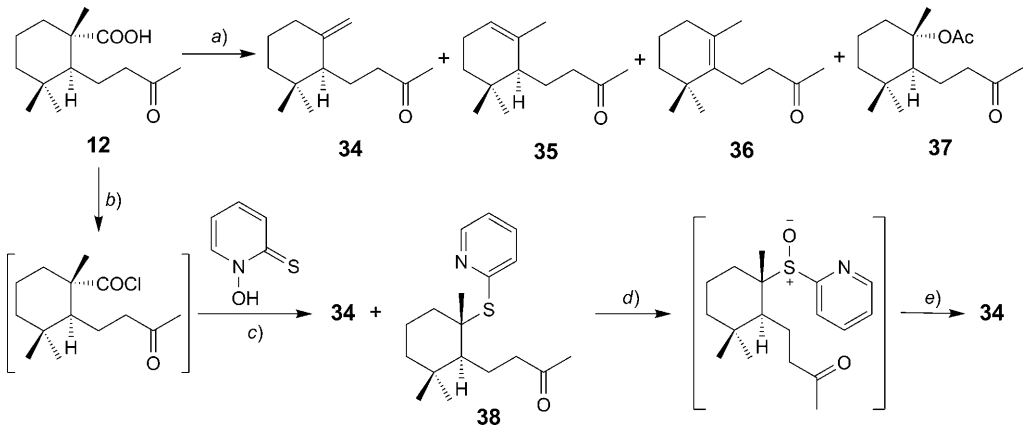
Scheme 6. *Oxidative Cleavage of* trans-*Triene* **21**



a) 1. O_3, AcOEt, $-78°$, 2 min; 2. Me_2S, r.t., 12 h; **12** (28%) and **13** (41%). *b*) $RuCl_3$, $NaIO_4$, acetone, H_2O, r.t., 30 min; **32** (32%) and **33** (42%).

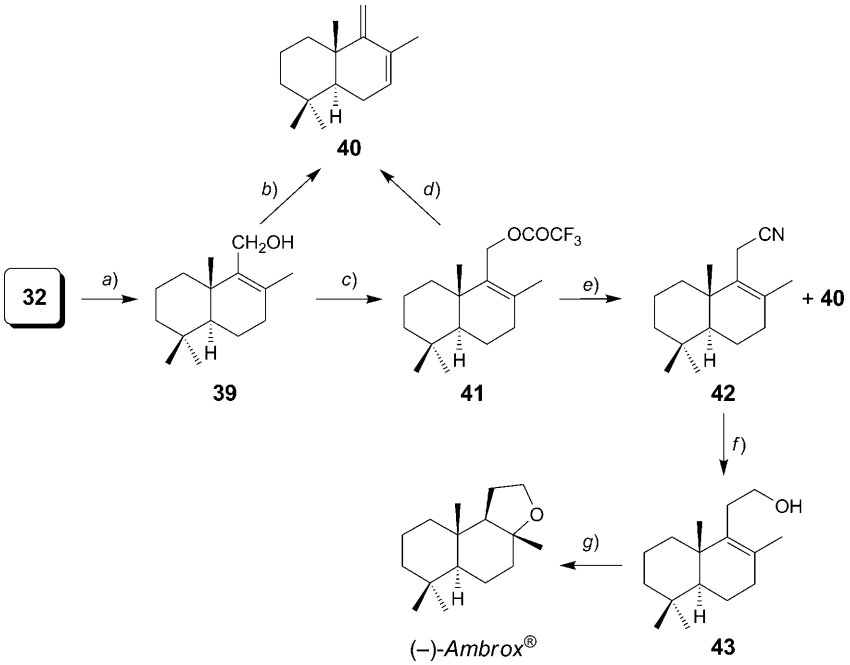
$-10°$ the desired cyano derivative **42** and the diene **40** were obtained. Treatment of the nitrile compound **42** with DIBALH followed by reduction with $NaBH_4$ rendered product **43** [38], which was cyclized under acidic conditions to (−)-*Ambrox*® [39].

Scheme 7. *Decarboxylation of Fragment* **12**



a) $Pb(OAc)_4$, $Cu(OAc)_2$, benzene/pyridine 3:1, reflux, 2 h; **34** (33%), **35** (22%), **36** (11%), and **37** (14%). *b*) $(COCl)_2$, CH_2Cl_2, r.t., 12 h. *c*) Pyridine-2-thiol *N*-oxide, pyridine, 4-(dimethylamino)pyridine (DMAP), benzene, reflux, 2 h; **34** (12%), **38** (24%). *d*) MCPBA, CH_2Cl_2, $-80°$, 3 h. *e*) Δ, 80 %.

Scheme 8. *Reactions of Fragment* **32**

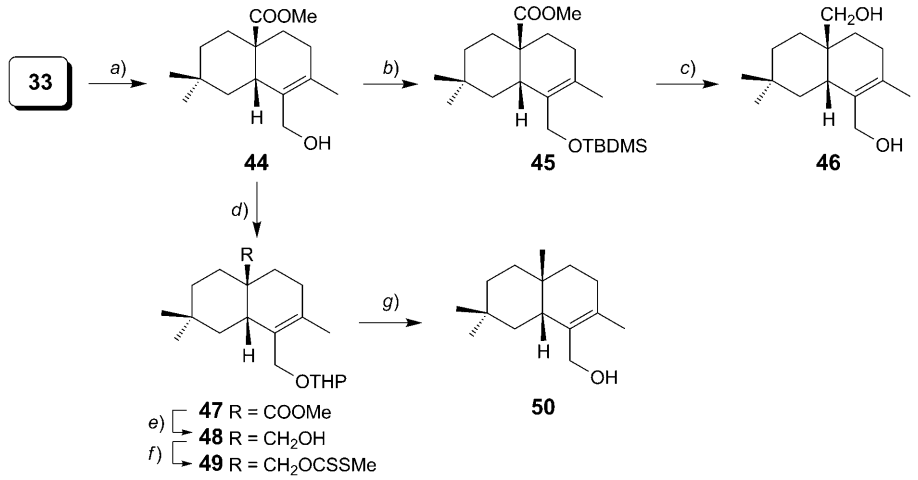


a) $NaBH_4$, i-PrOH, r.t., 2 h, 94%. *b*) TsCl, pyridine, r.t., 1 h, 72%. *c*) $(CF_3CO)_2O$, CH_2Cl_2/pyridine 3:1, −20°, 3 h, 99%. *d*) KCN, 130°, 3 h, 69%. *e*) $Me_3SiCN/BF_3 \cdot Et_2O$, CH_2Cl_2, −10°, 1 h; **40** (23%) and **42** (58%). *f*) 1. Diisobutylaluminium hydride (DIBALH), toluene, −78°, 1.5 h; 2. $NaBH_4$, i-PrOH, r.t., 2 h, 78%. *g*) According to [39].

It has been previously commented that the bicyclic *cis*-decalin system derived from the *D*- and *E*-rings is associated with skeletons of irregular triterpenes such as camelliols A and B, as well as other tetracyclic (*seco-C*-oleanane) and bicyclic ones (preoleanatetraene). A synthesis of a common bicyclic precursor for these compounds was developed from compound **33**, which only requires deoxygenation at C(15) (*Scheme 9*). First, compound **33** was treated with $NaBH_4$ in i-PrOH for the selective reduction of the aldehyde of C(12). Then, the new OH group was protected with *tert*-butyldimethylsilane chloride, providing with a good yield the corresponding derivative **45**. The subsequent reduction of the ester group of **45** with $LiAlH_4$ unexpectedly eliminated the protecting group, forming diol **46**. Therefore, a tetrahydropyranyl protecting group was introduced by treatment with DHP/TsOH (intermediate **47**), and reduction of **47** with $LiAlH_4$ in THF at room temperature led to compound **48**. The OH group at C(15) of **48** was eliminated through the xanthate intermediate **49**, which was treated with hypophosphorous acid to reduce the xanthate group and deprotect the OH group and to give the desired final compound **50** [40].

Conclusions. – In summary, with these processes the environmental impact of the solid waste from olive-oil industry is reduced, and several high added value bioactive

Scheme 9. *Reactions of Fragment* **33**



a) $NaBH_4$, i-PrOH, r.t., 3 h, 98%. *b*) (*t*-Bu)Me_2SiCl (TBDMSCl), pyridine, r.t., 12 h, 89%. *c*) $LiAlH_4$, THF, reflux, 1 h, 78%. *d*) 3,4-Dihydro-2*H*-pyran (DHP), TsOH, CH_2Cl_2, r.t., 1.5 h. *e*) $LiAlH_4$, THF, r.t., 3h. *f*) 1. NaH, THF, reflux, 3 h; 2. CS_2, reflux, 30 min; 3. MeI, reflux, 1 h. *g*) H_3PO_2, AIBN, Et_3N, dioxane, reflux, 3 h, 58% (from **44**).

compounds were obtained. Thus, methyl olean-12-en-28-oate (**5**) with several triene systems in the *C*-ring was used as the starting material in different oxidative processes to fragment the triterpene skeleton into several useful *trans*- and *cis*-decalin fragments. In this sense, a homodiene (**6**) in the *C*-ring was formed by a spontaneous bromination/dehydrobromination process, and several *trans*- and *cis*-triene compounds (**8**, **9**, **21**, and **22**) were formed from this ring by chemical and photolytic isomerizations. The treatment of the *cis*-triene **8** with several oxidative agents gave different oxidized triterpene products, but in all of them, the central C=C bond in (*Z*)-disposition was unaffected. Ozonolysis of the exocyclic triene **9** rendered 16-carbon fragments and *nor*-sesquiterpene compounds. In turn, oxidation of the *trans*-triene **21** with $NaIO_4/RuCl_3$ yielded two aldehyde sesquiterpenes by cleavage of the C=C bond of the opened *C*-ring. On the other hand, the reactivity of several sesquiterpene fragments was studied, and a suitable approximation to the synthesis of interesting lower-molecular-weight compounds was performed. Decarboxylation of the monocyclic fragment **12** gave synthons related to mono- and tricyclic triterpenes such as elengasidiol, achilleols A and B, and camelliol A. Moreover, the *trans*-decalin fragment **32**, formed from the *A*- and *B*-rings, was used as appropriate chiral synthon for the semisynthesis of products related to drimane and ambra oxide. Finally, deoxygenation of the *cis*-decalin fragment **33**, from the *D*- and *E*-rings of the original triterpene molecule, afforded a common bicyclic precursor for the skeleton of bicyclic, tetracyclic, and irregular triterpenes.

This work was supported by a grant from the *Comisión Interministerial de Ciencia y Tecnologia* and by a project from the *Ministerio de Educacion y Cultura*. We thank *David Nesbitt* for reviewing the manuscript concerning the English language.

Experimental Part

General. Flash chromatography (FC): silica gel (SiO_2; 40–60 μm); eluents: CH_2Cl_2 or $CHCl_3$, containing increasing amounts of Me_2CO (from 100:1 to 1:1), as well as mixtures of hexane/AcOEt (from 40:1 to 1:1). TLC: SiO_2-coated plates; visualization by spraying with H_2SO_4/AcOH, followed by heating to 120°. M.p.: *Kofler* apparatus; uncorrected. Optical rotations: *Perkin-Elmer 341* polarimeter at 25°. IR Spectra: *Mattson Satellite* FT-IR spectrometer. NMR Spectra (300.13 MHz for ^1H, and 75.47 MHz for ^{13}C): in $CDCl_3$ on a *Bruker AM-300* spectrometer; assignments of ^{13}C chemical shifts by DEPT using a flip angle of 135°; NOE experiments by irradiation for four seconds in series of eight scans. HR-MS: *Micromass Autospec-Q* spectrometer (EBE geometry).

Maslinic Acid (=*(2α,3β)-2,3-Dihydroxyolean-12-en-28-oic Acid*; **2**). Maslinic acid (**2**) was isolated from the solid waste of olive-oil pressing which was extracted in a *Soxhlet* apparatus with AcOEt. It was purified from these mixtures by CC over SiO_2 and transformed with ethereal CH_2N_2 or NaOH/MeI into the corresponding methyl ester which was deoxygenated in the *A*-ring to obtain *methyl olean-12-en-28-oate* (**5**) [18].

Methyl Oleana-9(11),12-dien-28-oate (**6**). Compound **5** (450 mg, 1 mmol) was dissolved in CCl_4 (15 ml), and NBS (212 mg, 1.2 mmol) and a cat. amount of AIBN were added. After 15 min under reflux, the mixture was washed with sat. aq. soln. of $NaHCO_3$ and extracted with CH_2Cl_2. The org. layer was dried (Na_2SO_4), evaporated to dryness, and chromatographed on a SiO_2 column to obtain **6** (370 mg, 83%) and *methyl (4a*S*,6b*R*,8a*S*,12a*S*,14*R*,14a*S*,14b*R*)-14-bromo-1,3,4,5,6b,7,8,8a,9,10,11,12,12a,12b,13,14,14a,14b-octadecahydro-2,2,6b,9,9,12a,14a-heptamethylpicene-4a(2*H*)-carboxylate* (**7**; 53 mg, 10%).

Data of **6**. White solid. M.p. 131–133°. $[\alpha]_D^{20} = +25$ ($c = 1$, $CHCl_3$). IR ($CHCl_3$): 2947, 1728, 1462, 1163. ^1H-NMR (300 MHz, $CDCl_3$): 5.57 (*d*, *J* = 5.9, 1 H), 5.54 (*d*, *J* = 5.9, 1 H); 3.63 (*s*, 3 H); 3.00 (*dd*, *J* = 3.7, 13.7, 1 H); 1.14 (*s*, 3 H); 1.01 (*s*, 3 H); 0.93 (*s*, 3 H); 0.92 (*s*, 3 H); 0.88 (*s*, 3 H); 0.88 (*s*, 3 H); 0.82 (*s*, 3 H). ^{13}C-NMR (75 MHz, $CDCl_3$): 18.6 (CH_2); 19.2 (CH_2); 20.3 (Me); 20.4 (Me); 21.9 (Me); 23.7 (Me); 23.9 (CH_2); 25.1 (Me); 27.0 (CH_2); 30.7 (C); 32.1 (CH_2); 32.3 (CH_2); 33.0 (Me); 33.5 (Me); 33.5 (C); 33.9 (CH_2); 38.9 (CH_2); 39.1 (C); 39.7 (CH); 40.8 (C); 41.6 (CH_2); 42.5 (C); 46.0 (CH_2); 46.2 (C); 51.7 (Me); 51.9 (CH); 115.2 (CH); 120.7 (CH); 144.8 (C); 155.4 (C); 178.3 (C). HR-MS: 452.3655 (M^+, $C_{31}H_{48}O_2^+$; calc. 452.3649).

Data of **7**. Colorless oil. $[\alpha]_D^{20} = +13$ ($c = 1$, $CHCl_3$). IR ($CHCl_3$): 3443, 2947, 1727, 1462, 1163. ^1H-NMR (300 MHz, $CDCl_3$): 5.66 (*dd*, *J* = 3.3, 7.7, 1 H); 4.86 (*dd*, *J* = 9.1, 9.1, 1 H); 3.55 (*s*, 3 H); 2.71 (*dd*, *J* = 6.0, 13.5, 1 H); 1.09 (*s*, 3 H); 0.97 (*s*, 3 H); 0.92 (*s*, 3 H); 0.87 (*s*, 3 H); 0.84 (*s*, 3 H); 0.82 (*s*, 3 H); 0.79 (*s*, 3 H). ^{13}C-NMR (75 MHz, $CDCl_3$): 15.6 (Me); 18.4 (CH_2); 19.1 (CH_2); 20.6 (Me); 21.5 (Me); 25.8 (Me); 27.7 (Me); 29.3 (CH_2); 30.9 (C); 31.9 (CH_2); 32.3 (Me); 32.5 (CH_2); 33.2 (C); 33.3 (CH_2); 34.0 (Me); 37.1 (CH_2); 38.2 (C); 39.5 (CH_2); 39.9 (C); 41.2 (CH); 41.5 (CH_2); 42.0 (CH_2); 43.7 (C); 51.2 (C); 51.6 (Me); 51.6 (CH); 56.6 (CH); 66.7 (CH); 121.3 (CH); 157.9 (C); 178.3 (C). HR-MS: 533.3001 (M^+, $C_{31}H_{49}BrO_2^+$; calc. 533.2910).

*Methyl (11*Z*)-8,14-Secoolea-8,11,13-trien-28-oate* (=*Methyl (4a*S*,8a*S*)-1,3,4,5,6,8a-Hexahydro-2,2,7-trimethyl-8-{(*Z*)-2-[(4a*S*,8a*S*)-3,4,4a,5,6,7,8,8a-octahydro-2,5,5,8a-tetramethylnaphthalen-1-yl]ethenyl}-naphthalene-4a(2*H*)-carboxylate*; **8**). Compound **6** (365 mg, 0.8 mmol) was dissolved in EtOH (70 ml) and irradiated in a borosilicate flask using a 125 W high-pressure Hg street lamp with the outermost glass shell removed. After 30 min, the soln. was evaporated and the residue chromatographed on a SiO_2 column to obtain **8** (175 mg, 46%) and *methyl (4a*S*,8a*S*)-1,3,4,5,6,8a-hexahydro-2,2,7-trimethyl-8-{(2*E*)-2-[(4a*S*,8a*S*)-octahydro-5,5,8a-trimethyl-2-methylidenenaphthalen-1(2*H*)-ylidene]ethyl}naphthalene-4a(2*H*)-carboxylate* (**9**, 137 mg, 38%). Compound **9** could be also obtained from **8** (363 mg, 0.8 mmol) when **8** was dissolved in EtOH (70 ml) and irradiated in a quartz flask using a 125 W high-pressure Hg street lamp with the outermost glass shell removed. After 1 h, the soln. was evaporated and the residue chromatographed on a SiO_2 column to obtain **9** (344 mg, 95%).

Data of **8**. Colorless oil. $[\alpha]_D^{20} = +179$ ($c = 1$, $CHCl_3$). IR ($CHCl_3$): 2945, 1731, 1461, 1249, 1169. ^1H-NMR (300 MHz, $CDCl_3$): 5.97 (*d*, *J* = 12.9, 1 H); 5.83 (*d*, *J* = 12.9, 1 H); 3.61 (*s*, 3 H); 2.79 (*dd*, *J* = 3.6, 12.5, 1 H); 1.49 (*s*, 3 H); 1.25 (*s*, 3 H); 1.01 (*s*, 3 H); 0.89 (*s*, 3 H); 0.89 (*s*, 3 H); 0.86 (*s*, 3 H); 0.85 (*s*, 3 H). ^{13}C-NMR ($CDCl_3$): 19.2 (CH_2); 19.3 (CH_2); 20.9 (Me); 21.6 (Me); 21.8 (Me); 22.0 (Me); 22.8 (CH_2); 25.0 (Me); 29.8 (CH_2); 29.8 (CH_2); 30.8 (C); 32.9 (CH_2); 33.0 (Me); 33.5 (Me); 33.5 (C); 34.1 (CH_2); 37.2

(CH); 38.0 (CH_2); 38.9 (C); 41.8 (CH_2); 43.0 (CH_2); 45.5 (C); 51.5 (CH); 51.7 (Me); 127.7 (CH); 127.7 (C); 129.5 (C); 132.4 (CH); 134.6 (C); 138.8 (C); 178.4 (C). HR-MS: 475.3555 ($[M+Na]^+$, $C_{31}H_{48}NaO_2^+$; calc. 475.3552).

Data of **9**. Colorless oil. $[\alpha]_D^{20} = +42$ ($c=1$, $CHCl_3$). IR ($CHCl_3$): 2949, 1730, 1462, 1253, 1168. ^{1}H-NMR (300 MHz, $CDCl_3$): 4.98 (*d*, *J* = 2.5, 1 H); 4.94 (*dd*, *J* = 4.5, 9.4, 1 H); 4.52 (*d*, *J* = 2.5, 1 H); 3.62 (*s*, 3 H); 1.52 (*s*, 3 H); 0.94 (*s*, 3 H); 0.91 (*s*, 3 H); 0.88 (*s*, 3 H); 0.86 (*s*, 3 H); 0.85 (*s*, 3 H). ^{13}C-NMR (75 MHz, $CDCl_3$): 19.0 (Me); 19.4 (CH_2); 20.7 (Me); 22.1 (Me); 23.1 (CH_2); 23.7 (CH_2); 24.3 (Me); 29.9 (CH_2); 30.6 (CH_2); 30.7 (C); 32.2 (CH_2); 33.0 (Me); 33.6 (Me); 34.0 (C); 34.1 (CH_2); 36.1 (CH); 37.5 (CH_2); 37.6 (CH_2); 40.8 (C); 41.6 (CH_2); 42.6 (CH_2); 45.8 (C); 51.7 (Me); 53.6 (CH); 111.6 (CH_2); 116.7 (CH); 124.9 (C); 133.7 (C); 146.1 (C); 151.8 (C); 178.4 (C). HR-MS: 475.3551 ($[M+Na]^+$, $C_{31}H_{48}NaO_2^+$; calc. 475.3552).

Methyl 8α,14α-Dihydroxy-9β,13β-oxy-8,14-secoolean-11-en-28-oate (= *Methyl (1*S*,4a*S*,4a″*S*,5′*R*,8a*R*, 8a″*S*)-3,3″,4,4″,4a″,5″,6,6″,7,7″,8,8″,8a,8a″-Tetradecahydro-2,2″-dihydroxy-2,2″,5″,5″,7,7,8a″-heptamethyl-2*H*,2″*H*-dispiro[naphthalene-1,2′-furan-5′,1″-naphthalene]-4a(5*H*)-carboxylate*; **10**). $NaIO_4$ (189 mg, 0.88 mmol) and $RuCl_3 \cdot 3\,H_2O$ (*ca.* 5 mg) in H_2O (2 ml) was added to a soln. of product **8** (100 mg, 0.22 mmol) in acetone (10 ml). The mixture was stirred at r.t. for 30 min, and then diluted with CH_2Cl_2. The org. layer was washed with H_2O and dried (Na_2SO_4). The soln. was evaporated at reduced pressure, and the residue was chromatographed on a SiO_2 column to yield **10** (88 mg, 80%). Colorless oil. $[\alpha]_D^{20} = +16$ ($c=1$, $CHCl_3$). IR ($CHCl_3$): 2946, 1724, 1057, 767. ^{1}H-NMR (300 MHz, $CDCl_3$): 5.70 (*d*, *J* = 6.4, 1 H); 5.51 (*d*, *J* = 6.4, 1 H); 3.67 (*s*, 3 H); 2.89 (*dd*, *J* = 4.3, 13.7, 1 H); 1.30 (*s*, 3 H); 1.22 (*s*, 3 H); 1.01 (*s*, 3 H); 0.98 (*s*, 3 H); 0.92 (*s*, 3 H); 0.89 (*s*, 3 H); 0.82 (*s*, 3 H). ^{13}C-NMR (75 MHz, $CDCl_3$): 18.5 (CH_2); 19.7 (Me); 20.1 (CH_2); 22.1 (Me); 23.2 (CH_2); 24.0 (Me); 26.9 (Me); 29.3 (Me); 30.4 (C); 33.5 (Me); 33.6 (Me); 34.2 (CH_2); 34.5 (CH_2); 35.0 (CH_2); 36.0 (CH_2); 38.7 (CH_2); 39.9 (CH_2); 41.9 (CH_2); 33.9 (C); 42.7 (C); 42.9 (CH); 47.0 (C); 47.1 (CH); 52.0 (Me); 74.2 (C); 74.6 (C); 95.6 (C); 103.6 (C); 124.8 (CH); 134.5 (CH); 179.5 (C). HR-MS: 525.3556 ($[M+Na]^+$, $C_{31}H_{50}NaO_5^+$; calc. 525.3556).

Methyl 8,9-Dioxo-(8,9),(8,14)-disecooleana-11,13-dien-28-oate (= *Methyl (4a*S*,8a*S*)-1,3,4,5,6,8a-Hexahydro-2,2,7-trimethyl-8-{(1*Z*)-3-oxo-3-[(1*S*,2*S*)-1,3,3-trimethyl-2-(3-oxobutyl)cyclohexyl]prop-1-en-1-yl}naphthalene-4a(2*H*)-carboxylate*; **11**). Compound **8** (285 mg, 0.63 mmol) was dissolved in AcOEt (10 ml), stirred at $-78°$, and an O_3 flow lower than 0.1 l/min (50% O_2/50% O_3) was passed through the soln. After 7 min, Me_2S (0.5 ml) was added. The mixture was maintained under stirring while being cooled for 1 h. Then, it was evaporated and purified over SiO_2 to yield **11** (37 mg, 12%), *(1*S*,2*S*)-1,3,3-trimethyl-2-(3-oxobutyl)cyclohexanecarboxylic acid* (**12**; 17 mg, 22%), *methyl (1a*S*,3a*S*,7a*R*,7b*R*)-7b-formyloctahydro-1a,6,6-trimethylnaphtho[1,2-*b*]oxirene-3a(1a*H*)-carboxylate* (**13**, 22 mg, 25%), and *(2*S*,4a*S*,8a*R*)-hexahydro-2-hydroxy-2,7,7-trimethyl-9-oxo-2*H*-1,4a-(epoxymethano)naphthalene-1(5*H*)-carbaldehyde* (**14**, 12 mg, 14%).

Data of **11**. Colorless oil. $[\alpha]_D^{20} = +99$ ($c=1$, $CHCl_3$). IR ($CHCl_3$): 2925, 2854, 1698, 773. ^{1}H-NMR (300 MHz, $CDCl_3$): 7.72 (*d*, *J* = 15.4, 1 H); 6.64 (*d*, *J* = 15.4, 1 H); 3.60 (*s*, 3 H); 3.15 (*dd*, *J* = 3.6, 13.9, 1 H); 2.00 (*s*, 3 H); 1.24 (*s*, 3 H); 1.19 (*s*, 3 H); 1.09 (*s*, 3 H); 0.94 (*s*, 3 H); 0.93 (*s*, 3 H); 0.92 (*s*, 3 H). ^{13}C-NMR (75 MHz, $CDCl_3$): 18.4 (CH_2); 19.6 (Me); 21.9 (CH_2); 22.1 (CH_2); 22.5 (Me); 24.2 (Me); 29.8 (CH_2); 29.9 (Me); 31.0 (C); 31.7 (CH_2); 32.0 (CH_2); 32.9 (Me); 33.4 (Me); 33.6 (Me); 34.0 (CH_2); 34.5 (CH); 36.5 (CH_2); 41.6 (C); 42.2 (CH_2); 45.2 (CH_2); 45.5 (C); 48.0 (CH); 51.8 (C); 52.0 (Me); 118.2 (CH); 132.0 (C); 139.8 (CH); 142.6 (C); 177.8 (C); 205.7 (C); 208.7 (C). HR-MS: 507.3458 ($[M+Na]^+$, $C_{31}H_{48}NaO_4^+$; calc. 507.3450).

Data of **12**. Colorless oil. $[\alpha]_D^{20} = +1$ ($c=1$, $CHCl_3$). IR ($CHCl_3$): 2925, 2854, 1698, 773. ^{1}H-NMR (300 MHz, $CDCl_3$): 2.11 (*s*, 3 H); 1.23 (*s*, 3 H); 0.96 (*s*, 3 H); 0.93 (*s*, 3 H). ^{13}C-NMR (75 MHz, $CDCl_3$): 17.5 (Me); 18.3 (CH_2); 22.1 (CH_2); 22.6 (Me); 29.9 (Me); 33.2 (Me); 34.4 (C); 37.5 (CH_2); 41.1 (CH_2); 45.2 (CH_2); 47.3 (C); 48.8 (CH); 184.2 (C); 208.9 (C). HR-MS: 263.1629 ($[M+Na]^+$, $C_{14}H_{24}NaO_3^+$; calc. 263.1623).

Data of **13**. Colorless oil. $[\alpha]_D^{20} = +34$ ($c=1$, $CHCl_3$). IR ($CHCl_3$): 3497, 2948, 1759, 1724, 1465, 1079. ^{1}H-NMR (300 MHz, $CDCl_3$): 9.41 (*s*, 1 H); 3.72 (*s*, 3 H); 3.25 (*ddd*, *J* = 1.7, 4.8, 12.9, 1 H); 1.34 (*s*, 3 H); 0.96 (*s*, 3 H); 0.94 (*s*, 3 H). ^{13}C-NMR (75 MHz, $CDCl_3$): 19.2 (Me); 23.0 (CH_2); 24.0 (Me); 28.5 (Me); 29.7 (C); 30.1 (CH_2); 30.7 (CH_2); 32.6 (Me); 33.9 (CH_2); 36.4 (CH_2); 43.7 (C); 51.9 (CH); 64.8 (C); 70.1 (C); 177.4 (C); 200.1 (CH). HR-MS: 303.1568 ($[M+Na]^+$, $C_{16}H_{24}NaO_4^+$; calc. 303.1572).

Data of **14**. White solid. M.p. 97–99°. $[\alpha]_D^{20} = +63$ ($c = 1$, $CHCl_3$). IR ($CHCl_3$): 3477, 1745, 1708, 1077, 772. ^{1}H-NMR (300 MHz, $CDCl_3$): 9.50 (*d*, *J* = 1.5, 1 H); 3.54 (*d*, *J* = 1.5, 3 H); 1.21 (*s*, 3 H); 1.03 (*s*, 3 H); 0.94 (*s*, 3 H). ^{13}C-NMR (75 MHz, $CDCl_3$): 20.4 (Me); 20.5 (CH_2); 24.1 (Me); 26.9 (CH_2); 28.8 (CH_2); 30.3 (C); 33.1 (Me); 33.1 (CH_2); 33.2 (CH_2); 34.7 (CH); 39.8 (C); 79.2 (C); 82.5 (C); 177.5 (C); 200.0 (CH). HR-MS: 289.1480 ($[M+Na]^+$, $C_{15}H_{22}NaO_4^+$; calc. 289.1416).

Methyl 8α,9α-Epoxy-8,14-secooleana-11,13-dien-28-oate (= *Methyl (4a*S*,8a*S*)-1,3,4,5,6,8a-Hexahydro-2,2,7-trimethyl-8-{(*Z*)-2-[(1a*R*,7a*S*,7b*S*)-octahydro-1a,4,4,7a-tetramethylnaphtho[1,2-*b*]oxiren-7b(1a*H*)-yl]ethenyl}naphthalene-4a(2*H*)-carboxylate*; **15**). Product **8** (100 mg, 0.5 mmol) was dissolved in CH_2Cl_2 (10 ml), and MCPBA (130 mg, 0.75 mmol) was added. The mixture was stirred at different temps. (*Table*). To stop the reaction, the mixture was diluted with CH_2Cl_2, and the org. layer was washed with sat. aq. soln. of $FeSO_4$, neutralized with sat. aq. soln. of $NaHCO_3$, dried (Na_2SO_4), filtered, and the soln. was evaporated to dryness. Depending on the reaction conditions (*Table*) and after chromatography on SiO_2, different amounts of **15**, *methyl (3a*S*,7a*R*,7b*R*)-octahydro-1a,6,6-trimethyl-7b-{(*Z*)-2-[(1a*R*,7a*S*,7b*S*)-octahydro-1a,4,4,7a-tetramethylnaphtho[1,2-*b*]oxiren-7b(1a*H*)-yl]ethenyl}naphtho[1,2-*b*]oxirene-3a(1a*H*)-carboxylate* (**16**), *methyl (3a*S*,7a*R*,7b*S*)-octahydro-1a,6,6-trimethyl-7b-{(*Z*)-2-[(1a*R*,7a*S*,7b*S*)-octahydro-1a,4,4,7a-tetramethylnaphtho[1,2-*b*]oxiren-7b(1a*H*)-yl]ethenyl}naphtho[1,2-*b*]oxirene-3a(1a*H*)-carboxylate* (**17**), *(1*S*,4a*S*,8a*R*)-octahydro-2-hydroxy-2,7,7-trimethyl-1-{(*Z*)-2-[(1a*R*,7a*S*,7b*S*)-octahydro-1a,4,4,7a-tetramethylnaphtho[1,2-*b*]oxiren-7b(1a*H*)-yl]ethenyl}-2*H*-1,4a-(epoxymethano)naphthalen-9-one* (**18**), *methyl (1*S*,4a*S*,8a*R*)-octahydro-1,2-dihydroxy-2,7,7-trimethyl-1-{(*Z*)-2-[(1a*R*,7a*S*,7b*S*)-octahydro-1a,4,4,7a-tetramethylnaphtho[1,2-*b*]oxiren-7b(1a*H*)-yl]ethenyl}naphthalene-4a(2*H*)-carboxylate* (**19**), and *methyl (1*S*,4a*S*,5′*S*,8a*R*,8a″*S*)-3,4,4a″,5″,6,6″,7,7″,8,8″,8a,8a″-dodecahydro-2-hydroxy-2,2″,5″,5″,7,7,8a″-heptamethyl-2*H*,4″H-dispiro[naphthalene-1,2′-furan-5′,1″-naphthalene]-4a(5*H*)-carboxylate* (**20**) were obtained.

Data of **15**. Colorless oil. $[\alpha]_D^{20} = +27$ ($c = 1$, $CHCl_3$). IR ($CHCl_3$): 2945, 772. ^{1}H-NMR (300 MHz, $CDCl_3$): 6.10 (*d*, *J* = 13.3, 1 H); 5.60 (*d*, *J* = 13.3, 1 H); 3.70 (*s*, 3 H); 3.50 (*dd*, *J* = 3.5, 13.0, 1 H); 1.50 (*s*, 3 H); 1.20 (*s*, 3 H); 1.10 (*s*, 3 H); 0.88 (*s*, 3 H); 0.83 (*s*, 3 H); 0.80 (*s*, 3 H); 0.78 (*s*, 3 H). ^{13}C-NMR (75 MHz, $CDCl_3$): 17.3 (CH_2); 18.4 (Me); 18.6 (CH_2); 20.8 (Me); 21.6 (Me); 22.4 (Me); 23.6 (CH_2); 25.0 (Me); 28.5 (CH_2); 29.5 (CH_2); 30.7 (C); 32.0 (CH_2); 32.5 (Me); 33.1 (Me); 33.8 (Me); 34.5 (CH_2); 35.2 (CH_2); 36.1 (CH); 38.6 (C); 41.6 (CH_2); 41.9 (CH); 42.8 (CH_2); 45.2 (C); 51.8 (Me); 60.7 (C); 72.1 (C); 126.6 (CH); 127.5 (C); 132.7 (C); 134.4 (CH); 178.6 (C). HR-MS: 491.3506 ($[M+Na]^+$, $C_{31}H_{48}NaO_3^+$; calc. 491.3501).

Data of **16**. Colorless oil. $[\alpha]_D^{20} = +33$ ($c = 1$, $CHCl_3$). IR ($CHCl_3$): 2946, 772. ^{1}H-NMR (300 MHz, $CDCl_3$): 5.89 (*d*, *J* = 13.6, 1 H); 5.66 (*d*, *J* = 13.6, 1 H); 3.68 (*s*, 3 H); 2.49 (*dd*, *J* = 3.3, 13.6, 1 H); 1.11 (*s*, 3 H); 1.10 (*s*, 6 H); 0.95 (*s*, 3 H); 0.86 (*s*, 3 H); 0.81 (*s*, 6 H). ^{13}C-NMR (75 MHz, $CDCl_3$): 17.2 (CH_2); 18.4 (CH_2); 18.7 (Me); 20.4 (Me); 20.9 (Me); 21.4 (Me); 22.6 (CH_2); 24.0 (Me); 28.4 (CH_2); 29.5 (CH_2); 30.0 (C); 31.5 (CH_2); 33.1 (Me); 33.1 (C); 33.6 (Me); 34.2 (CH_2); 34.8 (CH_2); 35.9 (CH); 37.3 (CH_2); 37.4 (C); 41.5 (CH); 41.8 (CH_2); 45.5 (C); 51.7 (Me); 61.1 (C); 62.4 (C); 65.5 (C); 72.1 (C); 125.8 (CH); 132.7 (CH); 178.4 (C). HR-MS: 507.3452 ($[M+Na]^+$, $C_{31}H_{48}NaO_4^+$; calc. 507.3450).

Data of **17**. Colorless oil. $[\alpha]_D^{20} = +25$ ($c = 1$, $CHCl_3$). IR ($CHCl_3$): 3409, 2940, 769. ^{1}H-NMR (300 MHz, $CDCl_3$): 5.85 (*d*, *J* = 12.3, 1 H); 5.68 (*d*, *J* = 12.3, 1 H); 3.76 (*s*, 3 H); 3.27 (*dd*, *J* = 4.1, 13.5, 1 H); 1.17 (*s*, 3 H); 1.11 (*s*, 3 H); 1.06 (*s*, 3 H); 0.90 (*s*, 3 H); 0.88 (*s*, 3 H); 0.78 (*s*, 6 H). ^{13}C-NMR (75 MHz, $CDCl_3$): 17.4 (CH_2); 18.6 (CH_2); 18.7 (Me); 19.8 (CH_2); 21.6 (Me); 21.7 (Me); 21.8 (Me); 24.9 (Me); 25.7 (CH_2); 28.9 (CH_2); 29.8 (CH_2); 30.5 (C); 31.9 (CH_2); 33.0 (C); 33.1 (Me); 33.6 (CH_2); 33.9 (Me); 36.8 (CH); 37.9 (C); 38.3 (CH_2); 41.5 (CH_2); 41.9 (CH); 42.6 (C); 51.4 (Me); 57.3 (C); 59.9 (C); 66.3 (C); 72.5 (C); 130.3 (CH); 178.6 (C). HR-MS: 507.3498 ($[M+Na]^+$, $C_{31}H_{48}NaO_4^+$; calc. 507.3450).

Data of **18**. Colorless oil. $[\alpha]_D^{20} = +38$ ($c = 1$, $CHCl_3$). IR ($CHCl_3$): 2866, 1750, 1457, 1082. ^{1}H-NMR ($CDCl_3$): 6.03 (*s*, 1 H); 5.80 (*d*, *J* = 14.1, 1 H); 5.59 (*d*, *J* = 14.1, 1 H); 1.25 (*s*, 3 H); 1.25 (*s*, 3 H); 1.11 (*s*, 3 H); 0.95 (*s*, 3 H); 0.83 (*s*, 3 H); 0.82 (*s*, 3 H). ^{13}C-NMR ($CDCl_3$): 16.8 (CH_2); 18.3 (CH_2); 18.6 (Me); 20.5 (CH_2); 20.6 (Me); 20.9 (Me); 21.2 (Me); 21.5 (Me); 24.2 (Me); 27.1 (CH_2); 27.8 (CH_2); 28.4 (CH_2); 30.5 (C); 33.1 (C); 33.3 (CH_2); 33.6 (Me); 37.4 (C); 37.5 (CH_2); 40.6 (C); 41.6 (CH_2); 41.8 (CH); 42.2 (CH); 67.1 (C); 74.5 (C); 74.7 (C); 84.7 (C); 121.1 (CH); 137.9 (CH); 179.0 (C). HR-MS: 493.3267 ($[M+Na]^+$, $C_{30}H_{46}NaO_4^+$; calc. 493.3294).

Data of **19**. Colorless oil. $[\alpha]_D^{20} = +33$ ($c = 1$, $CHCl_3$). IR ($CHCl_3$): 2946, 772. ^{1}H-NMR (300 MHz, $CDCl_3$): 6.07 (*d*, *J* = 13.7, 1 H); 5.71 (*d*, *J* = 13.7, 1 H); 4.65 (br. *s*, 1 H); 3.71 (*s*, 3 H); 2.59 (*dd*, *J* = 3.2, 13.7, 1 H); 1.24 (*s*, 6 H); 1.12 (*s*, 3 H); 1.11 (*s*, 3 H); 0.86 (*s*, 3 H); 0.80 (*s*, 3 H); 0.79 (*s*, 3 H). ^{13}C-NMR (75 MHz, $CDCl_3$): 17.0 (CH_2); 18.6 (CH_2); 18.8 (Me); 21.6 (Me); 21.9 (Me); 22.2 (CH_2); 23.5 (Me); 27.4 (Me); 28.4 (CH_2); 29.7 (CH_2); 30.7 (C); 33.0 (C); 33.3 (Me); 33.7 (CH_2); 34.1 (CH_2); 36.2 (CH_2); 37.6 (C); 37.9 (CH_2); 41.3 (CH_2); 41.6 (CH); 44.1 (C); 45.2 (CH); 51.4 (Me); 65.3 (C); 73.9 (C); 74.3 (C); 77.7 (CH); 123.4 (CH); 136.8 (CH); 179.7 (C). HR-MS: 525.3552 ($[M+Na]^+$, $C_{31}H_{50}NaO_5^+$; calc. 525.3556).

Data of **20**. Colorless oil. $[\alpha]_D^{20} = -43$ ($c = 1$, $CHCl_3$). IR ($CHCl_3$): 2946, 1715, 771. ^{1}H-NMR (300 MHz, $CDCl_3$): 6.11 (*d*, *J* = 6.3, 1 H); 5.89 (*d*, *J* = 6.3, 1 H); 5.55 (*dd*, *J* = 3.5, 5.0, 1 H); 3.50 (*s*, 3 H); 2.70 (*dd*, *J* = 3.2, 12.1, 1 H); 2.29 (*ddd*, *J* = 3.7, 13.4, 13.9, 1 H); 1.67 (*s*, 3 H); 1.17 (*s*, 3 H); 0.88 (*s*, 3 H); 0.87 (*s*, 6 H); 0.85 (*s*, 3 H); 0.83 (*s*, 3 H): ^{13}C-NMR (75 MHz, $CDCl_3$): 18.7 (Me); 18.7 (CH_2); 21.2 (Me); 22.7 (CH_2); 23.5 (Me); 23.7 (Me); 25.3 (CH_2); 29.8 (C); 30.8 (C); 31.4 (Me); 32.6 (Me); 33.4 (Me); 33.8 (CH_2); 34.2 (CH_2); 34.3 (CH_2); 34.9 (CH_2); 38.5 (CH_2); 40.9 (CH); 41.1 (C); 42.4 (CH_2); 44.2 (CH); 45.0 (C); 51.6 (Me); 74.9 (C); 93.7 (C); 97.1 (C); 127.1 (CH); 131.5 (CH); 132.5 (CH); 133.9 (C); 179.0 (C). HR-MS: 507.3444 ($[M+Na]^+$, $C_{31}H_{48}NaO_4^+$; calc. 507.3450).

*Methyl (11*E*)-8,14-Secoolea-8,11,13-trien-28-oate* (= *Methyl (4a*S*,8a*S*)-1,3,4,5,6,8a-Hexahydro-2,2,7-trimethyl-8-{(*E*)-2-[(4a*S*,8a*S*)-3,4,4a,5,6,7,8,8a-octahydro-2,5,5,8a-tetramethylnaphthalen-1-yl]ethenyl}-naphthalene-4a(2*H*)-carboxylate*; **21**). I_2 (5 mg, 0.02 mmol) was added to a soln. of **8** (50 mg, 0.1 mmol) in hexane (50 ml). After 5 h at reflux, 0.5 ml of sat. aq. soln. of $NaHSO_4$ was added, and the mixture was diluted with CH_2Cl_2. The org. layer was washed with H_2O, dried (Na_2SO_4), and evaporated to dryness. Chromatography on a SiO_2 column yielded **21** (30 mg, 65%). Colorless oil. $[\alpha]_D^{20} = +57$ ($c = 1$, $CHCl_3$). IR ($CHCl_3$): 2946, 1729, 1462, 1170, 757. ^{1}H-NMR (300 MHz, $CDCl_3$): 6.15 (*d*, *J* = 16.2, 1 H); 5.99 (*d*, *J* = 16.2, 1 H); 3.61 (*s*, 3 H); 3.14 (*dd*, *J* = 3.4, 13.0, 1 H); 1.67 (*s*, 3 H); 1.64 (*s*, 3 H); 1.01 (*s*, 3 H); 1.00 (*s*, 3 H); 0.88 (*s*, 3 H); 0.88 (*s*, 3 H); 0.84 (*s*, 3 H). ^{13}C-NMR (75 MHz, $CDCl_3$): 19.0 (Me); 19.0 (CH_2); 19.2 (CH_2); 20.4 (Me); 21.5 (Me); 21.7 (Me); 22.5 (CH_2); 24.1 (Me); 30.6 (CH_2); 30.9 (C); 32.1 (CH_2); 32.9 (CH); 33.3 (Me); 33.4 (Me); 33.4 (C); 33.7 (CH_2); 34.2 (CH_2); 38.3 (C); 38.5 (CH_2); 41.9 (CH_2); 42.2 (CH_2); 45.7 (C); 51.4 (Me); 51.6 (CH); 123.7 (CH); 126.4 (C); 129.1 (C); 130.9 (CH); 132.6 (C); 142.3 (C); 178.2 (C). HR-MS: 452.3668 (M^+, $C_{31}H_{48}O_2^+$; 452.3654).

Compound **21** could also be obtained by isomerization of **8** (200 mg, 0.44 mmol) dissolved in toluene (20 ml) and treated with TFA (20 µl) for 3.5 h under reflux. This mixture was evaporated to dryness and chromatographed over a SiO_2 column to give **21** (190 mg, 95%).

Methyl 8,14-Secoolea-7,9(11),13-trien-28-oate (= *Methyl (4a*S*,8a*S*)-1,3,4,5,6,8a-Hexahydro-2,2,7-trimethyl-8-{(2*E*)-2-[(4a*S*,8a*S*)-4a,5,6,7,8,8a-hexahydro-2,5,5,8a-tetramethylnaphthalen-1(4*H*)-ylidene]-ethyl}naphthalene-4a(2*H*)-carboxylate*; **22**). Trifluoroacetic acid (10 µl) was added to a soln. of **8** (100 mg, 0.22 mmol) in CH_2Cl_2 (10 ml). After 5 h under reflux, the mixture was evaporated to dryness. CC over SiO_2 yielded **21** (15 mg, 15%) and **22** (80 mg, 80%). Colorless oil. $[\alpha]_D^{20} = +81$ ($c = 1$, $CHCl_3$). IR ($CHCl_3$): 3417, 2947, 1727, 1443, 1168. ^{1}H-NMR (300 MHz, $CDCl_3$): 6.10 (*d*, *J* = 11.1, 1 H); 5.49 (*dd*, *J* = 1.8, 1.8, 1 H); 5.25 (*dd*, *J* = 11.7, 1 H); 3.67 (*s*, 3 H); 3.64 (*d*, *J* = 11.7, 1 H); 2.94 (*dd*, *J* = 12.6, 1 H); 1.64 (*s*, 3 H); 1.49 (*s*, 3 H); 0.90 (*s*, 3 H); 0.87 (*s*, 6 H); 0.87 (*s*, 3 H); 0.84 (*s*, 3 H); 0.80 (*s*, 3 H). ^{13}C-NMR ($CDCl_3$): 14.6 (Me); 19.0 (CH_2); 20.9 (Me); 22.2 (Me); 22.7 (CH_2); 23.1 (Me); 24.2 (CH_2); 24.7 (Me); 29.3 (CH_2); 30.9 (C); 33.1 (Me); 33.3 (C); 33.6 (Me); 34.2 (CH_2); 37.1 (C); 39.1 (CH); 39.5 (CH_2); 42.7 (CH_2); 42.8 (CH_2); 45.7 (C); 49.7 (CH); 52.1 (CH); 53.0 (Me); 121.9 (CH); 128.4 (C); 132.1 (CH); 132.4 (C); 132.7 (CH); 134.1 (CH); 178.6 (C). HR-MS: 452.3663 (M^+, $C_{31}H_{48}O_2^+$; calc. 452.3654).

*(2*R*,4a*S*,8a*S*)-Octahydro-5,5,8a-trimethyl-1*H*-spiro[naphthalene-2,2'-oxiran]-1-one* (**23**). Compound **9** (100 mg, 0.2 mmol) was dissolved in AcOEt (8 ml), and an O_3 flow of 0.1 l/min (10% O_2/90% O_3) was passed through the soln. for 2 min at $-78°$. Then, Me_2S (1 ml) was added, and the mixture was maintained at r.t. during 12 h with stirring, evaporated to dryness, and purified over SiO_2 to give **23** (12 mg, 24%), *methyl (1a*S*,3a*S*,7a*R*,7b*R*)-octahydro-1a,6,6-trimethyl-7b-(2-oxoethyl)naphtho[1,2-*b*]oxirene-3a(1a*H*)-carboxylate* (**24**, 10 mg, 32%) [18], and *[(2*S*,4a*S*,8a*R*)-hexahydro-2-hydroxy-2,7,7-trimethyl-9-oxo-2*H*-1,4a-(epoxymethano)naphthalen-1(5*H*)-yl]acetaldehyde* (**25**, 5 mg, 16%).

Data of **23**. Colorless oil. $[\alpha]_D^{20} = +10$ ($c = 1$, $CHCl_3$). IR ($CHCl_3$): 2929, 1716, 1460, 1007, 907. ^{1}H-NMR (300 MHz, $CDCl_3$): 3.21 (*d*, *J* = 5.5, 1 H); 2.55 (*d*, *J* = 5.5, 1 H); 1.22 (*s*, 3 H); 0.96 (*s*, 3 H); 0.93 (*s*, 3 H). ^{13}C-NMR (75 MHz, $CDCl_3$): 17.5 (Me); 17.9 (CH_2); 18.9 (CH_2); 22.2 (Me); 31.5 (CH_2); 33.2

(Me); 33.9 (CH_2); 34.4 (C); 41.6 (CH_2); 49.8 (C); 50.6 (CH_2); 50.7 (CH); 58.0 (C); 210.8 (C). HR-MS: 245.1618 ($[M+Na]^+$, $C_{14}H_{22}NaO_2^+$; calc. 245.1517).

Data of **25**. Colorless oil. $[\alpha]_D^{20} = +13$ ($c = 1$, $CHCl_3$). IR ($CHCl_3$): 2947, 1736, 1466, 1378, 1256, 1081. ^{1}H-NMR ($CDCl_3$): 9.07 (*dd*, $J = 1.3, 1.3, 1$ H); 2.82 (*dd*, $J = 1.3, 17.2, 1$ H); 2.74 (*dd*, $J = 1.3, 17.2, 1$ H); 2.03 (*dd*, $J = 3.2, 17.6, 1$ H); 1.32 (*s*, 3 H); 0.98 (*s*, 3 H); 0.84 (*s*, 3 H). ^{13}C-NMR (75 MHz, $CDCl_3$): 20.6 (CH_2); 20.6 (Me); 24.1 (Me); 26.8 (CH_2); 27.4 (CH_2); 29.8 (Me); 30.5 (C); 33.1 (CH_2); 34.5 (CH_2); 40.3 (C); 41.9 (CH); 50.7 (CH_2); 74.3 (C); 83.6 (C); 178.3 (C); 203.8 (CH). HR-MS: 303.1573 ($[M+Na]^+$, $C_{16}H_{24}NaO_4^+$; calc. 303.1572).

*(1*R,2R,*4a*S,*8a*S*)-Octahydro-5,5,8a-trimethyl-1*H*-spiro[naphthalene-2,2′-oxiran]-1-ol* (**26**). Compound **9** (100 mg, 0.22 mmol) was dissolved in AcOEt (8 ml), stirred at −78°, and an O_3 flow lower than 0.1 l/min (50% O_2/50% O_3) was passed through the soln. After 5 min, the mixture was evaporated. The residue was redissolved in i-PrOH, $NaBH_4$ (14 mg) was added, and the mixture stirred for 2 h at r.t. The mixture was diluted with CH_2Cl_2, and the org. layer was washed with H_2O, dried (Na_2SO_4), evaporated to dryness, and purified over SiO_2 to yield **26** (7 mg, 22%), *(1*R,2S,*4a*S,*8a*S*)-octahydro-5,5,8a-trimethyl-1*H*-spiro[naphthalene-2,2′-oxiran]-1-ol* (**27**, 3 mg, 9%), and *methyl (1a*S,*3a*S,*7a*R,*7b*R*)-octahydro-7b-(2-hydroxyethyl)-1a,6,6-trimethylnaphtho[1,2-*b*]oxirene-3a(1a*H*)-carboxylate* (**28**, 14 mg, 36%).

Data of **26**. Colorless oil. $[\alpha]_D^{20} = +2$ ($c = 0.1$, $CHCl_3$). IR ($CHCl_3$): 2926, 1718, 1459, 1085, 713. ^{1}H-NMR (300 MHz, $CDCl_3$): 3.28 (*d*, $J = 11.1, 1$ H); 2.87 (*d*, $J = 4.9, 1$ H); 2.32 (*d*, $J = 4.9, 1$ H); 0.91 (*s*, 3 H); 0.90 (*s*, 3 H); 0.88 (*s*, 3 H). ^{13}C-NMR (75 MHz, $CDCl_3$): 13.0 (Me); 18.3 (CH_2); 19.5 (CH_2); 22.2 (Me); 32.7 (CH_2); 33.2 (C); 33.6 (Me); 38.4 (CH_2); 41.0 (C); 42.1 (CH_2); 47.4 (CH_2); 51.2 (CH); 58.5 (C); 77.2 (CH). HR-MS: 247.1766 ($[M+Na]^+$, $C_{14}H_{24}NaO_2^+$; calc. 247.1674).

Data of **27**. White solid. M.p. 101–103°. $[\alpha]_D^{20} = +7$ ($c = 0.1$, $CHCl_3$). IR ($CHCl_3$): 2923, 2854, 1743, 1701, 1654, 772. ^{1}H-NMR (300 MHz, $CDCl_3$): 3.35 (*s*, 1 H); 3.05 (*dd*, $J = 1.8, 5.0, 1$ H); 2.58 (*d*, $J = 5.0$, 1 H); 0.90 (*s*, 3 H); 0.88 (*s*, 3 H); 0.85 (*s*, 3 H). ^{13}C-NMR (75 MHz, $CDCl_3$): 13.0 (Me); 18.4 (CH_2); 21.3 (CH_2); 21.9 (Me); 32.4 (CH_2); 33.2 (C); 33.5 (Me); 38.4 (CH_2); 40.9 (C); 42.1 (CH_2); 51.0 (CH_2); 52.3 (CH); 59.9 (C); 78.4 (CH). HR-MS: 247.1766 ($[M+Na]^+$, $C_{14}H_{24}NaO_2^+$; calc. 247.1674).

Data of **28**. White solid. M.p. 90–92°. $[\alpha]_D^{20} = -4$ ($c = 1$, $CHCl_3$). IR ($CHCl_3$): 3421, 2949, 2864, 1731, 1457, 1253, 1038. ^{1}H-NMR (300 MHz, $CDCl_3$): 3.75–3.90 (*m*, 2 H); 3.68 (*s*, 3 H); 2.50 (*dd*, $J = 5.9, 11.4$, 1 H); 1.26 (*s*, 3 H); 0.92 (*s*, 3 H); 0.88 (*s*, 3 H). ^{13}C-NMR (75 MHz, $CDCl_3$): 20.2 (Me); 23.1 (CH_2); 24.1 (Me); 29.7 (C); 30.5 (CH_2); 31.1 (CH_2); 32.8 (Me); 33.5 (CH); 34.2 (CH_2); 35.9 (CH_2); 36.7 (CH_2); 45.4 (C); 52.3 (Me); 59.8 (CH); 63.1 (C); 66.7 (C); 179.6 (C). HR-MS: 319.1890 ($[M+Na]^+$, $C_{17}H_{28}NaO_4^+$; calc. 319.1885).

*(1*R,2S,*4a*S,*8a*S*)-Decahydro-2,5,5,8a-tetramethylnaphthalene-1,2-diol* (**29**). Compound **9** (76 mg, 0.22 mmol) was dissolved in AcOEt (10 ml), stirred at −78°, and an O_3 flow lower than 0.1 l/min (50% O_2/50% O_3) was passed through the soln. After 5 min, the soln. was evaporated. The residue was redissolved in THF, 2 ml of a 1M soln. of $LiAlH_4$ in THF were added, and the mixture was stirred for 1 h at reflux. After that, the mixture was diluted with CH_2Cl_2, and the org. layer was washed with H_2O and dried (Na_2SO_4). The soln. was evaporated to dryness, and the residue was purified over SiO_2, yielding **29** (11 mg, 20%), *(1*R,2S,*4a*S,*8a*S*)-decahydro-5,5,8a-trimethylnaphthalene-1,2-diol* (**30**, 10 mg, 8%), and *(2*S,*4a*S,*8a*R*)-1-(2-hydroxyethyl)-octahydro-2,7,7-trimethyl-2*H*-1,4a-(epoxymethano)naphthalen-2-ol* (**31**, 12 mg, 25%).

Data of **29**. White solid. M.p. 97–99°. $[\alpha]_D^{20} = -5$ ($c = 0.6$, $CHCl_3$). IR ($CHCl_3$): 3410, 3284, 2927, 1063. ^{1}H-NMR (300 MHz, $CDCl_3$): 2.87 (*s*, 1 H); 1.20 (*s*, 3 H); 1.00 (*s*, 3 H); 0.87 (*s*, 3 H); 0.85 (*s*, 3 H). ^{13}C-NMR (75 MHz, $CDCl_3$): 13.6 (Me); 17.9 (CH_2); 18.1 (CH_2); 21.9 (Me); 29.6 (Me); 33.1 (C); 33.5 (Me); 38.8 (CH_2); 39.1 (CH_2); 39.9 (C); 42.0 (CH_2); 53.1 (CH); 72.6 (C); 84.4 (CH). HR-MS: 249.1834 ($[M+Na]^+$, $C_{14}H_{26}NaO_2^+$; calc. 249.1830).

Data of **30**. White solid. M.p. 160–162°. $[\alpha]_D^{20} = -3$ ($c = 0.5$, $CHCl_3$). IR ($CHCl_3$): 3432, 2924, 1461, 1044, 984. ^{1}H-NMR (300 MHz, $CDCl_3$): 3.96 (*d*, $J = 2.9, 1$ H); 3.10 (*d*, $J = 2.9, 1$ H); 1.04 (*s*, 3 H); 0.88 (*s*, 3 H); 0.86 (*s*, 3 H). ^{13}C-NMR (75 MHz, $CDCl_3$): 14.3 (Me); 16.4 (CH_2); 18.0 (CH_2); 21.9 (Me); 32.1 (CH_2); 33.0 (C); 33.5 (Me); 38.4 (CH_2); 39.8 (C); 42.1 (CH_2); 52.9 (CH); 70.6 (CH); 81.1 (CH). HR-MS: 235.1672 ($[M+Na]^+$, $C_{13}H_{24}NaO_2^+$; calc. 235.1674).

Data of **31**. White solid. M.p. 100–102°. $[\alpha]_D^{20} = +15$ ($c = 1$, $CHCl_3$). IR ($CHCl_3$): 3401, 2924, 1732, 1466, 1366, 1244, 1046. ^{1}H-NMR (300 MHz, $CDCl_3$): 3.86 (*ddd*, $J = 3.3, 9.4, 11.0, 1$ H); 3.76 (*d*, $J = 7.4$,

1 H); 3.60–3.75 (*m*, 1 H); 3.39 (*d*, *J* = 7.4, 1 H); 1.18 (*s*, 3 H); 0.98 (*s*, 3 H); 0.92 (*s*, 3 H). ^{13}C-NMR (75 MHz, $CDCl_3$): 24.0 (CH_2); 24.8 (Me); 26.8 (Me); 30.5 (CH_2); 30.8 (C); 31.5 (CH_2); 33.4 (Me); 34.5 (CH_2); 35.3 (CH_2); 35.7 (CH_2); 41.5 (C); 44.5 (CH); 59.1 (CH_2); 74.4 (C); 77.8 (CH_2); 86.7 (C). HR-MS: 291.1938 ([*M* + Na]$^+$, $C_{16}H_{28}NaO_3^+$; calc. 291.1936).

*Ozonolysis of (*E*)-Triene* **21**. Compound **21** (140 mg, 0.31 mmol) was dissolved in AcOEt (10 ml), and an O_3 flow of 0.1 l/min (10% O_2/90% O_3) was passed through the soln. for 2 min at −78°. After that, Me_2S (0.5 ml) was added, and the mixture stirred for 12 h, evaporated to dryness, and purified on SiO_2 to give the previously described products **12** (10 mg, 28%) and **13** (18 mg, 41%).

*(4a*S*,8a*S*)-3,4,4a,5,6,7,8,8a-Octahydro-2,5,5,8a-tetramethylnaphthalene-1-carbaldehyde* (**32**). Compound **21** (102 mg, 0.2 mmol) was dissolved in acetone (10 ml), and a soln. of *ca.* 5 mg of $RuCl_3 \cdot 3\,H_2O$ and $NaIO_4$ (171 mg, 0.87 mg) in H_2O (2 ml) was added. The mixture was stirred at r.t. for 30 min, diluted with CH_2Cl_2, and the org. layer was washed with H_2O and dried (Na_2SO_4). The soln. was evaporated at reduced pressure, and the residue was purified with SiO_2 CC to give **32** (14 mg, 32%) and *methyl (4a*S*,8a*S*)-8-formyl-1,3,4,5,6,8a-hexahydro-2,2,7-trimethylnaphthalene-4a(2*H*)-carboxylate* (**33**; 22 mg, 42%) [18].

Data of **32**. Colorless oil. $[\alpha]_D^{20} = -17$ (*c* = 0.4, $CHCl_3$). IR ($CHCl_3$): 2925, 1716, 1673. ^{1}H-NMR (300 MHz, $CDCl_3$): 9.97 (*s*, 1 H); 1.96 (*s*, 3 H); 1.11 (*s*, 3 H); 0.84 (*s*, 3 H); 0.79 (*s*, 3 H). ^{13}C-NMR (75 MHz, $CDCl_3$): 18.4 (CH_2); 19.0 (CH_2); 19.3 (Me); 20.3 (Me); 21.8 (Me); 33.4 (C); 33.5 (Me); 36.3 (CH_2); 36.7 (C, CH_2); 41.7 (CH_2); 51.7 (CH); 143.8 (C); 153.7 (C); 192.8 (CH). HR-MS: 243.1819 ([*M* + Na]$^+$, $C_{15}H_{24}NaO^+$; calc. 243.1725).

*4-[(1*S*)-2,2-Dimethyl-6-methylidenecyclohexyl]butan-2-one* (**34**). Compound **12** (80 mg, 0.33 mmol) was dissolved in benzene/pyridine 1:3 (3 ml), and $Pb(OAc)_4$ (219 mg, 5 equiv.) and $Cu(OAc)_2$ (2 mg) was added. The mixture was stirred under reflux for 2 h. Then, ethylene glycol was added, and the mixture was diluted with CH_2Cl_2. The org. layer was washed with H_2O, dried (Na_2SO_4), evaporated, and purified over SiO_2, yielding a mixture of isomers **34**, *4-[(1*S*)-2,6,6-trimethylcyclohex-2-en-1-yl]butan-2-one* (**35**), and *4-(2,6,6-trimethylcyclohex-1-en-1-yl)butan-2-one* (**36**) [32] (22 mg, 66% for all three compounds together), as well as *(1*S*,2*S*)-1,3,3-trimethyl-2-(3-oxobutyl)cyclohexyl acetate* (**37**; 9 mg, 14%).

Data of **37**. Colorless oil. $[\alpha]_D^{20} = +14$ (*c* = 1, $CHCl_3$). IR ($CHCl_3$): 2952, 1724, 1366, 1247. ^{1}H-NMR (300 MHz, $CDCl_3$): 2.17 (*s*, 3 H); 1.97 (*s*, 3 H); 1.52 (*s*, 3 H); 0.98 (*s*, 3 H); 0.88 (*s*, 3 H). ^{13}C-NMR (75 MHz, $CDCl_3$): 19.8 (CH_2); 20.4 (Me); 20.6 (CH_2); 22.4 (Me); 23.1 (Me); 29.9 (Me); 32.6 (Me); 35.7 (C); 37.6 (CH_2); 40.5 (CH_2); 46.3 (CH_2); 53.0 (CH); 87.7 (C); 170.1 (C); 209.2 (C). HR-MS: 277.1776 ([*M* + Na]$^+$, $C_{15}H_{26}NaO_3^+$; calc. 277.1780).

*4-[(1*S*,6*S*)-2,2,6-Trimethyl-6-(pyridin-2-ylsulfanyl)cyclohexyl]butan-2-one* (**38**). Compound **12** (80 mg, 0.33 mmol) was dissolved in CH_2Cl_2 (10 ml), and $(COCl)_2$ (1.1 ml) was added. The mixture was stirred at r.t. for 12 h and evaporated. After that, pyridine-2-thiol *N*-oxide (50 mg) and DMAP (4 mg) dissolved in benzene (10 ml) containing pyridine (0.06 ml) were added. The mixture was maintained under reflux during 2 h, concentrated, and purified with SiO_2 CC to yield **34** (8 mg, 12%) and **38** (24 mg, 24%).

Data of **38**. Colorless oil. $[\alpha]_D^{20} = +49$ (*c* = 1, $CHCl_3$). IR ($CHCl_3$): 2949, 1727, 1668. ^{1}H-NMR (300 MHz, $CDCl_3$): 8.49 (*d*, *J* = 4.8, 1 H); 7.49 (*dd*, *J* = 6.8, 1 H); 7.20–7.30 (*m*, 1 H); 7.07 (*dd*, *J* = 6.0, 1 H); 2.07 (*s*, 3 H); 1.38 (*s*, 3 H); 0.96 (*s*, 3 H); 0.88 (*s*, 3 H). ^{13}C-NMR (300 MHz, $CDCl_3$): 16.8 (Me); 21.4 (Me); 21.4 (CH_2); 21.7 (Me); 24.8 (CH_2); 28.3 (Me); 29.7 (CH_2); 37.6 (CH_2); 40.9 (C); 46.8 (CH_2); 50.7 (CH); 57.3 (C); 121.5 (CH); 127.5 (CH); 136.1 (CH); 149.6 (CH); 170.9 (C); 209.3 (C). HR-MS: 328.1796 ([*M* + Na]$^+$, $C_{18}H_{27}NNaOS^+$; calc. 328.1711).

In addition, compound **38** (24 mg, 0.08 mmol) was oxidized with *m*-chloroperbenzoic acid (MCPBA) in CH_2Cl_2 at −80° for 3 h. Then, the mixture was treated with sat. aq. soln. of $FeSO_4$ and diluted with CH_2Cl_2. The org. layer was neutralized with sat. aq. soln. of $NaHCO_3$, dried (Na_2SO_4), and evaporated to dryness. The resulting unstable residue was maintained in dioxane at 80° for 2 h, and the soln. was evaporated in vacuum. Purification with SiO_2 CC gave compound **34** (12 mg, 80%).

*[(4a*S*,8a*S*)-3,4,4a,5,6,7,8,8a-Octahydro-2,5,5,8a-tetramethylnaphthalen-1-yl]methanol* (**39**). Compound **32** (50 mg, 0.23 mmol) was dissolved in i-PrOH (4 ml), $NaBH_4$ (8 mg) was added, and the mixture was stirred at r.t. for 2 h. The excess of reagent was destroyed with sat. aq. soln. of $NaHSO_4$, and

the mixture was extracted with CH_2Cl_2. The org. extract was dried (Na_2SO_4), filtered, and concentrated under reduced pressure. The solid residue was purified with SiO_2 CC to give **39** (48 mg, 94%). Colorless oil. $[\alpha]_D^{20} = +77$ ($c = 1$, $CHCl_3$). IR ($CHCl_3$): 3317, 2922, 2863, 1457, 1374. ^{1}H-NMR (300 MHz, $CDCl_3$): 4.18 (*d*, *J* = 11.5, 1 H); 4.03 (*d*, *J* = 11.5, 1 H); 1.71 (*s*, 3 H); 0.95 (*s*, 3 H); 0.88 (*s*, 3 H); 0.83 (*s*, 3 H). ^{13}C-NMR (75 MHz, $CDCl_3$): 18.9 (CH_2); 19.0 (Me); 19.3 (C); 20.7 (Me); 21.6 (Me); 29.7 (CH_2); 33.3 (Me); 33.7 (CH_2); 36.9 (CH_2); 38.2 (C); 41.7 (CH_2); 51.8 (CH); 58.4 (CH_2); 132.5 (C); 141.1 (C). HR-MS: 245.1979 ($[M+Na]^+$, $C_{15}H_{26}NaO^+$; calc. 245.1881).

*(4a*S*,8a*S*)-1,2,3,4,4a,5,8,8a-Octahydro-1,1,4a,6-tetramethyl-5-methylidenenaphthalene* (**40**). Compound **39** (73 mg, 0.32 mmol) was dissolved in pyridine (3 ml), TsCl (85 mg) was added, and the mixture was stirred at r.t. for 1 h. After this time, the mixture was washed with a 2% aq. soln. of HCl and extracted with CH_2Cl_2. The org. extract was neutralized with sat. aq. soln. of $NaHCO_3$, dried (Na_2SO_4), filtered, and evaporated to dryness. SiO_2 CC yielded **40** (13 mg, 72%) [15].

*[(4a*S*,8a*S*)-3,4,4a,5,6,7,8,8a-Octahydro-2,5,5,8a-tetramethylnaphthalen-1-yl]methyl Trifluoroacetate* (**41**). Compound **39** (30 mg, 0.13 mmol) was dissolved in CH_2Cl_2/pyridine 3:1 (10 ml), $(CF_3CO)_2O$ (220 µl, 0.16 mmol) was added, and the mixture was stirred at $-20°$ for 3 h. After this time, the mixture was washed with a 2% aq. soln. of HCl and extracted three times with CH_2Cl_2. The org. layer was neutralized with sat. aq. soln. of $NaHCO_3$, dried (Na_2SO_4), and filtered. The soln. was evaporated, and the residue purified with SiO_2 CC to yield **41** (42 mg, 99%). Colorless oil. ^{1}H-NMR (300 MHz, $CDCl_3$): 4.90 (*dd*, *J* = 12.0, 15.1, 2 H); 1.71 (*s*, 3 H); 1.01 (*s*, 3 H); 0.93 (*s*, 3 H); 0.88 (*s*, 3 H). ^{13}C-NMR ($CDCl_3$): 18.8 (CH_2); 18.9 (Me); 19.6 (Me); 20.8 (Me); 21.6 (Me); 29.8 (C); 33.2 (Me); 33.9 (CH_2); 36.5 (CH_2); 37.9 (C); 41.6 (CH_2); 51.3 (CH); 64.4 (CH_2); 132.9 (C); 138.1 (C). FAB-MS (pos.): 349.1646 ($[M-CF_3]^+$), 363.2343 ($[M-CF_3+Na]^+$).

Treatment of **41** *with KCN.* KCN (14 mg, 0.21 mmol) was added to a soln. of compound **41** (25 mg, 0.07 mmol) in MeCN (10 ml), and the mixture was stirred for 3 h at 130°. Then, the mixture was washed with H_2O and extracted three times with CH_2Cl_2. The org. extract was dried (Na_2SO_4), filtered, and the soln. was concentrated in vacuum. Purification with SiO_2 CC gave **40** (10 mg, 69%).

*[(4a*S*,8a*S*)-3,4,4a,5,6,7,8,8a-Octahydro-2,5,5,8a-tetramethylnaphthalen-1-yl]acetonitrile* (**42**). A soln. of $BF_3 \cdot Et_2O$ (0.02 ml, 3 equiv.) and cyano(trimethyl)silane (0.03 ml, 4 equiv.) in CH_2Cl_2 (0.22 ml) was added to a soln. of **41** (11 mg, 0.05 mmol) in CH_2Cl_2 (0.5 ml) at $-10°$, and the mixture was stirred for 1 h. Then, a sat. aq. soln. of $NaHCO_3$ was added, and the mixture was stirred for further 45 min at r.t. The mixture was extracted with CH_2Cl_2, and the org. layer was washed with a 1N aq. soln. of HCl, neutralized with sat. aq. soln. of $NaHCO_3$, dried (Na_2SO_4), filtered, and the soln. was concentrated in vacuum. The residue was purified with SiO_2 CC to yield **40** (3 mg, 23%) and **42** (7 mg, 58%). Colorless oil each. ^{1}H-NMR (300 MHz, $CDCl_3$): 3.14 (*d*, *J* = 12.0, 2 H); 1.61 (*s*, 3 H); 1.01 (*s*, 3 H); 0.99 (*s*, 3 H); 0.86 (*s*, 3 H). ^{13}C-NMR (75 MHz, $CDCl_3$): 18.8 (CH_2); 18.9 (CH_2); 19.1 (Me); 21.9 (Me); 22.9 (Me); 23.4 (CH_2); 31.6 (CH_2); 32.1 (C); 32.9 (Me); 35.3 (C); 36.3 (CH_2); 41.3 (CH_2); 49.0 (CH); 118.2 (CN); 124.6 (C); 142.5 (C). HR-MS: 254.1882 ($[M+Na]^+$, $C_{16}H_{25}NNa^+$; calc. 254.1885).

*2-[(4a*S*,8a*S*)-3,4,4a,5,6,7,8,8a-Octahydro-2,5,5,8a-tetramethylnaphthalen-1-yl]ethanol* (**43**). To a soln. of **42** (40 mg, 0.17 mmol) in toluene (10 ml), a 1M soln. of DIBALH in toluene (0.34 ml, 0.34 mmol) was added, and the mixture was stirred at $-78°$ for 1.5 h. After this time, the mixture was diluted with a 2N aq. soln. of HCl, and then extracted with CH_2Cl_2. The solvent was evaporated at reduced pressure, the residue was redissolved in i-PrOH (4 ml), and $NaBH_4$ (6 mg) was added, and the mixture was stirred at r.t. for 2 h. A sat. aq. soln. of $NaHSO_4$ was added, and the mixture was extracted with CH_2Cl_2. The org. layer was dried (Na_2SO_4), filtered, and the soln. was concentrated under reduced pressure. The solid residue was purified with SiO_2 CC to afford **43** (31 mg, 78%) [22].

*Methyl (4a*S*,8a*S*)-1,3,4,5,6,8a-Hexahydro-8-(hydroxymethyl)-2,2,7-trimethylnaphthalene-4a(2*H*)-carboxylate* (**44**). Compound **33** (50 mg, 0.19 mmol) was dissolved in i-PrOH, $NaBH_4$ (7 mg) was added, and the mixture was stirred at r.t. for 3 h. The excess of reagent was destroyed with sat. aq. soln. of $NaHSO_4$, and the mixture was extracted with CH_2Cl_2. The org. layer was dried (Na_2SO_4), filtered, and the soln. was concentrated under reduced pressure. The solid residue was purified with SiO_2 CC to give **44** (49 mg, 98%) [18].

*Methyl (4a*S*,8a*S*)-8-({[*tert*-Butyl(dimethyl)silyl]oxy}methyl)-1,3,4,5,6,8a-hexahydro-2,2,7-trimethylnaphthalene-4a(2*H*)-carboxylate* (**45**). Compound **44** (20 mg, 0.075 mmol) was dissolved in pyridine

(5 ml), and TBDMSCl (22 mg, 0.15 mmol) was added. The mixture was stirred at r.t. for 12 h. After this time, it was washed with a 1M aq. soln. of HCl and extracted with CH_2Cl_2. The org. extract was neutralized with sat. aq. soln. of $NaHCO_3$, dried (Na_2SO_4), filtered, and the soln. was concentrated under reduced pressure. Purification with SiO_2 CC yielded **45** (25 mg, 89%). Colorless oil. $[\alpha]_D^{20} = +16$ ($c = 1$, $CHCl_3$). IR ($CHCl_3$): 2951, 2857, 1730, 830. ^{1}H-NMR (300 MHz, $CDCl_3$): 4.30 (*d*, $J = 11.0$, 1 H); 3.97 (*d*, $J = 11.0$, 1 H); 3.60 (*s*, 3 H); 2.74 (*dd*, $J = 4.6, 12.8$, 1 H); 1.68 (*s*, 3 H); 0.89 (*s*, 3 H); 0.84 (*s*, 3 H); 0.03 (*s*, 3 H); 0.02 (*s*, 3 H). ^{13}C-NMR (75 MHz, $CDCl_3$): −5.4 (2 Me); 18.4 (C); 19.7 (Me); 22.7 (CH_2); 24.1 (Me); 26.0 (3 Me); 29.8 (CH_2); 30.1 (C); 31.4 (CH_2); 32.0 (Me); 32.9 (CH); 34.0 (CH_2); 36.4 (CH_2); 44.9 (C); 51.8 (Me); 66.9 (CH_2); 126.8 (C); 132.2 (C); 178.4 (C). HR-MS: 403.2597 ($[M+Na]^+$, $C_{22}H_{40}NaO_3Si^+$; 403.2644).

*[(4a*S*,8a*R*)-3,5,6,7,8,8a-Hexahydro-2,7,7-trimethylnaphthalene-1,4a(4*H*)-diyl]dimethanol* (**46**). Compound **45** (25 mg, 0.06 mmol) was dissolved in THF, 2 ml of a 1M soln. of $LiAlH_4$ in THF were added, and the mixture was stirred at reflux for 1 h. After that, the mixture was diluted with CH_2Cl_2, the org. layer was washed with H_2O, dried (Na_2SO_4), and the soln. was evaporated to dryness. Purification over SiO_2 gave **46** (12 mg, 78%) [18].

*Methyl (4a*S*,8a*S*)-1,3,4,5,6,8a-Hexahydro-2,2,7-trimethyl-8-[(tetrahydro-2*H*-pyran-2-yloxy)methyl]-naphthalene-4a(2*H*)-carboxylate* (**49**). A soln. of **44** (80 mg, 0.3 mmol), 3,4-dihydro-2*H*-pyran (DHP; 0.14 ml, 1.5 mmol), and a cat. amount of TsOH in CH_2Cl_2 (8 ml) was stirred at r.t. for 1.5 h. Then, the mixture was successively washed with sat. aq. soln. of $NaHCO_3$, H_2O, and brine. The org. layer was dried (Na_2SO_4), filtered, and the solvent was evaporated under reduced pressure to give a yellow oil, which was purified with SiO_2 CC, to give the mixture of diastereoisomers **47**.

*Data of Methyl 1,3,4,5,6,8a-Hexahydro-2,2,7-trimethyl-8-[(tetrahydro-2*H*-pyran-2-yloxy)methyl]-naphthalene-4a(2*H*)-carboxylate* (**47**): HR-MS: 373.2201 ($[M+Na]^+$, $C_{21}H_{34}NaO_4^+$; calc. 373.2355).

The mixture of diastereoisomers **47** (76 mg, 0.24 mmol) was reduced with a 1M soln. of $LiAlH_4$ (0.3 ml) in THF at r.t. for 3 h to yield a mixture of diastereoisomers **48**.

*Data of {1,3,4,5,6,8a-Hexahydro-2,2,7-trimethyl-8-[(tetrahydro-2*H*-pyran-2-yloxy)methyl]naphthalen-4a(2*H*)-yl}methanol* (**48**): HR-MS: 345.2508 ($[M+Na]^+$, $C_{20}H_{34}NaO_3^+$; calc. 345.2406).

Finally, the mixture of diastereoisomers **48** (40 mg, 0.12 mmol) was dissolved in dried THF (20 ml), and NaH (31 mg, 1.24 mmol) was added. The mixture was stirred under reflux for 3 h. After this time, CS_2 (228 µl) was added, after 30 min, MeI (118 µl) was added, and the mixture was stirred under reflux for 1 h. After that, the mixture was diluted with CH_2Cl_2, the org. layer was washed with H_2O, dried (Na_2SO_4), filtered, and the soln. was evaporated to dryness. Purification over SiO_2 gave the diastereoisomeric mixture **49**.

Data of Tetrahydro-2-{[3,4,4a,5,6,7,8,8a-Octahydro-2,7,7-trimethyl-4a-{[(2-methyl-1λ^6,2λ^4-disulfyn-1-ylidyne)methoxy]methyl}naphthalen-1-yl]methoxy}-2 H-pyran (**49**): HR-MS: 435.2755 ($[M+Na]^+$, $C_{22}H_{36}NaO_3S_2^+$; calc. 435.2004). These three transformations were also followed by the ^{1}H-NMR spectra of diastereoisomeric mixtures of **47**, **48**, and **49**.

*[(4a*R*,8a*R*)-3,4,4a,5,6,7,8,8a-Octahydro-2,4a,7,7-tetramethylnaphthalen-1-yl]methanol* (**50**). Xanthate **49** (50 mg, 0.12 mmol) was dissolved in dioxane (5 ml), and Et_3N (0.03 ml, 0.3 mmol), H_3PO_2 (0.1 ml, 0.9 mmol), and a soln. of AIBN (15 mg) in dioxane (3 ml) were added, and the mixture was stirred under reflux for 3 h. Then, it was diluted with CH_2Cl_2, the org. layer was washed with H_2O, dried (Na_2SO_4), and the soln. was evaporated to dryness. Purification with SiO_2 CC yielded **50** (39 mg, 58% from **44**), which had physical and spectroscopic data identical to those given in [40].

REFERENCES

[1] Dictionary of Natural Products on CD-ROM, ver. 5 : 1, Chapman and Hall, 1996.
[2] H. Assefa, A. Nimrod, L. Walker, R. Sindelar, *Bioorg. Med. Chem. Lett.* **2001**, *11*, 1619.
[3] Y. Kashiwada, T. Nagao, A. Hashimoto, Y. Ikeshiro, H. Okabe, L. M. Cosentino, K.-H. Lee, *J. Nat. Prod.* **2000**, *63*, 1619.
[4] F. Mengoni, M. Lichtner, L. Battinelli, M. Marzi, C. M. Mastroianni, V. Vullo, G. Mazzanti, *Planta Med.* **2002**, *68*, 111.

[5] A. Garcia-Granados, A. Martinez, A. Parra, F. Rivas, PCT Int. Appl. W0 98 04331; *Chem Abstr.* **1998**, *128*, 179706.
[6] H. Matsuda, Y. Pongpiriyadacha, T. Morikawa, Y. Kashima, K. Nakano, M. Yoshikawa, *Bioorg. Med. Chem. Lett.* **2002**, *12*, 477.
[7] M. G. Bolster, B. J. M. Jansen, A. de Groot, *Tetrahedron* **2002**, *58*, 5275.
[8] J. M. Castro, S. Salido, J. Altarejos, M. Nogueras, A. Sánchez, *Tetrahedron* **2002**, *58*, 5941.
[9] T. Akihisa, J. Ogihara, J. Kato, K. Yasukawa, M. Ukiya, S. Yamanouchi, K. Oishi, *Lipids* **2001**, *36*, 507.
[10] A. F. Barrero, S. Arseniyadis, J. F. Quílez del Moral, M. M. Herrador, A. Rosellón, *Synlett* **2005**, 789.
[11] B. J. M. Jansen, A. de Groot, *Nat. Prod. Rep.* **1991**, *8*, 309.
[12] B. J. M. Jansen, A. de Groot, *Nat. Prod. Rep.* **2004**, *21*, 449.
[13] J. G. Urones, I. S. Marcos, B. Gómez Pérez, D. Díez, A. M. Lithgow, P. M. Gómez, P. Basabe, N. M. Garrido, *Tetrahedron* **1994**, *50*, 10995.
[14] A. F. Barrero, E. J. Alvarez-Manzaneda, R. Chahboun, *Tetrahedron* **1998**, *54*, 5635.
[15] A. Parra, F. Rivas, P. E. Lopez, A. Garcia-Granados, A. Martinez, F. Albericio, N. Marquez, E. Muñoz, *Bioorg. Med. Chem.* **2009**, *17*, 1139.
[16] A. García-Granados, P. E. López, E. Melguizo, A. Parra, Y. Simeó, *J. Org. Chem.* **2007**, *72*, 3500.
[17] A. García-Granados, P. E. López, E. Melguizo, A. Parra, Y. Simeó, *Tetrahedron* **2004**, *60*, 1491.
[18] A. García-Granados, P. E. López, E. Melguizo, A. Parra, Y. Simeó, *Tetrahedron* **2004**, *60*, 3831.
[19] A. García-Granados, P. E. López, E. Melguizo, A. Parra, Y. Simeó, *Synth. Commun.* **2006**, *36*, 3001.
[20] A. García-Granados, J. Dueñas, J. N. Moliz, A. Parra, F. L. Perez, J. A. Dobado, J. Molina, *J. Chem. Res., Miniprint* **2000**, 326.
[21] A. García-Granados, J. Dueñas, E. Melguzio, J. N. Moliz, A. Parra, F. L. Perez, J. A. Dobado, J. Molina, *J. Chem. Res., Miniprint* **2000**, 653.
[22] B. Schönecker, M. Reichenbächer, S. Gliesing, M. Gonschior, S. Griebenow, D. Scheddin, H. Mayer, *Steroids* **1998**, *63*, 28.
[23] D. H. Hua, X. Huang, Y. Chen, S. K. Battina, M. Tamura, S. K. Noh, S. I. Koo, I. Namatame, H. Tomoda, E. M. Perchellet, J.-P. Perchellet, *J. Org. Chem.* **2004**, *69*, 6065.
[24] A. V. Kurdyumov, R. P. Hsung, *J. Am. Chem. Soc.* **2006**, *128*, 6272.
[25] A. F. Barrero, J. M. Cuerva, E. J. Alvarez-Manzaneda, J. E. Oltra, R. Chahboun, *Tetrahedron Lett.* **2002**, *43*, 2793.
[26] M. Moolenaar, P. A. Desmond, D. J. Mascord, G. A. Starmer, B. Tattam, E. R. Volkerts, *Hum. Psychopharmacol.* **1999**, *14*, 415.
[27] M. B. Yunker, P. J. Scheuer, *J. Am. Chem. Soc.* **1978**, *100*, 307.
[28] A. Pommier, V. Stepanenko, K. Jarowicki, P. J. Kocienski, *J. Org. Chem.* **2003**, *68*, 4008.
[29] R. L. Snowden, J. C. Eichenberger, S. M. Linder, P. Sonnay, C. Vial, K. H. Schulte-Elte, *J. Org. Chem.* **1992**, *57*, 955.
[30] C. Tsangarakis, M. Stratakis, *Adv. Synth. Catal.* **2005**, *347*, 1280.
[31] R. A. Sheldon, J. K. Kochi, *Org. React.* **1972**, *19*, 279.
[32] T. Oritani, K. Yamashita, *Agric. Biol. Chem.* **1987**, *51*, 1271.
[33] E. J. Cochrane, S. W. Lazer, J. T. Pinhey, J. D. Whitby, *Tetrahedron Lett.* **1989**, *30*, 7111.
[34] I. Razmilic, J. Sierra, J. Lopez, M. Cortes, *Chem. Lett.* **1985**, 1113.
[35] S. V. Ley, P. L. Toogood, *Chem. Br.* **1990**, *26*, 31.
[36] I. C. Coste-Manière, J. P. Zahra, B. Waegell, *Tetrahedron Lett.* **1988**, *29*, 1017.
[37] P. Martres, P. Perfetti, J.-P. Zahra, B. Waegell, E. Giraudi, M. Petrzilka, *Tetrahedron Lett.* **1993**, *34*, 629.
[38] H. Hagiwara, F. Takeuchi, M. Nozowa, T. Hoshi, T. Suzuki, *Tetrahedron* **2004**, *60*, 1983.
[39] A. A. Vestegen-Haaksma, H. J. Swarts, B. J. M. Jansen, A. de Groot, *Tetrahedron* **1994**, *50*, 10095.
[40] E. E. Van Tamelen, M. P. Seiler, W. Wierenga, *J. Am Chem. Soc.* **1972**, *94*, 8229.

Received February 1, 2009