Chemical Transformations of Phyllocladane (=13*β*-Kaurane) Diterpenoids

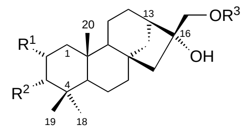
by **Gui Liu**, **Ralph Müller**, and **Peter Rüedi***

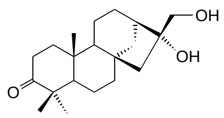
Organisch-chemisches Institut der Universität Zürich, Winterthurerstrasse 190, CH-8057 Zürich

Earlier phytochemical work on *Plectranthus ambiguus* (Lamiaceae) afforded a series of tetracyclic phyllocladane-type (=13*β*-kaurane) diterpenoids (see **1a–f**). In the course of investigations concerning the reaction behavior of this rare natural-products, a new constituent of *P. ambiguus* was isolated, (2*S*,3*R*,16*R*)-phyllocladane-2,3,16,17-tetrol 2,3-diacetate (**1g**), and another eighteen new phyllocladanes were prepared by chemical transformations and characterized. The main constituent **1b** of *P. ambiguus* was chemically transformed to the known natural diterpenoid calliterpenone (=(16*R*)-16,17-dihydroxyphyllocladan-3-one; **2**) thus unambiguously establishing its structure (*Scheme 1*). Epimerization at C(16) *via* the epoxy derivative **20** yielded 16-epicalliterpenone (**21**), 17-hydroxyphylloclad-15-ene-3-one (**22**), and (16*R*)-3-oxophyllocladan-17-al (**23**) (*Scheme 6*). Comparing this reaction sequence with the corresponding one starting from diastereoisomeric (16*R*)-16,17-dihydroxy-*ent*-kauran-3-one (=abbeokutone; **27**) showed basically the same outcome (*Scheme 7*). Furthermore, three new C(16)-substituted *ent*-kauran-3-ones were characterized.

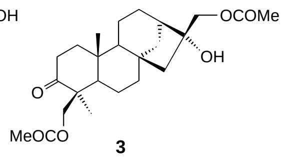
Reliable spectroscopic arguments for the determination of the configuration at C(16) in phyllocladanes and kauranes as well as for the differentiation of the diastereoisomeric skeletons are presented.

1. Introduction. – In connection with our research program concerning the isolation and synthesis of genuine constituents of African and Asian *Lamiaceae* species of the genera *Coleus*, *Plectranthus*, and *Solenostemon* with respect to antioxidants, inhibitors of the arachidonate metabolism, and allergens [1], we had reported on the isolation and structure elucidation of a series of tetracyclic diterpenoids of the phyllocladane-type (=13*β*-kaurane) from *Plectranthus ambiguus*, *i.e.* **1a–f** [2].





2



3

1a R^1 = R^3 = H, R^2 = OCOMe
b R^1 = OCOCH=C(Me)$_2$, R^2 = OCOMe, R^3 = H
c R^1 = OCOCH$_2$C(Me)$_2$, R^2 = OCOMe, R^3 = H
d R^1 = OCOCH=C(Me)$_2$, R^2 = R^3 = OCOMe
e R^1 = OCOCH$_2$C(Me)$_2$, R^2 = R^3 = OCOMe
f R^1 = OCOCH=C(Me)$_2$, R^2 = O, R^3 = H
g R^1 = R^2 = OCOMe, R^3 = H

Phyllocladane-type diterpenoids are very rare in nature as by far most of the tetracyclic diterpenoids belong to the diastereoisomeric *ent*-kaurane series. The scarcity of relevant data of phyllocladanes and the fact that misinterpretations and confusion concerning the correct denomination exist in the current literature[1]) prompted us to confirm the structures of the new natural products, which were based only on spectroscopic data. Therefore, the main constituent **1b** of *P. ambiguus* was chemically transformed to the known natural diterpenoid (16*R*)-16,17-dihydroxyphyllocladan-3-one (=calliterpenone; **2**) from *Callicarpa macrophylla* [3][2])[3]). Earlier we had isolated the closely related (16*R*)-17,19-bis(acetyloxy)-16-hydroxyphyllocladan-3-one (**3**) from *Plectranthus purpuratus* [5]. The constitution of **3** had been established by X-ray-analysis and the absolute configuration assigned by CD spectroscopy. Therefore, the successful chemical conversion of **3** to calliterpenone (**2**) assures an additional, independent confirmation of the structure of **1b**.

In the course of our investigations, a new natural product, (2*S*,3*R*,16*R*)-phyllocladane-2,3,16,17-tetrol 2,3-diacetate (**1g**), was isolated, and the chemical transformations of **1a**–**f** yielded a series of new phyllocladanes. Thus, the actual number of representatives of this skeletal type is significantly increased[4]). In this report, we give a full account of these interconversions, which yielded also some unexpected results [7]. Moreover, reliable spectroscopic arguments for the determination of the configuration at C(16) in phyllocladanes and kauranes as well as for the differentiation of such diastereoisomers are presented.

Because of the continuing confusion and to clear any inconsistencies and discrepancies concerning the denomination and the nomenclature, the correct skeletons and a part of the semisystematic numbering (C(19) is always axial!) are depicted in *Fig. 1*[5]).

2. Results and Discussion. – 2.1. *Transformation of* **1b** *and* **3** *into Calliterpenone* (**2**). First, **1b** was protected by forming the acetonide **4** [2] (*Scheme 1*), which was then treated with $LiAlH_4$ to yield the $2\alpha,3\alpha$-diol **5**. Tosylation of **5** furnished exclusively the mono-tosylate **6**. Subsequently, reaction of **6** with $LiAlH_4$ afforded the unexpected 3β-hydroxy acetonide **7** [7], which was oxidized with pyridinium chlorochromate (PCC)

---

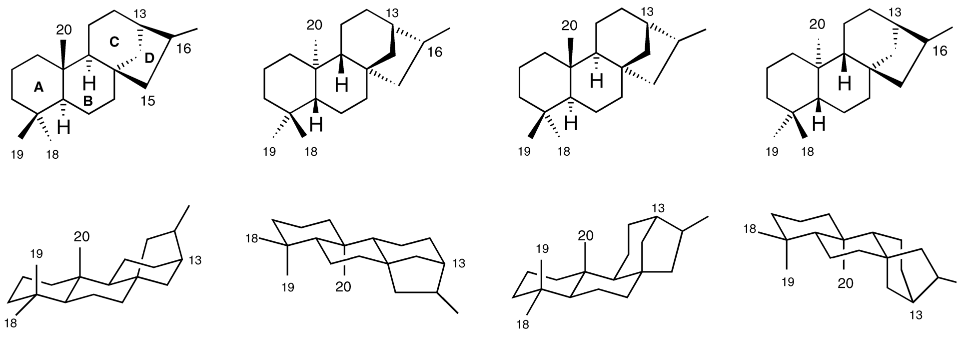
1) For recent examples of inadequacies, see, *e.g.* [3].

2) The history of the structure elucidation of calliterpenone (**2**) is typical of the problems encountered with these diastereoisomeric skeletons. Originally, an erroneous *ent*-kaurane structure had been assigned to **2** [4a]. It was revised in terms of a phyllocladane by chemical transformations [4b], and the revision was confirmed including the determination of the absolute configuration [4c]. Later the relative configuration was verified again by X-ray-analysis [4d].

3) Although the most straightforward route to ketone **2** is a simple transformation of the minor compound **1a**, the main constitutent **1b** was chosen since it allowed broader studies of the chemical reactivity of such phyllocladanes.

4) Only eleven phyllocladanes had been characterized [4][6] when the structures of **3** [5] and, later, **1a**–**f** [2] were disclosed.

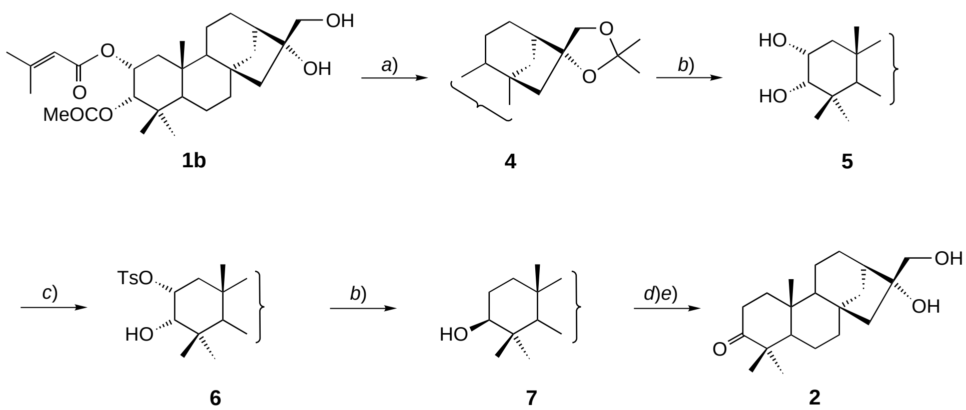
5) An alternative, applicable name for 'phyllocladane' is '13β-kaurane'. The term indicates the relative position of the 5-membered ring D (C(15)–C(16)) on the same side as the C(10)–C(20) bond. Unfortunately, the skeletons are sometimes not differentiated; in particular, phyllocladanes are mixed up with *ent*-kauranes. Moreover, as the prefix '*ent*' inverts all the following descriptors, the enantiomer of (2*S*,3*R*,16*R*)-phyllocladane-2,3,16,17-tetrol 2,3-diacetate (=(2*S*,3*R*,16*R*)-13β-kaurane-2,3,16,17-tetrol 2,3-diacetate; **1g**) must be called either *ent*-(2*S*,3*R*,16*R*)-phyllocladane-2,3,16,17-tetrol 2,3-diacetate (=*ent*-(2*S*,3*R*,16*R*)-13β-kaurane-2,3,16,17-tetrol 2,3-diacetate; *ent*-**1g**) or (2*R*,3*S*,16*S*)-*ent*-phyllocladane-2,3,16,17-tetrol 2,3-diacetate (=(2*R*,3*S*,16*S*)-13α-*ent*-kauran-2,3,16,17-tetrol 2,3-diacetate; *ent*-**1g**).



A Phyllocladane **B** *ent*-Phyllocladane **C** Kaurane **D** *ent*-Kaurane

Fig. 1. *Structures corresponding to the names phyllocladane* (**A**), ent-*phyllocladane* (**B**), *kaurane* (**C**), *and* ent-*aurane* (**D**). Note that *Chem. Abstr.* designates **D** with (16*S*) configuration as kaurane, this name implying (5β,8α,9β,10α,13α,16β) configuration as defined by *Chem. Abstr.*; the *Chem. Abstr.* name of **A** with (16*S*) configuration is thus (5α,9α,10β)-kaurane, and that of **B** with (16*S*) configuration is (8β,13β)-kaurane.

Scheme 1

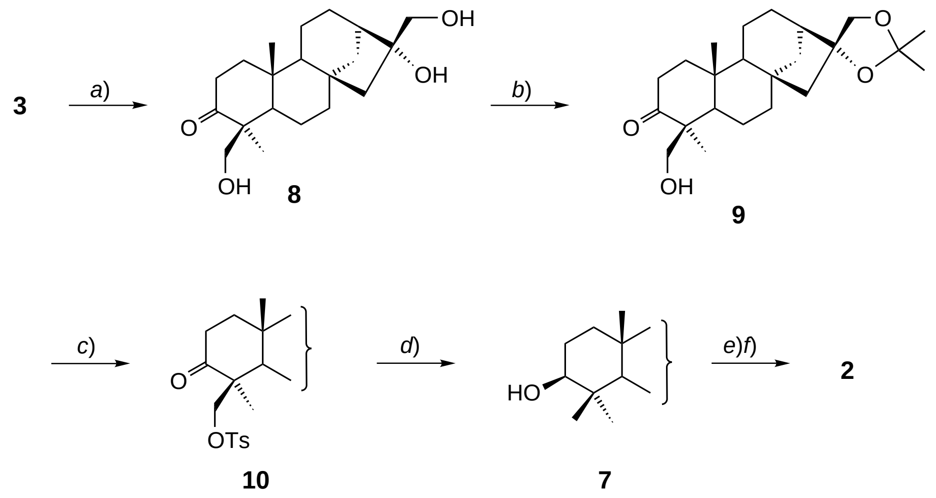


a) Acetone, anh. $CuSO_4$, refl.; 95%. *b*) $LiAlH_4$, THF, r.t.; **4** (94%); **7** (90%). *c*) TsCl, pyridine, r.t.; 92%. *d*) PCC, NaOAc, CH_2Cl_2, r.t. *e*) 2% H_2SO_4, MeOH, 70°; 91% (*d*) and *e*)).

and then hydrolyzed to the 16,17-dihydroxy ketone **2** (calliterpenone). Comparison of semisynthetic **2** with authentic calliterpenone (**2**) showed both compounds to be identical (TLC, m.p., mixed m.p., $[\alpha]_D$, CD, IR, ^{1}H- and ^{13}C-NMR, MS).

A very similar route was followed for transforming **3** to calliterpenone (**2**) (*Scheme 2*). As ketone **3** is prone to *retro*-aldol reactions, the most unefficient step in the sequence was the neat removal of the acetate groups to yield the trihydroxy ketone **8**. The tosylate **10**, prepared from the correspondig acetonide **9**, was then treated with $LiAlH_4$ to afford the 3β-hydroxy acetonide **7**, identical to that derived from **6**. It is remarkable that the analogous reduction of a related tosylate without the 3-oxo group yielded only traces of the desired hydrocarbon as the nucleophilic reaction almost

Scheme 2

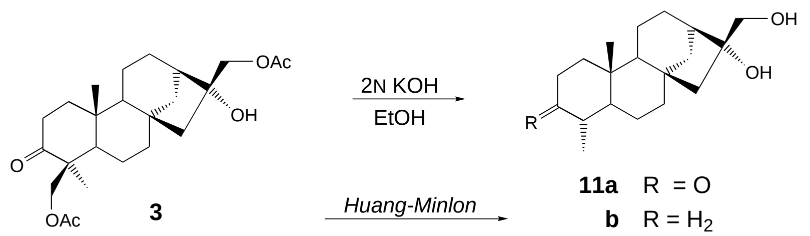


a) 5% H_2SO_4, EtOH, r.t.; 33%. *b*) Acetone, anh. $CuSO_4$, refl.; 89%. *c*) TsCl, pyridine, r.t.; 88%. *d*) $LiAlH_4$, THF, r.t.; 84%. *e*) PCC, NaOAc, CH_2Cl_2, r.t. *f*) 2% H_2SO_4, MeOH, 70°, 3 h; 83% (*e*) and *f*)).>

exclusively took place at the S-atom [6d]. This fact demonstrates that the reactivity of ring A in such diterpenoids strongly depends on its conformation. Usual oxidation and hydrolysis of the acetal yielded calliterpenone (**2**), identical in every respect to both the natural sample and that obtained from **1b**.

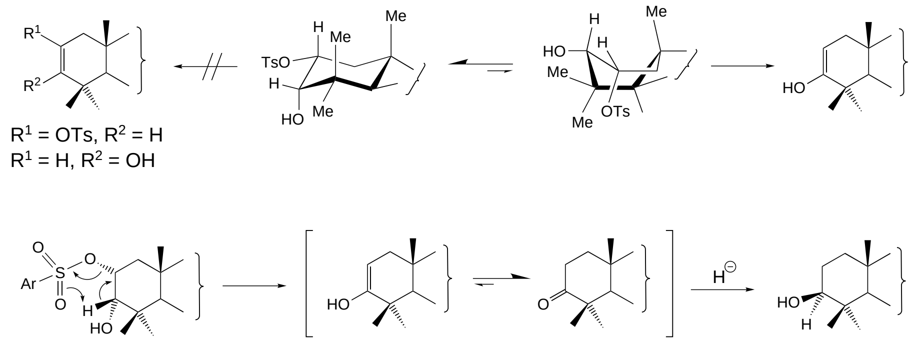
2.2. retro-*Aldol Reaction of* **3**. The natural product **3** was mentioned to undergo *retro*-aldol cleavage easily. This was exemplified by the basic hydrolysis leading to the 19-nor compound **11a** as well as by the attempted reduction according to *Huang-Minlon* to give **11b** (*Scheme 3*). The equatorial position of the remaining Me(18) group was established from its original orientation and by the coupling characteristics of **11a** (see *Exper. Part*). Both the unfavorable 1,3-diaxial interaction of the CH_2OAc group with Me(20) and its stereoelectronically optimal arrangement with the C(3) carbonyl group are the driving forces for the *retro*-aldol reaction.

Scheme 3



2.3. *Transformation of the 2α,3α-Dioxy-Substituted Derivative* **6** *to the 3β-Hydroxy Compound* **7**. The unexpected one-pot transformation **6** → **7** (*Scheme 1*) appears to proceed *via* an elimination yielding an enol(ate) and stereospecific reduction of the corresponding ketone. However, loss of TsOH in terms of an *E*2 mechanism is only feasible when ring A adopts the boat conformation; moreover, H–C(3) is less acidic than H–C(2) and is not expected to be abstracted primarily. But an alternative mechanism can be formulated in terms of an electrocyclic elimination of TsOH and hydride reduction from the less hindered 'α-side', as depicted in *Scheme 4*. Although the stereoelectronic requirements for ideal orbital overlap are neither given in this approach, an intramolecular six-membered ring transition state might be entropically favored.

Scheme 4



The proposed mechanisms were supported to some extent by the fact that **6** reacted with $LiAlD_4$ to generate exclusively the (3α-D) compound **12** and by the reactivity of the bis(methanesulfonate) derivative **13**. The results obtained from the reaction of **13** with $LiAlH_4$ (*Scheme 5*) seem to support the *E*2 mechanism: The predominant product is the 2β-alcohol **14** which, is easily formed from the favorable chair conformation, whereas the 3β-alcohol **7** that would be generated from the disfavored boat form or by the cyclic mechanism is only a minor product. Moreover, a minor amount of the starting diol **5** is regenerated due to nucleophilic reaction at the S-atom of the methanesulfonate groups. A full account on the elucidation of the mechanism is reported in the following paper [7].

With regard to the characterization of further potential phyllocladane-type natural product, (2*R*,3S,16*R)*-phyllocladane-2,3,16,17-tetrol (**15**), (3*S*,16*R*)-phyllocladane-3,16,17-triol (**18**)[6]), (2*R*,16*R)*-phyllocladane-2,16,17-triol (**16**), and (16R*)*-16,17-trihydroxyphyllocladan-2-one (**17**) were prepared from **5**[7]), **7**, and **14** by hydrolysis and/or oxidation (*Scheme 5* and *Exper. Part*)[8]).

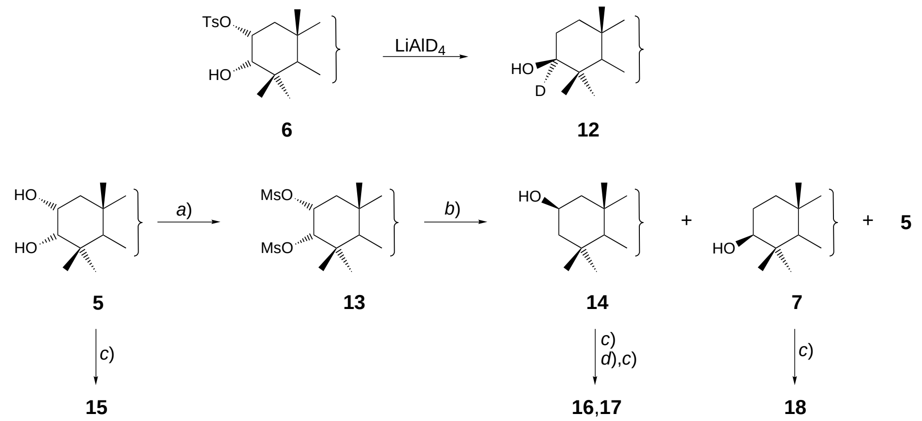
2.4. *Epimerization of Calliterpenone* (**2**). Inversion of the configuration at C(16) of **2** was attempted by the route depicted in *Scheme 6*. The tosylate **19** was treated under

[6]) The (3*S*,16*R*)-phyllocladanetriol **18** has been obtained by either microbiological or $NaBH_4$ reduction of **2** [3b]. The structure depicted in [3b] is a kaurane (see *Fig. 1*), and the physical data are not consistent.

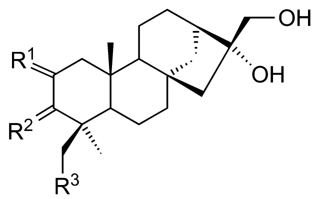
[7]) The tetrol **15** was also prepared from natural **1b** by $LiAlH_4$ reduction (see *Exper. Part*).

[8]) Until now, these compounds have not been isolated from natural sources.

Scheme 5



a) $MeSO_2Cl$, pyridine, r.t.; 88%. *b*) $LiAlH_4$, THF, r.t.; **5** (10%), **7** (10%), **14** (65%). *c*) 2% H_2SO_4, MeOH, 70°. *d*) PCC, NaOAc, CH_2Cl_2, r.t.

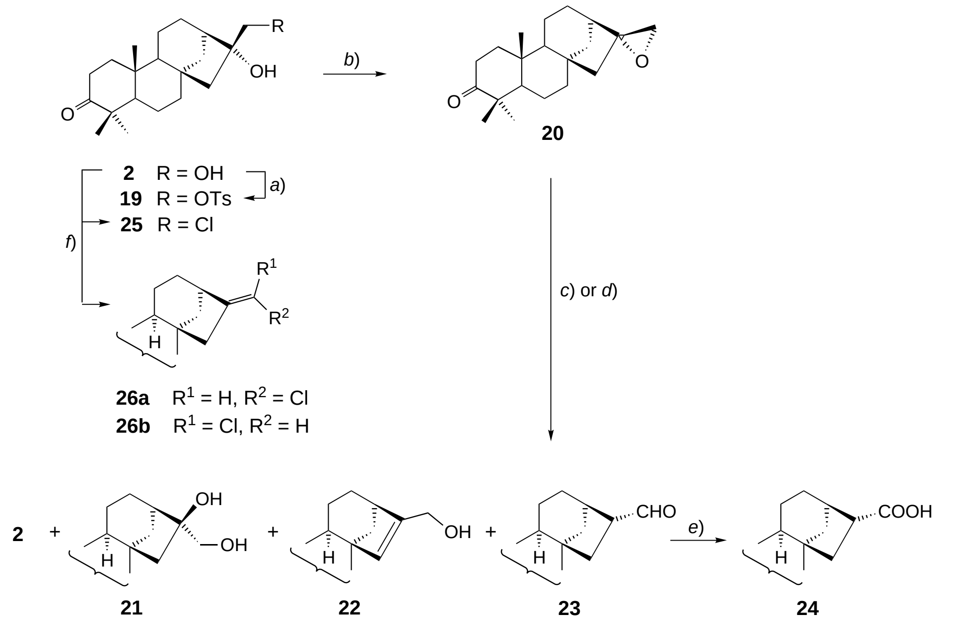


15 $R^1 = R^2 = \alpha$-OH,β-H, R^3 = H
16 $R^1 = \alpha$-H,β-OH, $R^2 = H_2$, R^3 = H
17 R^1 = O, $R^2 = H_2$, R^3 = H
18 $R^1 = H_2$, $R^2 = \alpha$-H,β-OH, R^3 = H
33 $R^1 = H_2$, $R^2 = \alpha$-OH,β-H, R^3 = H
34 $R^1 = \alpha$-OH,β-H, $R^2 = \alpha$-H,β-OH, R^3 = H
35 $R^1 = H_2$, $R^2 = \alpha$-H,β-OH, R^3 = OH

basic conditions to yield the epoxyphyllocladanone **20**, which was opened by dilute acid (5% H_2SO_4/H_2O) to afford the desired (16*S*)-epimer **21**, besides the regenerated epimeric calliterpenone (**2**) and the elimination product 17-hydroxyphylloclad-15-en-3-one (**22**) as the main products.

When epoxy derivative **20** was treated with 60% $HClO_4/H_2O$ [8], the main product was (16*R*)-3-oxophyllocladan-17-al (**23**) besides **22** and traces of **2** and its (16*S*)-epimer **21**. Upon standing in solution, **23** was spontaneously oxidized to (16*R*)-3-oxophyllocladan-17-oic acid (**24**).

Scheme 6



a) TsCl, pyridine, r.t.; 91%. *b*) K_2CO_3, MeOH, r.t.; 91%. *c*) 60% $HClO_4$, THF, r.t.; **2** and **21** (trace), **22** (4%), **23** (60%). *d*) 5% H_2SO_4, THF, r.t.; **2** (42%), **21** (5%), **22** (30%), **23** (0%). *e*) $CDCl_3/O_2$ (71%). *f*) TsCl, pyridine, refl.; **25** (87%), **26a/26b** (11%).

The structure of the substituted-ring-D moiety of **20**–**24** was supported by corresponding ^{1}H- and ^{13}C-NMR data (see *Exper. Part*). The (16*R*)-configuration of **23** was established by the chemical shift and coupling characteristics of H–C(17): It appeared at δ 9.65 (*d*, $^3J(17,16) = 1.7$ Hz). H–C(17) was reported to resonate at δ 9.45 as a *s* in (16*S*)-phyllocladan-17-al [9][9]).

All attempts to improve the yield of 16-epicalliterpenone (**21**; (16*S*)) were not satisfactory, obviously due to the fact that the required backside attack of the nucleophile (H_2O) is sterically hindered[10]).

2.5. *Chlorophyllocladanones* **25**, **26a**, *and* **26b**. In the course of the attempted preparation of tosylate **19**, unexpected reaction products were found (*Scheme 6*). When **2** was treated with excess *p*-toluenesulfonyl chloride in pyridine under reflux, the main compounds were (16*R*)-17-chloro-16-hydroxyphyllocladan-3-one (**25**) and the

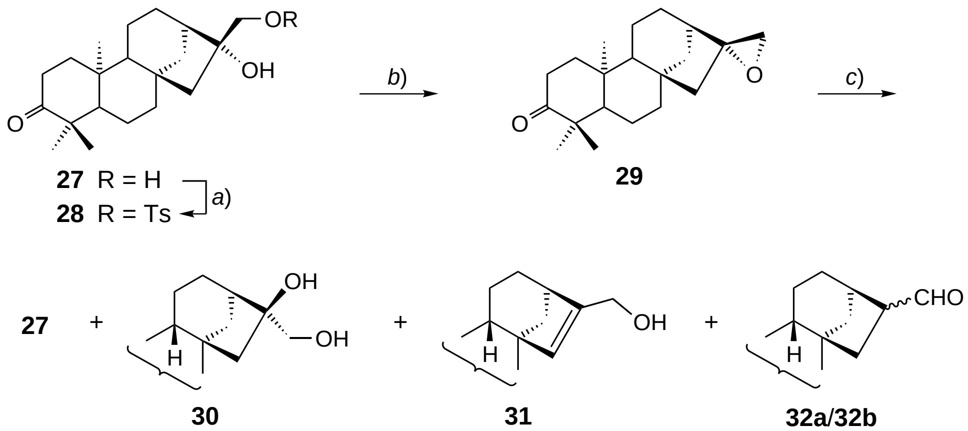
[9]) Reaction of **2** with borontrifluoride etherate was reported to yield (16*S*)-3-oxophyllocladan-17-al [10]. However, the ^{1}H-NMR data show H–C(17) at δ 9.6 (*d*, $^3J = 2$ Hz), and there is no comment on the determination of the configuration at C(16). Therefore, our report presents the first unambiguous characterization of **23**.

[10]) Under acidic conditions, the protonated epoxy moiety can either react by an S_N1 or S_N2 mechanism. In S_N1 mechanisms, which favor tertiary C-atoms, attack is expected at the more highly substituted C-atom. When protonated epoxides react by the S_N2 mechanism, attack is usually at the more highly substituted position. In neutral or basic solution, attack of the nucleophile will rather take place at the less highly substituted C-atom [8].

(16*E*)- and (16*Z*)-17-chlorophylloclad-16-en-3-ones (**26a** and **26b**, resp.) as an unseparable (*E*)/(*Z*)-mixture (2:1). Their structures were established by their MS and NMR data (see *Exper. Part*).

2.6. *Epimerization of (16*R*)-16,17-Dihydroxy-*ent*-kauran-3-one* (**27**). To compare the reactivities of phyllocladane- and kaurane-type diterpenoids, the *ent*-kauranone **27** (abbeokutone) [11] was subjected to the same series of reactions (*Scheme 7*). The tosylate **28** yielded the epoxy-*ent*-kauranone **29**[11]), which was opened by dilute acid (5% H_2SO_4/H_2O) to furnish the expected (16*S*)-epimer **30**[12]) and 17-hydroxy-*ent*-kaur-15-en-3-one (**31**)[11]). The predominant products were abbeokutone (**27**), (16*R*)-3-oxo-*ent*-kauran-17-al (**32a**) and (16*S*)-3-oxo-*ent*-kauran-17-al (**32b**) as a *ca.* 1:1 mixture[13]).

Scheme 7



a) TsCl, pyridine, r.t.; 95%. *b*) K_2CO_3, MeOH, r.t.; 95%. *c*) 5% H_2SO_4, THF, r.t.; **27** (4%), **30** (38%), **31** (22%), **32a/32b** (33%).

In the ^{1}H-NMR spectrum of **32a**, H−C(17) appeared at δ 9.67 (*d*, $^3J(17,16) = 1.7$ Hz), and that of **32b** at δ 9.89 (*s*, H−C(17)). As H−C(17) of (16*R*)-3-oxo-*ent*-kauran-17-al was reported to resonate at δ 9.65 (*d*, $^3J(17,16) = 1.2$ Hz) [13], the respective assignments are consistent (see also the argumentation for **23**)[14]).

2.7. *New Phyllocladane-Type Diterpenoids.* The (2*S*,3*R*,16*R*)-phyllocladane-2,3,16,17-tetrol 2,3-diacetate (**1g**) was detected in a fraction from *Plectranthus ambiguus* containing **1f**, and its structure was assigned by ^{1}H-NMR data. Acetalization of the mother liquor of **1f** resulted in an easy separation of the acetonide of **1g**, which

---

[11]) (16*R*)-16,17-Epoxy-*ent*-kauran-3-one (**29**) and 17-hydroxy-*ent*-kaur-15-en-3-one (**31**) are new compounds and characterized for the first time.

[12]) The 16-epiabbeokutone (**30**; (16*S*)) has been isolated first from *Euphorbia sieboldiana* [12a], later from *Homalanthus acuminatus* [12b], *Sapium rigidifolium* [12c], and *Euphorbia portulacoides* together with its 17-acetate [12d].

[13]) (16*S*)-3-Oxo-*ent*-kauran-17-al (**32b**) is a new compound, whereas (16*R*)-3-oxo-*ent*-kauran-17-al (**32a**) has been characterized as a reaction product of (16*R*)-17-hydroxy-*ent*-kauran-3-one [13].

[14]) Due to the enhanced flexibility of the kaurane skeleton (see below), the couplings between H−C(16), $CH_2(15)$, *etc.*, are not resolved.

was carefully hydrolyzed to afford the unknown genuine compound **1g** (for data, see *Exper. Part*). Further proof for the structure was obtained by the preparation of **1g** from **1b** *via* **5** (see *Scheme 1*), acetylation, and selective hydrolysis.

In addition to the new compounds **8** (*Sect. 2.1* and *Scheme 2*) and **15**–**18** (*Sect. 2.3* and *Scheme 5*), three further new phyllocladane derivatives were prepared, in view of the characterization of potential natural products: reduction of **1a**, **1f**, and **8** afforded **33**, **34**, and **35**, respectively (*Formulae* in *Sect. 2.3*).

The data of the nineteen new phyllocladanes **1g**, **8**, **11a**, **11b**, **15**–**18**, **20**–**26a**,**b**, and **33**–**35** and of the three new *ent*-kauran-3-ones **29**, **31**, and **32b** are presented in the *Exper. Part*.

2.8. *Determination of the Configuration at C(16) of Phyllocladane- and Kaurane-16,17-diols.* From the *ent*-kaurane series, it is known that the configuration at C(16) can be determined by using the ^{1}H- and ^{13}C-NMR-data of the 16,17-dihydroxy-*ent*-kauran-3-ones **27** and **30** and of the *ent*-kauran-16,17-diols **36** and **37** [12a,b][14]: In the (16*R*)-series (see **27** and **36**), CH_2(17) and C(16) are deshielded ($\Delta\delta$ *ca.* +0.3 and *ca.* +2 ppm, resp.), whereas C(17) is shielded ($\Delta\delta$ *ca.* −4 ppm) with respect to the (16*S*)-diastereoisomers (see **30** and **37**) ($\Delta\delta = \delta(16R) - \delta(16S)$; see *Fig. 2*). Comparing the spectral data of calliterpenone (**2**; (16*R*)) with that of the new 16-epicalliterpenone (**21**; (16*S*)) now established that the same set of arguments is valid in the phyllocladane series (*Fig. 2*). In addition, it seems to apply also to the corresponding 17-(acetyloxy) derivatives as shown for the relevant pair **3** (δ (16*R*); 4.19 and 4.26 and (16*S*)-17-(acetyloxy)-16-hydroxy-*ent*-kauran-3-one [12d] (δ 3.91 and 4.05).

2.9. *NMR-Spectroscopic Differentiation between Phyllocladanes and Kauranes.* Differences were worked out on very closely related compounds such as the phyllocladane-type calliterpenone (**2**) and the *ent*-kaurane-type abbeokutone (**27**) (see *Fig. 2*). A general feature that fundamentally differentiates the diastereoisomers is the enhanced flexibility of the kaurane skeleton, a fact that generally results in well-resolved ^{1}H-NMR spectra of the phyllocladanes compared to the *ent*-kauranes. Thus, in calliterpenone (**2**), CH_2(2) appears as a complex *ABXY* system at δ 2.38 (*ddd*, ^2J = 15.8 Hz, ^3J(2eq,1ax) = 7.1, ^3J(2eq,1eq) = 4.1, H_{eq}–C(2)) and 2.52 (*ddd*, ^2J = 15.8 Hz, ^3J(2ax,1ax) = 10.8, ^3J(2ax,1eq) = 7.2, H_{ax}–C(2)), but in abbeokutone (**27**), CH_2(2) is a *dd* at δ 2.47 (2 H, ^3J = 8.6, 6.3 Hz). Moreover, in the *ent*-kaurane derivative **27**, Me(18) and Me(20) are indistinguishable (*s* at δ 1.09 (6 H)), whereas they appear as 2 *s* at δ 1.08 (Me(18)) and 1.03 (Me(20)) in **2**. A further example is (16*R*)-3-oxophyllocladan-17-al (**23**), which afforded easily interpretable spectra, whereas the corresponding (16*R*)- and (16*S*)-3-oxo-*ent*-kauran-17-als (**32a**/**32b**) showed only poorly resolved ones[14]).

Concerning the relevance of ^{13}C-NMR data, *Wenkert* and co-workers stated in an early paper that only the chemical shifts of C(14), C(16), and C(20) are of relevant diagnostic value for the differentiation between phyllocladanes and kauranes [15]. However, as only phylloclad-15-ene and phylloclad-16-ene (**38**) could be directly compared with *ent*-kaur-16-ene (**39**) at that time, the significance might be moderate. The availability of recent data now clearly supports this statement (*Fig. 2*). In addition, also C(13) is shielded in the phyllocladane series ($\Delta\delta$ *ca.* −2 ppm); but this shielding intereferes in the 16,17-dioxy compounds where the influence of the *O*-substituents is

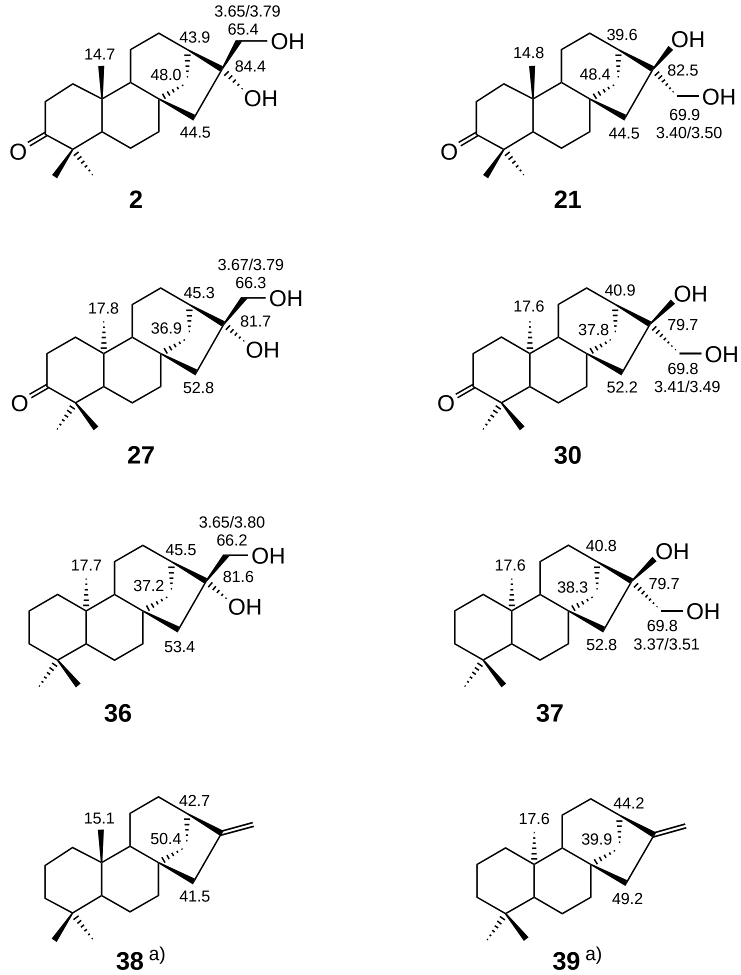


Fig. 2. *Diagnostic relevant NMR chemical shifts* ($CDCl_3$) *of selected phyllocladanes and* ent-*kauranes.* ^{1}H-NMR at 400 MHz, ^{13}C-NMR at 100.6 MHz. [a]) Values taken from [15].

predominant, and it is only reliable when closely related pairs (*e.g.*, **2**/**27** and **38**/**39**) are compared[15]). However, the most-significant value is C(20): Due to the absence of the extra δ-effect from C(12), the angular Me(20) group is shielded in the phyllocladanes and resonates at exceptionally high field (δ *ca.* 15)[16]).

---

[15]) C(13) is an additional probe for the configuration at C(16) in the 16,17-dioxy-substituted compounds as it is shielded in the (16*S*) series ($\Delta\delta$ *ca.* -4 ppm).

[16]) It was the crucial argument that enabled the discovery of the new phyllocladanes **1a**–**f**. Before discarding the not antioxidant fraction of *P. ambiguus* [2], its ^{13}C-NMR indicated a particular Me group at high field.

In recent times, a similar attempt has been made to correlate spectral data and configurational assignments of kauranoids [3c,d]. But the reports are a source of confusion of terms, compound types, and inconsistent conclusions[17]).

3. Remark. – Our recent investigations significantly increased the number of new phyllocladanes. Contrary to the situation in the kauranes, where the *ent*-series is predominant (*ca.* 95%), all phyllocladanes hitherto known belong to the 'normal' series, as no single enantiomer has been evidenced. 'hoffmanniaketone', a tetracyclic diterpenoid isolated from *Hoffmannia strigillosa*, together with its 17-(acetyloxy) derivative, was originally assigned the structure of (16*R*)-16,17-dihydroxy-*ent*-phyllocladan-3-one (*ent*-**2**) [16], and the absolute configuration was based on chiroptical data. However, thorough spectral comparison with calliterpenone (**2**) clearly showed the identity of the two compounds, including their congruent CD spectra[18]). As a consequence, the constituent of *Hoffmannia strigillosa* is calliterpenone (**2**) and the name 'hoffmanniaketone' has to be withdrawn from the literature.

The authors are indebted to the *Swiss National Science Foundation* for the financial support and to the analytical department of our institute for the MS and the *AMX-600* and *DRX-600* NMR spectra. Thanks are due to Prof. Dr. *T. Komori*, Osaka, Japan, for the generous gift of valuable reference samples.

Experimental Part

1. *General.* TLC: *Merck-60F₂₅₄* silica gel plates; detection by UV_{254} light or by spraying with 'mostain' solution ($(NH_4)_6Mo_7O_{24} \cdot 4\ H_2O$ (40 g), $Ce(SO_4)_2$ (0.8 g), 10% H_2SO_4 soln. (800 ml)) and heating (blue spots). Column chromatography (CC): *Merck* silica gel *60* (40 – 63 μm). M.p.: *Mettler FP 5/52*; not corrected. $[\alpha]_D$: *Perkin-Elmer-241-MC* polarimeter with thermostat *B. Braun Thermomix 1441*; 10-cm cell. UV: *Perkin-Elmer-Lambda-9*-UV/VIS/NIR spectrophotometer; λ_{max} (log ε) in nm. CD: *JASCO-J-500A* spectropolarimeter; λ ($\Delta\varepsilon$) in nm. IR: *Perkin-Elmer-1600*-FT-IR spectrometer; in cm^{-1}. ^1H- and ^{13}C-NMR: *Bruker-AC-300* or *-ARX-300* (300 and 75.4 MHz, resp.), *-AMX-400* (400 and 100.6 MHz, resp.), *-DRX-500* (500 and 125.7 MHz, resp.), *-AMX-600* or *-DRX-600* (600 and 150.9 MHz, resp.) spectrometers; chemical shifts δ in ppm rel. to the assigned solvent ($Me_4Si = 0$ ppm), coupling constants J in Hz; all assignments are based on extensive interpretations of ^1H,^1H-COSY, DEPT90, DEPT135, ^{13}C,^1H-COSY (HSQC), and ^{13}C,^1H-long-range (HMBC) experiments; spin-systems are interpreted according to 1st-order approximation, although in several complex cases significant *AB* character shows higher-order spectra; H_β–C(15) specifies the H-atom pointing to C(20). GC/MS: *Hewlett-Packard HP-5980* series *II* (GC), *HP-5971 MSD* (mass-selective detector, EI; 70 eV), column *HP-5*, 25 m × 0.2 mm, 0.33 μ; injector at 180°, detector at 330°; temp. program: 150° (2 min), 100° → 240° (rate 30°/min), 290° (5 min). MS: *Varian MAT 112s* and *Varian MAT 90* for electron impact (EI; 70 eV); *Varian MAT 7011* and *Finnigan MAT SSQ 700* for chemical ionization (CI) with NH_3, unless otherwise stated; *Finnigan MAT TSQ 7000* for electrospray ionization (ESI).

2. *Extraction of* P. ambiguus: *Phyllocladanes* **1a – g**. Air-dried leaves and stems of *P. ambiguus* (500 g) were extracted with hexane (3 l) at r.t. (20 h) and then re-extracted (4 ×) with Et_2O (each 2.5 l, 16 h). The hexane extract was evaporated to give a green semi-solid (6 g, 1.71%). CC (hexane/AcOEt 1:1) yielded **1b** (330 mg), **1c** (170 mg), and the inseparable *ca.* 6:1 mixture **1d/1e** (390 mg). Analogous treatment of the Et_2O extract afforded a green gum (18 g, 3.6%) which was purified by CC (hexane/AcOEt 1:1) to yield *Fractions A* (containing **1a – d**) and *B* (containing further **1b** and **1c**). After further CC and crystallization according to [2],

17) Unfortunately, the correct structure of 16-epiabbeokutone (**30**; (16*S*)) [12a] was erroneously revised due to the misapplication of the authors' own arguments [3c].

18) The CD spectrum of calliterpenone (**2**) shows a positive *Cotton* effect at 289 nm. This can be rationalized by the established *anti*-octant effect for the 8β-methyl group in 3-oxo triterpenes [17], see also [4c].

the following amounts of pure known compounds were isolated: **1a** (520 mg, 0.1%), **1b** (2.77 g, 0.55%), **1c** (1.45 g, 0.29%), **1d/1e** *ca.* 6:1 (390 mg, 0.08%), and **1f** (1.35 g, 0.27%)[19]).

*(2*S*,3*R*,16*R*)-Phyllocladane-2,3,16,17-tetrol 2,3-Diacetate* (**1g**). The mother liquor of **1f** contained an additional, unseparable genuine compound that was supposed to be a phyllocladane-2,3,16,17-tetrol diacetate according to ^{1}H-NMR. Preparation of the 16,17-acetonide (acetone, anh. $CuSO_4$, see *Exper. 7*) from the mother liquor of **1f** allowed the CC separation (toluene/AcOEt 12:1) of the new compound as an acetonide: ^{1}H-NMR (300 MHz, $CDCl_3$): 5.21 (*ddd*, ^3J(2,1ax) = 12.5, ^3J(2,1eq) = 4.5, ^3J(2,3) = 2.8, H–C(2)); 4.96 (*d*, ^3J(2,3) = 2.8, H–C(3)); 4.07, 3.90 (*AB*, ^2J = 8.6, CH_2(17)); 2.25 (*dd*, ^2J = 14.5, ^4J(15β,14ax) = 2.0, H_β–C(15)); 2.12, 1.97 (each *s*, 2 COMe); 1.38, 1.35 (each *s*, $Me_2C(O)_2$); 0.99, 0.98, 0.86 (each *s*, Me(18), Me(19), Me(20)).

The soln. of the acetonide (20 mg) in THF (0.5 ml) and 2% H_2SO_4 soln. (0.5 ml) was stirred at r.t. (20 h). Workup and CC (hexane/AcOEt 10:1) of the residue gave **1g** (10 mg, 41%). Colorless viscous oil. $[\alpha]_D^{20} = -2.6$ (*c* = 0.43, $CHCl_3$). IR ($CHCl_3$): 3568, 2942, 2875, 1734, 1457, 1375, 1261, 1156, 1034, 865, 806. ^{1}H-NMR (500 MHz, $CDCl_3$): 5.21 (*ddd*, ^3J(2,1ax) = 12.5, ^3J(2,1eq) = 4.5, ^3J(2,3) = 2.8, H–C(2)); 4.96 (*d*, ^3J(3,2) = 2.8, H–C(3)); 3.77, 3.62 (*AB*, ^2J = 8.9, CH_2(17)); 2.12, 1.97 (each *s*, 2 COMe); 1.00 (*s*, Me(20)); 0.98 (*s*, Me(18)); 0.87 (*s*, Me(19)). ^{13}C-NMR (125.7 MHZ, $CDCl_3$): 170.8, 170.7 (*C*OMe); 84.7 (C(16)); 68.2 (C(2)); 65.8 (C(17)); 56.5 (C(9)); 50.5 (C(5)); 48.6 (C(14)); 45.2 (C(15)); 44.1 (C(13)); 43.8 (C(8)); 41.2 (C(7)); 39.2 (C(10)); 38.3 (C(4)); 38.1 (C(1)); 28.2 (C18)); 26.8 (C(12)); 21.9 (C(19)); 21.3, 21.2 (CO*Me*); 19.6 (2C, C(6), C(11)); 15.9 (C(20)). ESI-MS (MeOH/CH_2Cl_2/NaI): 445 (100, $[M + Na]^+$).

An identical compound **1g** was also obtained from **1b** *via* **5** (see below) after acetylation and hydrolysis. The real content of **1g** in *P. ambiguus* could not be determined; it is estimated to be *ca.* 60 mg (0.01%).

3. *(2*R*,3*S*,16*R*)-16,17-(Isopropylidenedioxy)phyllocladane-2,3-diol 3-Acetate 2-(3-Methylbut-2-enoate)* (**4**). Preparation from **1b** and physical data, see [2].

4. *(2*R*,3*S*,16*R*)-16,17-(Isopropylidenedioxy)phyllocladane-2,3-diol* (**5**). $LiAlH_4$ (100 mg) was added to a soln. of **4** (61 mg) in abs. THF (8 ml) and stirred at r.t. (20 min). Then, EtOH and H_2O were added and some dil. H_2SO_4 soln. to dissolve the precipitate. The soln. was extracted with Et_2O, the org. phase washed with H_2O, dried ($MgSO_4$), and evaporated, and the residue purified by CC (CH_2Cl_2/MeOH 24:1) to yield a white solid that was crystallized from Et_2O/CH_2Cl_2: **5** (43 mg, 94%). White flakes. M.p. 188–190°. IR (KBr): 3200–3600 (br.), 2980, 2938, 2860, 1556, 1540, 1454, 1382, 1370, 1250, 1214, 1148, 1065, 1035, 992, 945, 926, 890, 860, 842, 806, 715, 670, 618. ^{1}H-NMR (300 MHz, $CDCl_3$): 4.07, 3.90 (*AB*, ^2J = 8.6, CH_2(17)); 3.98 (*ddd*, ^3J(2ax,1ax) = 12.4, ^3J(2ax,1eq) = 4.5, ^3J(2ax,3eq) = 2.7, H_{ax}–C(2)); 3.42 (*d*, ^3J(3eq,2ax) = 2.7, H_{eq}–C(3)); 2.24 (*dd*, ^2J = 12.4, ^4J(15β,14α) = 2.0, H_β–C(15)); 1.38, 1.34 (each *s*, $Me_2C(O)_2$); 1.01 (*s*, Me(20)); 0.91 (*s*, Me(18)); 0.85 (*s*, Me(19)). CI-MS (2-methylpropane): 379 (37, $[M + H]^+$), 362 (23), 361 (85, $[M + H - H_2O]^+$), 343 (16, $[361 - H_2O]^+$), 304 (17), 303 (100, $[361 - \text{acetone}]^+$), 286 (16), 285 (70, $[343 - \text{acetone}]^+$), 273 (15).

5. *(2*R*,3*S*,16*R*)-16,17-(Isopropylidenedioxy)phyllocladane-2,3-diol 2-(4-Methylbenzenesulfonate)* (**6**). TsCl (95 mg) was added to a soln. of **5** (70 mg) in abs. pyridine (4 ml). The mixture was stirred at r.t. (24 h), then H_2O was added. The mixture was extracted with Et_2O, the org. phase washed with H_2O, dried ($MgSO_4$), and evaporated, and the residue separated by CC (hexane/AcOEt 1:1): **6** (93 mg, 94%). White solid. M.p. 81–84°. IR (KBr): 3300–3600 (br.), 2985, 2935, 2870, 1600, 1560, 1545, 1455, 1370, 1245, 1215, 1190, 1180, 1125, 1100, 1060, 1000, 930, 920, 900, 840, 815, 745, 665. ^{1}H-NMR (300 MHz, $CDCl_3$): 7.81, 7.37 (*AA'BB'*, *J* = 8.2, arom. H); 4.86 (*ddd*, ^3J(2ax,1ax) = 9.4, ^3J(2ax,1eq) = 7.2, ^3J(2ax,3eq) = 2.5, H_{ax}–C(2)); 3.46 (*d*, ^3J(3eq,2ax) = 2.5, H_{eq}–C(3)); 4.05, 3.88 (*AB*, ^2J = 8.6, CH_2(17)); 2.47 (*s*, *Me*C_6H_4); 1.38, 1.34 (each *s*, $Me_2C(O)_2$); 0.97 (*s*, Me(20)); 0.85 (*s*, Me(18)); 0.80 (*s*, Me(19)). EI-MS: 532 (0.6, $M^{+\bullet}$), 517 (6, $[M - Me]^+$), 436 (7), 346 (9), 345 (33, $[517 - TsOH]^+$), 331 (7), 289 (27), 285 (62), 267 (11), 159 (13), 147 (22), 145 (16), 137 (12), 135 (15), 133 (22), 131 (11), 123 (16), 121 (20), 119 (20), 117 (11), 114 (13), 109 (27), 107 (32), 105 (25), 43 (100).

6. *(16*R*)-16,17,19-Trihydroxyphyllocladan-3-one* (**8**). A soln. of the natural product **3** (100 mg) in EtOH (5 ml) and 5% H_2SO_4 soln. (5 ml) was stirred at r.t. (15 h). As TLC still showed starting material, the mixture was refluxed at *ca.* 70° (4 h). H_2O was added, the mixture extracted with Et_2O, the org. phase washed with H_2O, dried ($MgSO_4$), and evaporated, and the white solid separated by CC (CH_2Cl_2/MeOH 24:1 → 9:1): **8** (26 mg, 33%). Colorless prisms (from CH_2Cl_2/MeOH). M.p. 162–164°. $[\alpha]_D^{20} = -4.4$ (*c* = 0.3, MeOH). IR (KBr): 3200–3500 (br.), 2930, 2850, 1705, 1455, 1435, 1385, 1315, 1260, 1190, 1130, 1095, 1070, 1045, 980, 916, 875, 750, 715, 690, 640. ^{1}H-NMR (300 MHz, CD_3OD): 4.00, 3.46 (*AB*, ^2J = 11.3, CH_2(19)); 3.70, 3.58 (*AB*, ^2J = 8.5, CH_2(17)); 2.71 (*ddd*, ^2J = 15.1, ^3J(2ax,1ax) = 13.4, ^3J(2ax,1eq) = 6.4, H_{ax}–C(2)); 2.25 (*ddd*, ^2J = 15.1, ^3J(2eq,1ax) = 5.2, ^3J(2eq,1eq) = 3.0, H_{eq}–C(2)); 1.14 (*s*, Me(18)); 1.12 (*s*, Me(20)). CI-MS: 354 (42,

---

[19]) The yield of **1f** could be improved as compared to the reported value (0.13%) [2].

$[M+NH_4]^+$), 337 (9), 336 (30, $M^{+\bullet}$), 325 (23), 324 (100), 323 (14, $[M+NH_4-CH_2OH]^+$), 322 (26, $[M+NH_4-MeOH]^+$), 306 (23, $[324-H_2O]^+$), 292 (19, $[324-MeOH]^+$).

7. *(16*R*)-19-Hydroxy-16,17-(isopropylidenedioxy)phyllocladan-3-one* (**9**). To a soln. of **9** (32 mg) in abs. acetone (4 ml) anh. $CuSO_4$ (50 mg) was added and the mixture refluxed under N_2 (6 h). The $CuSO_4$ was filtered off, the filtrate evaporated, and the residue purified by CC (CH_2Cl_2/MeOH 100:1 → 9:1): **9** (23 mg, 89%). Colorless solid. M.p. 212–214°. ^{1}H-NMR (300 MHz, $CDCl_3$): 4.07, 3.91 (*AB*, $^2J=8.6$, $CH_2(17)$); 3.92, 3.42 (*AB*, $^2J=11.2$, $CH_2(19)$); 2.92 (br. *s*, OH–C(19)); 2.57 (*ddd*, $^2J=16.1$, ^3J(2ax,1ax) = 9.1, ^3J(2ax,1eq) = 4.8, H_{ax}–C(2)); 2.40 (*ddd*, $^2J=16.1$, ^3J(2eq,1ax) = ^3J(2eq,1eq) = 8, H_{eq}–C(2)); 2.18 (*dd*, $^2J=14.5$, $^4J(15\beta,14\alpha)=2.0$, H_β–C(15)); 2.01 (*m*, H–C(13)); 1.39, 1.35 (each *s*, $Me_2C(O)_2$); 1.26 (*s*, Me(18)); 0.91 (*s*, Me(20)). CI-MS (2-methylpropane): 377 (100, $[M+H]^+$), 361 (8), 320 (17), 319 (80, $[M+H-\text{acetone}]^+$), 306 (9), 271 (5).

8. *(16*R*)-16,17-(Isopropylidenedioxy)-19-{[(4-methylphenyl)sulfonyl]oxy}phyllocladan-3-one* (**10**). A soln. of TsCl (40 mg) and **9** (15 mg) in abs. pyridine (2 ml) was stirred at r.t. (15 h). Then, H_2O was added, the mixture extracted with Et_2O, the org. phase washed with H_2O, dried ($MgSO_4$), and evaporated, and the residue separated by CC (CH_2Cl_2): **10** (19 mg, 86%). White solid. M.p. 60–64°. ^{1}H-NMR (300 MHz, $CDCl_3$): 7.75, 7.35 (*AA′BB′*, $J=8.2$, arom. H), 4.31, 3.98 (*AB*, $^2J=10$, $CH_2(19)$); 4.07, 3.90 (*AB*, $^2J=8.6$, $CH_2(17)$); 2.46 (*s*, MeC_6H_4); 2.37 (*m*, $CH_2(2)$); 2.19 (*dd*, $^2J=14.5$, $^4J(15\beta,14\alpha) < 1$, H_β–C(15)); 2.00 (*m*, H–C(13)); 1.41, 1.36 (each *s*, $Me_2C(O)_2$); 1.08 (*s*, Me(18)); 0.94 (*s*, Me(20)). EI-MS: 530 (2, $M^{+\bullet}$), 515 (7, $[M-Me]^+$), 283 (22), 137 (11), 121 (15), 91 (10).

9. *(3*S*,16*R*)-16,17-(Isopropylidenedioxy)phyllocladan-3-ol* (**7**). To a soln. of **6** (70 mg) in abs. THF (5 ml) was added $LiAlH_4$ (60 mg). The mixture was stirred at r.t. under N_2 (1 h). Workup as described in *Exper. 4* and CC (CH_2Cl_2) yielded **7** (43 mg, 90%). White solid.

An identical compound **7** (11 mg, 84%) was isolated after analogous treatment of **10** (18 mg) with $LiAlH_4$ (20 mg). M.p. 151–153°. IR (KBr): 3500, 2985, 2940, 2860, 1558, 1540, 1455, 1382, 1368, 1250, 1212, 1150, 1105, 1056, 1032, 1012, 982, 916, 890, 858, 842, 805, 735, 715. ^{1}H-NMR (400 MHz, $CDCl_3$): 4.06, 3.90 (*AB*, $^2J=8.6$, $CH_2(17)$); 3.20 (*dd*, ^3J(3,2ax) = 10.9, ^3J(3,2eq) = 4.4, H–C(3)); 2.25 (*dd*, $^2J=14.6$, $^4J(15\beta,14\alpha)=2.2$, H_β–C(15)); 1.99 (*m*, H–C(13)); 1.39, 1.34 (each *s*, $Me_2C(O)_2$); 0.98 (*s*, Me(18)); 0.87 (*s*, Me(20)); 0.77 (*s*, Me(19)). ^{1}H-NMR (400 MHz, C_5D_5N): 4.16, 4.00 (*AB*, $^2J=8.6$, $CH_2(17)$); 3.45 (*m*, $w_{1/2}=25$, H–C(3)); 2.28 (*dd*, $^2J=14.4$, $^4J(15\beta,14\alpha)=2.0$, H_β–C(15)); 2.07 (*m*, H–C(13)); 1.71 (*d*, $^2J=14.4$, H_α–C(13)); 1.51, 1.44 (each *s*, $Me_2C(O)_2$); 1.22 (*s*, Me(18)); 1.04 (*s*, Me(19)); 0.88 (*s*, Me(20)). EI-MS: 362 (4, $M^{+\bullet}$), 348 (15), 347 (84, $[M-Me]^+$), 329 (7, $[347-H_2O]^+$), 287 (10, $[M-OH-\text{acetone}]^+$), 269 (100, $[287-H_2O]^+$), 161 (17), 147 (18), 135 (22), 121 (19), 109 (19), 107 (19), 105 (17).

10. *(16*R*)-16,17-Dihydroxyphyllocladan-3-one* (= *Calliterpenone*; **2**). A soln. of **7** (31 mg) in abs. CH_2Cl_2 (0.5 ml) was added in one portion to a well-stirred suspension of PCC (39 mg) and a trace of NaOAc in abs. CH_2Cl_2 (0.5 ml). The mixture was stirred at r.t. under dry N_2 (2.5 h). Then, abs. Et_2O was added and the supernatant liquid decanted from a black tar. The insoluble residue was washed with abs. Et_2O (3×), the combined org. soln. passed through silica gel (Et_2O), the solvent evaporated, and the white solid residue subsequently dissolved in MeOH (3 ml) and 2% H_2SO_4 soln. (1 ml). The mixture was heated at *ca.* 70° (3 h). After cooling to r.t., H_2O was added, the mixture extracted with Et_2O, the org. layer washed with H_2O, dried ($MgSO_4$), and evaporated, and the white residue purified by CC (CH_2Cl_2 → CH_2Cl_2/MeOH 100:1): **2** (25 mg, 91%). White needles (from MeOH).

An analogous treatment of **7** (13 mg) that was derived from **3** yielded **2** (9 mg, 83%). M.p. 156–158°. $[\alpha]_D^{20}=+33.5$ ($c=0.24$, $CHCl_3$). CD (MeOH, $c=8.75\cdot10^{-4}$ M): 235 (0), 289 (+0.62), 315 (0), 321 (−0.06), 340 (0). IR (KBr): 3450–3400 (br.), 3330, 2970, 2930, 2860, 1705, 1558, 1540, 1480, 1454, 1438, 1415, 1385,1350, 1315, 1248, 1208, 1192, 1162, 1138, 1130, 1118, 1095, 1072, 1054, 1035, 1020, 1005, 985, 962, 940, 918, 872, 836, 700, 672, 655. ^{1}H-NMR (400 MHz, $CDCl_3$): 3.79, 3.65 (*AB*, $^2J=10.9$, $CH_2(17)$); 2.52 (*ddd*, $^2J=15.8$, ^3J(2ax,1ax) = 10.8, ^3J(2ax,1eq) = 7.2, H_{ax}–C(2)); 2.38 (*ddd*, $^2J=15.8$, ^3J(2eq,1ax) = 7.1, ^3J(2eq,1eq) = 4.1, H_{eq}–C(2)); 2.12–2.04 (*m*, H_β–C(15), H_{eq}–C(14)); 1.94–1.83 (*m*, H_{eq}–C(1), H_{eq}–C(7), H_{eq}–C(12), H–C(13)); 1.08 (*s*, Me(18)); 1.03 (*s*, Me(20)); 1.00 (*s*, Me(19)). ^{13}C-NMR (100.6 MHz, $CDCl_3$): 217.8 (C(3)); 84.4 (C(16)); 65.4 (C(17)); 55.7, 55.2 (C(5), C(9)); 48.0 (C(14)); 47.3 (C(4)); 44.5 (C(15)); 43.9 (C(13)); 43.4 (C(8)); 40.6(C(7)); 38.1 (C(1)); 37.1 (C(10)); 33.9 (C(2)); 26.7 (C(18)); 26.6 (C(12)); 21.5 (C(19)); 21.2, 19.6 (C(6), C(11)); 14.7 (C(20)). CI-MS (2-methylpropane): 321 (74, $[M+H]^+$), 304 (17), 303 (100, $[M+H-H_2O]^+$), 285 (19, $[303-H_2O]^+$).

Comparison of the dihydroxy ketones **2** derived from both **1b** and **3** with an authentic sample of the natural product calliterpenone (**2**) proved the compounds to be identical (TLC, m.p., mixed m.p., $[\alpha]_D$, CD, IR, ^{1}H- and ^{13}C-NMR, CI-MS).

11. *(16*R*)-16,17-Dihydroxy-19-norphyllocladan-3-one* (**11a**). A soln. of **3** (22 mg) in EtOH (2.5 ml) and 2N KOH (1 ml) was heated at 70° (3 h). Then, H_2O was added, the mixture extracted with Et_2O, the Et_2O phase washed with H_2O, dried ($MgSO_4$), and evaporated, and the residue purified by CC (CH_2Cl_2/MeOH 93 : 7): **11a** (11 mg, 65%). White solid. M.p. 180–183°. $[\alpha]_D^{20} = +16.7$ ($c = 0.15$, $CHCl_3$). IR (KBr): 3200–3600 (br.), 2935, 2860, 1705, 1557, 1540, 1453, 1385, 1300, 1245, 1184, 1132, 1070, 1040, 1016, 980, 912, 870, 732, 675, 645. ^{1}H-NMR (400 MHz, $CDCl_3$): 3.79, 3.66 (*AB*, $^2J = 10.9$, CH_2(17)); 2.60 (*dd*, ^3J(2ax,lax) = 12.6, ^3J(2ax,leq) = 6.4, H_{ax}–C(2)); 2.31 (*dq*, ^3J(4,18) = 6.4, ^3J(4ax,5ax) = 12.6, irradiation at δ 0.92 (Me(18)) → *d*, ^3J(4ax,5ax) = 12.1, H_{ax}–C(4)); 1.14 (*s*, Me(20)); 0.92 (*d*, ^3J (18,4) = 6.4, irradiation at δ 2.31 (H–C(4)) → *s*, Me_{eq}(18)). ^{13}C-NMR (100.6 MHz, $CDCl_3$): 215.1 (C(3)); 84.4 (C(16)); 65.6 (C(17)); 55.3 (C(9)); 54.4 (C(5)); 48.7(C(1)); 48.2 (C(14)); 44.9 (C(15)); 44.7 (C(4)); 44.0 (C(13)); 43.2(C(8)); 40.1 (C(7)); 37.5(C(10)); 31.2 (C(18)); 26.7 (C(12)); 23.6 (C(6)); 20.2 (C(11)); 13.7 (C(2)); 11.5 (C(20)). CI-MS (2-methylpropane): 307 (100, $[M + H]^+$), 289 (48, $[M + H - H_2O]^+$).

12. *(16*R*)-19-Norphyllocladan-16,17-diol* (**11b**). A mixture of **3** (10 mg), $N_2H_4 \cdot H_2O$ (212 mg), $N_2H_4 \cdot$ 2 HCl (50 mg), and ethylene glycol (1 g) was heated at 160° (2.5 h). Then, KOH (80 mg) was added, and the temp. was raised gradually to 210° to distill off the volatile substances. Then, the temp. was kept at 210–215° (2.5 h). After cooling, H_2O and dil. H_2SO_4 soln. were added. The mixture was extracted with Et_2O, the Et_2O layer washed with H_2O, dried ($MgSO_4$), and evaporated, and the residue purified by CC (CH_2Cl_2): **11b** (5 mg, 72%). White flakes. M.p. 91–93°. $[\alpha]_D^{20} = +12.9$ ($c = 0.26$, $CHCl_3$). IR (KBr): 3400, 3300, 2930, 2860, 2845, 1452, 1448, 1378, 1350, 1318, 1248, 1132, 1084, 1062, 1052, 1040, 1025, 1000, 968, 920, 874, 695, 685, 664. ^{1}H-NMR (300 MHz, $CDCl_3$): 3.78, 3.63 (*AB*, $^2J = 10.9$, CH_2(17)); 0.81 (*s*, Me(20)); 0.81 (*d*, ^3J(4,18) = 6.4, Me(18)). CI-MS: 310 (73, $[M + NH_4]^+$), 293 (15), 292 (79, $M^{+\cdot}$), 278 (9, $[M + NH_4 - MeOH]^+$), 276 (10), 275 (59, $[M + H - H_2O]^+$), 274 (61, $[M - H_2O]^+$), 258 (20), 257 (100, $[275 - H_2O]^+$).

13. *(3*S*,16*R*)-16,17-(Isopropylidenedioxy)[3-^{2}H]phyllocladan-3-ol* (**12**). $LiAlD_4$ (20 mg) was added to a soln. of **6** (24 mg) in abs. THF (3 ml) and the mixture stirred at r.t. under N_2 (1.5 h). Workup and CC as described in *Exper. 9* yielded **12** (15 mg, 92%). White solid. M.p. 146–148°. IR (KBr): 3510, 2980, 2938, 2864, 2140, 1556, 1540, 1455, 1434, 1380, 1368, 1246, 1210, 1148, 1105, 1058, 980, 955, 920, 895, 860, 840, 805, 715. ^{1}H-NMR (300 MHz, $CDCl_3$): 4.07, 3.91 (*AB*, $^2J = 8.6$, CH_2(17)); 2.25 (*dd*, $^2J = 14.6$, $^4J(15\beta,14\alpha) = 2.2$, H_β–C(15)); 1.99 (*m*, H–C(13)); 1.39, 1.35 (each *s*, $Me_2C(O)_2$); 0.98 (*s*, Me(20)); 0.87 (*s*, Me(18)); 0.77 (*s*, Me(19)). CI-MS (2-methylpropane): 364 (15, $[M + H]^+$), 346 (6, $[M + H - H_2O]^+$), 323 (20), 306 (15, $[M + H - \text{acetone}]^+$), 289 (16), 288 (100, $[306 - H_2O]^+$), 271 (11), 270 (72, $[288 - H_2O]^+$).

14. *(2*R*,3*S*,16*R*)-16,17-(Isopropylidenedioxy)phyllocladane-2,3-diol 2,3-Bis(methanesulfonate)* (**13**). Methanesulfonyl chloride (160 µl) was added to a soln. of **5** (40 mg) in abs. pyridine (2 ml) and the mixture kept at r.t. (40 h). Workup and CC as described in *Exper. 5* yielded **13** (50 mg, 88%). White crystals. M.p. 103–105°. ^{1}H-NMR (300 MHz, $CDCl_3$): 5.05 (*ddd*, ^3J(2,1ax) = 12.4, ^3J(2,1eq) = 4.5, ^3J(2,3) = 2.6, H–C(2)); 4.73 (*d*, ^3J(3,2) = 2.6, H–C(3)); 4.07, 3.91 (*AB*, $^2J = 8.6$, CH_2(17)); 3.15, 3.08 (each *s*, 2 $MeSO_3$); 1.39, 1.35 (each *s*, $Me_2C(O)_2$); 1.10 (*s*, Me(20)); 1.02 (*s*, Me(18), Me(19)). EI-MS: 534 (1.5, $M^{+\cdot}$), 520 (6), 519 (22, $[M - Me]^+$), 327 (11, $[519 - 2\ MeSO_3]^+$), 285 (12), 267 (100), 185 (10), 171 (14), 159 (14), 157 (10), 147 (15), 145 (29), 135 (25), 133 (44), 131 (13), 121 (16), 119 (57), 114 (17), 109 (27), 107 (21), 105 (25).

15. *(2*R*,16*R*)-16,17-(Isopropylidenedioxy)phyllocladan-2-ol* (**14**). Treatment of **13** (50 mg) with $LiAlH_4$ (100 mg) in abs. THF (5 ml) as described in *Exper. 9*, workup, and CC ($CH_2Cl_2 \rightarrow CH_2Cl_2$/MeOH 100 : 0.5) afforded **5** (3.5 mg, 10%), **7** (3.4 mg, 10%), and **14** (22 mg, 65%). **14**: White crystals. M.p. 185–187°. ^{1}H-NMR (300 MHz, $CDCl_3$): 4.08 (*m* and *A* of *AB*, $^2J = 8.6$, H–C(2), H_A–C(17)); 3.92 (*B* of *AB*, $^2J = 8.6$, H_B–C(17)); 2.25 (*dd*, $^2J = 14.5$, $^4J(15\beta,14\alpha) = 2.2$, H_β–C(15)); 2.00 (*m*, H–C(13)); 1.39, 1.35 (each *s*, $Me_2C(O)_2$); 1.12 (*s*, Me(20)); 0.99 (*s*, Me(18)); 0.92 (*s*, Me(19)). ^{1}H-NMR (300 MHz, C_5D_5N): 4.33 (*m*, $w_{1/2} \approx 12$, H–C(2)); 4.13, 3.98 (*AB*, $^2J = 8.6$, CH_2(17)); 2.30 (*dd*, $^2J = 14.4$, $^4J(15\beta,14\alpha) = 2.0$, H_β–C(15)); 2.05 (*m*, H–C(13)); 1.49, 1.42 (each *s*, $Me_2C(O)_2$); 1.29 (*s*, Me(20)); 1.17 (*s*, Me(19)); 0.93 (*s*, Me(18)). EI-MS: 362 (2, $M^{+\cdot}$), 348 (10), 347 (53, $[M - Me]^+$), 329 (4, $[347 - H_2O]^+$), 305 (3), 287 (11), 270 (12), 269 (65), 231 (4), 199 (3), 189 (9), 187 (8), 175 (9), 173 (11), 161 (17), 159 (12), 149 14), 147 (27), 145 (16), 135 (29), 133 (21), 123 (17), 119 (22), 117 (11), 114 (19), 109 (28), 107 (28), 105 (28), 104 (17), 43 (100).

16. *Epimerization of Calliterpenone* (**2**). *(16*R*)-16-Hydroxy-17-{[(4-methylphenyl)sulfonyl]oxy}phyllocladan-3-one* (**19**). As described in *Exper. 5*, reaction of **2** (23 mg) with TsCl (70 mg) afforded **19** (31 mg, 91%). White solid. M.p. 55–60°. IR (KBr): 3480, 2930, 2870, 1695, 1600, 1455, 1388, 1360, 1302, 1190, 1178, 1100, 1050, 1020, 960, 930, 845, 820, 750, 665. ^{1}H-NMR (300 MHz, $CDCl_3$): 7.82, 7.37 (*AA'BB'*, $J = 8.2$, arom. H); 4.20, 4.07 (*AB*, $^2J = 9.7$, CH_2(17)); 2.47(*s*, MeC_6H_4); 2.37 (*ddd*, $^2J = 15.8$, ^3J(2ax,1ax) = 7.1, ^3J(2ax,1eq) = 4.1, H_{ax}–C(2)); 2.11 (*ddd*, $^2J = 15.8$, ^3J(2eq,1ax) = 4.7, ^3J(2eq,1eq) = 2.3, H_{eq}–C(2)); 1.07 (*s*, Me(18)); 1.02 (*s*, Me(20)); 0.93 (*s*,

Me(19)). CI-MS: 492 (100, $[M+NH_4]^+$), 321 (15), 320 (75, $[M+H-TsOH]^+$), 304 (8), 303 (36), 302 (15, $[320-H_2O]^+$), 285 (18, $[303-H_2O]^+$).

*(16*R*)-16,17-Epoxyphyllocladan-3-one* (=*Epoxycalliterpenone*; **20**). A mixture of **19** (31 mg) in abs. MeOH (4 ml) and anh. K_2CO_3 (13 mg) was stirred at r.t. (1 h). H_2O was added, the mixture extracted with Et_2O, the org. phase washed with H_2O, dried ($MgSO_4$), and evaporated, and the white residue purified by CC (hexane/CH_2Cl_2 1:3 → 1:6): **20** (8 mg, 91%). White solid. M.p. 161–163°. $[\alpha]_D^{20}=+8.3$ ($c=0.58$, $CHCl_3$). IR (KBr): 2940, 2920, 2850, 1702, 1455, 1385, 1365, 1265, 1205, 1145, 1110, 1078, 1020, 1000, 974, 945, 935, 900, 848, 805, 780, 725. ^{1}H-NMR (300 MHz, $CDCl_3$): 2.88, 2.81 (*AB*, $^2J=4.7$, $CH_2(17)$); 2.53 (*ddd*, $^2J=15.8$, $^3J(2ax,1ax)=10.4$, $^3J(2ax,1eq)=7.3$, $H_{ax}-C(2)$); 2.41 (*ddd*, $^2J=15.8$, $^3J(2eq,1ax)=7.3$, $^3J(2eq,1eq)=4.3$, $H_{eq}-C(2)$); 2.31 (*dd*, $^2J=14.5$, $^4J(15\beta,14\alpha)=2.4$, $H_\beta-C(15)$); 1.10 (*s*, Me(18)); 1.04 (*s*, Me(20)); 1.02 (*s*, Me(19)). CI-MS: 320 (47, $[M+NH_4]^+$), 303 (92, $[M+H]^+$), 302 (16, $M^{+\bullet}$), 286 (21), 285 (100, $[M+H-H_2O]^+$), 109 (10).

Hydrolysis of **20**: *Products* **2**, **21**, **22**, *and* **23**. The mixture of **20** (100 mg) and 5% H_2SO_4 soln. (4 ml) in THF (20 ml) was stirred at r.t. (15 h). After workup according to *Exper. 24*, the residue was separated by CC (CH_2Cl_2/MeOH 99:1): **22** (30 mg, 30%). Further elution with CH_2Cl_2/MeOH 95:5 afforded calliterpenone (**2**; 45 mg, 42%) and its (16*S*)-epimer **21** (5 mg, 5%).

In a similar procedure, the mixture of **20** (42 mg) and 60% $HClO_4$ soln. (0.5 ml) in THF (2 ml) was stirred at r.t. (32 h). After workup, the residue was separated by CC (CH_2Cl_2/MeOH 99:1): **23** (25 mg, 60%), **22** (1.7 mg, 4%), and traces of **2** and **21**.

*(16*S*)-16,17-Dihydroxyphyllocladan-3-one* (=*16-Epicalliterpenone*; **21**): White needles (from CH_2Cl_2/MeOH). M.p. 210–212°. CD (MeOH, $c=8.16\cdot10^{-4}$ M): 235 (0), 289 (+0.58), 315 (0), 320 (−0.05), 337 (0). IR (KBr): 3450–3400 (br.), 3330, 2985, 2932, 2860, 1704, 1560, 1542, 1478, 1454, 1440, 1415, 1385, 1348, 1315, 1248, 1210, 1190, 1165, 1138, 1130, 1120, 1095, 1072, 1054, 1035, 1020, 1005, 985, 962, 940, 918, 872, 836, 700, 672, 655. ^{1}H-NMR (400 MHz, $CDCl_3$): 3.50, 3.40 (*AB*, $^2J=10.8$, $CH_2(17)$); 2.55 (*ddd*, $^2J=15.8$, $^3J(2ax,1ax)=11.0$, $^3J(2ax,1eq)=7.3$, $H_{ax}-C(2)$); 2.38 (*ddd*, $^2J=15.8$, $^3J(2eq,1ax)=7.0$, $^3J(2eq,1eq)=4.0$, $H_{eq}-C(2)$); 2.23 (*s*, OH); 1.08 (*s*, Me(18)); 1.05 (*s*, Me(20)); 1.03 (*s*, Me(19)). ^{13}C-NMR (100.6 MHz, $CDCl_3$): 217.8 (C(3)); 82.5 (C(16)); 69.9 (C(17)); 56.2 (C(9)); 55.4 (C(5)); 48.4 (C(14)); 47.4 (C(4)); 44.5 (C(15)); 42.6 (C(8)); 41.0 (C(7)); 39.6 (C(13)); 38.3 (C(1)); 37.2 (C(10)); 34.1 (C(2)); 27.7 (C(12)); 26.7 (C(18)); 21.6 (C(19)); 21.2 (C(6)); 20.2 (C(11)); 14.8 (C(20)). CI-MS: 338 (98, $[M+NH_4]^+$), 321 (63, $[M+H]^+$), 320 (45, $M^{+\bullet}$), 303 (100, $[M+H-H_2O]^+$), 285 (51, $[303-H_2O]^+$).

17-Hydroxyphylloclad-15-en-3-one (**22**): White crystals (from hexane/CH_2Cl_2). M.p. 165–166°. $[\alpha]_D^{20}=+10.0$ ($c=0.52$, $CHCl_3$). IR (KBr): 3440, 2930, 2850, 1694, 1560, 1542, 1450, 1420, 1385, 1362, 1336, 1320, 1265, 1245, 1215, 1200, 1136, 1115, 1040, 1022, 995, 960, 915, 895, 875, 832, 735, 650. ^{1}H-NMR (400 MHz, $CDCl_3$): 5.68 (br. *s*, $w_{1/2}\approx4$, H−C(15)); 4.22 (*d*, $^4J(17,15)=1.4$, $CH_2(17)$); 2.56 (*ddd*, $^2J=15.6$, $^3J(2ax,1ax)=12.6$, $^3J(2ax,1eq)=6.6$, $H_{ax}-C(2)$); 2.45 (*m*, H−C(13)); 2.31 (*ddd*, $^2J=15.6$, $^3J(2eq,1ax)=5.8$, $^3J(2eq,1eq)=3.4$, $H_{eq}-C(2)$); 1.89 (*ddd*, $^2J=13.3$, $^3J(1eq,2ax)=6.6$, $^3J(1eq,2eq)=3.4$, $H_{eq}-C(1)$); 1.81 (*ddd*, $^2J=9.8$, $^3J(14eq,13)=5.2$, $^4J(14eq,12eq)=2.0$, $H_{eq}-C(14)$); 1.70 (*dt*, $^2J=12.8$, $^3J(7eq,6ax)=^3J(7eq,6eq)=3.1$, $H_{eq}-C(7)$); 1.21 (*d*, $^2J=9.8$, $H_{ax}-C(14)$); 1.12 (*dd*, $^3J(9,11ax)=11.5$, $^3J(9,11eq)=4.5$, H−C(9)); 1.09 (*s*, Me(18)); 1.06 (*s*, Me(19)); 0.93 (*s*, Me(20)). ^{13}C-NMR (100.6 MHz, $CDCl_3$): 217.4 (C(3)); 145.1 (C(16)); 160.9 (C(15)); 61.2 (C(17)); 55.7 (C(5)); 54.5 (C(14)); 52.2 (C(9)); 47.6 (C(8)); 47.3 (C(4)); 39.5 (C(13)); 37.8 (C(7)); 36.85 (C(10)); 36.8 (C(1)); 34.3 (C(2)); 26.1 (C(18)); 24.8 (C(12)); 21.8 (C(19)); 21.1 (C(11)); 19.4 (C(6)); 14.7 (C(20)). CI-MS: 320 (63, $[M+NH_4]^+$), 304 (22), 303 (100, $[M+H]^+$), 302 (41, $M^{+\bullet}$), 301 (17), 287 (7), 286 (21), 285 (100).

*(16*R*)-3-Oxophyllocladan-17-al* (**23**). White foam. IR ($CHCl_3$): 2970, 2939, 2858, 1716, 1699, 1458, 1386, 1114. ^{1}H-NMR (300 MHz, $CDCl_3$): 9.65 (*d*, $^3J(17,16)=1.7$, H−C(17)); 2.61 (*ddd*, $^3J(16,15\beta)=9.3$, $^3J(16,15\alpha)=5.7$, $^3J(16,17)=1.7$, H−C(16)); 2.53 (*ddd*, $^2J=15.8$, $^3J(2ax,1ax)=10.6$, $^3J(2ax,1eq)=7.3$, $H_{ax}-C(2)$); 2.42 (*m*, *q*-like, $w_{1/2}\approx10$, H−C(13)); 2.39 (*ddd*, $^2J=15.8$, $^3J(2eq,1ax)=7.3$, $^3J(2eq,1eq)=4.2$, $H_{eq}-C(2)$); 2.13 (*ddd*, $^2J=13.6$, $^3J(15\beta,16)=9.3$, $^4J(15\beta,14ax)=2.3$, $H_\beta-C(15)$); 1.93 (*ddd*, $^2J=13.3$, $^3J(1eq,2ax)=7.3$, $^3J(1eq,2eq)=4.2$, $H_{eq}-C(1)$); 1.08 (*s*, Me(18)); 1.04 (*s*, Me(19), Me(20)). ^{13}C-NMR (75.4 MHz, $CDCl_3$): 217.5 (C(3)); 203.0 (C(17)); 56.0 (C(16)); 55.8 (C(9)); 55.4 (C(5)); 47.9 (C(14)); 47.4 (C(4)); 44.5 (C(8)); 39.8 (C(7)); 38.4 (C(1)); 37.2 (C(10)); 36.2 (C(13)); 34.0 (C(2)); 32.0 (2C, C(12), C(15)); 26.8 (C(18)); 21.5 (C(19)); 21.3 (C(11)); 20.0 (C(6)); 15.0 (C(20)). CI-MS: 320 (100, $[M+NH_4]^+$), 303 (5, $[M+H]^+$).

*(16*R*)-3-Oxophyllocladan-17-oic Acid* (**24**). Aldehyde **23** (15 mg) was left in $CDCl_3$ in an NMR tube for several weeks at 4°, until ^{1}H-NMR showed the disappearance of the C*H*O signal. CC (CH_2Cl_2/MeOH 98:2) gave pure **24** (11.3 mg, 71%). Colorless viscous oil. IR ($CHCl_3$): 3516, 3400–2500, 2974, 2939, 2858, 1701, 1459, 1386, 1280, 1130. ^{1}H-NMR (300 MHz, $CDCl_3$): 2.67 (*dd*, $^3J(16,15\beta)=9.3$, $^3J(16,15\alpha)=5.7$, H−C(16)); 2.53 (*ddd*, $^2J=15.8$, $^3J(2ax,1ax)=10.6$, $^3J(2ax,1eq)=7.3$, $H_{ax}-C(2)$); 2.42 (*m*, *q*-like, $w_{1/2}\approx10$, H−C(13)); 2.39 (*ddd*, $^2J=$

15.8, ^3J(2eq,1ax) = 7.3, ^3J(2eq,1eq) = 4.1, H_{eq}–C(2)); 2.32 (*ddd*, ^2J = 13.6, ^3J(15β,16) = 9.3, ^4J(15β,14ax) = 2.1, H_β–C(15)); 1.92 (*ddd*, ^2J = 13.3, ^3J(1eq,2ax) = 7.3, ^3J(1eq,2eq) = 4.1, H_{eq}–C(1)); 1.08 (*s*, Me(18)); 1.03 (*s*, Me(19), Me(20)). ^{13}C-NMR (75.4 MHz, $CDCl_3$): 217.7 (C(3)); 181.7 (C(17)); 55.7 (C(9)); 55.5 (C(5)); 48.4 (C(14)); 47.6 (C(16)); 47.4 (C(4)); 44.8 (C(8)); 39.8 (C(7)); 39.7 (C(13)); 38.4 (C(1)); 37.2 (C(10)); 36.6 (C(15)); 34.1 (C(2)); 32.2 (C(12)); 26.8 (C(18)); 21.5 (C(11)); 21.4 (C(19)); 19.7 (C(6)); 15.0 (C(20)). EI-MS: 290 (48, $[M - CO]^+$), 288 (100, $[M - H_2CO]^+$), 281 (31), 207 (54), 202 (59), 186 (91).

Chlorophyllocladanones **25** *and* **26a/26b**. A soln. of TsCl (98 mg) and **2** (36 mg) in abs. pyridine (4 ml) was refluxed (15 h). Workup according to *Exper. 5* and CC (CH_2Cl_2/MeOH 95 : 5) yielded **25** (33 mg, 87%) and an (*E*/*Z*)-mixture **26a/26b** 2 : 1 (4 mg, 11%), both as colorless oils.

*(16*R*)-17-Chloro-16-hydroxyphyllocladan-3-one* (= *17-Chlorocalliterpenone*; **25**): IR ($CHCl_3$): 3570, 2970, 2941, 2864, 1698, 1458, 1430, 1386, 1313, 1261, 1205, 1029. ^{1}H-NMR (600 MHz, $CDCl_3$): 3.86, 3.75 (*AB*, ^2J = 11.0, CH_2(17)); 2.55 (*ddd*, ^2J = 15.8, ^3J(2ax,1ax) = 10.9, ^3J(2ax,1eq) = 7.4, Hax–C(2)); 2.39 (*ddd*, ^2J = 15.8, ^3J(2eq,1ax) = 6.8, ^3J(2eq,1eq) = 3.9, H_{eq}–C(2)); 2.19 (*ddd*, ^2J = 11.3, ^3J(14eq,13) = 4.6, ^4J(14eq,12eq) = 2.7, H_{eq}–C(14)); 2.08 (*dd*, ^2J = 14.9, ^4J(15β,14ax) = 1.5, H_β–C(15)); 1.99 (*m*, *q*-like, $w_{1/2} \approx 9$, H–C(13)); 1.89 (*ddd*, ^2J = 13.2, ^3J(1eq,2ax) = 7.4, ^3J(1eq,2eq) = 3.9, H_{eq}–C(1)); 1.10 (*s*, Me(18)); 1.05 (*s*, Me(19)); 1.01 (*s*, Me(20)). ^{13}C-NMR (150.9 MHz, $CDCl_3$): 217.4 (C(3)); 83.2 (C(16)); 55.7 (C(9)); 55.3 (C(5)); 51.0 (C(17)); 47.8 (C(14)); 47.7 (C(4)); 45.3 (C(15)); 44.9 (C(13)); 44.0 (C(8)); 40.5 (C(7)); 38.2 (C(1)); 37.1 (C(10)); 34.0 (C(2)); 26.8 (C(18)); 26.5 (C(12)); 21.6 (C(19)); 21.2 (C(11)); 19.8 (C(6)); 16.5 (C(20)). CI-MS: 358 (29, $[M(^{37}Cl) + NH_4]^+$), 356 (100, $[M(^{35}Cl) + NH_4]^+$), 338 (5, $M(^{35}Cl)^{+\bullet}$), 320 (20, $[M - H_2O]^+$).

*(16*E*)- and (16*Z*)-17-Chlorophyllocladad-16-en-3-ones* (**26a/26b**): IR ($CHCl_3$): 2977, 2938, 2858, 1698, 1493, 1445, 1385, 1250, 1112, 1073. ^{1}H-NMR (300 MHz, $CDCl_3$): (*E*)-isomer **26a**[20]): 5.77 (*m*, *q*-like, $w_{1/2} \approx 5$, H–C(17)); 3.00 (*m*, *q*-like, $w_{1/2} \approx 10$, H–C(13)); 2.76 (*dd*, ^2J = 15.2, ^4J(15β,14ax) = 1.4, H_β–C(15)); 2.52 (*ddd*, ^2J = 15.8, ^3J(2ax,1ax) = 10.6, ^3J(2ax,1eq) = 7.3, H_{ax}–C(2)); 2.39 (*ddd*, ^2J = 15.8, ^3J(2eq,1ax) = 7.3, ^3J(2eq,1eq) = 4.1, H_{eq}–C(2)); 1.96–1.84 (*m*, H_{eq}–C(1), H_{eq}–C(12), H_α–C(15)); 1.08 (*s*, Me(18)); 1.03 (*s*, Me(19)); 1.01 (*s*, Me(20)). ^{13}C-NMR (75.4 MHz, $CDCl_3$): 217.4 (C(3)); 149.0 (C(16)); 106.5 (C(17)); 55.7 (C(9)); 55.3 (C(5)); 49.2 (C(14)); 47.4 (C(4)); 43.8 (C(8)); 39.9 (2C, C(7), C(15)); 39.6 (C(13)); 38.2 (C(1)); 37.1 (C(10)); 34.0 (C(2)); 29.8 (C(12)); 26.7 (C(18)); 21.5 (C(19)); 21.2 (C(11)); 19.8 (C(6)); 15.0 (C(20)); (*Z*)-isomer **26b**[20]): 5.77 (*m*, *q*-like, $w_{1/2} \approx 5$, H–C(17)); 2.82 (*m*, *t*-like, $w_{1/2} \approx 6$, H_β–C(15)); 2.66 (*m*, *q*-like, $w_{1/2} \approx 10$, H–C(13)); 2.52 (*ddd*, ^2J = 15.8, ^3J(2ax,1ax) = 10.6, ^3J(2ax,1eq) = 7.3, H_{ax}–C(2)); 2.39 (*ddd*, ^2J = 15.8, ^3J(2eq,1ax) = 7.3, ^3J(2eq,1eq) = 4.1, H_{eq}–C(2)); 1.96–1.84 (*m*, H_{eq}–C(1), H_{eq}–C(12), H_α–C(15)); 1.09 (*s*, Me(18)); 1.05 (*s*, Me(19)); 1.04 (*s*, Me(20)). ^{13}C-NMR (75.4 MHz, $CDCl_3$): 217.4 (C(3)); 150.1 (C(16)); 106.6 (C(17)); 55.7 (C(9)); 55.3 (C(5)); 50.1 (C(14)); 47.4 (C(4)); 42.5 (C(8)); 41.5 (C(13)); 40.0 (C(7)); 39.0 (C(15)); 38.2 (C(1)); 37.1 (C(10)); 34.0 (C(2)); 29.8 (C(12)); 26.7 (C(18)); 21.5 (C(19)); 21.2 (C(11)); 19.8 (C(6)); 15.0 (C(20)). CI-MS: 340 (33, $[M(^{37}Cl) + NH_4]^+$), 338 (100, $[M(^{35}Cl) + NH_4]^+$), 321 (5, $[M(^{35}Cl) + H]^+$), 296 (6), 234 (29).

17. *Epimerization of (16*R*)-16,17-Dihydroxy*-ent-*kauran-3-one* (= *Abbeokutone*; **27**). *Data of* **27**. CD (MeOH, $c = 1.38 \cdot 10^{-4}$ M): 228 (0), 290 (–1.05), 319 (0), 323 (+0.03), 340 (0). ^{1}H-NMR (300 MHz, $CDCl_3$): 3.79, 3.67 (*AB*, ^2J = 10.9, CH_2(17)); 2.47 (*dd*, ^3J = 8.6, 6.3, CH_2(2)); 2.08 (br. *m*, $w_{1/2} \approx 15$, H–C(13)); 2.00 (*dd*, ^2J = 13.1, ^3J = 6.3, H_{eq}–C(1)); 1.92 (*dd*, ^2J = 11.9, ^4J(15β,14ax) = 2.6, H_β–C(15)); 1.08 (*s*, Me(18), Me(20)); 1.03 (*s*, Me(19)). ^{13}C-NMR (100.6 MHz, $CDCl_3$): 217.9 (C(3)); 81.7 (C(16)); 66.3 (C(17)); 55.4 (C(9)); 54.3 (C(5)); 52.8 (C(15)); 47.2 (C(4)); 45.3 (C(13)); 44.4 (C(8)); 40.9 (C(7)); 39.2 (C(1)); 38.5 (C(10)); 36.9 (C(14)); 34.0 (C(2)); 27.2 (C(18)); 26.0 (C(12)); 21.6 (C(6)); 20.9 (C(19)); 18.8 (C(11)); 17.8 (C(20)). EI-MS: 302 (< 5, $M^{+\bullet}$), 289 (100, $[M - Me - H_2O]^+$), 271 (20), 247 (6). Further physical data in [11c–e].

*(16*R*)-16-Hydroxy-17-{[(4-methylphenyl)sulfonyl]oxy})*-ent-*kauran-3-one* (**28**). As described in *Exper. 5*, reaction of **27** (10 mg) with TsCl (30 mg) and CC (hexane/Et_2O 1 : 2) afforded **28** (14 mg, 95%). White foam. ^{1}H-NMR (300 MHz, $CDCl_3$): 7.81, 7.36 (*AA'BB'*, *J* = 8.1, arom. H); 4.19, 4.11 (*AB*, ^2J = 9.6, CH_2(17)); 2.46 (*dd*, ^3J = 8.4, 6.6, CH_2(2); *s*, *Me*C_6H_4); 2.08 (*m*, $w_{1/2} \approx 12$, H–C(13)); 1.07 (*s*, Me(18)); 1.05 (*s*, Me(20)); 1.01 (*s*, Me(19)).

*(16*R*)-16,17-Epoxy*-ent-*kauran-3-one* ('*Epoxyabbeokutone*'; **29**). As described in *Exper. 16*, reaction of **28** (14 mg) with anh. K_2CO_3 (14 mg) in MeOH (5 ml) yielded **29** (9 mg, 95%). White tiny crystals. ^{1}H-NMR (300 MHz, $CDCl_3$): 2.89, 2.82 (*AB*, ^2J = 4.7, CH_2(17)); 2.49 (*dd*, ^3J = 8.6, 6.3, CH_2(2)); 1.85 (*m*, $w_{1/2} \approx 12$, H–C(13)); 1.09 (*s*, Me(18), Me(20)); 1.05 (*s*, Me(19)).

---

[20]) The assignments are based on the respective shielding effects of the Cl-atom on H–C(13) and CH_2(15). Moreover, assuming an *E*2 mechanism, the (*E*)-isomer is expected to be predominant due to a favored conformation of **25**.

Hydrolysis of **29**: *Products* **27**, **30**, **31**, *and* **32a/32b**. As described in *Exper. 16*, hydrolysis of **29** (9 mg) in THF (2 ml) and 5% H_2SO_4 soln. (0.5 ml) followed by CC (hexane/Et_2O 1:2 → CH_2Cl_2/MeOH 95:5) gave abbeokutone (**27**; 3.6 mg, 38%), the 16-epimer **30** (0.4 mg, 4%), **31** (2 mg, 22%), and **32a/32b** (3 mg, 33%) as a 1:1 mixture of the 16-epimers.

*(16*S*)-16,17-Dihydroxy-*ent*-kauran-3-one* (*=16-Epiabbeokutone*; **30**). White foam. IR ($CHCl_3$): 3024, 3016, 2935, 2869, 1698, 1459, 1386, 1228, 1158, 1114, 1051, 1019. ^{1}H-NMR (300 MHz, $CDCl_3$): 3.49, 3.41 (*AB*, ^2J = 10.8, CH_2(17)); 2.47 (*dd*, ^3J = 8.6, ^3J = 6.3, CH_2(2)); 2.08 (*m*, $w_{1/2}$ ≈ 15, H−C(13)); 2.00 (*m*, *dd*-like, $w_{1/2}$ ≈ 22, CH_2(1)); 1.92 (*dd*, ^2J = 11.9, ^4J(15β,14ax) = 2.6, H_β−C(15)); 1.08 (*s*, Me(18), Me(20)); 1.03 (*s*, Me(19)). ^{13}C-NMR (75.4 MHz, $CDCl_3$): 217.9 (C(3)); 79.7 (C(16)); 69.8 (C(17)); 55.6 (C(5)); 54.3 (C(9)); 52.2 (C(15)); 47.1 (C(4)); 43.3 (C(8)); 40.9 (C(13)); 40.7 (C(7)); 39.2 (C(1)); 38.5 (C(10)); 37.8 (C(14)); 34.0 (C(2)); 27.2 (C(18)); 26.6 (C(12)); 21.2 (C(6)); 20.9 (C(19)); 19.3 (C(11)); 17.6 (C(20)). EI-MS: 302 (5, $M^{+\bullet}$), 289 (100, $[M - Me - H_2O]^+$), 271 (20), 247 (6). Further physical data in [12a,b].

*17-Hydroxy-*ent*-kaur-15-en-3-one* (**31**). White foam. IR ($CHCl_3$): 3025, 2934, 2864, 1698, 1460, 1386, 1368, 1112, 1002. ^{1}H-NMR (300 MHz, $CDCl_3$): 5.38 (br. *s*, $w_{1/2}$ ≈ 4, H−C(15)); 4.21 (br. *s*, $w_{1/2}$ ≈ 6, CH_2(17)); 2.58 (*m*, *q*-like, $w_{1/2}$ ≈ 11, H−C(13)); 2.48 (*m*, *td*-like, CH_2(2)); 2.04 (*m*, *ddd*-like, CH_2(1)); 1.12 (*s*, Me(18)); 1.09 (*s*, Me(20)); 1.03 (*s*, Me(19)). ^{13}C-NMR (75.4 MHz, $CDCl_3$): 217.9 (C(3)); 146.5 (C(16)); 135.1 (C(15)); 61.3 (C(17)); 54.4 (C(5)); 48.7 (C(8)); 47.7 (C(9)); 47.3 (C(4)); 43.6 (C(7)); 41.1 (C(13)); 39.4 (C(1)); 38.7 (C(10)); 38.3 (C(14)); 34.2 (C(2)); 27.1 (C(18)); 25.4 (C(12)); 21.0 (C(19)); 20.4 (C(6)); 19.2 (C(11)); 17.5 (C(20)). EI-MS: 302 (35, $M^{+\bullet}$), 244 (14), 216 (27), 159 (27), 91 (100).

*(16*R*)- and (16*S*)-3-Oxo-*ent*-kauran-17-al* (**32a/32b**). White foam. IR ($CHCl_3$): 3027, 2935, 2864, 1701, 1460, 1385, 1114. ^{1}H-NMR (300 MHz, $CDCl_3$): **32a** (16*R*): 9.67 (*d*, ^3J(17,16) = 1.7, H−C(17)); 2.84 (*m*, H−C(16)); 2.58 (*m*, H−C(13)); 2.47 (*m*, *td*-like, CH_2(2)); 2.00 (*m*, *td*-like, CH_2(1)); 1.85 (*m*, *dd*-like, CH_2(15)); 1.08 (*s*, Me(18)); 1.04 (*s*, Me(20)); 1.03 (*s*, Me(19)); **32b** (16*S*): 9.89 (*s*, H−C(17)); 2.77 (*s*, H−C(16)); 2.58 (*m*, H−C(13)); 2.47 (*m*, *td*-like, CH_2(2)); 2.00 (*m*, *td*-like, CH_2(1)); 1.80 (*m*, *dd*-like, CH_2(15)); 1.08 (*s*, Me(18)); 1.04 (*s*, Me(20)); 1.03 (*s*, Me(19)). EI-MS: 302 (40, $M^{+\bullet}$), 244 (49), 216 (95), 187 (42), 159 (100).

18. *Transformation of Derivatives into New Phyllocladanes.* For the characterization as potential natural products, the following compounds were prepared:

*(2*R*,16*R*)-Phyllocladane-2,16,17-triol* (**16**). As described in *Exper. 10*, acetonide **14** (14 mg) was hydrolyzed with 2% H_2SO_4 soln. (2 ml), worked up, and purified by CC (CH_2Cl_2/MeOH 9:1): **16** (12 mg, 96%). White solid. M.p. 200–204°. $[\alpha]_D^{20} = +44.8$ (*c* = 0.33, MeOH). IR (KBr): 3200–3600 (br.), 2930, 2860, 1460, 1455, 1385, 1366, 1200, 1125, 1072, 1035, 1000, 985, 965, 912, 870, 810, 678. ^{1}H-NMR (300 MHz, $(CD_3)_2CO$): 3.42 (*m*, $w_{1/2}$ ≈ 10, H−C(2)); 3.68, 3.51 (*AB*, ^2J = 11.0, CH_2(17)); 1.13 (*s*, Me(20)); 0.97 (*s*, Me(18)); 0.88 (*s*, Me(19)). CI-MS: 340 (100, $[M + NH_4]^+$), 323 (13), 322 (62, $M^{+\bullet}$), 305 (21), 304 (40, $[M - H_2O]^+$), 288 (12), 287 (56, $[M + H - 2 H_2O]^+$), 273 (5), 270 (9), 269 (44, $[287 - H_2O]^+$).

*(16*R*)-16,17-Dihydroxyphyllocladan-2-one* (**17**). Oxidation of **14** (24 mg) with PCC (32 mg), followed by hydrolysis of the acetal, workup, and CC as described in *Exper. 10* afforded **17** (17 mg, 79%). White crystals. M.p. 174–176°. $[\alpha]_D^{20} = +40.7$ (*c* = 0.41, $CHCl_3$). IR (KBr): 3500. 3430, 2930, 2898, 2850, 1702, 1460, 1390, 1370, 1300, 1280, 1188, 1145, 1125, 1055, 1038, 1028, 1008, 985, 965, 916, 870, 802, 755, 725, 670, 660. ^{1}H-NMR (300 MHz, $CDCl_3$): 3.79, 3.62 (*AB*, ^2J = 10.9, CH_2(17)); 1.07 (*s*, Me(20)); 0.88 (*s*, Me(18), Me(19)). CI-MS: 338 (100, $[M + NH_4]^+$), 321 (20, $[M + H]^+$).

*(3*S*,16*R*)-Phyllocladane-3,16,17-triol* (**18**). Hydrolysis of acetal **7** (10 mg) as described in *Exper. 10* and CC (CH_2Cl_2/MeOH, 90:1) afforded **18** (9 mg, 100%). White crystals (from CH_2Cl_2/MeOH). M.p. 148–150°. $[\alpha]_D^{20} = +18.5$ (*c* = 0.47, MeOH). IR (KBr): 3200–3600 (br.), 2930, 2860, 1454, 1436, 1382, 1368, 1348, 1305, 1255, 1205, 1128, 1088, 1074, 1032, 984, 918, 874, 855, 830, 745, 695, 642. ^{1}H-NMR (300 MHz, $(CD_3)_2CO$): 3.66, 3.51 (*AB*, ^2J = 10.8, CH_2(17)); 3.61 (*dd*, 3*J*(3,2ax) = 9.5, ^3J(3,2eq) = 4.7, H−C(3)); 0.96 (*s*, Me(18)); 0.89 (*s*, Me(20)); 0.75 (*s*, Me(19)). CI-MS: 340 (100, $[M + NH_4]^+$), 322 (7, M^+), 304 (2, $[M - H_2O]^+$).

The following compounds were prepared by reaction with excess $LiAlH_4$ in THF at r.t., workup, and CC separation as described in *Exper. 4*.

*(3*R*,16*R*)-Phyllocladane-3,16,17-triol* (**33**). From the natural product **1a** (10 mg), we obtained **33** (8 mg, 91%). White needles (from CH_2Cl_2/MeOH). M.p. 193–196°. $[\alpha]_D^{20} = -3.9$ (*c* = 0.21, MeOH). IR (KBr): 3300–3500 (br.), 2930, 2860, 1450, 1435, 1385, 1350, 1315, 1305, 1245, 1205, 1195, 1146, 1128, 1095, 1078, 1055, 1042, 1008, 985, 938, 918, 874, 800, 685, 665, 618. ^{1}H-NMR (300 MHz, $(CD_3)_2CO$): 3.68, 3.50 (*AB*, ^2J = 10.9, CH_2(17)); 3.31 (*m*, *t*-like, $w_{1/2}$ ≈ 7, H−C(3)); 0.91 (*s*, Me(20)); 0.90 (*s*, Me(18)); 0.80 (*s*, Me(19)). CI-MS: 340 (43, $[M + NH_4]^+$), 323 (9), 322 (45, $M^{+\bullet}$), 320 (6), 305 (21), 304 (33, $[M - H_2O]^+$), 288 (16), 287 (84, $[M + H - 2 H_2O]^+$), 270 (20), 269 (100, $[287 - H_2O]^+$), 248 (5).

*(2*R*,3*S*,16*R*)-Phyllocladane-2,3,16,17-tetrol* (**15**). From the natural product **1b** (55 mg), we obtained **15** (24 mg, 60%). White crystalline solid. M.p. 246–249°. $[\alpha]_D^{20} = +12.0$ ($c = 0.35$, MeOH). IR (KBr): 3500, 3390, 3290, 2945, 2870, 1558, 1540, 1450, 1380, 1350, 1325, 1305, 1295, 1285, 1255, 1212, 1195, 1150, 1130, 1085, 1075, 1040, 1010, 985, 952, 935, 915, 870, 830, 690, 620. ^{1}H-NMR (300 MHz, CD_3OD): 3.91 (*m*, $w_{1/2} \approx 24$, H–C(2)); 3.68, 3.54 (*AB*, $^2J = 11.3$, CH_2(17)); 3.30 (*m*, overlapping with the solvent peak, H–C(3)); 0.97 (*s*, Me(18)); 0.95 (*s*, Me(20)); 0.85 (*s*, Me(19)). ^{1}H-NMR (400 MHz, C_5D_5N): 4.37 (*m*, $w_{1/2} \approx 22$, H–C(2)); 4.18, 4.06 (*AB*, ^2J = 10.5, CH_2(17)); 3.84 (*d*, $^3J(3,2) \approx 1$, H–C(3)); 1.37 (*s*, Me(18)); 1.13 (*s*, Me(20)); 1.03 (*s*, Me(19)). CI-MS: 356 (100, $[M + NH_3]^+$), 339 (15), 338 (76, $M^{+\bullet}$), 324 (9, $[M + NH_3 - MeOH]^+$).

The same compound **15** (8.5 mg, 95%) was also obtained after hydrolysis of acetal **5** (10 mg).

*(2*R*,3*R*,16*R*)-Phyllocladane-2,3,16,17-tetrol* (**34**). From the natural product **1f** (25 mg), we obtained **34** (14 mg, 70%). White crystalline solid (from MeOH). M.p. 225–228°. $[\alpha]_D^{20} = +7.8$ ($c = 0.41$, MeOH). IR (KBr): 3200–3600 (br.), 2940, 2870, 1558, 1540, 1460, 1385, 1305, 1250, 1190, 1050, 1030, 1000, 975, 915, 870, 755, 675. ^{1}H-NMR (300 MHz, CD_3OD): 3.67, 3.55 (*AB*, $^2J = 11.3$, CH_2(17)); 3.60 (*ddd*, $^3J(2,1ax) = 11.3$, $^3J(2,3) = 9.6$, $^3J(2,1eq) = 4.4$, H–C(2)); 2.89 (*d*, $^3J(3,2) = 9.6$, H–C(3)); 0.99 (*s*, Me(18)); 0.86 (*s*, Me(20)); 0.79 (*s*, Me(19)). CI-MS: 356 (48, $[M + NH_4]^+$), 339 (22), 338 (100, M^+), 324 (5, $[M + NH_4 - MeOH]^+$), 320 (5, $[M - H_2O]^+$), 303 (8, $[M + H - 2\,H_2O]^+$), 285 (15, $[303 - H_2O]^+$).

*(3*S*,16*R*)-Phyllocladane-3,16,17,19-tetrol* (**35**). Trihydroxy ketone **8** (5 mg) yielded **35** (2.5 mg, 63%). Amorphous white solid. ^{1}H-NMR (300 MHz, CD_3OD): 4.11, 3.46 (*AB*, $^2J = 11.2$, CH_2(19)); 3.68, 3.55 (*AB*, ^2J = 11.3, CH_2(17)); 3.52 (*m*, H–C(3)); 1.18 (*s*, Me(18)); 0.89 (*s*, Me(20)). CI-MS: 356 (100, $[M + NH_4]^+$), 338 (100, M^+), 324 (46, $[M + NH_4 - MeOH]^+$), 323 (21).

*(16*R*)-17,19-Bis(acetyloxy)-16-hydroxyphyllocladan-3-one* (**3**). *Revision of NMR Data*[21]). ^{1}H-NMR (400 MHz, $CDCl_3$): 4.60, 3.91 (*AB*, $^2J = 11.3$, CH_2(19)); 4.26, 4.19 (*AB*, $^2J = 11.3$, CH_2(17)); 2.73 (*ddd*, ^2J = 15.4, $^3J(2ax,1ax) = 13.7$, $^3J(2ax,1eq) = 6.4$, H_{ax}–C(2)); 2.33 (*ddd*, $^2J = 15.4$, $^3J(2eq,1ax) = 5.1$, $^3J(2eq,1eq) = 2.8$, H_{eq}–C(2)); 2.13, 2.00 (each *s*, 2 COMe); 1.16 (*s*, Me(20)); 1.13 (*s*, Me(18)). ^{13}C-NMR (100.6 MHz, $CDCl_3$): 212.8 (C(3)); 170.9, 170.95 (2 *C*OMe), 82.1 (C(16)); 67.4 (C(17)); 65.8 (C(19)); 57.1 (C(9)); 55.5 (C(5)); 51.5 (C(4)); 47.6 (C(14)); 44.3 (C(15)); 44.1 (C(13)); 43.1 (C(8)); 40.7 (C(7)); 38.3 (C(1)); 36.9 (C(10)); 34.4 (C(2)); 26.3 (C(12)); 20.9 (C(11)); 20.6 (2C, CO*Me*), 20.5 (C(18)); 19.4 (C(6)); 14.6 (C(20)).

REFERENCES

[1] C. Bürgi, P. Rüedi, *Helv. Chim. Acta* **1993**, *76*, 1890; C. Bürgi, G. Liu, P. Rüedi, *Helv. Chim. Acta* **1993**, *76*, 1901; W. Breu, A. Sendl, C. Bürgi, P. Rüedi, H. Wagner, *Planta Med.* **1990**, *56*, 665; M. Juch, P. Rüedi, *Helv. Chim. Acta* **1997**, *80*, 436.

[2] G. Liu, P. Rüedi, *Phytochemistry* **1996**, *41*, 1563.

[3] a) A. K. Singh, P. K. Agrawal, *Phytochemistry* **1994**, *37*, 587; b) A. K. Singh, P. K. Agrawal, *Indian J. Chem. Sect. B* **1994**, *33*, 1205; c) P. K. Agrawal, V. Bishnoi, A. K. Singh, *Phytochemistry* **1995**, *39*, 929; d) P. K. Agrawal, A. K. Singh, R. S. Bhakuni, *Indian J. Chem. Sect. B* **1996**, *35*, 803.

[4] a) A. Chatterjee, S. K. Desmukh, S. Chandrasekharan, *Tetrahedron* **1972**, *28*, 4391; b) S. A. Ahmad, A. Zaman, *Tetrahedron Lett.* **1973**, *24*, 2179; c) E. Fujita, M. Ochiai, I. Ichida, A. Chatterjee, S. K. Deskmukh, *Phytochemistry* **1975**, *14*, 2249; d) W. H. Wong, C. Wei, S. E. Loke, T. C. W. Mak, *Acta Crystallogr. Sect. C* **1991**, *47*, 906.

[5] S. B. Katti, P. Rüedi, C. H. Eugster, *Helv. Chim. Acta* **1982**, *65*, 2189.

[6] a) M. Tsutsui, E. A. Tsutsui, *Chem. Rev.* **1959**, *59*, 1031; b) J. D. P. Campello, S. F. Fonseca, C. J. Chang, E. Wenkert, *Phytochemistry* **1975**, *14*, 243; c) E. F. Seratoni, A. Krajewski, R. Mongiorgi, L. R. D. Sanseverino, G. M. Sheldrick, *Acta Crystallogr., Sect. B* **1978**, *34*, 1311; d) R. F. Raffauf, M. D. Menachery, P. W. Le Quesne, E. V. Arnold, J. Clardy, *J. Org. Chem.* **1981**, *46*, 1094; e) R. Noble, J. Knox, R. Alexander, R. Kagi, *J. Chem. Soc., Chem. Commun.* **1985**, 32.

[7] R. Müller, P. Rüedi, *Helv. Chim. Acta* **2003**, *86*, 439.

[8] J. March, 'Advanced Organic Chemistry; Reactions, Mechanisms, and Structure', 3rd edn., J. Wiley & Sons, New York – Chichester – Brisbane – Toronto – Singapore, 1985, p. 325, 332, and ref. cit. therein.

[9] K. M. Baker, L. H. Briggs, J. G. St. C. Buchanan, R. C. Cambie, B. R. Davis, R. C. Hayward, G. A. S. Long, P. S. Rutledge, *J. Chem. Soc., Perkin Trans. 1* **1972**, 190.

[10] P. Sengupta, M. Sen, B. C. Pal, S. C. Pakrashi, E. Ali, *J. Indian Chem. Soc.* **1976**, *53*, 1172.

21) Due to a calibration error, the NMR data of **3** are not correctly reported in [5].

[11] a) D. A. H. Taylor, *J. Chem. Soc. (C)* **1967**, 1360; b) J. R. Hanson, A. F. White, *Tetrahedron* **1970**, *26*, 4839; c) F. Bohlmann, C. Zdero, B. L. Turner, *Phytochemistry* **1984**, *23*, 1055; d) P. Rüedi, E. Wollenweber, D. Marx, C. Scheele, *Z. Naturforsch. (C)* **1989**, *44*, 901; e) W. F. Tinto, G. Blyden. W. F. Reynolds, S. McLean, *J. Nat. Prod.* **1991**, *54*, 1127.

[12] a) Y. L. Ding, Z. J. Jia, *Phytochemistry* **1991**, *30*, 2413; b) K. R. Gustafson, M. G. H. Munro, J. W. Blunt, J. H. Cardellina II, J. B. McMahon, R. J. Gulakowski, G. M. Cragg, P. A. Cox, L. S. Brinen, J. Clardy, M. R. Boyd, *Tetrahedron* **1991**, *47*, 4547; c) K. Siems, J. Jakupovic, V. Castro, L. Poveda, *Phytochemistry* **1993**, *33*, 1465; d) T. Morgenstern, M. Bittner, M. Silva, P. Aqueveque, J. Jakupovic, *Phytochemistry* **1996**, *41*, 1149.

[13] R. Borgues-Argáez, L. Medina-Baizábal, F. Mayy-Pat, L. M. Peña-Rodríguez, *Can. J. Chem.* **1997**, *75*, 801.

[14] a) J. Kitajima, T. Komori, T. Kawasaki, *Chem. Pharm. Bull.* **1982**, *30*, 3912; b) J. T. Etse, A. I. Gray, P. G. Waterman, *J. Nat. Prod.* **1987**, *50*, 979.

[15] D. K. M. Duc, M. Fétizon, S. Lazare, P. K. Grant, J. Nicholls, H. T. L. Liau, M. J. Francis, J. Poisson, J.-M. Bernassau, N. F. Roque, P. M. Vovkulic, E. Wenkert, *Tetrahedron* **1981**, *37*, 2371.

[16] M. Jaensch, J. Jakupovic, H. Sanchez, X. A. Dominguez, *Phytochemistry* **1990**, *29*, 3587.

[17] P. Witz, H. Herrmann, J.-M. Lehn, G. Ourisson, *Bull. Soc. Chim. Fr.* **1963**, 1101.

Received August 27, 2002