Tetrahedron Vol. 25, pp. 3855 to 3867. Pergamon Press 1969. Printed in Great Britain

CHEMISTRY OF LAC RESIN—II

LAC ACIDS (Part 2): LACCIJALARIC ACID*†

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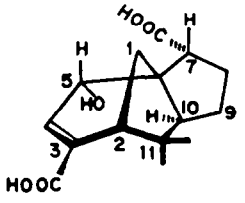
(*Received in the UK* 17 *March* 1969; *Accepted for publication* 16 *April* 1969)

Abstract—Isolation and structure elucidation of a new primary lac acid—laccijalaric acid—, which belongs to the cedrene group of sesquiterpenoids, is described. A direct chemical correlation of this acid with (−)-α-cedrene has also been accomplished.

A SEMI-quantitative method, for the estimation of various lac acid‡ constituents of lac resin, involves short-term hydrolysis of the resin, followed by oxidation (CrO_3), esterification and GLC estimation of the products. This method is discussed in Part IV of this series. While identifying the various products obtained by this sequence from a "pure" lac resin fraction, it became obvious that a new lac acid(s) must be present. The present communication describes the isolation and structure elucidation



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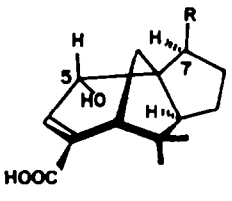


II, R = COOH

III, R = CHO

IV, R = CH_2OH

of three new acids I, II and III from lac hydrolysate, of which only acid III is considered to be the primary lac acid.

Laccishellolic acid and epi*laccishellolic acid.* During the course of the work, it had become clear that the new acid(s) must be less polar than shellolic acid[1,2] (V). The new isolation procedure involved saponification (10 days) of seedlac, esterification (CH_2N_2) and chromatography of the product over Al_2O_3. The first eluates, which were collected with C_6H_6 contained besides methyl butolate, two new esters. By systematic column chromatography both of these esters were obtained in a pure state. Table 1 summarizes the pertinent data of these esters and the corresponding

* Communication No. 1334, National Chemical Laboratory, Poona.

† Abstracted in part from the Ph.D. theses of M. S. Wadia (Poona University, 1967) and A. B. Upadhye (Bombay University, 1968).

‡ Lac acids of the shellolic groups could not be estimated directly by GLC (as Me esters) as, under a variety of conditions, their Me esters underwent decomposition on GLC columns.

acids. It will be shown in the sequel that these two acids are closely related to shellolic (V), *epi*shellolic acids (VII) and bear the same epimeric relationship with each other. In view of this the new acids have been named *laccishellolic** and epi*laccishellolic acids.*

TABLE 1. SOME CHARACTERISTICS OF LACCISHELLOLIC AND *EPI* LACCISHELLOLIC ACIDS

	Laccishellolic acid		*Epi*laccishellolic acid	
	Acid	Me ester	Acid	Me ester
m.p.	196–198°	85–87°	235–236°	94–95°
$[\alpha]_D$	—	+44·5	+43·0	+52·9
RRT*	—	2·3	—	2·9
R_f (paper)†	0·57	—	0·52	—
R_f (TLC)‡	—	0·78	—	0·70

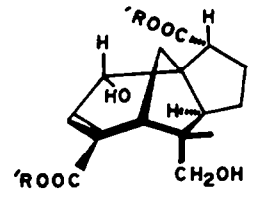
* RRT = Retention time relative to methyl butolate; temp: 240°; gas: 15 ml H_2/min; column: silicone SE-30 on chromosorb W.

† Solvent system consists of EtOH (35 parts), n-BuOH (35 parts) and ammonia buffer (30 parts; 7·2 g of ammonium carbonate dissolved in 95 ml water and 7·5 ml NH_4OH aq of sp. gr. 0·88) solvent front, 14 cm; temp 28°.

‡ Solvent system: toluene (7 parts), EtOAc (4 parts) and acetone (4 parts); solvent front, 10 cm; adsorbent, silica gel (0·3 mm layers); temp 28°.

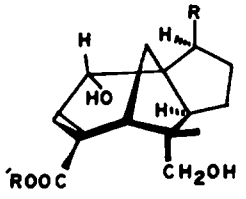
Epi*laccishellolic acid.* Work on the structure was carried out on the dimethyl ester, which analyses for $C_{17}H_{24}O_5$ and displays in its IR spectrum bands assignable to OH (3420, 1110, 1055 cm^{-1}), COOMe (1710 cm^{-1}) and, an olefinic linkage (1640 cm^{-1}), the latter, in all probability, being trisubstituted (815, 775 cm^{-1}). In the UV, it shows λ_{max} 226 mμ (ε 5600), suggesting an αβ-unsaturated ester linkage and a close relationship to other terpenic lac acids[2] (e.g. dimethyl shellolate, VI: λ_{max}^{EtOH} 230 mμ, ε 6000[1]).

Its PMR spectrum displays signals assignable to two quaternary methyls (3H, s at



V, R' = H

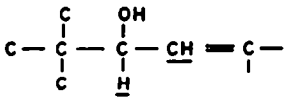
VI, R' = Me



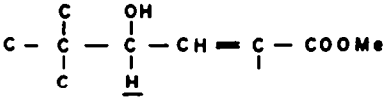
VII, R = COOH, R' = H

VIII, R = COOMe, R' = Me

IX, R = CHO; R' = H



X



XI

* The prefix *lacci* has been derived from *Laccifer lacca*, the lac insect.

55 and 64 c/s), two COOMe (3H, s at 220 and 222·5 c/s), one CHOH (1H d at 287 c/s, J = 2·5 c/s) and one olefinic H (1H d at 402 c/s, J = 2·5 c/s); its low field value suggests conjugation with an electronegative group. The presence of a CHOH proton and an olefinic proton which appear to be mutually coupled (cf. their J values), is reminiscent of the PMR spectra of several terpenic lac acids[2, 3] and points to the presence of the grouping X. This in view of the UV absorption of the new ester and the position of the olefinic proton in its PMR spectrum, can be extended XI, a structural feature characteristic of all the known terpenic lac acids.[2]

The data presented, taken in conjunction with the known structures of other terpenic lac acids[1, 2] and their PMR spectral characteristics,[2] point to the structure II for the new acid. The evidence for the stereochemistry at C_5 and C_7 is discussed below.

The OH at C_5 is placed α to the methylene bridge as in all other known terpenic lac acids.[2] This follows from the J-value (2·5 c/s) for the C_5—H, which is the same as has been observed for the C_5—H in shellolic acid (V)[3] and jalaric acid (IX),[2] thus indicating identical dihedral angles between the C_5—H and the C_4-olefinic proton. An examination of models (Dreiding) shows that had the C_5—OH been β-configurated, one would have seen a *larger* J-value. Experimental support for this conclusion is presented later, where PMR spectral data (Table 3) for a C_5—OH epimeric pair (XIV and XVI) is discussed.

The configuration at C_7 was assigned from a consideration of the possible effect of the stereochemistry of the C_7—COOMe on the chemical shift of C_5—H. A comparison of the C_5—H signals in the PMR spectra[2] of dimethyl shellolate (VI; 271 c/s) and dimethyl *epi*shellolate (VIII; 289 c/s), and an examination of molecular models, shows that the relative deshielding observed for the C_5—H in dimethyl *epi*shellolate can be ascribed to both C_7—COOMe and the C_5—H being on the same side. Since, the new ester displays its C_5—H signal at 287 c/s, that is at the field-strength observed for the C_5—H in dimethyl *epi*shellolate, the C_7—COOMe must be identically configurated in both the compounds. This is further supported by the PMR spectrum of the second new ester discussed later.

Though, the structure II is in full accord with the data presented, no *direct* evidence for the cedrane skeleton has yet been given. This aspect is discussed under laccijalaric acid, where a chemical correlation with α-cedrene is described. Thus, the new acid can be assigned the stereo-structure II and has been termed *epi*laccishellolic acid (*vide supra*).

Laccishellolic acid. The second new ester also analyses for $C_{17}H_{24}O_5$ and shows the following structural features: two quaternary methyls (PMR: 3H, s at 56 and 64 c/s), two COOMe groups (PMR: 6H, s at 225 c/s. IR: 1735 cm^{-1}), one CHOH (PMR: IH, d at 272, J = 2·5 c/s. IR: 3461, 1110, 1050 cm^{-1}) and a trisubstituted olefinic linkage, conjugated with a COOMe group (UV: λ_{max} 226 mμ, ε 6300; PMR: 1H, d centred at 395 c/s, J = 2·5 c/s. IR: C=C 1650 cm^{-1}). The data, interpreted in terms of *epi*laccishellolic acid (II), suggests that the second new acid has the formula I, and is a C_7-epimer of II. It may be noted that, as expected, the dimethyl ester of I displays its CHOH (C_5-H) signal at the same field-strength as observed for the C_5—H in dimethyl shellolate (VI; 271 c/s). The acid (I) has been termed laccishellolic acid (*vide supra*).

Estimation of laccishellolic and epi*laccishellolic acids in lac of various origin.* The procedure for the isolation and GLC estimation of these acids, was applied to seedlacs

of various origin and the results, summarized in Table 2, indicate the incorporation of these acids to a significant extent in various lacs.

TABLE 2. ESTIMATION OF LACCISHELLOLIC AND *EPI* LACCISHELLOLIC ACIDS IN LAC OF DIFFERENT ORIGIN

No.	Seedlac	Host tree	% of new acids in lac hydrolysate
1	*Palas*	*Butea monosperma* Linn.	10·0
2	*Kusmi*	*Zizyphus jujuba* Lam.	8·8
3	*Ber*	*Schleichera oleosa* Oken.	6·7
4	*Jalari*	*Shorea talura* Roxb.	8·9

Laccijalaric acid. The chemistry of jalaric acid (IX),[2] suggested that there may be an aldehydic acid, corresponding to *epi*laccishelloic acid (II) in the lac hydrolysate and in fact, such an acid may be the primary lac acid of the new series. The mother liquors from crude jalaric acid were screened by TLC and a 2,4-dinitrophenylhydrazine reagent spray, indicated the presence of another two such acids, besides jalaric acid and, of these, one was major. Finally, this new acid (major) was obtained in a pure, crystalline state (m.p. 164–165°).

The acid analyses for $C_{15}H_{20}O_4$ (M^+, $m/e = 264$) and readily yields an orange 2,4-DNP, m.p. 235–236°. Its PMR spectrum (DMSO-d_6; Fig. 1) shows two quaternary methyls (3H, s at 52 and 59 c/s), CHOH (1H, d at 271 c/s, J = 2·3 c/s; IR: 3380, 1040,

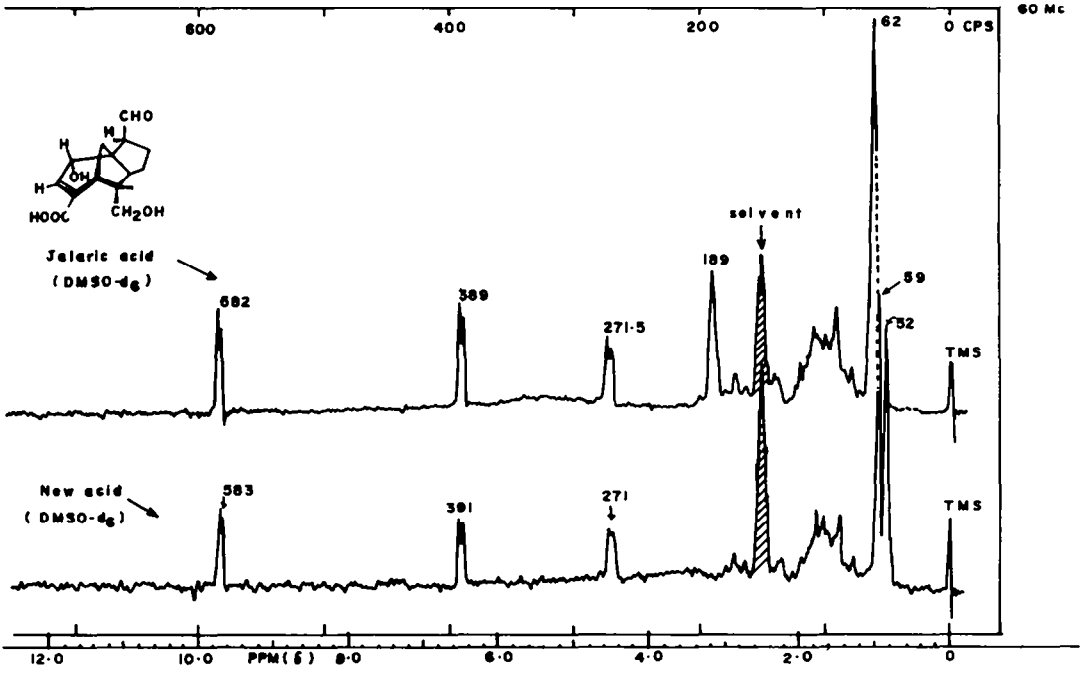


FIG. 1 PMR spectrum of jalaric acid and laccijalaric acid

1020 cm^{-1}, a trisubstituted olefinic linkage conjugated with COOH; (UV: λ_{max} 217 mμ, ε 7400; PMR: 1H, d at 391 c/s J = 2·3 c/s; IR: COOH 1690 cm^{-1}; C=C 1630

cm^{-1}) and, a —C(H)—CHO group (PMR: 1H, d at 583 c/s, J = 2·0 c/s). A comparison of its PMR spectrum with that of jalaric acid (Fig. 1) reveals that the two acids should have identical stereochemistry (see discussion under *epi*laccishellolic acid) at C_5 and C_7 and in fact, the only important difference in their PMR spectra is the replacement of the $C\underline{H}_2OH$ signal (189 c/s) in jalaric acid spectrum by an additional quaternary Me signal (52 c/s) in the spectrum of the new acid. Thus, the new acid can be formulated as III and in view of its relationship is named *laccijalaric acid*, by adding the prefix "lacci" adopted for this new series of lac acids.

As expected, alkaline silver oxide oxidation of laccijalaric acid furnished an excellent yield of *epi*laccishellolic acid (II).* Reduction with $NaBH_4$ gave the corresponding hydroxy acid (IV; *epi*laccilaksholic acid, *vide infra*).

Exposure of laccijalaric acid to aqueous alkali resulted in the formation of laccishellolic and *epi*laccishellolic acids together with their cannizzaro alcohol counterparts[2] [*laccilaksholic acid* and epi-*laccilaksholic acid* (IV)] as revealed by the TLC of the product before and after esterification (CH_2N_2) and comparison with authentic samples of I, II and IV (and their Me esters). These results, together with our inability to detect, to any significant extent, acids I, II after short-term (5 hr) saponification of lac, suggest that, in all probability, only laccijalaric acid is the primary acid of this series.

Correlation with (−)-α-cedrene. As already stated earlier, under *epi*laccishellolic acid, no *compelling* evidence for the cedrene skeleton of these acids has been provided. The cedrane skeleton for shellolic acid (and related compounds) is well-secured by sound degradative[1] and X-ray evidence.[4] In order to prove the structure of laccijalaric acid, (and hence, laccishellolic and *epi*laccishellolic acids) unequivocally, its chemical correlation with (−)-α-cedrene (XII)[5] has been carried out. The scheme successfully worked out for this purpose is outlined in Fig. 2.

Since α-cedrene (XII) and laccijalaric acid (III) have opposite configurations at C_7 it is essential to devise a correlation route which will eliminate this difference. Epimerization at C_7 in laccijalaric acid can be visualized and the results of alkali treatment of laccijalaric acid, indicate that the equilibrium position may not be very unfavourable for the other epimer; this is also supported by the detailed results obtained[2] with jalaric acid (IX), which is closely related to laccijalaric acid. Since, these aldehydic acids are highly susceptible to a Cannizzaro reaction epimerization with base, in a separate first step, appeared futile and it was decided to investigate the Wolff–Kishner reduction of laccijalaric acid with the hope that under the alkaline conditions of reaction some epimerization may precede reduction, resulting in the formation of reduction products of both series. This was realized in practice.

Conditions for Wolff–Kishner reduction (Huang–Minlon modification)[6] were standardized first on jalaric acid (IX), which is more easily accessible. The product, purified by chromatography of the derived methyl esters, consisted of the expected two epimers (XVIII and XIX), in which the isomer XVIII (having C_7-configuration identical to that in jalaric acid) predominated. The assignment of C_7-configuration to these products is based on the expected deshielding of the C_7—$C\underline{H}_3$, when this

* Under these new experimental conditions, jalaric acid also gave only *epi*shellolic acid, in contrast to the results obtained earlier[2] under somewhat different conditions.

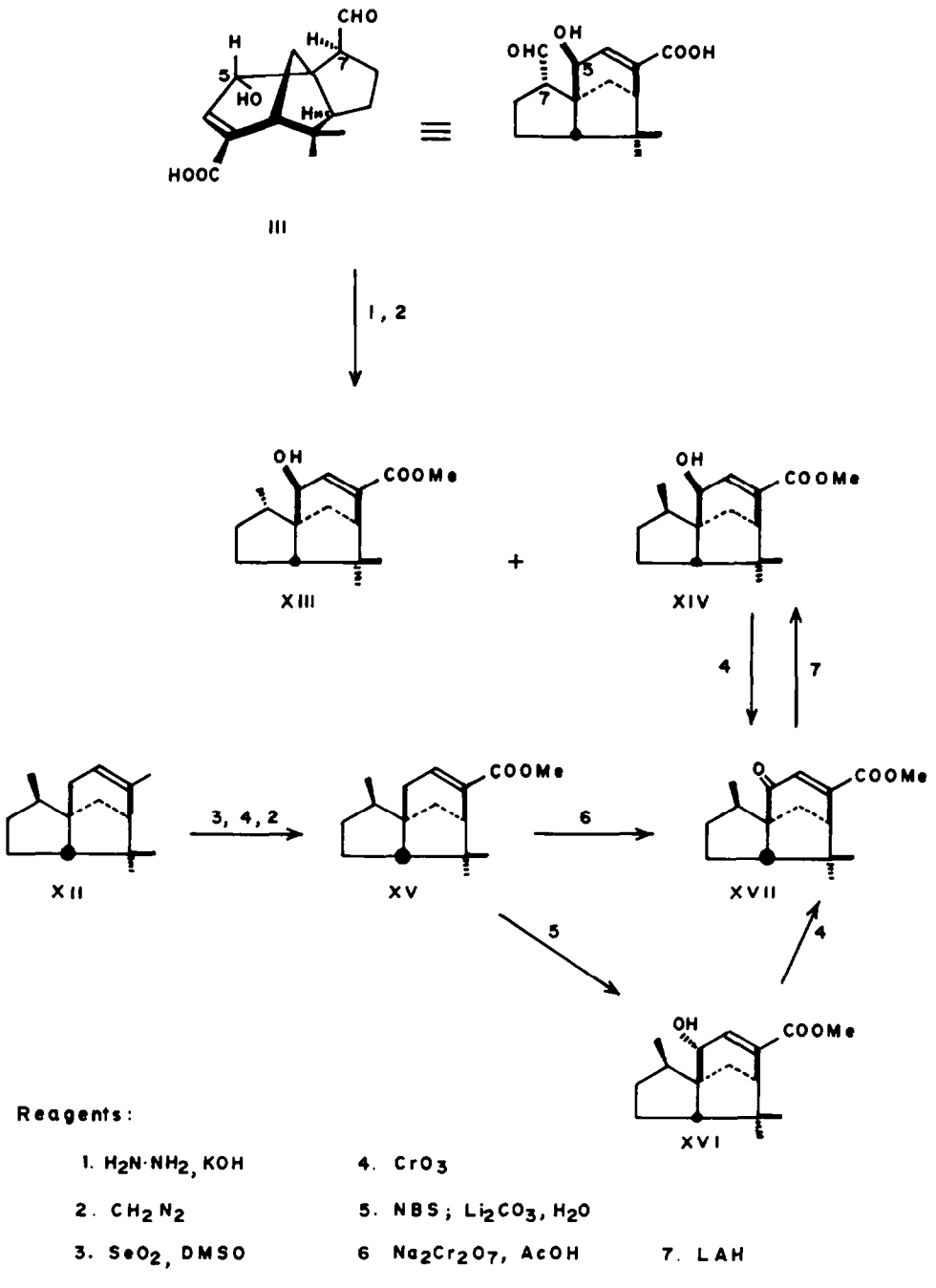
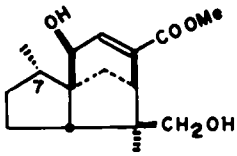
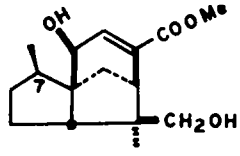


FIG. 2 Chemical correlation of laccijalaric acid with α-cedrene



XVIII



XIX

group and the C_5—OH are located on the same side (Table 3). Under these conditions laccijalaric acid was smoothly converted (after esterification) into a mixture of XIII and XIV, in which again the major component (XIII) had the C_7-configuration of the starting acid unchanged (Table 3).

TABLE 3. PMR SPECTRAL CHARACTERISTICS OF COMPOUNDS PREPARED DURING CORRELATION OF LACCIJALARIC ACID WITH CEDRENE

	Signal (c/s)* assignment†				
Compound	C(C)(C)—Me‡	CH—Me	COOMe‡	CHOH	—C=CH
XIX	67·5	66 (d, J = 6)	224·5	269 (d, J = 2·5)	391 (d, J = 2·5)
XVIII	66	52 (d, J = 6)	227	261 (d, J = 2)	398 (d, J = 2)
XIII	52·5 61·0	51 (d, J = 6)	222	263 (d, J = 2·5)	394 (d, J = 2·5)
XV	55 61	52 (d, J = 6)	220	—	402 (q, J = 3, 4·5)
XVII	57 72	75 (d, J = 6)	229	—	389 (s)
XIV	52 62	63 (d, J = 6)	220	269 (d, J = 2·5)	388 (d, J = 2·5)
XVI	50 63	60 (d, J = 6)	221	234 (d, J = 4·5)	398 (d, J = 4·5)

* All these spectra were recorded in CCl_4 solution.

† In case of multiplets, position given is that at the centre; s = singlet, d = doublet, q = quartet, J in c/s.

‡ All 3H singlets.

The next stage in the correlation envisaged the synthesis of XIV from α-cedrene. For this, (−)-α-cedrene (XII) was converted into the known α,β-unsaturated ester (XV).[7] Since the reported procedures did not prove efficient in our hands, new reagents were employed. Oxidation of α-cedrene to the corresponding allylic aldehyde (3-cedren-12-al) was best accomplished with SeO_2 in DMSO* Conversion of this aldehyde to the corresponding acid by the reported Ag_2O method,[8] having proved

* DMSO does not appear to have been used earlier as a solvent for SeO_2 oxidations. By using this solvent α-pinene and acetophenone gave myrtenal and phenylglyoxal in 60 and 50% yields respectively.

wasteful, this oxidation was more effectively carried out by Jones reagent;[9] a minor side product in this oxidation proved to be 5-keto-cedrenic acid (methyl ester, XVII; *vide infra*). α-Cedrenic acid, thus obtained, was converted to the methyl ester XV by CH_2N_2.

The next stage was the introduction of a β-OH at C_5 in the ester XV. A study of a molecular model of cedrene shows that approach to C_5 should be more hindered from the β-face (structures to be viewed as in XII), which is in line with several recent studies on the stereochemistry of cedrane derivatives.[10] It thus, became obvious that the introduction of a β-OH at C_5 should be possible by the hydride reduction of the C_5-keto ester (XVII), whence attack by the incoming hydride ion from α-face should result in the desired configuration at C_5. Preparation of the keto ester (XVII) was achieved by two methods. In the first method, cedrenic ester (XV) was treated with NBS and the crude bromo-derivative solvolysed in buffered aqueous dioxan[11] and the resulting alcohol mixture (*vide infra*) directly oxidized with Jones reagent to give XVII in 20% overall yield (based on XV). The second route, which proved more convenient and efficient involved allylic oxidation of cedrenic ester (XV) with $Na_2Cr_2O_7$ in AcOH,[12] which yielded XVII in ~45% yield. The preparations from the two routes were completely identical, and showed the required spectral characteristics (λ_{max} 245 mμ, ε, 6500. IR: 1745, 1698, 1640 and 790 cm^{-1}). In keeping with its formulation as XVII, its PMR spectrum shows a signal for two quaternary methyls (3H, s at 57 and 72 c/s), C<u>H</u>$_3$—CH (3H, d at 75 c/s, J = 6 c/s; in the ester XV, this signal occurs at 52 c/s, and this large downfield shift in XVII is in line with the carbonyl at C_5 and a β-Me at C_7), COO<u>Me</u> (3H, s at 229 c/s), and C<u>H</u>=C—COOMe (1H, s at 389 c/s).

TABLE 4. COMPARISON OF THE PHYSICAL PROPERTIES OF THE HYDROXY ESTER XIV PREPARED FROM LACCIJALARIC ACID AND CEDRENE

Property	Hydroxy ester XIV	
	From laccijalaric acid	From cedrene
m.p.	90–91°	90–91°
$[\alpha]_D^{26}$	+47·2 (*c*, 0·89%)	+45·5 (*c*, 1·5%)
λ_{max}^{EtOH}	232 mμ (ε 6430)	232 mμ (ε, 5730)
IR (Nujol):		
OH	3420 cm^{-1}	3420 cm^{-1}
COOMe	1715 cm^{-1}	1715 cm^{-1}
C=C	1645, 790, 760 cm^{-1}	1645, 790, 760 cm^{-1}
PMR (CCl_4)		
Quaternary methyls	53 (s); 62 (s)	54 (s); 63 (s)
CH—C<u>H</u>$_3$	63 (d, J = 6 c/s)	63 (d, J = 6 c/s)
COO—C<u>H</u>$_3$	222 (s)	222·5 (s)
C<u>H</u>OH	269 (d, J = 2·5 c/s)	270 (d, J = 2·5 c/s)
C=C<u>H</u>	388 (d, J = 2·5 c/s)	388·5 (d, J = 2·5 c/s)

The above keto ester (XVII) on reduction with LAH gave as the major product, the desired hydroxy ester (XIV),* identical in all respects (Table 4) with the product obtained

* In connection with other work it was demonstrated that the allylic ester function in these compounds was not reduced.

from laccijalaric acid (III) by Wolff–Kishner reduction. Since the two products have the same sign and magnitude of rotation,* this correlation also establishes the absolute stereochemistry of laccijalaric acid (and related compounds), as that of (−) α-cedrene (XII) is well-established.[13] Thus, the structures depicted in this communication represent absolute configurations.

Earlier, we have referred to an alcohol mixture obtained by the solvolysis of the bromo ester resulting from the action of NBS on XV. In view of our earlier discussion on the stereochemistry of attack at C_5 in cedrene skeleton, it was anticipated that the secondary allylic alcohol from the reaction mixture should have α-OH configura- at C_5. It was thought worthwhile to isolate this, and thus confirm the C_5-β-OH in laccijalaric acid and related compounds. An allylic secondary alcohol was isolated from this solvolysis product which was completely different from the alcohol XIV and displayed PMR spectral characteristics (Table 3) expected for structure XVI. It may be noted that in line with our earlier discussion on the sterochemistry of *epi*-laccishellolic acid this alcohol with C_5-α-OH shows a different chemical shift (234 c/s) and larger J value (4·5 c/s) for its coupling with the C_4 olefinic proton, as compared to the values (269 c/s, J = 2·5 c/s) in the C_5-β-OH isomer (XIV).

EXPERIMENTAL

For general remarks see Part I of the series.

Laccishellolic acid and epi*laccishellolic acid*

Isolation. Palas seedlac (10 g) was hydrolysed with KOHaq (20%, 50 ml) at room temp (30°) for 10 days. The alkaline soln was acidified with HClaq (1:1) and the product taken up in EtOAc (100 ml × 3), which was washed with water and dried (Na_2SO_4). The solvent was flashed off and the residue (9·13 g) esterified (CH_2N_2) and the resulting methyl ester mixture chromatographed on Al_2O_3/II (40 cm × 3 cm), the column being eluted with C_6H_6 (200 ml × 5). The eluted product (2·02 g), showed on GLC (temp 240°; gas flow, 15 ml/min) three peaks with RRT of 1, 2·3 and 2·9 with almost equal areas. This material was rechromatographed on Al_2O_3/II (27 cm × 2·3 cm) with TLC monitoring (solvent: 33% EtOAc in C_6H_6; temp 30°):

Frac. 1	pet. ether	300 ml × 2	0·92 g	single, elongated spot at R_f 0·8; essentially methyl butolate; GLC, RRT 1.
Frac. 2	pet. ether + 10% benzene	300 ml	0·251 g	two spots at R_f 0·65 and 0·56
Frac. 3	pet. ether + 25% benzene	200 ml × 2	0·310 g	
Frac. 4	pet. ether + 50% benzene	300 ml	0·13 g	three spots at R_f 0·65, 0·56 and 0·52.
Frac. 5	pet. ether + 75% benzene	300 ml × 2	0·196 g	laccishellolic ester (R_f 0·56) and its epimer (R_f 0·52).
Frac. 6	benzene	300 ml	0·086 g	TLC pure, R_f 0·52 (*epi*laccishellolate).

Frac. 6 on crystallization from pet. ether afforded *methyl* epi*laccishellolate* (80 mg), m.p. 94–95°. (Found: C, 66·73; H, 7·92. $C_{17}H_{24}O_5$ requires: C, 66·22; H, 7·78%). This material (40 mg) was hydrolysed with NaOHaq (1 ml, 10%) for 24 hr at room temp to yield *epi*laccishellolic acid (32 mg) m.p. 235–236° (MeOH), λ_{max} 224 mμ (ε 4800). IR spectrum: OH 3300, 1140, 1120, 1070, 1045, 1025 cm^{-1}; COOH 2658, 1700, 940 cm^{-1}; C=C—COOH 1680, 1640, 795, 784 cm^{-1}. PMR spectrum (DMSO-d_6): quaternary methyls (51 c/s, 3H, s; 59 c/s, 3H, s); C=CH—CHOH (274·5 c/s, 1H, d with J = 2 c/s); C=CH—CHOH (389 c/s, 1H, d with J = 2 c/s). (Found: C, 64·74; H, 7·21. $C_{15}H_{20}O_5$ requires: C, 64·28; H, 7·14%).

*This was further ensured by oxidizing the hydroxy ester from laccijalaric acid and comparing the rotations of the resulting keto ester (XVII) with the sample from cedrene.

Frac. 2 and 3 were mixed and rechromatographed on Al_2O_3/II (23 cm × 1 cm) with TLC monitoring as above:

Frac. a	pet. ether	300 ml	111 mg	streak, R_f 0·65
Frac. b	pet. ether + 25% benzene	300 ml × 2	210 mg	mixture, R_f 0·65, 0·56
Frac. c	pet. ether + 50% benzene	300 ml	50 mg	
Frac. d	pet. ether + 50% benzene	300 ml	42 mg	TLC pure, R_f 0·56 (laccishellolate)
Frac. e	pet. ether + 75% benzene	300 ml	35 mg	
Frac. f	benzene	300 ml	47 mg	mixture, R_f 0·56, 0·52

Frac. d and e were mixed and recrystallized from pet. ether to furnish needles of *methyl laccishellolate*, m.p. 85–87°. (Found: C, 66·52; H, 7·56. $C_{17}H_{24}O_5$ requires: C, 66·22; H, 7·78%). Hydrolysis (30 mg) as above afforded *laccishellolic acid* as crystals (MeOH) m.p. 196–198°, λ_{max} 223 mμ (ε 4200). IR spectrum: OH 3300, 1175, 1135, 1085, 1040 cm^{-1}; COOH 2600, 1720, 920 cm^{-1}; C=C—COOH 1680, 1645, 790 cm^{-1}. (Found: C, 64·57; H, 7·31. $C_{15}H_{20}O_5$ requires: C, 64·28; H, 7·14%).

Estimation in various seedlacs. Seedlacs of various origin (Table 2) were hydrolysed for 10 days as above and, the acids isolated and esterified in the same manner. In each case the total esters, were chromatographed (~1 g of ester mixture; Al_2O_3/II (25 g, 27 cm × 1 cm) and the benzene eluted material collected and the components estimated by GLC (see above under "isolation"). The yields of benzene eluted material, based on the total esters were 20% (*palas*), 18% (*kusmi*), 14% (*ber*) and 18% (*jalari*). The estimated yields of new acids are given in Table 2.

Laccijalaric acid

Isolation. Shellac (300 g) was saponified with NaOH aq (4%, 1500 ml) at 18–20° for 5 hr. The alkaline soln was acidified with H_3PO_4 aq (1:1, 300 ml) when a gum separated, which was collected by filtration (fluted filter paper) and washed with water (400 ml × 3). The combined filtrate and washings were extracted with EtOAc (1200 ml and 450 ml × 2). The EtOAc extract was washed with water (300 ml × 3), dried (Na_2SO_4) and concentrated to ~150 ml under reduced press. The crude jalaric acid (~10 g) which separated from this on keeping (~25°) was collected and the mother liquor processed for the isolation of laccijalaric acid.

From the above mother liquor, the solvent was flashed off (reduced press) and the gummy residue (~12 g) extracted with $CHCl_3$ (125 ml × 2). The $CHCl_3$ extracts were freed of solvent to give a solid foam (1·82 g). TLC (solvent system: 65% EtOAc in C_6H_6) of this material showed three spots at R_f 0·20, 0·37 and 0·55, all detectable with 2,4-dinitrophenylhydrazine reagent. This material (1·8 g) was chromatographed over silica gel/II (22 cm × 3 cm):

Frac. 1	8% EtOAc in C_6H_6	100 ml	—	
Frac. 2	12% EtOAc in C_6H_6	100 ml	—	
Frac. 3	12% EtOAc in C_6H_6	100 ml × 4	0·67 g	TLC pure, R_f 0·55 (laccijalaric acid)
Frac. 4	12% EtOAc in C_6H_6	100 ml × 2	0·18 g	mixture, R_f 0·37, 0·55
Frac. 5	20% EtOAc in C_6H_6	100 ml × 3	0·30 g	mixture, R_f 0·20, 0·37

Frac. 3, which was solid, was washed with benzene and then recrystallized from EtOAc to give colourless needles (260 mg) m.p. 164–165°, $[\alpha]_D^{25}$ +26·31 (*c*, 1·52%). (Found: C, 67·97; H, 7·5. $C_{15}H_{20}O_4$ requires: C, 68·18; H, 7·57%).

2,4-*Dinitrophenylhydrazone* (H_2SO_4 method) was obtained as an orange powder (EtOH), m.p. 235–236°. (Found: C, 57·06; H, 5·44; N, 13·00. $C_{21}H_{24}O_7N_4$ requires: C, 56·78; H, 5·40; N, 12·61%).

Oxidation of laccijalaric acid with silver oxide. Aq. NaOH (10%, 10 ml) was added to $AgNO_3$ (0·7 g, powdered) and the mixture was stirred at room temp for 5 min. To this reagent a soln of laccijalaric acid (300 mg) in dioxan was added in one lot. The oxidation was complete in 7 min (as tested by DNP reagent), after which the contents were stirred for another 15 min. The precipitated Ag was filtered off and thoroughly washed with water. The filtrate and washings were combined, acidified with 1N HCl and extracted with EtOAc. Removal of solvent after washing and drying (Na_2SO_4) yielded a crystalline material (300 mg)

which on recrystallization with EtOAc gave needles (200 mg), m.p. 235–236° characterized as *epi*laccishellolic acid.

Reduction of laccijalaric acid. To a stirred suspension of $NaBH_4$ (200 mg) in isopropanol (12 ml), laccijalaric acid (300 mg) was added in portions over a period of 10 min. After addition was complete the reaction mixture was stirred for 5 min. Usual work-up yielded a solid mass (300 mg) which was chromatographed on silica gel/II (18 g, 20 cm × 2 cm). The fraction (254 mg) eluted with benzene + 30% EtOAc was obtained as needles (EtOAc) m.p. 206–208°, $[\alpha]_D^{25}$ +35·5 (c, 1·07%), λ_{max} 218 mμ (ε 6270). IR spectrum: OH 3220, 3100, 1095, 1060, 1018 cm^{-1}; COOH 1710 cm^{-1}; C=C 1640, 820 cm^{-1}; C—Me_2 1380, 1365 cm^{-1}. (Found: C, 67·5; H, 8·49. $C_{15}H_{22}O_4$ requires: C, 67·66; H, 8·27%).

Methyl ester IV (CH_2N_2 method): m.p. 124–125° (EtOAc–C_6H_6). IR spectrum: OH 3350, 3250, 1040, 1010 cm^{-1}; COOMe 1690 cm^{-1}; C=C 1620, 805 cm^{-1}. PMR spectrum: quaternary methyls (54 c/s, 3H, s; 61 c/s, 3H, s); CH°. $C\underline{H}_2OH$ (216 c/s, 2 H, d with J = 7·5 c/s); C=CH—$C\underline{H}OH$ (283 c/s, 1H, d with J = 2·5 c/s); C=$C\underline{H}$—CHOH (398 c/s, 1H, d with J = 2·5 c/s). (Found: C, 68·06; H, 8·82. $C_{16}H_{24}O_4$ requires: C, 68·57; H, 8·57%).

Treatment of laccijalaric acid with alkali. Laccijalaric acid (0·17 g) dissolved in NaOH aq (0·7 ml, 20%) was kept at room temp. (~28°) for 10 days. Usual working up furnished the acid mixture (0·15 g), TLC of which [solvent system: EtOAc, C_6H_6, AcOH (70:39:0·5 v/v)] showed four spots (R_f 0·5, 0·47, 0·37, 0·2) three of which (R_f 0·5, 0·47 and 0·2) could be identified as laccishellolic, *epi*laccishellolic and *epi*laccilaksholic by comparison with authentic samples. TLC of the methyl esters [solvent system: toluene, EtOAc, acetone (7:4:4 v/v)] gave the four spots with $R_{laccishellolate}$ as 1·0, 0·94, 0·74 and 0·4 of which those with $R_{laccishellolate}$ 1·0, 0·94, and 0·4 were shown (by comparison with authentic samples) to represent laccishellolate, *epi*laccishellolate and *epi*laccilaksholate.

Chemical correlation of laccijalaric acid with cedrene

Huang–Minlon reduction of jalaric acid. Jalaric acid (IX) (1·5 g, 0·0053 mole) was added to a warm soln of KOH (0·9 g) in diethylene glycol (30 ml). The resulting soln was left at room temp (~30°) for 30 min. Hydrazine hydrate (6 ml, 99–100%) was added and the contents were heated for 2 hr at 120° (temp of reaction mixture). As the temp was raised to 180–190°, the excess hydrazine and water distilled off. After heating at 180–190° for 3 hr, it was cooled, diluted with water (300 ml), acidified with dil HCl (1 :1) and extracted with EtOAc (4 × 150 ml). The reduced product (1·32 g) obtained after usual work up was converted to the methyl ester (CH_2N_2). The methyl ester (300 mg) was chromatographed on SiO_2 gel/II (10 g, 12 cm × 1·5 cm).

Frac. 1	Benzene	150 ml	negligible	
Frac. 2	Benzene + 10% EtOAc	100 ml	12 mg	Impure
Frac. 3	Benzene + 10% EtOAc	100 ml	40 mg	TLC pure
Frac. 4	Benzene + 10% EtOAc	2 × 100 ml	120 mg	Impure
Frac. 5	Benzene + 10% EtOAc	3 × 60 ml	98 mg	TLC pure

Frac. 3 gave crystals of XIX, m.p. 75–76° (benzene–pet. ether) $[\alpha]_D^{25}$ +41·30 (c, 0·92%). IR spectrum: OH 3500, 3400, 1095, 1040 cm^{-1}; C=C—COOMe 1695, 1640 cm^{-1}. (Found: C, 68·31; H, 8·90. $C_{16}H_{24}O_4$ requires: C, 68·57; H, 8·57%).

Frac. 5 afforded crystals of XVIII m.p. 111–112° (benzene–pet. ether) $[\alpha]_D^{26}$ +48·6 (*c* 1·44%). IR spectrum: OH 3400, 3240, 1085, 1060, 1040, 1015 cm^{-1}, C=C—COOMe 1698, 1627, 820, 780 cm^{-1}. (Found: C, 68·60; H, 8·99. $C_{16}H_{24}O_4$ requires: C, 68·57; H, 8·57%).

Huang–Minlon reduction of laccijalaric acid (III) *to hydroxy ester* (XIV). Laccijalaric acid (520 mg) was added to a warm soln of KOH (0·3 g) in diethylene glycol (30 ml) under experimental conditions for the reduction of jalaric acid. The product (470 mg) showed on TLC two major (R_f 0·6, 0·65) and one minor spot (R_f 0·5); (solvent system: benzene, EtOAc, AcOH 6:3:1).

Chromatography on SiO_2 gel/act. II (35 g, 40 cm × 1·3 cm) furnished in the early benzene + 6% EtOAc fraction a pure component (R_f 0·65, 46 mg) whose methyl ester (XIV, CH_2N_2 method) m.p. 90–91° (pet. ether), was identical (TLC, IR, mixed m.p.) with that of XIV prepared from cedrene. [Oxidation of this hydroxy ester (30 mg) with Jones reagent (*vide supra*) afforded a compound b.p. bath 180–190°/2 mm. $[\alpha]_D^{30}$ −90·0 (c, 3·75%) characterized as the keto ester (XVII)].

The later benzene +6% EtOAc fraction afforded the other component (R_f 0·6, 122 mg) in pure form. It yielded needles ($CHCl_3$) m.p. 190–191°, $[\alpha]_D^{26}$ +60° (c, 1%). IR spectrum: OH 3250, 1045, 1020 cm^{-1};

COOH 1675 cm^{-1}; C=C 1630, 780 cm^{-1}. *Methyl ester* (XIII, CH_2N_2 method): m.p. 98–100° (C_6H_6–pet. ether), $[\alpha]_D^{29}$ +50° (*c*, 1%), λ_{max} 232 mμ (ε, 6650). IR spectrum: OH 3380, 1140, 1058, 1045 cm^{-1}; C=C—C=O 1680, 1625, 805, 772 cm^{-1}. (Found: C, 72·78; H, 9·15; $C_{16}H_{24}O_3$ requires: C, 72·72; H, 9·09%).

3-*Cedren*-12-*al*. α-Cedrene ($[\alpha]_D$ −91·3°; 15 g, ~0·07 mole), DMSO (75 ml) and SeO_2 (9·4 g, ~0·085 mole) was heated on steam bath for 10 min. The soln becomes dark, and the black ppt of selenium slowly began to separate. After 3 hr the reaction mixture was filtered and the selenium (4·5 g) washed thoroughly with water and pet. ether. The filtrate after dilution with water was extracted with ether. Usual work up gave a pale-yellow liquid (13·1 g; yield, 81·7%) b.p. 140°/4 mm, λ_{max} 240 mμ (ε, 4300), purity >95% (GLC); identified by comparison (GLC, IR) with a sample b.p. 136°/2 mm. (yield 76%); (Lit.[7] b.p. 163°/20 mm, yield 71·5%), prepared by the known method.[7] IR spectrum: CHO 2762, 1695 cm^{-1}; C=C 1639, 822, 803 cm^{-1}; PMR spectrum (CCl_4 solvent): CH—CH_3 (53 c/s, 3H, d with J = 6 c/s); quaternary methyls (50 c/s, 3H, s; 60 c/s, 3H, s); CH_2—CH=C—CHO (392 c/s, 1H, q with J = 3, 4·5 c/s); C=C—CHO (557 c/s, 1H, s).

3-*Cedren*-12-*oic acid*. Jones reagent [prepared from CrO_3 (1·25 g) in dil H_2SO_4 (10·8N, 5 ml)] was added dropwise to a cooled soln of the aldehyde (0·128 g) in acetone (5 ml). After keeping at room temp (~30°) for 1·5 hr with occasional swirling, the reaction mixture was diluted and extracted with ether. Usual work up afforded a neutral product (0·036 g, 27·5% yield, 6 components by GLC) and an acid (0·097 g, 70·2% yield) which afforded yellow prisms (0·02 g, 16% yield, from CH_3CN), m.p. 118–120°, $[\alpha]_D^{30}$ −71·4 (*c*, 1·4%). (Lit.[7] m.p. 124–125°, yield 46·8%). IR spectrum: COOH 2630, 1695, 935 cm^{-1}; C=C 1645, 793, 769 cm^{-1}.

Methyl ester (XV, CH_2N_2 method): b.p. 171°/10 mm. (Lit.[7] b.p. 167–169°/20 mm.), λ_{max} 229 mμ (ε, 6650); IR spectrum: COOMe 1730 cm^{-1}; C=C 1645, 787, 772 cm^{-1}.

Methyl 5-α-*hydroxy*-3-*cedren*-12-*oate* (XVI). To the above ester (0·10 g) dissolved in CCl_4 (4 ml) NBS (0·087 g, 1·2 eq.) and benzoyl peroxide (1·2 mg) was added. After gentle refluxing for 4 hr, the succinimide (0·04 g) was filtered off and washed with CCl_4. The filtrate was washed with water and dried (Na_2SO_4). Removal of solvent gave the crude bromide (0·126 g, 95·6% yield).

The above bromide (crude), Li_2CO_3 (0·016 g, 0·5 eq.) dioxan (3·3 ml) and water (1·1 ml) was heated on waterbath for 4 hr. Usual work up furnished a viscous liquid (0·073 g, 69·5%) b.p. bath 179–185°/1 mm. As this material (0·5 g) showed two spots by TLC (R_f 0·37 and 0·42; solvent system: EtOAc–toluene 4:21), it was chromatographed on Al_2O_3/II (15 g, 20 × 0·7 cm).

The first pet. ether–toluene (1:1) eluates contained pure material (R_f 0·42, 0·08 g), as a viscous liquid b.p. bath 175–180°/1 mm, λ_{max} 230 mμ (ε, 5500); IR spectrum: OH 3400 cm^{-1}, COOMe 1710 cm^{-1}; C=C 1650, 785 cm^{-1}. (Found: C, 77·52; H, 9·95. $C_{16}H_{24}O_3$ requires: C, 77·37; H, 9·74%).

Methyl-5-*keto*-3-*cedren*-12-*oate* (XVII). To the cooled stirred soln of the crude product, obtained after solvolysis (1·98 g), in acetone (25 ml) Jones reagent [prepared from CrO_3 (1·12 g) in aq. H_2SO_4 (10·8N, 4·5 ml)] was added in portions. Usual manipulations yielded the neutral material (1·766 g).

Chromatography of this material on Al_2O_3/II (60 g, 17 × 2·1 cm) yielded in the late pet. ether fractions a pure component (GLC) as a greenish viscous liquid (408 mg, 19Π yield based on ester XV) b.p. (bath) 180–190°/2 mm, $[\alpha]_D^{30}$ −93·5 (*e*, 1·24Π). (Found: C, 73·3; H, 8·48. $C_{16}H_{22}O_3$ requires: C, 73·24; H, 8·39%).

The keto ester (XVII) can be conveniently prepared by the following method:

The ester (XV, 1 g) $Na_2Cr_2O_7$ (powdered, 2 g), AcOH (30 ml) and benzene (50 ml) were heated and stirred on waterbath for 40 hr. The reaction mixture was then diluted with water and the C_6H_6 layer was separated without shaking (to prevent emulsion formation), the aqueous layer was then extracted with ether. The combined organic layer was washed with water, 5% NaOH aq, water and dried (Na_2SO_4). Distillation yielded a greenish liquid (755·7 mg, 72·5% yield) b.p. bath 190°/2 mm (mixture of ester and keto ester 1:7·5 by GLC). These components were separated by chromatography over Al_2O_3/II (28 g, 17 × 1·2 cm). The early pet. ether fraction contained the ester while the later fractions contained the desired keto ester (433·9 mg, ~45% yield) identified by comparison (GLC, IR) with the earlier prepared sample (*vide supra*).

Methyl 5β-*hydroxy*-3-*cedren*-12-*oate* (XIV). To a stirred suspension of LAH (50 mg, 1·33 mmole) in dry ether (5 ml), a soln of the above keto ester (100 mg, 0·4 mmole) in dry ether (7 ml) was added slowly. After stirring for 48 hr at room temp (~28°) the product was diluted with an aqueous soln of Rochelle salt. Usual work up furnished the crude product (96 mg, 94·32% yield) which showed on TLC the presence of four compounds of which one (R_f 0·54; solvent system: EtOAc–benzene 1:4) was predominant.

Chromatography over Al_2O_3/II (17 × 0·8 cm) gave in the benzene eluate a viscous liquid (46·6 mg, ~45% yield) m.p. 90–91° (pet. ether). (Found: C, 77·0; H, 9·68. $C_{16}H_{24}O_3$ requires: C, 77·37; H, 9·74%).

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