994. *Triterpenoids. Part XXVI.* The Triterpenoids of* Vangueria tomentosa.

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The saponin from the roots of *Vangueria tomentosa* affords on hydrolysis two isomeric triterpenoid acids, which have been shown to be 18-dehydro-20-epi- and 19-dehydro-ursolic acid (vanguerolic and tomentosolic acid, respectively). The biogenesis of these unusual compounds has been discussed.

In 1939 Merz and Tschubel[1] described the isolation of a triterpenoid hydroxy-acid, vanguerigenin, on hydrolysis of vanguerin, the saponin in the root bark of *Vangueria tomentosa*. This triterpenoid is of unusual biogenetic interest because it was reported to have the composition $C_{30}H_{46}O_3$ being, formally, a dehydro-acid of normal composition. Vanguerigenin was characterised by various simple derivatives (see Table 1). On treatment with acid it gave an isomeric lactone. It readily lost carbon dioxide on pyrolysis to furnish a compound, $C_{29}H_{46}O$, called vanguerol. Dehydrogenation with selenium afforded 1,2,7-trimethylnaphthalene.

A re-examination of this sapogenin revealed that it is in reality a mixture of two hydroxy-acids of the composition $C_{30}H_{46}O_3$. These compounds can be separated by fractional crystallisation of their methyl ester acetates. We propose that the strongly dextrorotatory acid be known as vanguerolic acid and the other as tomentosolic acid. A comparison (Table 1) of the constants recorded for vanguerigenin with those that we find for vanguerolic and tomentosolic acid shows that vanguerigenin was a mixture whose derivatives must have been substantially those of tomentosolic acid. The pyrolysis product, vanguerol, and the lactone from vanguerigenin were, however, essentially pure compounds.

Table 1.

	Acid		Acid Me ester		Acid acetate		Me ester acetate	
	m. p.	$[\alpha]_D$	m. p.	$[\alpha]_D$	m. p.	$[\alpha]_D$	m. p.	$[\alpha]_D$
" Vanguerigenin " ...	266°	+191°	195°	—	295°	—	248°	—
Vanguerolic acid ...	273	+306	162	+308°	181	+270°	190	+277°
Tomentosolic acid ...	285	+18	206	+15	321	+6	235 247	+9

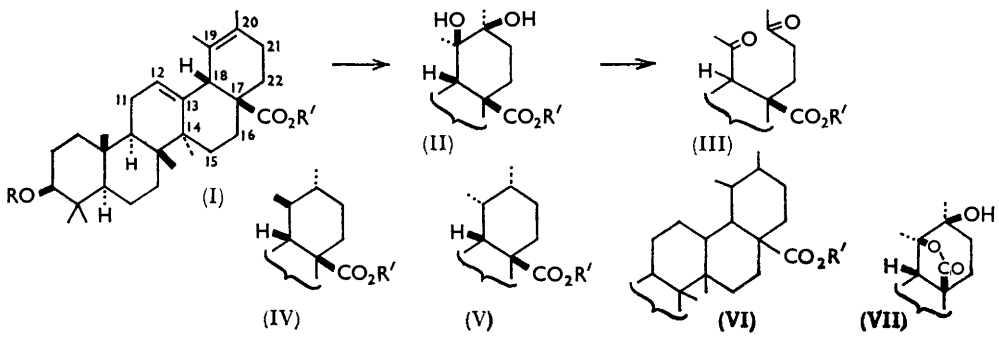
A third triterpenoid acid was also present, in minor amount. This was shown to be the ketone from tomentosolic acid, for reduction of the methyl ester with borohydride gave methyl tomentosolate.

The experiments reported in the present paper show that vanguerolic acid is 18-dehydro-20-epiursolic acid (IX; R = H, R′ = CO_2H), and that tomentosolic acid is the 19-dehydro-isomer (I; R = R′ = H). For convenience of exposition we discuss the chemistry of the latter acid first.

* Part XXV, *J.*, 1961, 255.

[1] Merz and Tschubel, *Ber.*, 1939, **72**, 1017.

Tomentosolic acid showed only terminal absorption in the ultraviolet region. The nuclear magnetic resonance spectrum of the methyl ester acetate indicated the presence of one vinyl hydrogen and of two vinyl-attached methyl groups. This was confirmed by reaction of the methyl ester acetate with osmium tetroxide, to give the glycol (II; R = Ac, R′ = Me) which on cleavage by lead tetra-acetate furnished the diketone (III; R = Ac, R′ = Me). The latter had two methyl ketone groups and one vinyl hydrogen in its nuclear magnetic resonance spectrum. If one assumes a conventional pentacyclic triterpenoid skeleton for tomentosolic acid then the only position where a double bond with two methyl groups attached can be placed is in the ursolic acid (IV; R = R′ = H) type of structure. We reasoned that if this kind of formulation were really correct then hydrogenation would proceed mainly by *cis*-addition to give a compound (V; R = R′ = H) which can be called dihydrotomentosolic acid. However, a small percentage of *trans*-addition might also be hoped for and this might, of course, give the well-known ursolic acid. Since only small quantities of vanguerolic and tomentosolic acid were available we decided to try first of all to detect ursolic acid by the isotope dilution method. Methyl tomentosolate was acetylated with [^{14}C] acetic anhydride, and the resulting methyl ester acetate was hydrogenated. The product was diluted with inactive methyl ursolate acetate and the yield of methyl ursolate acetate formed in the hydrogenation determined in the



usual way. It proved to be 10·5%. This was too great to be due to impurity in the methyl tomentosolate acetate, but the point was checked by repeating the dilution experiment with methyl ursolate acetate *before* the hydrogenation. In order to facilitate the subsequent reisolation of the methyl ursolate acetate the mixture was oxidised vigorously with chromic acid. The reagent destroys the methyl tomentosolate acetate (see below) and converts the ursolic acid derivative into the well-known 11-ketone (VIII; R = Ac, R′ = Me). Counting this derivative proved that less than 0·6% of ursolic acid could have been present in the tomentosolic acid.

With this important preliminary experiment completed, the hydrogenation of methyl tomentosolate acetate was repeated on a larger scale. The mixture of methyl ester acetates produced was converted into the corresponding benzoates and fractionally crystallised. In this way there was obtained (i) methyl ursolate benzoate (2%) (IV; R = Bz, R′ = Me), (ii) methyl dihydrotomentosolate benzoate (26%) (V; R = Bz, R′ = Me) (see below) and (iii) methyl tetrahydrotomentosolate benzoate (13%) (VI; R = Bz, R′ = Me). The formation of the tetrahydro-compound was unexpected since no prior hydrogenation of the 12(13)-double bond in pentacyclic triterpenoids has been recorded. The matter is discussed below. The formation of methyl ursolate acetate on hydrogenation, not only proves the constitution of tomentosolic acid, but also determines its complete stereochemistry.

We now turn to vanguerolic acid and show it to have the constitution (IX; R = H, R′ = CO_2H). Methyl vanguerolate acetate has peculiar ultraviolet absorption ($\lambda_{max.}$ 225 mμ; ε 7800). This is not due to an αβ-unsaturated ester chromophore because reduction

with lithium aluminium hydride and acetylation gave the corresponding diol diacetate (IX; R = Ac, R′ = CH_2·OAc) which had a very similar ultraviolet spectrum ($\lambda_{max.}$ 227·5 mμ; ε 9900). The nuclear magnetic resonance spectrum of methyl vanguerolate acetate was important because it showed the presence of one vinyl hydrogen and one vinyl-attached methyl group.

The carbon skeleton of vanguerolic acid was determined from investigations on its decarboxylation product, vanguerol (X; R = H). This decarboxylation occurs so readily that the presence of a βγ-unsaturated acid was at once suspected.[2] Vanguerol and its acetate had diene absorption of high intensity in the ultraviolet region. The spectrum had a triple maximum of the kind seen with noroleana-12,18(17)-dienyl acetate (XI; R = Ac).[2] A convenient synthesis of the latter compound was achieved by pyrolysis of the acid chloride of oleanolic acid acetate.[3] The same reaction sequence was then applied in the ursolic acid series. Ursolic acid acetate (IV; R = Ac, R′ = H) was converted into the acid chloride (XII; R = Ac) and pyrolysed to give norursa-12,18(17)-dienyl acetate (XIII; R = Ac). Again the ultraviolet spectrum was essentially identical with that of vangueryl acetate. The close agreement in spectroscopic and rotational properties can be seen in Table 2. In addition, the infrared spectra of the three dienes in the 1300—

TABLE 2.

Compound	$[\alpha]_D$	$\lambda_{max.}$ (mμ) and (in parentheses) ε		
Vangueryl acetate (X; R = Ac)	+116°	237 (19,100)	245 (20,300)	253 (12,900)
Noroleana-12,18(17)-dienyl acetate (XI; R = Ac)	+64	237 (18,000)	244 (20,000)	257 (14,300)
Norursa-12,18(17)-dienyl acetate (XIII; R = Ac)	+79	239 (18,700)	246 (20,700)	254 (14,100)
Nordihydrotomentosa-12,18(17)-dienyl acetate (XXI; R = Ac)	+42	239 (17,000)	246 (18,500)	254 (14,700)

1500 $cm.^{-1}$ (" methyl " and " methylene " region) were compared carefully. Vangueryl acetate had a spectrum in this region identical with that of norursa-12,18(17)-dienyl acetate (XIII; R = Ac), but different from that of noroleana-12,18(17)-dienyl acetate (XI; R = Ac). It was suspected, therefore, that vangueryl acetate was a stereoisomer of the norursadiene. This was proved by the experiments summarised below.

Norursa-12,18(17)-dienyl acetate (XIII; R = Ac) was treated with 1 mol. of peracid, to furnish the epoxide (presumably XIV; R = Ac) (no selective ultraviolet absorption). Without isolation this was treated with the boron trifluoride–ether complex, to furnish the corresponding triene. This compound is formulated as (XV; R = Ac) on the basis of its ultraviolet absorption (Table 3). Similarly noroleana-11,13,17(22)-trienyl acetate (XVI; R = Ac) was prepared (Table 3). It was argued that the norursatriene (XV; R = Ac) should be easily isomerised to the benzene derivative (XVII; R = Ac). Although we were not able to do this under acidic conditions, disproportionation over palladised charcoal in molten naphthalene was effected under mild conditions to furnish the styrene

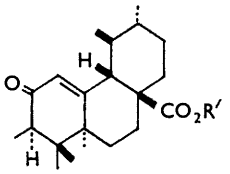
TABLE 3.

Compound	$[\alpha]_D$	$\lambda_{max.}$ (mμ) and (in parentheses) ε		
Dehydrovangueryl acetate (XX; R = Ac)	−315°	278 (25,500)	289 (34,600)	302 (25,100)
Noroleana-11,13,17(22)-trienyl acetate (XVI; R = Ac)	−314	278 (shoulder)	289 (37,500)	300 (shoulder)
Norursa-11,13,17(22)-trienyl acetate (XV; R = Ac) ...	−152	280 (22,800)	293 (32,500)	307 (26,000)

(XVIII; R = Ac) and norursa-12,18(17)-dienyl acetate (XIII; R = Ac). The use of naphthalene for this purpose appeared to have merit over more conventional solvents.

[2] See Barton and Brooks, *J.*, 1951, 257.
[3] Cf. Dietrich and Jeger, *Helv. Chim. Acta*, 1950, **33**, 711.

The styrene (XVIII; R = Ac) had one vinyl hydrogen, two aromatic methyl groups, and two *ortho*-hydrogens in its nuclear magnetic resonance spectrum. Our work does not exclude the rearranged formula (XIX; R = Ac) but we shall use the more simply derived formula (XVIII; R = Ac) for convenience. The oleanolic acid derivative (XVI; R = Ac) did not form any aromatic compound on dehydrogenation under our mild conditions.



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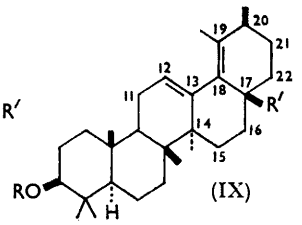

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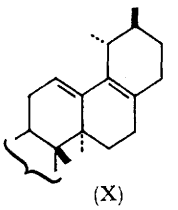

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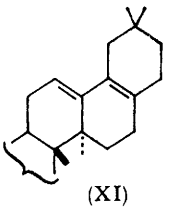

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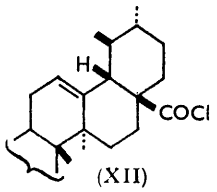

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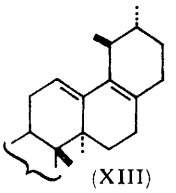

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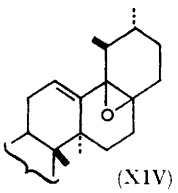

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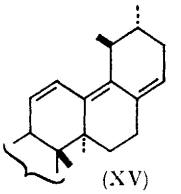

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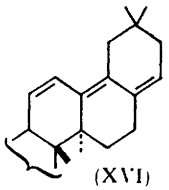

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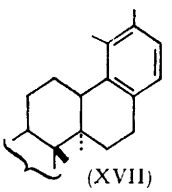

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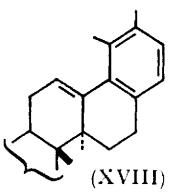
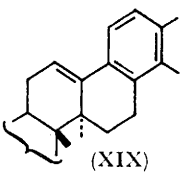
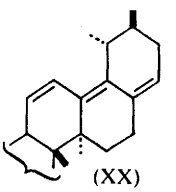


(XVIII)



(XIX)



(XX)

Vangueryl acetate (X; R = Ac) was then processed in the same way, giving dehydrovangueryl acetate (XX; R = Ac) with properties in accord (Table 3) with those of its analogues. Selective disproportionation of this triene gave the same styrene (XVIII; R = Ac) as from the norursa-11,13,17(22)-trienyl acetate (XV; R = Ac). The identity was established through a comparison of benzoates (XVIII; R = Bz). The constitution of vangueryl acetate (X; R = Ac) being thus proved, there is only one formula (IX; R = H, R′ = CO_2H) for vanguerolic acid which will explain the presence of a vinyl-attached methyl group and the ready decarboxylation.

It is clear that the ultraviolet absorption spectrum of vanguerolic acid is abnormal because of the highly crowded *cisoid* conformation of the diene system. Table 4 compares triterpenoid compounds of the 12,18-diene type.

TABLE 4.

Compound	$[\alpha]_D$	$\lambda_{max.}$ (mμ and (in parentheses) ε	Ref.
Methyl vanguerolate (IX; R = H, R′ = CO_2Me)	+308°	225 (7900)	This paper
Methyl oleana-12,18-dienolate	+214	237 (10,200)	Barton and Brooks, *J.*, 1951, 257
3β-Acetoxylupa-12,18-diene	+260	234 (9500)	Allison, Laurie, McLean, and Beaton, *J.*, 1961, 5224

We also studied the pyrolysis of the acid chloride (IX; R = Ac, R′ = COCl) of vanguerolic acid acetate. This afforded the styrene (XVIII; R = Ac) obtained earlier and, as major product, the benzene derivative (XVII; R = Ac). An authentic specimen of the latter was prepared by selective hydrogenation of the styrene (XVIII; R = Ac).

We now turn to the stereochemistry of vanguerolic acid. The *cis*-fusion of rings D and E in pentacyclic triterpenoids should direct the attack of reagents upon ring E to the β-face of the molecule. In agreement with this, the diol (II; R = Ac, R′ = Me) formed from tomentosolic acid must have the two hydroxyl groups in the β-configuration, because under a number of very mild conditions (acetic acid on the steam-bath, pyridine–acetic anhydride at room temperature, trace of hydrochloric acid in acetic acid, hydrogen chloride in chloroform at room temperature for 2 min.) it gave a lactone. We write this as (VII; R = Ac), or equivalent formulation with a δ-lactone ring. Although a considerable conformational change in rings D and E is needed to accommodate the lactone ring, it certainly could not be formed if the hydroxyl groups were on the α-side of the molecule. The same lactone (VII; R = Ac) was formed directly by the action of osmium tetroxide on tomentosolic acid acetate. Now, the same stereochemical selectivity would be expected for the preponderant course in the catalytic hydrogenation of methyl tomentosolate acetate (I; R = Ac, R′ = Me). Thus, methyl dihydrotomentosolate acetate must have the stereochemistry already written into (V; R = Ac, R′ = Me) (see above). When dihydrotomentosolic acid acetate (V; R = Ac, R′ = H) was converted into its acid chloride and pyrolysed, it gave another conjugated diene of familiar type (Table 2) which we can call nordihydrotomentosa-12,18(17)-dienyl acetate (XXI; R = Ac). This was not identical with vangueryl acetate (X; R = Ac). Since the pyrolysis of vanguerolic acid must involve a cyclic intramolecular transfer of hydrogen from the carboxyl group to C-19,[2] the configuration at C-19 in vanguerol must be that with the 19α-methyl group. Further, since the diene (XXI; R = Ac), of defined configuration at C-19 and C-20, is not identical with vangueryl acetate (X; R = Ac), the latter must differ only at C-20 and have the β-methyl configuration at this centre. The stereochemistry of all related compounds then follows as already written into the formulæ.

We also oxidised methyl dihydrotomentosolate benzoate to its 11-oxo-derivative (XXII; R = Bz, R′ = Me) and attempted epimerisation at C-18. A rearranged isomer could not be obtained in this way but, of course, enolisation towards C-18 is not easily effected in such compounds.

It is not possible to assign the stereochemistry of tetrahydrotomentosolic acid (VI; R = R′ = H). We have, however, confirmed its saturated nature by transforming the acetate acid (VI; R = Ac, R = H) into its acid chloride and pyrolysing that. The product showed *no* conjugated diene absorption and, therefore, the precursor cannot contain an ethylenic linkage, at least not at C-12(13). Methyl tetrahydrotomentosolate benzoate gave no colour with tetranitromethane and had no vinylic hydrogen or vinyl-attached methyl in its nuclear magnetic resonance spectrum.

The biogenesis of vanguerolic and tomentosolic acid presents points of marked interest. Since tomentosolic acid (I; R = R′ = H) has normal (β-hydrogen) stereochemistry at C-18 the 12(13)-ethylenic linkage has presumably been introduced by normal biogenetic processes.[4] The simplest interpretation of the constitutions and stereochemistry of vanguerolic and tomentosolic acid is that they are derived from the carbonium ion (XXIII) obtained by hydride-ion extraction (or equivalent oxygenation to give a 20-tertiary alcohol followed by hydroxyl-anion elimination) from ursolic acid (IV; R = R′ = H). Loss of a proton would furnish tomentosolic acid (I; R = R′ = H). Stereospecific hydride-ion migration as usually postulated in triterpenoid biogenesis [5] would then afford vanguerolic acid (IX; R = H, R′ = CO_2H) [see (XXIII, arrow)].

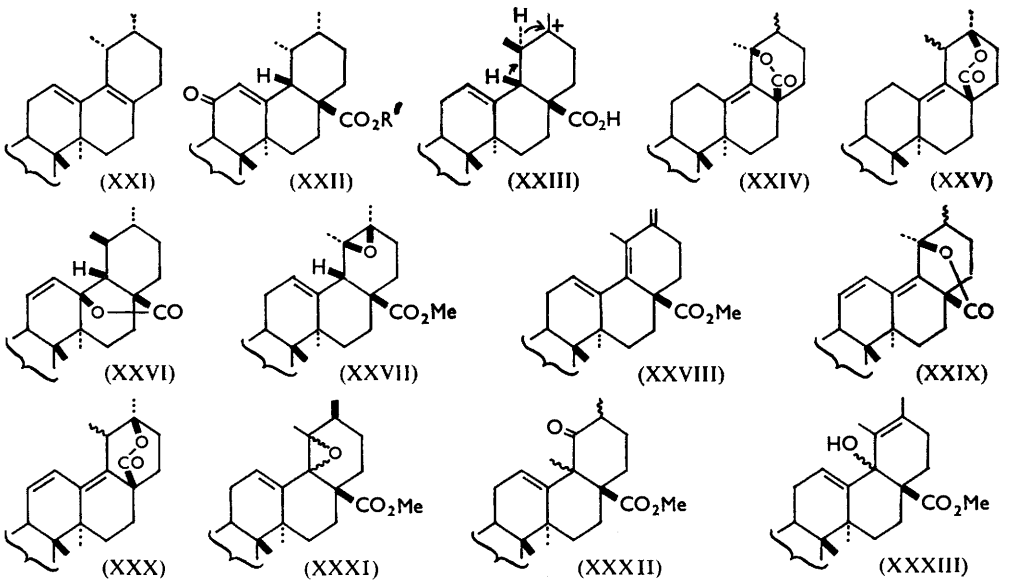
During the work on *Vangueria* triterpenoids a number of miscellaneous derivatives was prepared. Although these are not required for the derivation of constitutions and stereochemistry given above they nevertheless present points of interest.

The formation of a lactone from " vanguerigenin " was mentioned above. The same

[4] Ruzicka, *Experientia*, 1953, **9**, 357.
[5] Eschenmoser, Ruzicka, Jeger, and Arigoni, *Helv. Chim. Acta*, 1955, **38**, 1890.

compound is formed, as its acetyl derivative, by treatment of vanguerolic acid, tomentosolic acid, methyl vanguerolate acetate, or methyl tomentosolate acetate with acetic acid–hydrochloric acid on the steam-bath. The homogeneity of Merz and Tschubel's lactone [1] is, therefore, confirmed. The lactone itself could be oxidised to a ketone from which it was re-formed on reduction with borohydride. The lactone acetate has no hydrogen attached to the carbon bearing the terminus of the lactone ring (nuclear magnetic resonance spectrum) and has no vinyl hydrogen either. The obvious alternative formulæ for it are (XXIV and XXV; R = Ac). It showed a peculiar ultraviolet spectrum ($\lambda_{max.}$ 228 mμ; ε 5500) and an infrared lactone band at 1745 cm.$^{-1}$. For comparison, we prepared the known lactone [6] from reduction of 11-oxoursolic acid. This can be represented as (XXVI; R = H) since it showed only end-absorption in the ultraviolet region and had a normal γ-lactone band at 1770 cm.$^{-1}$.

Methyl tomentosolate acetate gave a monoepoxide which, since it retained one vinyl hydrogen in its nuclear magnetic resonance spectrum, must have formula (XXVII; R = Ac). With boron fluoride this gave a conjugated triene with $\lambda_{max.}$ 269 mμ. The low wavelength of this band could be explained by the provisional formula (XXVIII; R = Ac). Treatment of the epoxide with acetic acid–hydrochloric acid on the steam-bath afforded another lactone which was a conjugated diene. On hydrogenation it gave the lactone (XXIV or XXV; R = Ac) mentioned above. The obvious alternative formulæ for the epoxide-derived lactone are, therefore, (XXIX and XXX; R = Ac). This lactone also showed a peculiar ultraviolet spectrum, with the most intense band at 260 mμ (ε 28,000), about 10 mμ longer wavelength than would have been expected.



Methyl vanguerolate acetate also afforded a monoepoxide. Since this had one vinylic hydrogen it must be formulated as (XXXI; R = Ac). With the boron trifluoride–ether complex the epoxide rearranged to a ketone, possibly (XXXII; R = Ac). Alternative formulations can, of course, be easily written. On mild treatment with aqueous dioxan containing sulphuric acid methyl vanguerolate acetate epoxide afforded another conjugated diene-lactone. This substance had normal ultraviolet absorption and showed an infrared carbonyl band at 1750 cm.$^{-1}$.

[6] Huzii and Osumi, *Chem. Abs.*, 1940, **34**, 7293.

Nuclear magnetic resonance data suggest formulations for the " normal " and " abnormal " diene-lactones mentioned above. The " normal " diene-lactone has a band (in $CDCl_3$) at τ 8·42 which must be assigned to a methyl group attached to carbon bearing (lactonic) oxygen. This band is displaced from the expected position (τ ~8·7). In contrast the " abnormal " diene-lactone has a band (in $CDCl_3$) at τ 8·59, which is nearer to the expected position. The difference can be explained if an ethylenic linkage in allylic relationship is present in the " normal " diene-lactone. Accordingly the latter should be formulated as (XXIX; R = Ac), the " abnormal " isomer being (XXX; R = Ac). The lactone of Merz and Tschubel (see above) has a band for (CH_3·C·O–) at τ 8·61. We therefore formulate it as (XXV; R = Ac). The formulæ that we assign to these lactones are, however, tentative.

Methyl tomentosolate acetate, as expected for a compound with a doubly allylic C–H bond, was abnormally sensitive to oxidising agents. It was immediately attacked by selenium dioxide at room temperature. Although the product was not crystalline it gave the dehydro-lactone (XXX; R = Ac) on digestion with acetic acid–hydrochloric acid. Methyl tomentosolate acetate also reacted rapidly with chromic acid at room temperature, furnishing a non-conjugated tertiary alcohol which we formulate as (XXXIII; R = Ac).

Experimental

M. p.s were taken on the Kofler block. M. p.s designated (vac.) were taken in capillary tubes sealed at less than 2 mm. Unless specified to the contrary, $[\alpha]_D$ refer to $CHCl_3$, ultraviolet absorption spectra to EtOH solutions, and infrared absorption spectra to Nujol mulls. Grade III alumina was used for chromatography unless stated otherwise. Nuclear magnetic resonance measurements were made at 21° on approx. 10% w/v solutions in deuterochloroform or carbon tetrachloride, with tetramethylsilane as internal standard. The spectra were calibrated by the side-band technique. We cordially thank Drs. L. M. Jackman and J. W. Lown and Mr. R. G. Foster for the determination and interpretation of these spectra. The *Vangueria tomentosa* roots were kindly collected in East Africa by the Tropical Products Institute. Light petroleum refers to the fraction of b. p. 40—60° unless stated otherwise.

Isolation of Triterpenoids from Vangueria tomentosa *Roots.*—The coarsely ground root (14 kg.) was extracted under reflux with boiling 95% ethanol (60 l.) four times (3 hr. each time). The combined extracts were concentrated to 7 l. and hydrolysed with boiling concentrated hydrochloric acid (1 l.) for 15 min. The solution was made alkaline with sodium hydroxide, concentrated *in vacuo* to small volume, and extracted with ether (6 l.). The alkaline layer was acidified and the precipitated acids were taken into ether (5 l.). After removal of the dried (Na_2SO_4) ether the crude triterpenoid acids (140 g.) were methylated with diazomethane and then acetylated with acetic anhydride–pyridine overnight at room temperature. Chromatography over alumina gave, on elution with 1 : 4 benzene–light petroleum (b. p. 60—80°), a mixture of methyl ester acetates (15 g.). Further elution with 1 : 2 benzene–light petroleum (b. p. 60—80°) afforded methyl tomentosonate (0·94 g.) (see below). Systematic triangulation of the methyl ester acetates from chloroform–methanol furnished (in the less soluble fractions) *methyl tomentosolate acetate* (I; R = Ac, R′ = Me) (7·4 g.) as needles or blades, m. p. 234—236° or 246—248°, $[\alpha]_D$ +9° (*c* 2·00), ε 8000 at 215 mμ, $\nu_{max.}$ (in CCl_4) 1725 (acetate and methyl ester) and 1655 (C=C) cm.$^{-1}$, τ ($CDCl_3$) 4·60 (one vinyl H) and 7·13 (one diallylic H), τ (CCl_4) 8·52 and 8·36 (two vinyl-attached Me groups) (Found: C, 77·8; H, 9·65. $C_{33}H_{50}O_4$ requires C, 77·6; H, 9·85%). From the more soluble fractions came, on crystallisation from methanol, *methyl vanguerolate acetate* (IX; R = Ac, R′ = CO_2Me) (4·2 g.), as plates or prisms, m. p. 188—191°, $[\alpha]_D$ +277° (*c* 2·20), $\lambda_{max.}$ 225 mμ (ε 7800), $\nu_{max.}$ 1720 (OAc and Me ester) and 1650 (C=C) cm.$^{-1}$, τ (CCl_4) 4·66 (one vinyl H) and 8·31 (one vinyl-attached Me) (Found: C, 77·95; H, 9·5. $C_{33}H_{50}O_4$ requires C, 77·6; H, 9·85%).

Vanguerolic and tomentosolic acid (see below) were recovered unchanged in high yield after treatment with ethanolic hydrochloric acid as used in the hydrolysis of " vanguerin." An identical experiment with the corresponding methyl ester acetates gave the same result.

Tomentosolic Acid and its Derivatives.—Methyl tomentosolate acetate (1·0 g.) in dioxan–methanol (1 : 1; 40 ml.) containing 2% of potassium hydroxide was refluxed for 1·5 hr. Crystallisation from methanol afforded *methyl tomentosolate* (I; R = H, R′ = Me) as needles, m. p. 205—207°, $[\alpha]_D$ +15° (*c* 0·20), $\nu_{max.}$ 3480 and 3430 (OH) and 1715 (Me ester) cm.$^{-1}$ (Found: C, 79·5; H, 10·45. $C_{31}H_{48}O_3$ requires C, 79·45; H, 10·3%).

Methyl tomentosolate acetate (1·0 g.) in diethylene glycol (120 ml.) containing potassium hydroxide (30 g.) was refluxed for 20 hr. Crystallisation of the product from methanol gave *tomentosolic acid* (I; R = R′ = H) as needles, m. p. 284·5—286° (vac.), $[\alpha]_D$ +18° (*c* 1·00), ε 8700 at 210 mμ, $\nu_{max.}$ 3415 (OH) and 1695 (CO_2H) cm.$^{-1}$ (Found: C, 79·45; H, 10·15. $C_{30}H_{46}O_3$ requires C, 79·25; H, 10·2%).

Tomentosolic acid (650 mg.) was treated with pyridine (5 ml.) and acetic anhydride (4ml.) for 4 days at room temperature. Crystallisation of the product from chloroform–methanol furnished *tomentosolic acid acetate* (I; R = Ac, R′ = H) as blades, m. p. 318—323° (vac.), $[\alpha]_D$ +6° (*c* 0·54) (Found: C, 77·0; H, 9·8. $C_{32}H_{48}O_4$ requires C, 77·35; H, 9·75%).

Methyl tomentosolate acetate (500 mg.), treated with ethereal 0·7N-monoperphthalic acid (15 ml.) at room temperature for 4 days (1 mol. uptake) gave, on crystallisation from chloroform–methanol, *methyl tomentosolate acetate epoxide* (XXVII; R = Ac), m. p. 254—256°, $[\alpha]_D$ +53° (*c* 1·90), ε 3500 at 210 mμ, ε 700 at 220 mμ, $\nu_{max.}$ (in CCl_4) 1730 (OAc and Me ester) cm.$^{-1}$, τ ($CDCl_3$) 4·38 (triplet, one vinyl H) (Found: C, 75·55; H, 9·45. $C_{33}H_{50}O_5$ requires C, 75·25; H, 9·55%). It gave a yellow colour with tetranitromethane.

Methyl Tomentosonate.—The product isolated from the plant (see above) crystallised from chloroform–methanol as plates, m. p. 208—212°, $[\alpha]_D$ +45° (*c* 0·50), $\nu_{max.}$ (in CCl_4) 1705 (cyclohexanone) and 1725 (Me ester) cm.$^{-1}$ (Found: C, 76·95; H, 9·75. $C_{31}H_{46}O_3,H_2O$ requires C, 76·8; H, 10·0%). This ketone, when reduced with an excess of sodium borohydride in tetrahydrofuran–methanol at room temperature, gave methyl tomentosolate, identified by m. p., mixed m. p., and infrared spectrum.

Vanguerolic Acid and its Derivatives.—Methyl vanguerolate acetate (120 mg.) was refluxed with 2·5% ethanolic potassium hydroxide (10 ml.) for 1·5 hr. Crystallisation of the product from aqueous methanol furnished *methyl vanguerolate* (IX; R = H, R′ = CO_2Me) as needles, m. p. 161—163°, $[\alpha]_D$ +308° (*c* 1·40), $\lambda_{max.}$ 225 mμ (ε 7900), $\nu_{max.}$ 3510 (OH), 1700 (Me ester) and 1660 (C=C) cm.$^{-1}$ (Found: C, 79·6; H, 10·25. $C_{31}H_{48}O_3$ requires C, 79·45; H, 10·3%).

Methyl vanguerolate acetate (1·04 g.) in diethylene glycol (125 ml.) containing potassium hydroxide (30 g.) was refluxed for 18 hr. Crystallisation of the product from chloroform–methanol afforded *vanguerolic acid* (I; R = H, R′ = CO_2H) (820 mg.) as needles, m. p. 272—273° (vac., decomp.), $[\alpha]_D$ +306° (*c* 0·83), $\lambda_{max.}$ 227—228 mμ (ε 7600), $\nu_{max.}$ 3375 (OH) and 1690 (CO_2H) cm.$^{-1}$ (Found: C, 79·6; H, 10·25. $C_{30}H_{46}O_3$ requires C, 79·25; H, 10·2%).

Vanguerolic acid, treated with pyridine–acetic anhydride overnight at room temperature, gave *vanguerolic acid acetate* (IX; R = Ac, R′ = CO_2H). This crystallised from light petroleum as plates, m. p. 180—182° (decomp.), $[\alpha]_D$ +270° (*c* 1·00), $\lambda_{max.}$ 230 mμ (ε 7200) (Found: C, 77·2; H, 9·85. $C_{32}H_{48}O_4$ requires C, 77·35; H, 9·75%).

Methyl vanguerolate acetate (540 mg.) was treated with ethereal N-monoperphthalic acid (4 ml.) at room temperature for 4 days (1 mol. uptake), to give *methyl vanguerolate acetate epoxide* (XXXI; R = Ac). This crystallised as needles (230 mg.) (from aqueous methanol), m. p. 198—204° (vac.), $[\alpha]_D$ +96° (*c* 1·60), ε 5100 at 210 mμ, ε 1500 at 220 mμ, $\nu_{max.}$ 1730 (OAc and Me ester) cm.$^{-1}$, τ (CCl_4) 4·45 (one vinyl H) (Found: C, 75·35; H, 9·95. $C_{33}H_{50}O_5$ requires C, 75·25; H, 9·55%). It gave a yellow colour with tetranitromethane.

Reduction of Methyl Vanguerolate with Lithium Aluminium Hydride.—Methyl vanguerolate (33 mg.) in ether (10 ml.) was reduced with an excess of lithium aluminium hydride under reflux for 1 hr. The product was treated with pyridine–acetic anhydride overnight at room temperature, to give, after crystallisation from chloroform–methanol, the *diacetate* (IX; R = Ac, R′ = CH_2·OAc), m. p. 198—200°, $[\alpha]_D$ +224° (*c* 0·57), $\lambda_{max.}$ 227·5 mμ (ε 9900) (Found: C, 77·9; H, 10·2. $C_{34}H_{52}O_4$ requires C, 77·8; H, 10·0%). The same compound was also obtained in the same way from methyl vanguerolate acetate.

Formation of Vanguerolic Acid Lactone.—Vanguerolic acid (200 mg.) in concentrated hydrochloric acid (2·5 ml.) and glacial acetic acid (10 ml.) was heated on the steam-bath for 15 min. Crystallisation of the product from chloroform–methanol gave vanguerolic acid lactone acetate (XXV; R = Ac) as plates, m. p. 330—335° (vac.), $[\alpha]_D$ −62° (*c* 0·37), $\lambda_{max.}$ 209 and 228 mμ (ε 9100 and 5500, respectively), $\nu_{max.}$ (in CCl_4) 1745 (lactone) and 1730 (OAc) cm.$^{-1}$, τ ($CDCl_3$)

5·50 (one >CH·O·), 8·42 (one CH_3·C·O·) (Found: C, 77·55; H, 9·8. Calc. for $C_{32}H_{48}O_4$: C, 77·35; H, 9·75%). The lactone acetate was also formed in the same way from methyl vanguerolate acetate, tomentosolic acid, and methyl tomentosolate acetate. For the lactone acetate Merz and Tschubel recorded m. p. ~325°.

Vanguerolic acid lactone acetate (73 mg.), kept in benzene (5 ml.) and ethanol (5 ml.) containing 1% of potassium hydroxide at room temperature overnight, afforded vanguerolic lactone (XXV; R = H) (58 mg.). Recrystallised from methanol this formed plates, m. p. 278—280° (vac.), $[\alpha]_D$ −78° (*c* 0·90), $\lambda_{max.}$ 209 and 227 mμ (ε 8850 and 5300, respectively), $\nu_{max.}$ (in CCl_4) 3570 (OH) and 1750 (lactone) cm.$^{-1}$ (Found: C, 76·75; H, 9·8. Calc. for $C_{30}H_{46}O_3$,CH_3·OH: C, 76·5; H, 10·35%). For this compound Merz and Tschubel [1] recorded m. p. 281°.

Chromic acid oxidation of the hydroxy-lactone gave the corresponding *keto-lactone*. Crystallised from methanol this formed needles, m. p. 244—248° (vac.), $[\alpha]_D$ −76° (*c* 0·62), $\lambda_{max.}$ 208 and 227·5 mμ (ε 9300 and 5700, respectively), $\nu_{max.}$ (in CCl_4) 1755 (lactone) and 1705 (cyclohexanone) cm.$^{-1}$ (Found: C, 79·8; H, 9·8. $C_{30}H_{44}O_3$ requires C, 79·6; H, 9·8%). It gave a positive Zimmermann colour identical with that from other 3-oxo-triterpenoids.[7] The keto-lactone (52 mg.) in methanol (10 ml.) was reduced with potassium borohydride (50 mg.) for 1 hr. at room temperature, to vanguerolic lactone. The identity was confirmed by acetylation.

Pyrolysis of Vanguerolic Acid.—Vanguerolic acid (51 mg.) was heated under nitrogen at 272—290° for 7 min. The product crystallised from chloroform–methanol, to give vanguerol (X; R = H), m. p. 196—198°, $[\alpha]_D$ +108° (*c* 1·16), $\lambda_{max.}$ 237, 245, and 253 mμ (ε 17,000, 18,300, and 11,600, respectively) (Found: C, 84·8; H, 11·1. Calc. for $C_{29}H_{46}O$: C, 84·8; H, 11·3%). For this compound Merz and Tschubel recorded m. p. 207°. Vanguerol was recovered unchanged after treatment with hydrogen chloride in chloroform at room temperature and with concentrated hydrochloric acid and acetic acid (1 : 1) at 100°.

Treatment of vanguerol with pyridine–acetic anhydride overnight at room temperature gave *vangueryl acetate* (X; R = Ac). Crystallised from methanol this formed needles, m. p. 181—183°, $[\alpha]_D$ +116° (*c* 0·57), $\lambda_{max.}$ 237, 245, and 253 mμ (ε 19,100, 20,300, and 12,900), τ ($CDCl_3$) 4·46 (one vinyl H) (Found: C, 82·55; H, 10·85. $C_{31}H_{48}O_2$ requires C, 82·25; H, 10·7%).

Pyrolysis of Oleanoloyl and Ursoloyl Chloride Acetates.—(*a*) *Oleanoloyl chloride acetate.* The chloride acetate [8] (560 mg.) was heated at 230° under nitrogen for 10 min. Chromatography over alumina and elution with light petroleum–benzene (1 : 1) gave norolea-12,18(17)-dienyl acetate (XI; R = Ac) (190 mg.). This crystallised as needles (from chloroform–methanol), m. p. 185—187°, $[\alpha]_D$ +64° (*c* 0·70), $\lambda_{max.}$ 237, 244, and 257 mμ (ε 18,000, 20,000, and 14,300, respectively). The authentic specimen [2] had m. p. 187—188°, $[\alpha]_D$ +66°. (*b*) *Ursoloyl chloride acetate.* The chloride acetate [6, 9] (7·2 g.) was heated (in 1-g. portions) at 240—260° under nitrogen for 20 min. One equivalent of hydrogen chloride was evolved. Crystallisation of the product from chloroform–methanol afforded *norursa*-12,18(17)-*dienyl acetate* (XIII; R = Ac) as needles (1·54 g.), m. p. 198—200°, $[\alpha]_D$ +79° (*c* 1·00), $\lambda_{max.}$ 239, 246, and 254 mμ (ε 18,700, 20,700, and 14,100, respectively) (Found: C, 81·9; H, 10·35. $C_{31}H_{48}O_2$ requires C, 82·25; H, 10·7%).

Preparation of Noroleana- and Norursa-trienyl Acetate.—(*a*) *Noroleanatrienyl acetate.* Noroleana-12,18(17)-dienyl acetate (XI; R = Ac) (140 mg.) was treated with 0·7N-ethereal monoperphthalic acid (25 ml.) at room temperature for 18 hr. The product, which had no selective ultraviolet absorption, was taken up in ether (400 ml.) and treated with boron trifluoride–ether (8 ml.) at room temperature for 7 min. (ultraviolet control). The ethereal solution was washed with aqueous sodium hydrogen carbonate, and the product crystallised from chloroform–methanol to furnish *noroleana*-11,13,17(22)-*trienyl acetate* (XVI; R = Ac) (45 mg.) as prisms, m. p. 179—181° (vac.), $[\alpha]_D$ −314° (*c* 0·20), $\lambda_{max.}$ 275—280 (shoulder), 289 (ε 37,500), and 295—305 (shoulder) mμ (Found: C, 82·45; H, 10·3. $C_{31}H_{46}O_2$ requires C, 28·6; H, 10·3%).

(*b*) *Norursatrienyl acetate.* Norursa-12,18(17)-dienyl acetate (1·54 g.) was treated similarly, furnishing norursa-11,13,17(22)-trienyl acetate (XV; R = Ac) (850 mg.). Crystallised from methanol this had m. p. 226—229° (vac.), $[\alpha]_D$ −152° (*c* 0·51), $\lambda_{max.}$ 280, 293, and 307 mμ (ε = 22,800, 32,500, and 26,000, respectively).

Conjugated Triene from Vangueryl Acetate.—Vangueryl acetate (120 mg.) was treated with monoperphthalic acid and further processed as above, to give *dehydrovangueryl acetate* (XX;

[7] Barton and de Mayo, *J.*, 1954, 887.
[8] Ruzicka and Schellenberg, *Helv. Chim. Acta*, 1937, **20**, 1553.
[9] Sell and Kremers, *J. Biol. Chem.*, 1938, **125**, 451.

R = Ac) (87 mg.). From chloroform–methanol this formed blades, m. p. 214—215° (vac.), $[\alpha]_D$ −315° (*c* 1·05), $\lambda_{max.}$ 278, 289, and 302 mμ (ε 25,500, 34,600, and 25,100, respectively), $\nu_{max.}$ 1730 and 1245 (OAc) cm.$^{-1}$ (Found: C, 82·8; H, 10·5. $C_{31}H_{46}O_2$ requires C, 82·6; H, 10·3%).

Dehydrogenation of the Nortrienyl Acetates over Palladised Charcoal.—(*a*) *Norursatrienyl acetate.* The trienyl acetate (XV; R = Ac) (630 mg.) in molten naphthalene (50 g.) was heated at 190—200° with 10% palladised charcoal (640 mg.) under nitrogen for 3 hr. The naphthalene was removed by sublimation *in vacuo* and the product chromatographed over alumina. Elution with light petroleum–benzene (9 : 1) gave norursa-12,18(17)-dienyl acetate (m. p., mixed m. p., and ultraviolet spectrum). Further elution with light petroleum–benzene (7 : 3 and 3 : 2) afforded *norursa*-12,17,19,21-*tetraenyl acetate* (XVIII; R = Ac) (30 mg.). Crystallised from chloroform–methanol this had m. p. 227—229°, $[\alpha]_D$ +152° (*c* 0·16), $\lambda_{max.}$ 212 and 243 mμ (ε 25,700 and 10,800), $\nu_{max.}$ 1725 and 1255 (OAc) and 812 (styryl H) cm.$^{-1}$, τ ($CDCl_3$) 3·15 (quartet, *J* = 7·8 c./sec.) (two *ortho* aromatic H) (Found: C, 82·7; H, 10·15. $C_{31}H_{44}O_2$ requires C, 83·0; H, 9·9%).

Hydrolysis of the acetate with 2% ethanolic potassium hydroxide under reflux, followed by benzoylation with pyridine–benzoyl chloride, gave the *benzoate* (XVIII; R = Bz). From acetone–methanol this formed needles, m. p. 227—230°, $[\alpha]_D$ +114° (*c* 0·67), $\lambda_{max.}$ 215 and 232 mμ (ε 39,200 and 25,300, respectively), $\nu_{max.}$ (in CCl_4) 1715 and 1275 (OBz) cm.$^{-1}$ (Found: C, 83·65; H, 9·45. $C_{36}H_{46}O_2$ requires C, 84·65; H, 9·1%).

(*b*) *Noroleanatrienyl acetate.* Noroleana-11,13,17(22)-trienyl acetate (XVI; R = Ac) (4 mg.) in molten naphthalene (400 mg.) was heated with 10% palladised charcoal (3 mg.) at 160—180° under nitrogen for 3 hr. The product showed only terminal ultraviolet absorption (ε 22,900 at 215 mμ). Under identical conditions norursa-11,13,17(22)-trienyl acetate gave a product with $\lambda_{max.}$ 219 and 245 mμ (ε 22,000 and 12,600, respectively).

(*c*) *Dehydrovangueryl acetate.* The trienyl acetate (XX; R = Ac) (155 mg.) in molten naphthalene (15 g.) was heated with 10% palladised charcoal (155 mg.) at 190—200° under nitrogen for 3 hr. The product was chromatographed over alumina. Elution with light petroleum–benzene (4 : 1) and crystallisation from chloroform–methanol gave somewhat impure norursa-12,17,19,21-tetraenyl acetate. Hydrolysis, benzoylation, and crystallisation from acetone–methanol then gave the pure benzoate, m. p. and mixed m. p. 228—231°, $[\alpha]_D$ +116° (*c* 0·20), with ultraviolet and infrared spectra identical with those of authentic material (see above).

Pyrolysis of Vangueroloyl Chloride Acetate.—Refluxing vanguerolic acid acetate with an excess of purified thionyl chloride for 30 min., followed by removal of the excess *in vacuo* and crystallisation from light petroleum (b. p. 60—80°), gave vangueroloyl chloride acetate as needles, m. p. 190—193° (decomp.). This acid chloride (365 mg.) was heated (in six equal portions) in evacuated tubes at 180—200° for 2 min. Chromatography over alumina and elution with cyclohexane gave norursa-12,17,19,21-tetraenyl acetate (XVIII; R = Ac) (32 mg.) (identified by m. p., mixed m. p., spectra, and conversion into the benzoate). Further elution with cyclohexane afforded *norursa*-17,19,21-*trienyl acetate* (XVII; R = Ac) (50 mg.). This crystallised from methanol as needles, m. p. 170—171°, $[\alpha]_D$ +70° (*c* 0·30), $\lambda_{max.}$ (in cyclohexane) 272 and 279 mμ (ε 350 and 310, respectively), ε 12,200 at 220 mμ, τ (CCl_4) 7·83 (2 Me on an aromatic ring) and 3·33 (two aromatic H). An authentic specimen of this compound was prepared by hydrogenation of norursa-12,17,19,21-tetraenyl acetate (XVIII; R = Ac) (15 mg.) in acetic acid (2 ml.) over platinum oxide for 20 min., followed by chromatography over alumina. Identity was established by m. p., mixed m. p., and spectra (Found: C, 82·6; H, 10·4. $C_{31}H_{46}O_2$ requires C, 82·6; H, 10·3%).

Formation of the Diketone (III; R = Ac, R′ = Me) *from Methyl Tomentosolate Acetate* (I; R = Ac, R′ = Me).—Methyl tomentosolate acetate (315 mg.) in pyridine (1·5 ml.) was treated with osmium tetroxide (200 mg.) for 27 hr. at room temperature. After dilution with water and ether the mixture was saturated with hydrogen sulphide.[10] Crystallisation of the product from methanol gave *methyl tomentosolatediol acetate* (II; R = Ac, R′ = Me) (250 mg.) as needles, m. p. 230—231° (decomp.), resolidifying, and remelting at 280—294°, $[\alpha]_D$ +72° (*c* 0·20), $\nu_{max.}$ 3500 (OH) and 1720 (Me ester and OAc) cm.$^{-1}$ (Found: C, 72·6; H, 9·65. $C_{33}H_{52}O_6$ requires C, 72·75; H, 9·6%).

[10] Barton and Elad, *J.*, 1956, 2085.

The above diol (102 mg.) in acetic acid (55 ml.) containing lead tetra-acetate (1·5 mol.) was kept at room temperature for 1·5 hr. (1 mol. uptake). Crystallisation of the product from aqueous methanol gave the *diketone* (III; R = Ac, R′ = Me) (56 mg.) as blades, m. p. 209—210°, $[\alpha]_D$ −158° (*c* 0·25), $\lambda_{max.}$ 295—307 mμ (ε 360), $\nu_{max.}$ 1720 (Me ester and OAc) and 1700 (ketones) cm.$^{-1}$, τ ($CDCl_3$) 7·96, 7·92, and 7·77 (one acetate Me and two Me·CO) and 4·28 (one vinyl H) (Found: C, 72·95; H, 9·4. $C_{33}H_{50}O_6$ requires C, 73·05; H, 9·3%). It gave a positive Zimmermann reaction.

Radiochemical Experiments.—Methyl tomentosolate (I; R = H, R′ = Me) (290 mg.) was treated with [1-^{14}C]acetic anhydride (0·1 mc; 0·13 ml.) and pyridine (0·25 ml.) at 90° for 2 hr. The methyl tomentosolate acetate (220 mg.) thus obtained had m. p. 234—236° and a specific activity of 36·9 μc per g. It was hydrogenated in acetic acid (50 ml.) over platinum oxide (43 mg.) for 16 hr. The product was diluted with methyl ursolate acetate (98 mg.), and the mixture fractionally crystallised from chloroform–methanol. The labelled methyl ursolate acetate thus obtained, when crystallised to constant activity, had m. p. 246—247°, specific activity 6·5 μc per g.

To a suspension of anhydrous sodium [2-^{14}C]acetate (62 mg.; 0·01 mc) in pyridine (3 ml.) at 5° was added toluene-*p*-sulphonyl chloride (140 mg.) and then methyl tomentosolate (200 mg.), and the solution left at this temperature for 18 hr. The methyl tomentosolate acetate (28 mg.) thus obtained had a specific activity of 24·9 μc per g. It was mixed with methyl ursolate acetate (135 mg.) in 85% aqueous acetic acid (1·7 ml.) and heated under reflux with chromium trioxide (150 mg.) for 30 min. The product was chromatographed over alumina. Elution with light petroleum (b. p. 60—80°)–benzene (3 : 1) gave methyl 11-ketoursolate [2′-^{14}C]acetate. After crystallisation from methanol to constant activity, this formed needles, m. p. 247—249°, $\lambda_{max.}$ 250 mμ (ε 11,100) with a specific activity of 0·027 mc per g. The specific activity was unaltered by further attempted chromic acid oxidation.

Methyl ursolate [1′-^{14}C]acetate (55 mg.; specific activity 0·11 μc per g.) was oxidised in the same way, to give the 11-ketone (28 mg.), m. p. 247—249°, specific activity 0·09 μc per g.

Hydrogenation of Methyl Tomentosolate Acetate (I; R = Ac, R′ = Me).—Methyl tomentosolate acetate (1·99 g.) in acetic acid (450 ml.) was hydrogenated over platinum oxide for 20 hr. The product was hydrolysed with 1% methanolic potassium hydroxide (150 ml.) under reflux for 1 hr. and then treated with benzoyl chloride (3·0 ml.) in pyridine (37 ml.) at room temperature overnight. Chromatography over alumina gave a series of crystalline fractions. Systematic fractional crystallisation from ether–methanol and from chloroform–methanol gave (*a*) methyl ursolate benzoate (IV; R = Bz, R′ = Me) (45 mg., 1·9%) identified by m. p., mixed m. p., $[\alpha]_D$, and spectra, (*b*) *methyl dihydrotomentosolate benzoate* (V; R = Bz, R′ = Me) (630 mg., 26%), and (*c*) *methyl tetrahydrotomentosolate benzoate* (VI; R = Bz, R′ = Me) (310 mg., 13%).

Methyl dihydrotomentosolate benzoate formed blades, m. p. 193·5—195·5°, $[\alpha]_D$ +100° (*c* 0·89), $\lambda_{max.}$ 229 mμ (ε 15,000), $\nu_{max.}$ (in CCl_4) 1720 (Me ester and OBz) cm.$^{-1}$ (Found: C, 79·6; H, 9·4. $C_{38}H_{54}O_4$ requires C, 79·4; H, 9·45%).

Methyl tetrahydrotomentosolate benzoate formed needles, m. p. 213—214°, $[\alpha]_D$ +32° (*c* 0·71), $\lambda_{max.}$ 229 mμ (ε 17,000), $\nu_{max.}$ (in CCl_4) 1720 (Me ester and OBz) cm.$^{-1}$, no vinyl H in the nuclear magnetic resonance spectrum (Found: C, 79·15; H, 9·7. $C_{38}H_{56}O_4$ requires C, 79·1; H, 9·8%). It gave no colour with tetranitromethane under conditions where methyl dihydrotomentosolate benzoate showed a strong colour.

Dihydrotomentosolic Acid (V; R = R′ = H) *and its Derivatives.*—Methyl dihydrotomentosolate benzoate (V; R = Bz, R′ = Me) (353 mg.) in diethylene glycol (25 ml.) containing potassium hydroxide (7·5 g.) was heated at 170° for 18 hr. The resulting *dihydrotomentosolic acid* (V; R = R′ = H) crystallised from ethanol as needles (202 mg.), m. p. 286—289°, $[\alpha]_D$ +97° (*c* 0·22) (Found: C, 76·55; H, 10·85. $C_{30}H_{48}O_3,C_2H_6O$ requires C, 76·45; H, 10·85%).

The acid (200 mg.) was treated with acetic anhydride (1 ml.) and pyridine (1 ml.) overnight at room temperature. Crystallisation of the product from aqueous ethanol afforded *dihydrotomentosolic acid acetate* (V; R = Ac, R′ = H) as needles (170 mg.), m. p. 286—290° (vac.), $[\alpha]_D$ +86° (*c* 0·24) (Found: C, 77·55; H, 10·25. $C_{32}H_{50}O_4$ requires C, 77·05; H, 10·1%).

The acid acetate (95 mg.) in benzene (5 ml.) was treated with oxalyl chloride (0·45 ml.) at room temperature for 6 hr. Removal of the benzene and excess of oxalyl chloride *in vacuo* gave the crude acid chloride. This was heated at 235—245° under nitrogen for 15 min. and

then chromatographed over alumina. Elution with cyclohexane gave *nordihydrotomentosa-12,18(17)-dienyl acetate* (XXI; R = Ac) (40 mg.), which crystallised from ether–methanol as needles, m. p. 186—191° (marked depression in m. p. with vangueryl acetate), $[\alpha]_D$ +42° (*c* 0·49), $\lambda_{max.}$ 239, 246, and 254 mμ (ε 17,000, 18,500, and 14,700, respectively) (Found: C, 82·3; H, 10·55. $C_{31}H_{48}O_2$ requires C, 82·25; H, 10·7%).

Methyl dihydrotomentosolate benzoate (98 mg.) in 85% aqueous acetic acid (4·5 ml.) containing chromium trioxide (80 mg.) was heated under reflux for 75 min. and the product chromatographed over alumina. Elution with light petroleum (b. p. 60—80°)–benzene (1 : 1) furnished *methyl dihydro-11-oxotomentosolate benzoate* (XXII; R = Bz, R′ = Me) (36 mg.) as needles (from methanol), m. p. 222—223°, $[\alpha]_D$ +125° (*c* 0·36), $\lambda_{max.}$ 237 (ε 14,000), $\lambda_{shoulder}$ 250 mμ (ε 10,800), $\nu_{max.}$ (in CCl_4) 1715 (Me ester and OBz), 1650 (conjugated ketone) and 1620 (C=C) cm.$^{-1}$ (Found: C, 77·8; H, 8·85. $C_{38}H_{52}O_5$ requires C, 77·5; H, 8·9%). This ketone was recovered unchanged after treatment with 0·9N potassium t-butoxide in t-butyl alcohol at 50—60° for 30 min., followed by rebenzoylation and chromatography. It was also recovered unchanged after treatment with 50% hydrogen bromide in acetic acid for 4 days at room temperature.

Tetrahydrotomentosolic Acid and its Derivatives.—Methyl tetrahydrotomentosolate benzoate (195 mg.) in diethylene glycol (18 ml.) containing potassium hydroxide (4 g.) was heated at 170° under nitrogen for 18 hr., to give *tetrahydrotomentosolic acid* (VI; R = R′ = H) (149 mg.). This crystallised from ethanol as plates, m. p. 294—295°, $[\alpha]_D$ +11° (*c* 0·38) (Found: C, 78·55; H, 10·9. $C_{30}H_{50}O_3$ requires C, 78·55; H, 11·0%). It did not give a colour with tetranitromethane.

Acetylation with pyridine–acetic anhydride overnight at room temperature and crystallisation of the product from ethanol gave *tetrahydrotomentosolic acid acetate* (VI; R = Ac, R′ = H) (108 mg.) as prisms, m. p. 290—293° (decomp.), $[\alpha]_D$ +28° (*c* 0·31), ε 750 at 220 mμ (Found: C, 76·85; H, 10·4. $C_{32}H_{52}O_4$ requires C, 76·75; H, 10·45%). This acetate acid was converted into the chloride and pyrolysed as before (see above). The product showed no diene absorption in the ultraviolet region.

Treatment of methyl tetrahydrotomentosolate benzoate with chromic acid in aqueous acetic acid under reflux as above gave a product with no ultraviolet or infrared absorption for conjugated ketone.

Formation of the Hydroxy-lactone (VII; R = Ac).—The methyl ester diol (II; R = Ac, R′ = Me) (100 mg.) in acetic acid (5 ml.) was heated on the steam-bath for 10 min. Crystallisation of the product from methanol afforded the *hydroxy-lactone* (VII; R = Ac) (80 mg.) as blades, m. p. 296—306° (vac.), $[\alpha]_D$ −51° (*c* 0·65), ε 4600 at 215 mμ, $\nu_{max.}$ 3470 (OH) and 1725 (lactone and OAc) cm.$^{-1}$ (Found: C, 75·0; H, 9·45; OMe, 0·0. $C_{32}H_{48}O_5$ requires C, 74·95; H, 9·45; OMe, 0·0%). The same hydroxy-lactone was obtained by treatment of the diol (II; R = Ac, R′ = Me) with hydrogen chloride in chloroform at room temperature for 3 min., with acetic anhydride in pyridine at room temperature for 2 days or with 1 : 1 concentrated hydrochloric acid and acetic acid on the steam-bath for 20 min.

Tomentosolic acid acetate (122 mg.) in pyridine (1 ml.) was treated with osmium tetroxide (100 mg.) at room temperature for 3 days. Treatment with hydrogen sulphide and working up in the usual way gave the same hydroxy-lactone (59 mg.) (m. p., mixed m. p., and infrared spectrum).

Reactions of Methyl Vanguerolate Acetate Monoepoxide (XXXI, R = Ac).—The epoxide (60 mg.) in benzene (10 ml.) was treated with boron trifluoride–ether (0·5 ml.) for 3 min. ($[\alpha]_D$ +79° ⟶ +8°). Crystallisation of the product from aqueous methanol gave the *ketone* (XXXII; R = Ac) as needles, m. p. 155—159°, $[\alpha]_D$ +18° (*c* 0·72), ε 6400 at 220 mμ, $\nu_{max.}$ 1725 (Me ester, OAc, and ketone) cm.$^{-1}$ (Found: C, 75·35; H, 9·75. $C_{33}H_{50}O_5$ requires C, 75·25; H, 9·55%).

The epoxide (107 mg.) in dioxan (50 ml.) and water (15 ml.) containing concentrated sulphuric acid (2·5 ml.) was heated on the steam-bath for 16 min. Chromatography of the product over alumina (grade V) and elution with light petroleum–benzene (4 : 1 and 7 : 3) afforded the *iso-dehydro-lactone acetate* (XXIX; R = Ac). This formed needles (25 mg.) (from methanol), m. p. 295—297°, $[\alpha]_D$ +24° (*c* 0·14), $\lambda_{max.}$ 245, 250, and 257 mμ (ε 20,900, 27,000, and 18,800, respectively), $\nu_{max.}$ 1750 (lactone) and 1720 (OAc) cm.$^{-1}$, τ (CCl_4) 8·42 (CH_3·C·O·) (Found: C, 77·45; H, 9·35. $C_{32}H_{46}O_4$ requires C, 77·7; H, 9·35%).

Reactions of Methyl Tomentosolate Acetate Monoepoxide.—The epoxide (55 mg.) in acetic

acid (4·5 ml.) containing concentrated hydrochloric acid (0·5 ml.) was heated on the steam-bath for 10 min. Crystallisation of the product from chloroform–methanol gave the *dehydrolactone acetate* (XXX; R = Ac) as plates, m. p. 300—303° (vac.), $[\alpha]_D$ −169 (*c* 0·22), $\lambda_{max.}$ 252, 260, and 269 mμ (ε 23,100, 28,000, and 19,800, respectively), $\nu_{max.}$ 1735 (OAc and lactone) cm.$^{-1}$, τ ($CDCl_3$) 8·59 (one CH_3·C·O) (Found: C, 78·2; H, 9·3. $C_{32}H_{46}O_4$ requires C, 77·7; H, 9·35%). Hydrogenation in acetic acid over platinum (1 mol. uptake) gave vanguerolic acid lactone acetate (XXV; R = Ac) (see above), identified by m. p., mixed m. p., $[\alpha]_D$, and spectra.

Methyl tomentosolate acetate monoepoxide (350 mg.) in dry ether (340 ml.) was treated with boron trifluoride–ether (17·5 ml.) under nitrogen for 5·5 min. Fractional crystallisation of the product in the dark under carbon dioxide from chloroform–methanol gave starting material (150 mg.) and the *triene* (XXVIII; R = Ac) (12 mg.) m. p. 230—231° (vac.), $[\alpha]_D$ +441° (*c* 0·58), $\lambda_{max.}$ 260 mμ (ε 33,000), $\nu_{max.}$ (in $CHCl_3$) 1710 (OAc) and 1610 (conjugated C=C) cm.$^{-1}$ (Found: C, 78·05; H, 9·6. $C_{33}H_{48}O_4$ requires C, 77·9; H, 9·5%).

Oxidation of Methyl Tomentosolate Acetate (I; R = Ac, R′ = Me).—(*a*) *With selenium dioxide.* Methyl tomentosolate acetate (100 mg.) in dioxan (10 ml.) was treated with selenium dioxide (100 mg.) at room temperature for 3 hr. After filtration from selenium the product was heated in acetic acid (5 ml.) containing concentrated hydrochloric acid (0·7 ml.) on the steam-bath for 10 min. Crystallisation of the product from chloroform–methanol furnished the dehydrolactone acetate (XXX; R = Ac) (45 mg.), identified by m. p., mixed m. p., $[\alpha]_D$, and spectra.

(*b*) *With chromium trioxide.* Methyl tomentosolate acetate (200 mg.) in acetic acid (30 ml.) was treated with chromium trioxide in the same solvent (15 ml.; 1·0N) at room temperature for 15 min. The excess of oxidant was destroyed with sulphur dioxide. Chromatography over alumina, elution with light petroleum–benzene (1 : 1), and crystallisation from aqueous methanol gave methyl 18-*hydroxytomentosolate acetate* (XXXIII; R = Ac) as needles, m. p. 246—251°, $[\alpha]_D$ +106° (*c* 0·40), $\nu_{max.}$ 3616 (OH) and 1727 (OAc and CO_2Me) cm.$^{-1}$ (Found: C, 75·35; H, 9·35. $C_{33}H_{50}O_5$ requires C, 75·25; H, 9·55%).

Chromic Acid Oxidation of Methyl Ursolate Benzoate.—The methyl ester benzoate (130 mg.) in 85% aqueous acetic acid (1 ml.) containing chromium trioxide (100 mg.) was refluxed for 45 min. Crystallisation of the product from chloroform–methanol gave *methyl* 11-*oxoursolate benzoate* (70 mg.) as prisms, m. p. 140—143°, resolidifying, and remelting at 235—238°, $[\alpha]_D$ +92° (*c* 0·44), $\lambda_{max.}$ 232 mμ (ε 18,700), $\lambda_{shoulder}$ 250 mμ (ε 16,700), $\nu_{max.}$ (in CCl_4) 1715 (OBz and Me ester), 1665 (cyclohexenone) and 1625 (C=C) cm.$^{-1}$ (Found: C, 77·75; H, 8·85. $C_{38}H_{52}O_5$ requires C, 77·5; H, 8·9%).

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