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STEREOCHEMISTRY OF ADDITION REACTION TO SERRATENE AND SERRATENEDIOL*

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Abstract—Steric course of addition reactions (hydroboration, epoxidation, osmolation, and hydrogenation) to the double bond of serratene derivatives **1** and **17** have been discussed and established as proceeding essentially from a β-direction. For metal reduction of the β-epoxide **3**, the stereochemistry of the product is probably controlled not only by conformational stability of the intermediate carbanion but also by a steric factor of protonation to the carbanion. The β-epoxide **3** and **18**, on treatment with acid, rearranged into new skeletal compounds (*neo*serratane derivatives, **26** and **27**) whose stereochemistry is also discussed.

PREVIOUSLY we have reported[1] that serratene (**1**), when converted to saturated derivatives, produces two stereoisomers, α- and β-compounds, concerning the C_{14}. In this paper, we wish to establish their stereochemistries and to clarify the steric course of addition reactions to the double bond of this particular series of compounds, and also present an example of skeletal rearrangement: 14β, 15β-epoxyserratane to 15-oxoneoserratane.

Steric course of the addition reactions to serratene derivatives and the stereochemistry of the products

Hydroboration and epoxidation of serratene (**1**) are highly stereoselective. Hydroboration of **1**,[1] followed by oxidation with hydrogen peroxide yielded a high proportion (~70%) of β-serratan-15-ol (**2**). Oxidation of this with Jones' reagent gave β-serratan-15-one (**5**).[1] Epoxidation of **1** with monoperphthalic acid gave a single product, 14β, 15β-epoxyserratane (**3**). The isomeric epoxide was not found in the reaction mixture. The epoxide **3** resisted reduction with LAH but was reduced by lithium in ethylamine[2] to afford two isomeric alcohols, m.p. 174–177° (A) and m,p. 206–208° (B) in approximately equal amounts, one of which (A) was identical with β-serratan-15-ol (**2**) obtained above. The alchol (B) had a secondary OH group (NMR spectrum) and was oxidized to a different ketone, α-serratan-15-one (**6**). The two ketones could be equilibrated by alkaline treatment to give the same 4:1 mixture of α- and β-serratan-15-one from either compound. The results show that the α-isomer is thermodynamically more stable than the β-isomer. Of the two possible stereoisomers (14α-H

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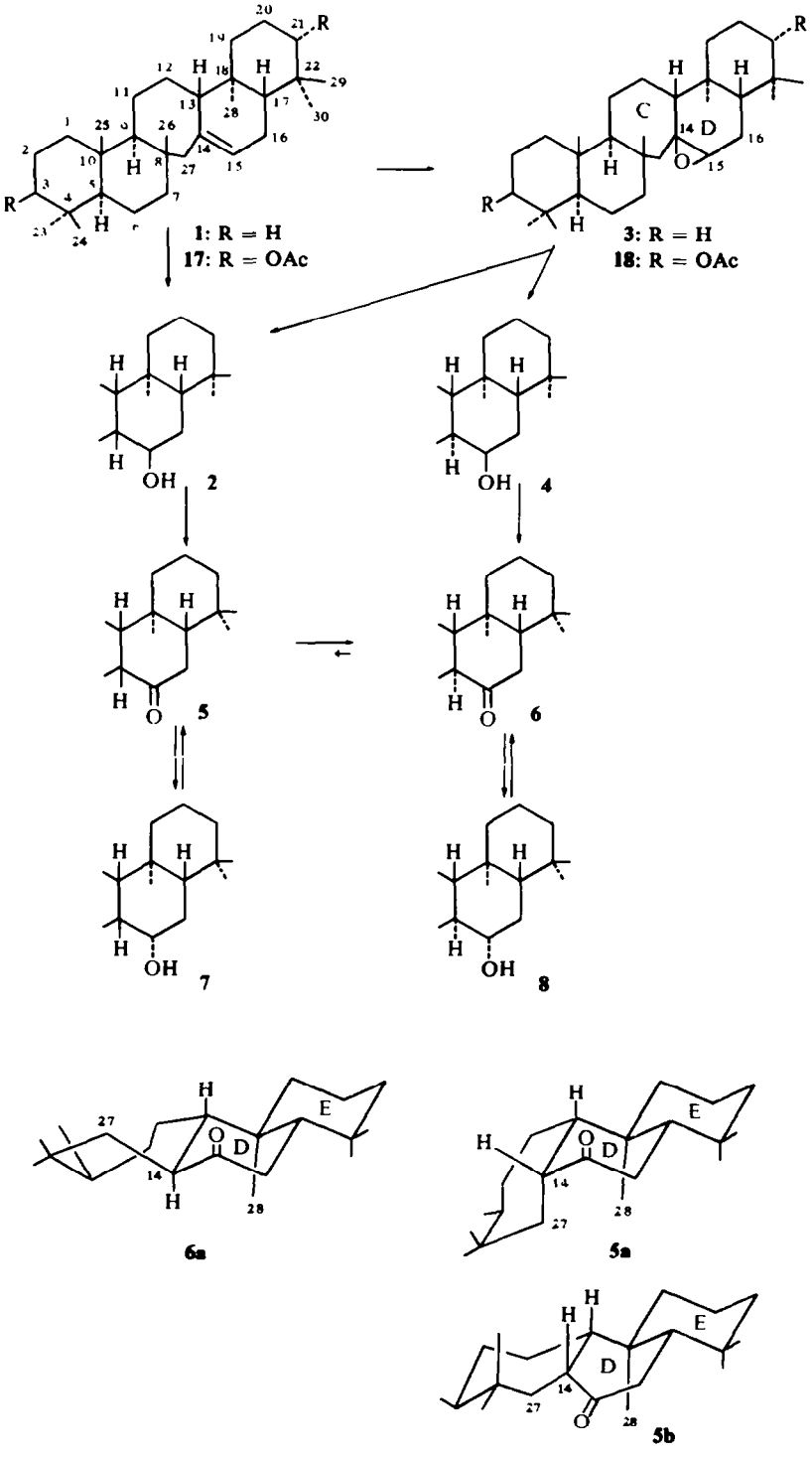
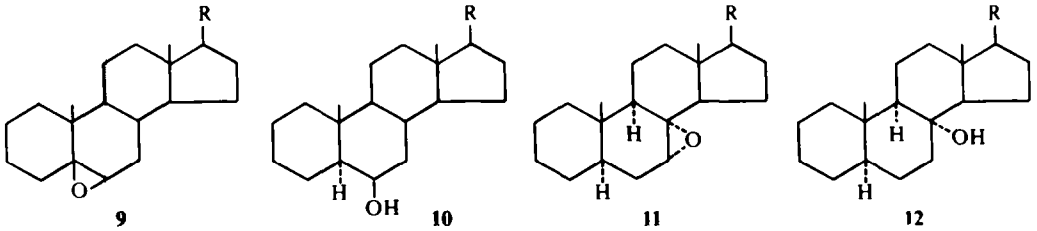
CHART 1

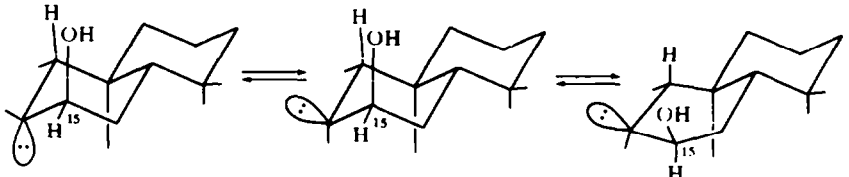


and 14β-H) of 15-one, the 14αH-15-one should be more stable, since the compound can have all chair conformation (**6a**) in which the 27-methylene group is in the favoured equatorial orientation to ring D. The 14β-H isomer, however, if it had all chair conformation (**5a**), would result in 1,3-diaxial interaction between the 27-methylene group and 28-methyl group, which could produce the conversion of ring D to the boat form (**5b**). In any case the 14β-H isomer is less stable than the 14α-H isomer. It follows then that the ketone (**6**) has α-configuration of hydrogen at C_{14}, while **5** has β-configuration. Actually solvent shifts of Me groups in the NMR (TH-effect) of each ketone clearly shows that the α-isomer has the 14α-H configuration with conformation **6a** and the β-isomer has 14β-H configuration with conformation **5b**.*

As the alcohol (A) gave the 14βH-15-one (**5**), this was assigned as 14β-serratan-15β-ol (**2**), since it was obtained stereoselectively by hydroboration-oxidation in which the steric course was known to be *cis*-addition.[4] It follows, therefore that the configuration of the oxide group of **3** is β, since it gave the alcohol **2** by metal reduction. This formulation is also supported by its resistance to reduction by LAH, for a 14α, 15α-epoxide should be reduced to an 14α-alcohol with no special difficulty. The other alcohol (B) is therefore 14α-serratan-15β-ol (**4**).



9 **10** **11** **12**



13 **14a** **14b**

Reduction of epoxides with lithium and ethylamine generally proceeds by attack of solvated electrons and the structures of products obtained are determined by conformational stability of an intermediate carbanion and by rule of axial opening of epoxides.[2] Thus 5β, 6β-epoxycholestane (**9**) affords cholestan-6β-ol (**10**) as a major product, while 7α, 8α-epoxycholestane (**11**) gives a single axial product, cholestan-8α-ol (**12**), as its ring B is in a boat conformation.[2] In contract to this latter example, 14β, 15β-epoxyserratane (**3**) gave no tertiary alcohol but furnished two secondary alcohols **2** and **4**. If epoxide **3** has a chair conformation in ring D (this assumption was

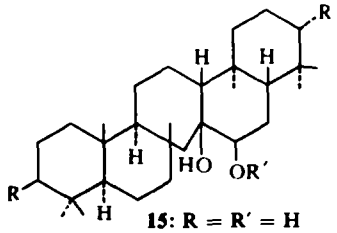
* This was preliminarily presented as the 1st International Symposium on Nuclear Magnetic Resonance (Ref. 3).

supported by its acid rearrangement reaction—see next section) these are the products of axial opening. However, the formation of 50% of the C/D-*cis* isomer (**2**) has still to be explained, since the carbanion will exist as an equilibration mixture **13** ⇌ **14** and the proportion of **13** should be higher than that of **6** in equilibration of ketones **6** ⇌ **5** due to tetrahedral charactor of C_{15}. On the other hand, addition of a proton (probably solvated) to the carbanion **13** from the α-side, gaving the more stable C/D-*trans* isomer **4**, is apparently suppressed by the steric hindrance due to interaction of the 28-Me group. Therefore, the overall result can be explained by balancing of two counter factors of conformational stability of an intermediate carbanion and steric hindrance of protonation to the carbanion, hence giving **2** and **4** in a ratio of approximately 1:1.

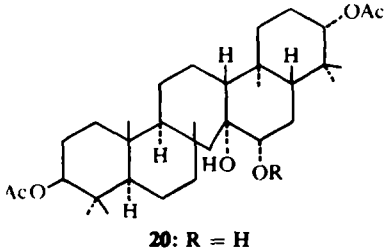
The above results show that non-catalytic addition reactions to the double bond of serratene exclusively take place from a β-direction.

Reduction of α- and β-serratan-15-one with LAH afforded two new alcohols, **8** and **7**, respectively, either of which on oxidation gave back the original ketones. Again β-face attack is predominant.

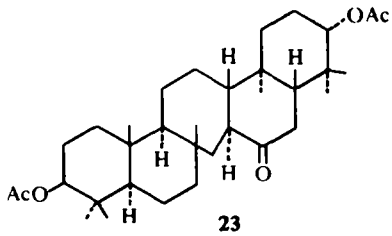
Osmolation of serratene (**1**) furnished a glycol, m.p. 255–259°, as a major product whose stereochemistry was assigened as 14β, 15β-diol (**15**) by analogy with the above evidence, presence of the minor glycol being recognized only by TLC. The same oxidation on serratenediol diacetate (**17**) gave an analogous result, two isomeric glycols, A (~50%) and B (~20%) being isolated in pure form after chromatography and crystallization of the product. The major glycol (A) was considered to be a 14β, 15β-diol (**19**), while the minor one (B) to be a 14α, 15α-diol (**20**). In order to prove their configurations, they were converted to the corresponding triacetates, (**21** and **22**), which were subjected to Serini reaction. Generally in the Serini reaction the configuration of the C_{14}-hydrogen of the resulting ketones are the same as the C_{15}-hydrogen of the original triacetates.[5] Reflux of each triacetate with zinc dust in toluene, however unexpectedly gave rise to the same 6-membered ketone **23**. Sublimation of the triacetates with zinc dust gave more stereoselective results, triacetate-A (**21**) affording a single product (**23**), while triacetate-B (**22**) gave, as expected, a mixture of 15-ketones as shown by TLC. The ketone **23** should have the more stable 14α-H configuration, since this could be prepared from either glycol in excellent yield by treatment with 3%-ethanolic hydrochloric acid, and under such a equilibration condition the product must be the thermodynamically more stable isomer. The lack of stereoselectivity in the Serini reaction may be rationalized by finding that 14β-seratan-15-one (**5**) was partly isomerized into the 14α-isomer **6** under reflux with zinc dust in toluene containing catalytic amounts of acetic acid.



15: R = R′ = H
16: R = H, R′ = Ac
19: R = OAc, R′ = H
21: R = OAc, R′ = Ac



20: R = H
22: R = Ac



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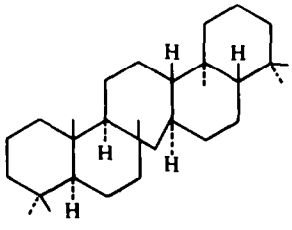
Catalytic hydrogenation of serratene (**1**) in acetic adid over platinum gave two stereoisomeric hydrocarbons, α- and β-serratane (**24** and **25**), with slight excess of the latter compound.[1] The stereochemistry of these hydrocarbons follows from the fact that Wolff–Kishner reduction of both 14α- and 14β-serratan-15-one, (**6** and **5**) gave α-serratane (**24**) as a major product.[1] Under this basic condition, both ketones (**6** and **5**) should exist in equilibration and the resulting hydrocarbon must have the more stable C/D-*trans* (14α-H) fusion. Reduction of stereoselectivity in hydrogenation is not surprising since by slow hydrogenation of a substituted double bond in a protic solvent, it has often been observed[6, 7] that the stereochemistry of the product is not



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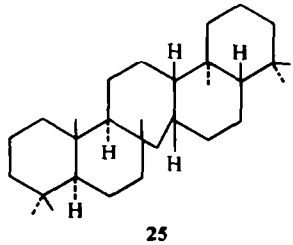

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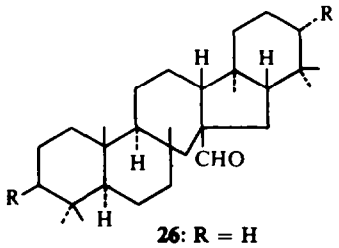
controlled by ease of the approach to the catalyst surface, but hydride transfer to the protonated double bond (carbonium ion) becomes an important step thus giving the thermodynamically more stable isomer.

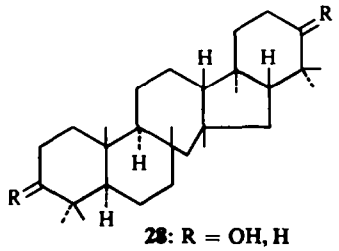
Rearrangement of 14β, 15β-*epoxyserratane to* 15-*oxoneoserratane*

When 14β, 15β-epoxyserratane (**3**) was treated with dilute hydrochloric acid, it was isomerized into an aldehyde (**26**) together with a small amount of conjugated diene mixture (UV λ_{max}: 231, 241, 249 and 280 mμ). A singlet at δ 9·50 in its NMR spectrum indicated the formation of an aldehyde function attached to a fully substituted carbon. Similarly 3β, 21α-diacetoxy-14β, 15β-epoxyserratane (**18**), which was stereoselectively prepared from serratenediol diacetate (**17**) by epoxidation or by ozonization, afforded the corresponding aldehyde (**27**; NMR signal, δ 9·55 s.) in good yield.

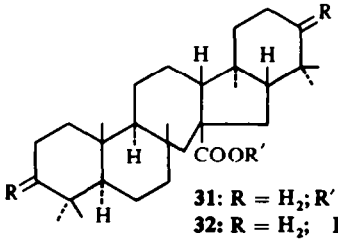
The most probable reaction pathway from the β-oxide (**3**) to the aldehyde (**26**) is the one in which migration of C_{15}—C_{16} bond to C_{14} proceeds concertedly with the breaking of the C_{14}—O linkage, consequently the configuration of the aldehyde function at C_{14} must be β. The mechanism via a discrete carbonium ion at C_{14} as presented[8] in acid catalysed cleavage of taraxerene-oxide (**38**) is unlikely, since if the



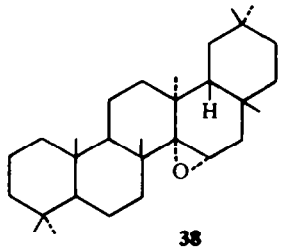
26: R = H
27: R = OAc



28: R = OH, H
29: R = O
30: R = H_2



31: R = H_2; R′ = H
32: R = H_2; R′ = CH_3
33: R = OAc, H; R′ = H
34: R = OAc, H; R′ = CH_3
35: R = OH, H; R′ = H
36: R = OH, H; R′ = CH_3
37: R = O; R′ = CH_3



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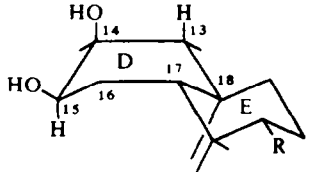

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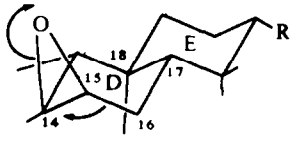

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carbonium ion were an intermediate, the β-glycol (**19**) must give the same reaction product as the β-epoxide (**18**), whereas both the α- and β-glycols, (**20** and **19**), did not afford an aldehyde but gave the same 15-one (**23**) under the similar acidic conditions (see above).

The difference in behavior of the β-oxide (**18**) and the β-glycol (**19**) in acidic medium was rationalized by assuming that ring D of the β-glycol exists in a boat conformation (**39**), as in 14β-serratan-15-one, having an anti-coplanar geometry of 14β-OH and 15α-H preferred to trans elimination, and that the β-epoxide possesses a chair conformation (**40**) in ring D where the migrating bond (C_{15}—C_{16}) and departing group (C_{14}-O) have an anti-coplanar geometry favorable for back side attack. The two serious non-bonded interactions between 28-Me and 27-methylene groups, and between 26-Me and C_{14}-OH groups in the β-glycol will be the chief driving forces preventing ring D from adopting chair conformation. Indeed the signal of C_{15}-hydrogen in the NMR spectrum of β-glycol (**19**) appears as a broad multiplet (δ 3·30) with band width 30 c/s, which indicates the hydrogen at C_{15} is in an axial orientation.

Wolff–Kishner reduction of the aldehyde-diacetate (**27**) gave the diol (**28**). Oxidation of **28**, followed by Wolff–Kishner reduction of the resulting diketone (**29**) gave the corresponding hydrocarbon (**30**). We now propose the name "*neo*serratane" for this carbon skeleton.

A similar rearrangement was observed in several oxidation reactions. Oxidation of serratenediol diacetate (**17**) by hydrogen peroxide in formic acid directly produced the aldehyde (**27**), apparently the epoxide being the intermediate in this case. Oxidation of serratene (**1**) with chromium trioxide in acetic acid yielded neoserratan-15-oic acid (**31**) as a main product (the methyl ester, m.p. 149–150°). Transformation of the aldehyde **26** to the methyl ester **32** confirmed its structure (Experimental)

EXPERIMENTAL

Unless otherwise stated, IR spectra were taken on Nujol mull, m.ps were determined on a Yanagimoto m.p. apparatus, and NMR spectra were measured in $CDCl_3$ by a Varian A-60 machine. Identities were confirmed by IR and by TLC comparisons.

14β, 15β-Epoxyserratane (**3**)

To a soln of **1** (760 mg) in ether (50 ml) an ether soln of monoperphthalic acid was added. The mixture was kept in the dark for a week at room temp. After being worked up as usual, the product was crystallized from benzene–n-hexane to give **3** (400 mg) as prisms, m.p. 248–250°. (Found: C, 84·39; H, 11·86. Calc, for $C_{30}H_{50}O$: C, 84·44; H, 11·81%).

Reduction of 14β, 15β-*epoxyserratane* (**3**)

Li (0·8 g) was added to a stirred soln of **3** (350 mg) in $EtNH_2$ (80 ml) at 0°. Stirring was continued for a further 6 hr at 0–6°. After addition of NH_4Cl, the mixture was kept overnight, diluted with water, and extracted with ether. The etheral extract was washed with water, dried over $MgSO_4$, and evaporated to give an oil which showed two spots on TLC. The separation of these was achieved by the preparative TLC [solvent: benzene–n-hexane (1:1)]. Stripping of the upper zone and extraction with $CHCl_3$ afforded 14α-*serratan*-15β-*ol* (**4**; 127 mg) as needles from acetone, m.p. 206–207°. (Found: C, 84·14; H, 12·49. Calc. for $C_{30}H_{52}O$: C, 84·04; H, 12·23%).

Similarly the lower zone gave 14β-*serratan*-15β-*ol* (**2**;[1] 133 mg) (needles from acetone), m.p. and mixed m.p. 174–178°.

Acetylation of **4** (82 mg) with Ac_2O (0·5 ml) and pyridine (1 ml) gave 15β-*acetoxy*-14α-*serratane* (needles from acetone), m.p. 186–188°. (Found: C, 81·76; H, 11·76. Calc. for $C_{32}H_{54}O_2$: C, 81·64; H, 11·56%).

Similarly acetylation of **2** gave 15β-acetoxy-14β-serratane,[1] m.p. 175–177°.

14α-*Serratan*-15-*one* (**6**)

To a soln of **4** (40 mg) in acetone (5 ml), a soln (1 ml) of CrO_3 in dil H_2SO_4 (1·03 g of CrO_3 in 30 ml of water and 8·7 ml of H_2SO_4) was added at 0°, and the mixture was stirred for 10 min. After decomposition of CrO_3 by addition of MeOH, the mixture was diluted with water, and the ppt was collected by filtration, then crystallized from $CHCl_3$–MeOH to give **6**[1] (30 mg) as needles, m.p. and mixed m.p. 196–198°.

Isomerization of serratan-15-*one*

(i) Compound **5** (76 mg) and 2% NaOMe–MeOH (10 ml) in benzene (5 ml) was stirred at room temp for 3 hr. The mixture was poured into water, extracted with $CHCl_3$, and the extract was evaporated to give a crystalline residue which showed two spots on a TLC. The separation was achieved by the preparative TLC [solvent: benzene–n-hexane (1:1)]. Stripping of the upper zone and extraction with $CHCl_3$ afforded **6** (52 mg) m.p. and mixed m.p. 196–198°. The lower zone gave the starting ketone **5** (10 mg) m.p. and mixed m.p. 202–204°.

(ii) Compound **6** (10 mg) in 2% NaOMe–MeOH (10 ml) was kept at room temp for 4 hr. The product

isolated showed two spots on TLC corresponding to the starting ketone **6** and **5**. The ratio was the same with that of the product described above.

14β-Serratan-15α-ol (**7**)

Compound **5** (62 mg) and LAH (100 mg) in THF (10 ml) was heated under reflux for 3 hr. The oily product isolated as usual, was acetylated with Ac_2O (0·5 ml) and pyridine (1 ml). Crystallization of the product from acetone gave *15α-acetoxy-14β-serratane* (40 mg) as needles, m.p. 179–181°. (Found: C, 81·69; H, 11·26. Calc. for $C_{32}H_{54}O_2$: C, 81·64; H, 11·56%).

Treatment of this (30 mg) with LAH (40 mg) in THF (10 ml) gave **7**, m.p. 95–97°, which was oxidized with Jones' reagent into **5** (prisms from $CHCl_3$–MeOH), m.p. and mixed m.p. 202–204°.

14α-Serratan-15α-ol (**8**)

Compound **6** (52 mg) was similarly reduced with LAH (100 mg) in THF (20 ml). Acetylation of the product and crystallization from acetone gave 15α-acetoxy-14α-serratane (28 mg) as needles, m.p. 166–168°. (Found: C, 81·76; H, 11·38. Calc. for $C_{32}H_{54}O_2$: C, 81·64; H, 11·56%).

Treatment of this (15 mg) with LAH (30 mg) in THF (10 ml) gave **8**, m.p. 185–190°, which was oxidized with Jones' reagent into **6**, m.p. and mixed m.p. 196–198°.

Osmolation of serratene (**1**)

A mixture of **1** (356 mg) and OsO_4 (220 mg) in pyridine (20 ml) was kept in the dark for 5 days at room temp. H_2S gas was passed into the mixture, the resulting ppt was filtered and washed with $CHCl_3$. The combined filtrate and washings were evaporated to give a crystalline residue which was chromatographed in benzene-n-hexane (1:1) over Al_2O_3 (4 g). First elution with the same solvent (10 ml) gave an oil (30 mg) which was discarded. Further elution with the same solvent (50 ml) gave a solid (62 mg) which showed two spots on TLC. The lower major spot corresponded to **15** described below. Elution with benzene gave a crystalline residue (179 mg) which was crystallized from $CHCl_3$–MeOH to give *14β, 15β-dihydroxyserratane* (**15**; 120 mg) as needles, m.p. 255–259°. Acetylation of this (80 mg) with Ac_2O (0·5 ml) and pyridine (1 ml) gave **16** (needles from $CHCl_3$–MeOH), m.p. 217–220°.

Osmolation of serratenediol diacetate (**17**)

Compound **17** (2·2 g) and OsO_4 (1·0 g) in pyridine (120 ml) was kept in the dark for a month. An aqueous soln (90 ml) of $NaHSO_3$ (5·6 g) was then added and the mixture was stirred for 30 min at room temp, and extracted with $CHCl_3$. The extract was washed with water and evaporated to dryness *in vacuo* to give a crystalline residue (2·3 g), which was washed with benzene and the insoluble part (1·2 g) was crystallized from $CHCl_3$–MeOH to give 3β, *21α-diacetoxy-14β, 15β-dihydroxyserratane* (**19**; 0·8 g) as needles, m.p. 316–318° (open capillary). NMR (δ): 0·87 (15H, s), 1·00 (3H, s), 1·19 (3H, s), 2·10 (6H, s), 3·70 (1H, m), 4·50 (2H, m). (Found: C, 72·32; H, 9·75. Calc. for $C_{34}H_{56}O_6$: C, 72·82; H, 10·06%).

The benzene soluble part was chromatographed in benzene over alumina and separated as follows, (i) Elution with benzene (100 ml) gave the starting material (0·4 g). (ii) Further elution with benzene (1 l.) gave 3β, *21α-diacetoxy-14α, 15α-dihydroxyserratane* (**20**; 0·54 g) (needles from benzene-n-hexane), m.p. 296–298° (open capillary); NMR (δ): 0·89 (9H, s), 0·92 (6H, s), 0·99 (3H, s), 1·01 (3H, s), 2·10 (6H, s), 3·30 (1H, m), 4·50 (1H, m). (Found: C, 72·71; H, 10·30. Calc. for $C_{34}H_{56}O_6$: C, 72·82; H, 10·06%). (iii) Further elution with $CHCl_3$ (300 ml) gave **19** (0·4 g) as needles, m.p. and mixed m.p. 316–318° (open capilary).

Acetylation of **19** (100 mg) with Ac_2O (1 ml) and pyridine (2 ml) gave 3β, 15β, *21α-triacetoxy-14β-hydroxyserratane* (**21**; 95 mg) as needles from benzene-n-hexane, m.p. 297–299°. (Found: C, 71·68; H, 9·63. Calc. for $C_{36}H_{58}O_7$: C, 71·72; H, 9·70%).

Acetylation of **20** (100 mg) with Ac_2O (1 ml) and pyridine (2 ml) gave **22** (97 mg) as needles from benzene-n-hexane, m.p. 257–259°. (Found: C, 71·64; H, 9·77. Clac. for $C_{36}H_{58}O_7$: C, 71·72; H, 9·70%).

Serini reaction of **16**

Compound **16** (12 mg) and Zn dust (242 mg) were mixed and sublimed at 250° and 1 mmHg. The TLV and IR of the crystalline sublimate showed that the product was a mixture of 14α and 14β-serratan-15-ones, the major product being **6**.

Serini reaction of **21** *and* **22**

(i) Compound **21** (60 mg) and Zn dust (1 g) in toluene (10 ml) were heated under reflux for 15 hr. removal of Zn dust and solvent left a crystalline residue which was crystallized from $CHCl_3$–MeOH to give 3β, 21α-*diacetoxy*-14α-*serratane*-15-*one* (**23**; 30 mg) as prisms, m.p. 294–296° (open capillary); IR 1725 (OAc) and 1960 cm^{-1} (ketone); NMR (δ): 0·85 (12H, s), 0·90 (3H, s), 0·92 (3H, s), 1·06 (3H, s), 2·05 (6H, s), 4·45 (2H, m). (Found: C, 75·52; H, 10·13. Calc. for $C_{34}H_{54}O_5$: C, 75·23; H, 10·03%).

(ii) Compound **22** (60 mg) and Zn dust (1 g) in toluene (10 ml) were similarly treated. Crystallization of the product from $CHCl_3$–MeOH afforded **23** (20 mg) m.p. and mixed m.p. 294–296°.

(iii) A mixture of **21** (10 mg) and Zn dust (120 mg) was sublimed at 270° and 1 mm. The TLC of the crystalline sublimate showed a single spot corresponding to **23**. The IR spectrum was superimposable on that of the sample obtained above.

(iv) A mixture of **22** (11 mg) and Zn dust (171 mg) was sublimed as described above. The TLC of the sublimate showed two spots, one of which was identical with that of **23**. The IR spectrum of the mixture exhibited a CO band at 1685 cm^{-1}, but no OH band.

Isomerization of 14β-*serratan*-15-*one under the condition of the Serini reaction*

Compound **5** (10 mg) and Zn dust (500 mg) in toluene (10 ml) containing 2 drops of AcOH, was refluxed for 5 hr. The TLC of the product showed two spots corresponding to **6** and **5**.

3β, 21α-*Diacetoxy*-14α-*serratan*-15-*one* (**23**)

(i) A soln of **19** (17 mg) in 3% HCl–EtOH (10 ml) was heated under reflux for 1 hr. The mixture was neutralized with 5% K_2CO_3 aq and extracted with $CHCl_3$. The extract was washed and water, dried over $MgSO_4$, and evaporated to dryness. The residue was acetylated with Ac_2O (1 ml) and pyridine (2 ml) at room temp to give **23** (11 mg), m.p. and mixed m.p. 294–296° (open capillary).

(ii) A soln of **22** (40 mg) in 3% HCl–EtOH (20 ml) and $CHCl_3$ (2 ml) was treated as described above. Acetylation of the product gave **23** (26 mg), m.p. 294–296° (open capillary).

3β, 21α-*Diacetoxy*-14β, 15β-*epoxyserratane* (**18**)

(i) Coupound **17**[1] (2·4 g) in $CHCl_3$ (30 ml) was treated with an ethereal soln of monoperphthalic acid (large excess) at room temp for a week. The reaction mixture was diluted with $CHCl_3$ and the organic layer was washed with 5% NaOH aq, water, dried over $MgSO_4$, and evaporated to dryness. Crystallization of the residue from benzene afforded *the oxide* (**18**) as prisms (1·58 g), m.p. 350–353° (open capillary), $[\alpha]_D$ +27·8° (*c* = 3·6 in $CHCl_3$); NMR (δ): 0·79 (3H, s), 0·90 (12H, s), 0·97 (3H, s), 1·04 (3H, s), 2·10 (6H, s), 2·88 (broad s), 4·50 (2H, m). (Found: C, 75·08; H, 9·83. Calc. for $C_{34}H_{54}O_5$: C, 75·23; H, 10·03%).

(ii) Ozonized O_2 was passed through a soln of **17** (728 mg) in $CHCl_3$ (15 ml) at 0° until the mixture was saturated to tetranitromethane. The mixture was diluted with water, extracted with $CHCl_3$, and the extract was washed with water, dried over $MgSO_4$, and evaporated to dryness. Crystallization of the residue from $CHCl_3$–MeOH gave **18** (600 mg) as prisms, m.p. and mixed m.p. 340–343°.

15-*Oxoneoserratane* (**26**)

Compound **3** (60 mg) in $CHCl_3$ (15 ml) was treated with a few drops of conc HCl under stirring for 30 min, and the product in n-hexane was chromatographed over alumina (1 g). The first eluate afforded a hydrocarbon mixture (10 mg), λ_{max} (EtOH): 231, 241, 249 and 280 mμ, further elution with n-hexane and benzene gave the *aldehyde* (**26**; 35 mg) as prisms from acetone, m.p. 176–178°; IR: 2703 and 1718 cm^{-1} (CHO); NMR (δ): 0·70 (3H, s), 0·76 (9H, s), 0·79 (12H, s), 9·50 (1H, s). (Found: C, 84·68; H, 11·98. Calc. for $C_{30}H_{50}O$: C, 84·44; H, 11·81%).

3β, 21α-*Diacetoxy*-15-*oxoneoserratane* (**27**)

(i) Compounds **18** (198 mg) in $CHCl_3$ (15 ml) was treated with conc HCl (0·1 ml) at room temp for 30 min with stirring. Crystallization of the product from benzene afforded the *aldehyde* (**27**; 90 mg) as needles, m.p. 245–247°; $[\alpha]_D$ +21·6° (*c* = 3·43 in $CHCl_3$); IR: 1730 cm^{-1} (CHO, OAc); NMR (δ): 0·75 (3H, s), 0·82 (3H, s), 0·88 (9H, s), 0·96 (6H, s), 2·09 (6H, s), 4·50 (2H, m), 9·55 (1H, s). (Found: C, 75·14; H, 9·84. Calc. for $C_{34}H_{54}O_5$: C, 75·23; H, 10·03%).

(ii) To a soln of **17** (500 mg) in AcOEt (50 ml) was added a soln of 80% HCOOH (10 ml) and 30% H_2O_2 (2 ml), and the mixture was heated under reflux for 1 hr, and concentrated to ca. ¼ volume *in vacuo*.

Collection of the ppt and crystallization from $CHCl_3$–MeOH gave **27** (260 mg), as leaflets, m.p. and mixed m.p. 245–246°.

(iii) Compound **17** (728 mg) in $CHCl_3$ (15 ml) was ozonized as described above. Zn dust (1·1 g) and AcOH (8 ml) were added to the mixture, and after stirring for 2 hr the ppt was filtered off and washed with $CHCl_3$. The combined filtrate and washings were washed with water, dried over $MgSO_4$, and evaporated to dryness. Chromatography of the product and crystallization from $CHCl_3$–MeOH gave **27** (350 mg), m.p. and mixed m.p. 247–248°.

Hydrolysis of **27** (100 mg) with 2% KOH–MeOH (30 ml) under reflux for 1 hr afforded the corresponding diol (70 mg) as needles from MeOH m.p. 209–211°; IR: 3390 cm^{-1} (OH), 1721 (CHO). (Found: C, 75·50; H, 10·89. Calc. for $C_{30}H_{50}O_3 . H_2O$: C, 75·58; H, 11·00%).

3β, 21α-*Diacetoxyneoserratan*-15-*oic acid* (**33**)

To a soln of **27** (290 mg) in pyridine (10 ml) was added $KMnO_4$ (240 mg) and the mixture was stirred for 7 hr at room temp. After decomposition of $KMnO_4$ by MeOH, the solvent was evaporated to dryness *in vacuo*. The residue was taken up in $CHCl_3$ and the extract was washed with $Na_2S_2O_3$ and dil H_2SO_4, water, dried over $MgSO_4$, and evaporated to dryness. Crystallization of the residue from MeOH afforded *the acid* (**33**; 170 mg) as needles, m.p. 285–287°, $[\alpha]_D$ −5·1° (c = 2·7 in $CHCl_3$); IR: 3250, 1705 (COOH), and 1726 cm^{-1} (OAc). (Found: C, 72·95; H, 9·85. Calc. for $C_{34}H_{54}O_6$: C, 73·08; H, 9·74%).

The acid **33** (110 mg) was methylated with excess of CH_2N_2 in ether. Crystallization of the product from $CHCl_3$–MeOH gave the *methyl ester* (**34**; 85 mg) as needles, m.p. 232–234°, $[\alpha]_D$ −17·1° (c = 2·8 in $CHCl_3$); IR: 1730 cm^{-1} (COOMe, OAc). (Found: C, 73·28; H, 10·11. Calc. for $C_{35}H_{56}O_6$: C, 73·39; H, 9·85%).

3β, 21α-*Dihydroxyneoserratane*-15-*oic acid* (**35**)

The diacetate **33** (115 mg) was hydrolysed with 10% KOH–MeOH (15 ml) under reflux for 4 hr. The mixture was poured into water, and crystallization of the ppt from $CHCl_3$–MeOH gave *the diol* (**36**; 85 mg) as needles, m.p. 345–347° (open capillary). (Found: C, 73·42; H, 10·72. Calc. for $C_{30}H_{50}O_4 \cdot H_2O$: C, 73·12; H, 10·64%).

The acid **35** (320 mg) in $CHCl_3$–MeOH (1:1) (30 ml) was methylated with CH_2N_2 in ether. Crystallization of the product from $CHCl_3$–MeOH gave *the methyl ester* (**36**; 292 mg) as needles, m.p. 255–257°; IR: 3390, 3322 (OH) and 1718 cm^{-1} (ester). (Found: C, 74·49; H, 10·83. Calc, for $C_{31}H_{52}O_4 \cdot \frac{1}{2} H_2O$: C, 74·79; H, 10·73%).

The diketo-ester (**37**)

A mixture of **36** (200 mg) and CrO_3 (400 mg) in pyridine (5 m,) was kept overnight at room temp. The product, isolated with $CHCl_3$, was chromatographed in benzene over alumina (2 g), and the eluate was crystallized from n-hexane to give *the diketo-ester* (**37**) as needles, m.p. 203–205°, $[\alpha]_D$ +35·6° (c = 3·6 in $CHCl_3$); IR: 1709 cm^{-1} (ester and ketone). (Found: C, 76·58; H, 9·91. Calc. for $C_{31}H_{48}O_4$: C, 76·81; H, 9·98%).

3β, 21α-*Dihydroxyneoserratane* (**28**)

Compound **27** (500 mg) and anhyd hydrazine (4 ml) in diethyleneglycol (50 ml) containing Na (4 g) were heated at 180° for 4 hr, then the temp was raised to 210° and the mixture was kept for 4 hr. The mixture was poured into water, extracted with $CHCl_3$ and the extract was washed with water, dried over $MgSO_4$, and evaporated to dryness. Crystallization of the residue (420 mg) from $CHCl_3$–MeOH gave **28** as prisms, m.p. 265–267°. (Found: C. 79·07; H, 11·52. Calc. for $C_{30}H_{52}O_2 \cdot \frac{1}{2} H_2O$: C, 79·40; H, 11·78%).

Acetylation of this (100 mg) with AC_2O (1 ml) and pyridine (2 ml) gave *the diacetate* (92 mg) as needles from $CHCl_3$–MeOH, m.p. 256–257°. (Found: C, 77·40; H, 10·88. Calc. for $C_{34}H_{56}O_4$: C, 77·22; H, 10·67%).

Neoserratane (**30**)

Compound **28** (200 mg) and CrO_3 (300 mg) in pyridine (5 ml) were stirred overnight at room temp. The mixture was poured into water and extracted with $CHCl_3$. The extract was washed with water, dried over $MgSO_4$, and evaporated to dryness. The residue was chromatographed in $CHCl_3$ over silica-gel to

give *neoserratan*-3, 21-*dione* (**29**; 160 mg) (needles from $CHCl_3$-MeOH), m.p. 140–143°. IR: 1695 cm^{-1} cyclohexanone).

Compound **29** (80 mg) and anhyd hydrazine (1 ml) in diethyleneglycol (20 ml) containing Na (1 g) were heated as described above. Chromatography of the product in n-hexane over Al_2O_3 gave **30** (40 mg) (leaflets from $CHCl_3$–MeOH). (Found: C, 87·08; H. 12.56. Calc. for $C_{30}H_{52}$: C, 87·30; H, 12·70%).

Methyl neoserratan-15-*oate* (**32**)

(i) The diketo-ester **37** (623 mg) and anhyd hydrazine (6 ml) in diethyleneglycol (42 ml) containing Na (3 g) were heated at 180° for 4 hr, and heating was continued at 210° for further 2 hr. The mixture was poured into water and extracted with $CHCl_3$. The extract was washed with water, dried over $MgSO_4$, and evaporated to dryness. The residue in ether (10 ml) was treated with CH_2N_2 to give *the methyl ester* (**32**; 510 mg) as needles from MeOH, m.p. 149–151°; IR: 3509 (OH) and 1724 cm^{-1} (COOMe). (Found: C, 79·89; H, 11·49. Calc. for $C_{31}H_{52}O_2 \cdot \frac{1}{2}MeOH$: 80·03; H, 11·50%).

(ii) The aldehyde **26** (100 mg) was oxidized with $KMnO_4$ in pyridine as described for **33**. Methylation of the crude product with CH_2N_2 afforded the methyl ester **32**, m.p. and mixed m.p. 149–151°.

Oxidation of serratene (**1**) *with chromium trioxide*

Serratene **1** (467 mg) in AcOH (150 ml) and CrO_3 (500 mg) in 90% AcOH (10 ml) were mixed and the mixture was warmed at 75° on a water bath for 3 hr. After decomposition of excess of CrO_3 with EtOH, AcOH was removed *in vacuo*, and the residue was taken up in $CHCl_3$, which was washed with water, dried over $MgSO_4$, and evaporated to dryness. Washing of the residue with n-hexane gave a crystalline residue (225 mg). Chromatography of this and crystallization of benzene and $CHCl_3$ eluates gave *neoserratan*-15-*oic acid* (**31**; 210 mg) (Prisms from $CHCl_3$–MeOH), m.p. >300°; IR: 1690 cm^{-1} (COOH). (Found: C, 81·42; H, 11·34. Calc. for $C_{30}H_{50}O_2$: C, 81·39; H, 11·38%).

Treatment of **31** (50 mg) with CH_2N_2 in ether gave **32** (42 mg) as needles from $CHCl_3$–MeOH, m.p. and mixed m.p. 149–151°.

The hexane-soluble oil (285 mg) was passed through a column of alumina and the eluate was crystallized from acetone to give serrat-13-en-15-one[1] as leaflets, m.p. and mixed m.p. 245–246°.

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