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STRUCTURE OF HIMACHALENES

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THE essential oil from Himalayan deodar (<u>Cedrus deodara</u>, Loud.) has been shown<sup>1</sup> to contain two sesquiterpene hydrocarbons, namely  $\alpha$  - and  $\beta$ himachalenes. We now report on their structure which confirms our original contention<sup>1</sup> that these hydrocarbons represent a new framework for sesquiterpenes.

The purified samples <sup>\*\*</sup> of these hydrocarbons had the following constants: a-himachalene<sup>+</sup> b.p.93-94°/2 mm,  $n_D^{25}$  1.5082,  $d_4^{25}$  0.9206,  $M_D$  65.85, [a]  $_D^{25}$  -187.1° (clean), [a]  $_D^{25}$  -192.3° (4.16% in CHCl<sub>3</sub>);  $\beta$ -himachalene, b.p. 121-22°/4 mm,  $n_D^{25}$  1.5130,  $d_4^{25}$  0.9330,  $M_D$  65.71, [a]  $_D^{25}$  + 225.8° (clean), [a]  $_D^{25}$  + 224.7° (4.76% in CHCl<sub>3</sub>). Though the experimental values for molecular refractivity are lower than those calculated (66.13) for  $C_{15}H_{24}F_{2}^{2}$ , the bicyclic nature of these compounds is confirmed by quantitative hydrogenation (AcOH and PtO<sub>2</sub> catalyst), and percamphoric acid titrations, as both of these methods showed the presence of two ethylenic linkages in the

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\*\* Vapour Phase Chromatography showed a single peak in each case. The details of vapour phase chromatographies discussed in this communication will be described in the full paper.

\* Ail compounds analysed correctly.

<sup>1</sup> G.S. Krishna Rao, Sukh Dev and P.C. Guha, <u>J.Ind.Chem.Soc</u>. <u>29</u>, 721 (1952).

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molecule. **a-Himachalene** yielded a crystalline di-a-epoxide, m.p.125-126°,  $\begin{bmatrix} a \end{bmatrix}_{D}^{30}$ -144° (1.25% in CHCl<sub>3</sub>), while the  $\beta$ -isomer furnished only a liquid product, b.p.126-30°/2 mm,  $n_{D}^{26}$  1.4939,  $\begin{bmatrix} a \end{bmatrix}_{D}^{26}$  + 87° (2% in CHCl<sub>3</sub>).

In the infrared, a-himachalene displayed bands assignable to  $\sum = CH_0$ (3060, 1770, 1625, 885 cm<sup>-1</sup>) and  $\Sigma = C \leq (1665, 865 \text{ cm}^{-1})$ , and three peaks at 1388, 1377 and 1362 cm<sup>-1</sup> due to methyl and <u>gem</u>-dimethyl groups.  $\beta$ -isomer showed bands due to a trisubstituted olefinic linkage only (1665, 857 cm<sup>-1</sup>?), a gem-dimethyl group (1360 cm<sup>-1</sup>) also being present. Since both hydrocarbons yield the same crystalline dihydrochloride<sup>1\*</sup>, the asymmetric di-substituted ethylenic bond of a-himachalene is replaced by a tri- or tetra-substituted olefinic function in the  $\beta$ -isomer. A decision on this point could be arrived at by a study of their nuclear magnetic resonance (NMR) spectra.\*\* On the lower field-strength side a-himachalene showed two peaks at -45 (singlet) and +1 cps (partly split) corresponding in intensity to one and two protons respectively, and readily assignable $^2$  to a trisubstituted and disubstituted ethylenic linkage; these assignments were confirmed by a study of the infra-red and NMR spectra of dihydro-a-himachalene (by the hydrogenation of a-himachalene over PtO catalyst in ethanol: b.p.98-100°/1 mm,  $n_D^{24}$  1.4972,  $d_L^{24}$  0.9105,  $[\alpha]_D^{24}$  + 59.2° in CHCl<sub>2</sub> solution).  $\beta$ -Himachalene displayed only one peak in this region at -37 cps and corresponded to one proton in its intensity; clearly the other ethylenic linkage in this isomer is tetrasubstituted.

Nil optical rotations recorded for both the dihydrochloride and the monohydrochloride are in error. These compounds are optically active: dihydrochloride,  $[a]_D^{30} + 22^\circ$  (9.6% in CHCl<sub>3</sub>); monohydrochloride,  $[a]_D^{30} + 113^\circ$  (2.5% in CHCl<sub>3</sub>).

<sup>\*</sup> All proton magnetic resonance spectra were determined at 60 mc rf. on 25 per cent solutions in CC1<sub>4</sub>. The chemical shifts are herein reported in cycles per second <sup>4</sup> relative to water (zero standard).

<sup>&</sup>lt;sup>2</sup> e.g. see: Sukh Dev, <u>Tetrahedron</u> <u>9</u>, 1 (1960).

The total number of methyl groups in these molecules have been estimated by quantitative infra-red absorption<sup>3,4,5</sup> and the values correspond approximately to three for a-himachalene and four for  $\beta$ -himachalene. This is confirmed and further elaborated by the NMR data: a-himachalene, sharp peaks at 236, 234 and 183 cps, each corresponding in intensity to three protons and assignable<sup>2</sup> to two methyl groups on a sp<sup>3</sup> carbon (s) and one methyl group on an olefinic bond;  $\beta$ -himachalene displayed two 'saturated methyl' proton peaks (246,231 cps) and one 'unsaturated methyl' proton peak (185 cps), the first two each corresponding in area to three protons, while 185 cps peak accounting for six protons.

The infra-red spectra of tetrahydro-a-(b.p.  $132^{\circ}/14$  mm,  $n_D^{24}$  1.4862,  $d_4^{24}$  0.8986,  $M_D$  66.48,  $[a]_D^{24}$  -8.25° in CHCl<sub>3</sub> solution) and tetrahydro- $\beta$ himachalene (b.p. 110-111°/3 mm,  $n_D^{26}$  1.4875,  $d_4^{26}$  0.8997,  $M_D$  66.65,  $[a]_D^{26}$  -21.1° in CHCl<sub>3</sub>), though quite similar, showed important differences in the intensities of several bands in the fingerprint region. This is readily explainable on the basis of formation of differing amounts of stereoisomers during hydrogenation. The vapour-phase chromatography (VPC) of the products, disclosed in each case at least two components; the component with lower retention time being present to the extent of 15% in the case of a-isomer and 66% in the  $\beta$ -isomer. The infra-red spectra and the physical constants differed from those recorded for several known perhydro bicyclic sesquiterpene systems<sup>6</sup>,7.

- <sup>3</sup> S.A. Francis, <u>J.Chem. Phys</u>. <u>18</u>, 861 (1950).
- <sup>4</sup> D.H.R. Barton, J.E. Page and E.W. Warnhoff, <u>J.Chem. Soc</u>. 2715 (1954)
- <sup>5</sup> L. Henry and G. Ourisson, <u>Bull.Soc. Chim. Fr</u>. 99 (1955)
- <sup>6</sup> J. Pliva and F.Šorm, <u>Coll.Czech.Chem.Comm</u>. <u>14</u>, 274 (1949).

<sup>&</sup>lt;sup>7</sup> J. Pliva, V.Herout, B. Schneider and F.Šorm, <u>Coll.Czech.Chem.Comm</u>. <u>18</u>, 500 (1953).

Himachalenes\* on selenium-dehydrogenation (305-310°; 48 hours) yielded three main products, two of these were readily identified as cadalene (I) (from the highest boiling fraction b.p.145-155°/11 mm; characterized by its ultra-violet spectrum, and trinitrobenzene complex, m.p. and mixed m.p. with an authentic sample 110-111°) and 2-methyl-6-(p-tolyl)-heptane (II) (from the lowest boiling fraction b.p.128-35<sup>0</sup>/11 mm; a purified sample had: b.p. 125-26°/11 mm,  $n_D^{26}$  1.4887,  $d_4^{26}$  0.8678,  $\lambda \frac{\text{heptane}}{\text{max}}$  260, 265 and 273 mµ. The compound on chromic acid oxidation vielded terephthalic acid. The infra-red spectrum was identical with that of an authentic material<sup>8</sup> prepared from bisabolene). The third product, which has not, so far, been obtained free from (II) is a new sesquiterpene-dehydrogenation product (III) and as will be shown in the seguel is characteristic of the himachalenes ring-skeleton. The percentage composition of the Se-dehydrogenation product was estimated by VPC to be 30% (I), 39% (II) and 28% (III). Since a cadalenic sesquiterpene is hardly expected to undergo cleawage to yield (II), it was argued that himachalenes have a carbon-skeleton capable of scission to an intermediate that can, later, give rise to both (I) and (II). This is supported by the results of sulphur-dehydrogenation (210-15°; 2 hr) of himachalenes. The products of S-dehydrogenation were found to consist of 56% (II) and 33% (III), only traces of cadalene (less than 5%, as revealed by VPC and confirmed by quantitative absorption at 325 mµ, the longest wavelength band of cadalene) were formed; clearly cadalene arises by a recyclization or a similar reaction.<sup>9</sup> A central cut

- L. Ruzicka and Van Veen, Liebigs Ann. 468, 133 (1929)
- <sup>9</sup> L. Ruzicka, J.Meyer and M.Mingazzini, <u>Helv.Chim.Acta 5</u>, 345 (1922)

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Since both  $\alpha$ - and  $\beta$ -himachalenes on Se-dehydrogenation yielded essentially the same products, further dehydrogenation experiments were carried out on the mixture of hydrocarbons which was more easily accessible.

of S-dehydrogenation product, consisting chiefly of (II) and (III) (~ 1:1) was examined in the 1650-1950 cm<sup>-1</sup> region to reveal the characteristic benzene-substitution patterns<sup>10</sup> and the results compared with similar absorption patterns, obtained under identical conditions for (II) and 2-methyl-benzosuberane. These data clearly indicate that compound (III) is a 1,2,4-trisubstituted benzene, as the pattern was a summation of (II) and 2-methylbenzosuberane patterns. This was confirmed by the nitric acid oxidation of this cut, when both terephthalic acid and trimellitic acid (anhydride, m.p. 161-162°, mixed m.p. with an authentic sample 162-163°) were obtained in approx. equal amounts.

Taking into consideration all the experimental results discussed above, it becomes apparent that himachalenes have the carbon-skeleton (IV), with carbon 1 attached to a position on the other part of the molecule. Noting the fact that  $\beta$ -himachalene has a tetra-substituted ethylenic linkage which



<sup>10</sup> C.W. Young, R.B. DuVall and N.Wright, <u>Analyt.Chem.</u> <u>23</u>, 709 (1951)

becomes asymmetric disubstituted in **a**-himachalene, and further bearing in mind the nature of the methyl groups, the linkage in (IV) must be between  $C_1$  and  $C_{11}$ ; structure (V) stands ruled out as it would have one terminus of the tetrasubstituted ethylenic linkage in  $\beta$ -himachalene at a bridge-head, and this is sterically prohibitive. In order to gain experimental evidence in favour of  $C_1 - C_{11}$  linkage, nitric acid oxidation of himachalenes was investigated. The composition of the product (as methyl esters; b.p.70-110°/10 mm; yield ~3.5 g/13 g of himachalenes) was determined by a combination of VPC, fractionation, and actual isolation (partitition chromatography) and characterization (by comparison with authentic samples) of acids to be: dimethyl malonic (4%),  $\alpha$ , $\alpha$ -dimethyl succinic (20%),  $\alpha$ , $\alpha$ -dimethyl-glutaric (38%),  $\alpha$ , $\alpha$ -dimethyl adipic (13%) and succinic acid (25%). These results clearly show the carbon framework of himachalenes as (VI), and then the new dehydrogenation product (III)\* can possibly be assigned the structure shown.

a- and  $\beta$ -Himachalenes can now be represented by the structures (VII) and (VIII) respectively. These structures have been preferred over the alternate structures\* with the trisubstituted ethylenic linkage in the 3,4-position, because of the formation of significant amounts of succinic acid during the nitric acid oxidation. The structure (VIII) for  $\beta$ -himachalene has been further confirmed by oxidative ozonolysis when the acidic products were identified as laevulinic and geronic acid (IX; Me ester, b.p.105-6°/10 mm,  $n_D^{24}$  1.4400; semicarbazone of methyl ester, m.p. with an authentic sample<sup>11</sup> 156-57°, the infra-red spectra of the two

<sup>\*</sup> Though a decision between these alternatives should be possible on the basis of NMR data, the treatment is inconclusive and will be discussed fully in the detailed paper.

<sup>&</sup>lt;sup>11</sup> H.H. Strain, <u>J. Biol. Chem</u>. <u>102</u>, 137 (1933).

samples were superimposable); these products can only arise from structure
(VIII).

Further work relating to  $\mathfrak{a}$ -himachalene and stereochemistry, and the biogenetic implications of these structures will be discussed in the fuller paper.

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