A Novel Rearrangement of Cyclobutanes to Cyclopropanes; Construction of Tricyclo[5.4.0.0^{1,3}]undecane and Bicyclo[4.1.0]heptane Systems

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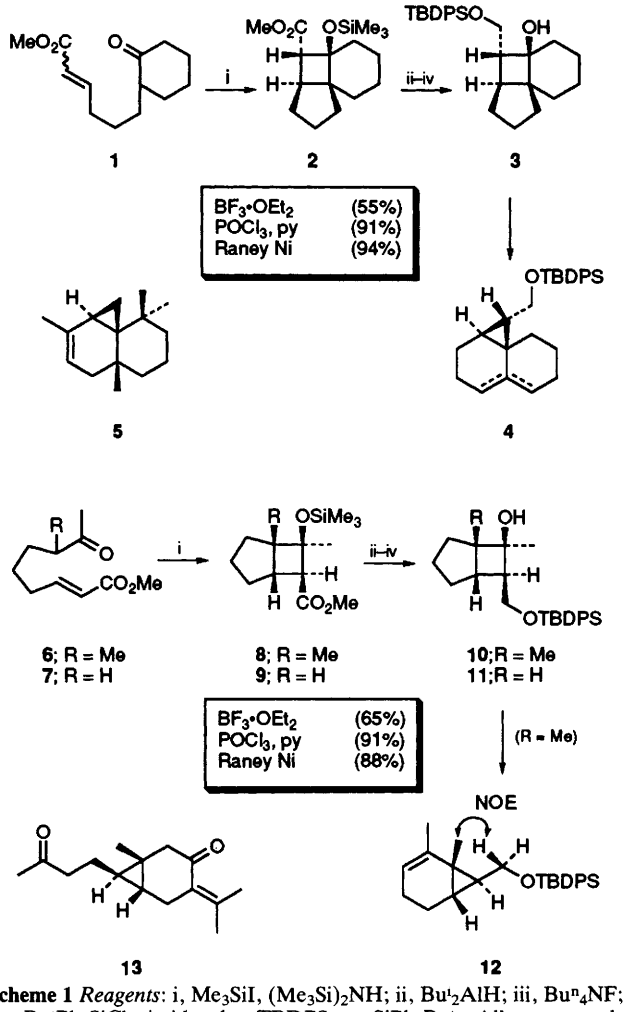
Treatment of hydroxylated cyclobutane derivatives with $BF_3{\cdot}OEt_2$, $POCl_3$ in the presence of pyridine or Raney nickel causes a novel rearrangement forming tricyclo[5.4.0.0^{1,3}]undecane and bicyclo[4.1.0]heptane systems.

The chemistry of small ring compounds is replete with various types of rearrangements.[1] The relief of ring strain is a driving force in assisting ring openings and ring expansions. Therefore, there are very few examples of contractions of cyclobutanes to cyclopropanes; only the pinacol type rearrangement[2] and ring contraction *via* carbenes[3] are known. We disclose here a new type of this rearrangement of cyclobutanes leading to cyclopropanes, which would provide a useful route to a number of three-membered compounds.

The tricyclic compound **2**,[4] prepared by the tandem intramolecular Michael–aldol reaction of the keto ester **1**, was converted, in three steps, into the alcohol **3**,† whose rearrangement was examined under various conditions (Scheme 1). The desired transformation was performed under three

† All new compounds gave spectral data (IR, NMR and MS) in accord with the assigned structure and satisfactory combustion analysis or accurate mass measurement.

different conditions, treatment with $BF_3{\cdot}OEt_2$ in tetrahydrofuran at room temperature (55% yield), treatment with $POCl_3$ in the presence of pyridine (Py) at room temperature (91% yield) and heating with an excess of Raney nickel (W-2) in refluxing toluene (94% yield). All reactions produced a separable 1:1 mixture of two tricyclo[5.4.0.0^{1,3}]undecane derivatives **4**,‡ which have the framework of thujopsene **5**.[5]



Scheme 1 *Reagents*: i, Me_3SiI, $(Me_3Si)_2NH$; ii, Bu^i_2AlH; iii, Bu^n_4NF; iv, Bu^tPh_2SiCl, imidazole. TBDPS = $SiPh_2Bu^t$. All compounds except natural products **5** and **13** racemic.

‡ Spectral data of **4** (two isomers): NMR: δ_H (500 MHz, $CDCl_3$) 7.71–7.36 (10 H, m), 5.40 (1 H, br s), 3.76 (1 H, dd, *J* 6.1, 11.0 Hz), 3.67 (1 H, dd, *J* 7.9, 11.0 Hz), 1.04 (9 H, s) and 0.71–0.69 (1 H, m); MS: *m/z* 416 (M^+) and NMR: δ_H (500 MHz, $CDCl_3$) 7.71–7.36 (10 H, m), 5.17 (1 H, br s), 3.80 (1 H, dd, *J* 5.5, 11.0 Hz), 3.54 (1 H, dd, *J* 8.5, 11.0 Hz), 1.05 (9 H, s) and 0.15 (1 H, m), 0.63–0.58 (1 H, m); MS: *m/z* 416 (M^+).

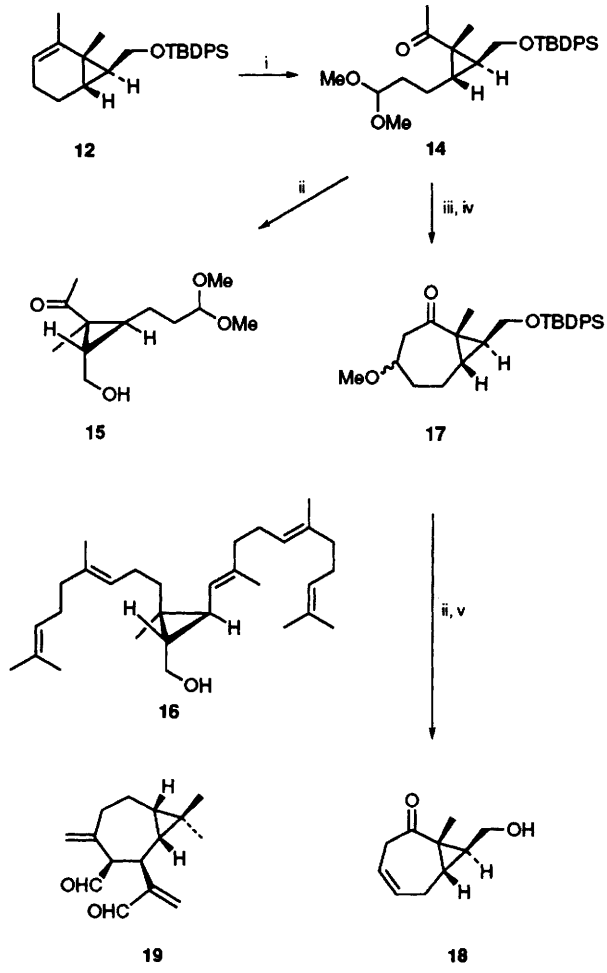
For **12**: NMR: δ_H (500 MHz, $CDCl_3$) 7.69–7.36 (10 H, m), 5.18 (1 H, br s), 3.82 (1 H, dd, *J* 6.1, 11.0 Hz), 3.54 (1 H, dd, *J* 8.6, 11.0 Hz), 1.81 (3 H, s), 1.14 (3 H, s), 1.05 (9 H, s) and 0.80–0.76 (1 H, m); δ_C (125 MHz, $CDCl_3$) 139.9, 135.73, 135.70, 134.3, 130.0, 127.6, 117.8, 64.3, 31.4, 27.2, 26.9, 21.8, 21.3, 19.4, 19.3 and 17.1; MS: *m/z* 390 (M^+).

For **15**: IR: ν_{max}/cm^{-1} (neat) 3400 (OH) and 1680 (C=O); NMR: δ_H (500 MHz, $CDCl_3$) 4.35 (1 H, t, *J* 5.5 Hz), 3.71 (1 H, dd, *J* 6.7, 11.6 Hz), 3.60 (1 H, dd, *J* 8.0, 11.6 Hz), 3.299 (3 H, s), 3.297 (3 H, s), 3.06 (1 H, m), 2.27 (3 H, s), 1.95 (1 H, dd, *J* 7.0, 14.6 Hz), 1.78–1.24 (3 H, m), 1.43 (3 H, s) and 1.02–0.68 (2 H, m); MS: *m/z* 199 (M^+-OMe).

For **18**: ν_{max}/cm^{-1} (neat) 3400 (OH) and 1665 (C=O); NMR: δ_H (500 MHz, $CDCl_3$) 5.68–5.61 (1 H, m), 5.56–5.49 (1 H, m), 3.89 (1 H, dd, *J* 6.1, 11.6 Hz), 3.62 (1 H, dd, *J* 8.6, 11.6 Hz), 3.23 (1 H, br d, *J* 17.1 Hz), 3.10 (1 H, dd, *J* 5.5, 17.1 Hz), 2.72 (1 H, br d, *J* 17.7 Hz), 2.50 (dt, *J* 17.7, 6.1 Hz), 2.27–2.21 (1 H, m), 1.63 (1 H, br s), 1.32 (3 H, s) and 1.28–1.23 (1 H, m); δ_C (125 MHz, $CDCl_3$) 207.0, 127.1, 122.7, 62.4, 44.3, 37.1, 31.9, 31.5, 26.4 and 15.4; MS: *m/z* 166 (M^+).

The bicyclic compounds **8** and **9**,[4] synthesised from **6** and **7**, were similarly transformed into alcohols **10** and **11**, respectively. The single stereoisomer of the bicyclo[4.1.0]heptane derivate **12**‡ was produced by reactions of **10** carried out under three different conditions. The best result (91% yield) was obtained by the reaction using $POCl_3$ in the presence of pyridine. The stereostructure **12** was determined by the observation of nuclear Overhauser effect (NOE) between the methyl group at the C(1) position and the methylene group at the C(2) position; the fact indicates that the stereochemistry at the C(2) and the C(3) positions was retained during rearrangement. None of the rearranged product was produced from **11** possessing hydrogen atom instead of methyl group at the angular position. This result suggests that the rearrangement proceeds through a carbonium ion or a radical intermediate.

The structural modification of the bicyclic product **12**, possessing the same ring skeleton as curcumenone **13**,[6] was next examined. The double bond of **12** was cleaved by ozonolysis to afford the ketone **14** in 83% yield. Removal of its silyl group provided quantitatively the alcohol **15**,‡ which has a similar structure to that of presqualene alcohol **16**.[7] Silyl enol ether formation from **14**, followed by reaction with trimethylsilyl trifluoromethanesulfonate,[8] provided a 1:1.4 epimeric mixture of the bicyclic compounds **17** in 72% yield. Treatment of **17** with an excess of $LiN(SiMe)_2$ gave the β,γ-unsaturated ketone **18**‡ in 83% yield. Many terpenes, for example



Scheme 2 *Reagents*: i, O_3, MeOH then Me_2S; ii, Bu^n_4NF; iii, $LiN(SiMe_3)_2$ then Me_3SiCl, iv, $Me_3SiOSO_2CF_3$; v, $LiN(SiMe_3)_2$. All compounds except natural products **16** and **19** racemic.

hanegokedial **19**,[9] having the bicyclo[5.1.0]octane skeleton have been isolated from nature.

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