Simple synthesis of allobetulin, 28-oxyallobetulin and related biomarkers from betulin and betulinic acid catalysed by solid acids

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Allobetulin (**3a**) and allobetulin acetate (**3b**) were efficiently prepared in excellent yield from betulin (**2a**) and betulin 3-acetate (**2b**) catalysed by a number of solid acids in refluxing dichloromethane. Sulfuric acid on silica, montmorillonite clays (both K10 and KSF), kaolinite, bleaching clay and toluene-*p*-sulfonic acid on silica are efficient catalysts for these conversions. Similarly, 28-oxyallobetulin (**3c**) and 28-oxyallobetulin acetate (**3d**) were obtained in good and excellent yield from betulinic acid (**2c**) and betulinic acid acetate (**2d**) respectively catalysed by montmorillonite K10. Two allobetulin related biomarkers, 19β,28-epoxy-A-*neo*-18α-olean-3(5)-ene (**4a**) and A-*neo*-18α-olean-3(5)-en-28→19β-olide (**4b**) were synthesised either from **3a** and **3c** or directly from **2a** and **2c** in refluxing benzene or cyclohexane catalysed by montmorillonite K10. Two other biomarkers, 19β,28-epoxy-18α-olean-2-ene (**10a**) and 18α-olean-2-en-28→19β-olide (**10b**) were also synthesised based on the above transformations. The direct formation of allobetulane related biomarkers from natural betulin **2a** and betulinic acid **2c** catalysed by clay mineral (montmorillonite) is of great geochemical interest.

Introduction

Birch is widespread in the northern latitudes of the world. Betulin **2a** constitutes about 12–30% of the birch bark.[1] Betulin **2a** itself currently has few applications. However, allobetulin **3a** has been used as an important intermediate in the further transformation of triterpenoids[2–6] and as a sample for biological studies.[7] For example, **3a** was further transformed into a highly active antifeedant for *Heliothis zea* larvae.[2] Some allobetulane related biomarkers such as 24-norallobetulanes,[8] 19β,28-epoxy-A-*neo*-18α-olean-3(5)-ene (**4a**), A-*neo*-18α-olean-3(5)-en-28→19β-olide (**4b**), 19β,28-epoxy-18α-olean-2-ene (**10a**) and 18α-olean-2-en-28→19β-olide (**10b**) have been identified in brown coal[9,10] and in petroleum.[11] Consequently, from the view points of synthesis, and biological and geochemical studies, the conversion of **2a** and betulinic acid **2c** to **3a** and 28-oxyallobetulin **3c** and the synthesis of allobetulane related biomarkers (**4a**, **b**; **10a**, **b**) from natural **2a** and **2c** are of great significance.

The transformation of **2a** to **3a** was reported as early as in 1922 by Schulze and Pieroh[12] in which **2a** was isomerised by formic acid, involving the formation and hydrolysis of allobetulin formate, to give **3a** in moderate yield.[2] In addition, a number of acidic reagents such as hydrobromic acid in chloroform,[13] sulfuric acid in acetic acid,[14] and concentrated hydrochloric acid in ethanol[15,16] were employed as catalysts for the betulin–allobetulin rearrangement. These methods have minor advantages over Schulze's procedure as there is no need to prepare the formate intermediate. Recently Linkowska[17] reported a modified preparation of **3a** from **2a** catalysed by dimethyl sulfate, a highly toxic reagent. The transformation of **2c** to **3c** was reported by Pakrashi *et al.*,[18,19] in which **2c** was isomerised by formic acid or hydrobromic acid–acetic acid or acetic acid–sulfuric acid, inevitably involving the formation and hydrolysis of 28-oxyallobetulin formate or acetate. Since then no facile and significant modified method for the transformations of **2** to **3** has been obtained.

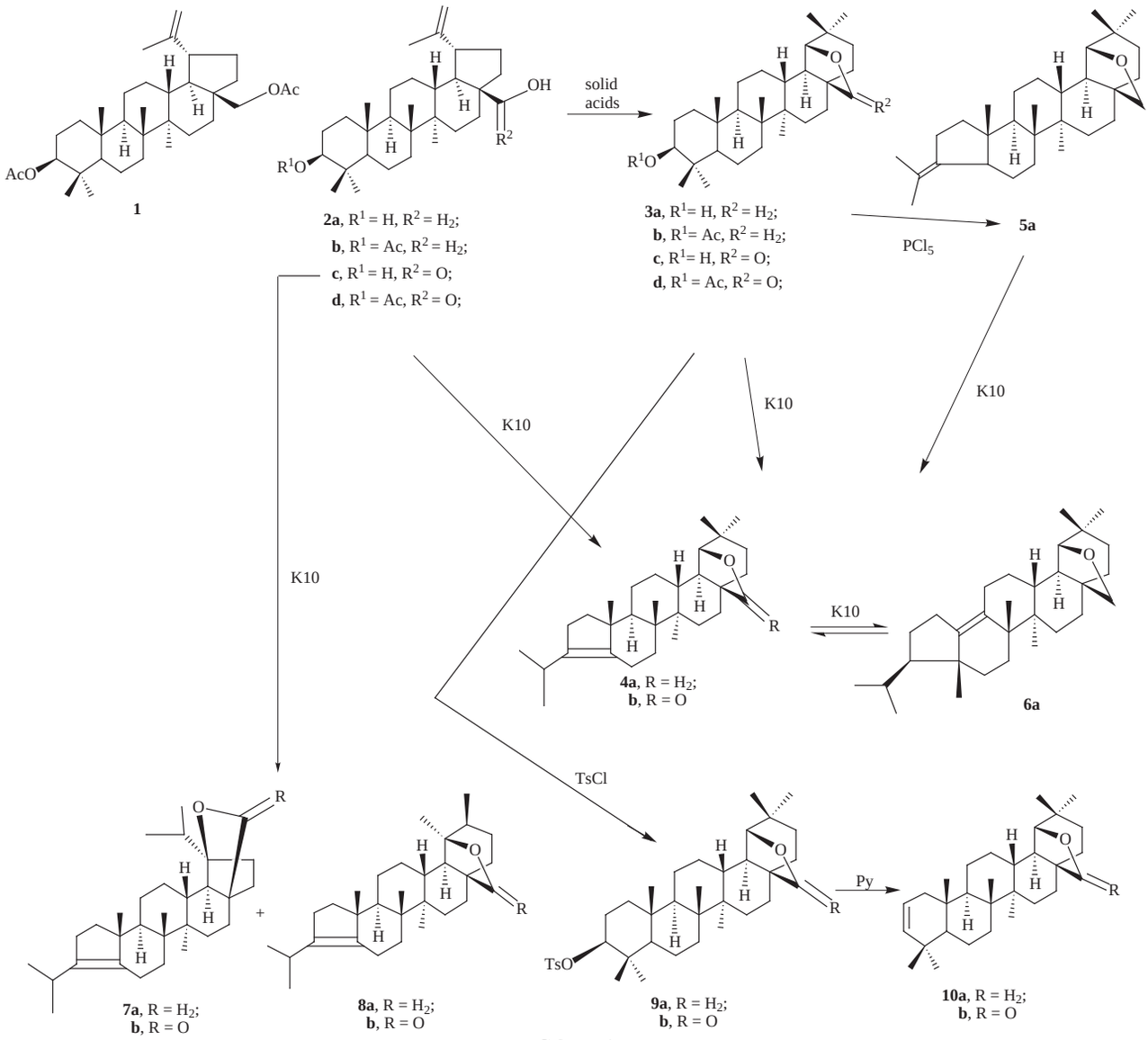
Recently, solid acids have been efficiently used for catalysis of a variety of organic reactions.[20] In connection with our research on the applications of solid acids in organic synthesis[21] and synthesis of biomarkers,[22] we are currently interested in synthesis of natural products in the presence of clay minerals. The naturally occurring clay minerals such as montmorillonite and kaolinite might play an important role in the diagenesis of natural products. We report here a simple, rapid and high yielding conversion of betulin derivatives **2a**–**d** to allobetulin derivatives **3a**–**d** and the synthesis of allobetulane related biomarkers (**4a**, **b**; **10a**, **b**) by employing a number of solid acids as catalysts with particular attention to montmorillonite K10 as a catalyst.

Results and discussion

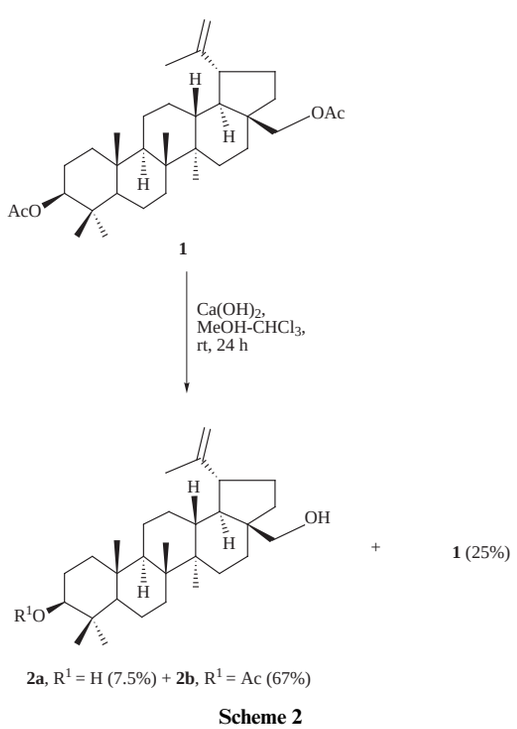
The structures of compounds and general transformations in this paper are summarised in Scheme 1.

Finely cut birch bark was extracted with hot ethanol to give crude betulin **2a**. This was acetylated with acetic anhydride in the presence of pyridine to provide crude betulin diacetate **1**. TLC showed that it was contaminated with small amounts of other components. The crude betulin diacetate was separated by SiO_2 column chromatography to give pure betulin diacetate **1** and small amounts of betulinic acid acetate **2d**. Hydrolysis of **1** in refluxing ethanol in the presence of excess KOH afforded betulin **2a** quantitatively. However, when **1** was stirred in a mixture of methanol–chloroform (1 : 1, v/v) with 5 equivalents of $Ca(OH)_2$ at room temp. for 24 h, a mixture of betulin 3-acetate **2b** and betulin **2a** was obtained in 89% and 10% net yield respectively with recovered **1** (25%) (Scheme 2). The present selective hydrolysis of betulin diacetate **1** is superior to the reported method by Xu *et al.*[23] in which **1** was stirred at room temp. for 3 days and 14 equivalents of $Mg(OMe)_2$ was used to furnish **2b** and **2a** in 81% and 14% yield respectively. Hydrolysis of **2d** with ethanol–KOH at refluxing temperature gave betulinic acid **2c** in 89% yield.

Having obtained the materials, we next need to carry out the betulin–allobetulin rearrangements. As shown in Scheme 3 and Table 1, for the conversion of **2a** and **2b** to **3a** and **3b**, a number of solid acids such as sulfuric acid on silica,[24] montmorillonite clays (K10 and KSF), kaolinite, bleaching clay, TsOH on silica,[25] expansive graphite,[26] anhydrous ferrous sulfate, silica and alumina were employed as catalysts. The reactions were carried out in refluxing dichloromethane and could be completed within 5 h (Table 1, entries 1–6 and 9–16). TLC showed the reactions were very clean and only one product (**3a** or **3b**) spot was observed. After removal of the catalysts by filtration



Scheme 1



Scheme 2

and evaporation of the solvent, the product **3a** or **3b** could be obtained in 93–99% isolated yield except for **2a** with expansive graphite as a catalyst (entry 11). The reason for the lower yield of this run may be due to the adsorption of some product (**3a**) on the catalyst since the TLC showed no formation of other products. The results in Table 1 show that sulfuric acid on silica, montmorillonite clays (both K10 and KSF), expansive graphite, kaolinite, bleaching clay and TsOH on silica are efficient catalysts for the conversions of **2a**, **b** to **3a**, **b**, while others such as anhydrous ferrous sulfate, silica and alumina are not. For comparison, TsOH was also used for this reaction and gave the same result (entry 17) as with TsOH on silica for the conversions of **2a** to **3a**, whereas the conversion of **2b** to **3b**, with TsOH as catalyst, needed longer reaction time (4.0 h, entry 18) than with TsOH on silica (1.2 h).

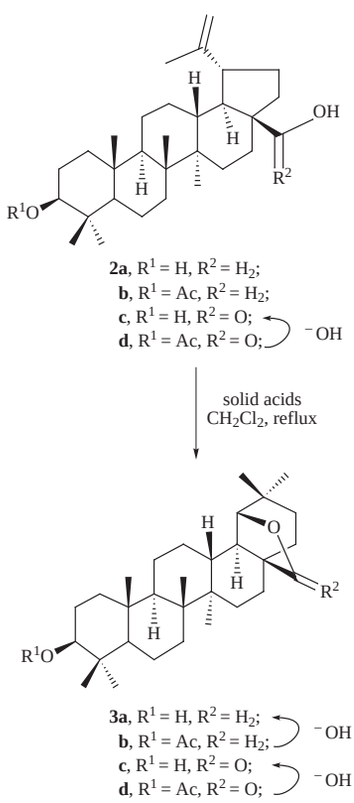
The conversion of **2a** to **3a** could be carried out on a large scale (5.13 g of **2a**) in the presence of K10 with an isolated yield of 93%. All these results indicated that solid acids were more efficient for these conversions than those traditional protic acids.

The montmorillonite K10 catalysed conversion of **2c** to **3c** was not so efficient as that of **2a** to **3a**. Treatment of **2c** with K10 in chloroform at 55 °C for 3 h provided **3c** and A-*neo*-18α-olean-3(5)-en-28→19β-olide **4b** in 57 and 22% isolated yield respectively (Scheme 4). However, betulinic acid acetate **2d** was easily transformed to 28-oxyallobetulin acetate **3d** in 94% net yield in

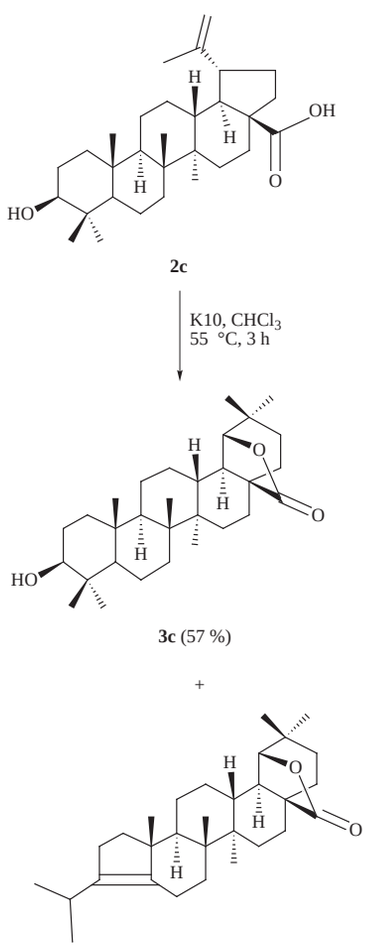
Table 1 Preparation of allobetulin derivatives catalysed by solid acids

Entry	Substrate[a]	Catalyst[a]	Time/h	Product (yield, %)
1	**2a**	H_2SO_4 on silica	0.5	**3a** (95)
2	**2b**	H_2SO_4 on silica	0.7	**3b** (99)
3	**2a**	Mont. KSF	5.0	**3a** (99)
4	**2b**	Mont. KSF	4.0	**3b** (99)
5	**2a**	Mont. K10	0.6	**3a** (96)
6	**2b**	Mont. K10	0.5	**3b** (99)
7	**2c**	Mont. K10	3.0	**3c** (57) + **4b** (22)
8	**2d**	Mont. K10	6.0	**3d** (94)[c]
9	**2a**	Bleaching clays[b]	1.0	**3a** (98)
10	**2b**	Bleaching clays[b]	3.5	**3b** (99)
11	**2a**	Expansive graphite	2.7	**3a** (62)
12	**2b**	Expansive graphite	2.0	**3b** (99)
13	**2a**	Kaolinite[b]	3.5	**3a** (99)
14	**2b**	Kaolinite[b]	5.0	**3b** (99)
15	**2a**	TsOH on silica	5.0	**3a** (93)
16	**2b**	TsOH on silica	1.2	**3b** (98)
17	**2a**	TsOH	5.0	**3a** (93)
18	**2b**	TsOH	4.0	**3b** (99)
19	**2a**	Anhydrous $FeSO_4$	12.0	**3a** (trace)[d]
20	**2b**	Anhydrous $FeSO_4$	10.0	**3b** (trace)[d]
21	**2a**	Silica gel[b]	6.0	no reaction[d]
22	**2a**	Alumina[b]	6.0	no reaction[d]

[a] The amount of substrate and solid acid are 100 mg and 50 mg respectively. [b] Activated at 130 °C for 3.0 h prior to use. [c] Net yield, conversion of **2d** 93%. [d] More than 95% substrate was recovered.



Scheme 3

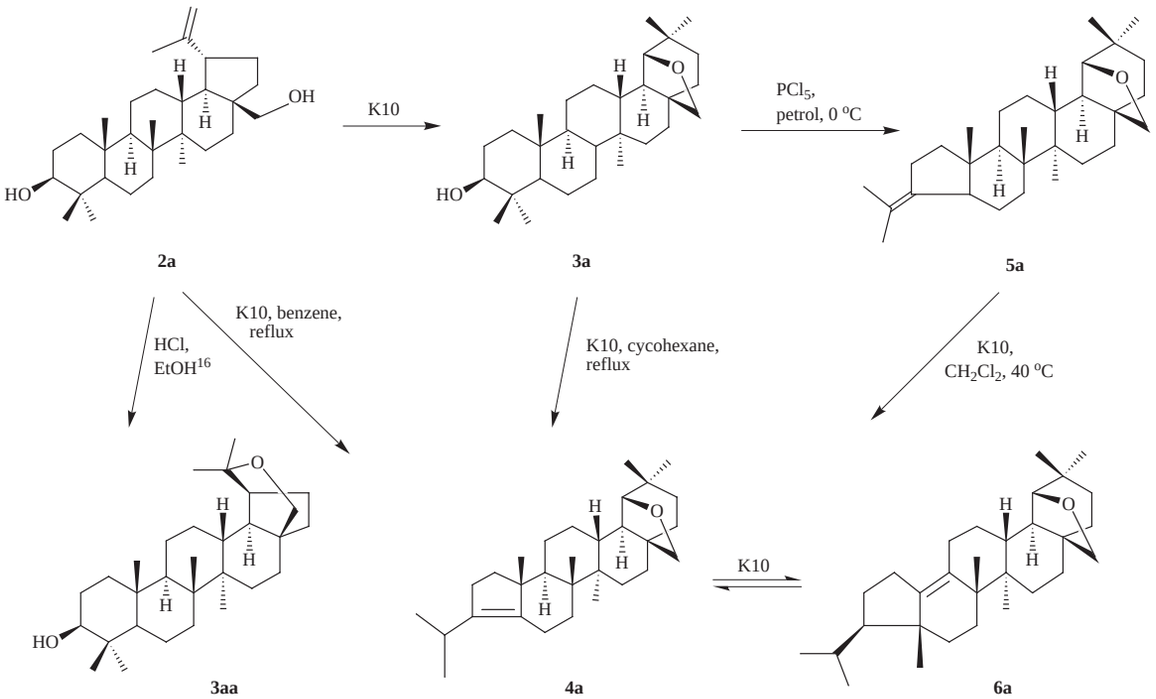


Scheme 4

dichloromethane at 30 °C for 6 h. There was no detectable formation of C-3-deacetic acid and rearranged product **4b**. Compounds **3b** and **3d** were easily hydrolysed in methanol by potassium hydroxide to give **3a** and **3c** respectively in yields of more than 90%.

Errington *et al.*[16] reported that betulin **2a** could be rearranged to 20,28-epoxy-19α(H)-lupan-3β-ol (**3aa**) (Scheme 5) by hydrochloric acid in ethanol in 20% yield along with allobetulin **3a** as the major product. However, in the present transformations with solid acid catalysts there was no detectable formation of 20,28-epoxy-19α(H)-lupane derivatives.

Under mild conditions,[27] treatment of **3a** with PCl_5 in petroleum ether at 0 °C provided 19β,28-epoxy-A-*neo*-18α-olean-3-ene (δ-allobetulin) **5a** in 68% yield. As shown in Scheme 5, 19β,28-epoxy-A-*neo*-18α-olean-3(5)-ene **4a** was obtained by three different procedures. (*a*) δ-Allobetulin **5a** was treated with K10 in dichloromethane at 40 °C and then chromatographed on a $AgNO_3$–SiO_2[28] column to give **4a** and 19β,28-epoxy-A-



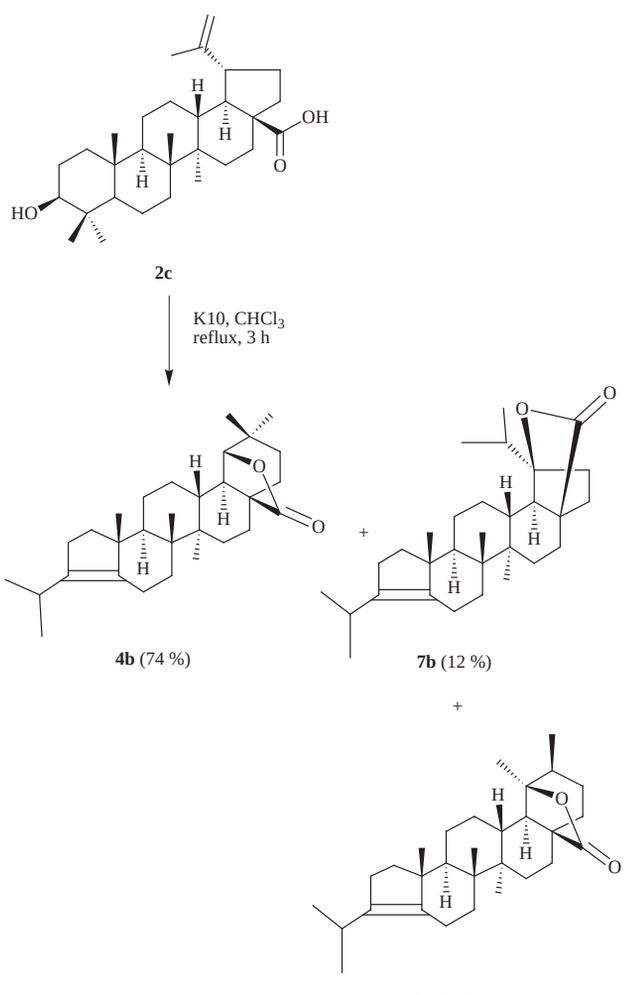
Scheme 5

neo-5β-methyl-25-nor-18α-olean-9-ene **6a** in 61 and 28% yields respectively. (*b*) In the presence of K10, **2a** was heated in benzene at 55–60 °C for 1 h. Compound **3a** was initially formed as indicated by TLC. The mixture was then continuously refluxed for 1 h and the products were separated on a $AgNO_3$–SiO_2 column to give **4a** and **6a** in 40 and 38% yields respectively. (*c*) Allobetulin **3a** was directly heated in refluxing cyclohexane catalysed by K10; **3a**, **4a** and **6a** could be initially observed on TLC. As the reaction proceeded, **3a** was completely converted to **4a** and **6a**. After workup they were obtained in 65 and 9.9% yield respectively. Olefins **4a** and **6a** reached an equilibrium under the above conditions. The ratio of **4a** to **6a** varied with the solvent and temperature. For example, in the presence of K10, a high temperature favoured the formation of **6a** in benzene. The ratio of **6a**:**4a** increased in benzene at reflux and decreased at room temp.

In the presence of K10, betulinic acid **2c** was heated in chloroform at refluxing temperature for 3 h to give a mixture of A-*neo*-18α-olean-3(5)-en-28→19β-olide **4b**, A-*neo*-lup-3(5)-en-28→19β-olide **7b** and A-*neo*-18α-taraxast-3(5)-en-28→19β-olide **8b** (Scheme 6). After separation of the mixture on a $AgNO_3$–SiO_2 column eluting with petroleum ether–dichloromethane, **4b**, **7b** and **8b** were obtained in 74, 12 and 6.4% yields respectively. The ^{1}H NMR spectrum of **7b** showed two doublets at 0.941 (J = 7.0 Hz) and 1.072 (J = 7.0 Hz) ppm assigned to 29- and/or 30-Me, while that of **8b** showed a doublet at δ 0.994 (J = 7.0 Hz) and a singlet at δ 1.322(s) assigned to 30- and 29-Me respectively. The mass spectra of **4a**, **4b**, **7b** and **8b** showed their molecular ions in moderate intensity (13–30%) and fragments resulting from loss of an isopropyl from the molecules ($M^+ - C_3H_7$) as base peak. The lactones **7b** and **8b** were two novel compounds. Cyclic ethers with this skeleton such as **7a** and **8a** (Scheme 1) were not observed from betulin–allobetulin rearrangement catalysed by K10 (Scheme 5). Plausible mechanisms for the formation of **7b** and **8b** are shown in Scheme 7.

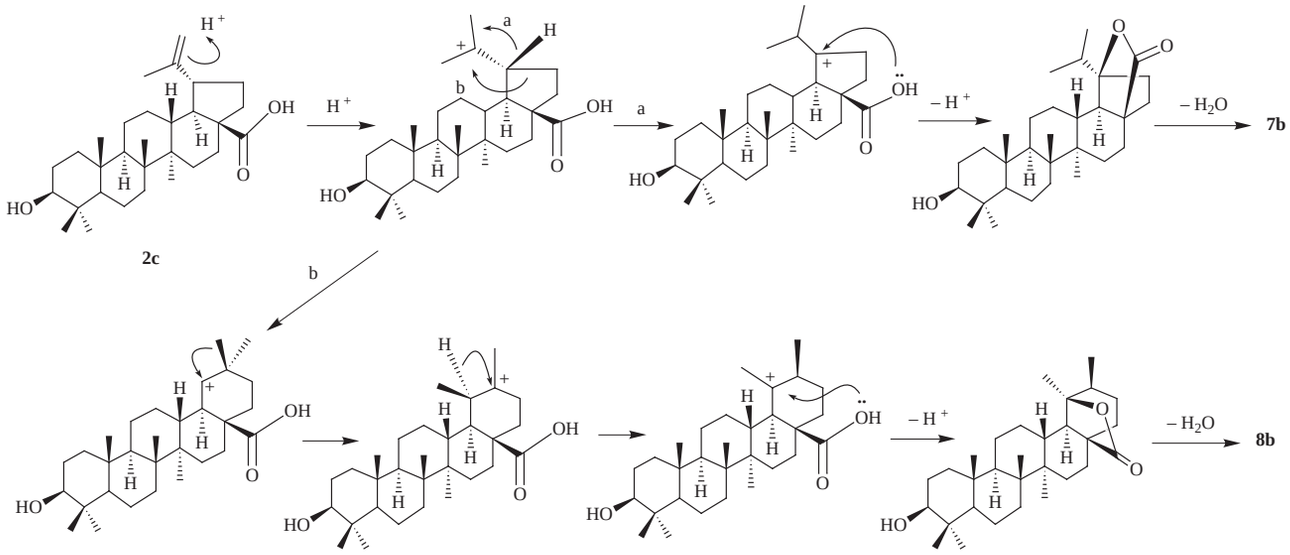
As shown in Scheme 8, allobetulin **3a** was tosylated in dry pyridine with TsCl to provide allobetulin tosylate **9a** in 72% isolated yield. The tosylate **9a** was heated in dry pyridine at reflux to provide crude 19β,28-epoxy-18α-olean-2-ene **10a**. The crude product was further purified on a $AgNO_3$–SiO_2 column to afford pure **10a** in 65% yield.

According to the reported method,[10] 28-oxyallobetulin **3c**

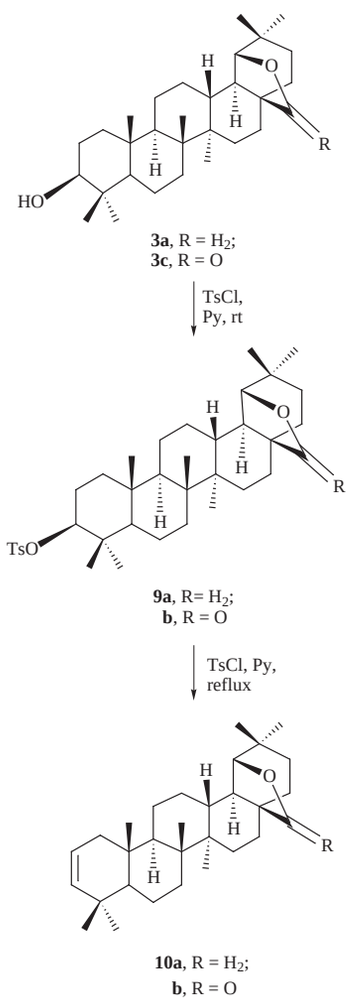


Scheme 6

was tosylated in dry pyridine with TsCl at room temperature and then the mixture was heated at reflux for 8 h. The crude product was separated by $AgNO_3$–SiO_2 column chrom-



Scheme 7



Scheme 8

atography to afford 18α-olean-2-en-28→19β-olide **10b** in 53% yield.

19β,28-Epoxy-A-*neo*-18α-olean-3(5)-ene **4a**, A-*neo*-18α-olean-3(5)-en-28→19β-olide **4b**, 19β,28-epoxy-18α-olean-2-ene **10a** and 18α-olean-2-en-28→19β-olide **10b** were biomarkers identified in geological samples.[9–11] The formation of Δ^2-triterpenes may be microbially mediated[29] and this series of compounds were regarded as precursors of the saturated counterparts[29] or aromatised species.[30] However, the fate of A-ring contracted triterpenes such as **4a** and **4b** during the course of geological evolution remains unknown.[29] The easy formation of allobetulane derivatives (**3a**–**d**) from natural betulin and betulinic acid in the presence of clay minerals such as montmorillonites and kaolinite and the direct formation of **4a** and **4b** catalysed by montmorillonite K10 should be helpful for clarification of the diagenesis of these natural products. Montmorillonite and kaolinite clays are an important class of clay minerals because of their widespread occurrence in various geological samples.[31] Although the commercially available montmorillonites and kaolinite deviate both in structure and acidity from naturally occurring clay minerals, the rather long time periods of the diagenesis of natural products involved may help to equalise the effect of the reduced catalytic activity and lamellar structure of natural clay minerals. Albrecht *et al*. reported the simulation of the geochemical transformations of cholestanol in the presence of montmorillonite or kaolinite.[32] Thus, we deduce that **4a** and **4b** in brown coal are presumably formed from natural betulin and betulinic acid catalysed by clay minerals. The simulation studies of betulin and betulinic acid in the presence of montmorillonite and/or kaolinite are being actively pursued in our laboratory.

Conclusions

A number of solid acids such as sulfuric acid on silica, montmorillonite clays (both K10 and KSF), kaolinite, bleaching clay and TsOH on silica are efficient catalysts for the conversion of betulin **2a**, betulin 3-acetate **2b**, betulinic acid **2c** and betulinic acid acetate **2d** to allobetulin **3a**, allobetulin acetate **3b**, 28-oxyallobetulin **3c** and 28-oxyallobetulin acetate **3d** respectively. The present method has the additional advantages of mild conditions, high yield, easy separation and inexpensive and environmentally friendly catalysts. Two allobetulin related biomarkers, 19β,28-epoxy-A-*neo*-18α-olean-3(5)-ene **4a** and A-*neo*-18α-olean-3(5)-en-28→19β-olide **4b** can also be directly obtained from betulin **2a** and betulinic acid **2c** catalysed by montmorillonite K10. These results have great significance for clarification of the geological fate of natural betulin and betulinic acid. Since 19β,28-epoxy-A-*neo*-5β-methyl-25-nor-18α-olean-9-ene **6a** and A-*neo*-lup-3(5)-en-28→19β-olide **7b** and A-*neo*-18α-taraxast-3(5)-en-28→19β-olide **8b** were also directly obtained from betulin and betulinic acid catalysed by montmorillonite, we venture to predict that **6a**, **7b** and **8b** should also be early intermediates in the diagenesis of betulin and betulinic acid. We are eagerly awaiting any report of the identification of these compounds from geological sources.

Experimental

Materials and methods

The catalysts sulfuric acid adsorbed on silica (3%), TsOH adsorbed on silica (7%) and expansive graphite were prepared according to the literature.[24–26] Montmorillonite K10 and KSF were purchased from Aldrich. Other catalysts and reagents were obtained from commercial suppliers without further purification. Melting points were uncorrected. Elemental analyses were performed on a Heraeus CHN-O Rapid instrument. IR Spectra were recorded on a PE-983G or on a Bio-Rad FTS-40 spectrometer as liquid films. ^{1}H and ^{13}C NMR spectra were measured on Varian-INOVA-500, Bruker AM-400, or Bruker AC-80 spectrometers by using TMS as internal standard and $CDCl_3$ as solvent unless otherwise stated. *J* Values are given in Hz. Mass spectra were determined on a VG-7070E spectrometer (EI, 70 eV).

Isolation of betulin diacetate 1 and betulinic acid acetate 2d

Finely cut birch bark (775 g) was extracted with ethanol on a Soxhlet apparatus for 15 h. The extract was evaporated to dryness under reduced pressure to give 240 g of crude betulin (**2a**). To the crude betulin (198.3 g) was added acetic anhydride (186 cm^3) and pyridine (2 cm^3). The mixture was heated at refluxing temperature for 2 h. The solution was concentrated to a quarter of its original volume and then diluted with hot ethanol (200 cm^3). The solution was kept at room temp. overnight. The precipitate was collected by filtration and washed with ethanol to provide 151.5 g of crude betulin diacetate **1**. The crude betulin diacetate (151.5 g) was separated by column chromatography on SiO_2 (1.2 kg, 200–300 mesh) eluted with a mixture of petroleum ether (bp 60–90 °C)–diethyl ether (from 40 : 1 to 10 : 1, v/v) to give 121.5 g of pure betulin diacetate **1** and 2.43 g of betulinic acid acetate **2d** successively. Betulin diacetate **1**, mp 224–226 °C, lit.,[12] 223–224 °C, lit.,[27] 220–222 °C. Betulinic acid acetate **2d**, mp 288–290 °C (colourless needles from dichloromethane–methanol) (lit.,[33] 288–290 °C, lit.,[34] >300 °C); ν_{max}/cm^{-1} 3600–2600, 3075, 1730, 1688, 1635; δ_H (400 MHz) 0.829 (3H, s, 24-CH_3), 0.845 (3H, s, 23-CH_3), 0.849 (3H, s, 27-CH_3), 0.930 (3H, s, 25-CH_3), 0.973 (3H, s, 26-CH_3), 1.696 (3H, s, 30-CH_3), 2.049 (3H, s, Ac), 3.013 (1H, dt, *J* 4.6 and 10.6, 19-H), 4.475 (1H, dd, *J* 5.8, 10.2, 3α-H), 4.614 (1H, s, 29-H_a), 4.745 (1H, s, 29-H_b); *m*/*z* 498 (M^+, 4%), 452 (6), 438 (40), 423 (17), 395 (19), 248 (30), 189 (100).

Betulin 2a

A mixture of betulin diacetate (**1**, 10.06 g, 19.13 mmol) and potassium hydroxide (11.45 g, 204.5 mmol) in ethanol (180 cm^3) was heated at refluxing temperature under stirring for 2 h. Then the solution was cooled to room temp. and colourless needles appeared. The crystals were collected by filtration and washed with water until the filtrate was neutral. The mother liquor was concentrated and a second crop was obtained. In total 8.14 g (96%) of betulin **2a** was furnished; mp 255–256 °C (95% ethanol, colourless needles) (lit.,[2] 255–256 °C; lit.,[19] 254–255 °C).

Betulin 3-acetate 2b

A mixture of betulin diacetate (**1**, 3.08 g, 5.86 mmol) and calcium hydroxide (2.17 g, 29.3 mmol) in methanol–chloroform (40 cm^3, 1 : 1, v/v) was stirred at room temp. for 24 h. After removal of the insoluble solid by filtration and evaporation of the solvent, the crude products were separated by column chromatography on silica eluting with a mixture of petroleum ether–diethyl ether to give betulin diacetate (**1**, 0.76 g, recovery 25%), betulin 3-acetate (**2b**, 1.90 g, 89% net yield) and betulin (**2a**, 0.195 g, 10% net yield) successively. Compound **2b** mp 259–261 °C (colourless needles from acetone–dichloromethane) (lit.,[23] 256–258 °C, lit.[33] 258–259 °C).

Betulinic acid 2c

A mixture of betulinic acid acetate (**2d**, 0.22 g, 0.44 mmol) and potassium hydroxide (2.65 g) in methanol (15 cm^3) was heated at refluxing under stirring for 3 h. After completion, the solvent was evaporated under reduced pressure to dryness. The residue was diluted with water (30 cm^3) and extracted with chloroform (3 × 30 cm^3). The combined organic layer was dried by Na_2SO_4 and evaporated under vacuum to give betulinic acid **2c** (0.18 g, 89%), mp 300–302 °C (colourless needles from methanol) (lit.,[19] 305–306 °C, lit.,[33] 291–292 °C).

Conversion of lupane derivatives 2 to oleanane derivatives 3 catalysed by solid acids. A typical procedure for the conversion of betulin 2a to allobetulin 3a

A mixture of betulin (**2a**, 100.0 mg, 0.226 mmol) and solid acid (40 mg) in dichloromethane (5 cm^3) was heated at refluxing temperature under stirring for the time as indicated in Table 1. After completion of the reaction, the catalyst was removed by filtration and the solvent was evaporated under reduced pressure to give allobetulin **3a**, mp 266–268 °C (colourless platelets from 95% methanol–dichloromethane) (lit.,[2] 265–266 °C); ν_{max}/cm^{-1} 3430, 1040; δ_H (80 MHz) 0.77 (3H, s, 24-CH_3), 0.80 (3H, s, 29-CH_3), 0.85 (3H, s, 23-CH_3), 0.92 (3H, s, 27-CH_3), 0.93 (3H, s, 30-CH_3), 0.98 (6H, s, 25 and 26-CH_3), 3.40 (1H, m, 3α-H), 3.43 (1H, d, *J* 7.7, 28-H_a), 3.53 (1H, s, 19-H), 3.78 (1H, d, *J* 7.7, 28-H_b).

Allobetulin acetate 3b. Mp 285–287 °C (colourless platelets from methanol–dichloromethane) (lit.,[35] 287–287.5 °C); ν_{max}/cm^{-1} 1722, 1030; δ_H (80 MHz) 0.80 (3H, s, 29-CH_3), 0.85 (6H, s, 23 and 24-CH_3), 0.87 (3H, s, 25-CH_3), 0.93 (6H, s, 27 and 30-CH_3), 0.98 (3H, s, 26-CH_3), 2.04 (3H, s, Ac), 3.43 (1H, d, *J* 7.7, 28-H_a), 3.53 (1H, s, 19-H), 3.78 (1H, d, *J* 7.7, 28-H_b), 4.50 (1H, m, 3α-H).

3β-Hydroxy-18α-olean-28→19β-olide (3c)

(1) A mixture of betulinic acid (**2c**, 46.4 mg, 0.102 mmol) and K10 (46 mg) in chloroform (15 cm^3) was heated at 55 °C under stirring for 3 h. After completion of the reaction, the catalyst was removed by filtration and the solvent was evaporated under reduced pressure. The residue was separated by column chromatography on 10% $AgNO_3$–SiO_2 and eluted with petroleum ether–dichloromethane (1 : 1, v/v) to give A-*neo*-18α-olean-3(5)-en-28→19β-olide **4b** (10.0 mg, 22%) and 3β-hydroxy-18α-olean-28→19β-olide **3c** (26.4 mg, 57%) successively. **3c**, mp 338–340 °C (colourless needles from petroleum ether–chloroform) (lit.,[19] >330 °C); ν_{max}/cm^{-1} 3495, 1758, 1044; δ_H (500 MHz) 0.680 (1H, dd, *J* 2.0, 11.5, 5α-H), 0.752 (3H, s, 24-CH_3), 0.830 (3H, s, 24-CH_3), 0.863 (3H, s, 30-CH_3), 0.902 (3H, s, 29-CH_3), 0.947 (3H, s, 25-CH_3), 0.960 (3H, s, 27-CH_3), 1.018 (3H, s, 26-CH_3), 1.695 (1H, t, *J* 3.5), 1.721 (1H, t, *J* 3.5), 1.792 (1H, d, *J* 11.5, 18α-H), 1.839 (1H, t, *J* 3.2), 1.865 (1H, t, *J* 3.2), 3.192 (1H, dd, *J* 5.0, 11.5, 3α-H), 3.932 (1H, s, 19-H); δ_C (125 MHz, number of carbon atoms) 13.65 (q, 27), 15.34 (q, 24), 15.50 (q, 26), 16.53 (q, 25), 18.13 (t, 6), 20.86 (t, 12), 23.94 (q, 29), 25.52 (t, 22), 26.50 (t, 11), 27.33 (d, 2), 27.88 (t, 15), 27.93 (q, 23), 28.74 (q, 30), 31.92 (t, 16), 32.29 (t, 21), 33.53 (s, 17), 33.69 (t, 7), 35.99 (d, 13), 37.23 (s, 10), 38.86 (s, 4), 38.92 (t, 1), 39.90 (s, 14), 40.53 (s, 8), 46.09 (s, 20), 46.69 (d, 18), 51.21 (d, 9), 55.47 (d, 5), 78.90 (d, 3), 86.00 (d, 19), 179.90 (s, 28); *m*/*z* 456 (M^+, 3%), 438 (100), 423 (32), 395 (65), 206 (40), 189 (80). **4b**, mp 291–293 °C (colourless needles from petroleum ether–dichloromethane) (lit.,[10] 292–294 °C); ν_{max}/cm^{-1} 1756, 1630, 1062; δ_H (500 MHz) 0.817 (3H, s, 27-CH_3), 0.844 (3H, s, 25-CH_3), 0.907 (3H, d, *J* 6.5, 24-CH_3), 0.949 (3H, s, 29-CH_3), 0.960 (3H, s, 30-CH_3), 0.966 (3H, d, *J* 6.5, 23-CH_3), 1.023 (3H, s, 26-CH_3), 1.822 (1H, d, *J* 11.5, 18α-H), 2.096 (1H, dd, *J* 9.0, 15.0), 2.238 (1H, dt, *J* 3.5, 15.0), 2.628 (1H, septet, *J* 6.5, 4-H), 3.953 (1H, s, 19-H); δ_C (125 MHz) 13.54 (q, 27), 14.06 (q, 26), 19.11 (q, 25),

19.63 (t, 6), 21.30 (q, 23), 21.83 (q, 24), 23.52 (t, 11), 23.97 (q, 29), 25.54 (t, 22), 26.30 (d, 4), 26.54 (t, 12), 27.34 (t, 2), 28.20 (t, 15), 28.74 (q, 30), 31.92 (t, 16), 32.32 (t, 21), 32.32 (t, 7), 33.55 (s, 17), 36.44 (d, 13), 39.70 (s, 14), 40.72 (s, 8), 42.25 (t, 1), 46.17 (s, 20), 46.70 (d, 18), 49.79 (s, 10), 50.23 (d, 9), 86.01 (d, 19), 136.42 (s, 3), 139.62 (s, 5), 179.95 (s, 28); *m*/*z* 438 (M^+, 13%), 423 (15), 395 (100), 189 (7).

(2) Hydrolysis of 28-oxyallobetulin acetate (**3d**, 111.6 mg, 0.2241 mmol) in EtOH–$CHCl_3$ (15 cm^3, 3:1, v/v) in the presence of KOH (31.3 mg, 0.559 mmol) at refluxing temperature for 6 h gave **3c** (101.0 g, yield 99%).

28-Oxyallobetulin acetate (3d)

A mixture of betulinic acid acetate (**2d**, 148.4 mg, 0.298 mmol) and K10 (130 mg) in dichloromethane (20 cm^3) was heated at 30 °C under stirring for 6 h. The catalyst was removed by filtration and the solvent was evaporated under reduced pressure. The crude products were further separated by column chromatography on SiO_2 and eluted with petroleum ether–dichloromethane (30:1, v/v) to give **3d** (128.7 mg, net yield 94%) and **2d** (10.9 mg, recovery 7%) successively. **3d**, mp >330 °C (colourless needles from petroleum ether–dichloromethane) (lit.,[19] >300 °C); ν_{max}/cm^{-1} 1759, 1726, 1080, 1020; δ_H (500 MHz) 0.778 (1H, dd, *J* 2.0, 11.3, 5α-H), 0.820 (3H, s, 24-CH_3), 0.832 (3H, s, 23-CH_3), 0.849 (3H, s, 30-CH_3), 0.854 (3H, s, 27-CH_3), 0.895 (3H, s, 29-CH_3), 0.941 (3H, s, 25-CH_3), 1.012 (3H, s, 26-CH_3), 1.700 (1H, td, *J* 3.5, 13.0), 1.792 (1H, d, *J* 11.5, 18α-H), 1.844 (1H, td, *J* 3.0, 13.0), 2.035 (3H, s, Ac), 3.926 (1H, s, 19-H), 4.458 (1H, dd, *J* 5.5, 11.0, 3α-H); δ_C (125 MHz) 13.60 (q, 27), 15.48 (q, 24), 16.43 (q, 26), 16.58 (q, 25), 17.99 (t, 6), 20.85 (t, 12), 21.31 (q, Ac-CH_3), 23.60 (d, 2), 23.91 (q, 29), 25.49 (t, 22), 26.45 (t, 11), 27.85 (t, 15), 27.85 (q, 23), 28.71 (q, 30), 31.89 (t, 21), 32.27 (t, 16), 33.50 (s, 17), 33.61 (t, 7), 35.96 (d, 13), 37.12 (s, 10), 37.75 (s, 4), 38.57 (t, 1), 39.87 (s, 14), 40.52 (s, 8), 46.06 (s, 20), 46.65 (d, 18), 51.12 (d, 9), 55.54 (d, 5), 80.79 (d, 3), 85.97 (d, 19), 171.03 (s, Ac–C=O), 179.87 (s, 28); *m*/*z* 498 (M^+, 2%), 438 (100), 423 (30), 189 (70).

Large scale synthesis of 3a

A mixture of betulin (**2a**, 5.13 g, 11.6 mmol) and montmorillonite K10 (2.0 g) in dichloromethane (180 cm^3) was heated at reflux under stirring for 7 h. After completion of the reaction, the catalyst was removed by filtration and the solvent was evaporated under reduced pressure to give allobetulin **3a** (4.75 g, 93%).

Synthesis of 3a and 3b catalysed by TsOH

A mixture of betulin **2a** or betulin 3-acetate **2b** (0.120 mmol) and TsOH (15.3 mg, 0.089 mmol) in dichloromethane (4 cm^3) was heated at reflux under stirring for 5 or 4 h. After completion of the reaction, the solvent was evaporated under reduced pressure to give crude allobetulin **3a** or allobetulin acetate **3b**. The TsOH was removed by a short SiO_2 column to provide pure **3a** (93%) or **3b** (99%).

19β,28-Epoxy-A-*neo*-18α-olean-3-ene (δ-allobetulin 5a)

A solution of allobetulin (**2a**, 800.0 mg, 1.81 mmol) in petroleum ether (100 cm^3) was cooled to 0 °C in a water–ice bath and then PCl_5 (1.60 g, 17.7 mmol) was added. The solution was continuously stirred for 30 min and then at room temp. for 45 min until **2a** was completely consumed as indicated by TLC. The solution was washed to neutral with water (20 cm^3), aqueous sodium hydroxide (5%, 20 cm^3) and brine (20 cm^3) successively. The organic layer was dried by $MgSO_4$ and evaporated to dryness *in vacuo*. The crude product was further purified by column chromatography on 10% $AgNO_3$–SiO_2 and eluted with petroleum ether–diethyl ether (150:1, v/v) to give **5a** (519.0 mg, yield 68%), mp 209–212 °C (colourless platelets from acetone–dichloromethane) (lit.,[27] 216–218 °C); ν_{max}/cm^{-1} 1035, 1011; δ_H (400 MHz) 0.612 (3H, s, 25-CH_3), 0.800 (3H, s, 29-CH_3), 0.931 (3H, s, 30-CH_3), 0.971 (3H, s, 26-CH_3), 1.579 (3H, s, 23-CH_3), 1.729 (3H, s, 24-CH_3), 3.446 (1H, d, *J* 7.8, 28-H_a), 3.541 (1H, s, 19-H), 3.788 (1H, d, *J* 7.8, 28-H_b); δ_C (100 MHz) 13.40 (q, 27), 15.05 (q, 26), 15.60 (q, 25), 19.36 (q, 23), 22.73 (q, 24), 23.21 (t, 6), 23.46 (t, 12), 24.53 (q, 29), 26.29 (t, 22), 26.37 (t, 11), 26.65 (t, 15), 28.26 (t, 2), 28.81 (q, 30), 32.71 (t, 21), 33.57 (t, 7), 34.22 (d, 13), 36.27 (s, 17), 36.79 (t, 16), 39.40 (t, 1), 40.36 (s, 8), 40.61 (s, 14), 41.48 (s, 20), 44.42 (s, 10), 46.69 (d, 18), 48.88 (d, 9), 56.30 (d, 5), 71.27 (t, 28), 87.96 (d, 19), 120.50 (s, 3), 135.38 (s, 4); *m*/*z* 424 (M^+, 45%), 409 (19), 381 (100), 355 (64), 189 (30), 161 (40), 135 (65), 121 (65).

19β,28-Epoxy-A-*neo*-18α-olean-3(5)-ene (α-allobetulin 4a) and 19β,28-epoxy-A-*neo*-5β-methyl-25-nor-18α-olean-9-ene (migrated α-allobetulin 6a)

(1) A mixture of **5a** (115.5 mg, 0.272 mmol) and K10 (222 mg) in dichloromethane (4 cm^3) was heated at 40 °C under stirring until the substrate **5a** had disappeared as indicated by 10% $AgNO_3$–SiO_2 TLC (5 h). The catalyst was removed by filtration and the solvent was evaporated under reduced pressure. The crude products were separated on a 10% $AgNO_3$–SiO_2 column and eluted with petroleum ether–dichloromethane (150:1 to 100:1, v/v) to give **6a** (32.2 mg, 28%) and **4a** (70.2 mg, 61%) successively. **4a**, mp 208–211 °C (colourless needles from methanol–chloroform) (lit.,[27] 210–211 °C); ν_{max}/cm^{-1} 1640, 1035, 1008; δ_H (400 MHz) 0.802 (3H, s, 29-CH_3), 0.863 (3H, s, 25-CH_3), 0.874 (3H, s, 27-CH_3), 0.921 (3H, d, *J* 6.8, 24-CH_3), 0.936 (3H, s, 30-CH_3), 0.981 (3H, d, *J* 6.8, 23-CH_3), 1.040 (3H, s, 26-CH_3), 2.645 (1H, septet, *J* 6.7, 4-H), 3.451 (1H, d, *J* 7.8, 28-H_a), 3.504 (1H, s, 19-H), 3.802 (1H, d, *J* 7.8, 28-H_b); δ_C (100 MHz) 13.43 (q, 27), 14.28 (q, 26), 19.15 (q, 25), 19.76 (t, 6), 21.33 (q, 23), 21.87 (q, 24), 23.89 (t, 12), 24.58 (q, 29), 26.28 (t, 22), 26.34 (d, 4), 26.52 (t, 11), 26.75 (t, 15), 27.41 (t, 2), 28.83 (q, 30), 32.55 (t, 7), 32.74 (t, 21), 34.65 (d, 13), 36.31 (s, 17), 36.78 (t, 16), 40.55 (s, 8), 40.83 (s, 14), 41.52 (s, 20), 42.22 (t, 1), 46.65 (d, 18), 49.89 (s, 10), 50.13 (d, 9), 71.32 (t, 28), 88.01 (d, 19), 136.22 (s, 3), 139.96 (s, 5); *m*/*z* 424 (M^+, 15%), 409 (15), 381 (100), 189 (11), 175 (15), 161 (40), 135 (36), 121 (38). **6a**, mp 148–150 °C (colourless needles from acetone–dichloromethane) (lit.,[35] 147–150 °C); ν_{max}/cm^{-1} 1625, 1034, 1010; δ_H (400 MHz) 0.792 (3H, s, 25-CH_3), 0.796 (3H, s, 26-CH_3), 0.815 (3H, s, 29-CH_3), 0.907 (3H, d, *J* 6.6, 24-CH_3), 0.945 (3H, s, 30-CH_3), 0.952 (3H, d, *J* 6.6, 23-CH_3), 1.084 (3H, s, 27-CH_3), 3.468 (1H, d, *J* 7.7, 28-H_a), 3.567 (1H, s, 19-H), 3.823 (1H, d, *J* 7.7, 28-H_b); δ_C (100 MHz) 15.49 (q, 27), 17.99 (q, 26), 22.90 (q, 23), 23.08 (q, 24), 24.58 (q, 29), 25.69 (q, 25), 26.03 (t, 6), 26.12 (t, 22), 26.46 (t, 11 or 15), 26.48 (t, 15 or 11), 27.13 (t, 7), 27.55 (t, 2), 28.83 (q, 30), 29.34 (t, 12), 29.83 (d, 3), 32.74 (t, 21), 35.68 (d, 13), 36.33 (s, 17), 36.68 (t, 16), 37.33 (t, 1), 40.26 (s, 8), 41.10 (s, 20), 41.72 (s, 5), 42.80 (s, 14), 46.82 (d, 18), 59.17 (d, 4), 71.32 (t, 28), 87.99 (d, 19), 131.25 (s, 10), 141.90 (s, 9); *m*/*z* 424 (M^+, 100%), 409 (19), 381 (40), 202 (38), 188 (60).

(2) A mixture of **2a** (108.1 mg, 0.245 mmol) and K10 (220 mg) in benzene (12 cm^3) was heated at 55–60 °C for 1 h and then at refluxing temperature under stirring for another 1 h. The same workup as described above was applied to provide **4a** (41.3 mg, 40%) and **6a** (39.3 mg, 38%).

(3) A mixture of **3a** (86.6 mg, 0.196 mmol) and K10 (90 mg) in cyclohexane (5 cm^3) was heated at refluxing temperature for 2.5 h. The same workup as described above was applied to give **4a** (53.7 mg, 65%) and **6a** (8.2 mg, 9.9%).

A-*neo*-18α-Olean-3(5)-en-28→19β-olide (28-oxyallobetulin 4b), A-*neo*-lup-3(5)-en-28→19β-olide 7b and A-*neo*-18α-taraxast-3(5)-en-28→19β-olide 8b

A mixture of betulinic acid (**2c**, 53.6 mg, 0.118 mmol) and K10

(40 mg) in chloroform (5 cm^3) was heated under stirring at refluxing temperature for 3 h. After completion, the catalyst was removed by filtration and the solvent was evaporated under reduced pressure to give the crude products. The crude products were separated on a 10% $AgNO_3$–SiO_2 column with petroleum ether–dichloromethane (30:1, v/v) as eluent to give **4b** (37.9 mg, yield 74%), **7b** (6.0 mg, yield 12%) and **8b** (3.3 mg, yield 6.4%) successively. **7b**, mp 245–247 °C (colourless needles from diethyl ether–dichloromethane) (Found: C, 82.0; H, 10.4; $C_{30}H_{46}O_2$ requires: C, 82.1; H, 10.6%); ν_{max}/cm^{-1} 1759, 1639; δ_H (500 MHz) 0.836 (3H, s, 27-CH_3), 0.842 (3H, s, 25-CH_3), 0.911 (3H, d, *J* 7.0, 24-CH_3), 0.941 (3H, d, *J* 7.0, 29-CH_3), 0.967 (3H, d, *J* 7.0, 23-CH_3), 1.004 (3H, s, 26-CH_3), 1.072 (3H, d, *J* 7.0, 30-CH_3), 2.098 (1H, dd, *J* 9.0, 15.0), 2.254 (1H, td, *J* 3.5, 14.0), 2.317 (1H, septet, *J* 7.0, 20-H), 2.630 (1H, septet, *J* 7.0, 4-H); δ_C (125 MHz) 13.73 (q, 27), 14.17 (q, 26), 17.64 (q, 30), 18.23 (q, 29), 19.01 (q, 25), 19.71 (t, 6), 21.30 (q, 23), 21.85 (q, 24), 22.69 (t, 22), 23.47 (t, 11), 26.28 (d, 4), 26.95 (t, 12), 27.38 (t, 2), 28.21 (t, 15), 28.37 (t, 21), 29.21 (d, 20), 29.69 (t, 16), 32.81 (t, 7), 35.12 (d, 13), 41.01 (s, 14), 41.23 (s, 8), 42.07 (t, 1), 49.69 (d, 9), 49.73 (s, 10), 53.41 (s, 17), 54.24 (d, 18), 95.93 (s, 19), 136.30 (s, 3), 139.57 (s, 5), 179.85 (s, 28); *m*/*z* 438 (M^+, 15%), 423 (17), 395 (100), 351 (9), 189 (12), 175 (16), 161 (28), 135 (45), 121 (71). **8b**, mp 224–226 °C (petroleum ether–chloroform, colourless needles) (Found: C, 81.95; H, 10.4; $C_{30}H_{46}O_2$ requires: C, 82.1; H, 10.6%); ν_{max}/cm^{-1} 1744, 1639; δ_H (500 MHz) 0.844 (3H, s, 25-CH_3), 0.871 (3H, s, 27-CH_3), 0.916 (3H, d, *J* 6.8, 24-CH_3), 0.973 (3H, d, *J* 6.8, 23-CH_3), 0.994 (3H, d, *J* 7.0, 30-CH_3), 1.001 (3H, s, 26-CH_3), 1.322 (3H, s, 29-CH_3), 2.036 (1H, dt, *J* 5.0, 13.0), 2.104 (1H, dd, *J* 9.5, 15.5), 2.253 (1H, td, *J* 3.5, 14.5), 2.639 (1H, septet, *J* 6.8, 4-H); δ_C (125 MHz) 14.15 (q, 27), 14.24 (q, 26), 18.77 (q, 30), 19.03 (q, 25), 19.68 (t, 6), 21.31 (q, 23), 21.88 (q, 24), 23.67 (t, 11), 24.01 (q, 29), 25.27 (t, 22), 26.31 (d, 12), 27.06 (t, 4), 27.41 (t, 2), 27.60 (t, 15), 29.70 (t, 21), 32.28 (t, 16), 32.56 (t, 7), 40.77 (s, 17), 40.88 (s, 14), 42.03 (t, 1), 42.03 (d, 20), 42.12 (s, 8), 43.34 (d, 13), 48.33 (d, 18), 49.65 (d, 9), 49.76 (s, 10), 84.15 (s, 19), 136.18 (s, 3), 139.82 (s, 5), 177.24 (s, 28); *m*/*z* 438 (M^+, 30%), 423 (16), 395 (100), 301 (6), 259 (6), 189 (6), 175 (11), 161 (15), 135 (30), 121 (36).

19β,28-Epoxy-18α-olean-3β-yl tosylate (allobetulin-3-yl tosylate 9a)

A mixture of **3a** (121.4 mg, 0.275 mmol) and TsCl (300 mg, 1.57 mmol) in pyridine (0.5 cm^3) was stirred at room temp. for 5 h. After completion, the solution was diluted with water (15 cm^3) and concentrated hydrochloric acid (10 cm^3). The mixture was extracted with dichloromethane (3 × 20 cm^3) and the extracts were dried over $MgSO_4$. The solvent was evaporated under reduced pressure to dryness. The crude product was further purified on an SiO_2 column with petroleum ether–dichloromethane (30:1, v/v) as eluent to give **9a** (118.4 mg, 72%), mp 171–172 °C (petroleum ether–dichloromethane, colourless needles) (lit.,[35] 164.5–165 °C); ν_{max}/cm^{-1} 3060, 1592, 1096, 1034, 1002; δ_H (80 MHz) 0.80 (9H, s), 0.83 (3H, s), 0.90 (3H, s), 0.93 (3H, s), 0.95 (3H, s), 2.44 (3H, s, Ar-CH_3), 3.43 (1H, d, *J* 7.7, 28-H_a), 3.51 (1H, s, 19-H), 3.77 (1H, d, *J* 7.7, 28-H_b), 4.25 (1H, m, 3α-H), 7.32 (2H, d, *J* 8.3, 2′,6′-H_2), 7.79 (2H, d, *J* 8.3, 3′,5′-H_2).

19β,28-Epoxy-18α-olean-2-ene 10a

A mixture of **9a** (103.0 mg, 0.173 mmol) and TsCl (300 mg, 1.57 mmol) in dry pyridine (3 cm^3) was heated at refluxing temperature for 6 h. After cooling, the solution was diluted with water (15 cm^3) and extracted with dichloromethane (3 × 15 cm^3), the combined organic layer was dried over Na_2SO_4. The solvent was evaporated under vacuum to dryness. The crude product was purified on a 10% $AgNO_3$–SiO_2 column with petroleum ether–dichloromethane (60:1, v/v) as eluent to give **10a** (47.5 mg, 65%), mp 245–247 °C (petroleum ether–dichloromethane, colourless needles) (lit.,[10] 250–250.5 °C, lit.,[35] 244.5–245 °C); ν_{max}/cm^{-1} 2993, 1033; δ_H (400 MHz) 0.799 (3H, s, 29-CH_3), 0.879 (6H, s, 23 and 25-CH_3), 0.922 (3H, s, 27-CH_3), 0.933 (3H, s, 30-CH_3), 0.948 (3H, s, 24-CH_3), 1.000 (3H, s, 26-CH_3), 1.982 (1H, dd, *J* 5.0, 16.5, 1α-H), 3.446 (1H, d, *J* 7.6, 28-H_a), 3.542 (1H, s, 19-H), 3.790 (1H, d, *J* 7.6, 28-H_b), 5.36–5.44 (2H, m, 2,3-H_2); δ_H (500 MHz, C_6D_6) 0.774 (3H, s), 0.836 (3H, s), 0.920 (3H, s), 0.937 (3H, s), 0.949 (3H, s), 1.015 (3H, s), 1.150 (3H, s), 1.935 (1H, dd, *J* 5.0, 16.5, 1α-H), 3.441 (1H, d, *J* 7.8, 28-H_a), 3.671 (1H, s, 19-H), 3.837 (1H, dd, *J* 1.5, 7.8, 28-H_b), 5.46–5.52 (2H, m, 2,3-H_2); δ_C (100 MHz) 13.50 (q, 27), 15.44 (q, 26), 16.75 (q, 25), 19.45 (t, 6), 21.37 (t, 12), 22.57 (q, 24), 24.57 (q, 29), 26.28 (t, 22), 26.44 (t, 11), 26.55 (t, 15), 28.83 (q, 30), 31.75 (q, 23), 32.75 (t, 21), 33.06 (t, 7), 34.28 (d, 13), 34.73 (s, 4), 36.30 (s, 17), 36.52 (s, 10), 36.79 (t, 16), 40.71 (s, 14), 41.53 (s, 8), 41.53 (t, 1), 46.64 (d, 18), 49.75 (d, 9), 52.37 (d, 5), 71.31 (t, 28), 87.75 (d, 19), 121.58 (d, 2), 138.04 (d, 3); *m*/*z* 424 (M^+, 69%), 409 (9), 393 (22), 353 (29), 189 (90), 177 (33), 134 (100).

18α-Olean-2-en-28→19β-olide 10b

A mixture of **3c** (75.8 mg, 0.166 mmol) and TsCl (270 mg, 1.42 mmol) in dry pyridine (5 cm^3) was stirred at room temp. for 2 days and then heated at refluxing temperature for 8 h. The same workup as described for **10a** was applied to give **10b** (38.9 mg, 53%), mp 356 °C (colourless needles from petroleum ether–dichloromethane) (lit.,[10] 363 °C); ν_{max}/cm^{-1} 3029, 1757, 1080; δ_H (300 MHz, C_6D_6) 0.890 (3H, s, 23-CH_3), 0.942 (6H, s, 25 and 29-CH_3), 0.950 (3H, s, 24-CH_3), 0.964 (3H, s, 27-CH_3), 1.026 (3H, s, 30-CH_3), 1.059 (3H, s, 26-CH_3), 1.809 (1H, d, *J* 11.5, 18α-H), 3.943 (1H, s, 19-H), 5.42–5.52 (2H, m, 2,3-H_2); δ_C (125 MHz, C_6D_6) 13.79 (q, 27), 15.36 (q, 26), 16.98 (q, 25), 19.56 (t, 6), 21.46 (t, 12), 22.72 (q, 24), 23.97 (q, 29), 25.79 (t, 22), 26.72 (t, 11), 28.08 (t, 15), 28.87 (q, 30), 31.88 (q, 23), 32.08 (t, 16), 32.55 (t, 21), 33.07 (t, 7), 33.71 (s, 17), 34.93 (s, 4), 36.35 (s, 10), 36.72 (d, 13), 40.10 (s, 14), 40.77 (t, 1), 41.75 (s, 8), 46.26 (s, 20), 46.83 (d, 18), 50.08 (d, 9), 52.58 (d, 5), 85.97 (d, 19), 121.70 (d, 2), 138.22 (d, 3), 179.82 (s, 28); *m*/*z* 438 (M^+, 51%), 423 (20), 356 (14), 234 (19), 203 (27), 189 (100), 175 (27), 147 (25), 135 (30), 121 (97), 107 (97).

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