Hydrogen isotope ratios of terrigenous n-alkanes in lacustrine surface sediment of the Tibetan Plateau record the precipitation signal

ZHONG-HUAN XIA,1,2 BAI-QING XU,1,3* I. MÜGLER,3 GUANG-JIAN WU,1 G. GLEIXNER,3 D. SACHSE3 and LI-PING ZHU3

1Institute of Tibetan Plateau Research, Chinese Academy of Sciences, Beijing 100085, China
2Graduate University of the Chinese Academy of Sciences, Beijing 100049, China
3Max-Planck-Institute for Biogeochemistry, Postfach 100164, D-07701 Jena, Germany

(Received September 29, 2007; Accepted March 19, 2008)

Hydrogen isotope ratios were measured on terrigenous alkanes (n-C21 to n-C33) extracted from recent lake surface sediments from the climatically and environmentally distinct basins Qiangyong Glacier Lake, Yamzho Lake, Nam Co Lake, Keluku Lake and Xiao Qaidam Lake along a S–N transect in the Tibetan Plateau to explore the climatic implication of these biomarkers. δD values of these n-alkanes are compared to that of precipitation spanning a wide range from −167‰ to −51‰ and clearly correlate with δD values of meteoric water, indicating that terrigenous alkanes record the precipitation signal. The fractionation between precipitation and n-C21, n-C22, n-C23, n-C24, n-C25, n-C26, n-C27, n-C28, n-C29, n-C30, n-C31 alkanes cover a range from −45‰ to −70‰ whilst that between precipitation and n-C29, n-C30, n-C31 alkane varies from −70‰ to −95‰, both being fairly constant along the S–N Tibetan transect with the mean at −57‰ and −82‰ respectively. By comparison with the fractionation of −130‰ along the S–N European transect, it implies that the hydrogen isotopic fractionation between meteoric water and terrestrial n-alkanes along the Tibetan transect represent distinct character.

Keywords: n-alkanes, lacustrine sediment, terrestrial origin, hydrogen isotope ratio, precipitation, climate

INTRODUCTION

With the development of compound-specific hydrogen isotope analysis using gas chromatography/thermal conversion/isotope ratio mass spectrometry (GC/TC/IRMS) in recent years (Burgoine and Hayes, 1998; Hilkert et al., 1999), compound-specific hydrogen isotope ratios of organic compounds are emerging as a new paleoclimatic and paleohydrological proxy (Andersen et al., 2001; Huang et al., 2004; Liu and Huang, 2005; Sachse et al., 2004; Sauter et al., 2001; Xie et al., 2000; Yang and Huang, 2003). Current knowledge suggests that the fractionation of H isotopes in biosynthesis is constant and mostly controlled by the biochemical pathway used (Sessions et al., 1999), therefore δD ratios of biomarkers have the potential to record changes in the isotopic composition of the H source. Aquatic and terrestrial n-alkanes from recent lake sediments along a S–N European climatic gradient record the meteoric water isotope composition in natural ecosystems (Sachse et al., 2004). The observed fractionation between source water and n-alkanes was constant at −157‰ for the aquatic substances, while that for the terrestrial n-alkanes was constant at −130‰, being somewhat enriched due to transpiration processes in the plant leaves.

The lake sediments in the Tibetan Plateau provide an excellent archive of past variation in climate and environments (Allen et al., 1999; Martinek et al., 2006; Yao and Zhu, 2006; Zheng and Li, 1999). In sediments from all geological time periods n-alkanes are among the most abundant lipids, since they are very stable compounds. Also, n-alkanes are relatively easy to extract and purify and all hydrogen atoms in n-alkanes are carbon-bound and therefore non-exchangeable at least at lower temperatures (Schimmelmann et al., 1999). Furthermore, molecular distribution of n-alkanes can differentiate the corresponding biological sources. High molecules (C25–C33) dominated at n-C27, n-C28 or n-C29 with a distinct odd-over-even carbon predominance (usually CPI > 5) are mainly from terrestrial plants (Glinton and Hamilton, 1967; Rieley et al., 1991). Middle-molecular-weight n-alkanes (C14–C23) dominated by C21, C22 or C23 with a slight odd-over-even predominance are mainly from submerged/ floating aquatic macrophytes (Ficken et al., 2000; Viso et al., 1993) whilst the short-chained n-alkanes (C14–C20) dominated by C16 (or C17, C18) are mainly from algae and bacteria, with no distinct odd-over-even predomi-
<table>
<thead>
<tr>
<th>Lake name</th>
<th>Geographic location</th>
<th>Altitude [m asl]</th>
<th>Water depth [m]</th>
<th>Lake area [km²]</th>
<th>Mean annual temperature [°C]</th>
<th>Mean annual precipitation [mm]</th>
<th>Mean annual evaporation amount [mm]</th>
<th>Mean annual relative humidity</th>
<th>Mean annual global solar radiation [MJ/m²]</th>
<th>Mean temperature in summer half year [°C]</th>
<th>Mean precipitation in summer half year [mm]</th>
<th>Mean evaporation amount in summer half year [mm]</th>
<th>Mean relative humidity in summer half year</th>
</tr>
</thead>
<tbody>
<tr>
<td>QY: Qiangyong Glacier Lake</td>
<td>28°53.906′N, 90°13.406′E</td>
<td>4855</td>
<td>17</td>
<td>0.1</td>
<td>3.80</td>
<td>379.0</td>
<td>1994.4</td>
<td>40%</td>
<td>7623 H</td>
<td>8.0 H</td>
<td>374.6 H</td>
<td>959.4 H</td>
<td>53% H</td>
</tr>
<tr>
<td>YZY: Yamzho Lake</td>
<td>29°31.867′N, 90°20.135′E</td>
<td>4445</td>
<td>15</td>
<td>0.4</td>
<td>3.88</td>
<td>379.0</td>
<td>1994.4</td>
<td>40%</td>
<td>7623 H</td>
<td>8.0 H</td>
<td>374.6 H</td>
<td>959.4 H</td>
<td>53% H</td>
</tr>
<tr>
<td>NC: Nam Co Lake</td>
<td>30°38.423′N, 90°36.134′E</td>
<td>4718</td>
<td>20</td>
<td>0.7</td>
<td>0.00</td>
<td>281.8</td>
<td>7528 E</td>
<td>53%</td>
<td>7528 M</td>
<td>6.2 M</td>
<td>281.5 H</td>
<td>945.3 M</td>
<td>64% M</td>
</tr>
<tr>
<td>KLK: Keluke Lake</td>
<td>37°16.600′N, 96°52.684′E</td>
<td>2812</td>
<td>7</td>
<td>57.960</td>
<td>196.1</td>
<td>2004 F</td>
<td>6967 F</td>
<td>39%</td>
<td>6967 F</td>
<td>12.6 F</td>
<td>182.1 G</td>
<td>1207 F</td>
<td>42% F</td>
</tr>
<tr>
<td>XQ: Xiao Qaidam Lake</td>
<td>37°28.110′N, 95°29.440′E</td>
<td>3163</td>
<td>2.5</td>
<td>40.6 I</td>
<td>96.3 F</td>
<td>2049 F</td>
<td>6967 F</td>
<td>32%</td>
<td>6967 F</td>
<td>11.6 F</td>
<td>90.5 K</td>
<td>1207 F</td>
<td>32% F</td>
</tr>
</tbody>
</table>

Longitude, latitude and altitude were determined on-site using a handheld GPS. Water depth of the sampling site was determined using an echosounder. Data refer to Zong et al., 2004; Data refer to Duan, 2005; Data are estimated using Google Earth ruler; Data refer to Shi, 1995; Data refer to You et al., 2007; Data refer to Hu and Cui, 2002; Data: Dali station, 1970–1980 (personal communication L. D. Tian, Institute of Tibetan Plateau Research, Chinese Academy of Sciences); Data: Delingha station, 2000–2003 (personal communication L. D. Tian, Institute of Tibetan Plateau Research, Chinese Academy of Sciences); Data: Nam Co station, 2003, 2005 and 2006, 8–10 (personal communication Q. L. You, Institute of Tibetan Plateau Research, Chinese Academy of Sciences); Data: Langkazi station, 1999 (personal communication L. D. Tian, Institute of Tibetan Plateau Research, Chinese Academy of Sciences); Data: Nam Co station, 2003, 2005 and 2006, 8–10 (personal communication S. Q. Zhou, Institute of Tibetan Plateau Research, Chinese Academy of Sciences); Data: Delingha station, 2000, 2000–2003 (personal communication L. D. Tian, Institute of Tibetan Plateau Research, Chinese Academy of Sciences); Data: Dachaidan station, 2005 (personal communication Q. L. You, Institute of Tibetan Plateau Research, Chinese Academy of Sciences); Data: Delingha station, 2003 (personal communication L. D. Tian, Institute of Tibetan Plateau Research, Chinese Academy of Sciences); Data: Delingha station, 2003 (personal communication L. D. Tian, Institute of Tibetan Plateau Research, Chinese Academy of Sciences); Data: Delingha station, 2003 (personal communication L. D. Tian, Institute of Tibetan Plateau Research, Chinese Academy of Sciences); Data: Delingha station, 2003 (personal communication L. D. Tian, Institute of Tibetan Plateau Research, Chinese Academy of Sciences); Data: Delingha station, 2003 (personal communication L. D. Tian, Institute of Tibetan Plateau Research, Chinese Academy of Sciences).
nance (Cranwell et al., 1987; Han and Calvin, 1969). Alkanes of \( n-C_{10} \), \( n-C_{25} \) and \( n-C_{31} \) can also be derived from sphagnum species (Baas et al., 2000). Up to now, the climatic implication for the hydrogen isotope ratios of \( n \)-alkanes in lacustrine sediment of the Tibetan Plateau is ambiguous and related research is scarce. In this article, we sampled surface sediments from climatically and environmentally distinct basins Qiangyong Glacier Lake, Yamzho Lake, Nam Co Lake, Keluke Lake and Xiao Qaidam Lake along a S–N transect in the Tibetan Plateau to explore the relationship between the \( \delta D \) of terrigenous biomarkers and that of precipitation.

**SAMPLES AND METHODS**

**Sampling site**

The sampled lakes are Qiangyong Glacier Lake (QY), Yamzho Lake (YZY), Nam Co Lake (NC), Keluke Lake (KLK) and Xiao Qaidam Lake (XQ) along a S–N transect and the precipitation sampling sites are Lhasa, NamCo, Delingha respectively (Fig. 1). Lake QY and YZY are located in the southern part of the Tibetan Plateau, the climate in this region is controlled by the Indian monsoon; NC is located in the middle part, its climate in this region is controlled by the upper westerly flow and Mongolia high. Among the five lakes, QY and KLK are fresh lakes, YZY is light-saline, NC is saline and XQ is a salt lake. Precipitation sampling site Lhasa is near QY and YZY, NamCo is the weather station near NC and Delingha is near KLK, XQ. The basic information about sediment sampling sites and precipitation sampling sites are shown in Tables 1 and 2 respectively and the mean weighted annual precipitation \( \delta D \) values are shown in Table 2.

**Sampling and experiment**

Surface sediments (top 1 cm) were sampled in August and September 2005 using a gravity corer (HTH-Teknik, Luleä, Sweden) operated from a dismountable raft.

The experiments involving \( n \)-alkanes identification, quantification and isotopic analysis were carried out in Max-Planck-Institute for Biogeochemistry, Jena, Germany. Sediment samples were ground and freeze-dried. Soluble organic matter were extracted by an accelerated solvent extractor (ASE200, Dionex Corp., Sunnyvale, USA). Aliphatic compounds were isolated by solid phase extraction on a silica-gel column using hexane. \( n \)-alkanes were identified and quantified from the aliphatic fraction by gas chromatography (GC) (Agilent6890, Agilent, Palo Alto, USA) with atomic emission detection (GC-AED) (Agilent6890, Agilent, Palo Alto, USA), by comparison to an external \( n \)-alkane standard mixture.

**Calculation of the isotopic fractionation \( \varepsilon \)**

The isotopic difference between the \( \delta D \) value of the meteoric water and the \( \delta D \) value of the \( n \)-alkanes was calculated using Eq. (1).
RESULTS AND DISCUSSION

n-alkane molecular distribution

The relative abundance of n-alkane homologues in the lacustrine surface sediments are shown in Fig. 2. A distinct odd-over-even carbon number predominance was found in all sediments and the carbon predominance indices between C25 and C31 (CPI_{25-31}) are greater than five, indicating terrestrial higher plants origin.

Woody plants have a kind of n-alkane distribution dominated by C27 compound and the grass represents the n-alkane distribution with C31 homologue as C_{max} (Cranwell, 1973; Cranwell et al., 1987; Meyers and Ishiwatari, 1993). Thus the ratio of C_{27}/C_{31} for n-alkanes can express the relative abundance between woody plants and grass (Cranwell, 1973; Fisher et al., 2003; Meyers and Ishiwatari, 1993). Ratios of C_{27}/C_{31} and the estimated relative abundance between wood plants and grass for each lake is shown in Table 3. C_{27}/C_{31} ratios for QY, YZY, NC and XQ are all below 1, implying that in these regions the herbaceous plants are more than woody plants, while the C_{27}/C_{31} ratio for KLK is over 1, suggesting that herbaceous plants are less than woody plants. These estimated results are consistent with the information on the dominant vegetation around sample sites (Table 1), because the dominant vegetation is steppe or desert steppe in the regions of QY, YZY, NC and XQ while the dominant vegetation is desert shrub and desert steppe in KLK (Table 1).

δD values of the terrigenous n-alkanes (n-C_{25} to n-C_{31})

The hydrogen isotope ratios of the terrigenous n-alkanes (n-C_{25}, n-C_{27}, n-C_{29}, n-C_{31}) have a strong linear relationship with precipitation values (Fig. 3), indicating that these alkanes record the precipitation signal. These four biomarkers show similar δD values in a given sample (Table 4), with δD values of n-C_{29} and n-C_{31} being a little depleted relative to that of n-C_{25} and n-C_{27}, indicating that some hydrogen isotope depletion mechanism might occur in the biosynthesis of n-C_{29} and n-C_{31} alkanes relative to n-C_{25} and n-C_{27}, but to our knowledge such mechanism has not been reported until now. The δD of n-alkanes from 34 modern terrestrial plants, including twenty-one C-3 plants and thirteen C-4 plants in northwestern China have been shown that the grasses have more negative δD values than the co-occurring trees and shrubs due to different water use strategies (Liu et al., 2006). For our sample sites, in spite of the dominant plant being grass or woody plant, n-C_{29} and n-C_{31} alkanes should originate relatively more from grass by comparison to n-C_{25} and n-C_{27} alkanes while n-C_{25} and n-C_{27} alkanes should originate relatively more from woody plants by comparison with n-C_{29} and n-C_{31} alkanes. Therefore another possible reason for the relatively lower isotope values of n-C_{29} and n-C_{31} is that compared with n-C_{25} and n-C_{27}, n-C_{29} and n-C_{31} were relatively more from grasses, leading to relatively more negative δD values.

Hydrogen isotope fractionation between precipitation and terrigenous n-alkanes

The hydrogen isotope fractionation between precipitation and n-C_{25}, n-C_{27}, n-C_{29}, n-C_{31} (ε_{n-C_{25}} \text{ to } ε_{n-C_{31}}) cover a range from −45‰ to −70‰ with a mean of −57‰ whilst that between precipitation and n-C_{29}, n-C_{31} (ε_{n-C_{29}} \text{ to } ε_{n-C_{31}}) varies from −70‰ to −95‰ with a mean of −82‰, both being fairly constant along the S–N Tibetan transect (Table 5).

| Table 3. C_{27}/C_{31} ratio and the estimated relative abundance between wood plants and grass |
|-----------------|-----------------|-----------------|-----------------|-----------------|
|                 | QY   | YZY  | NC   | KLK  | XQ   |
| C_{27}/C_{31}   | 0.46 | 0.62 | 0.49 | 1.34 | 0.4  |
| Woody plants/grass | 0.46 | 0.62 | 0.49 | 1.34 | 0.4  |
The biosynthetic isotope fractionation for \( n \)-alkanes is around \(-160\%\) (Sachse et al., 2004; Sessions et al., 1999). Besides the \( \delta D \) values of precipitation, some other factors such as relative humidity, plant class, plant taxonomy (woody plants or grasses), photosynthetic type (C3 or C4) can modify the hydrogen isotopic signal of plant leaf \( n \)-alkanes (Chikaraishi and Naraoka, 2003; Hou et al., 2007; Liu and Huang, 2005; Smith and Freeman, 2006). These factors modify the \( \delta D \) values of \( n \)-alkanes by modifying the \( \delta D \) values of the H source, which was used for \( n \)-alkanes biosynthesis, through evaporation from soil and evapotranspiration from leaf (Flanagan et al., 1991). Therefore the apparent isotope fractionation between precipitation and terrestrial biomarkers can be less than \(-160\%\) as the H source for biosynthesis becomes D-enriched by evaporation from soil and evapotranspiration from leaf.

Lake QY, YZY, NC, KLK and XQ are located in climatically distinct regions along the S–N transect of the Tibetan Plateau and the aridity extent is increasing from south to north. Due to arid climate, the relative humidity in KLK, XQ is lower than that in QY, YZY, especially in summer half year (Table 1), thus the transpiration from leaves and evaporation from soils in KLK, XQ should be stronger, leading to more D-enriched leaf water relative to local precipitation for \( n \)-alkanes biosynthesis than that in QY, YZY. However, the hydrogen isotope fractionation \( \varepsilon \) between precipitation and terrestrial plants is fairly constant along the transect. One possible reason is that most leaves fall into the lakes and get incorporated into the sedimentary record in late autumn when the modification of the isotope ratio of meteoric water through evaporation from leaves and soils do not differ significantly along the transect. Another possible reason is that the differences in plant class between regions contribute to the constant fractionation. Vegetations around the sampled lakes are approximately all C3 plants (Chen et al., 2003; Li et al., 2004; Li et al., 1999; Wang et al., 2005). The dominant vegetation for QY, YZY and NC is steppe, while that for KLK is desert shrub and desert steppe and that
for XQ is desert steppe (Table 1). The plants in KLK as well as in XQ might have been adapted to more arid conditions and have a higher water use efficiency and a lower transpiration rate than the plants in QY, YZY and NC. But this possible reason might not be clarified in this study and further investigation is required on the isotopic fractionation of the dominant vegetation along the Tibetan transect. In addition, there are very small quantities of reed swamp and reed meadow growing around the lakeside of KLK and very small quantities of reed meadow and leymus meadow growing around the lakeside of XQ (Editorial Board of Vegetation Map of China, C.A.S., 2001) due to some inflow water supply. These plants grow in a wet environment with relative high humidity and the

### Table 4. $\delta D$ values [%v] of n-alkanes, meteoric water, lake water and inflow water for each site

<table>
<thead>
<tr>
<th>Sample code</th>
<th>( n-C_{25} ) SD</th>
<th>( n-C_{26} ) SD</th>
<th>( n-C_{27} ) SD</th>
<th>( n-C_{28} ) SD</th>
<th>( \delta D ) lake water</th>
<th>( \delta D ) inflow water</th>
</tr>
</thead>
<tbody>
<tr>
<td>QY</td>
<td>183</td>
<td>186</td>
<td>199</td>
<td>214</td>
<td>135</td>
<td>132</td>
</tr>
<tr>
<td>YZY</td>
<td>180</td>
<td>183</td>
<td>187</td>
<td>189</td>
<td>122</td>
<td>107</td>
</tr>
<tr>
<td>NC</td>
<td>200</td>
<td>203</td>
<td>246</td>
<td>243</td>
<td>164</td>
<td>101</td>
</tr>
<tr>
<td>KLK</td>
<td>104</td>
<td>116</td>
<td>122</td>
<td>126</td>
<td>8</td>
<td>5</td>
</tr>
<tr>
<td>XQ</td>
<td>118</td>
<td>124</td>
<td>139</td>
<td>138</td>
<td>22</td>
<td>—</td>
</tr>
</tbody>
</table>

4\(^{\text{a}}\)Data are calculated using mean weighted annual meteoric water $\delta D$ in Lhasa (1998.9–2000.9) with elevation gradient of $-0.96%/100 \text{m}$ (Hou et al., 2003); 5\(^{\text{b}}\)Data are mean weighted annual meteoric water $\delta D$ in NamCo (2005.8–2006, 10); 6\(^{\text{c}}\)Data are calculated using mean weighted annual meteoric water $\delta D$ in Delingha (1993–1996) with elevation gradient of $-0.96%/100 \text{m}$ (Hou et al., 2003). 7\(^{\text{d}}\)Data: lake water was sampled from different depth and showed unvaried $\delta D$ values with depth, the measured standard deviation is below $0.05\%$. 8\(^{\text{e}}\)Data: inflow water of NC, the measured standard deviation is $0.7\%$ (personal communication Y. W. Xu, Institute of Tibetan Plateau Research, Chinese Academy of Sciences). 9\(^{\text{f}}\)Data: bayin river (entrance to KLK lake), the measured standard deviation is $0.9\%$.

### Table 5. Fractionation $\epsilon$ values for each site and mean values as well as $2\sigma$ standard deviation (SD) along the transect ($P$ represents precipitation)

<table>
<thead>
<tr>
<th>Sample code</th>
<th>( \epsilon_{C_{25}} )</th>
<th>( \epsilon_{C_{26}} )</th>
<th>( \epsilon_{C_{27}} )</th>
<th>( \epsilon_{C_{28}} )</th>
</tr>
</thead>
<tbody>
<tr>
<td>QY</td>
<td>-55</td>
<td>-59</td>
<td>-74</td>
<td>-91</td>
</tr>
<tr>
<td>YZY</td>
<td>-55</td>
<td>-47</td>
<td>-63</td>
<td>-66</td>
</tr>
<tr>
<td>NC</td>
<td>-50</td>
<td>-41</td>
<td>-95</td>
<td>-91</td>
</tr>
<tr>
<td>KLK</td>
<td>-56</td>
<td>-68</td>
<td>-79</td>
<td>-84</td>
</tr>
<tr>
<td>XQ</td>
<td>-67</td>
<td>-73</td>
<td>-89</td>
<td>-88</td>
</tr>
<tr>
<td>Mean</td>
<td>-57</td>
<td>-58</td>
<td>-80</td>
<td>-84</td>
</tr>
<tr>
<td>SD</td>
<td>6</td>
<td>14</td>
<td>13</td>
<td>10</td>
</tr>
</tbody>
</table>

### Table 6. Mean annual relative humidity (RH) and mean annual global solar radiation (SR) of the lake sites of Sachse et al. (2004)

|          | NAI | KEI | SOD003 | SOD007 | HYY | SYR | LAM | HZM | MAS | MEZ | LGM | LPM |
|----------|-----|-----|--------|--------|-----|-----|-----|-----|-----|-----|-----|-----|-----|
| RH (%)   | >70 | >70 | >70    | >70    | >70 | >70 | >70 | >70 | >70 | >70 | >70 | >70 |
| SR (MJ m\(^{-2}\)) | 200 | 200 | 200 | 200 | 200 | 200 | 200 | 200 | 200 | 200 | 200 | 200 |

evaporative enrichment should not be as strong as that for steppe, consequently leading to a relatively more negative source water for alkanes biosynthesis. However, considering that the population of reed swamp, reed meadow and leymus meadow are far lower than the dominant vegetation, this might not be the reason for the constant fractionation along the Tibetan transect.

By comparison with the apparent isotope fractionation along the S–N European transect, the hydrogen isotope fractionation along the Tibetan transect is much smaller. Considering the semiarid-arid climate in the Tibetan Plateau and the humid climate in the Europe, a possible reason for the smaller apparent fractionation might be the differences in climate between two transects. Mean annual relative humidity and annual mean global solar radiation in the Tibetan Plateau are around 40% and 7300 M J m\(^{-2}\) respectively (Table 1) while those in the Europe are around 70% and 3700 M J m\(^{-2}\) (Table 6). Due to different climatic conditions such as mean annual relative humidity and mean annual global solar radiation, evaporation from soil and evapotranspiration from leaf in the Tibetan Plateau might be much stronger than that in the Europe, resulting in a more enriched H source for n-alkanes biosynthesis. But this possibility might not be clarified in this study and further investigation is required on the isotopic fractionation between leaf water and n-alkanes and the isotopic fractionation between soil water and n-alkanes in the Tibetan Plateau. The dominant vegetation along the European and Tibetan transect are deciduous trees (Sachse et al., 2006) and steppe respectively, and trees might have less negative \(\delta D\) values than the co-occurring grasses (Hou et al., 2007; Liu et al., 2006), so the difference in ecological types of vegetation might not be the reason for the smaller fractionation along the Tibetan transect.

CONCLUSIONS

A comparison with \(\delta D\) values of precipitation, spanning a wide range from –167‰ to –51‰ along the S–N transect in the Tibetan Plateau, shows that hydrogen isotope ratios of terrigenous n-alkanes (n-C\(_{23}\) to n-C\(_{31}\)) extracted from recent lacustrine sediments clearly correlate with \(\delta D\) values of meteoric water, indicating that these alkanes record the precipitation signal. The isotope fractionation between precipitation and n-C\(_{25}\), n-C\(_{27}\) alkanes cover a range from –45‰ to –70‰, whilst that between precipitation and n-C\(_{29}\), n-C\(_{31}\) alkanes varies from –70‰ to –95‰, both being fairly constant along the S–N Tibetan transect with the mean at –57% and –82% respectively. By comparison with the apparent fractionation along the S–N European transect, it implies that the apparent hydrogen isotopic fractionation between meteoric water and terrestrial n-alkanes along the S–N Tibetan transect is much smaller.

Acknowledgments—We thank Professor L. D. Tian for providing needed meteorological data and hydrogen isotope ratio data of water samples, and Associate Professor S. Q. Zhou and Dr. Q. L. You for providing needed meteorological data, and Dr. Y. W. Xu for providing needed hydrogen isotope ratio data of water samples. We are also grateful to Dr. Yoshito Chikaraishi and an anonymous reviewer for constructive comments.

REFERENCES


Hilkert, A. W., Douthitt, C. B., Schluter, H. J. et al. (1999) \(\delta D\) of terrigenous n-alkanes in Tibet record precipitation signal 337


