Global increase in plant carbon isotope fractionation following the Last Glacial Maximum caused by increase in atmospheric pCO_2

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ABSTRACT

Changes in the carbon isotope composition of terrestrial plant tissue ($\delta^{13}C$) are widely cited for evidence of shifts in climate, vegetation, or atmospheric chemistry across a wide range of time scales. A global compilation of $\delta^{13}C$ data from fossil leaves and bulk terrestrial organic matter (TOM) spanning the past 30 k.y., however, shows wide variability and no discernable trend. Here we analyze these data in terms of a relative change in net carbon isotope fractionation between the $\delta^{13}C$ value of plant tissue and that of atmospheric CO_2 [$\Delta^{13}C = (\delta^{13}C_{CO_2} - \delta^{13}C)/(1 + \delta^{13}C/1000)$] and identify a global 2.1‰ shift in leaf and TOM $\Delta^{13}C$ that is synchronous with a global rise in pCO_2 documented from ice core data. We apply a relationship describing the effect of pCO_2 on $\Delta^{13}C$ to the global record of $\Delta^{13}C$ change documented here to reconstruct pCO_2 levels across the past 30 k.y. Our reconstructed pCO_2 levels are in excellent agreement with the ice core data and underscore the potential of the global terrestrial $\delta^{13}C$ record to serve as an accurate pCO_2 proxy.

INTRODUCTION

Changes in the carbon stable isotope composition of terrestrial plant-derived substrates ($\delta^{13}C$) have been observed in the geological record at both local and global scales (e.g., McInerney and Wing, 2011). Such changes have been variously interpreted to record a change in environmental variables, including plant species composition (e.g., Feakins et al., 2013; Tipple and Pagani, 2010), water availability (e.g., Stewart et al., 1995), atmospheric oxygen concentration (Tappert et al., 2013), the isotopic composition of CO_2 in the atmosphere ($\delta^{13}C_{CO_2}$) (e.g., Jahren et al., 2001), and atmospheric pCO_2 (e.g., Schubert and Jahren, 2013). Changes within an isotope record from a single locality may reflect changes in local climate and vegetation, and so multiple high-resolution records from diverse environments are necessary to analyze for changes in global climate. The Quaternary Period is particularly rich in terrestrial $\delta^{13}C$ records, as well as in high-precision environmental data (e.g., $\delta^{13}C_{CO_2}$, pCO_2) from ice cores. We compile the global record of C_3 plant-derived $\delta^{13}C$ values from the Late Glacial through the Holocene and quantify changes in the carbon isotope fractionation between the atmosphere and plant-derived substrates through time. We build upon our previous work (Schubert and Jahren, 2012) that quantified the dependence of carbon isotope fractionation on pCO_2 during photosynthesis, based on observations during plant growth experiments. Here we apply this relationship to the global record of bulk terrestrial organic matter (TOM) and plant leaf fossil $\delta^{13}C$ in order to reconstruct changes in atmospheric pCO_2 across the past 30 k.y. We then compare our reconstruction to the values of pCO_2 known from ice cores, thus evaluating the potential of the original relationship to serve as an accurate proxy for paleo-pCO_2.

METHODS

In order to examine the global plant $\delta^{13}C$ record for the past 30 k.y., we compiled $\delta^{13}C$ values of fossil leaves and bulk TOM (includes bulk organic carbon measured in sediments, soil organic matter, loess, and peat deposits) from records that spanned at least 5 k.y. or extended from the Holocene to at least part of the glacial-interglacial transition (Termination 1; 18,000–11,500 yr before A.D. 1950, herein yr ago). Because we sought records of C_3 land plant carbon in equilibrium with a well-mixed atmosphere, we only compiled records that contained $\delta^{13}C$ values between −18.5‰ and −32‰ (after Kohn, 2010; O'Leary, 1988). We therefore avoided records with $\delta^{13}C$ values representative of C_4 plants (e.g., Pendall et al., 1999) or understory vegetation within closed canopy forests (e.g., Giresse et al., 1994), and records with bulk organic matter that contained significant inputs from aquatic plants or planktonic algae (e.g., Ji et al., 2005). The resulting data set yielded a total of 614 $\delta^{13}C$ measurements from 23 distinct records reported in 19 published studies (Table DR1 and Fig. DR1 in the GSA Data Repository[1]), and represents a wide range of values, similar to that observed for modern studies of whole leaves (Kohn, 2010) and integrated C_3 ecosystems (Pataki et al., 2003); leaf tissue ranged from −20.80‰ to −30.00‰ and TOM ranged from −18.50‰ to −31.75‰ (Fig. 1A).

In order to eliminate the effects of changes in the $\delta^{13}C$ value of atmospheric CO_2 ($\delta^{13}C_{CO_2}$) on the $\delta^{13}C$ value of plant tissue, we calculated the net carbon isotope fractionation [$\Delta^{13}C = (\delta^{13}C_{CO_2} - \delta^{13}C) / (1 + \delta^{13}C/1000)$; Farquhar et al., 1989] for each data point using $\delta^{13}C_{CO_2}$ values obtained from high-resolution ice core data (Elsig et al., 2009; Lourantou et al., 2010; Smith et al., 1999) (Fig. DR2; Table DR1). Because the absolute $\Delta^{13}C$ value is known to differ among plants growing under the same environmental conditions (e.g., Flanagan et al., 1997; Leavitt and Newberry, 1992), we analyzed the data set in terms of a relative change in the $\Delta^{13}C$ value between some time, t, and a reference time (t = 0), designated here as $\Delta(\Delta^{13}C)$:

$$\Delta(\Delta^{13}C) = \Delta^{13}C_{(t)} - \Delta^{13}C_{(t=0)}. \quad (1)$$

Figure 1B shows $\Delta(\Delta^{13}C)$ calculated using Equation 1 for all the isotope records compiled in Figure 1A (for an analysis of error, see the Data Repository). Within Equation 1, values for $\Delta^{13}C_{(t=0)}$ were calculated using the average Holocene $\delta^{13}C$ value for each record (listed in Table DR1) and $\delta^{13}C_{CO_2}$ was set equal to the average Holocene $\delta^{13}C_{CO_2}$ value (−6.4‰) calculated from the ice core record (Lüthi et al., 2008). Values for $\Delta^{13}C_{(t)}$ were calculated using the $\delta^{13}C$ data plotted in Figure 1A and $\delta^{13}C_{CO_2}$ values obtained from ice core data (Fig. DR2). We used ages reported in the original publications for all data. When calendar ages were not reported in a published paper, radiocarbon ages were converted to calendar ages using the radiocarbon calibration program described by Fairbanks et al. (2005).

RESULTS AND DISCUSSION

We identify a global 2.1‰ increase in $\Delta(\Delta^{13}C)$ measured in both fossil leaves and TOM (Fig. 1B) that is not apparent within the wide range of absolute $\delta^{13}C$ values shown within Figure 1A. We here explain this global 2.1‰ increase in $\Delta(\Delta^{13}C)$ by considering the effect of pCO_2 on carbon isotope fractionation and noting the 80 ppmv rise in pCO_2 documented across this interval from ice core data (Fig. 1C). We previously demonstrated that change in $\Delta^{13}C$ per unit increase in pCO_2 follows a continuous function (Schubert and Jahren, 2012) and updated this work with published data on 17 additional species including trees, shrubs, and herbaceous plants, and for both angiosperm and gymnosperm taxa (Table DR2). Taken together,

[1]GSA Data Repository item 2015151, all data presented in Figures 1 and 2, and a description of the errors associated with our reconstructed pCO_2 levels, is available online at www.geosociety.org/pubs/ft2015.htm, or on request from editing@geosociety.org or Documents Secretary, GSA, P.O. Box 9140, Boulder, CO 80301, USA.

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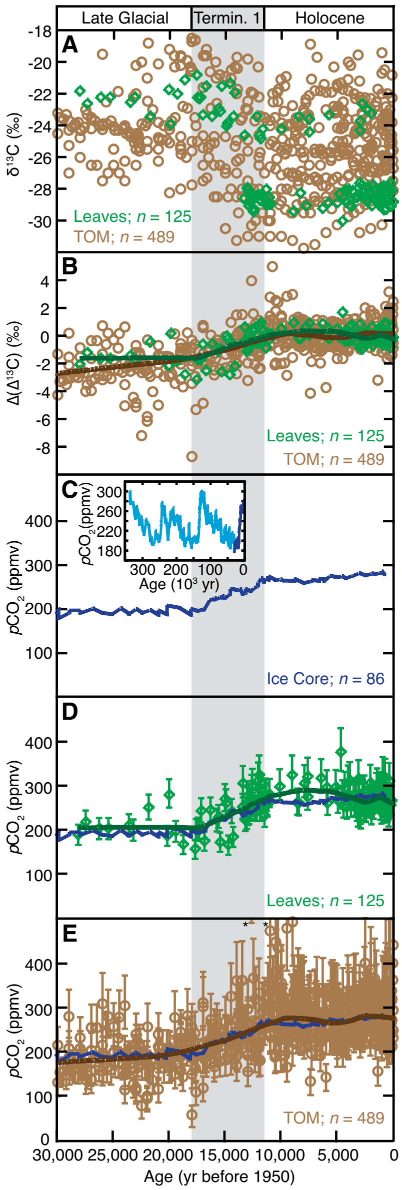

Figure 1. Carbon isotope values and pCO_2 levels across the past 30 k.y. A: $\delta^{13}C$ values from leaves (n = 125) and terrestrial organic matter (TOM; n = 489) compiled from 23 published records and used to calculate $\Delta(\Delta^{13}C)$. B: $\Delta(\Delta^{13}C)$ (Equation 1). C: pCO_2 levels from ice core records (Kawamura et al., 2007; Petit et al., 1999) (also plotted in D and E). D: pCO_2 levels through time reconstructed for leaves using Equation 4 and the $\Delta(\Delta^{13}C)$ data in B. E: pCO_2 levels through time reconstructed for TOM. Heavy curves in B, D, and E are locally weighted regression curves (loess, α = 0.25). Error bars in D and E indicate maximum cumulative error in the reconstructed pCO_2 values based upon the precision associated with determination of $\Delta(\Delta^{13}C)$ and $pCO_{2(t\,=\,0)}$, and constants A, B, and C in Equation 4 (for error analysis, see the Data Repository [see footnote 1]). Reconstructed pCO_2 levels >500 ppmv (n = 2) are marked with asterisks. The interval of pCO_2 change (18,000–11,500 yr ago) across Termination 1 (Termin. 1) is shaded gray. A complete list of all isotope data and calculated pCO_2 values and their errors are provided in Table DR1 (see footnote 1).

the data show that changes in $\Delta^{13}C$ per unit increase in pCO_2 (S, ‰/ppmv) decrease with increasing pCO_2 level according to the following general equation (r = 0.94, n = 40) (Fig. 2):

$$S = (A^2)(B)/[A + (B)(pCO_2 + C)]^2. \quad (2)$$

Integration of Equation 2 yields the following generalized hyperbolic relationship between $\Delta^{13}C$ and pCO_2:

$$\Delta^{13}C = [(A)(B)(pCO_2 + C)]/[A + (B)(pCO_2 + C)], \quad (3)$$

where A = 28.26, B = 0.22, and C = 23.9. The values for A, B, and C were determined iteratively such that $\Delta^{13}C$ = 4.4‰ at pCO_2 = 0 ppmv, and $\Delta^{13}C$ = 28.26‰ at pCO_2 = 10^6 ppmv (after Schubert and Jahren, 2012). The change in $\Delta^{13}C$ [$\Delta(\Delta^{13}C)$, Equation 1] that results from a change in pCO_2 can then be described by the following equation (after Equation 3 and Schubert and Jahren, 2013):

$$\Delta(\Delta^{13}C) = [(A)(B)(pCO_{2(t)} + C)]/[A + (B)(pCO_{2(t)} + C)] - [(A)(B)(pCO_{2(t\,=\,0)} + C)]/[A + (B)(pCO_{2(t\,=\,0)} + C)]. \quad (4)$$

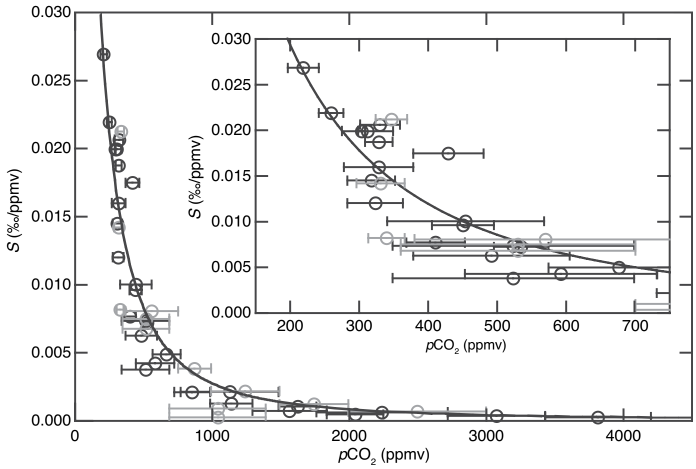

Figure 2. The effect of pCO_2 on C_3 land plant carbon isotope fractionation. Across field and chamber experiments on a wide range of C_3 land plant species, the amount of carbon isotope fractionation per change in pCO_2 (S, ‰/ppmv) decreases within increasing pCO_2 level according to Equation 2 (where A = 28.26, B = 0.22, and C = 23.9; r = 0.94; n = 40; black curve). Horizontal bars encompass the range of pCO_2 levels used within each experiment; the circle is plotted at the midpoint of the range. Inset shows the data plotted across pCO_2 = 150–750 ppmv. We updated the original data set (Schubert and Jahren, 2012) (black circles, n = 28) with additional published data (gray circles, n = 12). All values and references are provided in Table DR2 (see footnote 1).

We can therefore use $\Delta(\Delta^{13}C)$ data to solve for pCO_2 at any time t ($pCO_{2(t)}$), provided we know the pCO_2 level at reference time t = 0 (i.e., $pCO_{2(t\,=\,0)}$); values for A, B, and C are the same as in Equation 3.

We reconstructed pCO_2 levels for the past 30 k.y. using Equation 4 with $pCO_{2(t\,=\,0)}$ = 270 ppmv (the average preindustrial Holocene level; Kawamura et al., 2007) and the $\Delta(\Delta^{13}C)$ data shown in Figure 1B. The result shows excellent agreement with pCO_2 levels obtained from high-resolution ice core data spanning the past 30 k.y. (Figs. 1D and 1E). Both the fossil leaf and TOM records indicate a steady increase in pCO_2 across Termination 1 (18,000–11,500 yr ago) with little change in pCO_2 during the Holocene (11,500–100 yr ago) and the Late Glacial interval (30,000–18,000 yr ago), corroborated by the ice core record both with respect to trends as well as absolute values (Table 1). Across the entire record, the average absolute difference between the pCO_2 level determined from the ice core and the $pCO_{2(t)}$ level reconstructed using Equation 4 is small (23 and 39 ppmv for fossil leaves and TOM, respectively) and the correlations between the ice core record and the locally weighted regression (loess, α = 0.25) through each substrate are high (R^2 = 0.97 and R^2 = 0.80 for TOM and fossil leaves, respectively).

TABLE 1. COMPARISON OF pCO_2 LEVELS DETERMINED FOR SPECIFIC INTERVALS USING LEAF AND TERRESTRIAL ORGANIC MATTER (EQUATION 4) WITH HIGH-RESOLUTION ICE CORE DATA

Interval* (yr ago)	Ice core**	Leaves	TOM††
Holocene† 11,499–100	270 ± 7 ppmv (n = 38)	273 ± 27 ppmv (n = 76)	278 ± 52 ppmv (n = 281)
Termination 1§ 17,999–11,500	0.0102 ppmv/yr (n = 26)	0.0137 ppmv/yr (n = 38)	0.0096 ppmv/yr (n = 84)
Late Glacial† 30,000–18,000	193 ± 7 ppmv (n = 22)	209 ± 31 ppmv (n = 11)	188 ± 45 ppmv (n = 117)

*0 yr ago = A.D. 1950.
†Holocene and Late Glacial pCO_2 levels reported as mean ±1σ.
§Calculated as the slope of a best-fit line through the data spanning this interval.
**Ice core data calculated from Kawamura et al. (2007).
††TOM—terrestrial organic matter. Two values (marked with asterisks in Fig. 1E) were excluded from the calculations.

We note that all TOM and fossil leaf carbon isotope records are subject to variability arising from differential water availability, which has been shown to be a primary environmental driver of changes in $\delta^{13}C$ value, both in terms of mean annual precipitation (Diefendorf et al., 2010; Kohn, 2010) and seasonal precipitation (Schubert and Jahren, 2011). We examine the scatter about the mean for both $\Delta(\Delta^{13}C)$ records, calculated as the average absolute difference between the measured $\Delta(\Delta^{13}C)$ values (Equation 1) and the locally weighted regression curves (Fig. 1B). The scatter within both the TOM $\Delta(\Delta^{13}C)$ record (0.87‰ ± 0.82‰, n = 489) and the fossil leaf record (0.46‰ ± 0.38‰, n = 125) probably reflects the heterogeneous environmental influences (e.g., water availability) that cause $\delta^{13}C$ variability within and between ecosystems (reviewed by Dawson et al., 2002). The significantly ($p < 0.0001$) greater scatter within the TOM data set also reflects the changing contributions of different plant species and taxonomic groups, which are known to show different amounts of carbon isotope fractionation (Flanagan et al., 1997; Leavitt and Newberry, 1992). In contrast, the fossil leaf records are based on measurements across single species (e.g., *Pinus flexilis*; Van de Water et al., 1994); therefore, the variance within the fossil leaves data set (0.15) is 4.5× lower than the variance within the TOM data set (0.68), reflecting the reduced sources of isotopic variability within species-specific substrates. When we quantify the scatter in reconstructed pCO_2 values for each substrate, calculated as the absolute difference between $pCO_{2(t)}$ (calculated from Equation 4) and the locally weighted regression curve fit through the calculated $pCO_{2(t)}$ values, we find that for both fossil leaves and TOM this scatter is small; the average values (±1σ) are 21 ± 17 ppmv (n = 125) for fossil leaves and 39 ± 44 ppmv (n = 489) for TOM. Our analysis reinforces our claim that although local environmental factors influence plant $\delta^{13}C$ value, the governing influence of pCO_2 over carbon isotope fractionation is apparent within global data sets. We contend that global shifts in the amount of carbon isotope fractionation of C_3 terrestrial plant tissue are best interpreted to reflect a change in pCO_2 because a global record averages the effects of local or regional changes in environmental conditions, substrate heterogeneity, and plant community shifts.

Our results also illustrate how the effect of pCO_2 on changing plant carbon isotope composition, if not acknowledged, may lead to inappropriate paleoclimate interpretations. As an example, the combined leaf and TOM data set shows a global 2.1‰ relative increase in carbon isotope fractionation from the Late Glacial to the Holocene (Fig. 1B). If we hypothesize a Late Glacial mean annual precipitation (MAP) of 830 mm (the simulated Last Glacial Maximum MAP over land; Vettoretti et al., 2000) and apply the proposed relationship between MAP and $\Delta^{13}C$ values (Kohn, 2010, his equation 2), the 2.1‰ increase would require a 1442 mm increase to MAP = 2272 mm (i.e., ~3× greater than modern MAP), an extreme change not corroborated within the sedimentological, geochemical, or fossil records of the period. Similarly, there is no independent evidence across this interval that would support an interpretation of a global change in C_3 plant community composition. A significant rise in global temperatures coincided with the increases in pCO_2 level across Termination 1 (Parrenin et al., 2013), but the measured effect of an increase in temperature on plant carbon isotope fractionation varies (King et al., 2012; Schleser et al., 1999) and may be autocorrelated with changes in precipitation, cloudiness, and/or humidity (e.g., McCarroll and Pawellek, 2001). Moreover, the shift observed here is the opposite of what would be expected from an increase in global water stress due to a rise in global temperature across Termination 1. Thus, although climate change may affect the plant carbon isotope record of a single site, it cannot explain the global record presented here.

CONCLUSIONS

Our analysis reveals that the ~80 ppmv rise in pCO_2 level from the Late Glacial to preindustrial levels evident within air bubbles in glacial ice (Kawamura et al., 2007) is recorded by the global record of carbon isotope fractionation in C_3 land plants. Excellent agreement between our reconstructed levels and those measured from ice demonstrates the potential for using terrestrial carbon isotope records to reconstruct atmospheric pCO_2 for periods when any change in $\delta^{13}C_{CO_2}$ is independently constrained, either by the ice core record as illustrated here, or by the nonphotosynthetic marine record in the more distant past (Schubert and Jahren, 2013; Tipple et al., 2010). We warn that before interpreting environmental change from the $\delta^{13}C$ value of terrestrial substrates, the effect of changing pCO_2 levels must be considered, particularly for intervals with moderate to low pCO_2 levels that dominated much of the past 350 m.y. (Breecker et al., 2010; Franks et al., 2014). We note that changes in atmospheric oxygen concentrations (pO_2) may also prove to be important on these longer time scales (e.g., Beerling et al., 2002; Berner et al., 2000), but the systematic study of the effect of pO_2 in isolation from seed to maturity across the full range of pO_2 levels predicted for the geologic past is lacking. Changes in pCO_2 that result from changes in elevation also affect carbon isotope measurements (high-elevation plants show less fractionation than low-elevation plants and pCO_2 declines with increasing elevation; Körner et al., 1988), and therefore elevation changes should be considered when examining $\Delta^{13}C$ change on multimillion-year time scales. Independent of these effects, our work demonstrates the potential for terrestrial $\delta^{13}C$ measurements to be used for reconstructing pCO_2 levels in the geologic record.

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REFERENCES CITED

Beerling, D.J., Lake, J.A., Berner, R.A., Hickey, L.J., Taylor, D.W., and Royer, D.L., 2002, Carbon isotope evidence implying high O_2/CO_2 ratios in the Permo-Carboniferous atmosphere: Geochimica et Cosmochimica Acta, v. 66, p. 3757–3767, doi:10.1016/S0016-7037(02)00901-8.

Berner, R.A., et al., 2000, Isotope fractionation and atmospheric oxygen: Implications for Phanerozoic O_2 evolution: Science, v. 287, p. 1630–1633, doi:10.1126/science.287.5458.1630.

Breecker, D.O., Sharp, Z.D., and McFadden, L.D., 2010, Atmospheric CO_2 concentration during ancient greenhouse climates were similar to those predicted for A.D. 2100: National Academy of Sciences Proceedings, v. 107, p. 576–580, doi:10.1073/pnas.0902323106.

Dawson, T.E., Mambelli, S., Plamboeck, A.H., Templer, P.H., and Tu, K.P., 2002, Stable isotopes in plant ecology: Annual Review of Ecology and Systematics, v. 33, p. 507–559, doi:10.1146/annurev.ecolsys.33.020602.095451.

Diefendorf, A.F., Mueller, K.E., Wing, S.L., Koch, P.L., and Freeman, K.H., 2010, Global patterns in leaf ^{13}C discrimination and implications for studies of past and future climate: National Academy of Sciences Proceedings, v. 107, p. 5738–5743, doi:10.1073/pnas.0910513107.

Elsig, J., Schmitt, J., Leuenberger, D., Schneider, R., Eyer, M., Leuenberger, M., Joos, F., Fischer, H., and Stocker, T.F., 2009, Stable isotope constraints on Holocene carbon cycle changes from an Antarctic ice core: Nature, v. 461, p. 507–510, doi:10.1038/nature08393.

Fairbanks, R.G., Mortlock, R.A., Chiu, T.-C., Cao, L., Kaplan, A., Guilderson, T.P., Fairbanks, T.W., Bloom, A.L., Grootes, P.M., and Nadeau, M.-J., 2005, Radiocarbon calibration curve spanning 0 to 50,000 years BP based on paired $^{230}Th/^{234}U/^{238}U$ and ^{14}C dates on pristine corals: Quaternary Science Reviews, v. 24, p. 1781–1796, doi:10.1016/j.quascirev.2005.04.007.

Farquhar, G.D., Ehleringer, J.R., and Hubick, K.T., 1989, Carbon isotope discrimination and photosynthesis: Annual Review of Plant Physiology and Plant Molecular Biology, v. 40, p. 503–537, doi:10.1146/annurev.pp.40.060189.002443.

Feakins, S.J., Levin, N.E., Liddy, H.M., Sieracki, A., Eglinton, T.I., and Bonnefille, R., 2013, Northeast African vegetation change over 12 m.y.: Geology, v. 41, p. 295–298, doi:10.1130/G33845.1.

Flanagan, L.B., Brooks, J.R., and Ehleringer, J.R., 1997, Photosynthesis and carbon isotope discrimination in boreal forest ecosystems: A comparison of functional characteristics in plants from three mature forest types: Journal of Geophysical Research, v. 102, p. 28,861–28,869, doi:10.1029/97JD01235.

Franks, P.J., Royer, D.L., Beerling, D.J., Van de Water, P.K., Cantrill, D.J., Barbour, M.M., and Berry, J.A., 2014, New constraints on atmospheric CO_2 concentration for the Phanerozoic: Geophysical Research Letters, v. 41, p. 4685–4694, doi:10.1002/2014GL060457.

Giresse, P., Maley, J., and Brenac, P., 1994, Late Quaternary palaeoenvironments in the Lake Barombi Mbo (west Cameroon) deduced from pollen and carbon isotopes of organic matter: Palaeogeography, Palaeoclimatology, Palaeoecology, v. 107, p. 65–78, doi:10.1016/0031-0182(94)90165-1.

Jahren, A.H., Arens, N.C., Sarmiento, G., Guerrero, J., and Amundson, R., 2001, Terrestrial record of methane hydrate dissociation in the Early Cretaceous: Geology, v. 29, p. 159–162, doi:10.1130/0091-7613(2001)029<0159:TROMHD>2.0.CO;2.

Ji, S., Xingqi, L., Sumin, W., and Matsumoto, R., 2005, Palaeoclimatic changes in the Qinghai Lake area during the last 18,000 years: Quaternary International, v. 136, p. 131–140, doi:10.1016/j.quaint.2004.11.014.

Kawamura, K., Nakazawa, T., Aoki, S., Sugawara, S., Fujii, Y., and Watanabe, O., 2007, Dome Fuji ice core 338KYr wet extraction CO_2 data, *in* International Geosphere-Biosphere Programme PAGES/World Data Center for Paleoclimatology Data Contribution Series 2007-074: Boulder Colorado, National Oceanic and Atmospheric Administration National Climatic Data Center Paleoclimatology Program.

King, D.C., Schubert, B.A., and Jahren, A.H., 2012, Practical considerations for the use of pollen $\delta^{13}C$ value as a paleoclimate indicator: Rapid Communications in Mass Spectrometry, v. 26, p. 2165–2172, doi:10.1002/rcm.6333.

Kohn, M.J., 2010, Carbon isotope compositions of terrestrial C3 plants as indicators of (paleo)ecology and (paleo)climate: National Academy of Sciences Proceedings, v. 107, p. 19691–19695, doi:10.1073/pnas.1004933107.

Körner, C., Farquhar, G.D., and Roksandic, Z., 1988, A global survey of carbon isotope discrimination in plants from high altitude: Oecologia, v. 74, p. 623–632, doi:10.1007/BF00380063.

Leavitt, S.W., and Newberry, T., 1992, Systematics of stable-carbon isotopic differences between gymnosperm and angiosperm trees: Plant Physiology, v. 11, p. 257–262.

Lourantou, A., Lavrič, J.V., Köhler, P., Barnola, J.-M., Paillard, D., Michel, E., Raynaud, D., and Chappellaz, J., 2010, Constraint of the CO_2 rise by new atmospheric carbon isotopic measurements during the last deglaciation: Global Biogeochemical Cycles, v. 24, GB2015, doi:10.1029/2009GB003545.

Lüthi, D., et al., 2008, High-resolution carbon dioxide concentration record 650,000–800,000 years before present: Nature, v. 453, p. 379–382, doi:10.1038/nature06949.

McCarroll, D., and Pawellek, F., 2001, Stable carbon isotope ratios of *Pinus sylvestris* from northern Finland and the potential for extracting a climate signal from long Fennoscandian chronologies: The Holocene, v. 11, p. 517–526, doi:10.1191/095968301680223477.

McInerney, F.A., and Wing, S.L., 2011, The Paleocene–Eocene thermal maximum: A perturbation of carbon cycle, climate, and biosphere with implications for the future: Annual Review of Earth and Planetary Sciences, v. 39, p. 489–516, doi:10.1146/annurev-earth-040610-133431.

O'Leary, M.H., 1988, Carbon isotopes in photosynthesis: Bioscience, v. 38, p. 328–336, doi:10.2307/1310735.

Parrenin, F., Masson-Delmotte, V., Köhler, P., Raynaud, D., Paillard, D., Schwander, J., Barbante, C., Landais, A., Wegner, A., and Jouzel, J., 2013, Synchronous change of atmospheric CO_2 and Antarctic temperature during the last deglacial warming: Science, v. 339, p. 1060–1063, doi:10.1126/science.1226368.

Pataki, D.E., Ehleringer, J.R., Flanagan, L.B., Yakir, D., Bowling, D.R., Still, C.J., Buchmann, N., Kaplan, J.O., and Berry, J.A., 2003, The application and interpretation of Keeling plots in terrestrial carbon cycle research: Global Biogeochemical Cycles, v. 17, 1022, doi:10.1029/2001GB001850.

Pendall, E., Betancourt, J.L., and Leavitt, S.W., 1999, Paleoclimatic significance of δD and $\delta^{13}C$ values in piñon pine needles from packrat middens spanning the last 40,000 years: Palaeogeography, Palaeoclimatology, Palaeoecology, v. 147, p. 53–72, doi:10.1016/S0031-0182(98)00152-7.

Petit, J.R., et al., 1999, Climate and atmospheric history of the past 420,000 years from the Vostok ice core, Antarctica: Nature, v. 399, p. 429–436, doi:10.1038/20859.

Schleser, G.H., Helle, G., Lücke, A., and Vos, H., 1999, Isotope signals as climate proxies: The role of transfer functions in the study of terrestrial archives: Quaternary Science Reviews, v. 18, p. 927–943, doi:10.1016/S0277-3791(99)00006-2.

Schubert, B.A., and Jahren, A.H., 2011, Quantifying seasonal precipitation using high-resolution carbon isotope analyses in evergreen wood: Geochimica et Cosmochimica Acta, v. 75, p. 7291–7303, doi:10.1016/j.gca.2011.7208.7002.

Schubert, B.A., and Jahren, A.H., 2012, The effect of atmospheric CO_2 concentration on carbon isotope fractionation in C_3 land plants: Geochimica et Cosmochimica Acta, v. 96, p. 29–43, doi:10.1016/j.gca.2012.08.003.

Schubert, B.A., and Jahren, A.H., 2013, Reconciliation of marine and terrestrial carbon isotope excursions based on changing atmospheric CO_2 levels: Nature Communications, v. 4, 1653, doi:10.1038/ncomms2659.

Smith, H.J., Fischer, H., Wahlen, M., Mastroianni, D., and Deck, B., 1999, Dual modes of the carbon cycle since the Last Glacial Maximum: Nature, v. 400, p. 248–250, doi:10.1038/22291.

Stewart, G.R., Turnbull, M.H., Schmidt, S., and Erskine, P.D., 1995, ^{13}C natural abundance in plant communities along a rainfall gradient: A biological integrator of water availability: Australian Journal of Plant Physiology, v. 22, p. 51–55, doi:10.1071/PP9950051.

Tappert, R., McKellar, R.C., Wolfe, A.P., Tappert, M.C., Ortega-Blanco, J., and Muehlenbachs, K., 2013, Stable carbon isotopes of C3 plant resins and ambers record changes in atmospheric oxygen since the Triassic: Geochimica et Cosmochimica Acta, v. 121, p. 240–262, doi:10.1016/j.gca.2013.07.011.

Tipple, B.J., and Pagani, M., 2010, A 35 Myr North American leaf-wax compound-specific carbon and hydrogen isotope record: Implications for C_4 grasslands and hydrologic cycle dynamics: Earth and Planetary Science Letters, v. 299, p. 250–262, doi:10.1016/j.epsl.2010.09.006.

Tipple, B.J., Meyers, S.R., and Pagani, M., 2010, Carbon isotope ratio of Cenozoic CO_2: A comparative evaluation of available geochemical proxies: Paleoceanography, v. 25, PA3202, doi:10.1029/2009PA001851.

Van de Water, P.K., Leavitt, S.W., and Betancourt, J.L., 1994, Trends in stomatal density and $^{13}C/^{12}C$ ratios of *Pinus flexilis* needles during last glacial-interglacial cycle: Science, v. 264, p. 239–243, doi:10.1126/science.264.5156.239.

Vettoretti, G., Peltier, W.R., and McFarlane, N.A., 2000, Global water balance and atmospheric water vapour transport at last glacial maximum: Climate simulations with the Canadian Climate Centre for Modelling and Analysis atmospheric general circulation model: Canadian Journal of Earth Sciences, v. 37, p. 695–723, doi:10.1139/e99-092.

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Error Analysis

Errors are associated with the each of the parameters used to calculate $pCO_{2(t)}$ (equation 4): $\Delta(\Delta^{13}C)$, $pCO_{2(t=0)}$, and constants A, B, and C. To estimate the error associated with each measurement of $\Delta(\Delta^{13}C)$, we used the average absolute difference between the measured $\Delta(\Delta^{13}C)$ values (equation 1) and the locally weighted loess curves ($\alpha = 0.25$) (Fig. 1B) for each substrate (TOM = ±0.87‰; fossil leaves = ±0.46‰). In this way, the error in $pCO_{2(t)}$ calculated from TOM reflects the greater heterogeneity observed within the TOM $\delta^{13}C$ data compared with the fossil leaves. We assumed an error of ±7 ppmv for our estimate of $pCO_{2(t=0)}$, which was calculated as the standard deviation of the Holocene pCO_2 level (270 ± 7 ppmv, $n = 38$) (Kawamura et al., 2007). The error associated with the curve fit in Figure 2 is manifest in the constants A, B, and C within equation 4. The value of A = 28.26 quantifies the amount of fractionation by the enzyme RuBisCO and is based on our relationships between $\Delta^{13}C$ and pCO_2 described within Schubert and Jahren (2012). We note, however, that estimates of this value range in the literature from 26-30‰. We therefore determined values for B and C iteratively across this range in A values, such that equation 3 resulted in $\Delta^{13}C = 4.4‰$ at $pCO_2 = 0$ ppmv (no activity by RuBisCO) and $\Delta^{13}C = A$ at $pCO_2 = 10^6$ ppmv (after Schubert and Jahren, 2012). This resulted in values for B and C ranging from 0.16 to 0.27 and 19.2 to 32.9, respectively. The cumulative error from all of the above sources averaged +50 and -42 ppmv, for which an average of only ~3 ppmv was due to the fitting of the curve in our model and ~6-8 ppmv was caused by error in $pCO_{2(t=0)}$; the remaining error resulted from the precision of our estimates of $\Delta(\Delta^{13}C)$. Because $\Delta(\Delta^{13}C)$ provided the greatest source of error, the average error in our calculation of $pCO_{2(t)}$ was significantly less ($p < 0.001$) using the fossil leaves than the TOM (leaf = +31 and -28 ppmv; TOM = +55 and -45 ppmv). Errors in age dating were not quantified here, but do not affect the calculated pCO_2 level; they do, however, have some influence on direct comparison to the ice core record.

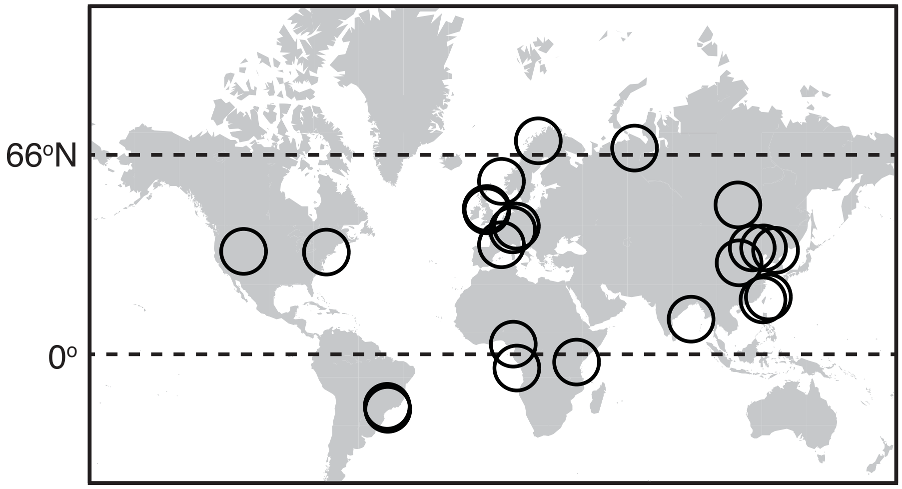

Figure DR1. Location of the 23 records from which $\delta^{13}C$ data were compiled, showing the global distribution of sites.

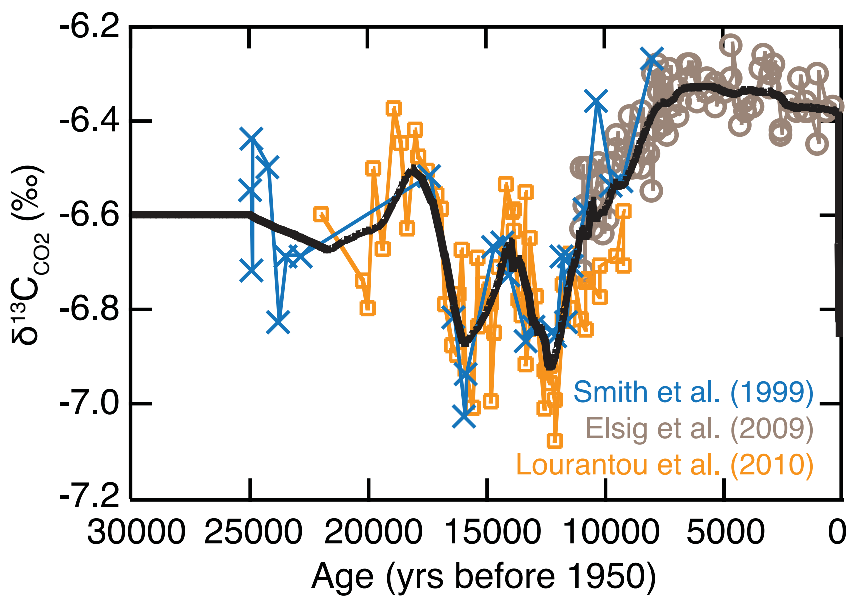

Figure DR2. Three records of $\delta^{13}C_{CO2}$ obtained from air bubbles trapped in ice (Elsig et al., 2009; Lourantou et al., 2010; Smith et al., 1999). Black curve shows the $\delta^{13}C_{CO2}$ values used at each time *t* in order to calculate $\Delta^{13}C_{(t)}$ within equation 1. The values for the black curve are presented in Table DR1 and are based on a locally weighted regression curve fit through the three combined datasets.

TABLE DR1. DATA USED TO CALCULATE $\Delta(\Delta^{13}C)$ AND $pCO_{2(t)}$

Reference	Substrate	Age* (yrs BP)	$\delta^{13}C_{(t)}$† (‰)	$\delta^{13}C_{(t=0)}$‡ (‰)	$\delta^{13}C_{CO2(t)}$§ (‰)	$\Delta^{13}C_{(t=0)}$‖ (‰)	$\Delta^{13}C_{(t)}$¶ (‰)	**$\Delta(\Delta^{13}C)$** (‰)**	**$pCO_{2(t)}$†† (ppmv)**	**+error‡‡ (ppmv)**	**-error‡‡ (ppmv)**
Andersson et al. (2012; Fig. 3; fen deposits)	SOM	2500	-28.00	-27.53	-6.35	21.73	22.27	**0.55**	**299**	**65**	**50**
Andersson et al. (2012; Fig. 3; fen deposits)	SOM	3600	-28.25	-27.53	-6.33	21.73	22.56	**0.83**	**315**	**70**	**53**
Andersson et al. (2012; Fig. 3; fen deposits)	SOM	4500	-28.25	-27.53	-6.33	21.73	22.56	**0.83**	**315**	**70**	**53**
Andersson et al. (2012; Fig. 3; fen deposits)	SOM	5200	-28.38	-27.53	-6.33	21.73	22.69	**0.96**	**323**	**73**	**54**
Andersson et al. (2012; Fig. 3; fen deposits)	SOM	6000	-27.80	-27.53	-6.33	21.73	22.08	**0.35**	**288**	**62**	**48**
Andersson et al. (2012; Fig. 3; fen deposits)	SOM	6700	-27.40	-27.53	-6.34	21.73	21.65	**-0.08**	**266**	**55**	**45**
Andersson et al. (2012; Fig. 3; fen deposits)	SOM	7500	-27.40	-27.53	-6.36	21.73	21.63	**-0.10**	**265**	**54**	**45**
Andersson et al. (2012; Fig. 3; fen deposits)	SOM	8250	-26.88	-27.53	-6.40	21.73	21.04	**-0.69**	**239**	**46**	**41**
Andersson et al. (2012; Fig. 3; fen deposits)	SOM	8600	-27.13	-27.53	-6.42	21.73	21.28	**-0.44**	**249**	**50**	**42**
Andersson et al. (2012; Fig. 3; fen deposits)	SOM	9000	-28.13	-27.53	-6.45	21.73	22.31	**0.58**	**300**	**66**	**50**
Andersson et al. (2012; Fig. 3; fen deposits)	SOM	9400	-27.00	-27.53	-6.48	21.73	21.09	**-0.64**	**241**	**47**	**41**
Andersson et al. (2012; Fig. 3; fen deposits)	SOM	9700	-25.75	-27.53	-6.50	21.73	19.76	**-1.97**	**191**	**36**	**35**
Beerling (1996; Fig. 1b)	*Salix* leaves	10926	-28.95	-28.56	-6.62	22.81	23.00	**0.18**	**279**	**39**	**33**
Beerling (1996; Fig. 1b)	*Salix* leaves	11114	-28.52	-28.56	-6.64	22.81	22.53	**-0.28**	**256**	**34**	**31**
Beerling (1996; Fig. 1b)	*Salix* leaves	11193	-28.83	-28.56	-6.65	22.81	22.84	**0.03**	**272**	**37**	**32**
Beerling (1996; Fig. 1b)	*Salix* leaves	11250	-28.97	-28.56	-6.65	22.81	22.99	**0.18**	**279**	**39**	**33**
Beerling (1996; Fig. 1b)	*Salix* leaves	11291	-29.00	-28.56	-6.66	22.81	23.01	**0.20**	**280**	**39**	**33**
Beerling (1996; Fig. 1b)	*Salix* leaves	11325	-28.76	-28.56	-6.66	22.81	22.75	**-0.06**	**267**	**36**	**32**
Beerling (1996; Fig. 1b)	*Salix* leaves	11361	-28.00	-28.56	-6.66	22.81	21.95	**-0.86**	**232**	**30**	**29**
Beerling (1996; Fig. 1b)	*Salix* leaves	11710	-28.36	-28.56	-6.70	22.81	22.29	**-0.52**	**246**	**32**	**30**
Beerling (1996; Fig. 1b)	*Salix* leaves	11761	-28.36	-28.56	-6.70	22.81	22.29	**-0.53**	**246**	**32**	**30**
Beerling (1996; Fig. 1b)	*Salix* leaves	11914	-28.69	-28.56	-6.72	22.81	22.62	**-0.19**	**261**	**35**	**31**
Beerling (1996; Fig. 1b)	*Salix* leaves	12075	-28.38	-28.56	-6.73	22.81	22.28	**-0.53**	**245**	**32**	**30**
Beerling (1996; Fig. 1b)	*Salix* leaves	12273	-28.43	-28.56	-6.75	22.81	22.31	**-0.50**	**247**	**32**	**30**
Beerling (1996; Fig. 1b)	*Salix* leaves	12457	-29.43	-28.56	-6.76	22.81	23.35	**0.54**	**298**	**43**	**35**
Beerling (1996; Fig. 1b)	*Salix* leaves	12513	-29.24	-28.56	-6.77	22.81	23.14	**0.33**	**287**	**41**	**34**
Beerling (1996; Fig. 1b)	*Salix* leaves	12677	-28.51	-28.56	-6.78	22.81	22.36	**-0.45**	**249**	**33**	**30**
Beerling (1996; Fig. 1b)	*Salix*	12696	-28.71	-28.56	-6.78	22.81	22.58	**-0.23**	**259**	**35**	**31**

	leaves										
Beerling (1996; Fig. 1b)	*Salix* leaves	12734	-28.45	-28.56	-6.79	22.81	22.30	**-0.51**	**246**	**32**	**30**
Beerling (1996; Fig. 1b)	*Salix* leaves	12753	-28.26	-28.56	-6.79	22.81	22.10	**-0.71**	**238**	**31**	**29**
Beerling (1996; Fig. 1b)	*Salix* leaves	12773	-28.78	-28.56	-6.79	22.81	22.65	**-0.16**	**262**	**35**	**31**
Beerling (1996; Fig. 1b)	*Salix* leaves	12813	-28.81	-28.56	-6.79	22.81	22.67	**-0.14**	**263**	**36**	**31**
Beerling (1996; Fig. 1b)	*Salix* leaves	12875	-28.24	-28.56	-6.79	22.81	22.07	**-0.74**	**236**	**30**	**29**
Beerling (1996; Fig. 1b)	*Salix* leaves	12896	-29.05	-28.56	-6.80	22.81	22.92	**0.10**	**275**	**38**	**33**
Beerling (1996; Fig. 1b)	*Salix* leaves	12957	-28.02	-28.56	-6.80	22.81	21.84	**-0.97**	**227**	**29**	**28**
Beerling (1996; Fig. 1b)	*Salix* leaves	13081	-27.91	-28.56	-6.81	22.81	21.70	**-1.11**	**222**	**29**	**28**
Beerling (1996; Fig. 1b)	*Salix* leaves	13336	-28.60	-28.56	-6.82	22.81	22.41	**-0.40**	**251**	**33**	**30**
Beerling and Rundgren (2000; Fig. 3a, ages rounded to the nearest 50 yrs)	*Salix* leaves	0	-28.80	-28.45	-6.86	22.70	22.59	**-0.11**	**265**	**36**	**32**
Beerling and Rundgren (2000; Fig. 3a, ages rounded to the nearest 50 yrs)	*Salix* leaves	100	-28.10	-28.45	-6.34	22.70	22.39	**-0.31**	**255**	**34**	**31**
Beerling and Rundgren (2000; Fig. 3a, ages rounded to the nearest 50 yrs)	*Salix* leaves	200	-29.10	-28.45	-6.35	22.70	23.43	**0.73**	**309**	**46**	**37**
Beerling and Rundgren (2000; Fig. 3a, ages rounded to the nearest 50 yrs)	*Salix* leaves	250	-27.60	-28.45	-6.36	22.70	21.85	**-0.85**	**232**	**30**	**29**
Beerling and Rundgren (2000; Fig. 3a, ages rounded to the nearest 50 yrs)	*Salix* leaves	300	-28.00	-28.45	-6.36	22.70	22.26	**-0.43**	**250**	**33**	**30**
Beerling and Rundgren (2000; Fig. 3a, ages rounded to the nearest 50 yrs)	*Salix* leaves	350	-27.90	-28.45	-6.36	22.70	22.15	**-0.54**	**245**	**32**	**30**
Beerling and Rundgren (2000; Fig. 3a, ages rounded to the nearest 50 yrs)	*Salix* leaves	400	-28.25	-28.45	-6.37	22.70	22.52	**-0.18**	**262**	**35**	**31**
Beerling and Rundgren (2000; Fig. 3a, ages rounded to the nearest 50 yrs)	*Salix* leaves	450	-28.30	-28.45	-6.37	22.70	22.57	**-0.13**	**264**	**36**	**32**
Beerling and Rundgren (2000; Fig. 3a, ages rounded to the nearest 50 yrs)	*Salix* leaves	500	-28.75	-28.45	-6.37	22.70	23.04	**0.35**	**288**	**41**	**34**
Beerling and Rundgren (2000; Fig. 3a, ages rounded to the nearest 50 yrs)	*Salix* leaves	550	-28.15	-28.45	-6.37	22.70	22.41	**-0.29**	**256**	**34**	**31**
Beerling and Rundgren (2000; Fig. 3a, ages rounded to the nearest 50 yrs)	*Salix* leaves	600	-29.25	-28.45	-6.37	22.70	23.56	**0.87**	**317**	**47**	**38**
Beerling and Rundgren (2000; Fig. 3a, ages rounded to the nearest 50 yrs)	*Salix* leaves	650	-27.85	-28.45	-6.38	22.70	22.09	**-0.61**	**242**	**31**	**30**
Beerling and Rundgren (2000; Fig. 3a, ages rounded to the nearest 50 yrs)	*Salix* leaves	700	-28.60	-28.45	-6.38	22.70	22.88	**0.18**	**279**	**39**	**33**
Beerling and Rundgren (2000; Fig. 3a, ages	*Salix*	800	-29.30	-28.45	-6.38	22.70	23.61	**0.92**	**320**	**48**	**39**

rounded to the nearest 50 yrs)	leaves										
Beerling and Rundgren (2000; Fig. 3a, ages rounded to the nearest 50 yrs)	*Salix* leaves	900	-27.80	-28.45	-6.38	22.70	22.03	**-0.66**	**240**	**31**	**29**
Beerling and Rundgren (2000; Fig. 3a, ages rounded to the nearest 50 yrs)	*Salix* leaves	950	-28.85	-28.45	-6.38	22.70	23.14	**0.44**	**293**	**42**	**34**
Beerling and Rundgren (2000; Fig. 3a, ages rounded to the nearest 50 yrs)	*Salix* leaves	1000	-28.00	-28.45	-6.38	22.70	22.24	**-0.45**	**249**	**33**	**30**
Beerling and Rundgren (2000; Fig. 3a, ages rounded to the nearest 50 yrs)	*Salix* leaves	1100	-28.60	-28.45	-6.38	22.70	22.88	**0.18**	**279**	**39**	**33**
Beerling and Rundgren (2000; Fig. 3a, ages rounded to the nearest 50 yrs)	*Salix* leaves	1150	-28.50	-28.45	-6.38	22.70	22.77	**0.07**	**274**	**38**	**32**
Beerling and Rundgren (2000; Fig. 3a, ages rounded to the nearest 50 yrs)	*Salix* leaves	1200	-28.50	-28.45	-6.38	22.70	22.77	**0.08**	**274**	**38**	**32**
Beerling and Rundgren (2000; Fig. 3a, ages rounded to the nearest 50 yrs)	*Salix* leaves	1300	-28.95	-28.45	-6.38	22.70	23.25	**0.55**	**299**	**43**	**35**
Beerling and Rundgren (2000; Fig. 3a, ages rounded to the nearest 50 yrs)	*Salix* leaves	1350	-28.80	-28.45	-6.38	22.70	23.09	**0.39**	**290**	**41**	**34**
Beerling and Rundgren (2000; Fig. 3a, ages rounded to the nearest 50 yrs)	*Salix* leaves	1400	-28.45	-28.45	-6.37	22.70	22.72	**0.03**	**271**	**37**	**32**
Beerling and Rundgren (2000; Fig. 3a, ages rounded to the nearest 50 yrs)	*Salix* leaves	1500	-28.40	-28.45	-6.37	22.70	22.67	**-0.02**	**269**	**37**	**32**
Beerling and Rundgren (2000; Fig. 3a, ages rounded to the nearest 50 yrs)	*Salix* leaves	1600	-28.05	-28.45	-6.37	22.70	22.31	**-0.39**	**252**	**33**	**30**
Beerling and Rundgren (2000; Fig. 3a, ages rounded to the nearest 50 yrs)	*Salix* leaves	1650	-28.05	-28.45	-6.37	22.70	22.31	**-0.39**	**252**	**33**	**30**
Beerling and Rundgren (2000; Fig. 3a, ages rounded to the nearest 50 yrs)	*Salix* leaves	1700	-28.50	-28.45	-6.37	22.70	22.78	**0.09**	**274**	**38**	**33**
Beerling and Rundgren (2000; Fig. 3a, ages rounded to the nearest 50 yrs)	*Salix* leaves	1800	-27.75	-28.45	-6.37	22.70	21.99	**-0.70**	**238**	**31**	**29**
Beerling and Rundgren (2000; Fig. 3a, ages rounded to the nearest 50 yrs)	*Salix* leaves	1900	-29.05	-28.45	-6.36	22.70	23.37	**0.67**	**306**	**45**	**36**
Beerling and Rundgren (2000; Fig. 3a, ages rounded to the nearest 50 yrs)	*Salix* leaves	1950	-28.30	-28.45	-6.36	22.70	22.58	**-0.12**	**264**	**36**	**32**
Beerling and Rundgren (2000; Fig. 3a, ages rounded to the nearest 50 yrs)	*Salix* leaves	2050	-28.30	-28.45	-6.36	22.70	22.58	**-0.12**	**264**	**36**	**32**
Beerling and Rundgren (2000; Fig. 3a, ages rounded to the nearest 50 yrs)	*Salix* leaves	2100	-28.20	-28.45	-6.36	22.70	22.48	**-0.22**	**259**	**35**	**31**
Beerling and Rundgren (2000; Fig. 3a, ages rounded to the nearest 50 yrs)	*Salix* leaves	2200	-28.20	-28.45	-6.36	22.70	22.48	**-0.22**	**260**	**35**	**31**
Beerling and Rundgren (2000; Fig. 3a, ages rounded to the nearest 50 yrs)	*Salix* leaves	2300	-27.85	-28.45	-6.35	22.70	22.11	**-0.58**	**243**	**31**	**30**
Beerling and Rundgren (2000; Fig. 3a, ages rounded to the nearest 50 yrs)	*Salix* leaves	2450	-28.70	-28.45	-6.35	22.70	23.01	**0.31**	**286**	**41**	**34**
Beerling and Rundgren (2000; Fig. 3a, ages rounded to the nearest 50 yrs)	*Salix* leaves	2550	-28.45	-28.45	-6.35	22.70	22.75	**0.05**	**273**	**38**	**32**
Beerling and Rundgren (2000; Fig. 3a, ages	*Salix*	2600	-28.55	-28.45	-6.35	22.70	22.86	**0.16**	**278**	**39**	**33**

rounded to the nearest 50 yrs)	leaves										
Beerling and Rundgren (2000; Fig. 3a, ages rounded to the nearest 50 yrs)	*Salix* leaves	2750	-28.15	-28.45	-6.34	22.70	22.44	**-0.26**	**258**	**34**	**31**
Beerling and Rundgren (2000; Fig. 3a, ages rounded to the nearest 50 yrs)	*Salix* leaves	2800	-27.75	-28.45	-6.34	22.70	22.02	**-0.68**	**239**	**31**	**29**
Beerling and Rundgren (2000; Fig. 3a, ages rounded to the nearest 50 yrs)	*Salix* leaves	2900	-28.40	-28.45	-6.34	22.70	22.70	**0.01**	**270**	**37**	**32**
Beerling and Rundgren (2000; Fig. 3a, ages rounded to the nearest 50 yrs)	*Salix* leaves	3000	-27.60	-28.45	-6.34	22.70	21.86	**-0.83**	**233**	**30**	**29**
Beerling and Rundgren (2000; Fig. 3a, ages rounded to the nearest 50 yrs)	*Salix* leaves	3100	-27.90	-28.45	-6.34	22.70	22.18	**-0.51**	**246**	**32**	**30**
Beerling and Rundgren (2000; Fig. 3a, ages rounded to the nearest 50 yrs)	*Salix* leaves	3200	-28.50	-28.45	-6.34	22.70	22.81	**0.12**	**276**	**38**	**33**
Beerling and Rundgren (2000; Fig. 3a, ages rounded to the nearest 50 yrs)	*Salix* leaves	3400	-28.50	-28.45	-6.33	22.70	22.82	**0.12**	**276**	**38**	**33**
Beerling and Rundgren (2000; Fig. 3a, ages rounded to the nearest 50 yrs)	*Salix* leaves	3650	-28.10	-28.45	-6.33	22.70	22.40	**-0.30**	**256**	**34**	**31**
Beerling and Rundgren (2000; Fig. 3a, ages rounded to the nearest 50 yrs)	*Salix* leaves	3750	-29.10	-28.45	-6.33	22.70	23.45	**0.76**	**311**	**46**	**37**
Beerling and Rundgren (2000; Fig. 3a, ages rounded to the nearest 50 yrs)	*Salix* leaves	3900	-29.00	-28.45	-6.33	22.70	23.35	**0.65**	**305**	**45**	**36**
Beerling and Rundgren (2000; Fig. 3a, ages rounded to the nearest 50 yrs)	*Salix* leaves	4000	-28.00	-28.45	-6.33	22.70	22.30	**-0.40**	**251**	**33**	**30**
Beerling and Rundgren (2000; Fig. 3a, ages rounded to the nearest 50 yrs)	*Salix* leaves	4200	-28.80	-28.45	-6.33	22.70	23.14	**0.44**	**293**	**42**	**34**
Beerling and Rundgren (2000; Fig. 3a, ages rounded to the nearest 50 yrs)	*Salix* leaves	4300	-28.05	-28.45	-6.33	22.70	22.35	**-0.35**	**254**	**34**	**31**
Beerling and Rundgren (2000; Fig. 3a, ages rounded to the nearest 50 yrs)	*Salix* leaves	4400	-28.50	-28.45	-6.33	22.70	22.82	**0.13**	**276**	**38**	**33**
Beerling and Rundgren (2000; Fig. 3a, ages rounded to the nearest 50 yrs)	*Salix* leaves	4550	-30.00	-28.45	-6.33	22.70	24.41	**1.71**	**375**	**60**	**49**
Beerling and Rundgren (2000; Fig. 3a, ages rounded to the nearest 50 yrs)	*Salix* leaves	4800	-28.30	-28.45	-6.33	22.70	22.61	**-0.08**	**266**	**36**	**32**
Beerling and Rundgren (2000; Fig. 3a, ages rounded to the nearest 50 yrs)	*Salix* leaves	5000	-28.85	-28.45	-6.33	22.70	23.19	**0.50**	**296**	**43**	**35**
Beerling and Rundgren (2000; Fig. 3a, ages rounded to the nearest 50 yrs)	*Salix* leaves	5800	-28.85	-28.45	-6.33	22.70	23.19	**0.49**	**296**	**43**	**35**
Beerling and Rundgren (2000; Fig. 3a, ages rounded to the nearest 50 yrs)	*Salix* leaves	6300	-29.20	-28.45	-6.34	22.70	23.55	**0.86**	**317**	**47**	**38**
Beerling and Rundgren (2000; Fig. 3a, ages rounded to the nearest 50 yrs)	*Salix* leaves	7800	-29.05	-28.45	-6.38	22.70	23.35	**0.66**	**305**	**45**	**36**
Beerling and Rundgren (2000; Fig. 3a, ages rounded to the nearest 50 yrs)	*Salix* leaves	8300	-28.25	-28.45	-6.40	22.70	22.48	**-0.21**	**260**	**35**	**31**
Beerling and Rundgren (2000; Fig. 3a, ages rounded to the nearest 50 yrs)	*Salix* leaves	8900	-29.40	-28.45	-6.44	22.70	23.66	**0.96**	**323**	**49**	**39**
Brincat et al. (2000; Fig. 1; Table 2)	Sediments/	681	-26.20	-26.16	-6.38	20.29	20.36	**0.07**	**273**	**57**	**46**

	SOM										
Brincat et al. (2000; Fig. 1; Table 2)	Sediments/ SOM	2791	-26.60	-26.16	-6.34	20.29	20.81	**0.52**	**297**	**64**	**50**
Brincat et al. (2000; Fig. 1; Table 2)	Sediments/ SOM	3575	-26.30	-26.16	-6.33	20.29	20.51	**0.22**	**281**	**59**	**47**
Brincat et al. (2000; Fig. 1; Table 2)	Sediments/ SOM	6538	-25.60	-26.16	-6.34	20.29	19.77	**-0.52**	**246**	**49**	**42**
Brincat et al. (2000; Fig. 1; Table 2)	Sediments/ SOM	10392	-26.10	-26.16	-6.57	20.29	20.06	**-0.24**	**259**	**52**	**44**
Brincat et al. (2000; Fig. 1; Table 2)	Sediments/ SOM	12666	-30.30	-26.16	-6.78	20.29	24.25	**3.96**	**632**	**224**	**139**
Brincat et al. (2000; Fig. 1; Table 2)	Sediments/ SOM	13723	-26.10	-26.16	-6.84	20.29	19.78	**-0.51**	**246**	**49**	**42**
Brincat et al. (2000; Fig. 1; Table 2)	Sediments/ SOM	16539	-25.40	-26.16	-6.76	20.29	19.13	**-1.16**	**220**	**42**	**38**
Brincat et al. (2000; Fig. 1; Table 2)	Sediments/ SOM	18816	-22.80	-26.16	-6.59	20.29	16.59	**-3.70**	**143**	**29**	**31**
Brincat et al. (2000; Fig. 1; Table 2)	Sediments/ SOM	19818	-23.70	-26.16	-6.57	20.29	17.55	**-2.74**	**168**	**32**	**33**
Brincat et al. (2000; Fig. 1; Table 2)	Sediments/ SOM	20246	-24.90	-26.16	-6.57	20.29	18.80	**-1.50**	**207**	**39**	**37**
Brincat et al. (2000; Fig. 1; Table 2)	Sediments/ SOM	20655	-24.90	-26.16	-6.59	20.29	18.78	**-1.51**	**207**	**39**	**37**
Brincat et al. (2000; Fig. 1; Table 2)	Sediments/ SOM	20956	-24.90	-26.16	-6.60	20.29	18.77	**-1.52**	**206**	**39**	**37**
Brincat et al. (2000; Fig. 1; Table 2)	Sediments/ SOM	21747	-23.60	-26.16	-6.65	20.29	17.36	**-2.93**	**163**	**32**	**33**
Brincat et al. (2000; Fig. 1; Table 2)	Sediments/ SOM	22161	-24.00	-26.16	-6.67	20.29	17.76	**-2.54**	**174**	**33**	**34**
Brincat et al. (2000; Fig. 1; Table 2)	Sediments/ SOM	22474	-23.90	-26.16	-6.69	20.29	17.63	**-2.66**	**170**	**33**	**33**
Brincat et al. (2000; Fig. 1; Table 2)	Sediments/ SOM	22798	-24.60	-26.16	-6.70	20.29	18.35	**-1.94**	**192**	**37**	**35**
Brincat et al. (2000; Fig. 1; Table 2)	Sediments/ SOM	23249	-22.20	-26.16	-6.71	20.29	15.85	**-4.44**	**126**	**26**	**30**
Brincat et al. (2000; Fig. 1; Table 2)	Sediments/ SOM	23679	-24.40	-26.16	-6.69	20.29	18.15	**-2.14**	**186**	**35**	**35**
Cathalot et al. (2013)	Sediments	50	-26.20	-24.81	-6.34	18.88	20.40	**1.52**	**361**	**86**	**63**
Cathalot et al. (2013)	Sediments	383	-27.80	-24.81	-6.37	18.88	22.05	**3.17**	**517**	**151**	**105**
Cathalot et al. (2013)	Sediments	546	-23.20	-24.81	-6.37	18.88	17.23	**-1.65**	**202**	**38**	**36**
Cathalot et al. (2013)	Sediments	602	-24.10	-24.81	-6.37	18.88	18.16	**-0.72**	**238**	**46**	**41**
Cathalot et al. (2013)	Sediments	655	-26.20	-24.81	-6.38	18.88	20.36	**1.48**	**358**	**85**	**63**
Cathalot et al. (2013)	Sediments	677	-26.80	-24.81	-6.38	18.88	20.99	**2.11**	**407**	**102**	**75**
Cathalot et al. (2013)	Sediments	760	-26.00	-24.81	-6.38	18.88	20.15	**1.27**	**343**	**80**	**59**
Cathalot et al. (2013)	Sediments	885	-24.30	-24.81	-6.38	18.88	18.37	**-0.51**	**246**	**49**	**42**
Cathalot et al. (2013)	Sediments	920	-24.30	-24.81	-6.38	18.88	18.37	**-0.51**	**246**	**49**	**42**

Cathalot et al. (2013)	Sediments	941	-25.90	-24.81	-6.38	18.88	20.04	**1.16**	**336**	**77**	**57**
Cathalot et al. (2013)	Sediments	1357	-21.70	-24.81	-6.38	18.88	15.66	**-3.21**	**155**	**30**	**32**
Cathalot et al. (2013)	Sediments	1874	-24.40	-24.81	-6.36	18.88	18.49	**-0.39**	**252**	**50**	**43**
Cathalot et al. (2013)	Sediments	1906	-25.20	-24.81	-6.36	18.88	19.32	**0.45**	**293**	**63**	**49**
Cathalot et al. (2013)	Sediments	1919	-25.30	-24.81	-6.36	18.88	19.43	**0.55**	**299**	**65**	**50**
Cathalot et al. (2013)	Sediments	1972	-25.30	-24.81	-6.36	18.88	19.43	**0.55**	**299**	**65**	**50**
Cathalot et al. (2013)	Sediments	2022	-25.40	-24.81	-6.36	18.88	19.54	**0.66**	**305**	**67**	**51**
Cathalot et al. (2013)	Sediments	2335	-25.50	-24.81	-6.35	18.88	19.65	**0.77**	**312**	**69**	**52**
Cathalot et al. (2013)	Sediments	2352	-24.70	-24.81	-6.35	18.88	18.81	**-0.07**	**267**	**55**	**45**
Cathalot et al. (2013)	Sediments	2546	-24.50	-24.81	-6.35	18.88	18.61	**-0.27**	**257**	**52**	**43**
Cathalot et al. (2013)	Sediments	2946	-23.80	-24.81	-6.34	18.88	17.89	**-0.99**	**226**	**43**	**39**
Cathalot et al. (2013)	Sediments	3214	-24.30	-24.81	-6.34	18.88	18.41	**-0.47**	**248**	**49**	**42**
Cathalot et al. (2013)	Sediments	3336	-24.30	-24.81	-6.33	18.88	18.41	**-0.47**	**248**	**49**	**42**
Cathalot et al. (2013)	Sediments	3344	-24.40	-24.81	-6.33	18.88	18.52	**-0.36**	**253**	**51**	**43**
Cathalot et al. (2013)	Sediments	3426	-24.50	-24.81	-6.33	18.88	18.62	**-0.26**	**258**	**52**	**43**
Cathalot et al. (2013)	Sediments	4402	-23.90	-24.81	-6.33	18.88	18.00	**-0.88**	**231**	**44**	**40**
Cathalot et al. (2013)	Sediments	4478	-24.10	-24.81	-6.33	18.88	18.21	**-0.67**	**240**	**47**	**41**
Cathalot et al. (2013)	Sediments	4662	-24.20	-24.81	-6.33	18.88	18.32	**-0.56**	**244**	**48**	**42**
Cathalot et al. (2013)	Sediments	6294	-25.80	-24.81	-6.33	18.88	19.98	**1.10**	**332**	**76**	**57**
Damsté et al., (2011; Fig. 3a, solid line; ages to the nearest 1,000 yrs)	Sediments	1000	-30.25	-30.80	-6.38	25.18	24.61	**-0.56**	**244**	**48**	**42**
Damsté et al., (2011; Fig. 3a, solid line; ages to the nearest 1,000 yrs)	Sediments	2000	-30.50	-30.80	-6.36	25.18	24.90	**-0.28**	**257**	**52**	**43**
Damsté et al., (2011; Fig. 3a, solid line; ages to the nearest 1,000 yrs)	Sediments	3000	-30.75	-30.80	-6.34	25.18	25.18	**0.01**	**270**	**56**	**45**
Damsté et al., (2011; Fig. 3a, solid line; ages to the nearest 1,000 yrs)	Sediments	4000	-29.75	-30.80	-6.33	25.18	24.14	**-1.04**	**225**	**43**	**39**
Damsté et al., (2011; Fig. 3a, solid line; ages to the nearest 1,000 yrs)	Sediments	5000	-30.25	-30.80	-6.33	25.18	24.67	**-0.51**	**247**	**49**	**42**
Damsté et al., (2011; Fig. 3a, solid line; ages to the nearest 1,000 yrs)	Sediments	6000	-30.75	-30.80	-6.33	25.18	25.19	**0.02**	**271**	**56**	**45**
Damsté et al., (2011; Fig. 3a, solid line; ages to the nearest 1,000 yrs)	Sediments	7000	-31.50	-30.80	-6.35	25.18	25.97	**0.79**	**313**	**70**	**52**
Damsté et al., (2011; Fig. 3a, solid line; ages to the nearest 1,000 yrs)	Sediments	8000	-31.75	-30.80	-6.38	25.18	26.20	**1.02**	**327**	**74**	**55**
Damsté et al., (2011; Fig. 3a, solid line; ages to the nearest 1,000 yrs)	Sediments	9000	-31.25	-30.80	-6.45	25.18	25.60	**0.43**	**292**	**63**	**49**
Damsté et al., (2011; Fig. 3a, solid line; ages to the nearest 1,000 yrs)	Sediments	10000	-31.00	-30.80	-6.53	25.18	25.25	**0.08**	**274**	**57**	**46**
Damsté et al., (2011; Fig. 3a, solid line; ages to the nearest 1,000 yrs)	Sediments	11000	-31.00	-30.80	-6.63	25.18	25.15	**-0.02**	**269**	**56**	**45**
Damsté et al., (2011; Fig. 3a, solid line; ages to the nearest 1,000 yrs)	Sediments	12000	-31.00	-30.80	-6.73	25.18	25.05	**-0.12**	**264**	**54**	**44**
Damsté et al., (2011; Fig. 3a, solid line; ages to the nearest 1,000 yrs)	Sediments	13000	-31.00	-30.80	-6.80	25.18	24.97	**-0.20**	**260**	**53**	**44**
Damsté et al., (2011; Fig. 3a, solid line;	Sediments	14000	-31.25	-30.80	-6.84	25.18	25.19	**0.02**	**271**	**56**	**45**

ages to the nearest 1,000 yrs)											
Damsté et al., (2011; Fig. 3a, solid line; ages to the nearest 1,000 yrs)	Sediments	15000	-30.50	-30.80	-6.84	25.18	24.40	**-0.77**	**235**	**45**	**40**
Damsté et al., (2011; Fig. 3a, solid line; ages to the nearest 1,000 yrs)	Sediments	16000	-28.50	-30.80	-6.79	25.18	22.34	**-2.83**	**165**	**32**	**33**
Damsté et al., (2011; Fig. 3a, solid line; ages to the nearest 1,000 yrs)	Sediments	17000	-26.50	-30.80	-6.72	25.18	20.32	**-4.86**	**118**	**25**	**30**
Damsté et al., (2011; Fig. 3a, solid line; ages to the nearest 1,000 yrs)	Sediments	18000	-27.75	-30.80	-6.64	25.18	21.71	**-3.46**	**149**	**29**	**32**
Damsté et al., (2011; Fig. 3a, solid line; ages to the nearest 1,000 yrs)	Sediments	19000	-28.00	-30.80	-6.58	25.18	22.03	**-3.14**	**157**	**31**	**32**
Damsté et al., (2011; Fig. 3a, solid line; ages to the nearest 1,000 yrs)	Sediments	20000	-28.25	-30.80	-6.57	25.18	22.31	**-2.86**	**164**	**32**	**33**
Damsté et al., (2011; Fig. 3a, solid line; ages to the nearest 1,000 yrs)	Sediments	21000	-26.25	-30.80	-6.60	25.18	20.18	**-5.00**	**115**	**25**	**29**
Damsté et al., (2011; Fig. 3a, solid line; ages to the nearest 1,000 yrs)	Sediments	22000	-25.50	-30.80	-6.66	25.18	19.33	**-5.84**	**99**	**23**	**29**
Damsté et al., (2011; Fig. 3a, solid line; ages to the nearest 1,000 yrs)	Sediments	23000	-26.50	-30.80	-6.70	25.18	20.34	**-4.84**	**118**	**25**	**30**
Damsté et al., (2011; Fig. 3a, solid line; ages to the nearest 1,000 yrs)	Sediments	24000	-26.25	-30.80	-6.68	25.18	20.10	**-5.07**	**113**	**25**	**29**
Galy et al (2008; Table 1; Fig. 6, using apparent age of 3,000 yrs)	Sediments	3363	-22.30	-21.19	-6.33	15.11	16.33	**1.22**	**340**	**78**	**58**
Galy et al (2008; Table 1; Fig. 6, using apparent age of 3,000 yrs)	Sediments	4033	-21.10	-21.19	-6.33	15.11	15.09	**-0.02**	**269**	**56**	**45**
Galy et al (2008; Table 1; Fig. 6, using apparent age of 3,000 yrs)	Sediments	4677	-21.30	-21.19	-6.33	15.11	15.30	**0.19**	**279**	**59**	**47**
Galy et al (2008; Table 1; Fig. 6, using apparent age of 3,000 yrs)	Sediments	6163	-21.40	-21.19	-6.33	15.11	15.40	**0.29**	**285**	**60**	**48**
Galy et al (2008; Table 1; Fig. 6, using apparent age of 3,000 yrs)	Sediments	9554	-20.90	-21.19	-6.49	15.11	14.72	**-0.39**	**252**	**50**	**43**
Galy et al (2008; Table 1; Fig. 6, using apparent age of 3,000 yrs)	Sediments	9713	-21.50	-21.19	-6.50	15.11	15.33	**0.22**	**281**	**59**	**47**
Galy et al (2008; Table 1; Fig. 6, using apparent age of 3,000 yrs)	Sediments	10382	-21.90	-21.19	-6.57	15.11	15.68	**0.57**	**300**	**65**	**50**
Galy et al (2008; Table 1; Fig. 6, using apparent age of 3,000 yrs)	Sediments	10745	-22.50	-21.19	-6.60	15.11	16.26	**1.15**	**335**	**77**	**57**
Galy et al (2008; Table 1; Fig. 6, using apparent age of 3,000 yrs)	Sediments	10786	-22.00	-21.19	-6.61	15.11	15.74	**0.63**	**303**	**66**	**51**
Galy et al (2008; Table 1; Fig. 6, using apparent age of 3,000 yrs)	Sediments	12053	-20.30	-21.19	-6.73	15.11	13.85	**-1.26**	**216**	**41**	**38**
Galy et al (2008; Table 1; Fig. 6, using apparent age of 3,000 yrs)	Sediments	13940	-20.40	-21.19	-6.84	15.11	13.84	**-1.27**	**216**	**41**	**38**
Galy et al (2008; Table 1; Fig. 6, using apparent age of 3,000 yrs)	Sediments	13949	-21.70	-21.19	-6.84	15.11	15.19	**0.08**	**274**	**57**	**46**
Galy et al (2008; Table 1; Fig. 6, using	Sediments	13963	-19.70	-21.19	-6.84	15.11	13.12	**-1.99**	**190**	**36**	**35**

apparent age of 3,000 yrs)											
Galy et al (2008; Table 1; Fig. 6, using apparent age of 3,000 yrs)	Sediments	14145	-20.30	-21.19	-6.85	15.11	13.73	**-1.38**	**212**	**40**	**38**
Galy et al (2008; Table 1; Fig. 6, using apparent age of 3,000 yrs)	Sediments	14474	-20.50	-21.19	-6.85	15.11	13.94	**-1.17**	**219**	**42**	**38**
Galy et al (2008; Table 1; Fig. 6, using apparent age of 3,000 yrs)	Sediments	15826	-21.00	-21.19	-6.80	15.11	14.50	**-0.61**	**242**	**47**	**41**
Galy et al (2008; Table 1; Fig. 6, using apparent age of 3,000 yrs)	Sediments	15882	-20.00	-21.19	-6.80	15.11	13.47	**-1.64**	**202**	**38**	**37**
Galy et al (2008; Table 1; Fig. 6, using apparent age of 3,000 yrs)	Sediments	16358	-20.60	-21.19	-6.77	15.11	14.12	**-0.99**	**226**	**43**	**39**
Galy et al (2008; Table 1; Fig. 6, using apparent age of 3,000 yrs)	Sediments	16707	-19.60	-21.19	-6.74	15.11	13.11	**-2.00**	**190**	**36**	**35**
Galy et al (2008; Table 1; Fig. 6, using apparent age of 3,000 yrs)	Sediments	16720	-19.20	-21.19	-6.74	15.11	12.70	**-2.41**	**178**	**34**	**34**
Galy et al (2008; Table 1; Fig. 6, using apparent age of 3,000 yrs)	Sediments	16768	-19.60	-21.19	-6.74	15.11	13.12	**-1.99**	**191**	**36**	**35**
Galy et al (2008; Table 1; Fig. 6, using apparent age of 3,000 yrs)	Sediments	16975	-19.60	-21.19	-6.72	15.11	13.14	**-1.97**	**191**	**36**	**35**
Galy et al (2008; Table 1; Fig. 6, using apparent age of 3,000 yrs)	Sediments	17712	-18.60	-21.19	-6.66	15.11	12.16	**-2.95**	**162**	**31**	**33**
Galy et al (2008; Table 1; Fig. 6, using apparent age of 3,000 yrs)	Sediments	18087	-20.60	-21.19	-6.63	15.11	14.26	**-0.85**	**232**	**44**	**40**
Galy et al (2008; Table 1; Fig. 6, using apparent age of 3,000 yrs)	Sediments	18139	-20.30	-21.19	-6.63	15.11	13.95	**-1.16**	**220**	**42**	**39**
Galy et al (2008; Table 1; Fig. 6, using apparent age of 3,000 yrs)	Sediments	18455	-19.90	-21.19	-6.61	15.11	13.56	**-1.55**	**205**	**39**	**37**
Galy et al (2008; Table 1; Fig. 6, using apparent age of 3,000 yrs)	Sediments	18965	-19.70	-21.19	-6.58	15.11	13.38	**-1.73**	**199**	**38**	**36**
Galy et al (2008; Table 1; Fig. 6, using apparent age of 3,000 yrs)	Sediments	19576	-19.60	-21.19	-6.57	15.11	13.29	**-1.82**	**196**	**37**	**36**
Galy et al (2008; Table 1; Fig. 6, using apparent age of 3,000 yrs)	Sediments	21904	-18.80	-21.19	-6.66	15.11	12.38	**-2.73**	**168**	**32**	**33**
Gouveia et al., (2002; Fig. 6)	SOM	295	-23.00	-22.53	-6.36	16.50	17.03	**0.53**	**298**	**65**	**50**
Gouveia et al., (2002; Fig. 6)	SOM	2734	-22.40	-22.53	-6.34	16.50	16.42	**-0.08**	**266**	**55**	**45**
Gouveia et al., (2002; Fig. 6)	SOM	4478	-22.50	-22.53	-6.33	16.50	16.55	**0.04**	**272**	**57**	**46**
Gouveia et al., (2002; Fig. 6)	SOM	4912	-22.80	-22.53	-6.33	16.50	16.86	**0.36**	**288**	**62**	**48**
Gouveia et al., (2002; Fig. 6)	SOM	5292	-22.80	-22.53	-6.33	16.50	16.86	**0.36**	**288**	**62**	**48**
Gouveia et al., (2002; Fig. 6)	SOM	10245	-21.70	-22.53	-6.55	16.50	15.48	**-1.02**	**225**	**43**	**39**
Gouveia et al., (2002; Fig. 6)	SOM	13000	-19.80	-22.53	-6.80	16.50	13.26	**-3.24**	**154**	**30**	**32**
Hatté et al., (1998, Fig. 3A, Achenheim)	Sediments	0	-26.70	-27.09	-6.86	21.27	20.38	-0.88	231	**44**	**40**
Hatté et al., (1998, Fig. 3A, Achenheim)	Sediments	1000	-26.80	-27.09	-6.38	21.27	20.98	-0.28	257	**52**	**43**
Hatté et al., (1998, Fig. 3A, Achenheim)	Sediments	2000	-26.90	-27.09	-6.36	21.27	21.11	-0.16	262	**54**	**44**
Hatté et al., (1998, Fig. 3A, Achenheim)	Sediments	3000	-27.10	-27.09	-6.34	21.27	21.34	0.07	274	**57**	**46**
Hatté et al., (1998, Fig. 3A, Achenheim)	Sediments	4000	-27.20	-27.09	-6.33	21.27	21.45	0.19	279	**59**	**47**
Hatté et al., (1998, Fig. 3A, Achenheim)	Sediments	5000	-27.25	-27.09	-6.33	21.27	21.51	0.24	282	**60**	**47**

Hatté et al., (1998, Fig. 3A, Achenheim)	Sediments	6000	-27.30	-27.09	-6.33	21.27	21.56	0.29	285	**61**	**48**
Hatté et al., (1998, Fig. 3A, Achenheim)	Sediments	7000	-27.25	-27.09	-6.35	21.27	21.49	0.22	281	**59**	**47**
Hatté et al., (1998, Fig. 3A, Achenheim)	Sediments	8000	-27.25	-27.09	-6.38	21.27	21.45	0.18	279	**59**	**47**
Hatté et al., (1998, Fig. 3A, Achenheim)	Sediments	9000	-27.20	-27.09	-6.45	21.27	21.33	0.07	273	**57**	**46**
Hatté et al., (1998, Fig. 3A, Achenheim)	Sediments	10000	-27.10	-27.09	-6.53	21.27	21.14	-0.12	264	**54**	**44**
Hatté et al., (1998, Fig. 3A, Achenheim)	Sediments	11000	-26.60	-27.09	-6.63	21.27	20.52	-0.75	236	**46**	**41**
Hatté et al., (1998, Fig. 3A, Achenheim)	Sediments	12000	-26.00	-27.09	-6.73	21.27	19.79	-1.48	208	**40**	**37**
Hatté et al., (1998, Fig. 3A, Achenheim)	Sediments	13000	-25.60	-27.09	-6.80	21.27	19.29	-1.97	191	**36**	**35**
Hatté et al., (1998, Fig. 3A, Achenheim)	Sediments	14000	-27.00	-27.09	-6.84	21.27	20.72	-0.55	245	**48**	**42**
Hatté et al., (1998, Fig. 3A, Achenheim)	Sediments	15000	-26.75	-27.09	-6.84	21.27	20.46	-0.81	234	**45**	**40**
Hatté et al., (1998, Fig. 3A, Achenheim)	Sediments	16000	-25.10	-27.09	-6.79	21.27	18.78	-2.49	175	**34**	**34**
Hatté et al., (1998, Fig. 3A, Achenheim)	Sediments	17000	-25.40	-27.09	-6.72	21.27	19.17	-2.10	187	**36**	**35**
Hatté et al., (1998, Fig. 3A, Achenheim)	Sediments	18000	-25.60	-27.09	-6.64	21.27	19.46	-1.81	197	**37**	**36**
Hatté et al., (1998, Fig. 3A, Achenheim)	Sediments	19000	-25.30	-27.09	-6.58	21.27	19.20	-2.06	188	**36**	**35**
Hatté et al., (1998, Fig. 3A, Achenheim)	Sediments	20000	-25.10	-27.09	-6.57	21.27	19.01	-2.26	182	**35**	**34**
Hatté et al., (1998, Fig. 3A, Achenheim)	Sediments	21000	-24.75	-27.09	-6.60	21.27	18.61	-2.66	170	**33**	**33**
Hatté et al., (1998, Fig. 3A, Achenheim)	Sediments	22000	-25.00	-27.09	-6.66	21.27	18.81	-2.46	176	**34**	**34**
Hatté et al., (1998, Fig. 3A, Achenheim)	Sediments	23000	-25.50	-27.09	-6.70	21.27	19.29	-1.98	191	**36**	**35**
Hatté et al., (1998, Fig. 3A, Achenheim)	Sediments	24000	-24.00	-27.09	-6.68	21.27	17.75	-3.52	147	**29**	**31**
Hatté et al., (1998, Fig. 3A, Achenheim)	Sediments	25000	-25.50	-27.09	-6.55	21.27	19.44	-1.82	196	**37**	**36**
Hatté et al., (1998, Fig. 3A, Achenheim)	Sediments	26000	-24.25	-27.09	-6.60	21.27	18.09	-3.18	156	**30**	**32**
Hatté et al., (1998, Fig. 3A, Achenheim)	Sediments	27000	-23.50	-27.09	-6.60	21.27	17.31	-3.96	137	**28**	**31**
Hatté et al., (1998, Fig. 3A, Achenheim)	Sediments	28000	-24.75	-27.09	-6.60	21.27	18.61	-2.66	170	**33**	**33**
Hatté et al., (1998, Fig. 3A, Achenheim)	Sediments	29000	-25.25	-27.09	-6.60	21.27	19.13	-2.13	186	**35**	**35**
Hatté et al., (1998, Fig. 3A, Achenheim)	Sediments	30000	-23.20	-27.09	-6.60	21.27	16.99	-4.27	130	**27**	**30**
Hatté et al., (1998, Fig. 3A, Nuβloch)	Sediments	0	-25.55	-25.57	-6.86	19.67	19.18	-0.49	247	**49**	**42**
Hatté et al., (1998, Fig. 3A, Nuβloch)	Sediments	1000	-25.55	-25.57	-6.38	19.67	19.67	0.00	270	**56**	**45**
Hatté et al., (1998, Fig. 3A, Nuβloch)	Sediments	2000	-25.55	-25.57	-6.36	19.67	19.69	0.02	271	**56**	**45**
Hatté et al., (1998, Fig. 3A, Nuβloch)	Sediments	3000	-25.55	-25.57	-6.34	19.67	19.71	0.04	272	**57**	**46**
Hatté et al., (1998, Fig. 3A, Nuβloch)	Sediments	4000	-25.60	-25.57	-6.33	19.67	19.78	0.10	275	**58**	**46**
Hatté et al., (1998, Fig. 3A, Nuβloch)	Sediments	5000	-25.65	-25.57	-6.33	19.67	19.83	0.16	278	**58**	**46**
Hatté et al., (1998, Fig. 3A, Nuβloch)	Sediments	6000	-25.70	-25.57	-6.33	19.67	19.88	0.21	280	**59**	**47**
Hatté et al., (1998, Fig. 3A, Nuβloch)	Sediments	7000	-25.70	-25.57	-6.35	19.67	19.86	0.19	279	**59**	**47**
Hatté et al., (1998, Fig. 3A, Nuβloch)	Sediments	8000	-25.65	-25.57	-6.38	19.67	19.77	0.10	275	**57**	**46**
Hatté et al., (1998, Fig. 3A, Nuβloch)	Sediments	9000	-25.60	-25.57	-6.45	19.67	19.66	-0.02	269	**56**	**45**
Hatté et al., (1998, Fig. 3A, Nuβloch)	Sediments	10000	-25.55	-25.57	-6.53	19.67	19.52	-0.15	263	**54**	**44**
Hatté et al., (1998, Fig. 3A, Nuβloch)	Sediments	11000	-25.20	-25.57	-6.63	19.67	19.05	-0.62	242	**47**	**41**
Hatté et al., (1998, Fig. 3A, Nuβloch)	Sediments	12000	-24.60	-25.57	-6.73	19.67	18.33	-1.35	213	**40**	**38**
Hatté et al., (1998, Fig. 3A, Nuβloch)	Sediments	13000	-24.90	-25.57	-6.80	19.67	18.56	-1.11	222	**42**	**39**
Hatté et al., (1998, Fig. 3A, Nuβloch)	Sediments	14000	-24.95	-25.57	-6.84	19.67	18.57	-1.10	222	**42**	**39**
Hatté et al., (1998, Fig. 3A, Nuβloch)	Sediments	15000	-24.70	-25.57	-6.84	19.67	18.31	-1.36	212	**40**	**38**
Hatté et al., (1998, Fig. 3A, Nuβloch)	Sediments	16000	-24.70	-25.57	-6.79	19.67	18.36	-1.31	214	**41**	**38**
Hatté et al., (1998, Fig. 3A, Nuβloch)	Sediments	17000	-24.65	-25.57	-6.72	19.67	18.38	-1.29	215	**41**	**38**
Hatté et al., (1998, Fig. 3A, Nuβloch)	Sediments	18000	-25.00	-25.57	-6.64	19.67	18.83	-0.84	232	**45**	**40**
Hatté et al., (1998, Fig. 3A, Nuβloch)	Sediments	19000	-24.70	-25.57	-6.58	19.67	18.58	-1.10	222	**42**	**39**
Hatté et al., (1998, Fig. 3A, Nuβloch)	Sediments	20000	-24.25	-25.57	-6.57	19.67	18.12	-1.55	205	**39**	**37**

Hatté et al., (1998, Fig. 3A, Nuβloch)	Sediments	21000	-23.80	-25.57	-6.60	19.67	17.62	-2.06	188	**36**	**35**
Hatté et al., (1998, Fig. 3A, Nuβloch)	Sediments	22000	-23.80	-25.57	-6.66	19.67	17.56	-2.12	187	**35**	**35**
Hatté et al., (1998, Fig. 3A, Nuβloch)	Sediments	23000	-24.70	-25.57	-6.70	19.67	18.45	-1.22	217	**41**	**38**
Hatté et al., (1998, Fig. 3A, Nuβloch)	Sediments	24000	-24.10	-25.57	-6.68	19.67	17.85	-1.82	196	**37**	**36**
Hatté et al., (1998, Fig. 3A, Nuβloch)	Sediments	25000	-24.05	-25.57	-6.55	19.67	17.93	-1.75	199	**38**	**36**
Hatté et al., (1998, Fig. 3A, Nuβloch)	Sediments	26000	-24.00	-25.57	-6.60	19.67	17.83	-1.85	195	**37**	**36**
Hatté et al., (1998, Fig. 3A, Nuβloch)	Sediments	27000	-24.20	-25.57	-6.60	19.67	18.04	-1.64	202	**38**	**37**
Hatté et al., (1998, Fig. 3A, Nuβloch)	Sediments	28000	-24.30	-25.57	-6.60	19.67	18.14	-1.53	206	**39**	**37**
Hatté et al., (1998, Fig. 3A, Nuβloch)	Sediments	29000	-24.30	-25.57	-6.60	19.67	18.14	-1.53	206	**39**	**37**
Hatté et al., (1998, Fig. 3A, Nuβloch)	Sediments	30000	-24.50	-25.57	-6.60	19.67	18.35	-1.32	214	**41**	**38**
Huang et al., (1996; Table 1; acid brown)	SOM	8	-26.70	-25.87	-6.82	19.99	20.43	**0.44**	**293**	**63**	**49**
Huang et al., (1996; Table 1; acid brown)	SOM	171	-25.70	-25.87	-6.35	19.99	19.86	**-0.13**	**264**	**54**	**44**
Huang et al., (1996; Table 1; acid brown)	SOM	1431	-26.20	-25.87	-6.37	19.99	20.36	**0.37**	**289**	**62**	**48**
Huang et al., (1996; Table 1; acid brown)	SOM	2218	-26.10	-25.87	-6.36	19.99	20.27	**0.29**	**285**	**60**	**48**
Huang et al., (1996; Table 1; acid brown)	SOM	2223	-26.20	-25.87	-6.36	19.99	20.38	**0.39**	**290**	**62**	**48**
Huang et al., (1996; Table 1; acid brown)	SOM	2597	-26.30	-25.87	-6.35	19.99	20.49	**0.50**	**296**	**64**	**49**
Huang et al., (1996; Table 1; acid brown)	SOM	3227	-26.10	-25.87	-6.34	19.99	20.29	**0.31**	**286**	**61**	**48**
Huang et al., (1996; Table 1; acid brown)	SOM	4133	-25.80	-25.87	-6.33	19.99	19.99	**0.00**	**270**	**56**	**45**
Huang et al., (1996; Table 1; acid brown)	SOM	4406	-25.80	-25.87	-6.33	19.99	19.99	**0.00**	**270**	**56**	**45**
Huang et al., (1996; Table 1; acid brown)	SOM	4531	-25.60	-25.87	-6.33	19.99	19.78	**-0.21**	**260**	**53**	**44**
Huang et al., (1996; Table 1; acid brown)	SOM	4551	-25.40	-25.87	-6.33	19.99	19.57	**-0.42**	**250**	**50**	**42**
Huang et al., (1996; Table 1; acid brown)	SOM	4828	-25.90	-25.87	-6.33	19.99	20.09	**0.11**	**275**	**58**	**46**
Huang et al., (1996; Table 1; acid brown)	SOM	5380	-25.30	-25.87	-6.33	19.99	19.46	**-0.52**	**246**	**49**	**42**
Huang et al., (1996; Table 1; pleaty gley)	SOM	5	-28.10	-25.33	-6.83	19.42	21.88	**2.46**	**440**	**114**	**83**
Huang et al., (1996; Table 1; pleaty gley)	SOM	45	-27.50	-25.33	-6.66	19.42	21.43	**2.01**	**399**	**99**	**73**
Huang et al., (1996; Table 1; pleaty gley)	SOM	540	-26.60	-25.33	-6.37	19.42	20.78	**1.36**	**349**	**82**	**61**
Huang et al., (1996; Table 1; pleaty gley)	SOM	707	-26.30	-25.33	-6.38	19.42	20.46	**1.04**	**328**	**75**	**56**
Huang et al., (1996; Table 1; pleaty gley)	SOM	1661	-26.80	-25.33	-6.37	19.42	20.99	**1.57**	**365**	**87**	**64**
Huang et al., (1996; Table 1; pleaty gley)	SOM	2574	-26.60	-25.33	-6.35	19.42	20.81	**1.38**	**351**	**82**	**61**
Huang et al., (1996; Table 1; pleaty gley)	SOM	5573	-26.20	-25.33	-6.33	19.42	20.41	**0.98**	**325**	**73**	**55**
Huang et al., (1996; Table 1; pleaty gley)	SOM	5651	-25.70	-25.33	-6.33	19.42	19.88	**0.46**	**294**	**63**	**49**
Huang et al., (1996; Table 1; pleaty gley)	SOM	6896	-25.70	-25.33	-6.35	19.42	19.86	**0.44**	**293**	**63**	**49**
Huang et al., (1996; Table 1; pleaty gley)	SOM	7963	-24.30	-25.33	-6.38	19.42	18.36	**-1.06**	**224**	**43**	**39**
Huang et al., (1996; Table 1; pleaty gley)	SOM	9218	-25.10	-25.33	-6.46	19.42	19.12	**-0.30**	**256**	**52**	**43**
Huang et al., (1996; Table 1; pleaty gley)	SOM	10559	-23.50	-25.33	-6.58	19.42	17.32	**-2.10**	**187**	**36**	**35**
Huang et al., (1996; Table 1; pleaty gley)	SOM	11896	-23.40	-25.33	-6.72	19.42	17.08	**-2.34**	**180**	**34**	**34**
Huang et al., (1996; Table 1; pleaty gley)	SOM	12383	-23.70	-25.33	-6.76	19.42	17.35	**-2.07**	**188**	**36**	**35**
Kao et al., (2008; TOC dates from Table 1)	Sediments	7817	-22.55	-22.50	-6.38	16.47	16.55	**0.08**	**274**	**57**	**46**
Kao et al., (2008; TOC dates from Table 1)	Sediments	12987	-22.45	-22.50	-6.80	16.47	16.01	**-0.46**	**248**	**49**	**42**
Kao et al., (2008; TOC dates from Table 1)	Sediments	15778	-22.60	-22.50	-6.81	16.47	16.16	**-0.31**	**255**	**51**	**43**
Kao et al., (2008; TOC dates from Table 1)	Sediments	16313	-22.90	-22.50	-6.77	16.47	16.51	**0.03**	**272**	**56**	**46**
Kao et al., (2008; TOC dates from Table 1)	Sediments	18404	-22.90	-22.50	-6.61	16.47	16.67	**0.20**	**280**	**59**	**47**
Kao et al., (2008; TOC dates from Table 1)	Sediments	21972	-22.45	-22.50	-6.66	16.47	16.15	**-0.32**	**255**	**51**	**43**
Kao et al., (2008; TOC dates from Table 1)	Sediments	24598	-21.85	-22.50	-6.61	16.47	15.58	**-0.89**	**230**	**44**	**40**
Li et al., (2013; Fig. 9g, 500-yr intervals)	Sediments	1500	-27.50	-26.64	-6.37	20.79	21.72	**0.93**	**321**	**72**	**54**
Li et al., (2013; Fig. 9g, 500-yr intervals)	Sediments	2000	-28.00	-26.64	-6.36	20.79	22.26	**1.47**	**357**	**84**	**63**

Li et al., (2013; Fig. 9g, 500-yr intervals)	Sediments	2500	-28.50	-26.64	-6.35	20.79	22.80	**2.01**	**399**	**99**	**73**
Li et al., (2013; Fig. 9g, 500-yr intervals)	Sediments	3000	-27.00	-26.64	-6.34	20.79	21.23	**0.44**	**293**	**63**	**49**
Li et al., (2013; Fig. 9g, 500-yr intervals)	Sediments	3500	-26.50	-26.64	-6.33	20.79	20.72	**-0.08**	**266**	**55**	**45**
Li et al., (2013; Fig. 9g, 500-yr intervals)	Sediments	4000	-25.50	-26.64	-6.33	20.79	19.67	**-1.12**	**221**	**42**	**39**
Li et al., (2013; Fig. 9g, 500-yr intervals)	Sediments	4500	-25.00	-26.64	-6.33	20.79	19.15	**-1.64**	**202**	**38**	**36**
Li et al., (2013; Fig. 9g, 500-yr intervals)	Sediments	5000	-25.00	-26.64	-6.33	20.79	19.15	**-1.64**	**202**	**38**	**37**
Li et al., (2013; Fig. 9g, 500-yr intervals)	Sediments	5500	-26.00	-26.64	-6.33	20.79	20.20	**-0.60**	**243**	**48**	**41**
Li et al., (2013; Fig. 9g, 500-yr intervals)	Sediments	6000	-23.00	-26.64	-6.33	20.79	17.06	**-3.73**	**142**	**29**	**31**
Li et al., (2013; Fig. 9g, 500-yr intervals)	Sediments	6500	-25.50	-26.64	-6.34	20.79	19.66	**-1.13**	**221**	**42**	**39**
Li et al., (2013; Fig. 9g, 500-yr intervals)	Sediments	7000	-25.50	-26.64	-6.35	20.79	19.65	**-1.14**	**220**	**42**	**39**
Li et al., (2013; Fig. 9g, 500-yr intervals)	Sediments	7500	-26.50	-26.64	-6.36	20.79	20.68	**-0.11**	**265**	**54**	**44**
Li et al., (2013; Fig. 9g, 500-yr intervals)	Sediments	8000	-26.00	-26.64	-6.38	20.79	20.14	**-0.66**	**240**	**47**	**41**
Li et al., (2013; Fig. 9g, 500-yr intervals)	Sediments	8500	-27.50	-26.64	-6.41	20.79	21.68	**0.89**	**319**	**71**	**53**
Li et al., (2013; Fig. 9g, 500-yr intervals)	Sediments	9000	-29.50	-26.64	-6.45	20.79	23.75	**2.96**	**492**	**138**	**98**
Li et al., (2013; Fig. 9g, 500-yr intervals)	Sediments	9500	-24.00	-26.64	-6.49	20.79	17.95	**-2.85**	**165**	**32**	**33**
Li et al., (2013; Fig. 9g, 500-yr intervals)	Sediments	10000	-28.00	-26.64	-6.53	20.79	22.09	**1.29**	**345**	**80**	**60**
Li et al., (2013; Fig. 9g, 500-yr intervals)	Sediments	10500	-28.50	-26.64	-6.58	20.79	22.56	**1.77**	**380**	**92**	**68**
Li et al., (2013; Fig. 9g, 500-yr intervals)	Sediments	11000	-29.50	-26.64	-6.63	20.79	23.57	**2.77**	**471**	**128**	**92**
Li et al., (2013; Fig. 9g, 500-yr intervals)	Sediments	11500	-27.00	-26.64	-6.68	20.79	20.89	**0.09**	**275**	**57**	**46**
Li et al., (2013; Fig. 9g, 500-yr intervals)	Sediments	12000	-28.00	-26.64	-6.73	20.79	21.89	**1.09**	**332**	**76**	**56**
Li et al., (2013; Fig. 9g, 500-yr intervals)	Sediments	12500	-28.50	-26.64	-6.77	20.79	22.37	**1.58**	**365**	**87**	**64**
Li et al., (2013; Fig. 9g, 500-yr intervals)	Sediments	13000	-27.50	-26.64	-6.80	20.79	21.28	**0.49**	**295**	**64**	**49**
Li et al., (2013; Fig. 9g, 500-yr intervals)	Sediments	13500	-28.50	-26.64	-6.83	20.79	22.31	**1.51**	**360**	**85**	**63**
Li et al., (2013; Fig. 9g, 500-yr intervals)	Sediments	14000	-28.50	-26.64	-6.84	20.79	22.29	**1.50**	**359**	**85**	**63**
Li et al., (2013; Fig. 9g, 500-yr intervals)	Sediments	14500	-28.00	-26.64	-6.85	20.79	21.76	**0.97**	**324**	**73**	**55**
Li et al., (2013; Fig. 9g, 500-yr intervals)	Sediments	15000	-27.00	-26.64	-6.84	20.79	20.72	**-0.07**	**266**	**55**	**45**
Li et al., (2013; Fig. 9g, 500-yr intervals)	Sediments	15500	-26.50	-26.64	-6.82	20.79	20.21	**-0.58**	**243**	**48**	**41**
Li et al., (2013; Fig. 9g, 500-yr intervals)	Sediments	16000	-26.50	-26.64	-6.79	20.79	20.24	**-0.55**	**245**	**48**	**42**
Li et al., (2013; Fig. 9g, 500-yr intervals)	Sediments	16500	-26.00	-26.64	-6.76	20.79	19.76	**-1.04**	**224**	**43**	**39**
Li et al., (2013; Fig. 9g, 500-yr intervals)	Sediments	17000	-27.50	-26.64	-6.72	20.79	21.37	**0.57**	**300**	**65**	**50**
Li et al., (2013; Fig. 9g, 500-yr intervals)	Sediments	17500	-25.00	-26.64	-6.68	20.79	18.79	**-2.00**	**190**	**36**	**35**
Li et al., (2013; Fig. 9g, 500-yr intervals)	Sediments	18000	-18.50	-26.64	-6.64	20.79	12.08	**-8.71**	**57**	**20**	**28**
Li et al., (2013; Fig. 9g, 500-yr intervals)	Sediments	18500	-26.00	-26.64	-6.61	20.79	19.91	**-0.88**	**231**	**44**	**40**
Li et al., (2013; Fig. 9g, 500-yr intervals)	Sediments	19000	-25.50	-26.64	-6.58	20.79	19.41	**-1.38**	**212**	**40**	**38**
Li et al., (2013; Fig. 9g, 500-yr intervals)	Sediments	19500	-23.50	-26.64	-6.57	20.79	17.34	**-3.46**	**149**	**29**	**32**
Li et al., (2013; Fig. 9g, 500-yr intervals)	Sediments	20000	-24.00	-26.64	-6.57	20.79	17.86	**-2.93**	**163**	**31**	**33**
Li et al., (2013; Fig. 9g, 500-yr intervals)	Sediments	20500	-24.00	-26.64	-6.58	20.79	17.85	**-2.95**	**162**	**31**	**33**
Li et al., (2013; Fig. 9g, 500-yr intervals)	Sediments	21000	-25.50	-26.64	-6.60	20.79	19.39	**-1.40**	**211**	**40**	**37**
Li et al., (2013; Fig. 9g, 500-yr intervals)	Sediments	21500	-23.00	-26.64	-6.63	20.79	16.76	**-4.04**	**135**	**28**	**31**
Li et al., (2013; Fig. 9g, 500-yr intervals)	Sediments	22000	-21.00	-26.64	-6.66	20.79	14.65	**-6.15**	**94**	**23**	**29**
Li et al., (2013; Fig. 9g, 500-yr intervals)	Sediments	22500	-20.00	-26.64	-6.69	20.79	13.58	**-7.21**	**77**	**21**	**28**
Li et al., (2013; Fig. 9g, 500-yr intervals)	Sediments	23000	-22.00	-26.64	-6.70	20.79	15.64	**-5.15**	**112**	**25**	**29**
Li et al., (2013; Fig. 9g, 500-yr intervals)	Sediments	23500	-24.50	-26.64	-6.70	20.79	18.25	**-2.55**	**173**	**33**	**34**
Li et al., (2013; Fig. 9g, 500-yr intervals)	Sediments	24000	-27.50	-26.64	-6.68	20.79	21.41	**0.62**	**303**	**66**	**51**
Li et al., (2013; Fig. 9g, 500-yr intervals)	Sediments	24500	-27.00	-26.64	-6.62	20.79	20.94	**0.15**	**277**	**58**	**46**
Li et al., (2013; Fig. 9g, 500-yr intervals)	Sediments	25000	-26.50	-26.64	-6.55	20.79	20.49	**-0.30**	**256**	**52**	**43**

Li et al., (2013; Fig. 9g, 500-yr intervals)	Sediments	25500	-27.00	-26.64	-6.60	20.79	20.97	**0.17**	**279**	**59**	**47**
Li et al., (2013; Fig. 9g, 500-yr intervals)	Sediments	26000	-27.50	-26.64	-6.60	20.79	21.49	**0.70**	**307**	**68**	**51**
Li et al., (2013; Fig. 9g, 500-yr intervals)	Sediments	26500	-26.50	-26.64	-6.60	20.79	20.44	**-0.35**	**253**	**51**	**43**
Li et al., (2013; Fig. 9g, 500-yr intervals)	Sediments	27000	-26.50	-26.64	-6.60	20.79	20.44	**-0.35**	**253**	**51**	**43**
Li et al., (2013; Fig. 9g, 500-yr intervals)	Sediments	27500	-23.00	-26.64	-6.60	20.79	16.79	**-4.01**	**136**	**28**	**31**
Li et al., (2013; Fig. 9g, 500-yr intervals)	Sediments	28000	-26.00	-26.64	-6.60	20.79	19.92	**-0.88**	**231**	**44**	**40**
Li et al., (2013; Fig. 9g, 500-yr intervals)	Sediments	28500	-24.00	-26.64	-6.60	20.79	17.83	**-2.97**	**162**	**31**	**33**
Li et al., (2013; Fig. 9g, 500-yr intervals)	Sediments	29000	-27.00	-26.64	-6.60	20.79	20.97	**0.17**	**279**	**59**	**47**
Lu et al., (2012; Horqin Field)	Sediments/ SOM	100	-20.81	-20.02	-6.40	13.90	14.72	**0.82**	**315**	**71**	**53**
Lu et al., (2012; Horqin Field)	Sediments/ SOM	760	-20.50	-20.02	-6.38	13.90	14.42	**0.52**	**297**	**64**	**50**
Lu et al., (2012; Horqin Field)	Sediments/ SOM	3150	-19.54	-20.02	-6.34	13.90	13.47	**-0.43**	**250**	**50**	**42**
Lu et al., (2012; Horqin Field)	Sediments/ SOM	10310	-22.49	-20.02	-6.56	13.90	16.30	**2.40**	**433**	**112**	**82**
Lu et al., (2012; Horqin Field)	Sediments/ SOM	10800	-25.00	-20.02	-6.61	13.90	18.86	**4.97**	**848**	**423**	**213**
Lu et al., (2012; Horqin Field)	Sediments/ SOM	19550	-20.31	-20.02	-6.57	13.90	14.03	**0.13**	**276**	**58**	**46**
Lu et al., (2012; Mu Us Dune Field)	Sediments/ SOM	100	-22.24	-22.91	-6.40	16.90	16.20	**-0.69**	**238**	**47**	**41**
Lu et al., (2012; Mu Us Dune Field)	Sediments/ SOM	290	-24.77	-22.91	-6.36	16.90	18.88	**1.98**	**397**	**98**	**72**
Lu et al., (2012; Mu Us Dune Field)	Sediments/ SOM	2390	-23.56	-22.91	-6.35	16.90	17.62	**0.73**	**309**	**68**	**52**
Lu et al., (2012; Mu Us Dune Field)	Sediments/ SOM	7290	-21.07	-22.91	-6.36	16.90	15.03	**-1.87**	**195**	**37**	**36**
Lu et al., (2012; Mu Us Dune Field)	Sediments/ SOM	7390	-18.87	-22.91	-6.36	16.90	12.75	**-4.15**	**133**	**27**	**30**
Lu et al., (2012; Mu Us Dune Field)	Sediments/ SOM	7560	-23.34	-22.91	-6.37	16.90	17.47	**0.58**	**300**	**66**	**50**
Lu et al., (2012; Mu Us Dune Field)	Sediments/ SOM	7560	-23.43	-22.91	-6.37	16.90	17.38	**0.48**	**295**	**64**	**49**
Lu et al., (2012; Mu Us Dune Field)	Sediments/ SOM	7810	-22.35	-22.91	-6.38	16.90	16.34	**-0.56**	**244**	**48**	**42**
Lu et al., (2012; Mu Us Dune Field)	Sediments/ SOM	8100	-23.84	-22.91	-6.39	16.90	17.88	**0.98**	**324**	**73**	**55**
Lu et al., (2012; Mu Us Dune Field)	Sediments/ SOM	8380	-24.01	-22.91	-6.41	16.90	18.04	**1.14**	**335**	**77**	**57**
Lu et al., (2012; Mu Us Dune Field)	Sediments/ SOM	8550	-23.76	-22.91	-6.42	16.90	17.77	**0.87**	**318**	**71**	**53**
Lu et al., (2012; Mu Us Dune Field)	Sediments/ SOM	9780	-23.09	-22.91	-6.51	16.90	16.97	**0.07**	**274**	**57**	**46**
Lu et al., (2012; Mu Us Dune Field)	Sediments/ SOM	9980	-23.85	-22.91	-6.53	16.90	17.75	**0.85**	**316**	**71**	**53**

Lu et al., (2012; Mu Us Dune Field)	Sediments/ SOM	10045	-21.09	-22.91	-6.53	16.90	14.87	**-2.03**	**189**	**36**	**35**
Lu et al., (2012; Mu Us Dune Field)	Sediments/ SOM	11000	-23.68	-22.91	-6.63	16.90	17.47	**0.57**	**300**	**65**	**50**
Lu et al., (2012; Mu Us Dune Field)	Sediments/ SOM	12700	-21.89	-22.91	-6.78	16.90	15.45	**-1.45**	**209**	**40**	**37**
Lu et al., (2012; Mu Us Dune Field)	Sediments/ SOM	13175	-22.94	-22.91	-6.81	16.90	16.51	**-0.39**	**252**	**50**	**43**
Lu et al., (2012; Mu Us Dune Field)	Sediments/ SOM	13650	-23.67	-22.91	-6.83	16.90	17.24	**0.35**	**288**	**62**	**48**
Lu et al., (2012; Mu Us Dune Field)	Sediments/ SOM	25680	-22.50	-22.91	-6.60	16.90	16.27	**-0.63**	**241**	**47**	**41**
Lu et al., (2012; Otindag Dune Field)	Sediments/ SOM	100	-23.80	-23.85	-6.40	17.88	17.83	**-0.05**	**268**	**56**	**45**
Lu et al., (2012; Otindag Dune Field)	Sediments/ SOM	130	-24.59	-23.85	-6.34	17.88	18.70	**0.83**	**315**	**70**	**53**
Lu et al., (2012; Otindag Dune Field)	Sediments/ SOM	140	-24.92	-23.85	-6.35	17.88	19.05	**1.17**	**337**	**77**	**58**
Lu et al., (2012; Otindag Dune Field)	Sediments/ SOM	430	-23.60	-23.85	-6.37	17.88	17.65	**-0.23**	**259**	**53**	**44**
Lu et al., (2012; Otindag Dune Field)	Sediments/ SOM	490	-23.45	-23.85	-6.37	17.88	17.49	**-0.39**	**252**	**50**	**43**
Lu et al., (2012; Otindag Dune Field)	Sediments/ SOM	560	-23.77	-23.85	-6.37	17.88	17.82	**-0.06**	**267**	**55**	**45**
Lu et al., (2012; Otindag Dune Field)	Sediments/ SOM	630	-23.77	-23.85	-6.38	17.88	17.82	**-0.06**	**267**	**55**	**45**
Lu et al., (2012; Otindag Dune Field)	Sediments/ SOM	630	-23.57	-23.85	-6.38	17.88	17.61	**-0.27**	**257**	**52**	**43**
Lu et al., (2012; Otindag Dune Field)	Sediments/ SOM	630	-22.81	-23.85	-6.38	17.88	16.82	**-1.06**	**224**	**43**	**39**
Lu et al., (2012; Otindag Dune Field)	Sediments/ SOM	660	-24.61	-23.85	-6.38	17.88	18.69	**0.82**	**314**	**70**	**52**
Lu et al., (2012; Otindag Dune Field)	Sediments/ SOM	680	-24.63	-23.85	-6.38	17.88	18.71	**0.84**	**316**	**70**	**53**
Lu et al., (2012; Otindag Dune Field)	Sediments/ SOM	710	-24.62	-23.85	-6.38	17.88	18.70	**0.83**	**315**	**70**	**53**
Lu et al., (2012; Otindag Dune Field)	Sediments/ SOM	740	-23.33	-23.85	-6.38	17.88	17.36	**-0.52**	**246**	**49**	**42**
Lu et al., (2012; Otindag Dune Field)	Sediments/ SOM	950	-23.52	-23.85	-6.38	17.88	17.55	**-0.32**	**255**	**51**	**43**
Lu et al., (2012; Otindag Dune Field)	Sediments/ SOM	980	-23.94	-23.85	-6.38	17.88	17.99	**0.11**	**276**	**58**	**46**
Lu et al., (2012; Otindag Dune Field)	Sediments/ SOM	1220	-23.32	-23.85	-6.38	17.88	17.35	**-0.53**	**245**	**48**	**42**
Lu et al., (2012; Otindag Dune Field)	Sediments/ SOM	1300	-23.99	-23.85	-6.38	17.88	18.05	**0.17**	**279**	**59**	**47**

Lu et al., (2012; Otindag Dune Field)	Sediments/ SOM	1530	-25.06	-23.85	-6.37	17.88	19.17	**1.29**	**345**	**80**	**60**
Lu et al., (2012; Otindag Dune Field)	Sediments/ SOM	1580	-22.78	-23.85	-6.37	17.88	16.79	**-1.08**	**223**	**42**	**39**
Lu et al., (2012; Otindag Dune Field)	Sediments/ SOM	1620	-23.83	-23.85	-6.37	17.88	17.89	**0.01**	**270**	**56**	**45**
Lu et al., (2012; Otindag Dune Field)	Sediments/ SOM	2030	-22.97	-23.85	-6.36	17.88	17.00	**-0.88**	**231**	**44**	**40**
Lu et al., (2012; Otindag Dune Field)	Sediments/ SOM	2340	-24.21	-23.85	-6.35	17.88	18.30	**0.42**	**292**	**63**	**49**
Lu et al., (2012; Otindag Dune Field)	Sediments/ SOM	2700	-23.98	-23.85	-6.34	17.88	18.07	**0.19**	**280**	**59**	**47**
Lu et al., (2012; Otindag Dune Field)	Sediments/ SOM	2730	-23.33	-23.85	-6.34	17.88	17.39	**-0.48**	**247**	**49**	**42**
Lu et al., (2012; Otindag Dune Field)	Sediments/ SOM	2760	-23.18	-23.85	-6.34	17.88	17.24	**-0.64**	**241**	**47**	**41**
Lu et al., (2012; Otindag Dune Field)	Sediments/ SOM	3320	-23.61	-23.85	-6.34	17.88	17.69	**-0.18**	**261**	**53**	**44**
Lu et al., (2012; Otindag Dune Field)	Sediments/ SOM	4040	-23.61	-23.85	-6.33	17.88	17.70	**-0.18**	**261**	**53**	**44**
Lu et al., (2012; Otindag Dune Field)	Sediments/ SOM	4060	-24.90	-23.85	-6.33	17.88	19.05	**1.17**	**336**	**77**	**58**
Lu et al., (2012; Otindag Dune Field)	Sediments/ SOM	4460	-23.08	-23.85	-6.33	17.88	17.15	**-0.73**	**237**	**46**	**41**
Lu et al., (2012; Otindag Dune Field)	Sediments/ SOM	4480	-23.25	-23.85	-6.33	17.88	17.33	**-0.55**	**245**	**48**	**42**
Lu et al., (2012; Otindag Dune Field)	Sediments/ SOM	4970	-24.15	-23.85	-6.33	17.88	18.26	**0.39**	**290**	**62**	**48**
Lu et al., (2012; Otindag Dune Field)	Sediments/ SOM	5020	-23.13	-23.85	-6.33	17.88	17.20	**-0.68**	**239**	**47**	**41**
Lu et al., (2012; Otindag Dune Field)	Sediments/ SOM	5150	-23.00	-23.85	-6.33	17.88	17.07	**-0.81**	**234**	**45**	**40**
Lu et al., (2012; Otindag Dune Field)	Sediments/ SOM	5240	-23.21	-23.85	-6.33	17.88	17.28	**-0.59**	**243**	**48**	**41**
Lu et al., (2012; Otindag Dune Field)	Sediments/ SOM	6640	-24.13	-23.85	-6.34	17.88	18.23	**0.35**	**288**	**62**	**48**
Lu et al., (2012; Otindag Dune Field)	Sediments/ SOM	7730	-23.39	-23.85	-6.37	17.88	17.42	**-0.45**	**249**	**50**	**42**
Lu et al., (2012; Otindag Dune Field)	Sediments/ SOM	7960	-23.19	-23.85	-6.38	17.88	17.21	**-0.67**	**239**	**47**	**41**
Lu et al., (2012; Otindag Dune Field)	Sediments/ SOM	8210	-24.97	-23.85	-6.40	17.88	19.05	**1.17**	**337**	**77**	**58**
Lu et al., (2012; Otindag Dune Field)	Sediments/ SOM	8680	-23.53	-23.85	-6.42	17.88	17.52	**-0.36**	**253**	**51**	**43**
Lu et al., (2012; Otindag Dune Field)	Sediments/ SOM	8720	-24.32	-23.85	-6.43	17.88	18.34	**0.46**	**294**	**64**	**49**

Lu et al., (2012; Otindag Dune Field)	Sediments/ SOM	8740	-24.62	-23.85	-6.43	17.88	18.65	**0.78**	**312**	**69**	**52**
Lu et al., (2012; Otindag Dune Field)	Sediments/ SOM	8880	-25.01	-23.85	-6.44	17.88	19.05	**1.17**	**337**	**77**	**58**
Lu et al., (2012; Otindag Dune Field)	Sediments/ SOM	9115	-23.91	-23.85	-6.45	17.88	17.88	**0.01**	**270**	**56**	**45**
Lu et al., (2012; Otindag Dune Field)	Sediments/ SOM	9370	-23.94	-23.85	-6.47	17.88	17.89	**0.02**	**271**	**56**	**45**
Lu et al., (2012; Otindag Dune Field)	Sediments/ SOM	9900	-24.84	-23.85	-6.52	17.88	18.79	**0.91**	**320**	**72**	**54**
Lu et al., (2012; Otindag Dune Field)	Sediments/ SOM	17730	-23.50	-23.85	-6.66	17.88	17.25	**-0.63**	**241**	**47**	**41**
Menking et al., (2012; Fig. 3, Minnewaska)	Sediments	4950	-28.50	-28.83	-6.33	23.10	22.82	**-0.27**	**257**	**52**	**43**
Menking et al., (2012; Fig. 3, Minnewaska)	Sediments	5298	-28.50	-28.83	-6.33	23.10	22.82	**-0.27**	**257**	**52**	**43**
Menking et al., (2012; Fig. 3, Minnewaska)	Sediments	5646	-28.00	-28.83	-6.33	23.10	22.30	**-0.80**	**234**	**45**	**40**
Menking et al., (2012; Fig. 3, Minnewaska)	Sediments	5994	-28.75	-28.83	-6.33	23.10	23.08	**-0.01**	**269**	**56**	**45**
Menking et al., (2012; Fig. 3, Minnewaska)	Sediments	6342	-27.80	-28.83	-6.34	23.10	22.08	**-1.02**	**225**	**43**	**39**
Menking et al., (2012; Fig. 3, Minnewaska)	Sediments	6689	-28.75	-28.83	-6.34	23.10	23.07	**-0.02**	**269**	**56**	**45**
Menking et al., (2012; Fig. 3, Minnewaska)	Sediments	7037	-28.50	-28.83	-6.35	23.10	22.80	**-0.30**	**256**	**52**	**43**
Menking et al., (2012; Fig. 3, Minnewaska)	Sediments	7385	-29.50	-28.83	-6.36	23.10	23.84	**0.75**	**310**	**69**	**52**
Menking et al., (2012; Fig. 3, Minnewaska)	Sediments	7733	-29.00	-28.83	-6.37	23.10	23.30	**0.21**	**280**	**59**	**47**
Menking et al., (2012; Fig. 3, Minnewaska)	Sediments	8081	-28.80	-28.83	-6.39	23.10	23.08	**-0.02**	**269**	**56**	**45**
Menking et al., (2012; Fig. 3, Minnewaska)	Sediments	8600	-29.00	-28.83	-6.42	23.10	23.26	**0.16**	**278**	**58**	**46**
Menking et al., (2012; Fig. 3, Minnewaska)	Sediments	9119	-29.50	-28.83	-6.45	23.10	23.75	**0.65**	**305**	**67**	**51**
Menking et al., (2012; Fig. 3, Minnewaska)	Sediments	9638	-29.25	-28.83	-6.50	23.10	23.44	**0.34**	**288**	**61**	**48**
Menking et al., (2012; Fig. 3, Minnewaska)	Sediments	10157	-29.00	-28.83	-6.54	23.10	23.13	**0.03**	**271**	**56**	**45**
Menking et al., (2012; Fig. 3, Minnewaska)	Sediments	10676	-28.50	-28.83	-6.60	23.10	22.55	**-0.55**	**245**	**48**	**42**
Menking et al., (2012; Fig. 3, Minnewaska)	Sediments	11195	-30.00	-28.83	-6.65	23.10	24.07	**0.98**	**324**	**73**	**55**
Menking et al., (2012; Fig. 3, Minnewaska)	Sediments	11714	-29.50	-28.83	-6.70	23.10	23.49	**0.40**	**291**	**62**	**48**
Menking et al., (2012; Fig. 3, Minnewaska)	Sediments	12295	-30.00	-28.83	-6.75	23.10	23.97	**0.87**	**318**	**71**	**53**
Menking et al., (2012; Fig. 3, Minnewaska)	Sediments	13828	-29.50	-28.83	-6.84	23.10	23.35	**0.25**	**283**	**60**	**47**
Menking et al., (2012; Fig. 3, Minnewaska)	Sediments	14780	-28.50	-28.83	-6.84	23.10	22.29	**-0.81**	**234**	**45**	**40**
Menking et al., (2012; Fig. 3, Minnewaska)	Sediments	15733	-28.50	-28.83	-6.81	23.10	22.33	**-0.77**	**235**	**45**	**40**
Menking et al., (2012; Fig. 3, Minnewaska)	Sediments	16686	-27.25	-28.83	-6.74	23.10	21.08	**-2.02**	**190**	**36**	**35**
Menking et al., (2012; Fig. 3, Minnewaska)	Sediments	17639	-24.00	-28.83	-6.67	23.10	17.76	**-5.34**	**108**	**24**	**29**
Norstrom et al., (2009; Fig. 5, 500-year intervals)	Peat	500	-22.00	-22.70	-6.37	16.68	15.98	**-0.70**	**238**	**46**	**41**
Norstrom et al., (2009; Fig. 5, 500-year intervals)	Peat	1000	-22.00	-22.70	-6.38	16.68	15.97	**-0.71**	**238**	**46**	**41**
Norstrom et al., (2009; Fig. 5, 500-year intervals)	Peat	1500	-22.50	-22.70	-6.37	16.68	16.50	**-0.18**	**261**	**53**	**44**
Norstrom et al., (2009; Fig. 5, 500-year intervals)	Peat	2000	-22.30	-22.70	-6.36	16.68	16.30	**-0.38**	**252**	**51**	**43**
Norstrom et al., (2009; Fig. 5, 500-year intervals)	Peat	2500	-22.25	-22.70	-6.35	16.68	16.26	**-0.42**	**251**	**50**	**42**
Norstrom et al., (2009; Fig. 5, 500-year	Peat	3000	-22.20	-22.70	-6.34	16.68	16.22	**-0.46**	**249**	**49**	**42**

intervals)											
Norstrom et al., (2009; Fig. 5, 500-year intervals)	Peat	3500	-22.00	-22.70	-6.33	16.68	16.02	**-0.66**	**240**	**47**	**41**
Norstrom et al., (2009; Fig. 5, 500-year intervals)	Peat	4000	-21.80	-22.70	-6.33	16.68	15.82	**-0.86**	**231**	**44**	**40**
Norstrom et al., (2009; Fig. 5, 500-year intervals)	Peat	4500	-21.70	-22.70	-6.33	16.68	15.71	**-0.96**	**227**	**43**	**39**
Norstrom et al., (2009; Fig. 5, 500-year intervals)	Peat	5000	-21.60	-22.70	-6.33	16.68	15.61	**-1.07**	**223**	**43**	**39**
Norstrom et al., (2009; Fig. 5, 500-year intervals)	Peat	5500	-21.90	-22.70	-6.33	16.68	15.92	**-0.76**	**236**	**46**	**40**
Norstrom et al., (2009; Fig. 5, 500-year intervals)	Peat	6000	-21.90	-22.70	-6.33	16.68	15.92	**-0.76**	**236**	**46**	**40**
Norstrom et al., (2009; Fig. 5, 500-year intervals)	Peat	6500	-21.80	-22.70	-6.34	16.68	15.81	**-0.87**	**231**	**44**	**40**
Norstrom et al., (2009; Fig. 5, 500-year intervals)	Peat	7000	-21.80	-22.70	-6.35	16.68	15.80	**-0.88**	**231**	**44**	**40**
Norstrom et al., (2009; Fig. 5, 500-year intervals)	Peat	7500	-22.10	-22.70	-6.36	16.68	16.09	**-0.59**	**243**	**48**	**41**
Norstrom et al., (2009; Fig. 5, 500-year intervals)	Peat	8000	-23.00	-22.70	-6.38	16.68	17.01	**0.33**	**287**	**61**	**48**
Norstrom et al., (2009; Fig. 5, 500-year intervals)	Peat	8500	-24.00	-22.70	-6.41	16.68	18.02	**1.34**	**348**	**81**	**60**
Norstrom et al., (2009; Fig. 5, 500-year intervals)	Peat	9000	-22.75	-22.70	-6.45	16.68	16.68	**0.01**	**270**	**56**	**45**
Norstrom et al., (2009; Fig. 5, 500-year intervals)	Peat	9500	-25.50	-22.70	-6.49	16.68	19.51	**2.83**	**478**	**131**	**94**
Norstrom et al., (2009; Fig. 5, 500-year intervals)	Peat	10000	-24.20	-22.70	-6.53	16.68	18.11	**1.43**	**354**	**83**	**62**
Norstrom et al., (2009; Fig. 5, 500-year intervals)	Peat	10500	-25.30	-22.70	-6.58	16.68	19.21	**2.53**	**446**	**116**	**85**
Norstrom et al., (2009; Fig. 5, 500-year intervals)	Peat	11000	-24.00	-22.70	-6.63	16.68	17.80	**1.12**	**333**	**76**	**57**
Norstrom et al., (2009; Fig. 5, 500-year intervals)	Peat	11500	-23.50	-22.70	-6.68	16.68	17.23	**0.55**	**299**	**65**	**50**
Norstrom et al., (2009; Fig. 5, 500-year intervals)	Peat	12000	-22.20	-22.70	-6.73	16.68	15.83	**-0.85**	**232**	**44**	**40**
Norstrom et al., (2009; Fig. 5, 500-year intervals)	Peat	12500	-22.00	-22.70	-6.77	16.68	15.57	**-1.10**	**222**	**42**	**39**
Norstrom et al., (2009; Fig. 5, 500-year intervals)	Peat	13000	-23.00	-22.70	-6.80	16.68	16.58	**-0.10**	**265**	**54**	**45**
Norstrom et al., (2009; Fig. 5, 500-year intervals)	Peat	13500	-23.50	-22.70	-6.83	16.68	17.07	**0.39**	**290**	**62**	**48**
Norstrom et al., (2009; Fig. 5, 500-year intervals)	Peat	14000	-22.00	-22.70	-6.84	16.68	15.50	**-1.18**	**219**	**42**	**38**
Norstrom et al., (2009; Fig. 5, 500-year	Peat	14500	-21.00	-22.70	-6.85	16.68	14.46	**-2.22**	**183**	**35**	**35**

intervals)											
Norstrom et al., (2009; Fig. 5, 500-year intervals)	Peat	15000	-20.90	-22.70	-6.84	16.68	14.36	**-2.32**	**180**	**34**	**34**
Norstrom et al., (2009; Fig. 5, 500-year intervals)	Peat	15500	-20.80	-22.70	-6.82	16.68	14.28	**-2.40**	**178**	**34**	**34**
Rommerskirchen et al (2006; Table 3)	Sediments	1000	-19.4	-20.58	-6.38	14.48	13.28	**-1.20**	**218**	**42**	**38**
Rommerskirchen et al (2006; Table 3)	Sediments	1000	-20.7	-20.58	-6.38	14.48	14.62	**0.15**	**277**	**58**	**46**
Rommerskirchen et al (2006; Table 3)	Sediments	2000	-22.3	-20.58	-6.36	14.48	16.30	**1.82**	**384**	**94**	**69**
Rommerskirchen et al (2006; Table 3)	Sediments	3000	-21.2	-20.58	-6.34	14.48	15.18	**0.70**	**308**	**68**	**51**
Rommerskirchen et al (2006; Table 3)	Sediments	3800	-20.2	-20.58	-6.33	14.48	14.16	**-0.32**	**255**	**51**	**43**
Rommerskirchen et al (2006; Table 3)	Sediments	4000	-20.0	-20.58	-6.33	14.48	13.95	**-0.53**	**246**	**49**	**42**
Rommerskirchen et al (2006; Table 3)	Sediments	5000	-21.4	-20.58	-6.33	14.48	15.40	**0.93**	**321**	**72**	**54**
Rommerskirchen et al (2006; Table 3)	Sediments	5300	-20.3	-20.58	-6.33	14.48	14.26	**-0.22**	**260**	**53**	**44**
Rommerskirchen et al (2006; Table 3)	Sediments	6800	-19.7	-20.58	-6.34	14.48	13.62	**-0.85**	**232**	**44**	**40**
Rommerskirchen et al (2006; Table 3)	Sediments	17000	-21.6	-20.58	-6.72	14.48	15.21	**0.73**	**309**	**68**	**52**
Rommerskirchen et al (2006; Table 3)	Sediments	18000	-18.7	-20.58	-6.64	14.48	12.29	**-2.19**	**184**	**35**	**35**
Rommerskirchen et al (2006; Table 3)	Sediments	18000	-20.5	-20.58	-6.64	14.48	14.15	**-0.33**	**254**	**51**	**43**
Rommerskirchen et al (2006; Table 3)	Sediments	19000	-20.2	-20.58	-6.58	14.48	13.90	**-0.58**	**243**	**48**	**41**
Rommerskirchen et al (2006; Table 3)	Sediments	19000	-19.6	-20.58	-6.58	14.48	13.28	**-1.20**	**218**	**42**	**38**
Rommerskirchen et al (2006; Table 3)	Sediments	20000	-19.2	-20.58	-6.57	14.48	12.88	**-1.60**	**204**	**39**	**37**
Rommerskirchen et al (2006; Table 3)	Sediments	21000	-20.1	-20.58	-6.60	14.48	13.78	**-0.70**	**238**	**46**	**41**
Rommerskirchen et al (2006; Table 3)	Sediments	23000	-20.2	-20.58	-6.70	14.48	13.77	**-0.70**	**238**	**46**	**41**
Rommerskirchen et al (2006; Table 3)	Sediments	26000	-19.5	-20.58	-6.42	14.48	13.34	**-1.14**	**221**	**41**	**38**
Ruiz Pessenda et al., (2009; Table 4)	SOM	115	-25.10	-26.48	-6.34	20.63	19.24	**-1.39**	**211**	**40**	**38**
Ruiz Pessenda et al., (2009; Table 4)	SOM	345	-25.10	-26.48	-6.36	20.63	19.22	**-1.41**	**211**	**40**	**37**
Ruiz Pessenda et al., (2009; Table 4)	SOM	575	-26.10	-26.48	-6.37	20.63	20.25	**-0.37**	**252**	**51**	**43**
Ruiz Pessenda et al., (2009; Table 4)	SOM	805	-26.70	-26.48	-6.38	20.63	20.88	**0.25**	**283**	**60**	**47**
Ruiz Pessenda et al., (2009; Table 4)	SOM	1245	-26.90	-26.48	-6.38	20.63	21.09	**0.46**	**294**	**64**	**49**
Ruiz Pessenda et al., (2009; Table 4)	SOM	1685	-26.70	-26.48	-6.37	20.63	20.89	**0.26**	**283**	**60**	**47**
Ruiz Pessenda et al., (2009; Table 4)	SOM	2125	-27.20	-26.48	-6.36	20.63	21.43	**0.80**	**313**	**70**	**52**
Ruiz Pessenda et al., (2009; Table 4)	SOM	2565	-26.90	-26.48	-6.35	20.63	21.12	**0.49**	**296**	**64**	**49**
Ruiz Pessenda et al., (2009; Table 4)	SOM	3988	-27.10	-26.48	-6.33	20.63	21.35	**0.72**	**309**	**68**	**52**
Ruiz Pessenda et al., (2009; Table 4)	SOM	5411	-27.40	-26.48	-6.33	20.63	21.67	**1.04**	**328**	**75**	**56**
Ruiz Pessenda et al., (2009; Table 4)	SOM	6834	-27.50	-26.48	-6.34	20.63	21.75	**1.13**	**334**	**76**	**57**
Ruiz Pessenda et al., (2009; Table 4)	SOM	8257	-25.70	-26.48	-6.40	20.63	19.81	**-0.82**	**233**	**45**	**40**
Ruiz Pessenda et al., (2009; Table 4)	SOM	9680	-25.80	-26.48	-6.50	20.63	19.81	**-0.82**	**233**	**45**	**40**
Ruiz Pessenda et al., (2009; Table 4)	SOM	11915	-25.70	-26.48	-6.72	20.63	19.48	**-1.14**	**220**	**42**	**39**
Ruiz Pessenda et al., (2009; Table 4)	SOM	14150	-25.30	-26.48	-6.85	20.63	18.93	**-1.69**	**200**	**38**	**36**
Ruiz Pessenda et al., (2009; Table 4)	SOM	16385	-25.20	-26.48	-6.77	20.63	18.91	**-1.72**	**200**	**38**	**36**
Ruiz Pessenda et al., (2009; Table 4)	SOM	18955	-25.80	-26.48	-6.58	20.63	19.72	**-0.90**	**230**	**44**	**40**
Ruiz Pessenda et al., (2009; Table 4)	SOM	22630	-25.40	-26.48	-6.69	20.63	19.19	**-1.43**	**210**	**40**	**37**
Ruiz Pessenda et al., (2009; Table 4)	SOM	22695	-25.60	-26.48	-6.70	20.63	19.40	**-1.23**	**217**	**41**	**38**
Ruiz Pessenda et al., (2009; Table 4)	SOM	22760	-25.10	-26.48	-6.70	20.63	18.88	**-1.75**	**199**	**38**	**36**
Ruiz Pessenda et al., (2009; Table 4)	SOM	22825	-24.90	-26.48	-6.70	20.63	18.66	**-1.96**	**192**	**36**	**35**
Ruiz Pessenda et al., (2009; Table 4)	SOM	22890	-24.50	-26.48	-6.70	20.63	18.25	**-2.38**	**178**	**34**	**34**
Ruiz Pessenda et al., (2009; Table 4)	SOM	22955	-24.50	-26.48	-6.70	20.63	18.24	**-2.38**	**178**	**34**	**34**

Ruiz Pessenda et al., (2009; Table 4)	SOM	23020	-24.80	-26.48	-6.70	20.63	18.56	**-2.07**	**188**	**36**	**35**
Ruiz Pessenda et al., (2009; Table 4)	SOM	23085	-24.80	-26.48	-6.70	20.63	18.56	**-2.07**	**188**	**36**	**35**
Ruiz Pessenda et al., (2009; Table 4)	SOM	23150	-25.10	-26.48	-6.71	20.63	18.87	**-1.76**	**198**	**38**	**36**
Ruiz Pessenda et al., (2009; Table 4)	SOM	23501	-24.70	-26.48	-6.70	20.63	18.45	**-2.17**	**185**	**35**	**35**
Ruiz Pessenda et al., (2009; Table 4)	SOM	23851	-24.50	-26.48	-6.69	20.63	18.26	**-2.36**	**179**	**34**	**34**
Ruiz Pessenda et al., (2009; Table 4)	SOM	24202	-24.20	-26.48	-6.66	20.63	17.98	**-2.65**	**170**	**33**	**33**
Ruiz Pessenda et al., (2009; Table 4)	SOM	24553	-24.30	-26.48	-6.62	20.63	18.12	**-2.50**	**175**	**33**	**34**
Ruiz Pessenda et al., (2009; Table 4)	SOM	24903	-24.30	-26.48	-6.57	20.63	18.17	**-2.45**	**176**	**34**	**34**
Ruiz Pessenda et al., (2009; Table 4)	SOM	25254	-23.70	-26.48	-6.60	20.63	17.52	**-3.11**	**158**	**31**	**32**
Ruiz Pessenda et al., (2009; Table 4)	SOM	25605	-23.90	-26.48	-6.60	20.63	17.72	**-2.90**	**163**	**32**	**33**
Ruiz Pessenda et al., (2009; Table 4)	SOM	25955	-23.90	-26.48	-6.60	20.63	17.72	**-2.90**	**163**	**32**	**33**
Ruiz Pessenda et al., (2009; Table 4)	SOM	26306	-24.00	-26.48	-6.60	20.63	17.83	**-2.80**	**166**	**32**	**33**
Ruiz Pessenda et al., (2009; Table 4)	SOM	26657	-23.70	-26.48	-6.60	20.63	17.52	**-3.11**	**158**	**31**	**32**
Ruiz Pessenda et al., (2009; Table 4)	SOM	27007	-23.60	-26.48	-6.60	20.63	17.41	**-3.22**	**155**	**30**	**32**
Ruiz Pessenda et al., (2009; Table 4)	SOM	27358	-23.30	-26.48	-6.60	20.63	17.10	**-3.53**	**147**	**29**	**31**
Ruiz Pessenda et al., (2009; Table 4)	SOM	27628	-24.10	-26.48	-6.60	20.63	17.93	**-2.69**	**169**	**33**	**33**
Ruiz Pessenda et al., (2009; Table 4)	SOM	27899	-24.30	-26.48	-6.60	20.63	18.14	**-2.49**	**175**	**34**	**34**
Ruiz Pessenda et al., (2009; Table 4)	SOM	28169	-23.80	-26.48	-6.60	20.63	17.62	**-3.01**	**161**	**31**	**33**
Ruiz Pessenda et al., (2009; Table 4)	SOM	28440	-23.90	-26.48	-6.60	20.63	17.72	**-2.90**	**163**	**32**	**33**
Ruiz Pessenda et al., (2009; Table 4)	SOM	28710	-24.10	-26.48	-6.60	20.63	17.93	**-2.69**	**169**	**33**	**33**
Ruiz Pessenda et al., (2009; Table 4)	SOM	28980	-23.70	-26.48	-6.60	20.63	17.52	**-3.11**	**158**	**31**	**32**
Ruiz Pessenda et al., (2009; Table 4)	SOM	29251	-23.30	-26.48	-6.60	20.63	17.10	**-3.53**	**147**	**29**	**31**
Ruiz Pessenda et al., (2009; Table 4)	SOM	29521	-23.60	-26.48	-6.60	20.63	17.41	**-3.22**	**155**	**30**	**32**
Ruiz Pessenda et al., (2009; Table 4)	SOM	29791	-23.50	-26.48	-6.60	20.63	17.31	**-3.32**	**152**	**30**	**32**
Van de Water et al. (1994; Table 1)	*Pinus* leaves	1960	-23.20	-23.57	-6.36	17.58	17.24	**-0.35**	**254**	**34**	**31**
Van de Water et al. (1994; Table 1)	*Pinus* leaves	2340	-23.00	-23.57	-6.35	17.58	17.04	**-0.55**	**245**	**32**	**30**
Van de Water et al. (1994; Table 1)	*Pinus* leaves	2760	-22.60	-23.57	-6.34	17.58	16.63	**-0.95**	**228**	**29**	**29**
Van de Water et al. (1994; Table 1)	*Pinus* leaves	2940	-23.70	-23.57	-6.34	17.58	17.78	**0.20**	**280**	**39**	**33**
Van de Water et al. (1994; Table 1)	*Pinus* leaves	2960	-24.30	-23.57	-6.34	17.58	18.41	**0.82**	**315**	**47**	**38**
Van de Water et al. (1994; Table 1)	*Pinus* leaves	5720	-23.30	-23.57	-6.33	17.58	17.38	**-0.21**	**260**	**35**	**31**
Van de Water et al. (1994; Table 1)	*Pinus* leaves	7510	-23.60	-23.57	-6.36	17.58	17.65	**0.07**	**273**	**38**	**32**
Van de Water et al. (1994; Table 1)	*Pinus* leaves	7510	-24.40	-23.57	-6.36	17.58	18.49	**0.90**	**320**	**48**	**39**
Van de Water et al. (1994; Table 1)	*Pinus* leaves	8420	-23.40	-23.57	-6.41	17.58	17.40	**-0.18**	**261**	**35**	**31**
Van de Water et al. (1994; Table 1)	*Pinus* leaves	10010	-24.20	-23.57	-6.53	17.58	18.11	**0.52**	**297**	**43**	**35**
Van de Water et al. (1994; Table 1)	*Pinus* leaves	11660	-24.20	-23.57	-6.69	17.58	17.94	**0.36**	**288**	**41**	**34**

Van de Water et al. (1994; Table 1)	*Pinus* leaves	11850	-24.80	-23.57	-6.71	17.58	18.55	**0.96**	**323**	**49**	**39**
Van de Water et al. (1994; Table 1)	*Pinus* leaves	11930	-24.60	-23.57	-6.72	17.58	18.33	**0.75**	**310**	**46**	**37**
Van de Water et al. (1994; Table 1)	*Pinus* leaves	12190	-23.40	-23.57	-6.74	17.58	17.06	**-0.53**	**246**	**32**	**30**
Van de Water et al. (1994; Table 1)	*Pinus* leaves	13300	-24.60	-23.57	-6.82	17.58	18.23	**0.64**	**304**	**45**	**36**
Van de Water et al. (1994; Table 1)	*Pinus* leaves	14170	-21.90	-23.57	-6.85	17.58	15.39	**-2.19**	**184**	**24**	**26**
Van de Water et al. (1994; Table 1)	*Pinus* leaves	14300	-23.40	-23.57	-6.85	17.58	16.95	**-0.64**	**241**	**31**	**30**
Van de Water et al. (1994; Table 1)	*Pinus* leaves	14600	-21.30	-23.57	-6.85	17.58	14.77	**-2.82**	**166**	**22**	**25**
Van de Water et al. (1994; Table 1)	*Pinus* leaves	14810	-23.80	-23.57	-6.84	17.58	17.37	**-0.22**	**260**	**35**	**31**
Van de Water et al. (1994; Table 1)	*Pinus* leaves	14910	-24.00	-23.57	-6.84	17.58	17.58	**0.00**	**270**	**37**	**32**
Van de Water et al. (1994; Table 1)	*Pinus* leaves	15340	-21.50	-23.57	-6.83	17.58	14.99	**-2.59**	**172**	**23**	**25**
Van de Water et al. (1994; Table 1)	*Pinus* leaves	15480	-23.10	-23.57	-6.82	17.58	16.66	**-0.92**	**229**	**30**	**29**
Van de Water et al. (1994; Table 1)	*Pinus* leaves	15620	-22.90	-23.57	-6.82	17.58	16.46	**-1.12**	**221**	**28**	**28**
Van de Water et al. (1994; Table 1)	*Pinus* leaves	16210	-23.40	-23.57	-6.78	17.58	17.02	**-0.57**	**244**	**32**	**30**
Van de Water et al. (1994; Table 1)	*Pinus* leaves	16750	-21.50	-23.57	-6.74	17.58	15.09	**-2.50**	**175**	**23**	**25**
Van de Water et al. (1994; Table 1)	*Pinus* leaves	17030	-23.30	-23.57	-6.72	17.58	16.98	**-0.61**	**242**	**31**	**30**
Van de Water et al. (1994; Table 1)	*Pinus* leaves	17250	-22.20	-23.57	-6.70	17.58	15.85	**-1.73**	**199**	**26**	**27**
Van de Water et al. (1994; Table 1)	*Pinus* leaves	17330	-22.30	-23.57	-6.69	17.58	15.96	**-1.62**	**203**	**26**	**27**
Van de Water et al. (1994; Table 1)	*Pinus* leaves	17506	-22.20	-23.57	-6.68	17.58	15.87	**-1.71**	**200**	**26**	**27**
Van de Water et al. (1994; Table 1)	*Pinus* leaves	17580	-20.80	-23.57	-6.67	17.58	14.43	**-3.16**	**157**	**22**	**25**
Van de Water et al. (1994; Table 1)	*Pinus* leaves	18650	-21.10	-23.57	-6.60	17.58	14.81	**-2.77**	**167**	**23**	**25**
Van de Water et al. (1994; Table 1)	*Pinus* leaves	19320	-22.00	-23.57	-6.57	17.58	15.77	**-1.81**	**197**	**26**	**26**
Van de Water et al. (1994; Table 1)	*Pinus* leaves	19900	-23.90	-23.57	-6.57	17.58	17.76	**0.17**	**279**	**39**	**33**
Van de Water et al. (1994; Table 1)	*Pinus* leaves	20070	-21.70	-23.57	-6.57	17.58	15.47	**-2.12**	**186**	**24**	**26**

Van de Water et al. (1994; Table 1)	*Pinus* leaves	21740	-23.40	-23.57	-6.65	17.58	17.16	**-0.43**	**250**	**33**	**30**
Van de Water et al. (1994; Table 1)	*Pinus* leaves	23110	-22.20	-23.57	-6.70	17.58	15.85	**-1.74**	**199**	**26**	**27**
Van de Water et al. (1994; Table 1)	*Pinus* leaves	23510	-22.50	-23.57	-6.70	17.58	16.16	**-1.42**	**210**	**27**	**27**
Van de Water et al. (1994; Table 1)	*Pinus* leaves	25330	-22.20	-23.57	-6.60	17.58	15.95	**-1.63**	**203**	**26**	**27**
Van de Water et al. (1994; Table 1)	*Pinus* leaves	26170	-22.20	-23.57	-6.60	17.58	15.95	**-1.63**	**203**	**26**	**27**
Van de Water et al. (1994; Table 1)	*Pinus* leaves	27370	-22.60	-23.57	-6.60	17.58	16.37	**-1.21**	**218**	**28**	**28**
Van de Water et al. (1994; Table 1)	*Pinus* leaves	28020	-21.80	-23.57	-6.60	17.58	15.54	**-2.05**	**189**	**25**	**26**
You and Liu, (2012; Fig. 4)	Sediments	500	-28.50	-28.44	-6.37	22.69	22.78	**0.09**	**275**	**57**	**46**
You and Liu, (2012; Fig. 4)	Sediments	1000	-28.00	-28.44	-6.38	22.69	22.24	**-0.44**	**249**	**50**	**42**
You and Liu, (2012; Fig. 4)	Sediments	1500	-28.00	-28.44	-6.37	22.69	22.25	**-0.43**	**250**	**50**	**42**
You and Liu, (2012; Fig. 4)	Sediments	2000	-28.75	-28.44	-6.36	22.69	23.05	**0.37**	**289**	**62**	**48**
You and Liu, (2012; Fig. 4)	Sediments	2500	-29.00	-28.44	-6.35	22.69	23.33	**0.64**	**304**	**67**	**51**
You and Liu, (2012; Fig. 4)	Sediments	3000	-29.25	-28.44	-6.34	22.69	23.60	**0.92**	**320**	**72**	**54**
You and Liu, (2012; Fig. 4)	Sediments	3500	-29.50	-28.44	-6.33	22.69	23.87	**1.19**	**338**	**78**	**58**
You and Liu, (2012; Fig. 4)	Sediments	4000	-29.25	-28.44	-6.33	22.69	23.61	**0.93**	**321**	**72**	**54**
You and Liu, (2012; Fig. 4)	Sediments	4500	-27.50	-28.44	-6.33	22.69	21.77	**-0.91**	**229**	**44**	**40**
You and Liu, (2012; Fig. 4)	Sediments	5000	-28.25	-28.44	-6.33	22.69	22.56	**-0.12**	**264**	**54**	**44**
You and Liu, (2012; Fig. 4)	Sediments	5500	-29.25	-28.44	-6.33	22.69	23.61	**0.93**	**321**	**72**	**54**
You and Liu, (2012; Fig. 4)	Sediments	6000	-28.50	-28.44	-6.33	22.69	22.82	**0.13**	**277**	**58**	**46**
You and Liu, (2012; Fig. 4)	Sediments	6500	-26.50	-28.44	-6.34	22.69	20.71	**-1.97**	**191**	**36**	**35**
You and Liu, (2012; Fig. 4)	Sediments	7000	-28.75	-28.44	-6.35	22.69	23.06	**0.38**	**290**	**62**	**48**
You and Liu, (2012; Fig. 4)	Sediments	7500	-29.00	-28.44	-6.36	22.69	23.31	**0.63**	**303**	**66**	**51**
You and Liu, (2012; Fig. 4)	Sediments	8000	-29.50	-28.44	-6.38	22.69	23.82	**1.13**	**334**	**77**	**57**
You and Liu, (2012; Fig. 4)	Sediments	8500	-27.75	-28.44	-6.41	22.69	21.95	**-0.74**	**237**	**46**	**41**
You and Liu, (2012; Fig. 4)	Sediments	9000	-27.00	-28.44	-6.45	22.69	21.12	**-1.56**	**205**	**39**	**37**
You and Liu, (2012; Fig. 4)	Sediments	9500	-28.00	-28.44	-6.49	22.69	22.13	**-0.55**	**245**	**48**	**42**
You and Liu, (2012; Fig. 4)	Sediments	10000	-28.75	-28.44	-6.53	22.69	22.88	**0.19**	**280**	**59**	**47**
You and Liu, (2012; Fig. 4)	Sediments	10500	-26.75	-28.44	-6.58	22.69	20.73	**-1.96**	**192**	**36**	**35**
You and Liu, (2012; Fig. 4)	Sediments	11000	-30.00	-28.44	-6.63	22.69	24.09	**1.41**	**353**	**83**	**61**
You and Liu, (2012; Fig. 4)	Sediments	11500	-28.50	-28.44	-6.68	22.69	22.46	**-0.22**	**259**	**53**	**44**
You and Liu, (2012; Fig. 4)	Sediments	12000	-26.50	-28.44	-6.73	22.69	20.31	**-2.37**	**179**	**34**	**34**
You and Liu, (2012; Fig. 4)	Sediments	12500	-28.00	-28.44	-6.77	22.69	21.84	**-0.84**	**232**	**45**	**40**
You and Liu, (2012; Fig. 4)	Sediments	13000	-28.00	-28.44	-6.80	22.69	21.81	**-0.88**	**231**	**44**	**40**
You and Liu, (2012; Fig. 4)	Sediments	13500	-28.00	-28.44	-6.83	22.69	21.78	**-0.90**	**230**	**44**	**40**
You and Liu, (2012; Fig. 4)	Sediments	14000	-26.25	-28.44	-6.84	22.69	19.93	**-2.76**	**167**	**32**	**33**

SOM = Soil Organic Matter

* 0 BP = 1950 AD

† $\delta^{13}C$ values are reported with respect to the VPDB or PDB scale, as indicated in each paper.

‡ Calculated as the average Holocene (100 – 11,500 yr before A.D. 1950) $\delta^{13}C$ value for each record.
§ Determined from ice core data (Figure DR2).
|| $\Delta^{13}C_{(t=0)} = (\delta^{13}C_{CO2(t=0)} - \delta^{13}C_{(t=0)})/(1 + \delta^{13}C_{(t=0)}/1000)$, where $\delta^{13}C_{CO2(t=0)}$ = -6.4‰ (after Lüthi et al., 2008; Smith et al., 1999).
¶ $\Delta^{13}C_{(t)} = (\delta^{13}C_{CO2(t)} - \delta^{13}C_{(t)})/(1 + \delta^{13}C_{(t)}/1000)$.
** Calculated using equation 1.
†† Calculated using equation 4 with A = 28.26, B = 0.22, and C = 23.9, and $pCO_{2(t=0)}$ = 270 ppmv (after Kawamura et al., 2007).
‡‡ Error is cumulative and includes: $\Delta(\Delta^{13}C)$ ± 0.46‰ (leaves) or ± 0.87‰ (TOM); $pCO_{2(t=0)}$ ± 7 ppmv; and A = 26-30, B = 0.16-0.27, and C = 19.2-32.9 (see Error Analysis).

TABLE DR2. THE AMOUNT OF FRACTIONATION PER 100 ppmv INCREASE IN pCO_2 (*S*) MEASURED IN C_3 LAND PLANTS (UPDATED FROM SCHUBERT AND JAHREN, 2012; 2013)

S (‰ per 100 ppmv)	pCO_2 range (ppmv)	Species	Reference
2.70	198 – 243	*Pinus flexilis*	(Van de Water et al., 1994)
2.20	243 – 279	*Pinus flexilis*	(Van de Water et al., 1994)
2.13	324 – 369	*Pinus sylvestris*	(Betson et al., 2007)
2.07	303 – 361	*Pinus sylvestris*	(Berninger et al., 2000)
2.00	300 – 310	Mixed (11)	(Peñuelas and Estiarte, 1997)
2.00	277 – 351	Mixed (4)	(Feng and Epstein, 1995)
1.88	310 – 350	Mixed (11)	(Peñuelas and Estiarte, 1997)
1.75	380 – 482	*Pinus contortus*	(Sharma and Williams, 2009)
1.60	280 – 380	*Sabina przewalskii*	(Wang et al., 2011)
1.45	285 – 354	*Swietenia macrophylla*	(Hietz et al., 2005)
1.42	296 – 366	*Larix sibirica*	(Knorre et al., 2010)
1.20	285 – 365	*Juniperus* spp.	(Treydte et al., 2009)
1.00	343 – 569	*Quercus ilex*	(Saurer et al., 2003)
0.96	407 – 497	*Raphanus sativus*	(Schubert and Jahren, 2012)
0.81	313 – 366	Mixed (32)	(Wang and Feng, 2012)
0.80	380 – 760	*Arabidopsis thaliana*	(Lomax et al., 2012)
0.76	370 – 455	*Arabidopsis thaliana*	(Schubert and Jahren, 2012)
0.75	360 – 700	*Arabidopsis thaliana*	(Igamberdiev et al., 2004)
0.73	350 – 700	*Quercus petrea*	(Kürschner, 1996)
0.72	497 – 576	*Raphanus sativus*	(Schubert and Jahren, 2012)
0.67	360 – 700	*Hordeum vulgare*	(Igamberdiev et al., 2004)
0.62	380 – 607	*Linaria dalmatica*	(Sharma and Williams, 2009)
0.48	576 – 780	*Raphanus sativus*	(Schubert and Jahren, 2012)
0.41	455 – 733	*Arabidopsis thaliana*	(Schubert and Jahren, 2012)
0.38	760 – 1000	*Arabidopsis thaliana*	(Lomax et al., 2012)
0.37	350 – 700	Mixed (17)	(Beerling and Woodward, 1995)
0.21	1000 – 1500	*Arabidopsis thaliana*	(Lomax et al., 2012)
0.20	733 – 995	*Arabidopsis thaliana*	(Schubert and Jahren, 2012)
0.20	780 – 1494	*Raphanus sativus*	(Schubert and Jahren, 2012)
0.12	995 – 1302	*Arabidopsis thaliana*	(Schubert and Jahren, 2012)
0.11	1500 – 2000	*Arabidopsis thaliana*	(Lomax et al., 2012)
0.096	1494 – 1766	*Raphanus sativus*	(Schubert and Jahren, 2012)
0.082	700 – 1400	*Arabidopsis thaliana*	(Igamberdiev et al., 2004)
0.066	1302 – 1843	*Arabidopsis thaliana*	(Schubert and Jahren, 2012)
0.060	2000 – 3000	*Arabidopsis thaliana*	(Lomax et al., 2012)
0.054	1766 – 2723	*Raphanus sativus*	(Schubert and Jahren, 2012)
0.039	1843 – 2255	*Arabidopsis thaliana*	(Schubert and Jahren, 2012)
0.029	2723 – 3429	*Raphanus sativus*	(Schubert and Jahren, 2012)
0.019	3429 – 4200	*Raphanus sativus*	(Schubert and Jahren, 2012)
0.017	700 – 1400	*Hordeum vulgare*	(Igamberdiev et al., 2004)

REFERENCES CITED

Andersson, R. A., Meyers, P., Hornibrook, E., Kuhry, P., and Mörth, C.-M., 2012, Elemental and isotopic carbon and nitrogen records of organic matter accumulation in a Holocene permafrost peat sequence in the East European Russian Arctic: Journal of Quaternary Science, v. 27, no. 6, p. 545-552.

Beerling, D., and Rundgren, M., 2000, Leaf metabolic and morphological responses of dwarf willow (*Salix herbacea*) in the sub-arctic to the past 9000 years of global environmental change: New Phytologist, v. 145, no. 2, p. 257-269.

Beerling, D. J., 1996, ^{13}C discrimination by fossil leaves during the late-glacial climate oscillation 12-10 ka BP: measurements and physiological controls: Oecologia, v. 108, no. 1, p. 29-37.

Beerling, D. J., and Woodward, F. I., 1995, Leaf stable carbon isotope composition records increased water-use efficiency of C_3 plants in response to atmospheric CO_2 enrichment: Functional Ecology, v. 9, no. 3, p. 394-401.

Berninger, F., Sonninen, E., Aalto, T., and Lloyd, J., 2000, Modeling ^{13}C discrimination in tree rings: Global Biogeochemical Cycles, v. 14, no. 1, p. 213-223.

Betson, N. R., Johannisson, C., Löfvenius, M. O., Grip, H., Granström, A., and Högberg, P., 2007, Variation in the $\delta^{13}C$ of foliage of *Pinus sylvestris* L. in relation to climate and additions of nitrogen: analysis of a 32-year chronology: Global Change Biology, v. 13, no. 11, p. 2317-2328.

Brincat, D., Yamada, K., Ishiwatari, R., Uemura, H., and Naraoka, H., 2000, Molecular-isotopic stratigraphy of long-chain *n*-alkanes in Lake Baikal Holocene and glacial age sediments: Organic Geochemistry, v. 31, no. 4, p. 287-294.

Cathalot, C., Rabouille, C., Tisnérat-Laborde, N., Toussaint, F., Kerhervé, P., Buscail, R., Loftis, K., Sun, M. Y., Tronczynski, J., Azoury, S., Lansard, B., Treignier, C., Pastor, L., and Tesi, T., 2013, The fate of river organic carbon in coastal areas: A study in the Rhône River delta using multiple isotopic ($\delta^{13}C$, $\Delta^{14}C$) and organic tracers: Geochimica et Cosmochimica Acta, v. 118, p. 33-55.

Damsté, J. S. S., Verschuren, D., Ossebaar, J., Blokker, J., van Houten, R., van der Meer, M. T. J., Plessen, B., and Schouten, S., 2011, A 25,000-year record of climate-induced changes in lowland vegetation of eastern equatorial Africa revealed by the stable carbon-isotopic composition of fossil plant leaf waxes: Earth and Planetary Science Letters, v. 302, no. 1-2, p. 236-246.

Fairbanks, R. G., Mortlock, R. A., Chiu, T.-C., Cao, L., Kaplan, A., Guilderson, T. P., Fairbanks, T. W., Bloom, A. L., Grootes, P. M., and Nadeau, M.-J., 2005, Radiocarbon calibration curve spanning 0 to 50,000 years BP based on paired $^{230}Th/^{234}U/^{238}U$ and ^{14}C dates on pristine corals: Quaternary Science Reviews, v. 24, no. 16–17, p. 1781-1796.

Feng, X., and Epstein, S., 1995, Carbon isotopes of trees from arid environments and implications for reconstructing atmospheric CO_2 concentrations: Geochimica et Cosmochimica Acta, v. 59, no. 12, p. 2599-2608.

Galy, V., François, L., France-Lanord, C., Faure, P., Kudrass, H., Palhol, F., and Singh, S. K., 2008, C4 plants decline in the Himalayan basin since the Last Glacial Maximum: Quaternary Science Reviews, v. 27, no. 13–14, p. 1396-1409.

Giresse, P., Maley, J., and Brenac, P., 1994, Late Quaternary palaeoenvironments in the Lake Barombi Mbo (West Cameroon) deduced from pollen and carbon isotopes of organic matter: Palaeogeography, Palaeoclimatology, Palaeoecology, v. 107, no. 1–2, p. 65-78.

Gouveia, S. E. M., Pessenda, L. C. R., Aravena, R., Boulet, R., Scheel-Ybert, R., Bendassoli, J. A., Ribeiro, A. S., and Freitas, H. A., 2002, Carbon isotopes in charcoal and soils in studies of paleovegetation and climate changes during the late Pleistocene and the Holocene in the southeast and centerwest regions of Brazil: Global and Planetary Change, v. 33, no. 1–2, p. 95-106.

Hatté, C., Fontugne, M., Rousseau, D.-D., Antoine, P., Zöller, L., Laborde, N. T., and Bentaleb, I., 1998, $\delta^{13}C$ variations of loess organic matter as a record of the vegetation response to climatic changes during the Weichselian: Geology, v. 26, no. 7, p. 583-586.

Hietz, P., Wanek, W., and Dünisch, O., 2005, Long-term trends in cellulose $\delta^{13}C$ and water-use efficiency of tropical *Cedrela a*nd *Swietenia* from Brazil: Tree Physiology, v. 25, no. 6, p. 745-752.

Huang, Y., Bol, R., Harkness, D. D., Ineson, P., and Eglinton, G., 1996, Post-glacial variations in distributions, ^{13}C and ^{14}C contents of aliphatic hydrocarbons and bulk organic matter in three types of British acid upland soils: Organic Geochemistry, v. 24, no. 3, p. 273-287.

Igamberdiev, A. U., Mikkelsen, T. N., Ambus, P., Bauwe, H., Lea, P. J., and Gardeström, P., 2004, Photorespiration contributes to stomatal regulation and carbon isotope fractionation: a study with barley, potato and *Arabidopsis* plants deficient in glycine decarboxylase: Photosynthesis Research, v. 81, p. 139-152.

Kao, S. J., Dai, M. H., Wei, K. Y., Blair, N. E., and Lyons, W. B., 2008, Enhanced supply of fossil organic carbon to the Okinawa Trough since the last deglaciation: Paleoceanography, v. 23, p. PA2207.

Kawamura, K., Nakazawa, T., Aoki, S., Sugawara, S., Fujii, Y., and Watanabe, O., 2007, Dome Fuji ice core 338KYr wet extraction CO_2 data, *in* IGBP PAGES/World Data Center for Paleoclimatology, ed.: Boulder CO, USA, NOAA/NCDC Paleoclimatology Program.

Knorre, A. A., Siegwolf, R. T. W., Saurer, M., Sidorova, O. V., Vaganov, E. A., and Kirdyanov, A. V., 2010, Twentieth century trends in tree ring stable isotopes ($\delta^{13}C$ and $\delta^{18}O$) of *Larix sibirica* under dry conditions in the forest steppe in Siberia: Journal of Geophysical Research-Biogeosciences, v. 115, no. G03002, p. 10.1029/2009jg000930.

Kürschner, W. M., 1996, Leaf stomata as biosensors of palaeoatmospheric CO_2 levels [Ph.D.: Utrecht University, 153 p.

Li, H.-C., Liew, P.-M., Seki, O., Kuo, T.-S., Kawamura, K., Wang, L.-C., and Lee, T.-Q., 2013, Paleoclimate variability in central Taiwan during the past 30 Kyrs reflected by pollen, $\delta^{13}C_{TOC}$, and n-alkane-δD records in a peat sequence from Toushe Basin: Journal of Asian Earth Sciences, v. 69, p. 166-176.

Lomax, B. H., Knight, C. A., and Lake, J. A., 2012, An experimental evaluation of the use of C_3 $\delta^{13}C$ plant tissue as a proxy for the paleoatmospheric $\delta^{13}CO_2$ signature of air: Geochemistry, Geophysics and Geosystems, v. 13, p. Q0AI03.

Lu, H., Zhou, Y., Liu, W., and Mason, J., 2012, Organic stable carbon isotopic composition reveals late Quaternary vegetation changes in the dune fields of northern China: Quaternary Research, v. 77, no. 3, p. 433-444.

Lüthi, D., Le Floch, M., Bereiter, B., Blunier, T., Barnola, J.-M., Siegenthaler, U., Raynaud, D., Jouzel, J., Fischer, H., Kawamura, K., and Stocker, T. F., 2008, High-resolution carbon dioxide concentration record 650,000-800,000 years before present: Nature, v. 453, no. 7193, p. 379-382.

Menking, K. M., Peteet, D. M., and Anderson, R. Y., 2012, Late-glacial and Holocene vegetation and climate variability, including major droughts, in the Sky Lakes region of southeastern New York State: Palaeogeography, Palaeoclimatology, Palaeoecology, v. 353–355, no. 0, p. 45-59.

Peñuelas, J., and Estiarte, M., 1997, Trends in plant carbon concentration and plant demand for N throughout this century: Oecologia, v. 109, no. 1, p. 69-73.

Rommerskirchen, F., Eglinton, G., Dupont, L., and Rullkötter, J., 2006, Glacial/interglacial changes in southern Africa: compound-specific $\delta^{13}C$ land plant biomarker and pollen records from southeast Atlantic continental margin sediments.: Geochemistry, Geophysics and Geosystems, v. 7, p. doi:10.1029/2005GC001223.

Ruiz Pessenda, L. C., De Oliveira, P. E., Mofatto, M., de Medeiros, V. B., Francischetti Garcia, R. J., Aravena, R., Bendassoli, J. A., Zuniga Leite, A., Saad, A. R., and Lincoln Etchebehere, M., 2009, The evolution of a tropical rainforest/grassland mosaic in southeastern Brazil since 28,000 14C yr BP based on carbon isotopes and pollen records: Quaternary Research, v. 71, no. 3, p. 437-452.

Saurer, M., Cherubini, P., Bonani, G., and Siegwolf, R., 2003, Tracing carbon uptake from a natural CO_2 spring into tree rings: an isotope approach: Tree Physiology, v. 23, no. 14, p. 997-1004.

Schubert, B. A., and Jahren, A. H., 2012, The effect of atmospheric CO_2 concentration on carbon isotope fractionation in C_3 land plants: Geochimica et Cosmochimica Acta, v. 96, p. 29-43.

Schubert, B. A., and Jahren, A. H., 2013, Reconciliation of marine and terrestrial carbon isotope excursions based on changing atmospheric CO_2 levels: Nature Communications, v. 4, no. 1653, p. 10.1038/ncomms2659.

Sharma, S., and Williams, D. G., 2009, Carbon and oxygen isotope analysis of leaf biomass reveals contrasting photosynthetic responses to elevated CO_2 near geologic vents in Yellowstone National Park: Biogeosciences, v. 6, no. 1, p. 25-31.

Smith, H. J., Fischer, H., Wahlen, M., Mastroianni, D., and Deck, B., 1999, Dual modes of the carbon cycle since the Last Glacial Maximum: Nature, v. 400, no. 6741, p. 248-250.

Treydte, K. S., Frank, D. C., Saurer, M., Helle, G., Schleser, G. H., and Esper, J., 2009, Impact of climate and CO_2 on a millennium-long tree-ring carbon isotope record: Geochimica et Cosmochimica Acta, v. 73, p. 4635-4647.

Turney, C. S. M., Beerling, D. J., Harkness, D. D., Lowe, J. J., and Scott, E. M., 1997, Stable carbon isotope variations in northwest Europe during the last glacial–interglacial transition: Journal of Quaternary Science, v. 12, no. 4, p. 339-344.

Van de Water, P. K., Leavitt, S. W., and Betancourt, J. L., 1994, Trends in stomatal density and $^{13}C/^{12}C$ ratios of *Pinus flexilis* needles during last glacial-interglacial cycle: Science, v. 264, p. 239-243.

Wang, G., and Feng, X., 2012, Response of plants' water use efficiency to increasing atmospheric CO_2 concentration: Environmental Science & Technology, v. 46, no. 16, p. 8610-8620.

Wang, W., Liu, X., Shao, X., Leavitt, S., Xu, G., An, W., and Qin, D., 2011, A 200 year temperature record from tree ring $\delta^{13}C$ at the Qaidam Basin of the Tibetan Plateau after identifying the optimum method to correct for changing atmospheric CO_2 and $\delta^{13}C$: Journal of Geophysical Research, v. 116, p. G04022.

Wooller, M. J., Zazula, G. D., Edwards, M., Froese, D. G., Boone, R. D., Parker, C., and Bennett, B., 2007, Stable carbon isotope compositions of Eastern Beringian grasses and sedges: Investigating their potential as paleoenvironmental indicators: Arctic, Antarctic, and Alpine Research, v. 39, no. 2, p. 318-331.

You, H. T., and Liu, J. Q., 2012, High-resolution climate evolution derived from the sediment records of Erlongwan Maar Lake since 14 ka BP: Chinese Science Bulletin, v. 57, no. 27, p. 3610-3616.