Geology

Paleosol carbonate multiple isotopologue signature of active East Asian summer monsoons during the late Miocene and Pliocene

Marina B. Suarez, Benjamin H. Passey and Anu Kaakinen

Geology published online 21 October 2011;
doi: 10.1130/G32350.1

Email alerting services	click www.gsapubs.org/cgi/alerts to receive free e-mail alerts when new articles cite this article
Subscribe	click www.gsapubs.org/subscriptions/ to subscribe to Geology
Permission request	click http://www.geosociety.org/pubs/copyrt.htm#gsa to contact GSA

Copyright not claimed on content prepared wholly by U.S. government employees within scope of their employment. Individual scientists are hereby granted permission, without fees or further requests to GSA, to use a single figure, a single table, and/or a brief paragraph of text in subsequent works and to make unlimited copies of items in GSA's journals for noncommercial use in classrooms to further education and science. This file may not be posted to any Web site, but authors may post the abstracts only of their articles on their own or their organization's Web site providing the posting includes a reference to the article's full citation. GSA provides this and other forums for the presentation of diverse opinions and positions by scientists worldwide, regardless of their race, citizenship, gender, religion, or political viewpoint. Opinions presented in this publication do not reflect official positions of the Society.

Notes

Advance online articles have been peer reviewed and accepted for publication but have not yet appeared in the paper journal (edited, typeset versions may be posted when available prior to final publication). Advance online articles are citable and establish publication priority; they are indexed by GeoRef from initial publication. Citations to Advance online articles must include the digital object identifier (DOIs) and date of initial publication.

© Geological Society of America

THE
GEOLOGICAL
SOCIETY
OF AMERICA

Geology, published online on 21 October 2011 as doi:10.1130/G32350.1

Paleosol carbonate multiple isotopologue signature of active East Asian summer monsoons during the late Miocene and Pliocene

Marina B. Suarez[1*†], Benjamin H. Passey[1*], and Anu Kaakinen[2*]
[1]Department of Earth and Planetary Sciences, Johns Hopkins University, Baltimore, Maryland 21218, USA
[2]Department of Geosciences and Geography, University of Helsinki, P.O. Box 64, FI00014 Helsinki, Finland

ABSTRACT

East Asian summer monsoon precipitation has a globally unique $\delta^{18}O$ signature characterized by low $\delta^{18}O$ values related to the precipitation "amount effect". We explore the history of this signature using carbonate clumped-isotope thermometry and $\delta^{18}O$ of paleosol carbonates from northern China. We find that soil water $\delta^{18}O$ throughout the late Miocene and Pliocene was indistinguishable from present-day summer meteoric water $\delta^{18}O$. Additionally, soil temperatures were similar to present-day summer temperatures, as were latitudinal gradients in temperature. Paleosol carbonate $\delta^{13}C$ values document a pattern of northward-increasing C_4 vegetation during 7–3 Ma, interpreted as marking a paleobiome transition from forest to steppe. The present-day summer monsoons give rise to a similar transition owing to latitudinal gradients in precipitation amount and seasonal duration. Taken together, these lines of evidence point to active East Asian summer monsoons during the warm climates of the late Miocene and Pliocene.

INTRODUCTION

The Asian speleothem records highlight the importance of the East Asian monsoons in the global climate system and their sensitivity to changes in solar insolation and other drivers of global climate change (e.g., Wang et al., 2008). Along with climate records from the loess-paleosol strata in the Chinese Loess Plateau (CLP; Fig. 1) (An et al., 1991; Liu and Ding, 1998), these data document a pattern of summer monsoon strengthening during warm intervals, regardless of whether the warm intervals are related to orbital or nonorbital phenomena. The pre-Pleistocene monsoon history is less understood and is a focus of active research. A pattern of monsoon circulation is inferred to have existed since the beginning of the Neogene (Sun and Wang, 2005). It is generally agreed that the dry "winter monsoons" were weaker prior to ca. 2.7 Ma (An et al., 2001; Xiong et al., 2003), whereas there is debate regarding the Pliocene summer monsoons and the basic question of whether climates were wetter or drier than present (Ding et al., 1999; An et al., 2001, 2005; Passey et al., 2009). The surface elevations of the Tibetan Plateau and Himalaya are important additional factors in monsoon evolution (Prell and Kutzbach, 1992; Boos and Kuang, 2010). The Pliocene is recognized as an analog of projected climates under continued greenhouse warming, and gaining a detailed understanding of monsoon dynamics during this time period remains an important goal.

We investigate Mio-Pliocene monsoon evolution by examining the histories of meteoric water $\delta^{18}O$, soil temperature, and C_4 vegetation at two localities in northern China, Lantian in the southernmost CLP (34°N, 109°E), and Baode in the northern CLP (39°N, 111°E) (Fig. 1). These localities reside near the limits of the inland reach of the summer monsoons, and thus are ideally situated for monitoring past changes in monsoon dynamics.

BACKGROUND

Carbonate isotopologues preserve information about climate and ecology. The mass 60 isotopologue, $^{12}C^{16}O_3$, serves as a baseline to which the other isotopologues are compared. The mass 63 isotopologue, primarily $^{13}C^{18}O^{16}O_2$, is the basis of the carbonate clumped-isotope thermometer (Ghosh et al., 2006) and records the temperature of carbonate mineralization. The mass 62 isotopologue, primarily $^{12}C^{18}O^{16}O_2$, is evaluated as $\delta^{18}O$ and has traditionally been used as a proxy for meteoric water $\delta^{18}O$ (Cerling, 1984). When combined with clumped-isotope temperatures, this parameter allows calculation of fluid $\delta^{18}O$ using traditional

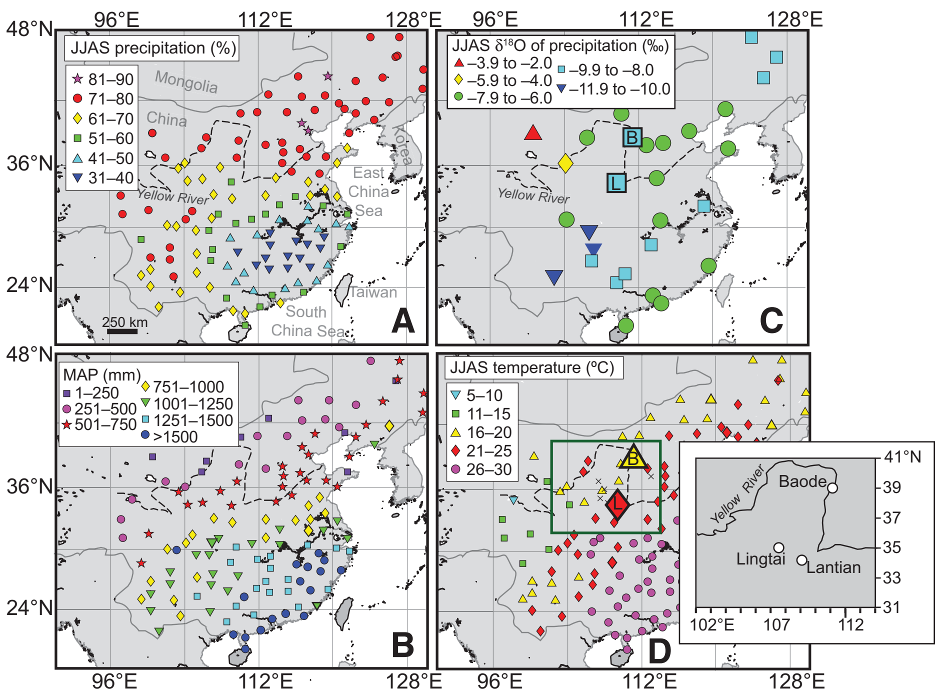

Figure 1. Climate of the study area, isotopic composition of rainfall, and location map. A: Percent of annual precipitation falling during June, July, August, and September (JJAS). B: Mean annual precipitation (MAP). C: Mean $\delta^{18}O$ of precipitation falling during JJAS. Large squares labeled "B" and "L" are mean soil water $\delta^{18}O$ values at Baode and Lantian reconstructed from clumped-isotope thermometry and $\delta^{18}O$ of soil carbonates for the period 7–3 Ma. D: JJAS temperature. Triangle labeled "B" and diamond labeled "L" are mean soil temperatures at Baode and Lantian inferred from clumped-isotope thermometry for 7–3 Ma. Inset shows localities discussed in the text and figures. Climate data are from UCAR (2006), and precipitation $\delta^{18}O$ data are from the GNIP database (IAEA/WMO, 2006).

*E-mails: msuarez5@jhu.edu; bhpassey@jhu.edu; anu.kaakinen@helsinki.fi.
†Present address: Department of Geological Sciences, University of Texas, 1 UTSA Circle, San Antonio, Texas 78249, USA

© 2011 Geological Society of America. For permission to copy, contact Copyright Permissions, GSA, or editing@geosociety.org.

$\delta^{18}O_{water}$-$\delta^{18}O_{carbonate}$-T equations. When applied to soil carbonates, clumped isotopes appear to record warm-season temperature (Passey et al., 2010) and allow calculation of soil water $\delta^{18}O$, which is related to meteoric water $\delta^{18}O$, itself an indicator of regional circulation and climate (Dansgaard, 1964). Mass 61 carbonate, primarily $^{13}C^{16}O_3$, is expressed as $\delta^{13}C$ and is primarily influenced by the photosynthetic pathway of vegetation and by atmospheric CO_2 concentrations (Cerling, 1984).

MATERIALS AND METHODS

Paleosol carbonates were sampled from red clay sections near Baode (northern CLP) and Lantian (southern CLP) (Fig. 1D). Lithostratigraphy, magnetostratigraphy, and descriptions of the paleosol carbonates are given in Kaakinen et al. (2006), Zhu et al. (2008), and Passey et al. (2009). We sampled primary micritic carbonate using a slow-speed drill. Stable isotopes ($\delta^{13}C$, $\delta^{18}O$, and Δ_{47}) were analyzed using a Thermo MAT 253 mass spectrometer at Johns Hopkins University following the methodology of Ghosh et al. (2006), as modified by Passey et al. (2010). Some samples were analyzed for $\delta^{13}C$ and $\delta^{18}O$ at the University of Kansas using a Kiel III carbonate device (75 °C reaction in 100% H_3PO_4) and a Thermo MAT 253. We report Δ_{47} values (a measure of isotopic clumping of ^{13}C and ^{18}O in the same molecule) relative to the "heated gas" Δ_{47} scale described by Huntington et al. (2009).

RESULTS AND DISCUSSION

Isotope data are reported in Tables DR1–DR3 in the GSA Data Repository[1]. Soil temperatures inferred from carbonate clumped-isotope thermometry average 18.2 ± 1.2 °C (1σ) at Baode, and 22.5 ± 1.0 °C at Lantian (Fig. 2B). Most of the temporal variability is within limits of precision (here taken as ±1.9 °C, the average standard error of our data). The absolute clumped-isotope temperatures are slightly lower (1–2 °C) than present-day mean summer (JJAS) air temperatures measured at climate stations nearest to each locality (~20 °C at Baode, and ~24 °C at Lantian; UCAR, 2006).

These temperatures are somewhat lower than expected, as clumped-isotope temperatures of Holocene soil carbonates are similar to mean summer air temperatures (Passey et al., 2010), reflecting a seasonal bias in the timing of carbonate precipitation (Breecker et al., 2009), whereas Pliocene air temperatures in this region are reconstructed as having been a few degrees higher than present (Salzmann

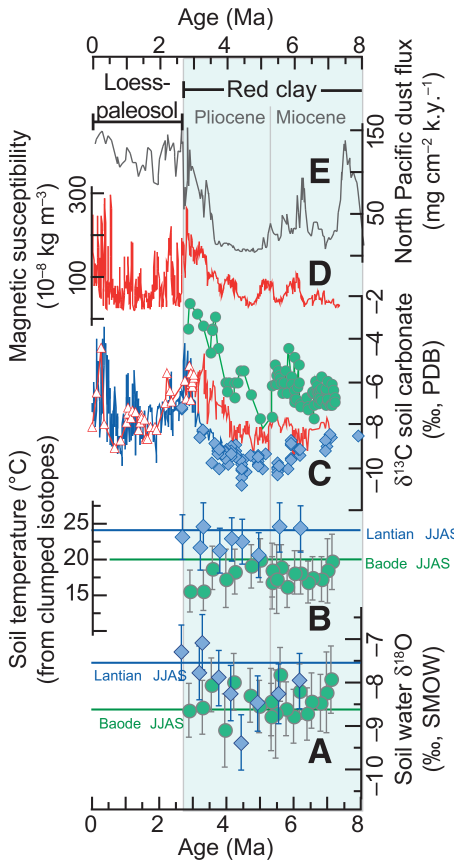

Figure 2. Temporal record of stable isotopes in paleosol carbonate and related proxy records in the Chinese Loess Plateau. A: $\delta^{18}O$ of soil water inferred from clumped-isotope thermometry and $\delta^{18}O$ of soil carbonate relative to the standard mean ocean water (SMOW) scale (Table DR1 [see footnote 1]). Blue diamonds—Lantian; green circles—Baode. B: Soil temperatures inferred from clumped-isotope thermometry. Horizontal lines in A and B show present June, July, August, September (JJAS) average air temperature (UCAR, 2006) and $\delta^{18}O$ values (Bowen, 2011; Bowen et al., 2005). C: Soil carbonate $\delta^{13}C$ values from Lantian (blue line: An et al., 2005; diamonds: this study and Kaakinen et al., 2006), Lingtai (red line and triangles: Ding and Yang, 2000), and Baode (green circles: this study and Passey et al., 2009). Some Lingtai symbols are omitted for clarity. Data are reported relative to the Peedee belemnite (PDB) standard. D: Magnetic susceptibility of eolian red clay and loess-paleosol strata at Lingtai (Sun et al., 2006). E: North Pacific dust flux record at site 885/886 from Rea et al. (1998).

et al., 2008; Lunt et al., 2010). Four scenarios may explain these "low" clumped-isotope temperatures: (1) summer temperatures in the CLP were similar to present summer temperatures, (2) summer temperatures were higher, but the soils were wet or shaded by vegetation from direct solar heating (or both), offsetting some of the potential increase in soil temperatures, (3) the soil carbonates formed after the peak warm season when soils were cooler, and (4) clumped isotopes have been partially reset during burial diagenesis.

The first scenario is plausible given uncertainties in proxy and GCM reconstructions, as is the "wet/shade" scenario. A postsummer timing of carbonate precipitation is also plausible (scenario 3). This would imply that summer rainfall and soil respiration were sufficiently high to maintain calcite-undersaturated soil waters during the summer. Partial diagenesis is also a possibility (scenario 4). The red clay strata have been buried only by their own thickness (~60 m) and that of the overlying loess-paleosol strata (<200 m), so burial temperatures would approximate mean annual temperatures (today ~10 °C), and hence resetting would lower apparent temperatures. We cannot exclude this possibility, but point out that our reconstructed temperatures are significantly warmer than burial temperatures, suggesting minimal resetting at most. Regardless of the precise scenario, it is clear that the timing of carbonate mineralization was focused toward the warm season (Fig. DR1 in the Data Repository), a conclusion consistent with the timing of mineralization inferred for recent soil carbonates spanning a range of settings (Breecker et al., 2009; Passey et al., 2010; Quade et al., 2011), including desert-steppe environments in Inner Mongolia ~300 km north of the study area (Passey et al., 2010).

Paleo-soil water $\delta^{18}O$ values calculated on the basis of clumped-isotope temperatures and soil carbonate $\delta^{18}O$ using the paleotemperature equation for calcite of Kim and O'Neil (1997) average −8.3‰ ± 0.3‰ (1σ; SMOW) at Baode, and −8.1‰ ± 0.6‰ at Lantian. These values are similar to modern summer precipitation in northern China (Figs. 1C and 2A), and distinctly lower than summer precipitation values elsewhere globally (Fig. 3). If soil water evaporative enrichment (Hsieh et al., 1998) influences our reconstructed soil water $\delta^{18}O$ values, then the actual meteoric water values must have been lower than approximately −8‰. Conversely, an ice-free Antarctica (an extreme scenario) would lead to a lowering of seawater $\delta^{18}O$ by ~0.9‰ (Shackleton and Kennett, 1975). The $\delta^{18}O$ values still plot within the field defined by Asian monsoon precipitation after correcting for this effect (Fig. 3).

The low $\delta^{18}O$ of modern summer precipitation in East Asia has been attributed to a precipitation "amount effect" and is reproduced in isotope-enabled GCMs (Hoffmann and Heimann, 1997; Vuille et al., 2005). These effects likely include local amount effects (Dansgaard, 1964), as well as amount effects imported from upstream regions experiencing heavy rainout (Vuille et al., 2005). The term "amount effect" refers to an inverse correlation between $\delta^{18}O$ and precipitation amount, as often observed in

[1]GSA Data Repository item 2011341, Tables DR1–DR3 (stable isotope data) and Figure DR1, is available online at www.geosociety.org/pubs/ft2011.htm, or on request from editing@geosociety.org or Documents Secretary, GSA, P.O. Box 9140, Boulder, CO 80301, USA.

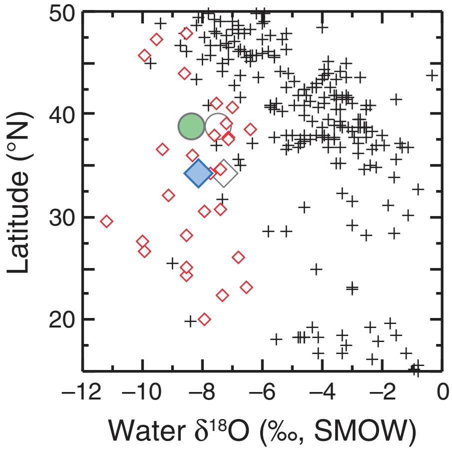

Figure 3. Warm-season (JJAS) $\delta^{18}O$ values for East Asia (longitudes between 104°E and 130°E; red diamonds) in the context of warm-season $\delta^{18}O$ values for all stations globally between 15°N and 50°N in the GNIP database (+ signs; IAEA/WMO, 2006). High-elevation stations (>1500 m) are excluded from this analysis. Soil water $\delta^{18}O$ values averaged over the 7–3 Ma interval are plotted for Baode (green circle) and Lantian (blue diamond). Standard error is smaller than the symbol size. Open symbols plotted immediately to the right of these represent "corrected" values for a scenario where paleoseawater $\delta^{18}O$ was 0.9‰ lower than present due to ice volume change (see text). SMOW—standard mean ocean water.

regions where condensing water masses have a significant vertical trajectory, driving Rayleigh distillation as saturated air ascends and cools. Excluding regions of high topography, eastern China has the lowest summertime $\delta^{18}O$ values globally in the 15°N to 50°N latitude band (Fig. 3). This unique signature of summer monsoon circulation provides a means of studying past monsoon circulation (Wang et al., 2008), and the low $\delta^{18}O$ values reconstructed for the 7–3 Ma interval are consistent with the hypothesis that the summer monsoons operated in a similar manner as present.

We note that it is possible to find soil carbonates with high clumped-isotope temperatures and low $\delta^{18}O$ values in nonmonsoon settings. These may occur in montane or Mediterranean settings where soil water is mainly recharged by isotopically light precipitation during the winter, and soil carbonates mineralize during the warm season (e.g., Mojave Desert locality studied in Passey et al., 2010). We do not believe that this situation applies to the CLP, which resides at low to moderate elevations (our study localities reside at ~1000 m [Baode] and ~500 m [Lantian]), and is too far inland to be influenced by a Mediterranean climate regime. Additionally, the existence of C_4 plants based on carbon isotopes in paleosols and fossil tooth enamel (Passey et al., 2009) suggests at least some warm-season precipitation, as C_4 plants are rare in regions lacking warm-season precipitation.

Our new $\delta^{13}C$ data from early Pliocene paleosols at Baode (Fig. 2C) add to existing data defining a pattern of northward-increasing C_4 vegetation across the CLP during the late Miocene and early Pliocene (Ding and Yang, 2000; An et al., 2005; Kaakinen et al., 2006). This pattern is interpreted to represent a paleobiome transition from C_3 forests in the south to C_3 + C_4 steppe in the north (Passey et al., 2009). This biome transition exists today, but is shifted south of its inferred Miocene location, and arises because the monsoons weaken as they penetrate overland (Fig. 1B). The increase in $\delta^{13}C$ values from ca. 4 to 2.7 Ma at multiple locations in the CLP may signal increasing C_4 vegetation owing to retreat of the summer monsoon front to more southerly latitudes, perhaps related to a shift toward the present pattern of focused summer rains and very little spring, autumn, and winter precipitation (Fig. 1A). Since C_3/C_4 ratios also respond to atmospheric CO_2 levels, we cannot exclude the possibility that decreasing CO_2 helped drive this region-wide expansion of C_4 vegetation after 4 Ma (Tripati et al., 2009; Pagani et al., 2010).

CONCLUDING REMARKS

Additional evidence for humid climates during 7–3 Ma includes (1) low dust flux to the North Pacific (Fig. 2E) (Rea et al., 1998), which receives much of its dust input from arid Asia, (2) intense pedogenesis of the eolian red clay strata in northern China (Ding et al., 1999), and (3) fossil mammalian herbivore faunas rich in browsing species (Fortelius et al., 2002). A key argument against strong summer monsoons prior to ca. 3.5 Ma is based on low magnetic susceptibility (MS) of Pliocene red clay strata (Fig. 2D) (An et al., 2001, 2005). Despite the success of MS as an indicator of monsoon strength in the younger loess-paleosol strata (Zhou et al., 1990; An et al., 1991), the relationship of MS to climate is not straightforward, and reductions in MS may occur under humid conditions (Ding et al., 1999; Liu et al., 2003). In this light, it may be reasonable to conclude that red clay MS is not a linear function of monsoon strength, and like C_4 vegetation may peak under conditions of intermediate monsoon strength.

GCMs correctly simulate the association between high-latitude warmth and strengthened summer monsoons observed during the Pleistocene, and generally predict increased summer monsoon precipitation as a consequence of global warming (Meehl et al., 2007), although predictions vary in the zonal distribution of precipitation change (Kitoh et al., 2005; Ueda et al., 2006). Whether the Pliocene is a good analog for future climates may depend on subsequent changes in Tibetan Plateau and Himalaya topography, and on anthropogenic factors such as land use change. If the Pliocene is a good analog for future climates, our results suggest that the summer monsoons will continue to provide significant moisture to northern China.

ACKNOWLEDGMENTS

Suarez was supported by the Morton K. Blaustein postdoctoral fellowship at Johns Hopkins University. We thank Luis González and Gregory Cane for use of the W.M. Keck Paleoenvironmental and Environmental Stable Isotope Lab at the University of Kansas, and Naomi Levin for commenting on an earlier version of the manuscript. We gratefully acknowledge three anonymous reviewers for comments that helped improve manuscript.

REFERENCES CITED

An, Z.S., Kukla, G., Porter, S.C., and Xiao, J.L., 1991, Late Quaternary dust flow on the Chinese Loess Plateau: CATENA, v. 18, p. 125–132, doi:10.1016/0341-8162(91)90012-M.

An, Z.S., Kutzbach, J.E., Prell, W.L., and Porter, S.C., 2001, Evolution of Asian monsoons and phased uplift of the Himalaya-Tibetan plateau since Late Miocene times: Nature, v. 411, p. 62–66, doi:10.1038/35075035.

An, Z.S., Huang, Y.S., Liu, W.G., Guo, Z.T., Clemens, S., Li, L., Prell, W., Ning, Y.F., Cai, Y.J., Zhou, W.J., Lin, B.H., Zhang, Q.L., Cao, Y.N., Qiang, X.K., Chang, H., and Wu, Z.K., 2005, Multiple expansions of C_4 plant biomass in East Asia since 7 Ma coupled with strengthened monsoon circulation: Geology, v. 33, p. 705–708, doi:10.1130/G21423.1.

Boos, W.R., and Kuang, Z.M., 2010, Dominant control of the South Asian monsoon by orographic insulation versus plateau heating: Nature, v. 463, p. 218–222, doi:10.1038/nature08707.

Bowen, G.J., 2011, The Online Isotopes in Precipitation Calculator, version 2.2: http://www.waterisotopes.org (July 2011).

Bowen, G.J., Wassenar, L.I., and Hobson, K.A., 2005, Global application of stable hydrogen and oxygen isotopes to wildlife forensics: Oecologia, v. 143, p. 337–348, doi:10.1007/s00442-004-1813-y.

Breecker, D.O., Sharp, Z.D., and McFadden, L.D., 2009, Seasonal bias in the formation and stable isotopic composition of pedogenic carbonate in modern soils from central New Mexico, USA: Geological Society of America Bulletin, v. 121, p. 630–640, doi:10.1130/B26413.1.

Cerling, T.E., 1984, The stable isotopic composition of modern soil carbonate and its relationship to climate: Earth and Planetary Science Letters, v. 71, p. 229–240, doi:10.1016/0012-821X(84)90089-X.

Dansgaard, W., 1964, Stable isotopes in precipitation: Tellus, v. 16, p. 436–468, doi:10.1111/j.2153-3490.1964.tb00181.x.

Ding, Z.L., and Yang, S.L., 2000, C_3/C_4 vegetation evolution over the last 7.0 Myr in the Chinese Loess Plateau: Evidence from pedogenic carbonate $\delta^{13}C$: Palaeogeography, Palaeoclimatology, Palaeoecology, v. 160, p. 291–299, doi:10.1016/S0031-0182(00)00076-6.

Ding, Z.L., Xiong, S.F., Sun, J.M., Yang, S.L., Gu, Z.Y., and Liu, T.S., 1999, Pedostratigraphy and paleomagnetism of a ~7.0 Ma eolian loess–red clay sequence at Lingtai, Loess Plateau, north-central China and the implications for paleomonsoon evolution: Palaeogeography, Palaeoclimatology, Palaeoecology, v. 152, p. 49–66, doi:10.1016/S0031-0182(99)00034-6.

Fortelius, M., Eronen, J., Jernvall, J., Liu, L.P., Pushkina, D., Rinne, J., Teaskov, A., Vislobokova, I., Zhang, Z.Q., and Zhou, L.P., 2002, Fossil mammals resolve regional patterns of Eurasian climate change over 20 million years: Evolutionary Ecology Research, v. 4, p. 1005–1016.

Ghosh, P., Adkins, J., Affek, H., Balta, B., Guo, W., Schauble, E.A., Schrag, D., and Eiler, J.M., 2006, ^{13}C-^{18}O bonds in carbonate minerals: A new kind of paleothermometer: Geochimica et Cosmochimica Acta, v. 70, p. 1439–1456, doi:10.1016/j.gca.2005.11.014.

Hoffmann, G., and Heimann, M., 1997, Water isotope modeling in the Asian monsoon region: Quaternary International, v. 37, p. 115–128, doi:10.1016/1040-6182(96)00004-3.

Hsieh, J.C.C., Chadwick, O.A., Kelly, E.F., and Savin, S.M., 1998, Oxygen isotopic composition of soil water: Quantifying evaporation and transpiration: Geoderma, v. 82, p. 269–293, doi:10.1016/S0016-7061(97)00105-5.

Huntington, K.W., Eiler, J.M., Affek, H.P., Guo, W., Bonifacie, M., Yeung, L.Y., Thiagarajan, H., Passey, B., Tripati, A., Daëron, M., and Came, R., 2009, Methods and limitations of 'clumped' CO_2 isotope (Δ_{47}) analysis by gas-source isotope ratio mass spectrometry: Journal of Mass Spectrometry, v. 44, p. 1318–1329, doi:10.1002/jms.1614.

IAEA/WMO (International Atomic Energy Association / World Meteorological Organization), 2006, Global network of isotopes in precipitation: The GNIP database: http://www.iaea.org/water (July 2011).

Kaakinen, A., Sonninen, E., and Lunkka, J.P., 2006, Stable isotope record in paleosol carbonates from the Chinese Loess Plateau: Implications for late Neogene paleoclimate and paleovegetation: Palaeogeography, Palaeoclimatology, Palaeoecology, v. 237, p. 359–369, doi:10.1016/j.palaeo.2005.12.011.

Kim, S.-T., and O'Neil, J.R., 1997, Equilibrium and nonequilibrium oxygen isotope effects in synthetic carbonates: Geochimica et Cosmochimica Acta, v. 61, p. 3461–3475, doi:10.1016/S0016-7037(97)00169-5.

Kitoh, A., Hosaka, M., Adachi, Y., and Kamiguchi, K., 2005, Future projections of precipitation characteristics in East Asia simulated by the MRI CGCM2: Advances in Atmospheric Sciences, v. 22, p. 467–478, doi:10.1007/BF02918481.

Liu, T.S., and Ding, Z.L., 1998, Chinese loess and the paleomonsoon: Annual Review of Earth and Planetary Sciences, v. 26, p. 111–145, doi:10.1146/annurev.earth.26.1.111.

Liu, X.M., Rolph, T., An, Z., and Hesse, P., 2003, Paleoclimatic significance of magnetic properties on the Red Clay underlying the loess and paleosols in China: Palaeogeography, Palaeoclimatology, Palaeoecology, v. 199, p. 153–166, doi:10.1016/S0031-0182(03)00504-2.

Lunt, D.J., Haywood, A.M., Schmidt, G.A., Salzmann, U., Valdes, P.J., and Dowsett, H.J., 2010, Earth system sensitivity inferred from Pliocene modelling and data: Nature Geoscience, v. 3, p. 60–64, doi:10.1038/ngeo706.

Meehl, G.A., Stocker, T.F., Collins, W.D., Friedlingstein, P., Gaye, A.T., Gregory, J.M., Kitoh, A., Knutti, R., Murphy, J.M., Noda, A., Raper, S.C.B., Watterson, I.G., Weaver, A.J., and Zhao, Z.-C., 2007, Global climate projections, *in* Solomon, S., et al., eds., Climate change 2007: The physical science basis. Contribution of Working Group I to the Fourth Assessment Report of the Intergovernmental Panel on Climate Change: Cambridge, UK, Cambridge University Press, p. 747–845.

Pagani, M., Liu, Z.H., LaRiviere, J., and Ravelo, A.C., 2010, High Earth-system climate sensitivity determined from Pliocene carbon dioxide concentrations: Nature Geoscience, v. 3, p. 27–30, doi:10.1038/ngeo724.

Passey, B.H., Ayliffe, L.K., Kaakinen, A., Zhang, Z.Q., Eronen, J.T., Zhu, Y.M., Zhou, L.P., Cerling, T.E., and Fortelius, M., 2009, Strengthened East Asian summer monsoons during a period of high-latitude warmth? Isotopic evidence from Mio-Pliocene fossil mammals and soil carbonates from northern China: Earth and Planetary Science Letters, v. 277, p. 443–452, doi:10.1016/j.epsl.2008.11.008.

Passey, B.H., Levin, N.E., Cerling, T.E., Brown, F.H., and Eiler, J.M., 2010, High-temperature environments of human evolution in East Africa based on bond ordering in paleosol carbonates: Proceedings of the National Academy of Sciences of the United States of America, v. 107, p. 11,245–11,249, doi:10.1073/pnas.1001824107.

Prell, W.L., and Kutzbach, J.E., 1992, Sensitivity of the Indian monsoon to forcing parameters and implications for its evolution: Nature, v. 360, p. 647–652, doi:10.1038/360647a0.

Quade, J., Breecker, D.O., Daëron, M., and Eiler, J.M., 2011, The paleoaltimetry of Tibet: An isotopic prespective: American Journal of Science, v. 311, p. 77–115.

Rea, D.K., Snoeckx, H., and Joseph, L.H., 1998, Late Cenozoic eolian deposition in the North Pacific: Asian drying, Tibetan uplift, and cooling of the northern hemisphere: Paleoceanography, v. 13, p. 215–224, doi:10.1029/98PA00123.

Salzmann, U., Haywood, A.M., Lunt, D.J., Valdes, P.J., and Hill, D.J., 2008, A new global biome reconstruction and data-model comparison for the Middle Pliocene: Global Ecology and Biogeography, v. 17, p. 432–447, doi:10.1111/j.1466-8238.2008.00381.x.

Shackleton, N.J., and Kennett, J.P., 1975, Paleotemperature history of the Cenozoic and the initiation of Antarctic glaciation: Oxygen and carbon isotope analyses in DSDP Sites 277, 279, and 281: Initial Reports of the Deep Sea Drilling Project, v. 29, p. 743–755.

Sun, X.J., and Wang, P.X., 2005, How old is the Asian monsoon system? Paleobotanical records from China: Palaeogeography, Palaeoclimatology, Palaeoecology, v. 222, p. 181–222.

Sun, Y.B., Lu, H., and An, Z.S., 2006, Grain size of loess, palaeosol and Red Clay deposits on the Chinese Loess Plateau: Significance for understanding pedogenic alteration and palaeomonsoon evolution: Palaeogeography, Palaeoclimatology, Palaeoecology, v. 241, p. 129–138, doi:10.1016/j.palaeo.2006.06.018.

Tripati, A.K., Roberts, C.D., and Eagle, R.A., 2009, Coupling of CO_2 and ice sheet stability over major climate transitions of the last 20 million years: Science, v. 326, p. 1394–1397, doi:10.1126/science.1178296.

UCAR (University Corporation for Atmospheric Research), 2006, China monthly station precipitation and temperature, 1951–1990: http://dss.ucar.edu/datasets/ds578.1 (July 2011).

Ueda, H., Iwai, A., Kuwako, K., and Hori, M.E., 2006, Impact of anthropogenic forcing on the Asian summer monsoon as simulated by eight GCMs: Geophysical Research Letters, v. 33, L06703, doi:10.1029/2005GL025336.

Vuille, M., Werner, M., Bradley, R.S., and Keimig, F., 2005, Stable isotopes in precipitation in the Asian monsoon region: Journal of Geophysical Research, v. 110, D23108, doi:10.1029/2005JD006022.

Wang, Y.J., Cheng, H., Edwards, R.L., Kong, X.G., Shao, X.H., Chen, S.T., Wu, J.Y., Jiang, X.Y., Wang, X.F., and An, Z.S., 2008, Millenial- and orbital-scale changes in the East Asian monsoon over the past 224,000 years: Nature, v. 451, p. 1090–1093, doi:10.1038/nature06692.

Xiong, S.F., Ding, Z.L., Jiang, W.Y., Yang, S.L., and Liu, T.S., 2003, Initial intensification of the East Asian winter monsoon at about 2.75 Ma as seen in the Chinese eolian loess–red clay deposit: Geophysical Research Letters, v. 30, 1524, doi:10.1029/2003GL017059.

Zhou, L.P., Oldfield, F., Winglt, A.G., Robinson, S.G., and Wang, J.T., 1990, Partly pedogenic origin of magnetic variations in Chinese loess: Nature, v. 346, p. 737–739, doi:10.1038/346737a0.

Zhu, Y.M., Zhou, L.P., Mo, D.W., Kaakinen, A., Zhang, Z.Q., and Fortelius, M., 2008, A new magnetostratigraphic framework for late Neogene *Hipparion* Red Clay in the eastern Loess Plateau of China: Palaeogeography, Palaeoclimatology, Palaeoecology, v. 268, p. 47–57, doi:10.1016/j.palaeo.2008.08.001.

Manuscript received 12 April 2011
Revised manuscript received 12 July 2011
Manuscript accepted 13 July 2011

Printed in USA

Table DR1. Summary of stable isotope data for late Miocene and Pliocene paleosol carbonates from northern China

Formation	Sample	Age (Ma)	*N**	$\delta^{13}C$ (‰, PDB)	$\delta^{18}O$ (‰, SMOW)	Δ_{47} (‰)†	SD Δ_{47} (‰)§	SE Δ_{47} (‰)#	T (°C)**	SE, T, (°C)††	$\delta^{18}O_{water}$ (‰) (SMOW)§§	SD $\delta^{18}O_{water}$ (‰)§	SE $\delta^{18}O_{water}$ (‰)##
	Baode, Shanxi Province, China, 39.0°N, 111.2°E												
Baode	CN2004-BD-117	7.11	5	-7.1	-9.2	0.669	0.017	0.008	20.1	1.8	-7.8	0.7	0.8
Baode	CN2004-BD-124	6.98	3	-6.8	-9.2	0.676	0.021	0.012	18.6	2.8	-8.1	0.9	0.9
Baode	CN2004-BD-141	6.78	3	-6.9	-9.2	0.675	0.014	0.008	18.6	1.9	-8.1	0.6	0.7
Baode	CN2004-BD-162	6.53	5	-6.5	-9.2	0.677	0.011	0.006	18.3	1.4	-8.2	0.5	0.6
Baode	CN2004-BD-70	6.40	3	-7.3	-9.4	0.684	0.009	0.008	16.8	1.8	-8.7	0.4	0.6
Baode	CN2004-BD-201	6.19	3	-7.0	-9.1	0.673	0.010	0.008	19.1	1.8	-8.0	0.4	0.6
Baode	CN2004-BD-95	5.98	3	-6.8	-9.7	0.676	0.009	0.008	18.6	1.8	-8.6	0.4	0.6
Baode	CN2005-BD-340	5.80	2	-6.5	-9.1	0.686	0.010	0.009	16.4	2.1	-8.5	0.4	0.6
Baode	CN2005-BD-347	5.58	3	-6.0	-8.9	0.674	0.010	0.008	18.8	1.8	-7.8	0.4	0.6
Baode	CN2004-BD-231	5.47	4	-6.1	-9.4	0.680	0.022	0.011	17.6	2.6	-8.6	0.9	1.0
Jingle	CN2004-BD-240	5.34	3	-7.6	-9.8	0.672	0.016	0.009	19.4	2.3	-8.6	0.8	0.8
Jingle	CN2004-BD-240spar***	5.34	3	-5.2	-9.1	0.684	0.017	0.010	16.9	2.2	-8.4	0.7	0.8
Jingle	CN2005-BD-361	4.98	3	-7.7	-9.8	0.671	0.004	0.008	19.6	1.8	-8.6	0.2	0.6
Jingle	CN2005-BD-364	4.70	3	-6.6	-9.4	0.672	0.011	0.008	19.4	1.8	-8.2	0.5	0.6
Jingle	CN2005-BD-371	4.22	3	-6.0	-8.9	0.678	0.014	0.008	18.1	1.9	-8.0	0.6	0.6
Jingle	CN2005-BD-375	3.95	3	-6.1	-9.8	0.678	0.018	0.011	18.1	2.5	-8.9	0.8	0.8
Jingle	CN2005-BD-385	3.56	3	-3.6	-9.1	0.675	0.009	0.008	18.6	1.8	-8.0	0.4	0.6
Jingle	CN2005-BD-391	3.27	3	-3.4	-9.0	0.686	0.006	0.008	16.4	1.8	-8.4	0.3	0.6
Jingle	CN2005-BD-395	2.91	5	-2.3	-9.0	0.688	0.010	0.006	16.0	1.4	-8.5	0.4	0.6
	Lantian, Shaanxi Province, China, 34.2°N, 109.1°E												
Lantian	B/L 1B	6.17	3	-9.2	-10.1	0.652	0.010	0.008	23.7	1.9	-8.0	0.5	0.6
Lantian	B/L 3K	5.54	3	-9.9	-10.5	0.652	0.014	0.008	23.6	2.1	-8.4	0.7	0.7
Lantian	B/L 5A	4.95	3	-9.5	-9.9	0.664	0.006	0.008	20.9	1.9	-8.3	0.2	0.6
Lantian	B/L 4K	4.46	3	-10.0	-11.2	0.655	0.007	0.008	22.9	1.9	-9.3	0.4	0.6
Lantian	B/L 6.5A	4.12	3	-9.4	-10.1	0.660	0.012	0.008	21.9	1.9	-8.4	0.5	0.6
Lantian	B/L 9K	3.78	3	-9.1	-9.4	0.662	0.012	0.008	21.6	1.9	-7.8	0.6	0.6
Lantian	B/L B112	3.31	3	-8.3	-9.3	0.652	0.005	0.008	23.7	1.9	-7.2	0.2	0.6
Lantian	B/L 120	3.19	3	-8.6	-9.4	0.660	0.007	0.008	22.0	1.9	-7.6	0.3	0.6
Lantian	B/L B155	2.67	3	-7.2	-9.3	0.659	0.012	0.008	22.2	1.9	-7.4	0.6	0.6

*Number of unique extractions and analyses of CO_2 from carbonate. Results from each extraction + analysis are reported in Table DR2.

† Values are reported on the Δ_{47} scale of Ghosh et al., (2006), as described in Huntington et al., (2009), and are normalized to a canonical heated gas intercept of -0.8453‰ relative to Oztech reference CO_2. An acid correction factor of +0.081‰ was used to normalize these data to 25 C phosphoric acid reactions (Passey et al., 2010).

§ These are standard deviations of the populations of *N* Δ_{47} or $\delta^{18}O_{water}$ values for each sample (individual analyses are reported in Table DR2).

Standard error is calculated as the standard devation of *N* Δ_{47} values divided by the squre root of *N*. When the computed SD of analyses is less than the long-term laboratory external precision (=0.013‰ as determined by repeated analyses of homogenous carbonate reference materials), the computed SD is replaced with a value of 0.013‰ before computing the standard error.

**Temperature is calculated from measured Δ_{47} values using the Ghosh et al. (2006) calibration: $\Delta_{47} = (0.0592 \times 10^6) / T^2 - 0.02$.

††Temperature error is calculated using the analytical error propagated with the estimated error in the acid correction factor (=0.0024‰, Passey et al., 2010), propagated through the paleotemperature equation of Ghosh et al., (2007).

§§ Water composition is calculated based on $\delta^{18}O$ of carbonate and temperatures inferred from clumped isotope thermometry using the paleotemperature equation for calcite repoted by Kim and O'Neil (1997): $1000\ln\alpha = (18.03 \times 10^3)/T - 32.42$.

The total error in $\delta^{18}O$ of soil water is calculated based on the temperature error and error in $\delta^{18}O$ of carbonate, propagated through the paleotemperature equation of Kim and O'Neil (1997).

*** Diagenetic spar associated with sample CN2005-BD-240.

Table DR2. Stable isotope data for individual analyses of paleosol carbonates.

Formation	Sample	Age (Ma)	Δ_{47} (‰)	SD (‰,1σ)	δ^{13}C* (‰,VPDB)	δ^{18}O* (‰,VPDB)	T (°C)[†]	$\delta^{18}O_{water}$ (‰, SMOW)[§]
Baode, Shanxi Province, China, 39.0°N, 111.2°E								
Baode	CN2004-BD-117	7.11	0.665	0.033	-7.22	-9.22	20.7	-7.72
Baode	CN2004-BD-117	7.11	0.641	0.041	-7.26	-9.26	26.1	-6.67
Baode	CN2004-BD-117	7.11	0.674	0.020	-7.23	-9.26	18.8	-8.17
Baode	CN2004-BD-117	7.11	0.676	0.037	-6.78	-9.02	18.6	-7.96
Baode	CN2004-BD-117	7.11	0.686	0.020	-6.81	-9.06	16.4	-8.46
Baode	CN2004-BD-124	6.98	0.677	0.036	-6.75	-9.17	18.4	-8.17
Baode	CN2004-BD-124	6.98	0.696	0.023	-6.78	-9.25	14.4	-9.08
Baode	CN2004-BD-124	6.98	0.655	0.044	-6.77	-9.18	23.1	-7.19
Baode	CN2004-BD-141	6.78	0.678	0.022	-6.85	-9.19	18.2	-8.22
Baode	CN2004-BD-141	6.78	0.661	0.045	-6.86	-9.17	21.7	-7.47
Baode	CN2004-BD-141	6.78	0.688	0.026	-6.86	-9.18	16.0	-8.67
Baode	CN2004-BD-162	6.53	0.671	0.038	-6.45	-9.22	19.6	-7.96
Baode	CN2004-BD-162	6.53	0.677	0.046	-6.48	-9.24	18.3	-8.24
Baode	CN2004-BD-162	6.53	0.684	0.042	-6.47	-9.18	16.9	-8.48
Baode	CN2004-BD-162	6.53	0.691	0.045	-6.44	-9.21	15.4	-8.84
Baode	CN2004-BD-162	6.53	0.663	0.032	-6.48	-9.03	21.3	-7.42
Baode	CN2004-BD-70	6.40	0.676	0.030	-7.30	-9.34	18.6	-8.29
Baode	CN2004-BD-70	6.40	0.694	0.026	-7.29	-9.34	14.8	-9.09
Baode	CN2004-BD-70	6.40	0.683	0.034	-7.30	-9.36	17.1	-8.61
Baode	CN2004-BD-201	6.19	0.677	0.035	-7.01	-9.04	18.4	-8.03
Baode	CN2004-BD-201	6.19	0.663	0.057	-7.00	-9.15	21.3	-7.53
Baode	CN2004-BD-201	6.19	0.681	0.022	-6.97	-9.17	17.5	-8.35
Baode	CN2004-BD-95	5.98	0.684	0.043	-6.80	-9.70	16.8	-9.03
Baode	CN2004-BD-95	5.98	0.676	0.031	-6.77	-9.72	18.4	-8.71

Baode	CN2004-BD-95	5.98	0.666	0.043	-6.78	-9.66	20.5	-8.20
Baode	CN2005-BD-340	5.80	0.679	0.027	-6.54	-9.13	17.9	-8.23
Baode	CN2005-BD-340	5.80	0.693	0.025	-6.54	-9.14	15.0	-8.85
Baode	CN2005-BD-347	5.58	0.682	0.034	-6.02	-8.91	17.3	-8.13
Baode	CN2005-BD-347	5.58	0.663	0.024	-6.01	-8.91	21.2	-7.32
Baode	CN2005-BD-347	5.58	0.678	0.020	-6.03	-8.94	18.0	-8.01
Baode	CN2004-BD-231	5.47	0.670	0.018	-5.99	-9.47	19.8	-8.17
Baode	CN2004-BD-231	5.47	0.660	0.024	-6.02	-9.53	22.0	-7.78
Baode	CN2004-BD-231	5.47	0.712	0.039	-6.14	-9.36	11.3	-9.88
Baode	CN2004-BD-231	5.47	0.679	0.031	-6.13	-9.40	17.8	-8.52
Jingle	CN2004-BD-240	5.34	0.677	0.025	-7.60	-9.77	18.2	-8.80
Jingle	CN2004-BD-240	5.34	0.653	0.035	-7.62	-9.75	23.4	-7.71
Jingle	CN2004-BD-240	5.34	0.684	0.024	-7.57	-9.83	16.7	-9.17
Jingle	CN2004-BD-240spar	5.34	0.679	0.050	-5.21	-9.09	17.9	-8.19
Jingle	CN2004-BD-240spar	5.34	0.670	0.029	-5.21	-9.05	19.8	-7.75
Jingle	CN2004-BD-240spar	5.34	0.702	0.029	-5.27	-9.06	13.2	-9.17
Jingle	CN2005-BD-360	5.08	ND**	ND**	-8.16	-9.26	ND**	ND**
Jingle	CN2005-BD-361	4.98	0.666	0.019	-7.70	-9.82	20.6	-8.35
Jingle	CN2005-BD-361	4.98	0.675	0.031	-7.73	-9.85	18.8	-8.76
Jingle	CN2005-BD-361	4.98	0.671	0.029	-7.74	-9.86	19.5	-8.61
Jingle	CN2005-BD-361	4.98	ND**	ND**	-7.67	-9.70	ND**	ND**
Jingle	CN2005-BD-364	4.70	0.672	0.026	-6.60	-9.43	19.4	-8.20
Jingle	CN2005-BD-364	4.70	0.661	0.021	-6.59	-9.42	21.8	-7.70
Jingle	CN2005-BD-364	4.70	0.683	0.037	-6.56	-9.39	17.1	-8.65
Jingle	CN2005-BD-368	4.48	ND**	ND**	-5.46	-9.06	ND**	ND**

Jingle	CN2005-BD-369	4.39	ND**	ND**	-5.50	-8.83	ND**	ND**
Jingle	CN2005-BD-370	4.29	ND**	ND**	-6.03	-9.43	ND**	ND**
Jingle	CN2005-BD-371	4.22	0.686	0.028	-6.02	-8.91	16.5	-8.30
Jingle	CN2005-BD-371	4.22	0.686	0.023	-6.01	-8.91	16.4	-8.32
Jingle	CN2005-BD-371	4.22	0.663	0.047	-6.03	-8.94	21.4	-7.32
Jingle	CN2005-BD-371	4.22	ND**	ND**	-6.75	-9.67	ND**	ND**
Jingle	CN2005-BD-373	4.07	ND**	ND**	-6.06	-9.45	ND**	ND**
Jingle	CN2005-BD-374	4.00	ND**	ND**	-6.41	-9.55	ND**	ND**
Jingle	CN2005-BD-375	3.95	0.681	0.042	-6.11	-9.83	17.5	-9.01
Jingle	CN2005-BD-375	3.95	0.695	0.027	-6.10	-9.88	14.6	-9.67
Jingle	CN2005-BD-375	3.95	0.659	0.038	-5.95	-9.83	22.2	-8.03
Jingle	CN2005-BD-380	3.72	ND**	ND**	-4.41	-9.48	ND**	ND**
Jingle	CN2005-BD-382	3.63	ND**	ND**	-2.97	-9.03	ND**	ND**
Jingle	CN2005-BD-385	3.56	0.675	0.042	-3.57	-9.10	18.6	-8.04
Jingle	CN2005-BD-385	3.56	0.685	0.052	-3.61	-9.08	16.7	-8.43
Jingle	CN2005-BD-385	3.56	0.666	0.036	-3.60	-9.10	20.5	-7.65
	CN2005-BD-385	3.56	ND**	ND**	-3.52	-8.94	ND**	ND**
Jingle	CN2005-BD-387	3.49	ND**	ND**	-4.62	-9.41	ND**	ND**
Jingle	CN2005-BD-391	3.27	0.688	0.031	-3.37	-8.95	16.1	-8.43
Jingle	CN2005-BD-391	3.27	0.691	0.017	-3.35	-8.99	15.3	-8.63
Jingle	CN2005-BD-391	3.27	0.679	0.038	-3.34	-8.97	17.9	-8.07
Jingle	CN2005-BD-393	3.12	ND**	ND**	-2.80	-9.07	ND**	ND**
Jingle	CN2005-BD-395	2.91	0.685	0.027	-2.33	-9.01	16.6	-8.39
Jingle	CN2005-BD-395	2.91	0.701	0.028	-2.31	-8.99	13.4	-9.05
Jingle	CN2005-BD-395	2.91	0.683	0.027	-2.30	-8.99	17.0	-8.27

Jingle	CN2005-BD-395	2.91	0.696	0.027	-2.43	-8.99	14.3	-8.85
Jingle	CN2005-BD-395	2.91	0.675	0.046	-2.34	-9.07	18.7	-7.99
Jingle	CN2005-BD-397	2.84	ND**	ND**	-3.53	-8.27	ND**	ND**
Lantian, Shaanxi Province, China, 34.2°N, 109.1°E								
Lantian	B/L 1B	6.17	0.644	0.019	-9.13	-10.11	25.4	-7.67
Lantian	B/L 1B	6.17	0.663	0.020	-9.21	-10.15	21.3	-8.54
Lantian	B/L 1B	6.17	0.648	0.018	-9.20	-10.14	24.6	-7.85
Lantian	B/L 3K	5.54	0.647	0.025	-9.92	-10.48	24.8	-8.15
Lantian	B/L 3K	5.54	0.641	0.040	-9.87	-10.46	26.1	-7.89
Lantian	B/L 3K	5.54	0.669	0.043	-9.87	-10.51	20.1	-9.15
Lantian	B/L 5A	4.95	0.666	0.040	-9.47	-9.87	20.6	-8.40
Lantian	B/L 5A	4.95	0.658	0.057	-9.48	-9.90	22.3	-8.07
Lantian	B/L 5A	4.95	0.669	0.034	-9.47	-9.87	19.9	-8.54
Lantian	B/L 4K	4.46	0.649	0.037	-10.01	-11.19	24.3	-8.96
Lantian	B/L 4K	4.46	0.664	0.032	-10.04	-11.24	21.1	-9.66
Lantian	B/L 4K	4.46	0.654	0.023	-10.04	-11.22	23.3	-9.20
Lantian	B/L 6.5A	4.12	0.647	0.029	-9.39	-10.12	24.8	-7.78
Lantian	B/L 6.5A	4.12	0.665	0.030	-9.37	-10.12	20.9	-8.59
Lantian	B/L 6.5A	4.12	0.668	0.041	-9.37	-10.13	20.1	-8.76
Lantian	B/L 9K	3.78	0.667	0.043	-9.15	-9.44	20.4	-8.01
Lantian	B/L 9K	3.78	0.670	0.029	-9.15	-9.44	19.8	-8.14
Lantian	B/L 9K	3.78	0.648	0.030	-9.14	-9.40	24.6	-7.11
Lantian	B/L B112	3.31	0.657	0.034	-8.24	-9.34	22.6	-7.46
Lantian	B/L B112	3.31	0.652	0.037	-8.26	-9.30	23.7	-7.20
Lantian	B/L B112	3.31	0.647	0.023	-8.29	-9.32	24.8	-6.98
Lantian	B/L 120	3.19	0.652	0.031	-8.59	-9.39	23.7	-7.27

Lantian	B/L 120	3.19	0.664	0.030	-8.59	-9.40	21.1	-7.82
Lantian	B/L 120	3.19	0.664	0.027	-8.62	-9.40	21.1	-7.83
Lantian	B/L B155	2.67	0.645	0.045	-7.18	-9.16	25.3	-6.73
Lantian	B/L B155	2.67	0.665	0.021	-7.22	-9.33	20.9	-7.80
Lantian	B/L B155	2.67	0.667	0.028	-7.17	-9.26	20.5	-7.81

Note. The data reported in each row correspond to single analyses consisting of reaction of soil carbonate in phosphoric acid, extraction and purification of CO_2, and analysis in the mass spectrometer over eight 'acquisitions', where each acquisition consists of eight sample gas versus reference gas comparison cycles, with an idle time of 20 s and an integration time of 20 s for each cycle, resulting in a 1280 s counting time for each gas. Detailed analytical methods are given in Passey et al., 2010.

* Analytical precision for $\delta^{13}C$ and $\delta^{18}O$ is better than 0.1‰.

† Temperature is calculated based on measured Δ_{47} values using the Ghosh et al. (2006) calibration: $\Delta_{47} = (0.0592 \times 10^6) / T^2 - 0.02$.

§ Water composition is calculated based on $\delta^{18}O$ of carbonate and temperatures inferred from clumped isotope thermometry using the paleotemperature equation for calcite repoted by Kim and O'Neil (1997): $1000\ln\alpha = (18.03 \times 10^3)/T - 32.42$.

**No clumped isotope analysis. Samples were analyzed for $\delta^{13}C$ and $\delta^{18}O$ at the Keck Paleoenvironmental and Environmental Stable Isotope Lab at the University of Kansas.

Table DR3. Raw and corrected clumped isotope data for samples, standards, heated gases, and equilibrated gases.

Type	Date	Sequence Number	Laboratory ID	Sample ID	δ_{47} ‰, WG*	Δ_{47} ‰, WG*	δ_{48} ‰, WG*	Δ_{48} ‰, WG*	Modeled Heated Gas Slope†	Modeled Heated Gas Intercept†	Δ_{47} linearity corrected§ ‰, WG	Δ_{47} ‰, Ghosh#	Δ_{47} ‰, Ghosh acid corrected**	Δ_{47} accepted standard††	Δ_{48} ‰, Heated Gas §§	Modeled Equil. Gas Slope##	Modeled Equil. Gas Intercept##	Δ_{47} ‰, Equilibrium Scale***	Δ_{47} ‰, Equilibrium Scale*** acid corrected**
Sample Series 1, January through May 2010																			
Heated Gas	21_Jan_10	148	GH0015	Heated Gas	-0.442	-0.827	5.082	0.655	-0.002	-0.832	-0.828	0.004			-0.053	-0.001	0.022	0.031	
Standard	21_Jan_10	152	GH-102-GC-AZ01-2	102-GC-AZ01	2.837	-0.276	-1.630	0.160	-0.002	-0.832	-0.270	0.571	**0.652**	0.650	-0.372	-0.001	0.021	0.612	0.693
Heated Gas	22_Jan_10	155	GH0020	Heated Gas	-0.664	-0.825	4.268	0.649	-0.002	-0.833	-0.826	0.006			-0.041	-0.001	0.020	0.033	
Standard	22_Jan_10	160	GH-102-GC-AZ01-1	102-GC-AZ01	3.009	-0.262	-1.449	0.226	-0.002	-0.833	-0.256	0.585	**0.666**	0.650	-0.306	-0.001	0.019	0.628	0.709
Heated Gas	23_Jan_10	162	GH0028	Heated Gas	14.182	-0.862	34.912	1.593	-0.002	-0.833	-0.834	-0.001			0.026	-0.001	0.019	0.026	
Heated Gas	24_Jan_10	170	GH0025	Heated Gas	15.670	-0.851	37.867	1.812	-0.002	-0.833	-0.821	0.012			0.107	-0.001	0.017	0.040	
Standard	25_Jan_10	172	GH-UU-Carrara-1	UU Carrara	17.320	-0.593	25.067	1.357	-0.002	-0.833	-0.560	0.277	**0.358**	0.352	0.026	-0.001	0.016	0.312	0.393
Heated Gas	26_Jan_10	181	GH0023	Heated Gas	15.207	-0.864	36.833	1.796	-0.002	-0.834	-0.837	-0.003			0.036	-0.001	0.014	0.024	
Heated Gas	27_Jan_10	186	MBS-CI-5	MBS_11-16-09_EnrCO2-1	14.301	-0.882	35.926	1.772	-0.002	-0.834	-0.857	-0.023			0.002	-0.001	0.013	0.003	
Standard	28_Jan_10	188	MBS-CI-7	UU Carrara	17.236	-0.584	25.008	1.385	-0.002	-0.834	-0.554	0.284	**0.365**	0.352	-0.030	-0.001	0.013	0.321	0.402
Heated Gas	28_Jan_10	191	MBS-CI-10	MBS_11-11-09_Tank1CO2-3	-0.024	-0.848	5.434	0.856	-0.002	-0.835	-0.848	-0.014			0.103	-0.001	0.012	0.013	
Standard	29_Jan_10	196	MBS-CI-15	UU Carrara	17.091	-0.581	24.669	1.239	-0.002	-0.835	-0.553	0.285	**0.366**	0.352	-0.209	-0.001	0.011	0.323	0.404
Heated Gas	30_Jan_10	197	MBS-CI-16	MBS_11-11-09_Tank1CO2-2	0.103	-0.846	5.469	0.748	-0.002	-0.835	-0.846	-0.011			-0.012	-0.001	0.011	0.016	
Equilibrated Gas	30_Jan_10	198	BP-CI-665	Depleted 25C Equilibration	-2.323	0.001	-0.522	0.001	-0.002	-0.835	-0.003	0.843			-0.542	-0.001	0.011	0.901	
Equilibrated Gas	30_Jan_10	199	BP-CI-666	Enriched 25C Equilibration	16.473	0.004	38.313	1.397	-0.002	-0.835	0.030	0.876			-0.569	-0.001	0.011	0.936	
Heated Gas	30_Jan_10	200	BP-CI-667	Caltech BOC Heated Gas	-3.369	-0.846	8.876	0.839	-0.002	-0.835	-0.851	-0.016			-0.050	-0.001	0.010	0.010	
Equilibrated Gas	30_Jan_10	201	BP-CI-669	Depleted 25C Equil CO2	-2.177	0.001	-0.384	-0.149	-0.002	-0.835	-0.002	0.843			-0.696	-0.001	0.010	0.902	
Heated Gas	30_Jan_10	202	BP-CI-668	Caltech Heated Gas	-2.419	-0.848	10.516	0.800	-0.002	-0.835	-0.852	-0.017			-0.154	-0.001	0.010	0.010	
Equilibrated Gas	30_Jan_10	203	BP-CI-670	Enriched Equil Gas, 27C	16.514	0.004	38.276	1.295	-0.002	-0.835	0.030	0.876			-0.706	-0.001	0.010	0.936	
Heated Gas	30_Jan_10	204	BP-CI-671	Caltech Heated Gas	21.593	-0.864	61.058	2.736	-0.002	-0.835	-0.830	0.005			-0.138	-0.001	0.009	0.032	
Equilibrated Gas	4_Feb_10	208	GH-CI-04	Enriched Equil Gas, 27C	16.412	-0.007	38.088	1.286	-0.002	-0.836	0.018	0.863			-0.756	-0.001	0.009	0.924	
standard	4_Feb_10	209	GH-CI-05	NBS-19	16.833	-0.574	24.288	1.300	-0.001	-0.836	-0.549	0.290	**0.371**	0.352	-0.211	-0.001	0.008	0.329	0.410
Heated Gas	5_Feb_10	212	GH-CI-08	Heated Gas, GH0019	-0.515	-0.855	4.707	0.793	-0.001	-0.836	-0.856	-0.020			0.046	-0.001	0.008	0.006	
Standard	7_Feb_10	216	GH-CI-12	UU Carrara	17.306	-0.580	25.030	1.338	-0.001	-0.836	-0.555	0.284	**0.365**	0.352	-0.246	-0.001	0.007	0.322	0.403
Equilibrated Gas	7_Feb_10	217	GH-CI-13	Depleted Equil Gas, 27C	6.341	0.135	-4.140	-0.254	-0.001	-0.836	0.144	0.991			-0.641	-0.001	0.007	1.059	
Heated Gas	7_Feb_10	219	GH-CI-15	Heated Gas, GH0018	0.437	-0.808	6.441	0.741	-0.001	-0.836	-0.807	0.029			-0.086	0.000	0.007	0.057	
standard	8_Feb_10	222	GH-CI-18	102-GC-AZ01	3.046	-0.264	-1.436	0.106	-0.001	-0.836	-0.260	0.583	**0.664**	0.650	-0.390	0.000	0.006	0.635	0.716
Equilibrated Gas	8_Feb_10	223	GH-CI-19	Enriched Equil Gas, 27C	16.458	-0.005	38.452	1.558	-0.001	-0.837	0.017	0.862			-0.648	0.000	0.006	0.927	
Standard	9_Feb_10	225	GH-CI-21	NBS-19	16.817	-0.597	24.612	1.617	-0.001	-0.837	-0.575	0.264	**0.345**	0.352	-0.008	0.000	0.005	0.303	0.384
Heated Gas	9_Feb_10	226	GH-CI-22	Heated Gas, GH0022	15.479	-0.842	38.086	2.297	-0.001	-0.837	-0.822	0.015			0.076	0.000	0.005	0.043	
Standard	9_Feb_10	228	GH-CI-24	UU Carrara	17.353	-0.581	25.413	1.626	-0.001	-0.837	-0.559	0.281	**0.362**	0.352	-0.055	0.000	0.005	0.320	0.401
Equilibrated Gas	10_Feb_10	229	GH-CI-25	Depleted Equil Gas, 27C	-2.037	0.004	-0.003	-0.034	-0.001	-0.837	0.001	0.847			-0.589	0.000	0.005	0.911	
Heated Gas	10_Feb_10	230	GH-CI-26	Heated Gas, GH0021	15.408	-0.869	37.960	2.282	-0.001	-0.837	-0.850	-0.013			0.025	0.000	0.005	0.014	
Standard	22_Feb_10	233	GH-CI-30	102-GC-AZ01	3.095	-0.241	-1.324	0.180	-0.001	-0.837	-0.237	0.606	**0.687**	0.650	-0.314	0.000	0.004	0.660	0.741
Heated Gas	23_Feb_10	235	GH-CI-32	Heated Gas, GH0065	14.416	-0.826	35.224	1.632	-0.001	-0.837	-0.809	0.029			-0.552	0.000	0.004	0.057	
Standard	23_Feb_10	238	GH-CI-35	UU Carrara	17.333	-0.576	25.142	1.407	-0.001	-0.838	-0.556	0.284	**0.365**	0.352	-0.331	0.000	0.003	0.324	0.405
Heated Gas	24_Feb_10	241	GH-CI-38	Heated Gas, GH0024	14.812	-0.872	36.435	2.054	-0.001	-0.838	-0.855	-0.018			-0.248	0.000	0.003	0.008	
Standard	24_Feb_10	243	GH-CI-40	102-GC-AZ01	3.024	-0.293	-1.159	0.235	-0.001	-0.838	-0.290	0.553	**0.634**	0.650	-0.261	0.000	0.002	0.606	0.687
Standard	24_Feb_10	247	GH-CI-44	UU Carrara	17.338	-0.574	25.508	1.692	-0.001	-0.838	-0.556	0.285	**0.366**	0.352	-0.130	0.000	0.002	0.325	0.406
Heated Gas	24_Feb_10	248	GH-CI-45	Heated Gas, GH0016	0.017	-0.836	5.545	0.821	-0.001	-0.838	-0.836	0.002			-0.009	0.000	0.001	0.029	
Equilibrated Gas	24_Feb_10	249	GH-CI-46	Depleted Equil Gas, 27C	-2.159	0.034	-0.224	0.002	-0.001	-0.838	0.032	0.877			-0.538	0.000	0.001	0.947	
Heated Gas	25_Feb_10	253	BP-CI-681	Heated Reg CO2	-0.114	-0.834	5.862	0.973	-0.001	-0.839	-0.834	0.004			0.119	0.000	0.001	0.032	
Standard	26_Feb_10	255	BP-CI-679	NBS-19	16.859	-0.557	24.828	1.799	-0.001	-0.839	-0.541	0.300	**0.381**	0.352	-0.049	0.000	0.000	0.342	0.423
Standard	26_Feb_10	257	MBS-CI-17	UU Carrara	17.384	-0.558	25.755	1.927	-0.001	-0.839	-0.542	0.299	**0.380**	0.352	0.015	0.000	0.000	0.341	0.422
Sample	26_Feb_10	258	MBS-CI-18	CN2004-BD-124	1.448	-0.249	9.874	0.742	-0.001	-0.839	-0.248	0.596	**0.677**		-0.333	0.000	0.000	0.653	0.734
Sample	26_Feb_10	259	MBS-CI-19	CN2005-BD-340	1.698	-0.247	9.930	0.711	-0.001	-0.839	-0.246	0.598	**0.679**		-0.370	0.000	0.000	0.655	0.736
Sample	27_Feb_10	260	MBS-CI-20	CN2004-BD-240spar	3.028	-0.248	10.023	0.726	-0.001	-0.839	-0.245	0.598	**0.679**		-0.363	0.000	0.000	0.655	0.736
Sample	27_Feb_10	261	MBS-CI-21	CN2004-BD-240spar	3.064	-0.257	10.137	0.757	-0.001	-0.839	-0.254	0.589	**0.670**		-0.342	0.000	-0.001	0.646	0.727
Standard	27_Feb_10	262	MBS-CI-22	102-GC-AZ01	3.032	-0.284	-0.956	0.268	-0.001	-0.839	-0.281	0.562	**0.643**	0.650	-0.230	0.000	-0.001	0.617	0.698
Heated Gas	27_Feb_10	263	MBS-CI-23	MBS_11-13-09_Tank1CO2-1	0.409	-0.843	6.457	0.917	-0.001	-0.839	-0.843	-0.004			0.014	0.000	-0.001	0.023	
Sample	28_Feb_10	264	MBS-CI-24	CN2004-BD-124	1.364	-0.230	9.723	0.721	-0.001	-0.839	-0.229	0.615	**0.696**		-0.364	0.000	-0.001	0.673	0.754
Sample	28_Feb_10	265	MBS-CI-25	CN2004-BD-240spar	3.021	-0.225	10.108	0.731	-0.001	-0.839	-0.223	0.621	**0.702**		-0.378	0.000	-0.001	0.680	0.761
Sample	28_Feb_10	267	MBS-CI-27	CN2004-BD-124	1.405	-0.271	9.705	0.602	-0.001	-0.839	-0.270	0.574	**0.655**		-0.491	0.000	-0.001	0.630	0.711
Sample	28_Feb_10	268	MBS-CI-28	CN2005-BD-340	1.706	-0.233	9.934	0.710	-0.001	-0.840	-0.232	0.612	**0.693**		-0.399	0.000	-0.002	0.671	0.752
Heated Gas	28_Feb_10	269	MBS-CI-29	MBS_11-16-09_EnrCO2-2	14.824	-0.858	36.730	2.610	-0.001	-0.840	-0.847	-0.007			-0.022	0.000	-0.002	0.019	
Standard	01_Mar_10	270	MBS-CI-30	UU Carrara	17.297	-0.587	25.649	1.929	-0.001	-0.840	-0.574	0.267	**0.348**	0.352	-0.083	0.000	-0.002	0.308	0.389
Equilibrated Gas	01_Mar_10	271	MBS-CI-31	Equil Gas Enriched, 27C	16.381	-0.007	38.983	2.206	-0.001	-0.840	0.005	0.850			-0.579	0.000	-0.002	0.922	
Sample	01_Mar_10	272	MBS-CI-32	CN2005-BD-364	1.331	-0.254	9.341	0.732	-0.001	-0.840	-0.253	0.591	**0.672**		-0.355	0.000	-0.002	0.649	0.730
Sample	01_Mar_10	273	MBS-CI-33	CN2004-BD-95	0.871	-0.241	8.804	0.732	-0.001	-0.840	-0.240	0.603	**0.684**		-0.327	0.000	-0.002	0.662	0.743
Sample	01_Mar_10	274	MBS-CI-34	CN2005-BD-364	1.344	-0.265	9.332	0.710	-0.001	-0.840	-0.264	0.580	**0.661**		-0.383	0.000	-0.002	0.637	0.718
Standard	02_Mar_10	276	MBS-CI-36	102-GC-AZ01	3.400	-0.266	-0.669	0.179	-0.001	-0.840	-0.264	0.580	**0.661**	0.650	-0.329	0.000	-0.003	0.638	0.719
Sample	02_Mar_10	277	MBS-CI-37	CN2004-BD-95	0.863	-0.249	8.837	0.822	-0.001	-0.840	-0.248	0.595	**0.676**		-0.250	0.000	-0.003	0.654	0.735
Sample	02_Mar_10	278	MBS-CI-38	CN2005-BD-364	1.425	-0.243	9.528	0.821	-0.001	-0.840	-0.242	0.602	**0.683**		-0.296	0.000	-0.003	0.661	0.742
Heated Gas	03_Mar_10	279	MBS-CI-39	MBS_11-16-09_EnrCO2-3	14.835	-0.842	36.551	2.865	-0.001	-0.840	-0.833	0.007			0.123	0.000	-0.003	0.035	
Sample	03_Mar_10	281	MBS-CI-41	CN2004-BD-95	0.903	-0.259	8.890	0.762	-0.001	-0.840	-0.258	0.585	**0.666**		-0.325	0.000	-0.003	0.644	0.725
Equilibrated Gas	04_Mar_10	283	MBS-CI-43	Equil Gas Depleted, 27C	-2.077	-0.012	-0.070	-0.054	-0.001	-0.841	-0.013	0.832			-0.597	0.000	-0.004	0.905	
Standard	04_Mar_10	285	MBS-CI-45	102-GC-AZ01	3.087	-0.284	-1.232	0.173	-0.001	-0.841	-0.282	0.561	**0.642**	0.650	-0.297	0.000	-0.004	0.619	0.700

Sample	04_Mar_10	286	MBS-CI-46	CN2004-BD-117	0.935	-0.260	9.820	0.786	-0.001	-0.841	-0.260	0.584	**0.665**		-0.374	0.000	-0.004	0.644	0.725
Sample	04_Mar_10	287	MBS-CI-47	CN2005-BD-375	1.393	-0.245	8.500	0.707	0.000	-0.841	-0.244	0.600	**0.681**		-0.373	0.000	-0.004	0.660	0.741
Heated Gas	05_Mar_10	288	MBS-CI-48	MBS_11-17-09_EnrCO2-1	15.345	-0.852	38.598	3.055	0.000	-0.841	-0.845	-0.004			0.072	0.000	-0.004	0.023	
Sample	05_Mar_10	289	MBS-CI-49	CN2004-BD-231	1.869	-0.256	9.382	0.872	0.000	-0.841	-0.255	0.589	**0.670**		-0.270	0.000	-0.004	0.649	0.730
Standard	05_Mar_10	290	MBS-CI-50	UU Carrara	17.259	-0.580	25.839	2.082	0.000	-0.841	-0.572	0.270	**0.351**	0.352	-0.114	0.000	-0.004	0.312	0.393
Sample	05_Mar_10	291	MBS-CI-51	CN2004-BD-117	0.836	-0.284	9.788	0.849	0.000	-0.841	-0.284	0.560	**0.641**		-0.326	0.000	-0.005	0.619	0.700
Heated Gas	06_Mar_10	292	MBS-CI-52	MBS_11-13-09_Tank1CO2-2	-0.356	-0.831	5.128	0.882	0.000	-0.841	-0.831	0.010			0.005	0.000	-0.005	0.038	
Sample	06_Mar_10	293	MBS-CI-53	CN2005-BD-375	1.377	-0.231	8.404	0.690	0.000	-0.841	-0.230	0.614	**0.695**		-0.402	0.000	-0.005	0.675	0.756
Sample	06_Mar_10	294	MBS-CI-54	CN2004-BD-117	0.891	-0.251	9.776	0.824	0.000	-0.841	-0.251	0.593	**0.674**		-0.360	0.000	-0.005	0.654	0.735
Sample	06_Mar_10	295	MBS-CI-55	CN2005-BD-375	1.535	-0.267	8.496	0.719	0.000	-0.841	-0.266	0.578	**0.659**		-0.384	0.000	-0.005	0.637	0.718
Sample	06_Mar_10	296	MBS-CI-56	CN2004-BD-231	1.784	-0.266	9.318	0.920	0.000	-0.841	-0.265	0.579	**0.660**		-0.241	0.000	-0.005	0.639	0.720
Equilibrated Gas	07_Mar_10	297	MBS-CI-57	Equil Gas Depleted, 27C	-2.116	-0.007	-0.196	-0.090	0.000	-0.842	-0.008	0.838			-0.623	0.000	-0.005	0.912	
Standard	07_Mar_10	298	MBS-CI-58	102-GC-AZ01	2.884	-0.297	-1.457	0.154	0.000	-0.842	-0.296	0.548	**0.629**	0.650	-0.295	0.000	-0.005	0.606	0.687
Sample	07_Mar_10	299	MBS-CI-59	CN2004-BD-240	0.010	-0.248	8.657	0.741	0.000	-0.842	-0.248	0.596	**0.677**		-0.385	0.000	-0.006	0.657	0.738
Sample	07_Mar_10	300	MBS-CI-60	CN2004-BD-201	1.341	-0.249	10.314	0.897	0.000	-0.842	-0.249	0.596	**0.677**		-0.344	0.000	-0.006	0.657	0.738
Sample	07_Mar_10	301	MBS-CI-61	CN2004-BD-240	0.160	-0.272	9.015	0.736	0.000	-0.842	-0.272	0.572	**0.653**		-0.420	0.000	-0.006	0.632	0.713
Heated Gas	08_Mar_10	302	MBS-CI-62	MBS_11-11-09_Tank1CO2-1	-0.155	-0.840	5.067	0.789	0.000	-0.842	-0.840	0.002			-0.102	0.000	-0.006	0.029	
Sample	08_Mar_10	303	MBS-CI-63	CN2004-BD-201	1.212	-0.263	10.086	0.924	0.000	-0.842	-0.263	0.582	**0.663**		-0.312	0.000	-0.006	0.642	0.723
Standard	08_Mar_10	304	MBS-CI-64	UU Carrara	17.379	-0.570	26.187	2.358	0.000	-0.842	-0.566	0.277	**0.358**	0.352	0.009	0.000	-0.006	0.320	0.401
Sample	08_Mar_10	305	MBS-CI-65	CN2004-BD-252	6.971	-0.252	9.744	0.959	0.000	-0.842	-0.250	0.594	**0.675**		-0.261	0.000	-0.006	0.655	0.736
Sample	08_Mar_10	306	MBS-CI-66	CN2004-BD-252	7.000	-0.234	9.691	0.864	0.000	-0.842	-0.232	0.612	**0.693**		-0.356	0.001	-0.006	0.674	0.755
Sample	08_Mar_10	307	MBS-CI-67	CN2004-BD-201	1.240	-0.245	9.978	0.839	0.000	-0.842	-0.245	0.600	**0.681**		-0.404	0.001	-0.006	0.662	0.743
Sample	09_Mar_10	308	MBS-CI-68	CN2004-BD-252	6.936	-0.233	9.871	0.919	0.000	-0.842	-0.232	0.613	**0.694**		-0.320	0.001	-0.007	0.676	0.757
Heated Gas	09_Mar_10	309	MBS-CI-69	MBS_11-17-09_EnrCO2-2	14.779	-0.862	37.807	3.418	0.000	-0.842	-0.859	-0.017			0.200	0.001	-0.007	0.009	
Sample	09_Mar_10	310	MBS-CI-70	CN2004-BD-240	-0.005	-0.241	8.497	0.684	0.000	-0.842	-0.241	0.603	**0.684**		-0.465	0.001	-0.007	0.666	0.747
Standard	09_Mar_10	311	MBS-CI-71	UU Carrara	17.311	-0.560	26.108	2.357	0.000	-0.843	-0.558	0.286	**0.367**	0.352	-0.054	0.001	-0.007	0.330	0.411
Standard	09_Mar_10	317	GH-CI-51	102-GC-AZ01	2.926	-0.279	-1.588	0.006	0.000	-0.843	-0.279	0.566	**0.647**	0.650	-0.422	0.001	-0.007	0.626	0.707
Heated Gas	11_Mar_10	322	GH-CI-56	GH0061	15.040	-0.835	38.441	3.689	0.000	-0.843	-0.835	0.008			0.236	0.001	-0.008	0.035	
Standard	11_Mar_10	323	GH-CI-57	UU Carrara	17.376	-0.579	26.432	2.603	0.000	-0.843	-0.580	0.264	**0.345**	0.352	0.049	0.001	-0.008	0.307	0.388
Standard	11_Mar_10	326	GH-CI-60	UU Carrara	17.410	-0.545	26.538	2.648	0.000	-0.844	-0.547	0.298	**0.379**	0.352	0.055	0.001	-0.008	0.343	0.424
Equilibrated Gas	12_Mar_10	329	GH-CI-63	Equil Gas Depleted, 27C	-2.096	0.013	-0.015	0.073	0.000	-0.844	0.013	0.859			-0.470	0.001	-0.008	0.938	
Standard	12_Mar_10	331	GH-CI-65	102-GC-AZ01	3.023	-0.264	-1.319	0.182	0.000	-0.844	-0.265	0.580	**0.661**	0.650	-0.258	0.001	-0.009	0.643	0.724
Heated Gas	13_Mar_10	335	GH-CI-69	GH0063	15.804	-0.822	40.792	4.272	0.000	-0.844	-0.826	0.019			0.432	0.001	-0.009	0.047	
Standard	13_Mar_10	336	GH-CI-70	102-GC-AZ01	3.064	-0.256	-1.458	0.118	0.000	-0.844	-0.257	0.588	**0.669**	0.650	-0.308	0.001	-0.009	0.651	0.732
Equilibrated Gas	13_Mar_10	338	GH-CI-72	Equil Gas Enriched, 27C	16.400	0.013	40.522	3.693	0.000	-0.845	0.008	0.854			-0.174	0.001	-0.009	0.933	
Equilibrated Gas	15_Mar_10	339	BP-CI-684	Equil Gas Depleted, 27C	-2.125	-0.005	-0.198	-0.077	0.000	-0.845	-0.004	0.841			-0.605	0.001	-0.009	0.920	
Heated Gas	16_Mar_10	346	BP-CI-682	Heated Reg CO2	0.154	-0.842	5.996	1.029	0.000	-0.845	-0.842	0.003			-0.026	0.001	-0.010	0.030	
Standard	17_Mar_10	349	BP-CI-693	102-GC-AZ01	2.976	-0.289	-1.516	0.116	0.000	-0.845	-0.290	0.555	**0.636**	0.650	-0.297	0.001	-0.010	0.617	0.698
Heated Gas	17_Mar_10	352	BP-CI-672	Heated Evap CO2	14.982	-0.872	39.130	4.114	0.001	-0.846	-0.880	-0.034			0.134	0.001	-0.010	-0.009	
Standard	17_Mar_10	354	BP-CI-697	UU Carrara	17.366	-0.563	26.822	3.015	0.001	-0.846	-0.573	0.273	**0.354**	0.352	0.093	0.001	-0.010	0.317	0.398
Heated Gas	18_Mar_10	358	BP-CI-705	Heated Reg CO2	0.051	-0.842	5.761	1.105	0.001	-0.846	-0.842	0.004			0.040	0.001	-0.011	0.031	
Standard	19_Mar_10	361	BP-CI-702	2-8-E	1.858	-0.306	16.794	1.812	0.001	-0.846	-0.307	0.538	**0.619**	0.641	-0.272	0.001	-0.011	0.600	0.681
Equilibrated Gas	19_Mar_10	365	BP-CI-721	Equil Gas Enriched, 27C	16.501	0.009	41.045	3.991	0.001	-0.847	-0.003	0.842			-0.387	0.001	-0.011	0.923	
Standard	20_Mar_10	367	BP-CI-711	NBS-19	16.878	-0.568	25.863	2.773	0.001	-0.847	-0.581	0.265	**0.346**	0.352	-0.210	0.001	-0.011	0.309	0.390
Heated Gas	20_Mar_10	369	BP-CI-674	Heated Evap CO2	15.059	-0.827	39.086	4.272	0.001	-0.847	-0.839	0.008			0.008	0.001	-0.011	0.035	
Standard	21_Mar_10	373	BP-CI-716	102-GC-AZ01	2.780	-0.281	-1.581	0.220	0.001	-0.847	-0.283	0.562	**0.643**	0.650	-0.172	0.001	-0.011	0.626	0.707
Standard	22_Mar_10	377	GH-CI-73	2-8-E	1.892	-0.296	16.999	1.963	0.001	-0.848	-0.298	0.548	**0.629**	0.641	-0.260	0.001	-0.011	0.611	0.692
Heated Gas	22_Mar_10	380	GH-CI-76	GH0064	14.586	-0.836	38.567	4.520	0.001	-0.848	-0.851	-0.003			0.115	0.001	-0.012	0.024	
Standard	23_Mar_10	382	GH-CI-78	NBS-19	16.852	-0.534	26.443	3.211	0.001	-0.848	-0.552	0.295	**0.376**	0.352	-0.005	0.001	-0.012	0.341	0.422
Equilibrated Gas	23_Mar_10	384	GH-CI-80	Equil Gas Depleted, 27C	-3.401	-0.044	-2.854	-0.258	0.001	-0.848	-0.040	0.805			-0.513	0.001	-0.012	0.884	
Standard	24_Mar_10	387	GH-CI-83	2-8-E	2.029	-0.285	16.823	1.930	0.001	-0.848	-0.287	0.559	**0.640**	0.641	-0.353	0.002	-0.012	0.622	0.703
Equilibrated Gas	24_Mar_10	388	GH-CI-85	Equil Gas Depleted, 27C	-3.335	-0.007	-2.816	-0.315	0.001	-0.849	-0.003	0.842			-0.569	0.002	-0.012	0.924	
Equilibrated Gas	24_Mar_10	389	GH-CI-86	Equil Gas Depleted, 27C	-3.362	-0.030	-2.769	-0.231	0.001	-0.849	-0.026	0.819			-0.488	0.002	-0.012	0.900	
Heated Gas	25_Mar_10	390	GH-CI-87	GH0079	-0.862	-0.857	4.094	0.951	0.001	-0.849	-0.856	-0.007			-0.024	0.002	-0.012	0.019	
Standard	25_Mar_10	394	GH-CI-91	NBS-19	16.822	-0.535	26.779	3.372	0.001	-0.849	-0.557	0.291	**0.372**	0.352	-0.028	0.002	-0.012	0.337	0.418
Heated Gas	26_Mar_10	396	GH-CI-92	GH0060	15.181	-0.823	39.943	4.861	0.001	-0.849	-0.843	0.006			0.021	0.002	-0.012	0.033	
Standard	26_Mar_10	398	GH-CI-95	2-8-E	2.354	-0.298	17.857	2.246	0.001	-0.849	-0.301	0.546	**0.627**	0.641	-0.237	0.002	-0.012	0.608	0.689
Standard	27_Mar_10	399	GH-CI-96	NBS-19	16.907	-0.513	26.405	3.107	0.001	-0.849	-0.536	0.312	**0.393**	0.352	-0.316	0.002	-0.012	0.359	0.440
Heated Gas	27_Mar_10	400	GH-CI-97	GH0080	-0.491	-0.843	5.176	1.125	0.001	-0.850	-0.842	0.007			0.012	0.002	-0.012	0.035	
Standard	28_Mar_10	404	GH-CI-101	NBS-19	16.911	-0.515	27.078	3.421	0.001	-0.850	-0.540	0.308	**0.389**	0.352	-0.141	0.002	-0.012	0.355	0.436
Standard	28_Mar_10	405	GH-CI-102	2-8-E	2.140	-0.293	17.334	2.264	0.001	-0.850	-0.296	0.551	**0.632**	0.641	-0.221	0.002	-0.012	0.614	0.695
Heated Gas	28_Mar_10	406	GH-CI-103	GH0062	15.461	-0.824	41.422	5.311	0.002	-0.850	-0.847	0.003			0.113	0.002	-0.012	0.030	
Heated Gas	28_Mar_10	407	GH-CI-104	GH0083	-0.936	-0.857	3.945	0.965	0.002	-0.850	-0.856	-0.005			-0.028	0.002	-0.012	0.021	
Heated Gas	29_Mar_10	408	GH-CI-105	GH0066	-59.618	-0.990	-55.400	-6.531	0.002	-0.850	-0.897	-0.047			-0.805	0.002	-0.012	-0.023	
Standard	29_Mar_10	409	RK-CI-013	UU Carrara	17.549	-0.539	27.818	3.647	0.002	-0.850	-0.567	0.282	**0.363**	0.352	-0.065	0.002	-0.012	0.327	0.408
Heated Gas	30_Mar_10	414	RK-CI-008a	Evap CO2	14.514	-0.825	38.881	5.067	0.002	-0.851	-0.849	0.001			0.001	0.002	-0.012	0.029	
Standard	30_Mar_10	416	RK-CI-020	102-GC-AZ01	2.881	-0.272	-1.766	-0.015	0.002	-0.851	-0.277	0.570	**0.651**	0.650	-0.357	0.002	-0.012	0.635	0.716
Standard	31_Mar_10	420	RK-CI-024	UU Carrara	17.353	-0.539	27.610	3.814	0.002	-0.851	-0.570	0.279	**0.360**	0.352	-0.026	0.002	-0.012	0.325	0.406
Heated Gas	31_Mar_10	421	RK-CI-003	Reg CO2	1.271	-0.842	7.592	1.387	0.002	-0.851	-0.844	0.007			-0.071	0.002	-0.012	0.034	
Standard	1_Apr_10	426	BP-CI-726	102-GC-AZ01	3.141	-0.276	-1.596	-0.064	0.002	-0.852	-0.282	0.565	**0.646**	0.650	-0.419	0.002	-0.012	0.629	0.710
Heated Gas	1_Apr_10	428	BP-CI-673	Heated Evap CO2	15.223	-0.814	40.738	5.526	0.002	-0.852	-0.844	0.008			-0.044	0.002	-0.012	0.036	
Standard	1_Apr_10	431	BP-CI-730	UU Carrara	17.334	-0.539	27.499	3.746	0.002	-0.852	-0.574	0.276	**0.357**	0.352	-0.235	0.002	-0.012	0.321	0.402
Heated Gas	2_Apr_10	436	BP-CI-706	Heated Reg CO2	-0.195	-0.851	5.028	1.113	0.002	-0.853	-0.851	0.002			-0.079	0.002	-0.012	0.029	
Standard	2_Apr_10	437	BP-CI-738	102-GC-AZ01	2.836	-0.266	-1.770	0.128	0.002	-0.853	-0.272	0.576	**0.657**	0.650	-0.198	0.002	-0.012	0.640	0.721

Standard	4_Apr_10	441	BP-CI-742	NBS-19	16.834	-0.542	26.893	3.850	0.002	-0.853	-0.579	0.271	**0.352**	0.352	-0.197	0.002	-0.012	0.316	0.397
Standard	5_Apr_10	447	MBS-CI-75	UU Carrara	17.363	-0.534	27.823	4.022	0.002	-0.854	-0.575	0.276	**0.357**	0.352	-0.235	0.002	-0.012	0.321	0.402
Heated Gas	6_Apr_10	448	MBS-CI-76	MBS_3-24-10_RegCO2-5	0.398	-0.858	6.623	1.536	0.002	-0.854	-0.859	-0.005			0.097	0.002	-0.012	0.021	
Heated Gas	7_Apr_10	453	MBS-CI-81	MBS_3-24-10_RegCO2-2	-0.346	-0.882	5.567	1.389	0.002	-0.854	-0.881	-0.027			0.075	0.002	-0.012	-0.001	
Heated Gas	8_Apr_10	456	MBS-CI-85	MBS_3-25-10_EnrCO2	13.812	-0.799	38.394	5.936	0.003	-0.854	-0.834	0.020			0.085	0.003	-0.012	0.048	
Sample	8_Apr_10	457	MBS-CI-86	CN2004-BD-162	1.686	-0.254	10.694	1.651	0.003	-0.854	-0.258	0.590	**0.671**		-0.385	0.003	-0.012	0.655	0.736
Sample	8_Apr_10	458	MBS-CI-87	CN2004-BD-141	1.342	-0.248	10.803	1.688	0.003	-0.855	-0.251	0.597	**0.678**		-0.370	0.003	-0.011	0.662	0.743
Sample	9_Apr_10	460	MBS-CI-89	CN2004-BD-162	1.653	-0.248	10.796	1.779	0.003	-0.855	-0.252	0.596	**0.677**		-0.290	0.003	-0.011	0.661	0.742
Sample	9_Apr_10	461	MBS-CI-90	CN2004-BD-141	1.330	-0.265	10.801	1.671	0.003	-0.855	-0.269	0.580	**0.661**		-0.405	0.003	-0.011	0.644	0.725
Heated Gas	10_Apr_10	462	RAK-CI-001	Reg CO2	-1.221	-0.853	4.506	1.116	0.003	-0.855	-0.850	0.005			-0.077	0.003	-0.011	0.032	
Standard	10_Apr_10	463	RK-CI-027	102-GC-AZ01	2.897	-0.257	-1.618	0.213	0.003	-0.855	-0.265	0.584	**0.665**	0.650	-0.115	0.003	-0.011	0.648	0.729
Standard	11_Apr_10	467	RK-CI-031	UU Carrara	17.382	-0.538	28.206	4.348	0.003	-0.855	-0.586	0.266	**0.347**	0.352	-0.270	0.003	-0.011	0.310	0.391
Heated Gas	11_Apr_10	468	RK-CI-007	Evap CO2	15.047	-0.835	41.648	6.316	0.003	-0.855	-0.877	-0.021			-0.260	0.003	-0.011	0.004	
Standard	12_Apr_10	473	RK-CI-036	102-GC-AZ01	2.953	-0.288	-1.811	-0.024	0.003	-0.856	-0.297	0.552	**0.633**	0.650	-0.316	0.003	-0.011	0.615	0.696
Heated Gas	12_Apr_10	474	RK-CI-002	Reg CO2	0.209	-0.850	6.386	1.515	0.003	-0.856	-0.851	0.005			0.011	0.003	-0.011	0.033	
Standard	13_Apr_10	479	RK-CI-041	UU Carrara	17.394	-0.515	28.336	4.463	0.003	-0.856	-0.568	0.285	**0.366**	0.352	-0.367	0.003	-0.010	0.330	0.411
Heated Gas	14_Apr_10	481	RK-CI-009	Evap CO2	14.086	-0.818	39.011	6.206	0.003	-0.857	-0.861	-0.005			-0.278	0.003	-0.010	0.022	
Standard	14_Apr_10	482	RK-CI-043	102-GC-AZ01	3.005	-0.265	-1.921	-0.110	0.003	-0.857	-0.274	0.575	**0.656**	0.650	-0.379	0.003	-0.010	0.638	0.719
Heated Gas	14_Apr_10	484	RK-CI-004	Reg CO2	-0.961	-0.876	4.760	1.232	0.003	-0.857	-0.873	-0.016			-0.061	0.003	-0.010	0.010	
Standard	15_Apr_10	488	RK-CI-048	UU Carrara	17.386	-0.523	28.617	4.773	0.003	-0.857	-0.579	0.274	**0.355**	0.352	-0.249	0.003	-0.010	0.318	0.399
Heated Gas	15_Apr_10	490	RK-CI-012	Evap CO2	14.023	-0.785	38.811	6.467	0.003	-0.858	-0.831	0.026			-0.190	0.003	-0.010	0.055	
Heated Gas	16_Apr_10	494	RK-CI-005	Reg CO2	-0.003	-0.848	6.068	1.475	0.003	-0.858	-0.848	0.010			-0.056	0.003	-0.009	0.037	
Standard	16_Apr_10	495	RK-CI-053	102-GC-AZ01	3.013	-0.259	-1.536	-0.008	0.003	-0.858	-0.269	0.580	**0.661**	0.650	-0.327	0.003	-0.009	0.643	0.724
Standard	17_Apr_10	497	GH-CI-106	102-GC-AZ01	2.986	-0.283	-1.548	0.015	0.003	-0.858	-0.293	0.556	**0.637**	0.650	-0.301	0.003	-0.009	0.618	0.699
Standard	17_Apr_10	501	GH-CI-110	UU Carrara	17.419	-0.521	29.051	5.152	0.004	-0.859	-0.583	0.272	**0.353**	0.352	-0.163	0.003	-0.009	0.315	0.396
Heated Gas	18_Apr_10	503	GH-CI-112	Evap CO2	15.571	-0.803	43.655	7.532	0.004	-0.859	-0.859	0.000			-0.222	0.003	-0.009	0.027	
Standard	18_Apr_10	507	GH-CI-116	102-GC-AZ01	2.946	-0.272	-1.760	-0.047	0.004	-0.859	-0.283	0.567	**0.648**	0.650	-0.321	0.003	-0.008	0.628	0.709
Standard	19_Apr_10	510	GH-CI-120	102-GC-AZ01	2.968	-0.277	-1.628	0.040	0.004	-0.859	-0.288	0.562	**0.643**	0.650	-0.254	0.003	-0.008	0.623	0.704
Standard	19_Apr_10	513	GH-CI-124	UU Carrara	17.449	-0.516	29.404	5.416	0.004	-0.860	-0.583	0.272	**0.353**	0.352	-0.172	0.003	-0.008	0.316	0.397
Heated Gas	19_Apr_10	514	GH-CI-125	Evap CO2	15.134	-0.819	42.981	7.763	0.004	-0.860	-0.877	-0.017			-0.168	0.003	-0.008	0.009	
Equilibrated Gas	20_Apr_10	515	GH-CI-126	Enriched Equil Gas, 27C	16.488	0.035	44.651	7.533	0.004	-0.860	-0.029	0.817			-0.712	0.003	-0.008	0.893	
Heated Gas	20_Apr_10	516	RK-CI-006	Reg CO2	0.442	-0.853	6.813	1.792	0.004	-0.860	-0.855	0.005			0.046	0.003	-0.008	0.032	
Standard	21_Apr_10	521	RK-CI-059	102-GC-AZ01	2.925	-0.285	-2.004	-0.257	0.004	-0.860	-0.297	0.554	**0.635**	0.650	-0.477	0.004	-0.007	0.613	0.694
Heated Gas	21_Apr_10	524	RK-CI-010	Evap CO2	15.574	-0.800	44.685	8.357	0.004	-0.861	-0.864	-0.003			-0.143	0.004	-0.007	0.024	
Standard	22_Apr_10	527	RK-CI-064	UU Carrara	17.402	-0.511	29.781	5.866	0.004	-0.861	-0.583	0.273	**0.354**	0.352	-0.047	0.004	-0.007	0.315	0.396
Equilibrated Gas	22_Apr_10	530	RK-CI-068	Equil Gas Enriched, 27C	16.516	0.066	45.314	8.146	0.004	-0.861	-0.004	0.841			-0.637	0.004	-0.006	0.917	
Standard	23_Apr_10	532	RK-CI-070	102-GC-AZ01	2.884	-0.299	-1.738	0.022	0.004	-0.862	-0.311	0.540	**0.621**	0.650	-0.237	0.004	-0.006	0.598	0.679
Heated Gas	24_Apr_10	536	RK-CI-076	Reg CO2	0.821	-0.858	7.372	2.011	0.004	-0.862	-0.862	0.000			0.071	0.004	-0.006	0.027	
Sample	24_Apr_10	537	MBS-CI-92	CN2004-BD-162	1.726	-0.240	11.464	2.324	0.004	-0.862	-0.248	0.603	**0.684**		-0.381	0.004	-0.005	0.664	0.745
Standard	24_Apr_10	538	MBS-CI-93	102-GC-AZ01	2.876	-0.278	-2.055	-0.193	0.004	-0.862	-0.291	0.560	**0.641**	0.650	-0.388	0.004	-0.005	0.619	0.700
Sample	24_Apr_10	539	MBS-CI-94	CN2004-BD-141	1.355	-0.237	11.669	2.516	0.004	-0.862	-0.243	0.607	**0.688**		-0.242	0.004	-0.005	0.668	0.749
Sample	24_Apr_10	540	MBS-CI-95	CN2005-BD-391	4.999	-0.221	12.069	2.437	0.004	-0.862	-0.243	0.607	**0.688**		-0.404	0.004	-0.005	0.668	0.749
Heated Gas	25_Apr_10	541	MBS-CI-96	MBS_3-25-10_EnrCO2-5	13.950	-0.820	41.156	8.306	0.005	-0.862	-0.883	-0.020			-0.014	0.004	-0.005	0.006	
Sample	25_Apr_10	542	MBS-CI-97	CN2005-BD-395	5.935	-0.219	11.999	2.510	0.005	-0.863	-0.246	0.604	**0.685**		-0.334	0.004	-0.005	0.665	0.746
Sample	25_Apr_10	543	MBS-CI-98	CN2005-BD-391	4.975	-0.217	12.252	2.695	0.005	-0.863	-0.240	0.610	**0.691**		-0.205	0.004	-0.005	0.672	0.753
Standard	25_Apr_10	544	MBS-CI-100	102-GC-AZ01	2.897	-0.274	-1.772	-0.061	0.005	-0.863	-0.287	0.564	**0.645**	0.650	-0.304	0.004	-0.005	0.622	0.703
Standard	25_Apr_10	545	MBS-CI-101	UU Carrara	17.400	-0.494	30.390	6.487	0.005	-0.863	-0.574	0.283	**0.364**	0.352	0.112	0.004	-0.005	0.326	0.407
Heated Gas	25_Apr_10	546	MBS-CI-102	MBS_3-24-10_RegCO2-4	-1.227	-0.848	4.424	1.482	0.005	-0.863	-0.842	0.020			0.055	0.004	-0.004	0.048	
Sample	26_Apr_10	547	MBS-CI-103	CN2005-BD-395	5.997	-0.202	12.254	2.699	0.005	-0.863	-0.230	0.620	**0.701**		-0.234	0.004	-0.004	0.681	0.762
Sample	26_Apr_10	548	MBS-CI-104	CN2005-BD-399	5.647	-0.271	14.309	3.220	0.005	-0.863	-0.297	0.554	**0.635**		-0.117	0.004	-0.004	0.612	0.693
Sample	26_Apr_10	549	MBS-CI-105	CN2005-BD-395	5.991	-0.220	12.268	2.719	0.005	-0.863	-0.248	0.602	**0.683**		-0.234	0.004	-0.004	0.662	0.743
Sample	26_Apr_10	550	MBS-CI-106	CN2005-BD-391	4.982	-0.229	12.250	2.685	0.005	-0.863	-0.253	0.598	**0.679**		-0.272	0.004	-0.004	0.658	0.739
Standard	27_Apr_10	551	MBS-CI-107	2-8-E	2.290	-0.279	19.318	4.271	0.005	-0.863	-0.290	0.561	**0.642**	0.641	-0.070	0.004	-0.004	0.619	0.700
Heated Gas	27_Apr_10	552	MBS-CI-108	MBS_3-25-10_EnrCO2-4	13.790	-0.797	41.285	8.678	0.005	-0.864	-0.863	0.001			0.036	0.004	-0.004	0.028	
Heated Gas	28_Apr_10	557	MBS-CI-114	MBS_3-24-10_RegCO2-3	-0.118	-0.876	6.505	1.871	0.005	-0.864	-0.875	-0.011			-0.005	0.004	-0.003	0.015	
Heated Gas	30_Apr_10	561	MBS-CI-119	MBS_3-25-10_EnrCO2-1	14.491	-0.792	43.158	9.222	0.005	-0.864	-0.865	0.000			-0.044	0.004	-0.003	0.027	
Heated Gas	01_May_10	566	MBS-CI-124	MBS_3-24-10_RegCO2-1	-0.310	-0.868	6.088	1.879	0.005	-0.865	-0.866	-0.001			0.046	0.004	-0.002	0.026	
Heated Gas	02_May_10	569	MBS-CI-128	MBS_3-25-10_EnrCO2-3	14.947	-0.771	44.777	9.830	0.005	-0.865	-0.849	0.016			-0.003	0.004	-0.001	0.044	
Equilibrated Gas	02_May_10	570	BP-CI-753	Equil Gas Depleted, 27C	-2.409	-0.011	-0.957	-0.277	0.005	-0.865	0.002	0.847			-0.669	0.004	-0.001	0.918	
Standard	02_May_10	571	BP-CI-745	NBS-19	16.987	-0.484	29.968	6.674	0.005	-0.865	-0.574	0.285	**0.366**	0.352	-0.143	0.004	-0.001	0.327	0.408
Standard	03_May_10	575	BP-CI-749	2-8-E	1.934	-0.308	19.506	4.684	0.005	-0.866	-0.318	0.534	**0.615**	0.641	-0.014	0.004	-0.001	0.589	0.670
Heated Gas	04_May_10	578	BP-CI-704	Heated Reg CO2	-0.458	-0.871	6.412	2.021	0.005	-0.866	-0.869	-0.002			0.065	0.004	0.000	0.025	
Equilibrated Gas	04_May_10	580	BP-CI-754	Equil Gas Enriched, 27C	16.349	0.066	47.329	10.407	0.006	-0.866	-0.024	0.822			-0.310	0.004	0.000	0.890	
Equilibrated Gas	04_May_10	581	BP-CI-755	Roth Equil, 50C	0.419	-0.085	6.517	1.536	0.006	-0.867	-0.087	0.760			-0.457	0.005	0.000	0.825	
Equilibrated Gas	05_May_10	582	BP-CI-756	Roth Equil, 0C	11.982	0.221	34.943	7.596	0.006	-0.867	0.154	0.996			-0.521	0.005	0.001	1.072	
Equilibrated Gas	05_May_10	583	BP-CI-756	Roth Equil, 25C	6.401	0.018	21.055	4.756	0.006	-0.867	-0.018	0.828			-0.386	0.005	0.001	0.896	
Heated Gas	05_May_10	584	BP-CI-718	Heated Evap CO2	15.509	-0.774	46.376	10.807	0.006	-0.867	-0.861	0.006			0.165	0.005	0.001	0.033	
Equilibrated Gas	04_May_10	585	BP-CI-764	Equil Gas Depleted, 27C	-2.212	-0.018	-0.431	-0.118	0.006	-0.867	-0.006	0.840			-0.620	0.005	0.001	0.908	
Standard	06_May_10	587	BP-CI-759	UU Carrara	17.381	-0.492	31.606	7.707	0.006	-0.867	-0.591	0.269	**0.350**	0.352	0.198	0.005	0.001	0.309	0.390
Equilibrated Gas	07_May_10	592	BP-CI-765	Equil Gas Enriched, 27C	16.480	0.086	47.902	10.725	0.006	-0.868	-0.010	0.835			-0.517	0.005	0.002	0.902	
Equilibrated Gas	07_May_10	593	BP-CI-766	Equil Roth Water, 0C	11.983	0.203	35.134	7.876	0.006	-0.868	0.133	0.975			-0.554	0.005	0.002	1.048	
Equilibrated Gas	07_May_10	594	BP-CI-766	Equil Roth Water, 50C	1.042	-0.106	7.880	1.868	0.006	-0.868	-0.112	0.736			-0.494	0.005	0.003	0.798	
Standard	07_May_10	595	BP-CI-768	102-GC-AZ01	2.961	-0.265	-2.027	-0.255	0.006	-0.868	-0.283	0.570	**0.651**	0.650	-0.401	0.005	0.003	0.624	0.705
Heated Gas	08_May_10	599	BP-CI-733	Heated Evap CO2	15.478	-0.779	47.368	11.663	0.006	-0.868	-0.872	-0.004			0.304	0.005	0.003	0.023	

Standard	09_May_10	600	JHV-CI-001	UU Carrara	17.459	-0.477	31.756	7.751	0.006	-0.869	-0.583	0.278	**0.359**	0.352	-0.086	0.005	0.004	0.318	0.399
Equilibrated Gas	10_May_10	605	JHV-CI-012	Equil Gas Depleted, 27C	-1.960	0.006	0.062	-0.128	0.006	-0.869	0.018	0.863			-0.747	0.005	0.004	0.929	
Standard	10_May_10	606	JHV-CI-006	102-GC-AZ01	2.858	-0.276	-2.080	-0.325	0.006	-0.869	-0.294	0.560	**0.641**	0.650	-0.448	0.005	0.005	0.612	0.693
Standard	11_May_10	611	JHV-CI-011	UU Carrara	17.487	-0.481	32.113	8.045	0.006	-0.870	-0.592	0.270	**0.351**	0.352	-0.130	0.005	0.005	0.309	0.390
Heated Gas	11_May_10	612	JHV-CI-014	heated reg co2	0.242	-0.868	7.174	2.235	0.006	-0.870	-0.870	0.000			-0.069	0.005	0.006	0.027	
Standard	12_May_10	617	JHU-CI-023	102-GC-AZ01	2.939	-0.281	-1.582	-0.093	0.007	-0.870	-0.300	0.554	**0.635**	0.650	-0.324	0.005	0.007	0.604	0.685
Sample Series 2, May through September 2010																			
Heated Gas	27_May_10	646	JHU-CI-063	Heated Evap CO2	15.527	-0.757	48.582	12.653	0.006	-0.850	-0.848	0.002	**0.083**		-0.327	0.004	0.011	0.029	0.110
Standard	28_May_10	648	JHU-CI-061	102-GC-AZ01	3.103	-0.263	-1.459	-0.026	0.006	-0.850	-0.281	0.566	**0.647**	0.650	-0.368	0.004	0.010	0.604	0.685
Equilibrated Gas	26_May_10	649	JHU-CI-069	Equil Gas Enriched, 30C	15.987	0.085	48.377	12.173	0.006	-0.850	-0.010	0.835	**0.916**		-0.870	0.004	0.010	0.879	0.960
Equilibrated Gas	28_May_10	650	JHU-CI-070	Equil Gas Depleted, 30C	-2.478	0.005	-1.129	-0.298	0.006	-0.850	0.020	0.865	**0.946**		-0.717	0.004	0.010	0.909	0.990
Heated Gas	30_May_10	655	JHU-CI-015	Heated Reg CO2	0.713	-0.859	7.967	2.572	0.006	-0.851	-0.863	-0.012	**0.069**		-0.194	0.005	0.008	0.015	0.096
Standard	30_May_10	656	JHU-CI-75	UU Carrara	17.494	-0.462	33.209	9.122	0.006	-0.851	-0.570	0.279	**0.360**	0.352	-0.229	0.005	0.008	0.312	0.393
Heated Gas	02_June_10	667	JHU-CI-065	Evap CO2	14.208	-0.775	47.055	13.324	0.007	-0.852	-0.868	-0.015	**0.066**		-0.027	0.005	0.005	0.011	0.092
Standard	02_June_10	670	JHU-CI-086	102-GC-AZ01	2.935	-0.262	-1.984	-0.326	0.007	-0.853	-0.281	0.566	**0.647**	0.650	-0.448	0.005	0.004	0.608	0.689
Equilibrated Gas	02_June_10	671	JHU-CI-097	Enriched Equil Gas, 30C	15.657	0.084	49.062	13.490	0.007	-0.853	-0.020	0.825	**0.906**		-0.546	0.005	0.004	0.874	0.955
Standard	03_June_10	678	JHU-CI-102	102-GC-AZ01	3.018	-0.264	-1.830	-0.341	0.007	-0.854	-0.285	0.563	**0.644**	0.650	-0.478	0.006	0.002	0.607	0.688
Heated Gas	04_June_10	681	JHU-CI-067	Heated Reg CO2	0.422	-0.861	8.276	3.019	0.007	-0.854	-0.864	-0.010	**0.071**		0.060	0.006	0.001	0.017	0.098
Standard	04_June_10	684	JHU-CI-107	UU Carrara	17.526	-0.457	34.713	10.521	0.007	-0.854	-0.581	0.270	**0.351**	0.352	0.083	0.006	0.001	0.306	0.387
Equilibrated Gas	05_June_10	688	JHU-CI-117	Equil Gas Depleted, 30C	-3.123	-0.016	-3.020	-0.918	0.007	-0.855	0.006	0.852	**0.933**		-0.684	0.006	0.000	0.906	0.987
Standard	05_June_10	689	JHU-CI-112	102-GC-AZ01	3.102	-0.266	-1.954	-0.374	0.007	-0.855	-0.288	0.560	**0.641**	0.650	-0.441	0.006	-0.001	0.605	0.686
Standard	06_June_10	693	JHU-CI-116	UU Carrara	17.605	-0.432	35.285	10.966	0.007	-0.855	-0.561	0.290	**0.371**	0.352	0.153	0.006	-0.001	0.327	0.408
Heated Gas	06_June_10	694	JHU-CI-118	Heated Evap CO2	15.434	-0.749	52.146	16.090	0.007	-0.855	-0.863	-0.007	**0.074**		0.372	0.006	-0.002	0.019	0.100
Standard	07_June_10	699	JHU-CI-093	102-GC-AZ01	2.873	-0.239	-2.362	-0.578	0.008	-0.856	-0.261	0.588	**0.669**	0.650	-0.497	0.006	-0.003	0.635	0.716
Equilibrated Gas	07_June_10	700	JHU-CI-119	Enriched Equil Gas, 30C	15.700	0.102	50.679	14.981	0.008	-0.856	-0.017	0.829	**0.910**		-0.514	0.006	-0.003	0.885	0.966
Standard	09_June_10	711	JHU-CI-129	UU Carrara	17.583	-0.446	35.641	11.334	0.008	-0.857	-0.585	0.269	**0.350**	0.352	0.009	0.007	-0.005	0.306	0.387
Standard	14_June_10	712	JHU-CI-096	UU Carrara	17.531	-0.441	34.155	9.907	0.008	-0.857	-0.580	0.274	**0.355**	0.352	-0.992	0.007	-0.005	0.311	0.392
Sample	14_June_10	713	JHU-CI-131	B/L B155	0.816	-0.259	12.618	3.795	0.008	-0.857	-0.265	0.584	**0.665**		-0.614	0.007	-0.006	0.633	0.714
Sample	15_June_10	714	JHU-CI-134	B/L 1B	-1.874	-0.301	10.500	3.308	0.008	-0.858	-0.286	0.563	**0.644**		-0.466	0.007	-0.006	0.612	0.693
Sample	15_June_10	715	JHU-CI-137	B/L B112	-0.200	-0.275	12.842	4.046	0.008	-0.858	-0.273	0.576	**0.657**		-0.445	0.007	-0.006	0.625	0.706
Heated Gas	15_June_10	716	JHU-CI-147	Reg CO2 GH 0082	-0.917	-0.838	5.321	2.310	0.008	-0.858	-0.831	0.027	**0.108**		0.100	0.007	-0.006	0.055	0.136
Sample	15_June_10	717	JHU-CI-140	B/L 6.5A	-2.133	-0.301	10.573	3.392	0.008	-0.858	-0.284	0.566	**0.647**		-0.421	0.007	-0.006	0.615	0.696
Sample	15_June_10	718	JHU-CI-143	B/L 3K	-3.020	-0.308	9.644	3.200	0.008	-0.858	-0.284	0.566	**0.647**		-0.335	0.007	-0.007	0.615	0.696
Standard	16_June_10	719	JHU-CI-146	102-GC-AZ01	2.816	-0.255	-2.160	-0.420	0.008	-0.858	-0.278	0.572	**0.653**	0.650	-0.347	0.007	-0.007	0.621	0.702
Sample	16_June_10	720	JHU-CI-132	B/L B155	0.948	-0.256	13.228	4.241	0.008	-0.858	-0.264	0.586	**0.667**		-0.404	0.007	-0.007	0.636	0.717
Equilibrated Gas	16_June_10	721	JHU-CI-148	Depleted Equil Gas, 30C	-2.807	-0.045	-2.046	-0.610	0.008	-0.858	-0.022	0.824	**0.905**		-0.567	0.007	-0.007	0.884	0.965
Sample	16_June_10	722	JHU-CI-138	B/L B112	-0.177	-0.280	13.380	4.487	0.008	-0.858	-0.279	0.571	**0.652**		-0.219	0.007	-0.007	0.621	0.702
Sample	16_June_10	723	JHU-CI-141	B/L 6.5A	-2.104	-0.283	10.807	3.622	0.008	-0.858	-0.266	0.584	**0.665**		-0.297	0.007	-0.008	0.634	0.715
Sample	17_June_10	724	JHU-CI-144	B/L 3K	-2.968	-0.314	9.832	3.372	0.008	-0.859	-0.289	0.560	**0.641**		-0.252	0.007	-0.008	0.610	0.691
Standard	17_June_10	729	JHU-CI-153	UU Carrara	17.482	-0.451	35.846	11.706	0.008	-0.859	-0.598	0.257	**0.338**	0.352	-0.065	0.007	-0.009	0.295	0.376
Heated Gas	18_June_10	734	JHU-CI-159	Evap CO2	14.815	-0.703	51.337	16.790	0.009	-0.860	-0.829	0.030	**0.111**		0.035	0.008	-0.009	0.058	0.139
Standard	18_June_10	735	JHU-CI-160	102-GC-AZ01	2.975	-0.255	-2.146	-0.457	0.009	-0.860	-0.280	0.570	**0.651**	0.650	-0.356	0.008	-0.010	0.621	0.702
Equilibrated Gas	19_June_10	736	JHU-CI-161	Enriched Equil Gas, 30C	15.604	0.097	52.107	16.538	0.009	-0.860	-0.037	0.809	**0.890**		-0.518	0.008	-0.010	0.871	0.952
Standard	19_June_10	740	JHU-CI-165	UU Carrara	17.583	-0.436	36.628	12.317	0.009	-0.860	-0.589	0.267	**0.348**	0.352	0.076	0.008	-0.010	0.305	0.386
Heated Gas	19_June_10	741	JHU-CI-166	Reg. CO2	0.073	-0.864	7.640	3.101	0.009	-0.860	-0.865	-0.004	**0.077**		0.090	0.008	-0.011	0.023	0.104
Standard	20_June_10	746	JHU-CI-171	102-GC-AZ01	2.902	-0.268	-2.290	-0.608	0.009	-0.861	-0.294	0.557	**0.638**	0.650	-0.443	0.008	-0.011	0.609	0.690
Equilibrated Gas	20_June_10	747	JHU-CI-172	Depleted Equil Gas, 30C	-2.776	-0.039	-2.007	-0.613	0.009	-0.861	-0.014	0.831	**0.912**		-0.537	0.008	-0.011	0.896	0.977
Standard	21_June_10	753	JHU-CI-178	UU Carrara	17.576	-0.426	36.941	12.633	0.009	-0.861	-0.585	0.271	**0.352**	0.352	0.037	0.008	-0.012	0.311	0.392
Heated Gas	21_June_10	754	JHU-CI-179	Evap CO2	13.275	-0.716	46.968	15.944	0.009	-0.862	-0.836	0.025	**0.106**		0.059	0.008	-0.012	0.053	0.134
Standard	22_June_10	760	JHU-CI-185	102-GC-AZ01	2.961	-0.235	-2.224	-0.606	0.009	-0.862	-0.262	0.588	**0.669**	0.650	-0.444	0.008	-0.013	0.643	0.724
Equilibrated Gas	22_June_10	762	JHU-CI-187	Depleted Equil. Gas, 30C	-2.768	-0.026	-1.972	-0.591	0.009	-0.862	0.000	0.845	**0.926**		-0.510	0.008	-0.013	0.912	0.993
Standard	23_June_10	767	JHU-CI-192	UU Carrara	17.516	-0.431	37.107	12.910	0.009	-0.863	-0.595	0.262	**0.343**	0.352	0.001	0.009	-0.014	0.302	0.383
Heated Gas	23_June_10	768	JHU-CI-193	Reg CO2	-0.826	-0.862	6.088	2.669	0.009	-0.863	-0.854	0.008	**0.089**		0.071	0.009	-0.014	0.036	0.117
Standard	24_June_10	773	JHU-CI-198	102-GC-AZ01	2.798	-0.254	-2.483	-0.623	0.010	-0.863	-0.281	0.570	**0.651**	0.650	-0.363	0.009	-0.015	0.626	0.707
Sample	24_June_10	774	JHU-CI-135	B/L 1B	-1.978	-0.288	11.437	4.300	0.010	-0.863	-0.269	0.582	**0.663**		-0.113	0.009	-0.015	0.638	0.719
Sample	24_June_10	775	JHU-CI-145	B/L 3K	-2.999	-0.292	10.209	3.817	0.010	-0.863	-0.263	0.588	**0.669**		-0.189	0.009	-0.015	0.644	0.725
Heated Gas	24_June_10	776	JHU-CI-200	Evap CO2 Heated Gas	14.298	-0.726	52.042	18.242	0.010	-0.864	-0.863	0.000	**0.081**		0.147	0.009	-0.015	0.027	0.108
Sample	24_June_10	777	JHU-CI-142	B/L 6.5A	-2.112	-0.284	11.312	4.130	0.010	-0.864	-0.264	0.587	**0.668**		-0.257	0.009	-0.015	0.644	0.725
Standard	25_June_10	778	JHU-CI-201	UU Carrara	17.494	-0.422	37.390	13.202	0.010	-0.864	-0.591	0.267	**0.348**	0.352	0.006	0.009	-0.015	0.307	0.388
Sample	25_June_10	779	JHU-CI-139	B/L B112	-0.233	-0.288	13.904	5.056	0.010	-0.864	-0.286	0.566	**0.647**		-0.218	0.009	-0.015	0.621	0.702
Sample	25_June_10	780	JHU-CI-136	B/L 1B	-1.978	-0.304	11.399	4.251	0.010	-0.864	-0.285	0.567	**0.648**		-0.182	0.009	-0.015	0.622	0.703
Sample	25_June_10	781	JHU-CI-133	B/L B155	1.015	-0.278	14.293	5.117	0.010	-0.864	-0.288	0.564	**0.645**		-0.302	0.009	-0.015	0.619	0.700
Equilibrated Gas	25_June_10	782	JHU-CI-202	Enriched Equil Gas, 30C	15.748	0.131	54.619	18.704	0.010	-0.864	-0.023	0.823	**0.904**		-0.405	0.009	-0.016	0.892	0.973
Standard	25_June_10	783	JHU-CI-203	102-GC-AZ01	2.896	-0.282	-2.087	-0.406	0.010	-0.864	-0.310	0.542	**0.623**	0.650	-0.274	0.009	-0.016	0.596	0.677
Equilibrated Gas	30_June_10	784	JHU-CI-204	Equil Gas Depleted, 30C	-2.820	-0.031	-1.978	-0.502	0.010	-0.864	-0.003	0.842	**0.923**		-0.407	0.009	-0.016	0.912	0.993
Equilibrated Gas	01_Ju3_10	785	JHU-CI-205	Equil Gas Enriched, 30C	15.670	0.113	52.744	17.035	0.010	-0.864	-0.041	0.805	**0.886**		-1.507	0.009	-0.016	0.873	0.954
Heated Gas	06_Jul_10	796	JHU-CI-220	Heated Reg CO2 (SL0007/0008)	-1.155	-0.878	4.920	2.444	0.010	-0.865	-0.866	-0.001	**0.080**		0.160	0.009	-0.017	0.026	0.107
Standard	07_Jul_10	797	JHU-CI-221	2-8-E	1.950	-0.276	23.519	8.515	0.010	-0.865	-0.296	0.556	**0.637**	0.641	-0.196	0.009	-0.017	0.612	0.693
Heated Gas	07_Jul_10	799	JHU-CI-217	Heated Evap CO2	14.543	-0.737	54.476	19.685	0.010	-0.866	-0.884	-0.018	**0.063**		0.238	0.009	-0.017	0.008	0.089
Standard	08_Jul_10	803	JHU-CI-226	UU Carrara	17.336	-0.403	37.963	14.012	0.010	-0.866	-0.580	0.279	**0.360**	0.352	0.221	0.009	-0.017	0.320	0.401
Equilibrated Gas	08_Jul_10	806	JHU-CI-232	Equil Gas Depleted, 30C	-3.081	-0.057	-3.008	-1.042	0.010	-0.866	-0.025	0.821	**0.902**		-0.590	0.010	-0.017	0.891	0.972
Equilibrated Gas	13_Aug_10	815	JHU-CI-233	Enriched Equil Gas, 30C	15.764	0.134	54.533	18.522	0.010	-0.867	-0.031	0.815	**0.896**		-1.271	0.010	-0.018	0.885	0.966
Equilibrated Gas	13_Aug_10	816	JHU-CI-234	Depleted Equil Gas, 30C	-2.936	-0.075	-2.450	-0.755	0.011	-0.867	-0.044	0.802	**0.883**		-0.501	0.010	-0.018	0.872	0.953

Equilibrated Gas	13_Aug_10	817	JHU-CI-235	Enriched Equil Gas, 30C	16.106	0.129	55.462	18.776	0.011	-0.867	-0.040	0.806	**0.887**		-1.383	0.010	-0.018	0.876	0.957
Equilibrated Gas	14_Aug_10	818	JHU-CI-236	Depleted Equil Gas, 30C	-2.771	-0.030	-2.286	-0.881	0.011	-0.867	-0.001	0.845	**0.926**		-0.686	0.010	-0.018	0.917	0.998
Equilibrated Gas	14_Aug_10	819	JHU-CI-237	Enriched Equil Gas, 30C	15.786	0.145	54.644	18.688	0.011	-0.867	-0.022	0.824	**0.905**		-1.220	0.010	-0.018	0.895	0.976
Equilibrated Gas	14_Aug_10	820	JHU-CI-238	Depleted Equil Gas, 30C	-2.786	-0.042	-2.202	-0.793	0.011	-0.867	-0.013	0.833	**0.914**		-0.629	0.010	-0.018	0.905	0.986
Heated Gas	14_Aug_10	821	JHU-CI-239	Reg CO2	-0.246	-0.862	7.711	3.272	0.011	-0.867	-0.859	0.008	**0.089**		-0.072	0.010	-0.018	0.035	0.116
Heated Gas	15_Aug_10	822	JHU-CI-219	Evap CO2	15.588	-0.709	56.009	19.884	0.011	-0.867	-0.875	-0.007	**0.074**		-0.563	0.010	-0.018	0.020	0.101
Standard	15_Aug_10	823	JHU-CI-240	NBS-19	17.062	-0.429	36.883	13.345	0.011	-0.868	-0.611	0.250	**0.331**	0.352	-0.343	0.010	-0.018	0.291	0.372
Standard	16_Aug_10	827	JHU-CI-244	102-GC-AZ01	2.975	-0.250	-2.495	-0.781	0.011	-0.868	-0.282	0.571	**0.652**	0.650	-0.519	0.010	-0.018	0.628	0.709
Heated Gas	16_Aug_10	828	JHU-CI-248	Reg CO2	-0.033	-0.876	8.398	3.560	0.011	-0.868	-0.876	-0.007	**0.074**		-0.055	0.010	-0.018	0.019	0.100
Standard	16_Aug_10	832	JHU-CI-249	NBS-19	17.100	-0.402	37.381	13.791	0.011	-0.868	-0.587	0.274	**0.355**	0.352	-0.186	0.010	-0.018	0.315	0.396
Equilibrated Gas	17_Aug_10	833	JHU-CI-250	Enriched Equil Gas, 30C	15.763	0.159	55.920	19.969	0.011	-0.868	-0.012	0.834	**0.915**		-0.642	0.010	-0.018	0.906	0.987
Standard	17_Aug_10	837	JHU-CI-254	102-GC-AZ01	2.975	-0.253	-2.241	-0.595	0.011	-0.869	-0.285	0.567	**0.648**	0.650	-0.435	0.010	-0.018	0.625	0.706
Heated Gas	18_Aug_10	838	JHU-CI-218	Evap CO2	18.186	0.222	63.396	22.428	0.011	-0.869	0.023	0.868	**0.949**		-0.947	0.010	-0.018	0.941	1.023
Standard	18_Aug_10	842	JHU-CI-258	NBS-19	17.100	-0.390	37.794	14.214	0.011	-0.869	-0.578	0.283	**0.364**	0.352	-0.027	0.010	-0.018	0.325	0.406
Equilibrated Gas	18_Aug_10	843	JHU-CI-259	Depleted Equil Gas, 30C	-2.765	-0.044	-2.193	-0.815	0.011	-0.869	-0.013	0.832	**0.913**		-0.680	0.010	-0.018	0.904	0.985
Sample	19_Aug_10	844	JHU-CI-260	B/L 5A	-1.947	-0.289	12.823	5.100	0.011	-0.869	-0.267	0.585	**0.666**		-0.173	0.010	-0.018	0.644	0.725
Sample	19_Aug_10	845	JHU-CI-261	B/L 120	-0.595	-0.289	14.143	5.437	0.011	-0.869	-0.282	0.571	**0.652**		-0.317	0.010	-0.018	0.628	0.709
Sample	19_Aug_10	846	JHU-CI-262	B/L 5A	-1.991	-0.298	12.650	5.001	0.011	-0.869	-0.276	0.577	**0.658**		-0.220	0.010	-0.018	0.635	0.716
Sample	19_Aug_10	847	JHU-CI-263	B/L 5A	-1.943	-0.286	12.729	5.018	0.011	-0.869	-0.264	0.588	**0.669**		-0.236	0.010	-0.018	0.647	0.728
Heated Gas	20_Aug_10	848	JHU-CI-264	Evap. CO2	14.075	-0.725	52.985	20.044	0.011	-0.869	-0.882	-0.012	**0.069**		0.254	0.010	-0.018	0.015	0.096
Standard	20_Aug_10	849	JHU-CI-265	NBS-19	17.056	-0.378	37.742	14.224	0.011	-0.870	-0.568	0.293	**0.374**	0.352	-0.075	0.010	-0.018	0.336	0.417
Sample	20_Aug_10	850	JHU-CI-266	B/L 120	-0.601	-0.277	14.156	5.468	0.011	-0.870	-0.270	0.583	**0.664**		-0.317	0.010	-0.018	0.641	0.722
Sample	21_Aug_10	851	JHU-CI-267	B/L 120	-0.625	-0.277	14.268	5.571	0.011	-0.870	-0.270	0.583	**0.664**		-0.260	0.010	-0.018	0.641	0.722
Sample	21_Aug_10	852	JHU-CI-268	B/L 9K	-1.183	-0.280	14.085	5.475	0.011	-0.870	-0.267	0.586	**0.667**		-0.295	0.010	-0.018	0.645	0.726
Sample	21_Aug_10	853	JHU-CI-269	B/L 9K	-1.179	-0.277	14.191	5.576	0.011	-0.870	-0.264	0.589	**0.670**		-0.237	0.010	-0.018	0.648	0.729
Heated Gas	21_Aug_10	854	JHU-CI-270	Reg CO2	0.072	-0.859	9.104	4.017	0.011	-0.870	-0.860	0.010	**0.091**		0.041	0.011	-0.018	0.037	0.118
Sample	22_Aug_10	855	JHU-CI-271	B/L 4K	-3.867	-0.329	8.435	3.474	0.011	-0.870	-0.285	0.568	**0.649**		-0.263	0.011	-0.018	0.625	0.706
Standard	22_Aug_10	856	JHU-CI-272	NBS-19	17.036	-0.405	38.176	14.655	0.011	-0.870	-0.597	0.265	**0.346**	0.352	0.127	0.011	-0.018	0.307	0.388
Sample	22_Aug_10	857	JHU-CI-273	B/L 9K	-1.159	-0.300	14.326	5.664	0.011	-0.870	-0.287	0.567	**0.648**		-0.219	0.011	-0.018	0.624	0.705
Sample	22_Aug_10	858	JHU-CI-274	B/L 4K	-3.935	-0.315	8.227	3.351	0.011	-0.870	-0.271	0.583	**0.664**		-0.323	0.011	-0.018	0.641	0.722
Sample	22_Aug_10	859	JHU-CI-275	B/L 4K	-3.923	-0.325	8.400	3.484	0.011	-0.870	-0.281	0.573	**0.654**		-0.257	0.011	-0.018	0.631	0.712
Equilibrated Gas	23_Aug_10	860	JHU-CI-276	Enriched Equil Gas, 30C	15.759	0.142	57.397	21.370	0.011	-0.870	-0.037	0.810	**0.891**		-0.183	0.011	-0.018	0.880	0.961
Standard	23_Aug_10	861	JHU-CI-277	102-GC-AZ01	2.997	-0.254	-2.420	-0.814	0.011	-0.870	-0.288	0.566	**0.647**	0.650	-0.628	0.011	-0.018	0.623	0.704
Equilibrated Gas	24_Aug_10	865	JHU-CI-281	Depleted Equil Gas, 30C	-2.866	-0.039	-2.633	-1.064	0.011	-0.871	-0.006	0.839	**0.920**		-0.808	0.011	-0.018	0.911	0.992
Standard	24_Aug_10	866	JHU-CI-283	UU Carrara	17.570	-0.394	39.307	14.975	0.011	-0.871	-0.595	0.268	**0.349**	0.352	-0.060	0.011	-0.018	0.309	0.390
Heated Gas	24_Aug_10	869	JHU-CI-286	Reg CO2	0.378	-0.883	9.066	4.095	0.011	-0.871	-0.887	-0.016	**0.065**		0.072	0.011	-0.018	0.010	0.091
Standard	25_Aug_10	872	JHU-CI-289	102-GC-AZ01	2.986	-0.269	-2.375	-0.660	0.012	-0.871	-0.303	0.551	**0.632**	0.650	-0.514	0.011	-0.018	0.607	0.688
Heated Gas	25_Aug_10	876	JHU-CI-293	Evap CO2 HG	15.183	-0.698	57.039	21.607	0.012	-0.871	-0.874	-0.003	**0.078**		-0.008	0.011	-0.018	0.024	0.105
Standard	26_Aug_10	878	JHU-CI-295	UU Carrara	17.615	-0.380	39.295	14.920	0.012	-0.872	-0.585	0.278	**0.359**	0.352	-0.215	0.011	-0.018	0.320	0.401
Equilibrated Gas	27_Aug_10	881	JHU-CI-298	Enriched Equil Gas, 30C	15.666	0.146	56.634	20.852	0.012	-0.872	-0.037	0.809	**0.890**		-0.666	0.011	-0.017	0.879	0.960
Standard	27_Aug_10	884	JHU-CI-301	102-GC-AZ01	2.958	-0.284	-2.533	-0.769	0.012	-0.872	-0.319	0.536	**0.617**	0.650	-0.595	0.011	-0.017	0.591	0.672
Equilibrated Gas	28_Aug_10	886	JHU-CI-303	Depleted Equil Gas, 30C	-3.099	-0.038	-3.030	-0.990	0.012	-0.872	-0.002	0.844	**0.925**		-0.639	0.011	-0.017	0.915	0.996
Standard	28_Aug_10	889	JHU-CI-306	UU Carrara	17.628	-0.368	39.223	14.843	0.012	-0.872	-0.576	0.287	**0.368**	0.352	-0.349	0.011	-0.017	0.329	0.410
Heated Gas	29_Aug_10	891	JHU-CI-309	Reg CO2	0.092	-0.865	8.927	3.946	0.012	-0.872	-0.866	0.006	**0.087**		-0.115	0.011	-0.017	0.034	0.115
Standard	30_Aug_10	895	JHU-CI-315	102-GC-AZ01	3.049	-0.259	-2.060	-0.586	0.012	-0.873	-0.295	0.559	**0.640**	0.650	-0.617	0.011	-0.016	0.615	0.696
Sample	30_Aug_10	896	JHU-CI-317	CN2004-BD-162r	1.743	-0.222	14.961	5.822	0.012	-0.873	-0.243	0.610	**0.691**		-0.481	0.011	-0.016	0.668	0.749
Sample	30_Aug_10	897	JHU-CI-318	CN2004-BD-231r	1.901	-0.199	14.397	5.557	0.012	-0.873	-0.222	0.631	**0.712**		-0.543	0.011	-0.016	0.690	0.771
Standard	31_Aug_10	898	JHU-CI-320	102-GC-AZ01	2.959	-0.256	-2.527	-0.732	0.012	-0.873	-0.291	0.563	**0.644**	0.650	-0.600	0.011	-0.016	0.619	0.700
Sample	31_Aug_10	899	JHU-CI-321	CN2004-BD-70	0.746	-0.250	14.404	5.562	0.012	-0.873	-0.259	0.595	**0.676**		-0.549	0.011	-0.016	0.652	0.733
Heated Gas	31_Aug_10	900	JHU-CI-322	Evap CO2	14.187	-0.703	54.016	20.377	0.012	-0.873	-0.873	0.000	**0.081**		-0.338	0.011	-0.016	0.027	0.108
Sample	31_Aug_10	901	JHU-CI-323	CN2004-BD-117r	1.587	-0.240	15.541	6.026	0.012	-0.873	-0.259	0.595	**0.676**		-0.513	0.011	-0.016	0.652	0.733
Sample	31_Aug_10	902	JHU-CI-324	CN2004-BD-162r	1.851	-0.250	15.545	6.082	0.012	-0.873	-0.272	0.582	**0.663**		-0.462	0.011	-0.016	0.638	0.719
Equilibrated Gas	01_Sept_10	903	JHU-CI-325	Depleted Equil Gas, 30C	-3.145	-0.035	-3.396	-1.281	0.012	-0.873	0.003	0.848	**0.929**		-0.845	0.011	-0.016	0.918	0.999
Sample	01_Sept_10	904	JHU-CI-326	CN2004-BD-70	0.769	-0.231	14.771	5.917	0.012	-0.873	-0.240	0.613	**0.694**		-0.350	0.011	-0.016	0.671	0.752
Sample	01_Sept_10	905	JHU-CI-327	CN2004-BD-231r	1.836	-0.233	14.363	5.640	0.012	-0.873	-0.255	0.598	**0.679**		-0.481	0.011	-0.016	0.656	0.737
Standard	01_Sept_10	906	JHU-CI-328	NBS-19	17.077	-0.385	38.122	14.537	0.012	-0.873	-0.591	0.274	**0.355**	0.352	-0.354	0.011	-0.015	0.314	0.395
Sample	01_Sept_10	907	JHU-CI-329	CN2004-BS-117r	1.527	-0.230	15.491	6.052	0.012	-0.873	-0.248	0.605	**0.686**		-0.494	0.011	-0.015	0.662	0.743
Sample	01_Sept_10	908	JHU-CI-330	CN2004-BD-70	0.734	-0.243	14.502	5.689	0.012	-0.874	-0.252	0.602	**0.683**		-0.496	0.011	-0.015	0.659	0.740
Heated Gas	01_Sept_10	909	JHU-CI-331	Reg CO2	-0.847	-0.903	5.921	2.821	0.012	-0.874	-0.893	-0.019	**0.062**		-0.201	0.011	-0.015	0.008	0.089
Sample	02_Sept_10	910	JHU-CI-332	CN2005-BD-347	2.461	-0.223	16.096	6.338	0.012	-0.874	-0.253	0.601	**0.682**		-0.443	0.011	-0.015	0.658	0.739
Sample	02_Sept_10	911	JHU-CI-333	CN2005-BD-395r	5.916	-0.166	15.808	6.180	0.012	-0.874	-0.238	0.615	**0.696**		-0.499	0.011	-0.015	0.673	0.754
Standard	02_Sept_10	912	JHU-CI-334	102-GC-AZ01	3.186	-0.244	-1.850	-0.478	0.012	-0.874	-0.283	0.572	**0.653**	0.650	-0.643	0.011	-0.015	0.627	0.708
Sample	02_Sept_10	913	JHU-CI-335	CN2005-BD-385	4.653	-0.203	15.324	5.959	0.012	-0.874	-0.260	0.594	**0.675**		-0.550	0.011	-0.015	0.651	0.732
Equilibrated Gas	02_Sept_10	914	JHU-CI-336	Enriched Equil Gas, 30C	15.663	0.158	57.017	21.238	0.012	-0.874	-0.032	0.814	**0.895**		-0.668	0.011	-0.015	0.881	0.962
Sample	03_Sept_10	915	JHU-CI-337	CN2005-BD-371	0.714	-0.240	13.133	5.272	0.012	-0.874	-0.249	0.605	**0.686**		-0.436	0.011	-0.015	0.661	0.742
Sample	03_Sept_10	916	JHU-CI-338	CN2005-BD-395r	5.897	-0.188	15.535	6.090	0.012	-0.874	-0.260	0.594	**0.675**		-0.509	0.011	-0.014	0.650	0.731
Sample	03_Sept_10	917	JHU-CI-339	CN2005-BD-361	-0.159	-0.271	13.118	5.277	0.012	-0.874	-0.269	0.585	**0.666**		-0.433	0.011	-0.014	0.641	0.722
Standard	03_Sept_10	918	JHU-CI-340	NBS-19	17.079	-0.376	38.595	15.016	0.012	-0.874	-0.585	0.280	**0.361**	0.352	-0.106	0.011	-0.014	0.321	0.402
Heated Gas	03_Sept_10	919	JHU-CI-341	Enriched CO2	13.279	-0.695	52.621	20.388	0.012	-0.874	-0.857	0.016	**0.097**		0.082	0.011	-0.014	0.044	0.125
Sample	03_Sept_10	920	JHU-CI-342	CN2005-BD-385	4.652	-0.193	15.594	6.174	0.012	-0.874	-0.250	0.604	**0.685**		-0.462	0.011	-0.014	0.660	0.741
Sample	04_Sept_10	921	JHU-CI-343	CN2005-BD-347	2.446	-0.242	16.119	6.380	0.012	-0.874	-0.272	0.582	**0.663**		-0.454	0.011	-0.014	0.637	0.718
Sample	04_Sept_10	922	JHU-CI-344	CN2005-BD-371	0.772	-0.239	13.398	5.441	0.012	-0.874	-0.248	0.605	**0.686**		-0.392	0.011	-0.014	0.661	0.742
Sample	04_Sept_10	923	JHU-CI-345	CN2005-BD-371	0.723	-0.264	13.219	5.311	0.012	-0.874	-0.273	0.582	**0.663**		-0.460	0.011	-0.014	0.636	0.717
Sample	04_Sept_10	924	JHU-CI-346	CN2005-BD-385	4.624	-0.212	15.389	6.029	0.012	-0.874	-0.269	0.585	**0.666**		-0.547	0.011	-0.014	0.640	0.721

Equilibrated Gas	05_Sept_10	925	JHU-CI-347	Depleted Equil Gas, 30C	-3.171	-0.076	-3.351	-1.198	0.012	-0.875	-0.037	0.810	**0.891**		-0.857	0.011	-0.013	0.875	0.956
Standard	05_Sept_10	926	JHU-CI-348	102-GC-AZ01	3.020	-0.260	-2.303	-0.647	0.012	-0.875	-0.297	0.558	**0.639**	0.650	-0.697	0.011	-0.013	0.612	0.693
Sample	05_Sept_10	927	JHU-CI-349	CN2005-BD-361	-0.211	-0.263	12.976	5.197	0.012	-0.875	-0.260	0.594	**0.675**		-0.499	0.011	-0.013	0.649	0.730
Sample	05_Sept_10	928	JHU-CI-350	CN2005-BD-347	2.411	-0.227	16.096	6.419	0.012	-0.875	-0.257	0.597	**0.678**		-0.433	0.012	-0.013	0.652	0.733
Heated Gas	05_Sept_10	929	JHU-CI-351	Reg CO2	-0.420	-0.898	7.413	3.404	0.012	-0.875	-0.893	-0.017	**0.064**		-0.246	0.012	-0.013	0.009	0.090
Sample	05_Sept_10	930	JHU-CI-352	CN2005-BD-361	-0.234	-0.267	12.750	5.001	0.012	-0.875	-0.264	0.590	**0.671**		-0.623	0.012	-0.013	0.645	0.726
Standard	06_Sept_10	931	JHU-CI-353	NBS-19	17.021	-0.409	38.190	14.709	0.012	-0.875	-0.620	0.247	**0.328**	0.352	-0.310	0.012	-0.013	0.285	0.366
Standard	06_Sept_10	935	JHU-CI-357	102-GC-AZ01	3.002	-0.227	-2.453	-0.756	0.012	-0.875	-0.264	0.590	**0.671**	0.650	-0.788	0.012	-0.012	0.644	0.725
Equilibrated Gas	07_Sept_10	938	JHU-CI-366	Enriched Equil Gas, 30C	15.543	0.195	56.514	21.040	0.012	-0.875	0.002	0.847	**0.928**		-0.757	0.012	-0.012	0.912	0.993
Standard	07_Sept_10	940	JHU-CI-361	NBS-19	17.147	-0.376	38.368	14.705	0.012	-0.875	-0.590	0.276	**0.357**	0.352	-0.403	0.012	-0.011	0.315	0.396
Heated Gas	08_Sept_10	944	JHU-CI-365	Reg CO2	-1.086	-0.897	5.646	2.851	0.013	-0.876	-0.883	-0.008	**0.073**		-0.205	0.012	-0.011	0.019	0.100
Equilibrated Gas	08_Sept_10	945	JHU-CI-367	Depleted Equil Gas, 30C	-3.267	-0.045	-3.777	-1.416	0.013	-0.876	-0.004	0.841	**0.922**		-1.004	0.012	-0.011	0.906	0.987
Standard	08_Sept_10	946	JHU-CI-368	102-GC-AZ01	3.095	-0.239	-2.304	-0.736	0.013	-0.876	-0.278	0.577	**0.658**	0.650	-0.872	0.012	-0.011	0.630	0.711
Standard	09_Sept_10	950	JHU-CI-372	NBS-19	17.142	-0.378	38.497	14.798	0.013	-0.876	-0.594	0.272	**0.353**	0.352	-0.373	0.012	-0.010	0.311	0.392
Heated Gas	09_Sept_10	954	JHU-CI-376	Evap CO2	14.369	-0.702	55.025	21.215	0.013	-0.876	-0.883	-0.007	**0.074**		-0.037	0.012	-0.009	0.020	0.101
Equilibrated Gas	09_Sept_10	955	JHU-CI-377	Depleted Equil Gas, 30C	-3.221	-0.057	-3.419	-1.168	0.013	-0.876	-0.016	0.830	**0.911**		-0.936	0.012	-0.009	0.892	0.973
Standard	09_Sept_10	956	JHU-CI-378	102-GC-AZ01	2.982	-0.249	-2.526	-0.708	0.013	-0.876	-0.287	0.569	**0.650**	0.650	-0.809	0.012	-0.009	0.620	0.701
Standard	10_Sept_10	960	JHU-CI-382	NBS-19	17.098	-0.367	38.777	15.184	0.013	-0.876	-0.584	0.282	**0.363**	0.352	-0.097	0.012	-0.008	0.321	0.402
Heated Gas	11_Sept_10	963	JHU-CI-386	Reg C02	-0.864	-0.873	6.079	2.947	0.013	-0.877	-0.862	0.014	**0.095**		-0.345	0.012	-0.008	0.042	0.123
Standard	11_Sept_10	965	JHU-CI-388	102-GC-AZ01	3.044	-0.249	-2.356	-0.734	0.013	-0.877	-0.288	0.568	**0.649**	0.650	-0.943	0.012	-0.007	0.618	0.699
Heated Gas	12_Sept_10	970	JHU-CI-393	Heated Reg CO2	-0.651	-0.870	6.951	4.464	0.013	-0.877	-0.862	0.015	**0.096**		0.825	0.012	-0.006	0.042	0.123
Standard	12_Sept_10	973	JHU-CI-396	UU Carrara	17.515	-0.384	39.426	15.220	0.013	-0.877	-0.608	0.259	**0.340**	0.352	-0.292	0.012	-0.006	0.296	0.377
Equilibrated Gas	13_Sept_10	975	JHU-CI-403	Equil Gas Enriched, 30C	15.660	0.178	57.058	21.330	0.013	-0.877	-0.023	0.824	**0.905**		-0.614	0.012	-0.005	0.882	0.963
Standard	14_Sept_10	980	JHU-CI-402	102-GC-AZ01	2.928	-0.271	-2.653	-0.813	0.013	-0.877	-0.309	0.548	**0.629**	0.650	-0.995	0.012	-0.004	0.595	0.676
Heated Gas	14_Sept_10	981	JHU-CI-405	Heated Evap CO2	15.525	-0.682	58.301	22.264	0.013	-0.877	-0.882	-0.004	**0.077**		-0.104	0.012	-0.004	0.023	0.104
Standard	15_Sept_10	986	JHU-CI-414	UU Carrara	17.606	-0.379	39.657	15.267	0.013	-0.878	-0.606	0.262	**0.343**	0.352	-0.305	0.012	-0.003	0.298	0.379
Equilibrated Gas	16_Sept_10	991	JHU-CI-422	Equil Gas Depleted, 30C	-3.141	-0.034	-3.587	-1.460	0.013	-0.878	0.007	0.852	**0.933**		-1.369	0.012	-0.002	0.908	0.989
Heated Gas	16_Sept_10	992	JHU-CI-406	Heated Evap CO2	15.452	-0.688	57.958	22.354	0.013	-0.878	-0.888	-0.010	**0.071**		0.180	0.012	-0.002	0.017	0.098
Standard	17_Sept_10	995	JHU-CI-424	102-GC-AZ01	2.832	-0.258	-2.487	-0.642	0.013	-0.878	-0.295	0.562	**0.643**	0.650	-0.973	0.012	-0.001	0.607	0.688
Standard	19_Sept_10	999	JHU-CI-420	102-GC-AZ01	3.168	-0.240	-1.933	-0.582	0.013	-0.878	-0.281	0.575	**0.656**	0.650	-1.137	0.012	0.000	0.620	0.701
Equilibrated Gas	19_Sept_10	1000	JHU-CI-428	Enriched Equil Gas, 30C	15.724	0.176	57.526	21.475	0.013	-0.878	-0.028	0.818	**0.899**		-0.483	0.012	0.000	0.871	0.952
Heated Gas	20_Sept_10	1002	JHU-CI-430	Evap CO2	14.762	-0.670	56.720	21.702	0.013	-0.878	-0.862	0.016	**0.097**		0.051	0.012	0.000	0.043	0.124

Note. Sample unknowns for this study are highlighted in light green. All other data are equilibrium gas standards used to normalize the data, and carbonate reference materials used to monitor accuracy and precision.

* WG: working gas. These are raw values relative to Oztech working gas with $\delta^{13}C$ = 3.60‰ (PDB) and $\delta^{18}O$ = 24.97‰ (SMOW).

† Modeled time varying slope and intercept of 'heated gas line' (see Huntington et al., 2009, for description of heated gas line concept). Models are based on inverse modeling of heated gas data, fit to the assumption that the heated gas slope and intercept vary as 2nd order polynomial functions of sequence number. See Passey et al., (2010) for a description of this m

§ Values corrected for non-zero slope in heated gas line. See Huntington et al. (2009).

Δ_{47} values relative to the 'Ghosh' scale (Ghosh et al., 2006), as described in Huntington et al. (2009), using a canonical heated gas intercept of 0.8453‰.

** Δ_{47} values normalized to 25°C reactions by addition of a 0.081‰ temperature correction factor for 90°C reactions (Passey et al., 2010). These are the 'final' Δ_{47} values utilized in this study.

†† Long-term mean Δ_{47} values of in-house carbonate standards developed at the California Institute of Technology. See Passey et al. (2010), Table S5.

§§ Δ_{48} values normalized to modeled time varying Δ_{48} heated gas line.

Modeled time varying slope and intercept of 'equilibrated gas line'. 'Equilibrated gases' are CO_2 equilibrated with water at low temperature (0 - 50°C) and are low-temperature analogs of 'heated gases'.

*** Δ_{47} values reported on an 'equilibrium' scale based on theoretical equilibrium values of CO2, as described in Dennis et al. (in revision, Geochimica et Cosmochimica Acta).

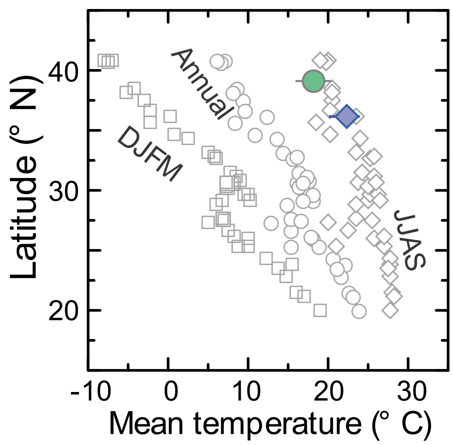

Figure DR1. Mean clumped isotope temperatures of paleosol carbonates averaged over the entire 7 - 3 Ma interval at Baode (large circle) and Lantian (large diamond). Present day temperatures are plotted for comparison for climate stations in China between 104 ° E and 112 ° E longitude. These are given for December-January-February-March (DJFM) mean temperature (squares); mean annual temperature (circles); and June-July-August-September (JJAS) mean temperature (diamonds). Modern climate data are from UCAR (2006).