ed variations of 1.5 to 6.0 weight % H_2O and rhyolitic host quartz that indicated a blank level of 0.3 weight % H_2O. Four specimens were examined, including two from Minas Gerais, Brazil (U.S. National Museum 117434 and 83325) and two uncataloged samples from Antelope, OR, studied by Frondel (*12*). Elemental oscillations were most pronounced in the Oregon agates, as was consistent with SEM and optical observations of the iris bands. Detection of elemental variations required high precision in the orientation of sections parallel to the banding (within 0.5°).

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23. We thank E. P. Vicenzi, J. E. Post, E. A. Smelik, and D. R. Veblen for helpful discussions. C. Frondel and the U.S. National Museum kindly lent specimens used in this study. Supported by NSF grants EAR92-06031 and EAR94-18031.

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Late Glacial Climate Record of Midwestern United States from the Hydrogen Isotope Ratio of Lake Organic Matter

R. V. Krishnamurthy, K. A. Syrup, M. Baskaran, A. Long

A hydrogen isotope time series obtained from an analysis of organic matter extracted from a lake core in Kalamazoo, southwestern Michigan, reveals four distinct isotope stages within the last 12,000 years that can be interpreted in terms of oscillations between cold and warm, dry climates. The most dramatic are a cold phase between 12,000 and 9000 years before present (B.P.), a warm, dry period between 8500 and 2000 years B.P., a cold period between 2000 and 1000 years B.P., and a warming trend since 1000 years B.P. The warming trend of the last 1000 years is comparable in magnitude to the mid-Holocene warm phase.

The stable hydrogen isotope composition [expressed as δD values (*1*)] of plant materials has been used to infer paleoclimatic conditions (*2*). These studies rely on the demonstrable link between the δD of a single plant component, namely the carbon-bound hydrogen of cellulose, and the δD of water used by the plants during their growth. Because the water used by plants is mostly the local meteoric water and the δD of local meteoric water correlates with local mean annual temperature, the δD of cellulose can be translated into climatic factors. In many instances, however, even young sedimentary systems contain negligible amounts of plant remains that can be isolated for this type of study. Extractable sedimentary organic matter, on the other hand, can be found in a wide variety of geologic environments.

Here we report the paleoclimatic information obtained from organic matter (kerogen) extracted from a lake core from southwestern Michigan, analyzed for δD by digestion of the sediments with hydrofluoric and hydrochloric acids (*3*). This procedure is essential to make sure that other hydrogen-containing phases, mostly inorganic minerals, are removed. We assume that (i) the kerogen in lake sediments originates from photosynthesizing aquatic plant biomass that grew in the lake and (ii) that the source of hydrogen for these plants was the local meteoric water recharging the lake. If the δD of kerogen does indeed contain climate information, the scope of its applicability is enormous because kerogen can commonly be extracted from a variety of sediments.

An ~4-m-long core was raised in 1993 from Austin Lake in Kalamazoo (42.10°N, 85.30°W), southwestern Michigan (Fig. 1). This lake is typical of the several "kettle" lakes in the region that were formed by the melting of a mass or masses of ice isolated from the glacier (*4*). At 4.5 km^2, Austin Lake is a relatively large lake for this region and has extensive aquatic vegetation. The sediments are relatively rich in organic carbon (up to 20 weight % on a carbonate-free basis), the source of which must be vegetation in the lake because the lake is isolated from other possible sources of organic matter such as wetlands, streams, and rivers. The lake receives its recharge almost entirely from direct precipitation and is a point of recharge for adjacent ground water.

The H/C ratio (Fig. 2) and the δD values (Fig. 3) of the kerogen samples as a function of age show that lack of significant long-term trends in H/C and δD with age supports the contention that the δD variations are not related to diagenesis (*5*). The δD data can be subdivided into four phases (Table 1 and Fig. 3).

The hydrogen isotope ratio of kerogen in lake sediments with substantial primary productivity reflects the hydrogen of plants that eventually form the source material for sedimentary organic matter. There is ample evidence that the hydrogen in plants is almost entirely derived from the source water, the local precipitation in most cases (*2*). In the present case, we examined if this was true for these lake samples by comparing the δD of kerogen extracted from the top of the core with the δD of environmental water. The δD of kerogen extracted from the surface sample from the top of the core was −80 per mil. For the hydrogen isotope fractionation between the nonexchangeable hydrogen in cellulose extracted from aquatic plants and their environmental water, the δD of the environmental water out of which the lake kerogen was generated should be around −54 per mil (*6*). The one

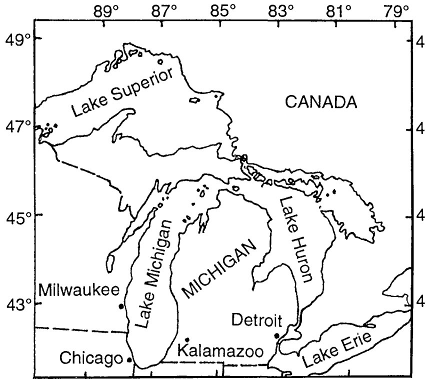

Fig. 1. Map showing Kalamazoo in southwest Michigan, where Austin Lake was cored.

R. V. Krishnamurthy and K. A. Syrup, Department of Geology, Western Michigan University, Kalamazoo, MI 49008, USA.
M. Baskaran, Department of Marine Sciences, Texas A&M University, Galveston, TX 77553–1675, USA.
A. Long, Department of Geosciences, University of Arizona, Tucson, AZ 85721, USA.

analysis of lake water collected on a windy, spring day gave a more positive value than this (−40 per mil), whereas the mean of several local ground-water samples gave a value of −53 ± 4 per mil. The ground waters probably represent a better average of the lake water because, as mentioned earlier, the adjacent ground waters are recharged by water from this lake. Moreover, the weighted annual mean δD of precipitation in Kalamazoo is −57 per mil, on the basis of an analysis of every individual precipitation that fell in the area for the year between June 1992 and June 1993 (*7*) (Fig. 4). The one measurement of actual lake water may have been on a sample subjected to excessive surficial evaporation.

A relation between the δD of kerogen and the δD of local meteoric water, similar to that between the δD of cellulose of aquatic plants and local meteoric water, is indeed intriguing because in the latter case the comparison was made on the basis of the carbon-bound hydrogen of a single component, namely cellulose. There are two possible explanations: (i) The δD of HF-HCl residue approximates the δD of cellulose carbon-bound hydrogen, and interference from any exchangeable hydrogen in the residue, perhaps up to 10%, is minimized by the identical experimental conditions of extraction of the residues, or (ii) it is a fortuitous coincidence that deserves more detailed studies from this and other lakes. Given the close relation between δD in the kerogen and δD of local meteoric water, the variations observed downcore can be translated into temporal variations in the δD of local meteoric water. The mean annual δD of precipitation in mid-latitudes varies by 4 to 6 per mil °C^{-1} (*8*). Our own measurements of δD in precipitation in Kalamazoo, covering one year's samples, gave a temperature coefficient of 4.5 per mil °C^{-1}, a reasonable value in view of the shorter sampling interval. The temperature coefficient for the nonexchangeable hydrogen in cellulose is similar to the long-term precipitation values at ~7 to 8 per mil °C^{-1} (*2*). If these are extrapolated to our results, the ~32 per mil increase in the δD at 8500 years B.P. (Fig. 3) would correspond to a temperature increase in the region of ~5° to 7°C. Likewise, the decrease by ~54 per mil around ~2000 years B.P. would correspond to a cooling by ~7° to 12°C. The subsequent increase by ~25 per mil around 1200 years B.P. suggests an increase in temperature by ~4° to 6°C. Similarly, Dorale *et al.* (*9*) used oxygen isotope ratios of speleothems from the Cold Water Cave in northeast Iowa to infer that there was a rapid warming of 3°C around 5900 years B.P. and a cooling by 4°C at 3600 years B.P. Prairie was dominant in central Iowa between 8000 to 3000 years B.P., and the climate was drier during this time than it is in the present (*10*). Other evidence for warm, dry climates in Ohio, Indiana, Minnesota, South Dakota, and other interior northwestern American regions during the mid-Holocene comes from palynological studies (*11*). The cold climate that followed the mid-Holocene warm phase was also inferred in some other regions of the country, for example, Minnesota and the White Mountains in New Hampshire (*12*).

The magnitude of temperature changes deduced from our hydrogen isotope record is likely an overestimate. The δD of cellulose and of kerogen could reflect the influence of atmospheric processes that affect the δD of local precipitation. The annual δD distribution in Kalamazoo precipitation (Fig. 4) shows a strong seasonality: summer precipitation is isotopically heavier than winter precipitation because of a combination of the influences of temperature and the history of the air masses. Today moisture in the study area originates principally from warm air masses from the Gulf of Mexico, maritime air masses from the Pacific and Atlantic, and cold, dry air masses from the Canadian Arctic (*13*). It is likely that superimposed on the temperature increase during the mid-Holocene there were changes in the relative importance of various air masses bringing precipitation to this region. Rain derived from air masses originating in the Gulf of Mexico, which make up at least 60% of the air flow during the summer months, are also isotopically high (δD = −35 per mil) (*7*). Therefore, if the mid-Holocene warm episode was characterized by longer summers associated with an intensified water-vapor transport from the Gulf of Mexico and shorter, drier winters, a simple mechanism is available to produce local meteoric water and thus organic matter in the lake with higher δD values (*10, 14*).

Feng and Epstein, studying δD values from a bristlecone pine, argue that except for a brief warming around 7000 years B.P., the region around the White Mountains in

Table 1. Subdivision of the hydrogen isotope record in Austin Lake organic matter into four stages and the inferred climatic conditions.

Stage	Time interval (years B.P.)	Avg. δD (per mil)	Inferred climate
1	12,000–8500	−108	Cold
2	8500–2000	−76	Warm, dry
3	2000–1200	−130	Cold
4	1200–present	−105	Warming trend

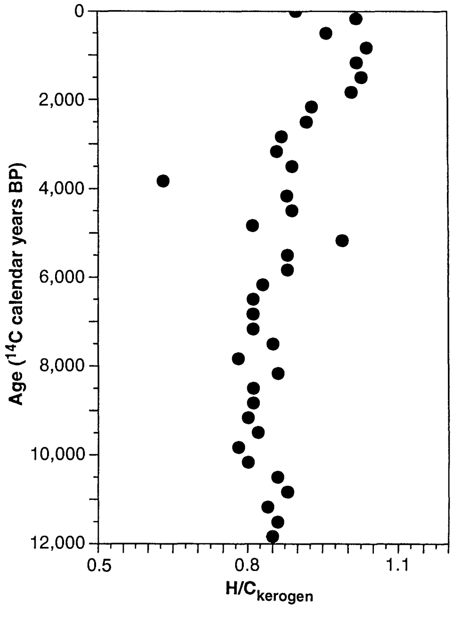

Fig. 2. The H/C ratio versus age of kerogen in Austin Lake sediments.

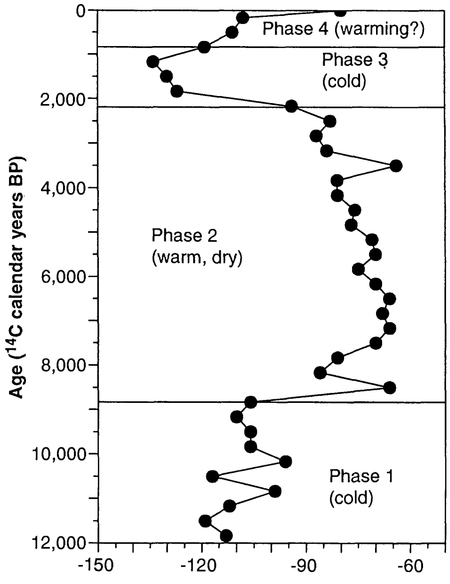

Fig. 3. The δD values of kerogen plotted against time. The arrows indicate the direction of δD change during warmer or cooler climates.

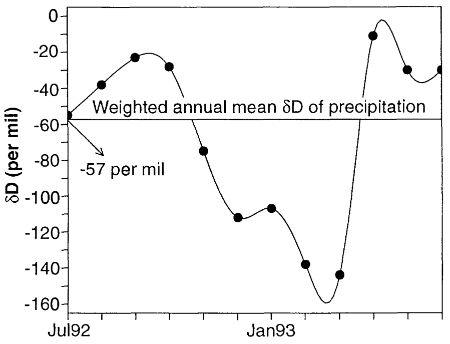

Fig. 4. The weighted mean δD values of monthly precipitation in Kalamazoo based on analysis of 1 year's collection (June 1992 through June 1993).

California has been cooling (*15*). Curiously, their isotope record also points to cooling by ~7°C, although they caution that the actual temperature effect is close to 3°, the rest being an effect related to variations in the history of air masses.

If valid, the contrasting trends in climate between the midwestern and western United States can be reconciled by examining present-day weather systems and how climate is influenced by the position of the jet stream. Whenever the midwestern regions lie on a high-pressure ridge, drawing in warm moisture from the Gulf of Mexico and blocking off the dry, cool continental air masses, the western regions experience milder temperatures, and vice versa. Therefore, if the mid-Holocene period was marked by sustained intrusion of the Gulf of Mexico air mass into the midwestern region, contrasting climatic conditions within the continental United States are indeed conceivable.

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1. Stable isotope compositions are expressed in the δ notation in units of per mil

$$\delta = \frac{R_{\text{sample}} - R_{\text{standard}}}{R_{\text{standard}}} \times 1000$$

where R = D/H and the standard is standard mean ocean water (SMOW). The δ values of organic materials could be determined with an overall analytical precision better than 2 per mil.
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5. The freeze-dried kerogen was combusted in sealed glass (Vycor) tubes containing cupric oxide at 900°C for 3 hours. Water produced by combustion was cryogenically separated from CO_2 and passed over hot uranium metal to produce hydrogen gas [I. Friedman, *Geochim. Cosmochim. Acta* **4**, 89 (1953)]. Dating of the samples was carried out using the $^{210}Pb_{excess}$ method for the top ~50 cm [S. Krishnaswami *et al.*, *Earth. Planet. Sci. Lett.* **11**, 407 (1971); S. L. Harden, D. J. DeMaster, C. A. Nittrouer, *Mar. Geol.* **193**, 69 (1992)]. Additionally, three ^{14}C dates were obtained on the organic fraction. The ^{14}C dates indicated a linear sedimentation rate of 0.035 cm year^{-1} (r = 0.98) and, when extrapolated to the surface, gave a surface age of 160 years, showing no or negligible contribution from "dead" carbon. Individual samples have been fitted to ages based on the above sedimentation rates based on ^{14}C dates.
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14. As shown in Fig. 4, the weighted mean annual δD (−57 per mil based on a year's sampling) in Kalamazoo precipitation is made up of 7 months of higher (spring and summer) and 5 months of lower (winter) values of δD. It is clear that the annual average can become higher if instead of 7, precipitation of 8 or more months had higher δD values, that is, if the spring and summer seasons were longer than they are today. Similarly, the average δD of precipitation would be lower than today's if the summer and spring seasons were shorter. Changes in the lengths of seasons would be linked to the position of the jet stream and the extent to which the air masses from the Gulf of Mexico reach and sustain in the midwestern parts of the United States. The change in the lengths of seasons will also involve attendant changes in the mean annual temperatures. Thus, periods of higher values of δD will result from an increase in mean annual temperatures and longer spring and summer seasons of increased moisture transport from the Gulf. With several years of analysis, it would be possible to estimate quantitatively the "air mass effect" on the mean annual isotope ratio.
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Requirement for Src Family Protein Tyrosine Kinases in G_2 for Fibroblast Cell Division

Serge Roche,* Stefano Fumagalli, Sara A. Courtneidge†‡

The protein tyrosine kinase c-Src is transiently activated at the transition from the G_2 phase to mitosis in the cell cycle of mammalian fibroblasts. Fyn and Yes, the other members of the Src family present in fibroblasts, were also found to be activated at mitosis. In cells microinjected with a neutralizing antibody specific for Src, Fyn, and Yes (anti-cst.1) during G_2, cell division was inhibited by 75 percent. The block occurred before nuclear envelope breakdown. Antibodies specific for phosphatidylinositol-3 kinase α and phospholipase C–γ1 had no effect. Microinjection of the Src homology 2 (SH2) domain of Fyn was also inhibitory. Functional redundancy between members of the Src family was observed; a Src-specific antibody had no effect in NIH 3T3 cells but inhibited cell division in fibroblasts in which the only functional Src family kinase was Src itself. Thus, Src family kinases and proteins associating with their SH2 domains are required for entry into mitosis.

The proto-oncogene product cSrc and related enzymes are activated during the transition from the G_0 to the G_1 phase of the cell cycle in response to some growth factors (*1–3*), and microinjection studies have shown that they are necessary for some growth factors to transmit mitogenic signals (*4*, *5*). c-Src is also activated as fibroblasts enter mitosis (*6*). Mitotic activation of c-Src involves NH_2-terminal serine and threonine phosphorylations—probably by the cyclin-dependent protein kinase Cdc2—concomitant with a net dephosphorylation of Tyr^{527}, the regulatory site (*7*). A mitotic substrate of Src, known as p68 or Sam68, associates with the Src homology 3 (SH3) and SH2 domains of Src (*8–10*). Sam68 is a heterogenous ribonuclear protein (*11*) and may have a function in RNA transport, stability, or splicing. The fact that mitotic substrates of Src can be detected suggests that signal transduction pathways involving tyrosine kinases may function in mitosis. Here, we address whether the Src kinases are required for cell division.

NIH 3T3 cells express three members of the Src family: Src, Fyn, and Yes. To determine whether Fyn and Yes, like Src, become activated during mitosis, we measured their activities in NIH 3T3 cells overexpressing these enzymes, both during interphase and in cells blocked in mitosis by nocodazole treatment (Fig. 1). After immunoprecipitation of Fyn or Yes with antibodies specific to each protein, both autophosphorylation and phosphorylation of enolase were assessed. We observed activation of these enzymes that was three to five times

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Differentiation Programme, European Molecular Biology Laboratory, Postfach 10.2209, Meyerhofstrasse 1, 69012 Heidelberg, Germany.

*Present address: CJF9207, Institut National de la Santé et de la Recherche Médicale (INSERM) faculté de Pharmacie, Avenue Ch. Flahaut, 34090 Montpellier, France.

†Present address: Sugen Inc., 515 Galveston Drive, Redwood City, CA 94063, USA. E-mail: sarac@sugen.sf.ca.us

‡To whom correspondence should be addressed.