Seasonal Cycles in Dissolved Inorganic Carbon Stable Isotopes and Implications for Sedimentary $\delta^{13}C$ Records in Small Lakes

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ABSTRACT

δ13C values of sedimentary organic matter and carbonate minerals are routine proxies for paleoproductivity in both marine and lacustrine systems. The geochemical, ecological, and morphometric diversity of lacustrine basins precludes generalization; it is also well known that basic assumptions developed for $\delta^{13}C$ records from the oceans cannot be applied *a priori* to small and/or productive lakes. This paper presents results from a three-summer sampling program of $\delta^{13}C$ of dissolved inorganic carbon ($\delta^{13}C_{DIC}$) in a pair of small lakes in east-central Minnesota, and considers the implications of these findings for the interpretation of the lakes' Holocene sedimentary records. Data indicate that lakes which are geochemically similar may nevertheless have quite different $\delta^{13}C_{DIC}$ behavior, and that biological productivity may be less important than morphometry in determining $\delta^{13}C_{DIC}$ values (and consequently $\delta^{13}C$ values of carbonate and organic matter).

The study also addresses the problem of the disappearance of carbonate minerals from lakes which have had calcareous sediments early in their histories: sediments of Spectacle Lake in this study are essentially carbonate-free after about 4,000 ^{14}C years before present, while Green Lake, 1 km away, has calcareous sediments throughout the record. Water-column data show that calcite still precipitates in Spectacle Lake, but dissolves before it can be sequestered in the sediments. The timing and nature of carbonate loss in Spectacle is consistent with that previously observed in Williams Lake in the Itasca region, suggesting a possible common climatic cause.

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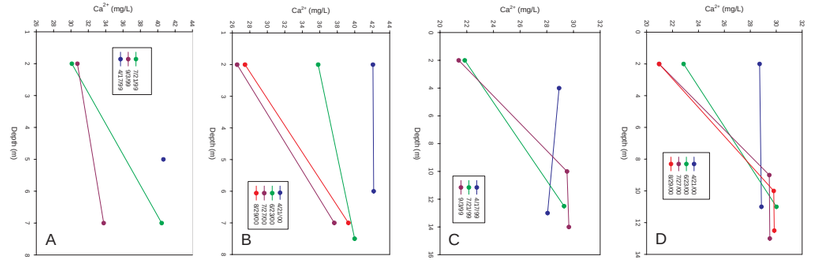
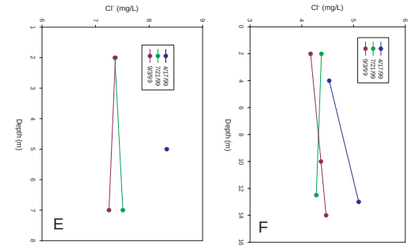
Chemistry of inflowing groundwater and streams (callouts) and open water (table, right). Open water values are mixed-lake chemistry, given in mg/L except alkalinity. $\delta^{13}C$ in standard per mil notation relative to VPDB.

Lake	Ca	Mg	Na	K	Fe	Mn	Alk (mg/L as CaCO3)	Cl	SO4	Trophic status
Green	40.6	14.6	6.5	1.7	0	~0	~150	8.3	9.7	Eutrophic
Spectacle	29.0	9.3	4.5	0.7	~0	~0	~100	4.5	3.3	Mesotrophic



Surface- and deep-water dissolved calcium measurements (above) show that calcite is precipitating in both Green Lake (A, B) and Spectacle Lake (C, D). An increase in hypolimnetic Ca^{2+} in Spectacle Lake indicates that the mineral is dissolving before it reaches the sediment surface. Cl^- measurements (right) show that the Ca^{2+} changes are not simply due to dilution by rain, runoff or groundwater.

$\delta^{13}C_{DIC}$ (below) in Spectacle Lake shows "textbook" behavior, as ^{13}C-depleted photosynthetic organic carbon is remineralized in the hypolimnion. Green Lake, however, is polymictic, and light DIC is reincorporated into surface waters during the course of the growing season. Calcite precipitated in Green Lake would be more negative in $\delta^{13}C$ than calcite from Spectacle Lake, even though Green Lake is much more productive.

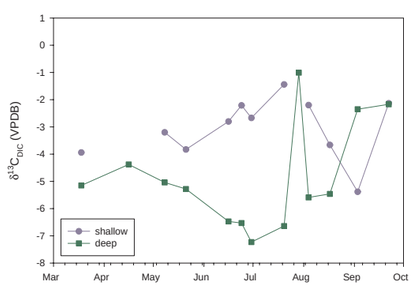


Below: Carbonate (cc) and organic (org) abundance, accumulation rates, and carbonate and organic carbon isotopes from Green and Spectacle Lake sediments.

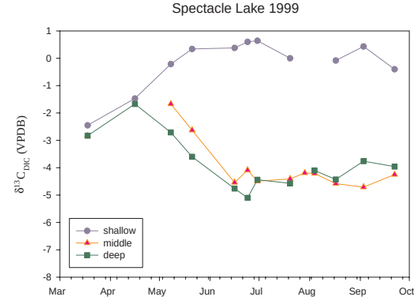
Green Lake sediments are consistently carbonate-rich throughout the core. Accumulation rates based on ^{210}Pb chronology show a much better correlation with isotopic trends than do straight percentage data.

Note high-amplitude fluctuations of carbonate in Spectacle Lake sediments, and complete disappearance after approximately 4000 ^{14}C years before present. Highly enriched $\delta^{13}C$ values of carbonate suggest a periodic contribution of diagenetic carbonate formed in methanogenic sediments. Gray ellipse surrounds samples which may be offset (positively) by 2-3 per mil due to differences in sample treatment.

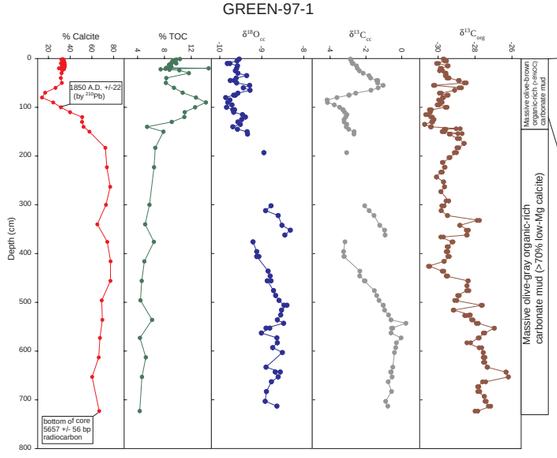
Green Lake 1999



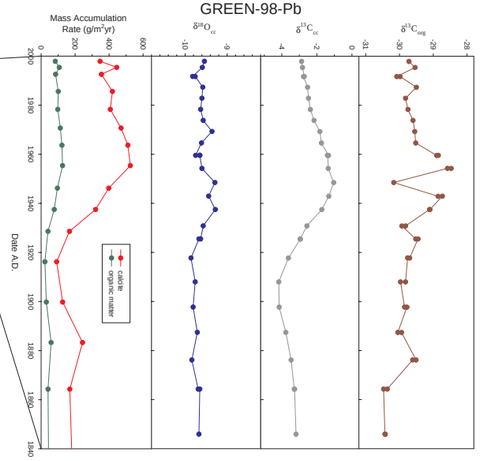
Spectacle Lake 1999



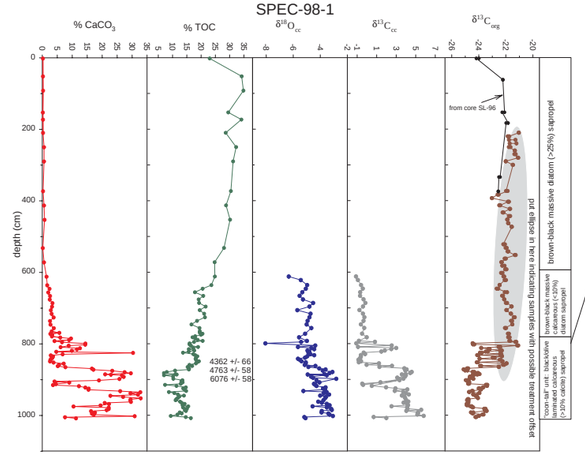
GREEN-97-1



GREEN-98-Pb



SPEC-98-1



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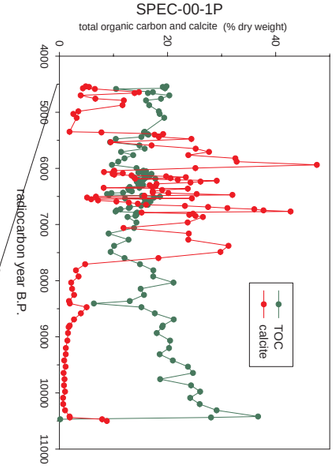

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