Note

Acidification and metal contamination in Whitepine Lake (Sudbury, Canada): a paleolimnological perspective

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Received 17 December 1992; accepted 25 May 1993

Key words: diatoms, chrysophytes, acidification, Al, Ni, Sudbury, recovery

Abstract

Diatom and chrysophyte assemblages from a sediment core from Whitepine Lake were examined to infer changes in lakewater pH, nickel and aluminum concentrations since pre-industrial times, and to help determine the cause of the virtual extirpation of the lake trout population from the lake during the 1960s and 1970s. Our study indicates that acidification started in the 1920s, and that the maximum inferred pH decline (from 6.2 to 5.8) occurred between 1960 and 1970, coincident with the peak in metal mining and smelting activity in the Sudbury basin. Lakewater [Al] and [Ni], as inferred from our diatom transfer functions, increased. It appears that in addition to the pH decline, elevated [Al] may have played an important role in the decline of lake trout from Whitepine Lake in the 1960s and 1970s. Diatom-inferred lakewater pH and [Ni] have recovered slightly in the recent sediments, which coincides with reductions in emissions that have occurred since the mid-1970s.

Introduction

Lakewater quality in a large number of lakes has deteriorated due to metal mining and smelting activities in the Sudbury area (Gorham & Gordon, 1960; Keller et al., 1986). In the absence of past water chemistry data, paleolimnological techniques have been used extensively in the Sudbury region to identify the timing, rate, and extent of degradation and recovery in lakes (Nriagu et al., 1982; Dixit et al., 1987, 1989a, b, 1992a, b; Dickman & Fortescue, 1991).

In the Sudbury region, Dixit et al. (1989a, 1991) have developed transfer functions using chrysophyte scales and diatoms to infer lakewater pH and other environmental variables (e.g. Al and Ni). In this paleolimnological study, sedimentary diatom and chrysophyte assemblages have been used to evaluate post-industrial changes in lakewater pH and trends in Al and Ni concentrations in Whitepine Lake. This lake was selected because, during the 1970s and early 1980s, the indigenous fish community exhibited many signs of acid-stress.

Whitepine Lake (47° 17′ N, 80° 50′ W) is located 90 km north of Sudbury in a forested area. It is a clear, dilute headwater lake, with a surface area of 67 ha, and a maximum depth of 22 m. The Whitepine Lake discussed in this paper is different from the nearby Whitepine Lake (located east of Smoothwater Lake) studied by Dickman & Rao (1989) and Dickman & Fortescue (1991)
(M. Dickman, pers. comm.). The lake receives wet and dry inputs of sulphur, but it is not within the zone of high deposition of metal particulates from the Sudbury smelters (Gunn & Keller, 1990). The Ontario Ministry of Natural Resources and the Ontario Ministry of Environment began monitoring Whitepine Lake in 1980 because the lake has had lake trout (Salvelinus namaycush) recruitment problems since the 1960s. The lake-water pH was 6.2, and Ni and Al concentrations were 30 and 130 µg/l, respectively, for an integrated water sample collected from the deepest basin of the lake during the field work in June 1987.

Methods

In June 1987, a 20 cm long sediment core was taken from the deep basin of the lake using a modified K-B gravity corer. The core was sectioned at close intervals using an extrusion device similar to the one designed by Glew (1988). The top 1 cm was sectioned at 0.25 cm intervals, between 1–5 cm at 0.5 cm intervals, between 5–10 cm at 1 cm intervals, and the rest of the core was sectioned at 2 cm intervals. The samples were cleaned by acid digestion, and aliquots of the resulting slurry were evaporated on coverglasses following the Battarbee (1973) method. A minimum of 500 diatom valves and/or chrysophyte scales was counted for each sample. Diatom taxonomy generally followed the PIRLA (Paleoecological Investigation of Recent Lake Acidification) Diatom Iconograph (Camburn et al., 1984–1986). Chrysophyte taxonomy was based on Takahashi (1978), Wee (1984), Nicholls (1982), Smol et al. (1984), Asmund & Kristiansen (1986), Siver et al. (1990), and the reference collection at Queen’s University. To date the core, sediment subsamples were analyzed for 210Pb activity at the Chalk River Nuclear Laboratory, Chalk River, Ontario and the constant rate of supply (CRS) model was used to compute the dates using Binford’s (1990) computer program. Weighted-averaging regression and calibration (Line & Birks, 1990) models were used for diatom-inferred pH, [Al], and [Ni], and chrysophyte-inferred pH reconstructions. The statistics for calibration models are presented in Table 1. For details on calibration models see Dixit et al. (1989a, 1991). The chrysophyte-inferred pH calibration was modified from Dixit et al. (1989a), because Mallomonas crassisquama (Asmund Fott has now been separated from M. duerrschmidtiae Siver, Hamer and Kling. Similar to Siver et al. (1990) and Cumming et al. (1992), we observed that in Sudbury lakes M. duerrschmidtiae is generally more common in lower pH waters [AWM (abundance weighted mean) pH = 5.6], whereas M. crassisquama is generally more abundant in circumneutral to alkaline waters (AWM pH = 6.9).

Results and discussion

Mallomonas crassisquama, M. duerrschmidtiae, and M. caudata Ivanov em. Krieger were found to be the most common chrysophyte scales throughout the core (Fig. 1). Although a decline of M. pseudocoronata Prescott and M. allorgei (Defl.) Conrad, and an increase of M. hamata Asmund and M. galeiformis Nicholls since about 1960 would suggest a modest decline in lakewater pH, it appears that the overwhelming dominance of a few taxa that have a wider pH tolerance (e.g. M. duerrschmidtiae) masked any possible pH decline that could be inferred from the chrysophyte stratigraphy (Fig. 1). A modest increase of M. allorgei (a circumneutral taxon) in the recent

<table>
<thead>
<tr>
<th>Model</th>
<th>r²</th>
<th>RMSE</th>
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<tbody>
<tr>
<td>Diatom-inferred pH</td>
<td>0.78</td>
<td>0.50</td>
</tr>
<tr>
<td>log₆ Al (µg/L)</td>
<td>0.54</td>
<td>0.83</td>
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<tr>
<td>log₆ Ni (µg/L)</td>
<td>0.64</td>
<td>1.03</td>
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<tr>
<td>Chrysophyte-inferred pH</td>
<td>0.84</td>
<td>0.39</td>
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