Trophic Relationships in Lake Waters of the Northern Minnesota/Southern Canada Boundary Region

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Introduction

This study of a series of lakes in the Boundary Waters Canoe Area Wilderness--Quetico Provincial Park, was undertaken July-August 1988. A geologic contact runs NE-SW through the BWCA, separating the Vermilion batholith, a relatively homogeneous medium-grained pink granite, from a series of more mafic, fine-grained metasedimentary migmatites to the south. Lakes underlain by the granite batholith are generally clear and blue-green in color, whereas lakes underlain by the metasediments are dark brown and murky. Through collection of field data and water samples, this study attempted to determine the relationship of bedrock-chemistry to lakewater chemistry, in hopes of explaining this marked difference in water color of the lakes on either side of the geologic contact.

Water color and lake chemistry are not simple phenomena; they are affected by complex processes occurring both inside and outside the lake. This paper explores some of the physical, chemical and biological processes that determine lake chemistry, and draws conclusions about possible relationships between bedrock and lakewater chemistry in the BWCA.

Data Collection

Standard water quality field measurements were taken in lakes spanning the contact: temperature, turbidity (Secchi disk), pH, dissolved oxygen, conductivity, color, alkalinity, and Ca and Mg hardness. Atomic absorption analyses of the following ions were run in the laboratory: Ca, Mg, Na, K, HCO3, SO4, NO3, Cl, SiO2 and dissolved organic carbon were measured (AA analysis done by Ben Morris, Williams College). Rock samples were collected for XRF analysis.

Classification of Lakes by Trophic Level

Eutrophication is most simply defined as an increase in nutrient supply per unit volume of water in a lake which results in an increase in productivity per unit volume of the lake. Eutrophication is part of the natural aging of a lake; as a lake fills with sediment, it loses its capacity to assimilate the steady rain of organic detritus from above. The bottom of the lake, or hypolimnion (see Fig. 1, thermal zoning in Craig Lake), becomes anoxic in eutrophic lakes as the oxygen is consumed in bacterial decomposition of organic material. A steep thermal gradient (called the metalimnion) between the upper, well-mixed epilimnion and the deep, stagnant hypolimnion prevents the hypolimnion from being replenished in oxygen. The hypolimnion cannot be re-oxygenated until fall or spring overturn of the thermal stratification of the lake. This thermal gradient is essential to the metabolism of the lake; it affects not only oxygen distribution but also pH and distribution of some ions (Wetzel, 1975). In a eutrophic lake, nutrients will accumulate at the bottom of the lake, stimulating more rapid plant growth, and the cycle reproduces itself.

Eutrophication of a lake can result from causes inside or outside of its basin. A bulk nutrient loading from outside the lake can cause eutrophication: in populated areas, the dominant source of loaded nutrients might be phosphorous-rich runoff from agricultural fields or septic tank leakage. In wilderness areas, sources include vegetative runoff, bedrock weathering, and precipitation. Within the lake basin, eutrophication also results from the aging, filling and resultant dissolved oxygen and nutrient levels. The causes of eutrophication of a lake likely include both inside and outside factors.

Classification of lakes on the basis of trophic level is not absolute; it depends on the geology, climate and activity in the lake basin. Lakes range from oligotrophic through mesotrophic to eutrophic. In general, oligotrophic lakes are clear or blue, well oxygenated with no oxygen depletion of the hypolimnion in the summer, low in dissolved nutrients and low in productivity. Eutrophic lakes have murky, green or brown water, algal mats floating on the surface, high nutrient concentrations, high productivity and therefore high oxygen demand; the hypolimnion becomes very depleted in oxygen in the summer season. A mesotrophic lake lies somewhere between the two (Colinvaux, 1973).

Based on data collected, it is clear that the metasedimentary lakes are more eutrophic than the batholith lakes. This conclusion is based on dissolved oxygen readings, color readings, Secchi disc readings (turbidity), ion concentrations, and observed levels of biologic activity. The question is: why? What causes the difference in trophic levels? Is the difference in nutrient and ionic contribution from the metasediments versus the batholith significant enough to account for the difference in trophic level? Interestingly, the metasedimentary lakes average 4 to 7 meters, where the batholith lakes are much deeper--Craig lake measures 18 meters at its deepest point. Could the difference in depth, and thus in volume, and thus in available oxygen, be the dominant cause of the difference in trophic level? And why are the two lakes so different in depth?

Conclusions

Rocks in the metasedimentary terrain contain more of the ions essential to lake metabolism in their bulk composition than do rocks in the granitic batholith. Therefore, there ought to be a difference in bulk nutrient loading to the two lakes. Moreover, the fine grained, more mafic and fault-riddled metasediments will weather more quickly than the crystalline, medium-grained, quartz-feldspar granite. This means that lake basins in the metasedimentary units ought to have filled faster, accelerating their "aging" process of gradual eutrophication. Although we did not measure the depth to bedrock underlying the lakes, and therefore do not know the original basin depth, this difference in sedimentation rates seems reasonable given the mineralogy and structure of the two types of bedrock. The observed difference in trophic level--and therefore in color--of the two sets of lakes is likely due to a combination of two factors: bulk nutrient loading and sedimentation rates.

References

1. Wetzel, R.G. Limnology. (Pennsylvania: W.B. Saunders Company, 1975.)
2. Colinvaux, Paul. Introduction to Ecology. (New York: Wiley, 1973.)

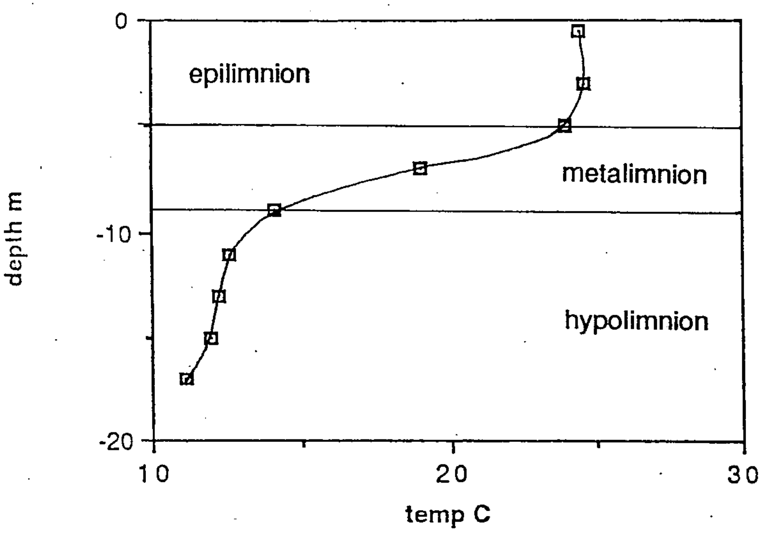

Figure 1 : Depth-temperature curve for Craig Lake (batholith), 8/4/88.

Fig. 2 a

b

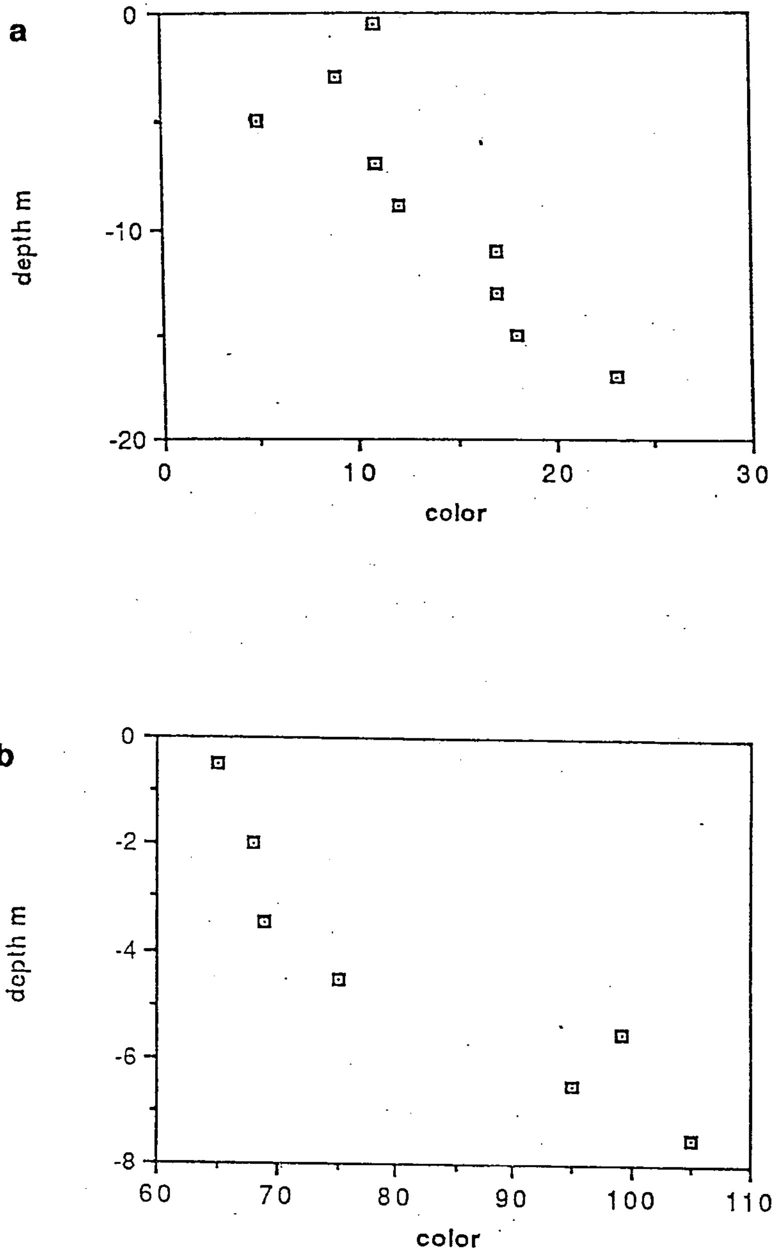

Figure 2 : Depth vs. color for (a) Craig Lake (batholith) and (b) Horse Lake (metasedimentary). Note the much higher values of Horse Lake, and the linear relationship of depth and color.

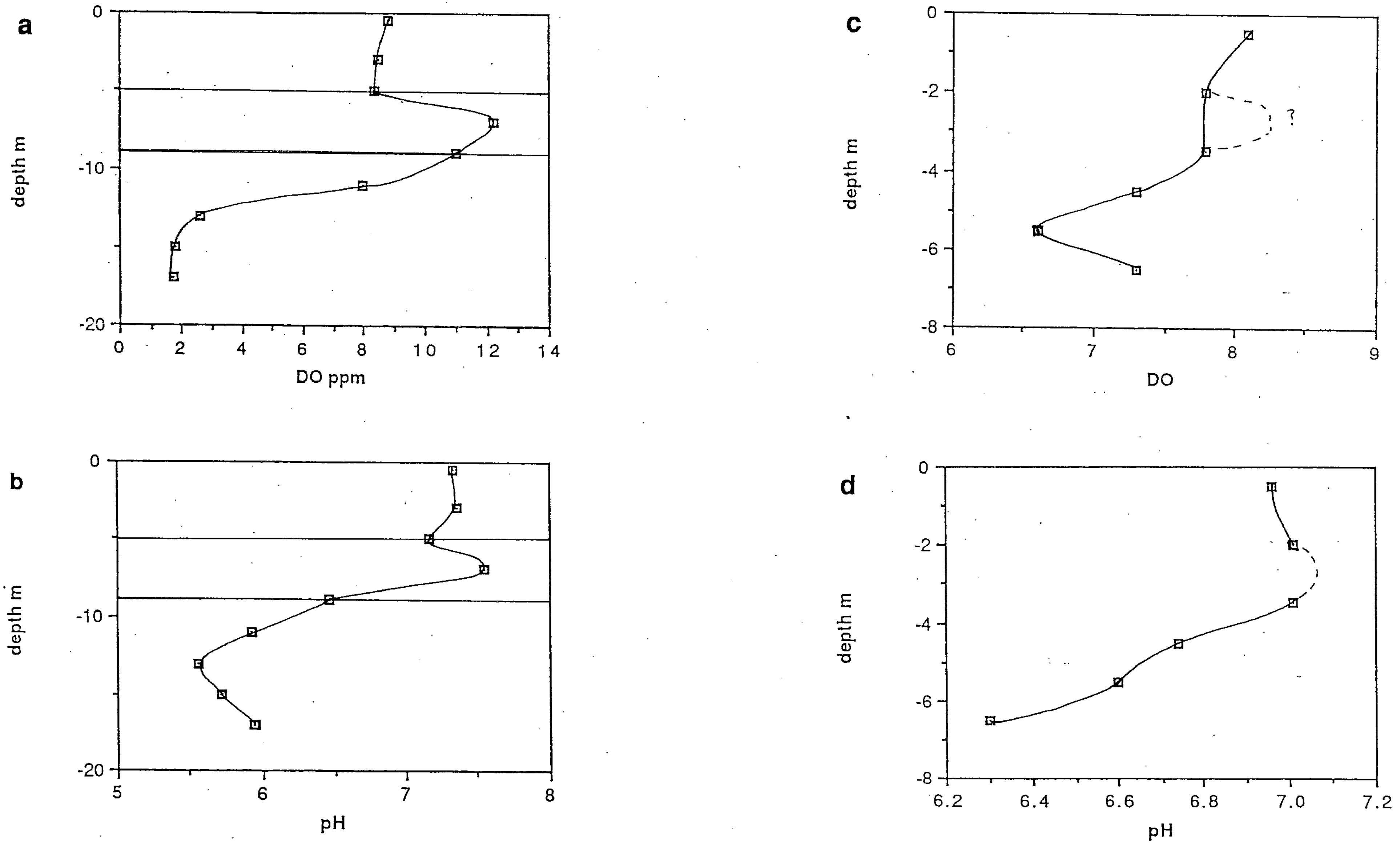

Figure 3 : a, b : Depth-dissolved oxygen and depth-pH curves for Craig Lake (batholith). Note the similarity between the two, and the relationship of both to the thermal stratification shown in Fig. 1.
c, d : Depth-dissolved oxygen and depth-pH curves for Horse Lake (metasedimentary).