CHEMISTRY AND ORGANIC PRODUCTIVITY IN LAKES OF THE BOUNDARY WATERS CANOE AREA WILDERNESS - QUETICO PROVINCIAL PARK, MINNESOTA - ONTARIO

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The color difference between the waters draining the Vermilion Batholith (clear) and metasedimentary rocks (brown) of the BWCA - Quetico Wilderness Area can be attributed to the amount of organic matter present in solution and as particulates in the lakes of this area. I divided the 18 sampled lakes into three categories based on bedrock composition (Batholithic = Class 1, metasedimentary = Class 2, mixed = Class 3) and analyzed the water from these lakes for cation, anion, dissolved organic carbon, and silica concentrations. Statistical analysis was completed for all 95 samples. In addition, I have focused on 8 lakes with exclusive batholithic or metasedimentary bedrock, as well as 2 arms of the Crooked Lake system which drain bedrock. The catchments of these lakes were mapped and classified by the percent of lake surface, wetlands, and forested uplands.

From the analyses of the major constituent ions, the mean values for the cations were plotted for the three lake classifications to determine the extent to which the bedrock influences the chemical characteristics of the lake water (Figure 1). In a humid climate such as that of the BWCA - Quetico, as much as 90% of the streamwater output of calcium, magnesium, potassium, and sodium may originate from rock weathering (Likens et al., 1977). The data indicate that the lakes draining the metasediments (Class 2) have higher concentrations of Ca and Mg than the lakes draining the Batholith (Class 1).

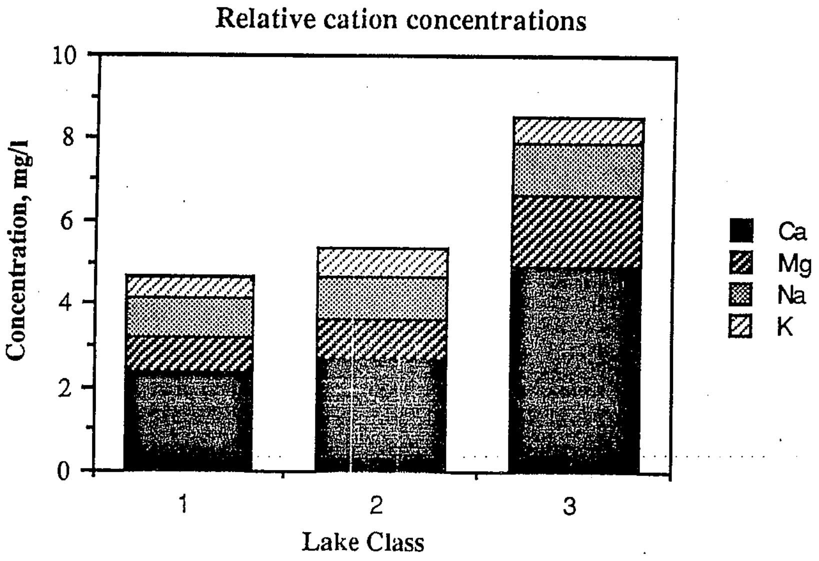

Figure 1. Cation concentrations for the three lake classes.

This suggests that the metasedimentary units of granite - rich migmatites, amphibolite migmatites, and biotite schists are being weathered faster than the rocks of the Batholith. The Batholith is composed of a series of basaltic lava flows containing quartz diorite to granitic intrusions (Sims and Morey, 1972). The lakes of mixed drainages have the highest Ca, Mg, and Na concentrations whereas the highest K concentration is in the Class 1 lakes. Table 1 summarizes the mean concentrations of the cations and anions for the three lake classes. Without data for the ratios of weathered to fresh rock, and the mineralogy of the source rocks it is difficult to suggest specific weathering reactions: silicate hydrolysis must dominate.

Table 1. Mean values for cations and anions

Cations

Class	Ca ±	SD	Mg ±	SD	Na ±	SD	K ±	SD
1	2.37 ±	1.37	0.79 ±	0.47	0.97 ±	0.20	0.50 ±	0.16
2	2.67 ±	0.65	0.98 ±	0.13	0.97 ±	0.24	0.74 ±	0.12
3	4.93 ±	1.80	1.70 ±	0.70	1.25 ±	0.28	0.65 ±	0.27

Anions

Class	SO_4 ±	SD	NO_3 ±	SD	Cl ±	SD
1	3.36 ±	2.55	0.09 ±	0.25	0.96 ±	0.67
2	2.37 ±	0.32	0.02 ±	0.02	1.01 ±	0.70
3	3.75 ±	0.49	0.03 ±	0.04	1.05 ±	0.42

Note: SD = Standard Deviation, values in mg/l.

Using Pearson correlation analysis, I measured the relationship between color and all other variables. I found color to be statistically associated with four major lake water characteristics. Color is highly positively correlated with DOC and lake class, and highly negatively correlated with Secchi disk depth and pH. Figure 2 depicts the relationship between color and depth for Craig and Horse lakes. Craig lake is of Batholithic drainage, while Horse lake drains the metasediments. Color frequently increases with depth in stratified lakes due to increased concentrations of dissolved organic matter and iron compounds near the bottom (Wetzel, 1975). The clearer lakes of the Batholith have color values ranging from 1 to 50 APHA Pt - Co units while the lakes of the metasediments range from 38 to 160 Pt - Co units. Figure 2 demonstrates that the color in a lake with metasedimentary drainage may increase more rapidly than a lake with Batholithic drainage as Horse Lake exhibits a slope of -0.14 for the depth color relationship while Craig lake's slope is -0.92.

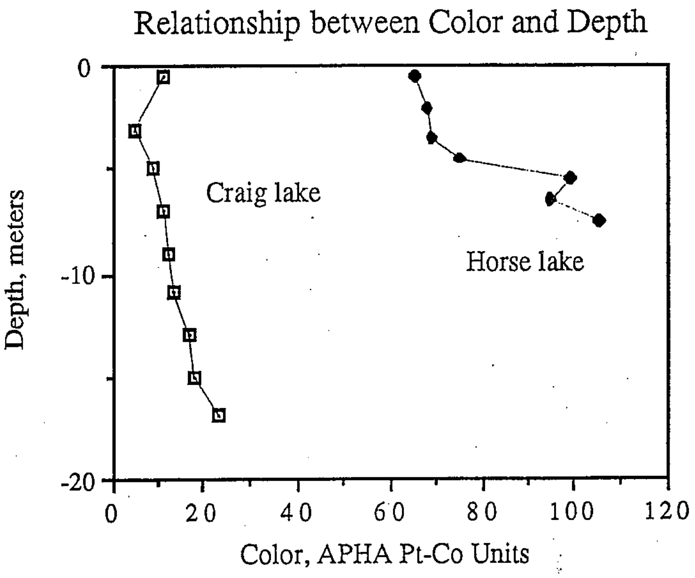

Figure 2. Color variance with respect to depth for two lakes.

The concentration of dissolved organic carbon may provide insight into the organic activity as the values for DOC reflect dissolved organic material which passes through a 0.45 micron filter (Drever, 1982). Not only does the DOC value indicate the amount of organic activity, but a strong correlation exists between the brown organic color which is derived chiefly from peat and marsh detritus, and the amount of dissolved organic carbon in the surface waters (Juday and Birge, 1933). Hence, to investigate the relative wetland contribution of this organic matter to the lakes, I selected 4 lakes on either side of the contact as well as 2 bays of the mixed drainage lake - river system of Crooked lake.

For these ten drainage areas, the catchments were measured and the fraction of wetland area was determined. These data are summarized in Table 2.

Table 2. Lake drainage areas and the percentage of wetlands

Lake	Catchment Area	Lake Surface Area	Swamp Area	Lake/Total A.	Swamp/Total A.	Class
Cecil	2.73 km^2	0.47 km^2	0	0.18	0	1
Craig	1.18 km^2	0.30 km^2	0.16 km^2	0.26	0.11	1
Deer	3.25 km^2	0.90 km^2	0.58 km^2	0.28	0.18	1
Horse	13.0 km^2	2.75 km^2	2.0 km^2	0.20	0.15	2
Jackfish	8.32 km^2	0.84 km^2	2.02 km^2	0.10	0.24	2
Kett	6.05 km^2	1.61 km^2	0.87 km^2	0.26	0.14	1
Leach	0.24 km^2	0.04 km^2	0.03 km^2	0.20	0.13	2
Wobosons	0.90 km^2	0.13 km^2	0.07 km^2	0.13	0.16	2
Sat. Bay	20.23 km^2	2.27 km^2	8.84 km^2	0.11	0.44	3
N. Fri. Bay	5.85 km^2	0.97 km^2	0.76 km^2	0.17	0.13	3

For Class 1 lakes, the ratio of the lake surface to the total drainage area ranges from 0.18 to 0.28 while the lakes draining the metasediments have lake area fractions ranging from 0.10 to 0.20. The lower values for Class 2 lakes suggest that there is more area of soil cover and swamp, which would result in a greater region for biologic activity and geochemical processes to alter the water which eventually reaches the lakes. As for the fraction of the total catchment which is covered by wetlands, Class 1 lakes varied from 0 to 0.18, Class 2 lakes varied from 0.13 to 0.24, and Class 3 lakes, those of mixed drainages, demonstrated the largest variation in swamp cover, ranging from 0.13 to 0.44. Since wetlands may be the source of much of the organic detritus which colors the lakes, the relative abundances of swamp area provides an explanation for the darker, browner Class 2 and 3 lakes.

The silica content of a lake is another useful indicator of the biologic productivity. Diatom algae use silica in the construction of their skeletons. This results in the depletion of silica in the epilimnion and an increase in silica in the hypolimnion as the diatoms die and settle to the lake bottom. Previous studies of lake bottom sediment in the area have shown that the diatoms form more than 30% of the dry sediment weight and have a concentration of more than 2×10^8 cells per square centimeter (Bradbury, 1975). Figure 3 represents two silica profiles, one for Horse (Class 2) and one for Craig (Class 1), which illustrates the increase in SiO_2 in the hypolimnion.

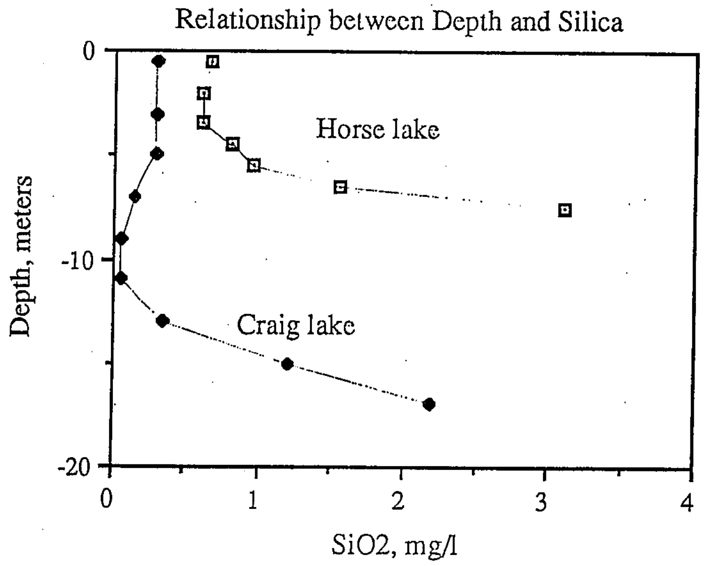

Figure 3. Silica profiles for two lakes

The metasedimentary lakes tend to have higher silica concentrations than those lakes draining the Batholith. The diatoms bloom during the spring and early winter and use silica derived from lake water or from the stems of plants in the lakes as a silica source as these stems have been shown to be easily soluble (Jorgensen, 1957). The diatoms must use the silica derived from plants growing in the near shore, or littoral regions of the lakes since there is little SiO_2 input from the surrounding area. The low influx of SiO_2 is due to the insolubility of local beds and the thin layer of red gravelly glacial drift of the substrate, which supplies only small amounts of nutrient material to the lake waters (Eddy, 1966).

To further investigate the relationship between the diatom productivity and the lakes of differing drainages, I have examined the maximum sample depths for each lake. The results are illustrated in Figure 4, which depicts the three lake classes and the average depth for each class. The lakes draining the metasediments (Class 2) tend to be more shallow than the lakes to the north of the contact (Class 1). This correlates with the work done by Eddy, in which he found that the shallower lakes of northeatern Minnesota were more productive than the deeper lakes due to a larger percentage of littoral area.

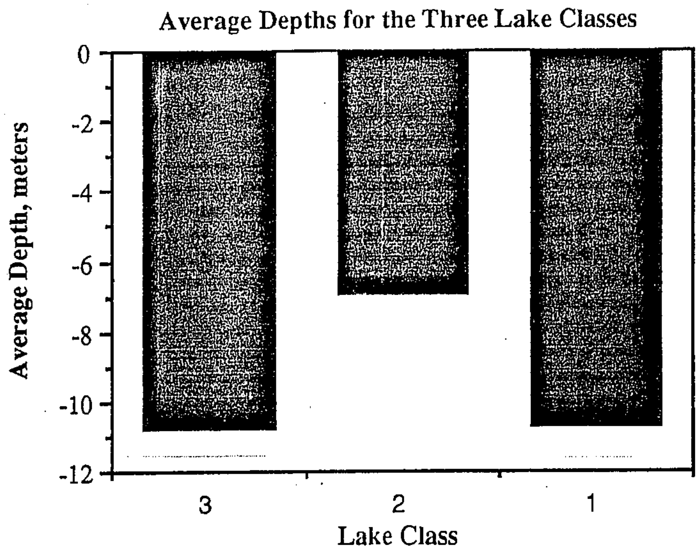
Average Depths for the Three Lake Classes

Figure 4. Average maximum sample depths

Hence it is the morphometry of the lake basin which results in increased sedimentation and higher fertility in the shallow lakes (Eddy, 1966). This project provides evidence that the bedrock of the BWCA - Quetico does not directly control lake color. However, the configurations of the lake basins, resulting from the late Wisconsin ice sheet, control the productivity in the lakes and surrounding wetlands, which contribute the organics that determine lake color.

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