CHEMICAL, PHYSICAL AND BIOLOGICAL IMPACTS ON SANDPIT LAKE IN THE BOUNDARY WATERS CANOE AREA WILDERNESS

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Introduction

For the past ten summers, groups from Beloit College under Dr. Henry Woodard's guidance have been mapping a contact zone in the Boundary Waters Canoe Area Wilderness. The contact roughly follows the border between southern Ontario and northern Minnesota. The Vermillion Batholith, a relatively homogeneous pink granite, lies to the north of the contact zone, while metasedimentary migmatites make up the rocks to the south. The mapping groups noticed a marked color difference between the waters of lakes located in the batholith and those located in the metasedimentary area. The lakes underlain by the granite were generally clear and blue-green in color, and the lakes with migmatite basins were brown and often rather murky. Our group set out to discover whether there is a geologic explanation for this difference. The question is really too large for one individual to handle, so we broke the study into parts. I concentrated my study on Sandpit Lake, one of the metasedimentary lakes, to find what correlations exist between the rock, the sediment and the water and how these affect the lake.

Methods

We collected water, lake bottom sediment and rock samples. In the field, we determined temperature, pH, dissolved oxygen content, conductivity, color, clarity, alkalinity and calcium and magnesium hardness for the water samples. Further analysis in the lab included atomic absorption to test for some of the major elements such as calcium, sodium, aluminum, magnesium, manganese and potassium. X-ray fluorescence was used to determine the composition of the sediment and rock samples.

Findings

Our group had no trouble concurring with the earlier observations that lakes north of the contact are clearer and bluer while the lakes to the south were darker, less clear and brown or tea-colored. Why this difference exists proved to be far more complicated than we had anticipated. It turns out that the "determination of color . . . has no direct chemical significance" (Hem, 1970) and that the major influence of water color is dependent upon the lake's productivity level. The local mineralogy and its related chemical impact on the water do influence organic productivity, as certain elements are necessary for different biological processes, but size, shape, depth, age and location of the lake, local climate, topography and vegetation also play a role in determining the organic content of a lake. Eutrophic, or highly productive, lakes tend to be murky and brown in color. Oligotrophic, or non-productive, lakes are generally clear and blue-green in color. Sandpit was neither of these extremes, rather it was more greenish-brown in color. So,how did it get to this point? With all the factors involved it's difficult to find a place to begin. It's a kind of "Which came first, the chicken or the egg?" question, but there are more variables to be taken into account.

Since our first hypothesis involved the mineralogical influence on a lake, I'll begin with that. As was mentioned before, chemistry by itself does not have an impact on water color, but it is necessary for certain biological functions. So, depending on the solubilibty and availability of the specific elements, they are taken into solution and can then be utilized by organisms (see fig. 1). Over time various factors have fragmented and weathered the lake basin's rock, a biotite schist migmatite, with the resulting sediments filling into the lake's basin. For all intents and purposes, the inorganic chemical compostion of this sediment is the same as that of the rock (see fig. 2a and 2b). Both the rock and sediment are composed largely of silica (about 68%). Silica enters the lake almost entirely from the erosion of these rocks and the surrounding soils, but it is relatively insoluble and therefore found only in low concentrations in the water. Most algae and animals have little need for silicon, but silica constitutes the building material for diatoms. Diatoms absorb silica from the water to build their frustules, or outer shells. Aluminum also constitutes a significant portion of the rock (about 13%). Aluminum is also found only in low concentrations (less than one mg/L), but it is an important component involved in the direct precipitation of inorganic phosphate phases which are integral to productivity. Three to four percent of the rock consist of both sodium and potassium, sodium being necessary for plant growth and potassium being required as an enzyme activator in aquatic biota. Both of these elements are found in the water in amounts of one to two mg/L. Calcium and iron constitute one to two percent of the rock. Calcium is an essential element for metabolic processes in all living organisms and often as structural or skeletal material. In comparison with the other elements calcium is quite abundant in the water relative to its original percent composition in the rock and sediment, probably due to its high degree of solubility. Iron is essential to many enzymatic and cellular processes. No numbers are available for its concentration in Sandpit Lake water. Phosphorus, manganese, and magnesium each make up less than one percent of the rock's composition. Inorganic phosphorus compounds usually occur in small amounts in natural waters, but phosphorus is an essential nutrient for primary producers. Once again, no numbers are available for phosphorous abundance in the water. Manganese is needed by plants for the oxygen-evolving process in photosynthesis, and magnesium is necessary for the major short-term energy-transferring reaction in cells. Both these elements are more abundant in the water relative to their original percentages in the rock and in comparison with some of the other elements.

So, it is apparent that inorganic elements derived from the weathering of a lake basin are important to the organic growth within such an ecosystem, but once again, these factors alone cannot deterine the level of productivity in a lake. Depth of the lake is another important influence. Sandpit Lake being only about sixteen meters deep at its deepest point can be considered relatively shallow.

> Shallow lakes are generally more productive (per unit area) than deeper lakes in the same regions. This is because the organic matter formed within them does not sink down to be lost for ever or recirculated only intermittently. Instead it is broken down and its constituent nutrients are frequently stirred back into the lighted zone and quickly reused to produce more organic matter . . . [A] greater portion of the water in a shallow lake is in the lighted zone, and the water of shallow lakes is frequently warmer than that of deep lakes which speeds decomposition and production" (Burghis and Morris, 1987).

The age of a lake also has an indirect impact since lakes become shallower with time due to sediment deposition, and size and shape can influence the amount of stirring and mixing of the water. The surrounding topography is one more physical characteristic which has an impact on a lake, controlling certain aspects of weathering and erosional processes.

Climate and temperature also influence a lake's productivity. In photosynthesis, plants trap energy from sunlight with the aid of chlorophyll and use this to combine carbon dioxide and water into sugars. Oxygen is a waste product in this process which is in turn used by all plants and animals for respiration. Temperature plays a role in two complimentary ways. As mentioned above, warmer temperatures speed decomposition and production, but colder water can hold a large volume of dissolved gases such as oxygen and carbon dioxide.

Further considerations

Though a valient beginning, this project has a few holes in it. Upon starting we hypothesized that we could find a purely geologic explanation for differences in the batholith and the metasedimentary lake waters. As it turns out, however, the processes involved in a lake ecosystem are so interconnected that it is impossible to completely differentiate the separate influences. For this reason, more extensive research must be done with regard to the biological aspect of lakes and used in conjunction with the other findings. With this sort of information, far more conclusive results could be given.

figure 1: relative amounts of certain elements found in the rock, sediment and water

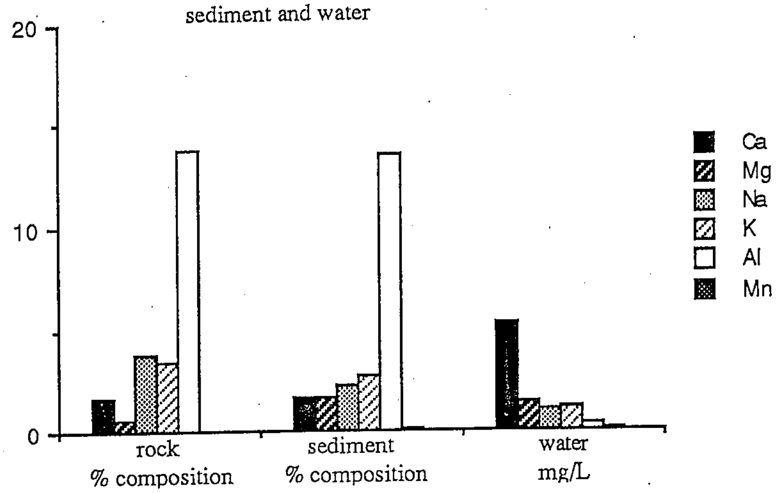


figure 2b: percent composition of sediment

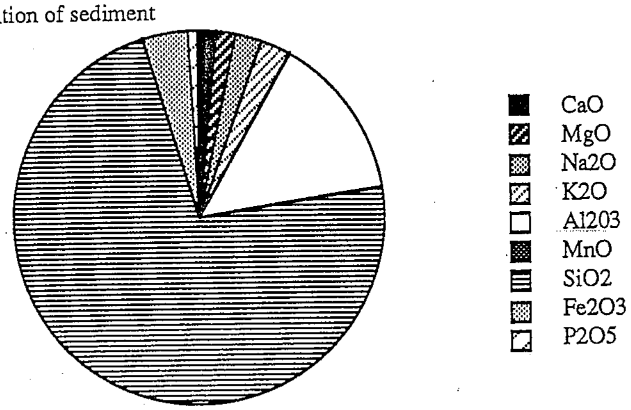
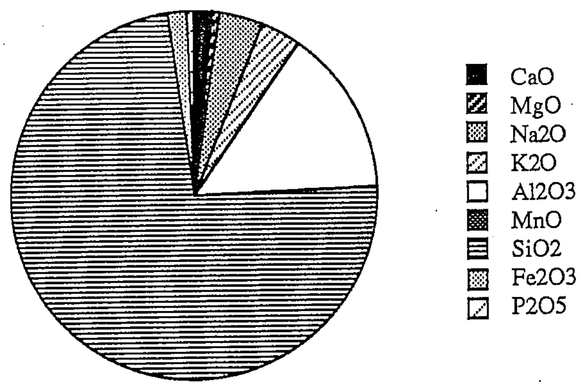


figure 2a: percent compostion of rock



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