

Geomorphology and Vegetation as Determinants Of Surface Water Chemistry at Denali

The national parks and preserves in Alaska provide an excellent opportunity to acquire benchmark surface water chemistry against which potential human-induced change may be assessed. Such undisturbed systems make it possible to assess the role of natural ecological factors in effecting noted variations. Much study has taken place on understanding biogeochemical cycles within a watershed context – mostly intensive studies, concentrating on one or a few drainages. Hypotheses from such studies regarding the regulation of stream chemistry tend to be confined to specific areas.

What is needed for the expansive Alaskan areas are general hypotheses more widely applicable to a given region. Our approach was to select a large number of small watersheds stratified by geologic substrate, aspect and elevation, in order to 1) obtain baseline surface water quality data and 2) examine some of the natural factors responsible for noted variation in water chemistry, especially those chemical species having the most potential value as indicators of ecosystem change.

In New England the use of long-term trends in surface water chemistry to detect trends in anthropic atmospheric deposition has been adequately demonstrated. Such data also permit projecting future surface water change should present air quality change. But there are numerous sources of *natural* variation in surface water chemical trends such as elevation, aerial extent of bed-rock type, and ecosystem succession. In Denali another factor may be topographic aspect which determines, to considerable degree, the presence or absence of permafrost.

Denali National Park and Preserve (2.5 million ha),

located about 600 km east from the coast of the Bering Sea, occupies the northernmost portion of the Alaska Range in the Pacific Mountain System. Geology here is dominated by Precambrian slate and marble, quartzite and mica-quartz schist; to a lesser extent Mesozoic basalts, sandstones and shales, and Tertiary granitics and sandstones, shales and conglomerates. The north and west sections of the study area are dominated by Quaternary gravel and glacial deposits. The region's climate is continental, with large diurnal and annual temperature variation. Mean annual precipitation varies from 50 cm at lower elevations, where one-third occurs as snow, to 200 cm at high points. Lower elevations of the park are underlain by isolated masses of permafrost; higher levels have discontinuous permafrost.

The sampled watersheds occur in the eastern and central portions of the park in headwaters of the Teklanika, Toklat, McKinley and Kantishna River drainages. Most watersheds above 1000 m elevation are vegetated by low productivity moist or barren and sparse dry tundra (Fig. 1). At lower elevations and on south facing slopes mixed evergreen and deciduous forests prevail. Over 60 watersheds were sampled in the fall of 1985. A subset of >20 were sampled seasonally in 1987, and intensive study of the effects of vegetation on surface water quality was continued in a few carefully selected watersheds (Fig. 2). Access to most sites was by helicopter. In each watershed a stream sampling site was selected where discharge measurements could be taken by Pygmy meter. The determination of pH, alkalinity, and specific conductance was completed upon return to base camp. Samples for ionic analyses were shipped in coolers to our laboratory at Michigan Tech.

Surface waters of Denali are concentrated and very well buffered. Only one stream had significant levels of dissolved carbon. Stream chemistry was dominated by calcium, magnesium, bicarbonate and sulfate. In no instance did sulfate concentration exceed bicarbonate –

testimony to the high natural buffering and near absence of atmospheric contaminant input in the park. The pH increased from 6.5 in the most dilute stream to 8.7 in the most concentrated, where there was evidence of calcium carbonate precipitating out. This was found in watersheds with a basalt-rhyolite bedrock (Teklanika Formation).

Stream chemistry concentrations greatly exceeded those found at multiple sites in Glacier Bay and Lake Clark NPs. This reflects regional geologic differences. Bedrock at Lake Clark (*Park Science*, Vol. 8, No. 4, pp. 23-24) and Glacier Bay (*Park Science* Vol. 8, No. 3, pp. 20-21) is dominated by Tertiary intrusive rock while Denali is dominated by Mesozoic and Quaternary sedimentary rock. Stream nitrate values at Denali were slightly higher. This likely is due to the combination of nitrogen fixers in these predominantly early successional headwater ecosystems, relatively low biological uptake and minimal nitrate retention in very young, poorly developed soils.

To further evaluate the role of bedrock character we related stream water chemistry to rock type by grouping bedrock types dominated by similar geochemistry. Stream water from watersheds with bedrock dominated by calcium and potassium feldspars or mixed sediments and gravels was significantly higher in concentration of calcium, magnesium, and potassium than stream water from watersheds with bedrock dominated by sodium feldspars or volcanics. Conversely, the concentration of these chemical species was significantly lower in streams draining watersheds with volcanic substrates, clear evidence of the geochemistry of this substrate. Such watersheds are found on the north slope of Mt. McKinley (Fig. 1). The till observed in these drainages consisted solely of granite, which is the only bedrock upslope from these watersheds.

Stream concentrations of sulfate were high in the Kantishna Hills region, apparently due to high frequency of sulfide bearing minerals associated especially with



Figure 1. The granite substrate of the Cache Creek watershed results in very dilute, relatively sensitive stream water.



Figure 2. Remote automated monitoring station to assess effect of temperature, moisture, and radiation on vegetation production, decomposition, and nutrient cycling.

vein-faults. Some instances of high heavy/trace metal concentrations also were found in streams undisturbed by mining. Such levels likely are the result of mineral-rich springs. However, at our study sites the high pH of the stream rapidly complexes many if not most of the trace metal input thus reducing or eliminating its potential for biological impact.

It is always desirable to be able to extrapolate from such results, and predict stream water chemistry in other park drainages. Use of such easily measured physiographic characteristic as watershed area, elevation, topographic aspect would be the simplest and most economical. Using step-wise multiple regression we tested a number of models using basin area, elevation, difference in elevation within the drainage, and aspect, but found no single or combination of variables that would account for a significant amount of the noted variation in stream chemistry. This points to a need for more baseline spatial data and further understanding of natural factors responsible for variation in some of the key tools, (as water chemistry), we use to detect long-term change.

Precipitation chemistry does not appear to be a major factor responsible for seasonal variation in surface water chemistry. The only possible exception was nitrate concentration in precipitation. The relatively high nitrate concentration observed in spring, coupled with snow melt losses of nitrate and low biological uptake, could all be factors in why stream nitrate concentration is high in early summer.

The data give some quantification of the relationship of geomorphology to surface water chemistry. The influence of bedrock quality can be seen clearly in those inorganic chemical species not generally found to be

ecologically limiting. However, the presence of nitrate, a commonly limiting nutrient in terrestrial ecosystems, in stream water was not related to bedrock since it is of biological origin. Nitrate is also a common atmospheric contaminant, and while such inputs are not now high in Denali there is potential for their increase in the near future. In the summer of 1988 we examined several watersheds with significantly different concentrations of stream water nitrate to find out what process(es) might be responsible. Since nitrification is the most probable source of this output and is an acidifying process, this subgroup of watersheds appears to contain good sites for obtaining assessment of the effects of ecosystem biological differences (vegetation type, succession) on basic change in watershed soils and therefore surface water chemistry.

The time and fiscal constraints of our study will not permit addressing all sources of natural variation in key ecosystem indicators of stress. However, our design should quantify some of the major sources. Further, the stratified approach in watershed selection and extensive coverage of site types now would permit deductive site selection for long-term inventory and monitoring. Because inventory and monitoring is a substantial commitment of funds and time, site selection must be made with great care. Most important, site selection must not be based upon short-term considerations. Objective evaluation is necessary to get sites that have the highest probability of yielding answers to a wide range of environmental threats, some not yet even perceived.

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