Physical controls on the bioavailability of soil phosphorus in the Dry Valleys of Antarctica

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Introduction:

Phosphorus is an essential element for all organisms, therefore it is important to understand controls over phosphorus availability and retention in soil ecosystems. Available phosphorus, typically in the form of the phosphate anion (PO$_4^{3-}$), is derived from the weathering of primary minerals in soil parent material. Measuring available phosphorus is challenging due to the large number of chemical fractions where phosphorus may reside in soils. Within soils, some forms of phosphorus are more readily available to organisms than are others, and the ability to distinguish among these various fractions often limits the interpretation of analytical data. Therefore, much of the work with phosphorus involves the use of operationally defined phosphorus fractions distinguished by their physical and chemical characteristics.

My objective is to examine the physical controls over phosphorus availability in soils, using the Hedley fractionation (Cross and Schlesinger, 1995) to distinguish among different phosphorus pools, which vary in their availability to organisms.

The Dry Valleys of Antarctica provide an ideal location for this type of study, as they have very limited biota and contain distinct gradients in soil-forming factors, such as soil age and exposure to physical factors. Different forms of phosphorus:

- Resin-extractable (Very labile; non-occluded)
- NaOH-extractable P (Low labile; associated with Ca and P; exchangeable, non-occluded)
- NaOH-extractable P (Ca-bound; non-exchangeable, non-occluded)
- HCl-extractable P (Co-bonded; non-exchangeable in the short-term, non-occluded)
- Residual P (Mostly occluded)

Preliminary results:

The graphs below show the partial results from a Hedley Fractionation of surface soils from seven sites within the Dry Valleys. They show the concentration of three forms of phosphorus (resin-extractable, NaOH-extractable, and HCl-extractable) plotted against the age of the till. The following observations can be taken from these results:

- The youngest site has, by far, the greatest concentration of all phosphorus forms. This shows the effect of weathering on the total phosphorus concentration.
- Resin-extractable P, which is the most available to organisms, shows a sharp drop between the first and second sites, and then a steady decline with age. This can be explained by a combination of soil age and greater biological activity at the younger sites, which may promote the cycling of available P.
- NaOH- and HCl-extractable P drop sharply between the first and second sites, and then show a potential steady increase. This may be explained by erosion transport, with greater rates of sediment deposition at some of the older sites examined in this study (Lancaster, 2002).

Different forms of phosphorus:

Throughout the development of a soil, phosphorus can be found in various forms, shown here as $P_0$, $P_{occluded}$, and $P_{organic}$. The distribution of phosphorus as a function of time, as shown below.

Soil in Antarctica?

The McMurdo Dry Valleys, at 4800 km$^2$, make up the largest ice-free area of Antarctica (Fountain et al. 2000). They are also a site for the National Science Foundation’s Long Term Ecological Research (LTER) program.

•The Dry Valley region of Antarctica is a polar desert, with less than 10 cm of precipitation per year.

•Mean annual temperature in Taylor Valley is approximately -20°C, with summer temperatures typically 0-5°C.

•Liquid water is present for only a few weeks each year.

Why Antarctica?

- Distinct gradients in state factors, such as age and soil moisture, within a fairly small geographic area.
- Low levels of biological activity, making for a simplified system in which physical factors are much more easily isolated and examined.

Continued work:

I am currently working on a Hedley Fractionation of samples from various depths across several sites in Taylor Valley. This will provide a more quantitative inventory of the various phosphorus fractions, and insight into the effects of age and physical weathering on the bioavailability of phosphorus.

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Sources:


