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

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Introduction:

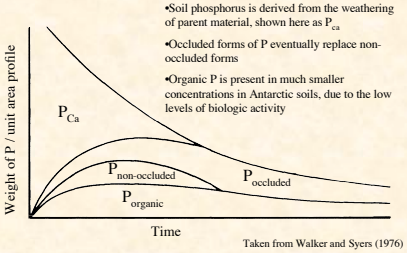
Phosphorus is an essential element for all organisms, therefore it is important to understand controls over phosphorus availability and retention in soil ecosystems. Available phosphorus, typically in the form of the phosphate anion (PO_4^{-}) is derived from the weathering of primary minerals in soil 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 a study, as they have very limited biota and contain distinct gradients in soil-forming factors, such as soil age and exposure to liquid water, within a small geographic area.

Different forms of phosphorus:

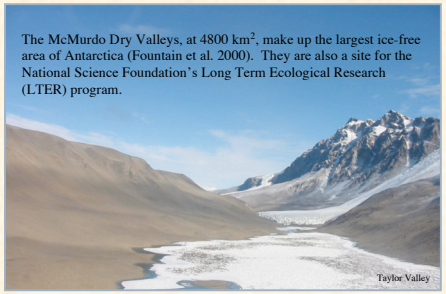
Throughout the development of a soil, phosphorus can be found in any of several different fractions. Walker and Syers (1976) described the distribution of phosphorus as a function of time, as shown below.



- Soil phosphorus is derived from the weathering of parent material, shown here as P_{ca}
- Occluded forms of P eventually replace non-occluded forms
- Organic P is present in much smaller concentrations in Antarctic soils, due to the low levels of biologic activity

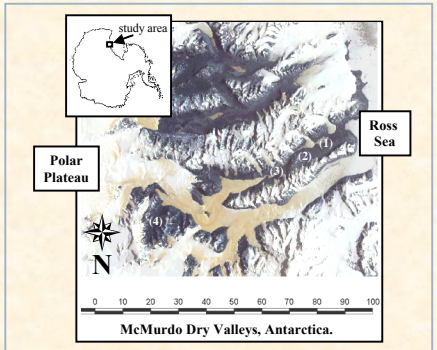
Taken from Walker and Syers (1976)

Soil in Antarctica?

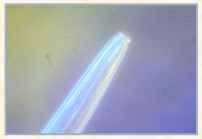


- The Dry Valley region of Antarctica is a polar desert, with less than 10 cm of precipitation per year.
- Mean annual temperature in Taylor Valley is approximately -20°C, with summer temperatures typically 0-5°C.
- Liquid water is present for only a few weeks each year.

(Fountain et al., 2000)



Sites used in this study include: 1. Lake Fryxell, 2. Lake Hoare and 3. Lake Bonney, all in Taylor Valley and 4. Beacon Valley.



Nematodes (shown left) are the largest invertebrates found in the Dry Valleys. There are no vascular plants, and food webs are dominated by microbes.

Photo credit: D.H. Wall, Natural Resource Ecology Laboratory, Colorado State University, Ft. Collins, CO.

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

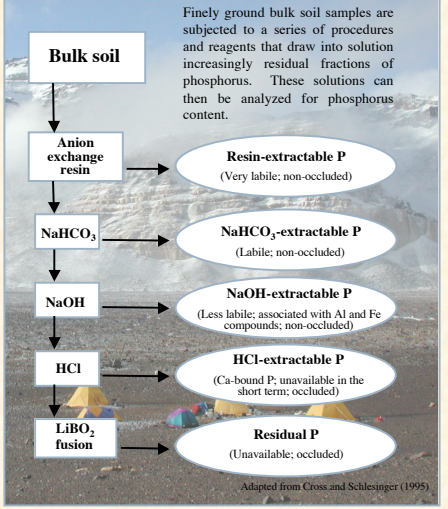
Preliminary results:

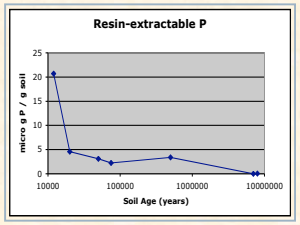
The graphs below show the partial results from a Hedley Fractionation of surface soils from seven sites within the Dry Valleys. They show the concentration of three forms of phosphorus (resin-extractable, NaOH-extractable, and HCl-extractable) plotted against the age of the till. The following observations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

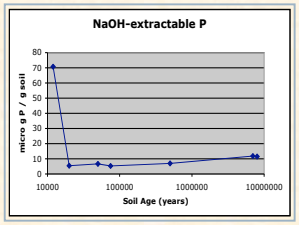
- The youngest site has, by far, the greatest concentration of all types of phosphorus. This shows the effect of weathering on the total phosphorus concentration.
- Resin-extractable P, which is the most available to organisms, shows a sharp drop between the first and second sites, and then a steady 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 eolian transport, with greater rates of sediment deposition at some of the older sites examined in this study (Lancaster, 2002).

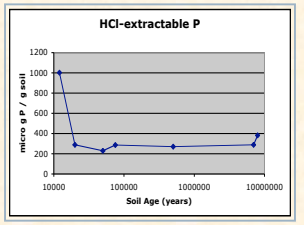
Hedley Fractionation Procedure

Finely ground bulk soil samples are subjected to a series of procedures and reagents that draw into solution increasingly residual fractions of phosphorus. These solutions can then be analyzed for phosphorus content.









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.

Acknowledgements:
This work was supported by the Dartmouth College Dean of Faculty Richter Grant, the Dartmouth College Environmental Studies Program, the Dartmouth College Institute of Arctic Studies, and the McMurdo Long Term Ecological Research Program (National Science Foundation Grant OPP-0096250).

Sources:

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