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Title of article Chemical Weathering in two Adirondack watersheds: Past and present-day rates

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APPENDIX A

CONVERSION OF CROSS-HATCHED AREA IN HORNBLENDE DEPLETION CURVES TO WEATHERING RATES

WOODS WATERSHED

Integrated area (Figure 5) = $970 \frac{\text{cm-\% hbld}}{\text{heavies}}$

1. $970 \frac{\text{cm-\% hbld}}{\text{heavies}} \times 0.01^{*} \times 0.0908 \frac{\text{heavies}}{\text{total sample}} = 0.881$ cm-hbld

2. $0.881 \text{ cm-hbld} \times 1.65 \frac{\text{gms}^{**}}{\text{cm}^3} \times 1 \times 10^8 \frac{\text{cm}^2}{\text{ha}} = 1.45 \times 10^8 \frac{\text{gms hbld}}{\text{ha soil}}$

3. $1.45 \times 10^8 \frac{\text{gms hbld}}{\text{ha soil}} \times \frac{1}{14000 \text{ yrs}} \times 0.5 \text{ soil cover} = 5.19 \times 10^3 \frac{\text{gms hbld}}{\text{ha of watershed} \cdot \text{yr}}$

PANTHER WATERSHED

Integrated area (Figure 6) = $1808 \frac{\text{cm-\% hbld}}{\text{heavies}}$

1. $1808 \frac{\text{cm-\% hbld}}{\text{heavies}} \times 0.01^{*} \times 0.0898 \frac{\text{heavies}}{\text{total sample}} = 1.624$ cm-hbld

2. $1.624 \text{ cm-hbld} \times 1.50 \frac{\text{gms}^{**}}{\text{cm}^3} \times 1 \times 10^8 \frac{\text{cm}^2}{\text{ha}} = 2.44 \times 10^8 \frac{\text{gms hbld}}{\text{ha soil}}$

3. $2.44 \times 10^8 \frac{\text{gms hbld}}{\text{ha soil}} \times \frac{1}{14000 \text{ yrs}} \times 0.7 \text{ soil cover} = 1.21 \times 10^4 \frac{\text{gms hbld}}{\text{ha of watershed} \cdot \text{yr}}$

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*This value returns the percent value to a ratio value.

**This value represents the measured average bulk density of soil.

APPENDIX B

MINERAL WEATHERING REACTIONS

On the basis of mineral compositions and analyses of the clay fraction of soils, reaction stoichiometries were formulated for the dissolution of hornblende, plagioclase, and K-feldspar - the 3 most volumetrically important minerals in the Panther Lake and Woods Lake watersheds.

Hornblende. Hornblende can weather congruently to its constituent ions and oxides/hydroxides or incongruently to a solid aluminosilicate byproduct plus ions and oxides/hydroxides. For the first case, the weathering reaction may take the following form:

1. Hornblende + acidic soil water → Oxides and hydroxides, silicic acid, cations and anions in solution

1.

$$\underbrace{(Na_{.62}K_{.34})\ Ca_{1.78}Mn_{.06}(Mg_{1.41}Fe^{2+}_{2.53}\ Fe^{3+}_{.61}\ Al_{.75})(Si_{6.37}Ti_{.26}Al_{1.37})\ O_{22}\ (OH)_{2.86}(F_{.23}Cl_{.14})}_{\text{Hornblende}} + 6.97\ H^{+} + 11.00\ H_2O + 0.67\ O_2 \rightarrow$$

$$1.57\ Fe_2O_3 + 2.12\ Al(OH)_3 + 0.26\ TiO_2 + 0.06\ MnO_2 + 6.37\ H_4SiO_4 + 0.62\ Na^{+} + 0.34\ K^{+} + 1.78\ Ca^{2+} + 1.41\ Mg^{2+} + 0.23\ F^{-} +$$

$$0.14\ Cl^{-}$$

Because vermiculite is abundant in the upper part of soil profiles where hornblende is depleted, the incongruent dissolution of hornblende to vermiculite plus ions in solution is a second possible reaction:

2. Hornblende and acidic soil waters ➡ Vermiculite and ions in solution

2.

$$\underbrace{(Na_{.62}K_{.34})Ca_{1.78}Mn_{.06}(Mg_{1.41}Fe^{2+}_{2.53}Fe^{3+}_{.61}Al_{.75})(Si_{6.37}Ti_{.26}Al_{1.37})O_{22}(OH)_{2.86}(F_{.23}Cl_{.14})}_{\text{Hornblende}} + 0.66\ O_2 + 6.45\ H^+ + 4.02\ H_2O$$

$$+ 0.06\ P^{5+} \rightarrow \underbrace{0.79\ Mg_{.04}Ca_{.02}Na_{.04}K_{.11}P_{.08}(Fe^{2+}_{.23}Al_{1.84})(Si_{3.08}Al_{.85}Ti_{.07})O_{10}(OH)_2}_{\text{Vermiculite}} + 1.48\ Fe_2O_3 + 3.94\ H_4SiO_4 + 0.59\ Na^+$$

$$+ 0.25\ K^+ + 1.76\ Ca^{2+} + 1.38\ Mg^{2+} + 0.23\ F^- + 0.14\ Cl^- + 0.06\ MnO_2 + 0.20\ TiO_2.$$

Since the vermiculite found in the till is composed primarily of aluminum, silicon and oxygen, the only major difference between Reaction 1 and Reaction 2 is in the amounts of aluminum-hydroxide and silicic acid formed during weathering.

Potassium is the only base cation present in any significant quantity in the vermiculite, and therefore its molar concentration in solution varies slightly from Reaction 1 to Reaction 2 (Table 13). Given the relatively small differences between the two reactions, it appears that either could be used to represent the release of base cations during hornblende weathering.

Feldspar. Although trends in the abundance of light minerals are not detectable in the soils, feldspar weathering is an important process in Adirondack soils. Feldspar weathering reactions are commonly written as incongruent dissolutions to kaolinite, but the possibility exists that vermiculite is also a byproduct in soil environments.

Like the hornblende weathering reaction, it is necessary to know if the feldspars weather congruently or incongruently. The choice is further complicated by difficulties in identifying the products of feldspar weathering. In this case, three possible reactions have been written to represent plagioclase weathering. Two of these reactions assume incongruent dissolution with the product of one kaolinite, and the other vermiculite. The third reaction is written assuming congruent dissolution.

Reaction 3 shows the incongruent dissolution of plagioclase to kaolinite:

3.

$$(Na_{.84}Ca_{.16})\ Al\ (Si_{2.83}Al_{.17})\ O_8 + 1.17\ H^+ + 3.91\ H_2O \rightarrow 0.59\ [Al_2Si_2O_5\ (OH)_4] + 0.84\ Na^+ + 0.16\ Ca^{2+} + 1.66\ H_4\ SiO_4.$$

Reaction 4 is somewhat speculative and assumes incongruent dissolution to vermiculite:

4. Plagioclase + soil waters ➡ Vermiculite + cations in solution

4.

$$(Na_{.84}Ca_{.16})\ Al\ (Si_{2.83}Al_{.17})\ O_8 + 0.02\ Mg^{2+} + 0.05\ K^+ + 0.3\ P^{5+} + 0.05\ Fe_2O_3 + 0.03\ TiO_2 + 3.69\ H_2O \longrightarrow 0.43\ [Mg_{.04}Ca_{.02}Na_{.04}K_{.11}P_{.08}(Fe^{3+}_{.23}Al_{1.84})(Si_{3.08}Al_{.85}Ti_{.07})\ O_{10}\ (OH)_2] + 1.51\ H_4\ SiO_4 + 0.15\ Ca^{2+} + 0.82\ Na^+ + 0.47\ H^+ + 0.35\ O_2.$$

The congruent dissolution of plagioclase to its constituent ions is shown in Reaction 5:

5. Plagioclase + acidic soil waters ➡ Al-hydroxide + ions in solution

5.

$$(Na_{.84}Ca_{.16})\ Al\ (Si_{2.83}Al_{.17})\ O_8 + 1.16\ H^+ + 6.83\ H_2O \longrightarrow 0.84\ Na^+ + 0.16\ Ca^{2+} + 1.17\ Al(OH)_3 + 2.83\ H_4\ SiO_4.$$

It is notable that with the exception of $Al(OH)_3$, the amounts of silicic acid, sodium and potassium released into solution are similar, regardless of the process by which plagioclase weathers (Table 13).

The weathering of potassium feldspar is similar to that of plagioclase but only the congruent dissolution of potassium feldspar is presented here:

6. Potassium Feldspar + acidic soil waters → Al-hydroxide + ions in solution

6.

$$(K_{.9}Na_{.1})\ Al\ Si_3O_8 + H^+ + 7\ H_2O \rightarrow 0.9\ K^+ + 0.1\ Na^+ + 3\ H_4\ SiO_4 + Al(OH)_3.$$