Quantification of the effect of plants on weathering: influence of a residual soil layer on chemical fluxes

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The weathering of Ca and Mg silicate minerals on the continents has exerted a major control on atmospheric CO_2 over geologic time, and vascular plants may have played an important role in this process (e.g. Berner, 1997 and references therein). Before the Devonian, the land may have been populated by algae or lichens (Retallack, 1990) which can affect weathering (Barker *et al.*, 1997), but the very slow metabolism of these plants and the lack of a fine root mass with high surface area argues against their having as strong an effect as vascular plants in accelerating weathering (Cochran and Berner, 1996). We have examined the role of plants in weathering by measuring the chemistry of waters draining adjacent portions of some basaltic rocks of western Iceland which are either 1) completely bare rock, 2) essentially unvegetated with soil cover, or 3) populated by trees. The study area was chosen to maximize vegetational differences and to minimize differences in microclimate, slope, aspect, and lithology, while avoiding hydrothermal waters and anthropogenic acid rain. In addition, the barren area without soil is compared to one with soil to assess the effect of residual soil cover on chemical fluxes. Results, which are corrected for evapo-transpiration and include data on cation uptake by growing trees, indicate that the rate of weathering release of Ca and Mg is 3 to 8 times higher in vegetated areas than in 'bare' ones.

Field Area

The field area at Skorradalur Lake contains small (0.2 to 6 km^2) drainage basins of varying vegetational and soil cover, underlain entirely by basalt. The areas with trees (evergreens on the north side of the lake and native birch on the north and south sides) are part of a protected region which has been administered by the Icelandic forest service since the early 1900's. Soil thickness in the vegetated plots ranges from 100 to 150 cm thick. The barren area on Dragafell has no soil cover and exhibits only bare rock, while the barren area of Thvergil exhibits soil thickness from 0 to 150 cm, and contains sporadic mosses and lichens. The barren areas were stripped of plants by overgrazing of sheep over a century ago, some of which have undergone intense soil erosion resulting in bare bedrock. Removing plants by overgrazing has the effect of exposing the rock and remaining soil to weathering without further modification by plants. It is possible that the residual, newly exposed soil would behave differently than bare bedrock or a soil with plants. To assess this possibility, the authors have compared both a barren, soil-less area and a residual soil with presently vegetated soils.

Results and conclusions

The results of flux and tree storage calculations are

TABLE 1. Results from stream flux and tree storage calculations

	Stream Flux (mol/yr ha)							Tree Storage (mol/yr ha)		
	SO_4^{2-}	HCO_3^-	Na^+	K^+	Mg^{2+}	Ca^{2+}	Si	K	Mg	Ca
Bare, no soil	0.3	297	87	1	24	43	204	–	–	–
Bare, soil	8	290	170	4	12	23	216	–	–	–
S. Birch	26	815	129	19	181	197	510	6	3	16
N. Birch	22	532	133	11	104	113	332	6	3	16
Evergreen	31	501	220	11	101	117	347	13	8	39

TABLE 2. Ratios of vegetated to unvegetated (no soil) weathering fluxes

	HCO_3^-	Na^+	K^+	Mg^{+2}	Ca^{+2}	Si
S. Birch/Bare, no soil	3	2	27	8	5	3
N. Birch/Bare, no soil	2	2	19	5	3	2
Evergreen/Bare, no soil	2	3	27	5	4	2

shown in Table 1. Results from streams on the north and south side of the lake agree independently of the presence of a small road on the north side. The fluxes show that much more Na^+ is released from the barren area with soil than that without soil, while the opposite is true for Mg^{2+} and Ca^{2+}. Fluxes of bicarbonate and Si are similar for barren areas with and without soil. These results suggest that the presence of a residual soil layer does not significantly alter the

weathering regime with respect to HCO_3^- and Si, but that ion exchange may exert an effect on the release of Na^+, Ca^{2+}, and Mg^{2+}, with Na^+ stored on exchange sites in the soil being displaced by Ca^{2+} and Mg^{2+} within the soil profile.

Ratios of vegetated to barren (without soil) weathering fluxes are shown in Table 2. The ratios for Ca^{2+} and Mg^{2+} show that the release of these elements from vegetated areas is between 3 and 8 times higher than that from the barren area. The ratios for K^+ are between 19 and 27. For bicarbonate, Na^+, and Si the effect is about two-fold. The difference in element mobility between the nutrient cations (K^+, Ca^{2+}, and Mg^{2+}), and bicarbonate, Na^+, and Si may be the result of inefficient scavenging of the nutrient cations lost by leaching from vegetation. Because Na^+, HCO_3^- and Si are not involved in biologic processes to any great extent, the higher flux of these from vegetated areas relative to barren areas is likely due solely to an enhanced weathering effect by the trees.

These results support the suggestion that the rise of vascular plants could have exerted a major control on atmospheric CO_2 during the Palaeozoic era by enhancing the weathering of silicate rock. The results for Ca and Mg silicate weathering, when applied to the GEOCARB model of Berner (Berner, 1997), produce a significant drop in the calculated level of atmospheric CO_2 during the Devonian, which agrees well with palaeoclimate data based on independent palaeosol and stomatal index methods (see Berner, 1997 for a summary of data).

References

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