Chemical Weathering in Central Iceland: An Analog of Pre-Silurian Weathering

Abstract. *The rate of chemical weathering in central Iceland is two to three times more rapid in areas with plant cover than in barren areas. This relatively small difference in chemical weathering rates suggests that atmospheric CO_2 pressures no greater than five times the present value were needed to sustain present-day rates of chemical weathering before the development of higher land plants in the Silurian.*

The partial pressure of CO_2 in soils below higher land plants is normally 10 to 100 times greater than in the atmosphere (*1*). Rainwater passing through soil zones absorbs much CO_2; such absorption accelerates the process of chemical weathering. Trendall (*2*) has suggested that higher land plants may affect rates of chemical weathering profoundly, and that, for this reason, the CO_2 pressure in the earth's atmosphere may have been much greater prior to the development of higher land plants than it is at present. It therefore seemed worthwhile to determine just how much the presence of higher land plants accelerates chemical weathering, that is, to determine the relation between the density of vegetative cover and the rate of removal of dissolved salts by streams.

An area in central Iceland (Fig. 1) was suitable as a field area. The headwaters of the Skjalfandafljót and its tributary systems are fed by glacial meltwater; surface runoff and springs contribute to the river systems farther north. The upper (southern) part of the river system passes through a well-watered region essentially barren of macroscopic plants (*3*). Toward the lower reaches of the river system vegetation becomes progressively more dense. Thin belts of vegetation along the river banks gradually expand into heaths and meadows of grass, moss, dwarf willows, and occasional wild flowers. Toward its mouth, the river flows through farmland.

Basaltic lava and till of basaltic composition are the dominant rock types of the area. The nearest acidic rocks are rhyolitic tuffs of the 1875 Askja eruption. Very little of this material is found in the Skjalfandafljót basin, but some source waters of the Svarta springs may pass through this material in the Dyngjufjalladular.

At each sampling site (Fig. 1) water temperature and *p*H were recorded, and two 500-ml water samples were taken in carefully cleaned polyethylene bottles. Bicarbonate concentration in one of each pair of samples was determined by *p*H titration in the field within 12 hours of collection. Titrations carried out several weeks later in the laboratory confirmed the field results. Concentrations of sodium, potassium, calcium, and magnesium were determined by atomic absorption spectrometry. Chloride was determined by the method of Huang and Johns (*4*). Sulfate was precipitated with $BaCl_2$ (*5*) labeled with Ba^{133}, and activity of the $BaSO_4$ precipitate was counted in a gamma-ray spectrometer. The concentration of chloride was less than 0.1 meq/liter (3.5 ppm) in all samples except those collected within a few miles of the river mouth. Contamination by sea salts is therefore very slight. Cation

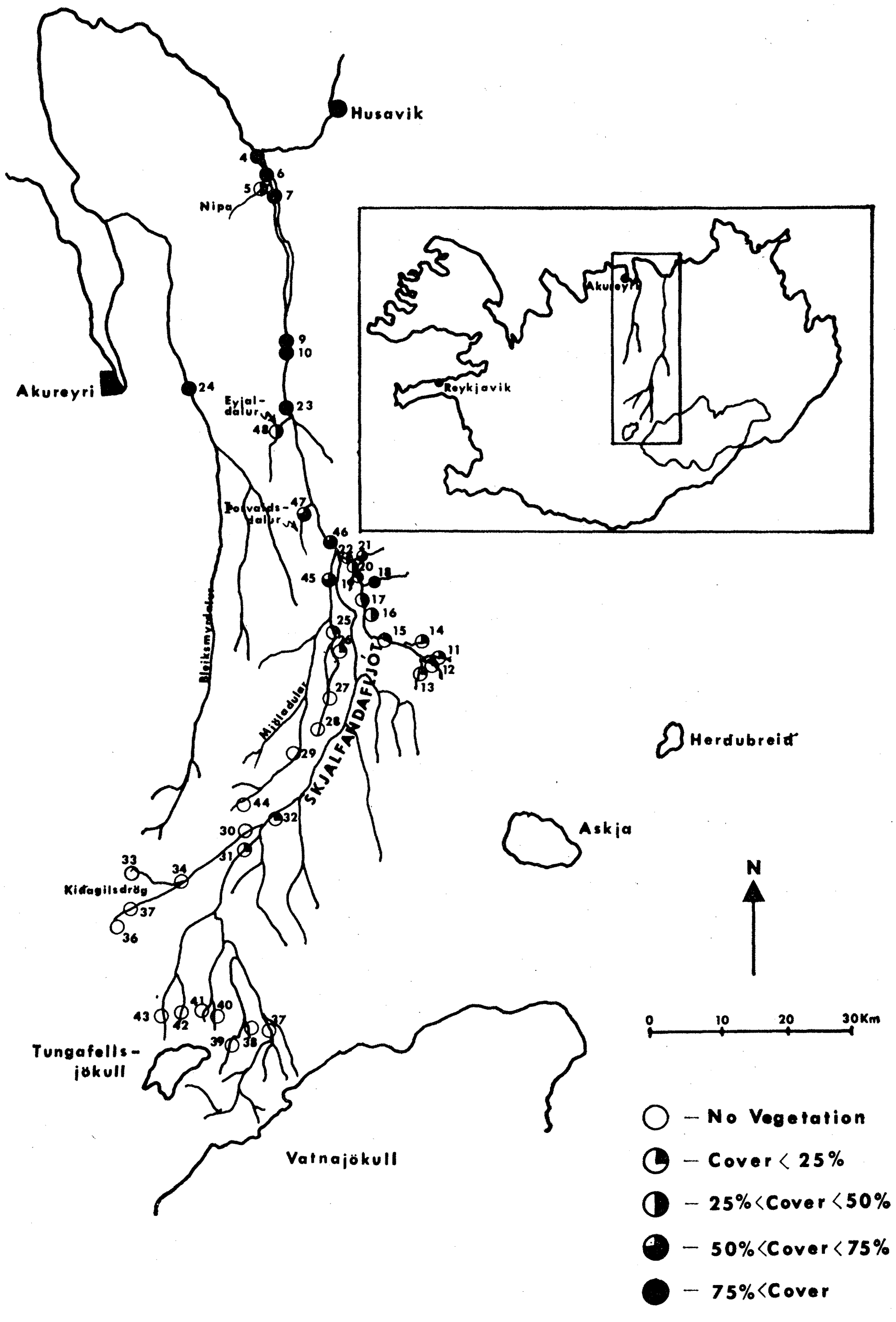
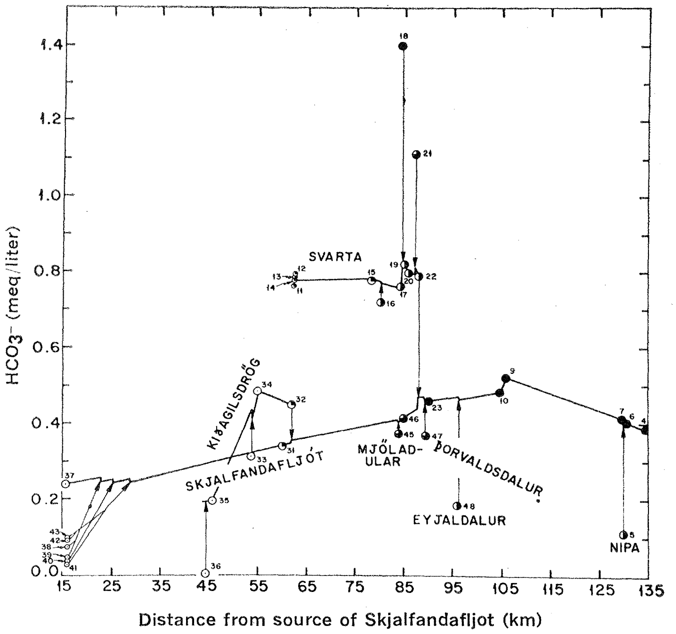


Fig. 1. Vegetation density at sampling sites in central Iceland.



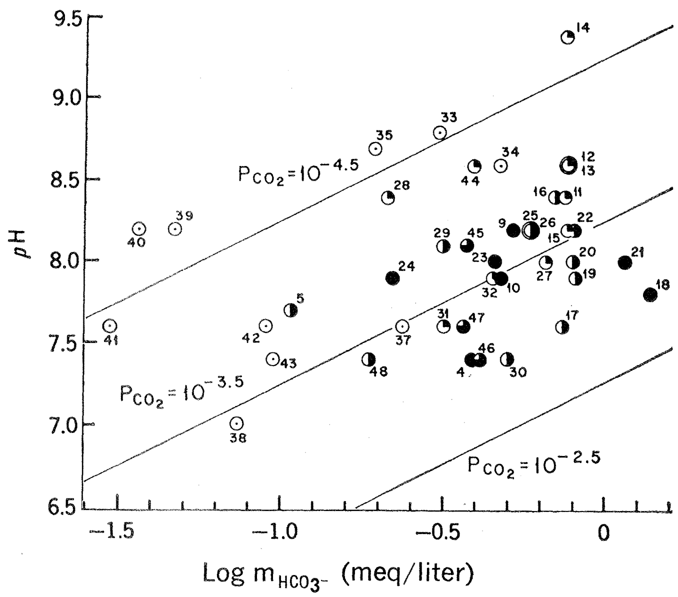


Fig. 2. Bicarbonate concentration in water from the Skjalfandafljót river system; symbols for degree of plant cover are those used in Fig. 1. Fig. 3. The *p*H, bicarbonate concentration, and effective CO_2 pressure in water samples from central Iceland; symbols for degree of plant cover are those used in Fig. 1.

ratios are normal for rivers draining basaltic terrains (*6*), and total cation charge equaled total anion charge. Sulfate concentration ranged from 0.008 meq/liter in a sample of snow to 0.20 meq/liter in a sample from springs of the Svarta river. Bicarbonate concentration (Fig. 2) is extremely low in meltwater from snow and in samples from Skjalfandafljót taken close to the Vatnajökull. Bicarbonate concentrations in excess of 0.5 meq/liter occurred, however, in water that had passed through virtually vegetation-free country. The highest bicarbonate concentrations (1.40, 1.15 meq/liter) were found in tributaries of the Svarta, which were traversing farmland.

Bicarbonate is the major anion in these water samples. No hot spring activity has been recorded from this area. All of the springs sampled were less than 5°C, and the very low chloride concentration and absence of sodium anomalies suggest that the contribution of dissolved salts by hot springs is negligible. Our data therefore suggest that the bicarbonate in our samples is largely due to chemical weathering, and that its concentration can build up to one-half the maximum observed value in the absence of higher land plants. This, in turn, indicates that the influence of higher land plants on rates of chemical weathering in this area is not overwhelming.

An analysis of *p*H and bicarbonate data shows that the effective P_{CO_2} in river waters from the areas free of vegetation is generally less than atmospheric P_{CO_2} (Fig. 3). Carbon dioxide is apparently being dissolved continuously in such river waters, and continues the process of chemical weathering begun in the soil zone. On the other hand river waters in heavily vegetated terrains are typical of most rivers in that they have an effective P_{CO_2} equal to or in excess of atmospheric CO_2 pressure and tend to lose CO_2 to the atmosphere.

The bicarbonate concentrations found in Iceland are comparable to those in surface and ground waters of basaltic terrains in other parts of the world. Visher and Mink (*7*) report a range of 0.6 to 2.0 meq/liter in uncontaminated ground water from various sources in southern Oahu, Hawaii. A summary (*6*) of chemical composition of ground waters from gabbros and basalts gives a range of 0.33 to 4.57 meq/liter in samples containing less than 1.0 meq of chloride per liter. Livingstone (*8*) estimates that the mean concentration of bicarbonate in the rivers of the world is 0.96 meq/liter. The harsh climate in central Iceland does not, therefore, appear to produce abnormally low rates of chemical weathering.

The relatively unweathered nature of near-surface materials in central Iceland tends to accentuate differences between rates of chemical weathering in vegetated and barren areas. We therefore suggest that rates of chemical weathering in the absence of higher land plants in pre-Silurian times were not very different from present-day rates. In view of the Icelandic data, it seems unlikely that weathering rates could have been less than about one-fifth of present weathering rates under comparable climatic and geographic conditions. This suggests that an atmospheric CO_2 pressure no more than about five times the present value would have been needed to produce present-day mean rates of chemical weathering under comparable climatic and geographic conditions before the development of higher land plants (*9*).

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References and Notes

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