Technical Comment

Land Plants and Weathering

R. A. Berner (*1*), T. Volk (*2*), and M. A. Knoll and W. C. James (*3*) link silicate weathering, atmospheric CO_2, and land plant evolution. Using data from Likens *et al.* (*4*), the latter authors argue (*2, 3*) that deciduous angiosperms weather rock more effectively than evergreen gymnosperms, thus the advent of the angiosperms during the Cretaceous caused a major increase in rates of weathering. In Berner's standard run, the largest increase in plant-induced weathering occurs during the Carboniferous; the increase during the Cretaceous is relatively small. If one excludes sites on soluble substrate from the data in (*4*), the postulated difference between angiosperm and gymnosperm ecosystems disappears (Fig. 1). If deciduous plants increase weathering, there should have been rapid weathering in Mesozoic ecosystems dominated by metasequoia, ginkgo, *Taxodium*, glossopterids, and deciduous pteridosperms.

Data on living plants are too scarce to test the angiosperm weathering hypothesis or the increase in Carboniferous weathering rates assumed by Berner. Most gymnosperm weathering data are derived from pinaceous species which, having evolved in competition with angiosperms, are atypical of ancient gymnosperms. Few weathering measurements are available for pteridophytes, sphenopsids, lycopsids, or other ancient taxa. Rooting trends could be reconstructed from the fossil record, but the analysis has not been done.

The faluvial record (*5*), paleosols (*6, 7*), and evolutionary physiology (*7, 8*) all show progressive expansion of vegetation into colder and drier environments over the last 400 million years. Expansion was rapid in the Devonian, with the evolution of leaves, roots, and secondary tissues, and in the Eocene and Oligocene, with the radiation of grasses and forbs. Presumably, post-*Cooksonia* niche expansion has increased the volume of soil exposed to plant activity by one to two orders of magnitude and merits explicit representation.

A scarcity of CO_2 decreases the water-use efficiency of plants. Simulations by Berner show a fivefold decline in CO_2 level 430 to 330 million years ago. This could explain increases in tracheid diameter (*8*) and developments in foliage and rooting organs (7) that occurred during the Silurian through the Devonian (*8*). Selection for resistance to CO_2 starvation would preadapt plants to drought and cold and would have helped the plant kingdom survive the cooling and drying of the Late Paleozoic. CO_2 increases in the Permian through Cretaceous may have permitted range increases.

Over its evolution, the plant kingdom has accumulated a large repertoire of mechanisms for coping with cold, drought, and CO_2 starvation. Presumably these mechanisms have weakened the relation between CO_2 and productivity and have reduced the effect of CO_2 fertilization and greenhouse warming on vegetation. For example, had grasses and herbs not evolved in the Tertiary, cooling and drying would have produced much more desert and much less grassland.

As the range of vegetation expanded, the negative feedback effect of CO_2 on vegetation would have been weakened, and the reduction of CO_2 during the Cenozoic would have been strengthened and shifted toward the Late Tertiary. This explanation is consistent with the fact that little cooling took place during the Cretaceous and that major cooling has occurred from the Oligocene to the present.

JENNIFER M. ROBINSON
Earth System Science Center, Pennsylvania State University, University Park, PA 16802

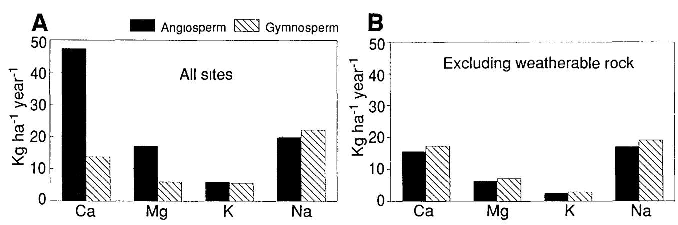

Fig. 1. Average net cation losses from temperate angiosperm (deciduous) and gymnosperm (evergreen) ecosystems. (**A**) Data from Knoll and James (*3*); (**B**) the same data, excluding sites on weatherable substrates. Number of observations in (A), 8 to 10; (B), 6 to 9.

REFERENCES AND NOTES

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Response: One of the weakest aspects of my model for the long-term carbon cycle is that it relies on assumptions about the effect of plant evolution on the weathering of silicate rocks. Little current data can be applied to the ancient world, and there are essentially no data on the response of plant-mediated rock weathering to changes in atmospheric CO_2.

J. L. Cawley *et al.* (*1*) have studied the chemistry of water draining from young volcanic rocks that are undergoing floral colonization. Measuring, under controlled CO_2 atmospheres, the rate of release of dissolved elements from soils with and without plants could also be illuminating. Until more studies such as these are conducted, estimates of the quantitative effects of land biota on weathering in the geological past will be speculative in nature.

I would also like to point out that the arrows were erroneously reversed in the first reaction in my original report. The reaction going from left to right refers to weathering, and the same reaction going from right to left refers to metamorphism and magmatism.

ROBERT A. BERNER
Department of Geology and Geophysics, Yale University, New Haven, CT 06511

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