PALEOSOLS AND THEIR RELEVANCE TO PRECAMBRIAN ATMOSPHERIC COMPOSITION: A DISCUSSION 2[1]

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Palmer et al. (1989) have recently offered a provocative opinion: that Precambrian paleosols of South Africa cannot be used as evidence of ancient atmospheric composition. They argue (1) that rocks hitherto identified as paleosols are really zones of hydrothermal alternation and (2) that hydrothermal and metamorphic processes have obliterated any original chemical signal of weathering. I disagree with both arguments.

The generality of the first argument can be demolished by demonstrating clearly pedogenic structures in a single South African Precambrian paleosol: the Waterval Onder clay paleosol. This contains excellent examples of blocky peds, illuviation argillans and mukkara structure (discussed and illustrated by Retallack 1986). These are evidence of multiple episodes of cracking, infilling, and closure of clayey material under randomly oriented, small scale extensional and compressional forces at moderate temperatures and negligible pressures: not found under conditions of deep burial or hydrothermal injection. The Waterval Onder clay paleosol also shows rock varnish and trace element variation compatible with microbial colonization and a gradational depth function in texture, mineral content and chemical composition (at least above 2.5 m), that are normal for soils, as opposed to other geological phenomena. How widespread these kinds of features are in South African Precambrian rocks remains to be established, but their existence in one case is more effective evidence for paleosols than any number of cases of hydrothermally altered rocks, such as those discussed by Palmer et al. (1989).

Nor is the existence of Precambrian paleosols in South Africa threatened by the common observation that certain forms of hydrothermal argillic alteration are indistinguishable from weathering *on chemical grounds*. Claims have been made that hydrothermally altered rocks are distinct from paleosols in their enrichment in potash (Palmer et al. 1989; Duchac and Hanor 1987). Out of 128 modern North American soils reported by Marbut (1935), 33% show enrichment in potash toward the surface, and 74% of these are aridland soils showing enrichment also in soda or trace elements often mobile during weathering. Much of the surficial depletion of potash in the other modern soils is due to the impressive efficiency of vascular land plants in extracting potassium ions from soil solutions (Knoll and James 1987). Thus potash-rich soils may well have been the rule in all but the most hot and humid climates before Ordovician times. In addition, potassium can be added to paleosols by dissolution of potassium-bearing minerals in overlying sandstones during low temperature diagenesis. These two sources of potassium enrichment are sufficient to explain the chemical composition of paleosols such as the Waterval Onder clay, without any metamorphic or hydrothermal addition (Retallack 1986). Arguments for a hydrothermal vs. pedogenic origin of mineralogically and chemically unusual rocks also have been made on the basis of trace element distributions and extreme enrichments of alumina (Schreyer et al. 1981). These arguments underestimate the variability of trace element behavior in soil systems, and the extremes of bauxitization that may have been possible under a primordial acid rain. Chemical arguments so far published are not sufficient to make such distinctions: structures or a geological context compatible with hydrothermal or pedogenic alteration are much more compelling evidence.

From these considerations, the second argument of Palmer et al. (1989) can be modified to a question of the extent to which later metamorphism or hydrothermal alteration has obscured original effects of weathering in Precambrian paleosols. In particular they imply that metamorphic and hydrother-

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mal alteration has reduced and removed iron from paleosols that may originally have been more iron-rich and oxidized. Consider some specific counter examples. Ordovician and Silurian paleosols of the Appalachian Mountains are metamorphosed to greenschist facies (Retallack 1985), like the Waterval Onder clay and other Precambrian paleosols, and yet red-colored and hematite-rich, unlike many Precambrian examples. Permian paleosols in Austria are metamorphosed to amphibolite facies, with conversion of hematite to magnetite, and yet they still show clear surficial iron enrichment and potash depletion (Barrientos and Selverstone 1987). These and other metamorphosed redbeds are evidence that metamorphism in itself is not necessarily the overriding determinant of redox state (Thompson 1972). Hydrothermal reduction of a paleosol such as the Waterval Onder clay would also have disrupted its evident soil structures into breccias and boxworks of a kind that are not seen. Each case needs to be assessed on its own merits, and the unravelling of some metamorphic or hydrothermal alteration remains a challenging problem, but it does not seem to have altered the clear chemical signal of oxidation in the Paleozoic paleosols already mentioned. Nor is there any compelling reason to suspect metamorphic reduction of Precambrian paleosols that show clear soil structure. The expertise of soil science may be threateningly unfamiliar in the context of Precambrian geology, but will have to be increasingly employed in evaluating paleosols as potential windows on Precambrian non-marine environments.

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