Paleosols and Devonian Forests
Dennis Dahms, *et al.*
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Paleosols and Devonian Forests

Gregory J. Retallack states that the Rosemary paleosol described from Victoria Land, Antarctica, "is the most ancient known soil of well-drained forest ecosystems" (*1*). The paleosol is said to exhibit both a Bt horizon and an argillic horizon with a ped structure defined by slickensided clay skins and deeply penetrating sand-filled cracks; Retallack interprets it as a fossil Alfisol from an ecosystem much like that of the present monsoon forests of northern India. We question the horizon designations, the interpretations of the profile description and data, and the inference that these horizon characteristics are necessarily diagnostic of soils developed beneath a Devonian forest.

Retallack infers the presence of a Bt and argillic horizon in this soil on the basis of clay enrichment and high alumina/silica ratios. The designation "argillic" denotes that some clay was translocated (*2*), but no evidence is presented: the clay could be secondary, but it also could be primary. Figure 2 in this report does not show that the clay in the Bt horizon increases relative to the clay content in either the C or the A horizon. The upper part of the A horizon even has an estimated clay content equal to that of the Bt horizon. The increase in silt content in the Bk horizon could mean that the clay increase in the Bt horizon is the result of parent material layering. Further, Retallack used alumina/silica ratios to indicate Al enrichment in clay minerals in the B horizon. The ratios illustrated in fig. 2 in (*1*) vary only between 0.1 and 0.2 in any horizon. We do not see a necessarily pedogenic pattern in the down-profile Al/Si variability. Clay mineralogy must be known to make these interpretations because Al/Si varies with mineral species.

The question of clay enrichment is crucial to the interpretation that the soil is an Alfisol, which then becomes an important component of the paleoenvironmental reconstruction. If the zone in question is an argillic horizon, the interpretation is still unclear because modern argillic horizons form under a wide variety of environmental conditions (*3, 4, 5*). Moreover, Alfisols are but one soil order that include argillic horizons; others range in environmental setting from deserts to warm, humid climates.

From the profile description, the paleosol appears more like a modern Vertisol (shrinking-swelling, cracking soils found in regions with strong seasonal contrasts in wetting and drying) than an Alfisol. Characteristics such as common, irregular sandy patches at the surface; blocky angular ped structure; slickensides; and deeply penetrating, sand-filled cracks are common in such soils high in expandable clays.

Retallack proposes that the soil formed in well-drained conditions under a warm paleoclimate, on the basis of the depth of red color (ferruginization), formation of calcareous nodules and ferruginous concretions, undocumented weathering of minerals, and depth of roots. Iron concretions would indicate poor drainage for part of the year (*5*). Red color and weathering of minerals can be as much a result of lengthy pedogenesis as of some climate (*4, 6*). The 10R hue given in the report is about as red as soils get, and, in the United States, such red soils were formed ≥ 1 Ma (*4*). The significance of the color is problematic, however, because the parent material (C horizon) has 10R hues.

No mention is made in the report of diagenetic changes during 400 My of burial. Can the red color or the Fe nodules be diagenetic? Can the calcite in the Bk be diagenetic and not pedogenic? Base saturation, a critical property in classifying any soil as an Alfisol (*2*), must have been altered extensively during diagenesis. What proxy data are used for this requirement?

Retallack also compares early Paleozoic red paleosols (which are the most weathered and clayey at the surface) with mid-Paleozoic "forested" paleosols that express the Alfisol pattern of subsurface maxima in clay content in the Bt horizon. How many profiles is this comparison based on? In a fluvial setting such as this one, an Alfisol can experience surface erosion that puts the clay maxima at the surface. Therefore, the position of the clay maxima in these profiles may be of no environmental significance.

Figure 3 in the report shows variation in several soil indices over long geologic time, yet we do not know how common they are. How many soils are they based on?

The interesting and important report by Retallack has ramifications for many sciences, but given the implications of the interpretations, it leaves many significant points unclear or unsubstantiated.

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Response: The many issues of paleosol recognition, classification, and burial alteration raised by Dahms *et al.* cannot all be adequately addressed here. They are discussed at length in three of my books (*1*, *2*). Their particular application to Devonian paleosols of the Aztec Siltstone has been addressed by John McPherson (*3*). In view of this published background, my report (*4*) aimed to advance understanding of wider issues.

Nevertheless, the soil texture and chemical data in my report (*4*) included evidence pertinent to the main points raised by Dahms *et al.* The diffuse, microcrystalline-to-colloidal nature of calcareous rhizoconcretions and nodules [figure 1C in (*4*)] and ferruginous concretions [figure 1E in (*4*)] are evidence of formation in place within the paleosol. They are unlikely to be the result of burial alteration, which would have calcified and ferruginized the coarser-grained sandy clastic dikes; these show no such alteration either chemically or petrographically. The same argument, among others, can be used to rule out a burial diagenetic origin of the banded clay skins [figure 2D in (*4*)] as evidence of illuviation and an argillic horizon. This is not to say that the profiles were unaltered by burial: they show clear signs of burial gleization, organic decomposition, pigment reddening, and clay illitization (*1–3*). I used an alumina/bases ratio of less than 2, together with free carbonate, to infer base saturation within the range of Alfisols (*2*). Such an interpretation is also indicated by the smooth curve of chemical depth functions, unlike the jagged depth functions found in Entisols and interbedded sandstone and shale. The photograph of the whole profile [figure 1B in (*4*)] is visually unimpressive because it lacks the mukkara, gilgai, lentil peds, and festooned slickensides so spectacularly documented for other Devonian Vertisols (*2, 5*). More than a few slickensides and cracks are needed to identify a paleosol as a Vertisol (*1, 2*).

As for the trees, there is evidence of them from fossil root traces, wood, and spores of progymnosperms in the Aztec Siltstone (*6*). Finally, with regard to numbers of paleosols, I used standard graphical notation in my report. Each point or box represents a single paleosol, though many plotted points were calculated from several observations within a profile [figure 3, A and B, in (*4*)]. Points with boxes and error bars, on the other hand, were from multiple observations [figure 3D in (*4*)]. These plotted points, from profiles selected for detailed study, are representative of thousands of paleosols now known as evidence for long-term trends in evolution of paleosols through the Paleozoic (*1–7*). No one has yet found a tree or argillic horizon older than Middle Devonian. While I differ from Dahms *et al.* in many points of approach to this subject, I share their hope for continued testing of this simple yet important observation.

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