How to Find a Precambrian Paleosol

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Abstract

Precambrian paleosols have been discovered in unprecedented numbers in recent years and it is likely that many remain unrecognized for what they are. This essay attempts to aid the search by outlining diagnostic versus common but not necessarily distinctive features of Precambrian paleosols. Three general classes of criteria can be used to recognize Precambrian paleosols: biological traces, soil horizons, and soil structures.

Precambrian paleosols do not contain the root traces that are so helpful in identifying Phanerozoic paleosols. Moreover, the microbial traces in paleosols, such as ministromatolites, rock varnish, and microbial borings, are not yet distinguishable from similar phenomena on the floors of shallow lakes or marine shelves. The most diagnostic microbial indicator of Precambrian paleosols yet reported is the upward lightening of isotopic ratios of $^{18}$O vs. $^{16}$O and $^{13}$C vs. $^{12}$C in weathered carbonate rocks.

Soil horizons of Precambrian paleosols, like those of the Phanerozoic, ideally exhibit gradational changes in color, texture, mineralogy, and chemical composition downward from a sharp upper contact. Subsurface horizons enriched in quartz, clay, sesquioxides, or humus have not yet been demonstrated in paleosols older than the Devonian advent of trees. There are, however, Precambrian examples of surface horizons enriched in clay and of subsurface horizons enriched in carbonate minerals, gypsum, amorphous silica, or manganese. There also are Precambrian examples of bauxitic, kaolinitic, and iron-rich deep weathering.

Some soil structures are diagnostic in that they demonstrate multiple episodes of breaking, infilling, and closure due to randomly oriented, small-scale extensional and compressional forces at atmospheric temperatures and pressures. Examples include subangular near-equant soil clods (blocky ped), veins of clay washed down soil cracks (clay skins or illuviation argillans), tepee or pseudoanticline (mukkara) structures of swelling-clay soils, sand wedges and other features of periglacial soils, and certain kinds of microfabric in which birefringent clays are arranged as random streaks in a less-oriented matrix (insepic, mosepic, and masepic plasmic fabric).

Most Precambrian paleosols are deformed, metamorphosed, and poorly exposed, so can be confused with upward-finng fluvial sequences, mudflow deposits, ash beds, marine hardgrounds, fault mylonites, or zones altered by either groundwater or hydrothermal fluids. Argillic hydrothermal alteration is particularly troublesome because its effects cannot yet be distinguished from the wide range of known soil-forming conditions on compositional criteria alone. To distinguish a paleosol from hydrothermally altered rock, evidence is best sought from horizonation, soil structure, and geologic context.

1 Introduction

Are Precambrian paleosols rare? Compared to Precambrian komatiites, placer uraninites, stromatolites, microfossils, or fluvial rocks, the number of known Precambrian paleosols remains meager (Sokolov and Heiskanen 1984; Pinto and Holland 1988). However, Precambrian paleosols have been discovered in unprecedented numbers in recent years and it is likely that many remain unrecognized for what they are. Few geologists have extensive knowledge of soil science, and few soil scientists have carefully studied Precambrian rocks. It is only in the past two decades that the expertise of soil science has been diligently applied to Phanerozoic fluvial rocks. As a result, literally thousands of paleosols have been discovered (Bown and Kraus 1981; Retallack 1983; Allen 1986).

Paleosol studies have not been as successful in the Precambrian as in the Phanerozoic for at least two reasons. Precambrian paleosols lack obvious and diagnostic biologic features, such as root traces (Retallack 1988a) and many Precambrian paleosols have...
been so obscured by metamorphic alteration that they are difficult to distinguish from hydrothermally altered rocks (Lowe et al. 1985; Duchac and Hanor 1987). Despite these problems, considerable progress has been made recently on where and how to look for Precambrian paleosols. This essay outlines diagnostic versus common but not necessarily distinctive features of Precambrian paleosols. In looking for Precambrian paleosols, as in all science, fortune favors the prepared mind.

Given that it is premature to judge how common Precambrian paleosols may be, it is difficult to predict their significance for reconstructing Precambrian life and landscapes. Precambrian, like Phanerozoic, paleosols potentially may provide evidence of past climates, organisms, topographic relief, parent materials, and duration of soil formation (Retallack 1986b). The history of Precambrian atmospheric oxygenation (Holland 1984; Pinto and Holland 1988) and the tectonic style of continental accretion and differentiation (Retallack 1990) are two perennial problems of Precambrian geology that are being profitably addressed through study of paleosols. A comparison of Precambrian paleosols with surficial alteration of equivalent or greater age on the Moon, Mars, Venus, and other planetary bodies may elucidate the early history of our Solar System (Retallack 1986a, 1990). Paleosols also provide evidence for the origin and early evolution of life on land (Retallack 1986a, 1990).

The discovery of additional Precambrian paleosols would enhance these studies. Three aspects of Precambrian paleopedology are emphasized herein to facilitate such discoveries: where to look for Precambrian paleosols, what features are diagnostic of them, and how they are distinct from other geologic phenomena.

2 Where to Look for Precambrian Paleosols

Perhaps the most direct way to find Precambrian paleosols is to advertise among geologists. Holland (1988) has tried this, with some success. A less direct, but perhaps more promising, approach involves “reading between the lines” of Precambrian studies. As in Phanerozoic sequences, Precambrian paleosols may be expected along major unconformities and within nonmarine sedimentary or volcanic strata.

Paleosol reconnaissance should start with a geological map. Unconformities overlain by fluvial rocks are especially promising candidates for paleosols (Gay and Grandstaff 1980; Farrow and Mossman 1988). Some rivers erode canyons deep into fresh bedrock but others bury weathered hill-sides or plains under alluvium (Fig. 1). Colluvium also may bury soil. Irregularity of a mapped geological contact occasionally records paleotopography rather than tectonism (Williams 1969). Highly irregular contacts characterize some carbonate sequences and some of these irregularities have proven to be ancient karst (Button and Tyler 1981; Schau and Henderson 1983; James and Choquette 1987).

Fig. 1. Sheigra clay paleosol beneath Torridonian (1 Ga) alluvial fan deposits in sea cliffs near Sheigra, NW Scotland. (Retallack 1986a)