Are Paleosols Really Ancient Soils?

Peter Klevberg, Michael J. Oard, and Richard Bandy*

Abstract

Paleosols, or fossil soils, are being reported by uniformitarian geologists in increasing numbers. This is to be expected, since the "deep time" of the traditional view of earth history would naturally result in the burial and preservation of many soils. However, not only do uniformitarian assumptions guide the investigation of paleosols, but their very definition is unscientific, a "mixed question." This paper addresses the question of whether paleosols can exist, how they may be identified, and how diluvialists should approach the investigation of alleged paleosols.

Introduction

Many define a paleosol simply as a buried soil (Bates and Jackson, 1984, p. 367), though disputes among paleopedologists about the definition of a paleosol (Froede, 1998, p. 26) are very easy to find. We understand a paleosol to be a "fossil soil," i.e. a soil that has been preserved in the geologic record or buried deeply enough that it is no longer subject to soil forming processes. This implies recognizable soil horizons. However, paleosols are more commonly *inferred* from the rock record. According to some, paleosols can even exist on the surface and be inactive—as if that were possible to determine (Retallack, 1990, p. 9)! Paleosols have been widely recognized in the "Quaternary" for over 100 years (Mahaney, 1978).

With the exception of underclays, paleosols were long considered rare to nonexistent in pre-"Quaternary" sedimentary rocks. Then in the 1960s, the "renaissance" began (Retallack, 1990, pp. 6–7). Ever since, claims of paleosols have become much more abundant (Retallack, 1988, p. 11; Kraus, 1999). It seems one can hardly read an article on strata or sedimentary rocks without reference to a paleosol. Retallack (1983) even managed to discover eighty-seven paleosols in a 143-meter stratigraphic section in Badlands National Park, South Dakota! From a uniformitarian perspective of long ages, paleosols really should be common in "terrestrial" deposits:

> In view of the principle of uniformitarianism as applied to present-day alluvial sequences, we believe that fluvial rocks that do not contain pedogenic features are probably exceptional (Bown and Kraus, 1981).

Paleopedology[1] is the basis for much modern research in "Quaternary" geology, and is certainly foundational to paleoclimatology and paleogeography. Paleosols have been used to distinguish between various glaciations, especially the four "ice ages" in the Midwest of the United States (Leighton and MacClintock, 1961; Retallack, 1990, pp. 4–5) and two or more "ice ages" in the Rocky Mountains of the United States (Hall and Shroba, 1993; 1995). These paleosols are assumed to represent interglacial weathering between glacial ages (Cioppa et al., 1995; Horberg, 1956; Karlstrom, 1982; 1987; 1988; 1990; 1991). That these paleosols are often absent or dubious and not essential to the multiple glaciation time schemes is evident from some of the literature (Lemke et al., 1965). In recent years, some paleopedologic interpretations have run aground on physical evidences or the preference of many researchers for deep-sea cores or other methods (Froede, 1998, p. 23). Nonetheless, paleopedology remains an important discipline in stratigraphy (Klevberg, 2000a), and it probably will remain so for the foreseeable future.

Implications of Paleosols

Modern soils, as well as "Quaternary paleosols," are assumed to form over long periods of time: "The time spans required to form soils are thousands to millions of years" (Retallack, 1990, p. 13). Paleosols are not only used to infer long periods of time, but also to interpret ancient environments (Retallack, 1990, p. 115). By comparing the properties of a paleosol to a modern soil, uniformitarian scientists infer the ancient environment: "If a paleosol is very similar to a modern soil, then perhaps environments similar to those that formed the soil can be inferred for the paleosol" (Retallack, 1993, p. 1636). Although some researchers urge caution in using paleosols to infer paleoclimate, most still deduce the mean annual temperature and precipitation during "paleosol development" (Kraus,

[1]This and other important terms are included in the glossary near the end of this paper.

*Peter Klevberg, B.S, P.E., 512 Seventh Avenue North, Great Falls, MT 59401
Michael J. Oard, M.S., 34 West Clara Court, Bozeman, MT 59715
Richard Bandy, B.S., 1105 Valleyview Drive, Great Falls, MT 59404
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1999). Some diluvialists have incorporated paleosol interpretations and paleoclimatic interpretations into their own research (Williams et al., 1995; Froede, 1996), as have neocuvierists (Robinson, 1996, p. 55).

While the diluvial geologic paradigm (DGP) can accommodate the theoretical concept of paleosols (depending on how they are defined), they are certainly not expected to be common. The establishment geologic paradigm (EGP), on the other hand, virtually demands ubiquitous paleosols because of the assumptions of gradualism, localized catastrophes, and vast periods of time for earth history (Froede, 1998, pp. 27–28). Thus, the proliferation of paleosols in the literature in recent decades is predictable. There is no doubt that the traditional understanding of paleosols conflicts with the Biblical timescale of thousands of years for the age of the earth and a global flood that laid down practically all the sedimentary rocks that contain "paleosols." How can these "paleosols" represent so much time? Are they really buried soils? Can one really estimate the paleoclimate from a paleosol? Are there alternative interpretations for the features that are considered indicative of paleosols by uniformitarian scientists?

Can Paleosols Exist?

Because the concept of a paleosol generally represents an event that happened in the prehistoric past, the study of paleosols is really a mixed question. Fields in which knowledge may be properly acquired from more than one source or using more than one method require proper attention to their differences lest false conclusions be reached (Ancil, 1985; Brand, 1985; 1996; Frangos, 1991; Plantinga, 1997a, p. 23; Reed, 2001). These interdisciplinary questions are sometimes termed "mixed questions" (Adler, 1965). Historical geology is a field that deals with mixed questions, principally history and science (Klevberg, 1999, pp. 75–76; Morris, 1984, p. 302; Reed 1996a; 1996b; Reed and Woodmorappe, 2002). Thus, how one interprets the layers in question depends upon one's view of the past.

The historical part of the mixed question is the part that existed in the past. The EGP approach to natural history can be generalized as an ad hoc scenario based on naturalistic presuppositions (Morris, 1984; Reed, 2000, 2001). Assertions about past events or denials of the same are largely outgrowths of the religious conviction of evolution tempered more or less by scientific constraints. The DGP approach can be generalized as a natural history based principally on the Bible with lesser contributions from other historic sources and with extrapolations tempered by scientific constraints. If, on the other hand, one must depend only on technical inferences without historical sources, the number of possibilities is limitless, and science may be incapable of disproving any of the concocted scenarios. Thus, it should be evident that the EGP possesses more degrees of freedom from an historical perspective and is therefore less likely, on a purely probabilistic basis, to arrive at "what actually happened." This part of the mixed question is clearly not neutral religiously or philosophically (views of natural history and theology are intrinsically related).

The scientific part of the mixed question is the part that exists in the present. In theory, the EGP and DGP approaches to the scientific part of the mixed question should be identical; unfortunately, because of a lack of understanding of mixed questions or a lack of commitment to the scientific method, this is seldom the case. EGP adherents frequently invoke radiometric dating and other methods without distinguishing data from inferences. DGP adherents must avoid the error of confusing historical assumptions with field data if scientifically meaningful work is to be accomplished. In regard to possible paleosols, this requires careful attention to properties that may distinguish soil-forming processes from other weathering processes and recognition of the tentative nature of any natural history reconstruction.

Do Paleosols Exist?

Since soils have been buried by various natural phenomena in historic times, we can safely assert that *if paleosols are defined as buried soil horizons in which soil forming processes are no longer operative, paleosols do exist*. Figure 1 is a photograph of a buried soil exposed in the bank of Cottonwood Creek, Fergus County, Montana. Note that while the A horizon has been somewhat disturbed, it is distinct and well preserved beneath slightly less than one meter of flood-deposited material. A new soil is forming in the flood alluvium, complete with a new A horizon. Because the annual average depth of wetting at this site is deeper than the buried A horizon, the pre-Flood soil is merely a buried soil and not a paleosol. Figure 2 shows the Goertzen homestead near Hodgeville, Saskatchewan, Canada. During the Dust Bowl, approximately a meter of eolian deposits buried the pre-1930s soil. As shown by Figure 3, eolian transport during the Dust Bowl was often dramatic (Lauber, 1963). Climatic changes and improvements in agricultural practices have resulted in considerable soil stabilization since the 1930s, and soil forming processes are active in the eolian material indicated in Figure 2. Although the pre-1930s soil is now buried, it is not certain whether it qualifies as a paleosol. If the average annual wetting depth is less than one meter, it would constitute a paleosol, since it would be deeper than the operative depth of soil-forming processes. It would be necessary to excavate a test pit to determine this. If a combination of permeability and microclimate (e.g. snow accumulation on a shaded lee slope or behind vegetation) enable the wet-

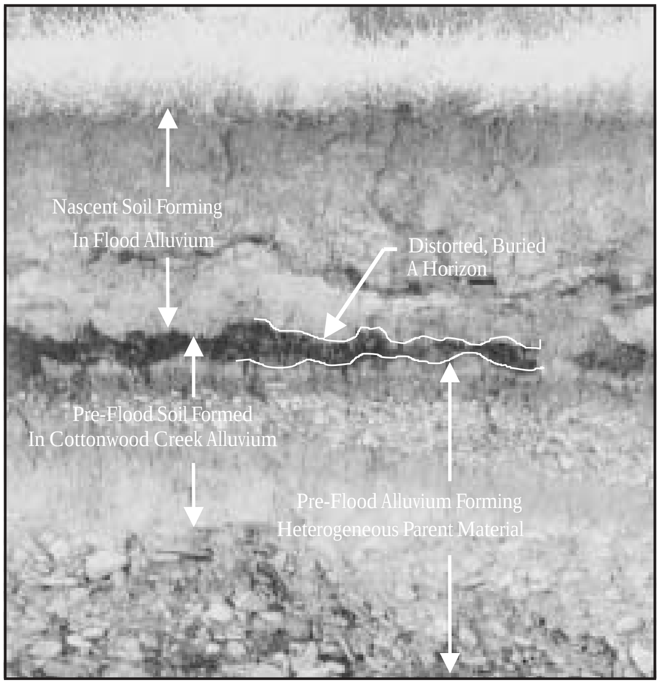

Figure 1. Buried soil in flood plain of Cottonwood Creek, Fergus County, Montana. Although slightly disturbed, the A horizon has been completely preserved. U.S.D.A. photograph.

Figure 3. Springfield, Colorado, in 1934. Photograph courtesy Cecil and Lynn Walborn.

ting depth to extend deeper than one meter, it would be merely a buried soil and not a paleosol. Similarly, if climate change results in increased depth of soil formation, a paleosol can be destroyed. Figure 4 shows the lee mountainside covered by the Hebgen Lake Earthquake slide in Montana. The pre-1959 soil is at least several meters beneath the present ground surface, too deep for most soil-forming mechanisms to be operative and too deep to act as a rooting medium for nearly all plants, and is therefore a paleosol. Many other examples exist. Volcanic eruptions, debris flows, or other events have buried soils well beyond the reach of soil-forming processes, forming paleosols.

Nonetheless, since the vast majority of alleged paleosols are prehistoric deposits, the question is not so easily an-

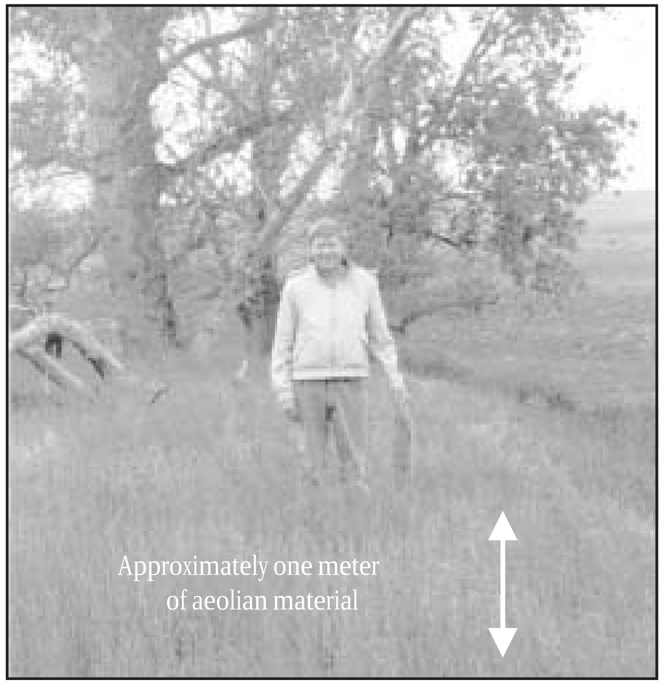

Figure 2. Goertzen Homestead, near Hodgeville, Saskatchewan. Aeolian material during the Dust Bowl buried soil around the fence line to a depth of up to one meter.

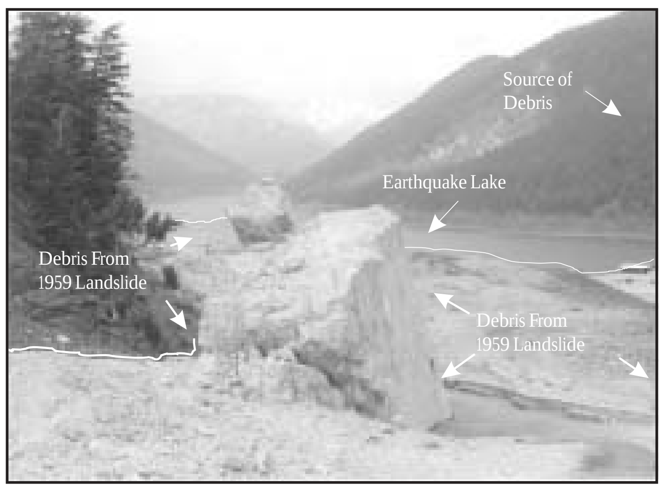

Figure 4. A 1995 photograph of the Hebgen Lake Earthquake slide in southwestern Montana which formed Earthquake Lake. Landslide debris from the other side of the valley moved up the slope to bury the pre-1959 soil, forming a paleosol.

swered in many cases. Based on recognition of the mixed nature of the question, one should realize that there is no "yes" or "no" answer for most of these deposits. The scientific method can, however, be employed to disprove many inferences in individual cases. Such applications of the scientific method require physical data and diagnostic properties. Froede (1998, p. 25) recognized this need for data:

> Uniformitarians state that soils have existed on earth for hundreds of millions of years, with some

surviving into the present due to burial and preservation. This interpretation should be supported by the physical evidence (i.e. paleosols) if it is to be accepted.

Recognizing Soil Profiles

Many earth materials form horizontal or subhorizontal layers, but not all of these represent soil profiles. Soil profiles show specific characteristics resulting from soil-forming processes (Klevberg and Bandy, 2003a). These characteristics are often specific to individual horizons and can be observed upon close examination of undisturbed samples from the horizons. Since diagenesis (post-depositional changes, such as lithification) can be considered a form of "disturbance," diagenesis may destroy these diagnostic properties. The horizons also assume a particular order if the sequence of strata actually represents a soil profile. This order is shown in Table I. Although some of the horizons could be missing in a paleosol, those present will be in the order shown in the table.

Distinguishing Paleosols

Soils can appear structureless to the non-soil scientist. However, as described above, they do possess structure; modern soils have definite soil horizons where the soil changes composition with depth due to soil-forming processes. Paleosols (as we have defined them here), in contrast with modern soils, have been buried and hence have undergone some degree of compaction and diagenesis. Although often subject to significant alteration, supposedly they can still be distinguished from other sedimentary layers. According to establishment researchers, paleosols are recognized in the field by three main features: 1) root traces, 2) soil horizons, and 3) soil structures (Retallack, 1990, p. 20). Important distinguishing characteristics of paleosols and problems with the paleosol interpretation or alternative explanations associated with each criterion are summarized in Table II.

Trace Fossils

Retallack (1988, p. 21, 22) believes that root traces *alone* are diagnostic of a paleosol. However, he admits that it is sometimes difficult to distinguish between a "root trace," a "burrow" and a gas escape structure (Retallack, 1990, p. 21, 22). Trace fossils may be classified using relatively scientific (i.e., descriptive) terminology, e.g. *Skolithos*, *Zoophycos*, *Ophiomorpha* (Tucker, 1990, pp. 75–79). These may then be interpreted to represent evidence of specific organisms, interpretations not always free from equivocation (Woodmorappe, 2002). If one feels confident about his inference about the identity of the organism forming the trace fossil, he may then assume that the conditions at the time of formation were "normal" conditions and not catastrophic, and that the trace fossils are indica-

Table I. Soil Horizon Descriptions.

	Horizon	Description
Surface of Soil ▸	O horizon	An O horizon is considered a horizon dominated by organic material in various stages of decomposition. Little or no mineral material is present in this horizon.
	A horizon	The A horizon is a mineral horizon that occurs either at the soil surface or directly below an O horizon. (Soil Survey Manual 1993). This horizon typically is enriched with some organic material that causes a darkening of the horizon.
	E horizon	The E horizon is a mineral horizon in which the main feature is loss of silicate clay, iron, aluminum, or some combination of these (cf. *Soil Survey Manual*, 1993). This horizon is highly leached and tends to be a very light gray to white color with little or no organic matter present.
◂ Base of Solum	B horizon	The B horizon is a subsurface horizon that, if present, is found below an A and/or E horizon. It shows one or more of the following features (cf. *Soil Survey Manual*, 1993): • illuvial concentration of silicate clay, iron, aluminum, humus, carbonates, gypsum, or silica • evidence of removal of carbonates • residual concentrations of sesquioxides • coatings of sesquioxides that make the horizon different in color from adjacent horizons • granular, blocky, or prismatic structure; or • brittleness.
	C horizon	The C horizon is little affected by pedogenic processes and lacks properties of O, A, E, B horizons (cf. *Soil Survey Manual*, 1993).
	R horizon	The R horizon is hard bedrock.

Table II. Distinguishing criteria for paleosol identification.

Criterion	EGP Interpretation	Alternative Processes
Trace fossils	Roots indicate growth position; burrows usually represent ordinary conditions.	"Trace fossils" may be evulsion structures; burrows may not indicate ordinary conditions (including escape burrows); root debris may have been simply buried, often upright.
Contrasting Horizons ("Profile")	Soil profile development has been preserved as a paleosol.	Mineralogic or sedimentologic stratification may produce horizons, as may nonpedogenic weathering processes.
Clay-Rich Horizons	Clay-rich horizons are indicative of illuviation and diagnostic of pedogenesis.	Clay-rich horizons may be syndepositional, hydrothermal, or due to diagenetic epigenesis.
Carbonate Horizons	Calcic or petrocalcic horizons are indicative of soil horizon formed in arid or semi arid climate.	Carbonate may be syndepositional or deposited by ground water.
Oxidation	Oxidation is indicative of surficial weathering in the zone of soil formation.	Oxidation may be syndepositional or diagenetic rather than pedogenic.
Underclays	Underclays represent soil in which forest grew or beneath swamp which was source of organic material for coal formation.	Underclays result from typical hydrodynamic sedimentation effects (cyclothems, fining upward sequences); most coals are allochthonous, not

tive of soil-dwelling organisms. This, as all diluvialists will immediately recognize, is not a good assumption. Trace fossils may represent escape routes of organisms in danger of burial rather than dwelling or feeding burrows, or may consist of casts of root fragments buried in diluvial sediments rather than preserved in growth position. Evulsion structures or other physical phenomena may easily be misinterpreted as trace fossils (Tucker, 1990, p. 62). Far from being diagnostic, the trace fossil criterion for paleosol identification is highly equivocal.

Soil horizons

One of the diagnostic criteria of an altered "soil" is a sharply truncated upper horizon and a gradational lower horizon (Retallack, 1990, p. 30). The truncated upper horizon usually means that the organic enriched A horizon is missing (Birkeland, 1984, p. 33; Boardman, 1985, p. 71), leaving behind a clay layer, a calcium carbonate layer, a red layer, etc. These are *inferred* to be fossil soil horizons. However, it is the A horizon that would most readily identify a layer as a paleosol. So we are left with other equivocal variables in determining whether certain strata represent a paleosol. Thus, "soil profiles" identified as paleosols require skepticism. Since "paleosols" are commonly missing the A horizon, they are often just a clay layer or a "weathered layer" (Retallack, 1990, pp. 15, 126). As shown in Figure 1, preservation of the A horizon should not be unusual. Diagenetic processes may result in formation of lignite or some other carboniferous horizon, but complete absence of the A horizon makes a paleosol claim suspect. Any alleged paleosol should be scrutinized to see to what extent it corresponds to the sequence illustrated in Table I.

Paleosol literature often focuses on the inferred B horizon. The "B horizon" is not only used to infer the presence of a paleosol, but often the amount of time it represents based on the "degree of development":

> The degree of development of a soil or paleosol is evaluated by the clayeyness of the B horizon and its type of clay, thickness of the B horizon, and the presence and strength of clayey structures, colors, and nodules… (Bestland, 1997, p. 848).

Development of B_t or other B horizons does not represent just a time factor; parent material, topography, and climate (probably even biology) have a strong influence on its formation (Klevberg and Bandy, 2003a). Depressional potholes in glacial till are a good example. These soils have thick, high clay content B_t horizons. The surrounding soils have B_t horizons that are not as thick and do not have as much clay even though they came from the same parent material, thus indicating that initial conditions, not time, must be primarily responsible for this difference.

Soils with clay enriched horizons are common. These horizons typically have formed from clays leaching from surface horizons (eluviation) and being deposited in underlying horizons (illuviation). They may also have formed from different parent materials being deposited on top of one another. Clay films on ped surfaces can usually be used to differentiate between the two situations. Illuvial movement of clays into lower horizons should have clay films present on ped surfaces. Clay translocation can occur much more rapidly than is commonly assumed (Klevberg and Bandy, 2003b).

Carbonate horizons (often called caliche) do, of course, form pedogenically. Carbonate horizons are common in areas with dry climates where leaching does not occur beyond the depth of the solum. The carbonate horizons form when $CaCO_3$ is leached deeper into the solum by water to the point where the average annual wetting depth of the soil occurs. Most soils in arid and semiarid areas have a carbonate enriched horizon. Soil scientists call these calcic horizons (petrocalcic horizons or sometimes "calcrete" if cemented) when they are encountered in soils. Geologists utilize a variety of descriptive terms (e.g. lime-cemented conglomerate, carbonaceous sandstone, marl) to describe carbonate-dominated geologic units. Outside an actual soil profile (i.e., modern soil), *petrocalcic horizon* is a genetic term, revealing its mixed question nature.

Strata or horizons cemented by calcium carbonate are frequently cited as evidence for paleosols. While calcium carbonate enriched horizons commonly occur in modern soils in arid climates, pedogenesis is only one potential source for calcium carbonate in a geologic formation. Petrocalcic horizons typically form from $CaCO_3$ in the ground water. As the water evaporates or is used by plants, the $CaCO_3$ is deposited within the soil pores, plugging the pores and cementing the soil particles together. This process is observed in soils today, and evidence of petrocalcic horizons is described in some soil series. However, carbonate may also be supplied by ground water, or it may be syndepositional. Some deposits may have had complex histories with more than one source of carbonate. B_k horizons in extant soils are not usually cemented.

Oxidation occurs in most soils regardless of degree of weathering or depth of horizons. Reduction only occurs when anaerobic conditions are present along with the following:

- A food source,
- Temperatures above 5°C,
- Anaerobic bacteria present, and
- Saturated soils

Where these conditions do not exist, oxidation takes place. Oxidized minerals are often found where hydrothermal alteration or other geologic processes have occurred. Many alleged paleosols are more readily explained by hydrothermal and metamorphic processes (Palmer, Phillips, and McCarthy, 1989).

Underclays are probably the most commonly invoked "paleosols" of pre-"Quaternary" rocks, at least in the past (Froede, 1998, p. 24). These are clay strata, often relatively structureless, subjacent to coal beds. The EGP traditional explanation for coal formation is peat accumulation in swamps, and the underclay is supposedly the C horizon of a histosol (Klevberg and Bandy, 2003a). However, soil profile development is not observed in underclays (Scheven, 1996), and the swamp (autochthonous) theory for coal formation has been widely refuted (Coffin, 1968; 1969; Rupke, 1969; Snelling and Mackay, 1984; Woodmorappe, 1999, pp. 215, 216). "Underclays" often occur in cyclothems, suggesting their formation was part of a rapid depositional process (Berthault, 1986; Woodmorappe, 1999, pp. 199–220).

Soil Structures

Of special interest in the study of paleosols are peds (soil aggregates), cutans (the surfaces of peds), glaebules (aggregates of distinctive composition), and mineral crystals such as gypsum. Unfortunately, peds and cutans are hard to identify in paleosols because of compaction and diagenesis (Retallack, 1990, p. 38, 40). Glaebules are not diagnostic of paleosols, since they can form in other types of sediments (Retallack, 1990, p. 46). Crystals can, of course, form in many different environments and hence are not diagnostic of a paleosol either (Retallack, 1990, p. 47).

Glaebules could have arisen from any process or combination of processes capable of producing inclusions within the soil matrix that are recognizably different. To assume isotropy for parent material, epigenetic processes, or the history of many soils is grossly simplistic at best (Klevberg and Bandy, 2003a). The complexity of pedogenesis rather suggests that glaebules unrelated to paleosols should be common in many soils.

Physil species sometimes considered diagnostic of soil-forming processes have been observed in circumstances indicative of syngenetic or diagenetic processes (Klevberg and Bandy, 2003b). Although they may be useful in testing various pedogenesis scenarios, they have multiple possible sources of origin and are not diagnostic of a paleosol. Physils can actually be diagnostic of parent material, not pedogenic history (Birkeland, 1974, p. 141).

Froede (1998, pp. 25, 26) pointed out the general difficulty facing paleopedologists in distinguishing paleosols in the geologic record:

> Presently, there is no standardized technique by which paleosols can be defined. Some investigators use modern soil science methods while others have developed their own schemes.... In many cases paleopedologists claim to be able to identify multiple buried soil horizons.... The identification of the purported paleosol horizons is based on a variety of soil classification techniques which allow for a highly interpretative framework.... This suggests an element of subjectivity involved in the "science."

We do well to heed the warning of James, Mack, and Monger (1993, p. 1637):

> …many paleosols do not possess adequate characteristics to allow for proper classification at the order level following Soil Taxonomy. This is a fact.

Diagnostic criteria for paleosols are lacking, and perhaps because of this, methodology is often scientifically weak (White, 1998).

Rates of Soil Formation

Moderns soils, and by extension paleosols, are *assumed* to form over long periods of time. One reason for this time scale is that "Quaternary" soils have been used as analogs for the time of development of paleosols (Retallack, 1990, p. 13). Since the "Quaternary" is considered to be the past two million years or so, it is no wonder that long ages are *automatically* built into "paleosols." Thus, the postulated time for soil formation is simply a uniformitarian outgrowth of their hugely inflated time scale and displays gross negligence in accommodating the mixed question nature of the problem (Klevberg and Bandy, 2003a; 2003b).

The assertion of long ages for soil development comes in spite of modern soil forming rates being *unknown* (Boardman, 1985). Birkeland (1984, pp. 118, 119) admits, "It should be pointed out that it is very difficult to determine soil processes because few actual measurements can or have been made." Soils can form quickly under the right conditions. For instance, a 24 cm thick soil (an andisol, 10 inches thick) with distinct horizons formed within seventy-four years on Kodiak Island, Alaska (Ping, 2000, p. 1265), and a 36 cm (14 in) thick andisol formed in just forty-five years on the volcanic ash deposited from the eruption of Krakatau (Leet and Judson, 1965, pp. 83–84). Other soil orders, though not typically formed as quickly as andisols, may take much less time to form than commonly asserted, and some may be partial relicts of geologic processes (Klevberg and Bandy, 2003a; 2003b). Soil formation in the limestone of Kamenetz Fortress in Ukraine in a xeric moisture regime (in a region dominated by mollisols; cf. Figure 1 in Klevberg and Bandy, 2003b) amounted to 30 cm (12 in) in 230 years, and comparable rates of soil formation have been observed in sand dunes and moraines in even relatively cool and dry climates (Jenny, 1941, pp. 35–44). Caliche may form quickly enough to clog drain pipes (Hunt, 1972, p. 45). While pedogenesis is very complex (Klevberg and Bandy, 2003a) and rates often difficult to estimate, observed rates of formation for many soils have been much faster than traditionally assumed (Burykin and Zasorinal, 1989; Klevberg and Bandy, 2003b).

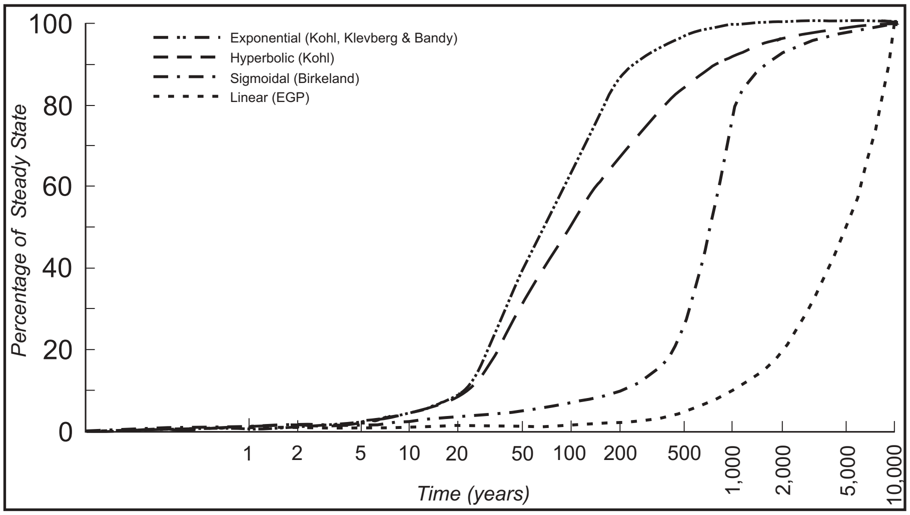

Figure 5. Disparate models for rates of pedogenesis. The term "steady state" refers to dynamic equilibrium of soil-forming processes with environmental factors (Klevberg and Bandy, 2003a; Lavkulich, 1969). The example used here is entirely arbitrary; ten thousand years might be accepted for a slow-forming mollisol, a typical alfisol, or a quick-forming ultisol.

Even if we grant the EGP assumption that a given soil takes, for example, ten thousand years to reach steady state ("maturity"), various anticipated rates at which this particular soil formed may differ greatly. Thus, although many EGP adherents have come to recognize the rapidity with which some individual soils or soil series may have formed in specific cases, the assumption of great ages continues (Crocker, 1960, p. 84; Guggenberger, Bäumler, and Zech, 1998; Klevberg and Bandy, 2003b). Interpretive differences arising from disparate natural history views are illustrated by Figure 5. As has been shown elsewhere (Klevberg and Bandy, 2003a; 2003b), pedogenic processes are not generally linear. This has been recognized by Birkeland (1974, p. 257), who proposed that soil formation generally is a sigmoidal function of time. We believe this is much more realistic than the linear assumption, but because Birkeland's EGP bias caused him to overestimate the time required for pedogenesis, this is still an unrealistic function. Note that if one selects an arbitrary percentage of steady state, say 50 percent, the inferred time of formation may differ by orders of magnitude. This shows how important historic presuppositions are to interpretation of the same data.

We believe that early pedogenesis probably occurs more rapidly than Birkeland recognizes and that an exponential or hyperbolic function is more realistic, as some diluvialists have suggested (Klevberg and Bandy, 2003b; Kohl, 2002) and as illustrated in Figure 5. The superiority of diluvial models can be demonstrated by many examples in addition to those given above. Rapid soil development has occurred in many irrigated regions of the American West where land was leveled to prepare it for surface irrigation. Deep cuts on the ridges exposed subsoil which was rapidly brought into production with good management (Kohl, 2002). Development of natriustalfs (alfisols with natric horizons) has been observed in South Dakota in less than sixty years (Westin, 1970, p. 17) and, in cases of high-sodium irrigation water, as little as two years (Kohl, 2003). The presence and chemistry of water, particularly ground water, has probably been much more important in pedogenesis than many researchers have formerly recognized (Jenny, 1941, p. 92; Klevberg and Bandy, 2003a). Plant succession can result in a highly nonlinear, decreasing-rate pedogenesis function (Bormann and Sidle, 1990; Crocker, 1960). Spodic and albic horizons have been observed to form in soils in Alaska in fewer than 150 years (Bormann et al., 1995).

Alternative Explanations for Paleosols

Assuming that some layers in rock, such as a clay or calcium carbonate rich layer, can be interpreted as a paleosol within the EGP, are there alternative explanations within the DGP? It is mainly the properties of these layers (one or more apparent soil horizons) and not root traces nor soil structures that can possibly be diagnostic. There are at least three other possible explanations, other than a paleosol, within the DGP for these layers:

- First, a clay, calcium carbonate, or a red layer could simply be a result of flood (or other fluid) deposition. A clay layer can be deposited rapidly by flocculation, while a red layer can be the result of iron-rich water. While clay particles will not settle readily, even in still water, aggregates of clay particles (flocs) will settle much more rapidly. Flocculation is commonly induced by the introduction of salts (e.g. $CaCO_3$, $CaSO_4$, $Fe_2(SO_4)_3$, and especially $Al_2(SO_4)_3$, alum)[2]. Introducing approximately 25 milligrams alum for each liter of severely turbid water (or 300 milligrams of gypsum per liter) typically clears the water of suspended clay particles in only a few hours (Hargreaves, 1999). Physical means (typically limited to careful piping layout and discharge geometry) are used successfully to provide rapid deposition of clay-size tailings at many mines. Thus, contrary to the arguments of some (Bowden, 2000; 2001; Froede, 2001; Klevberg, 2001), rapid deposition of clays–especially in the presence of iron and other salts–is not only possible but likely

[2]An exception is NaCl, since Na^+ is effective as a dispersing agent.

to have occurred during the year-long upheaval of the Deluge (Genesis 7:11), as well as on a smaller scale subsequently.

- Second, a sediment or rock can be modified anytime after deposition by ground water. When heat and moving fluids affect mineralogy, this is called hydrothermal alteration. During rapid deposition of sediments during the global Flood event—perhaps hundreds of meters in less than a day—the pressure of the accumulating sediment would tend to squeeze the water out. The water, under high pressure and charged with chemicals, could quickly alter the sediment through which it flowed. Even practitioners of the EGP recognize this. For instance, gray loams in the rocks of the Rhenish Massif have been interpreted as *both* the product of surficial weathering and the result of rock decomposition by hydrothermal ascending solutions (Meyer et al., 1983, p. 41). Deeply kaolinized granite in southwest England (the Cornubian batholith) is believed to be a reaction product of hydrothermal origin by some researchers (Thomas, 1994, p. 24). Many other batholiths exhibit weathering that is probably diagenetic rather than epigenetic (Snelling and Woodmorappe, 1998). Supposed "Precambrian paleosols" in South Africa may be better interpreted as indications of hydrothermal alteration along lithological contacts (Palmer, Phillips and McCarthy, 1989). This appears to be true of at least some similar deposits (Williams, 1969). Cliff Ollier and Colin Pain (1996, p. 62) admit:

  > Rising water, steam and other emanations from deep in the earth move upwards through enclosing country rock and bring about some alteration. This may include the formation of tourmaline or fluorite in hard rocks, but it may also include the formation of clays. This is not [surficial] weathering, but hydrothermally altered rocks may come to look very like weathered rocks....

- Third, a "paleosol" can be formed by diagenesis, which is the alteration of a sediment, exclusive of weathering and metamorphism, that includes compaction, cementation, oxidation, reduction, hydrolysis, bacterial action, and replacement. Froede (1998, p. 28) points out that diagenetic changes can be misidentified as paleosol horizons. During the Deluge, one would expect a large variety of diagenetic changes due to various combinations of heat, pressure, chemistry, etc., that those adhering to the EGP would exclude from their thinking. Diagenetic effects can easily mimic paleosols (Valentine and Dalrymple, 1976; Bowen, 1978, p. 182). Some investigators have found that early diagenetic ground water alteration can mimic hydromorphic soil features, such as pseudogley mottling and calcic horizons (Kraus, 1999, p. 61).

Identifying soil profiles and structures in the geologic record can be fraught with difficulties and requires caution. One should be suspicious of the "paleosol" interpretation when it is admitted that if the layer was once a soil, compaction and diagenesis have altered it (Retallack, 1990, p. 20). If altered or metamorphosed enough, the layer may become indistinguishable from a zone of hydrothermal alteration (Retallack, 1990, p. 129). Since alleged paleosols seldom exhibit a recognizable soil profile (Table I), creationists–or anyone–should be cautious about accepting the existence of paleosols in the rocks. Furthermore, the existence of roots or "root traces" should not automatically define a paleosol. This is crass uniformitarianism. One would expect all kinds of roots and root traces in sediments or sedimentary rocks caused by the Deluge, since the Flood-borne sediments would have buried many. One should especially be suspicious when the supposed soil-forming process was not enough to wipe out bedding planes or even ripple marks, as admitted by Retallack (1990, pp. 11, 31). Alternative explanations for alleged paleosols not only exist, they often appear much more likely (White, 1998).

The Equivocal Nature of Important "Paleosols"

The "paleosols" used to distinguish between various glaciations are difficult to identify, patchy, lack the A-horizon, and have been simply fit into the multiple glaciation assumption, among other problems (Valentine and Dalrymple, 1976; Oard, 1990, pp. 149–166). The American Midwest glacial/interglacial scheme is now considered wrong because there supposedly are many more glaciations over a longer period than earlier indicated by the "paleosols" (Boellstorff, 1978; Woida and Thompson, 1993). These many supposed glaciations are based on oxygen isotope ratios in deep-sea cores (Oard, 1984a; 1984b; 1985), yet another mixed question blending historical speculations with scientific data. This brings up the question of how the earlier geologists working in the Midwest could have correlated these geographically patchy soils over regional distances to deduce three interglacials between four ice ages.

Underclays are often relatively structureless and do not exhibit evidence of soil profile development. The overlying coal generally exhibits evidence of allochthonous, not autochthonous, depositional processes. These deposits are often stacked in a recognizable sequence (cyclothem) which, based on recent work by Berthault (1986; 2002a; 2002b) and others, is more likely an indication of rapid, energetic deposition than soil formation.

Vertical sequences of alleged paleosols, in contrast with cyclothems, do not generally form a recognizable sequence. Instead, the number of paleosols and their vertical extent are often matters of debate (Froede, 1998, pp. 26, 27). Such distinctions are essential if a pedostratigraphic column is to be formulated. That stratigraphic column then forms the basis for interpretations of age, paleogeography, and paleoclimatology. Whereas visitors to national parks and viewers of television programs are typically presented with such interpretive scenarios as if they were historic fact, the very basis for the inferences is often suspect, and all resulting interpretation becomes mere conjecture.

A Diluvial Approach to the Paleosol Question

In light of the information presented above, let us again consider the question, "Can paleosols exist?" Both the EGP and DGP allow for the existence of paleosols (Froede, 1998, pp. 21–28), if *paleosol* is defined as "a buried soil horizon in which soil forming processes are no longer operative." However, the DGP does not admit the genesis of paleosols in the way envisioned by the EGP. Indeed, it is on this point of *history* that the mixed question produces conflict between the EGP and DGP. If soil formation requires the length of time widely credited to it by the EGP, then formation of a single soil horizon, let alone multiple paleosols, becomes impossible within the diluvial timescale. However, since pedogenesis can be significantly faster than professed by the EGP, and since catastrophes can (and do) bury soil horizons, paleosols can form, and certainly have. The DGP approach to natural history predicts that paleosols will be less common, less extensive laterally, and more rapidly formed than the EGP predicts (Froede, 1998, p. 28; Klevberg and Bandy, 2003b).

A danger in investigating a mixed question phenomenon such as paleosols arises at even the data collection stage. Evolutionists will be tempted to see a paleosol at every turn. Diluvialists may, for the same reason, tend to miss paleosols. Can one avoid this dilemma? Yes, if careful attention is paid to the separate lines of evidence demanded by the mixed question: careful collection of scientific data, logical analysis of the historical predictions, and careful testing of the historical predictions by means of the scientific data. This requires recognition of alternative explanations for alleged paleosols and uncertainties in rates of pedogenesis.

Implications for Paleopedology and Pedostratigraphy

In scientific research, error ranges or degrees of precision are very important and regularly reported. It is often critical to know the confidence interval of a result, and no measurement is complete without an implicit or explicit statement of precision. In historical research a similar situation exists. One of the most important tasks of the historian is to render a judgment on the reliability of a given witness to a given event versus the testimony of another, possibly conflicting witness. In neither case can we reach "absolute truth." Both forms of research are human endeavors and subject to human limitations. Yet geologists and paleopedologists can display incredible dogmatism at times (unfortunately, this is not limited to evolutionists). It is vital that we remember that any paleopedologic interpretation is just that: an *interpretation*, and the answers we give to these mixed questions are always tentative, only as good as our historical and scientific data and inferences. We are limited by our ability to concoct historical scenarios and our ability to scientifically disprove them.

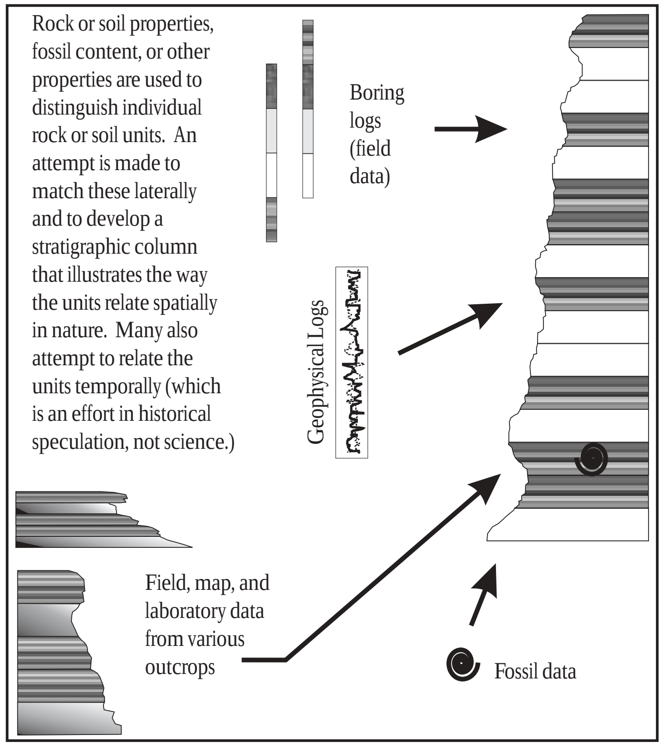

Figure 6. How a stratigraphic column is assembled.

Pedostratigraphy naturally derives from paleopedology. Stratigraphy is the correlation of discrete bodies of earth materials to deduce their geometric orientation and relation to each other. Various methods can be used to develop local columns that represent this relationship vertically. The data may be of many kinds: lithologic, fossil, geophysical, etc., and from various sources: outcrops, borehole chips, geophysical surveys, etc. They may be gathered from widely scattered locations. These data are compared to see spatial trends in each kind of data, and these sequences compared in an effort to determine the local stratigraphic sequence. The local stratigraphic column that results can be displayed similarly to an outcrop or boring log, as shown on Figure 6. Where the earth materials investigated are soils, the correlation is called pedostratigraphy. Since none of us is satisfied to limit his inquiry to science, and knowledge of history is a basic human need, stratigraphy soon moves from descriptive correlation to historical speculation (Klevberg, 1999; Reed, 1996b;

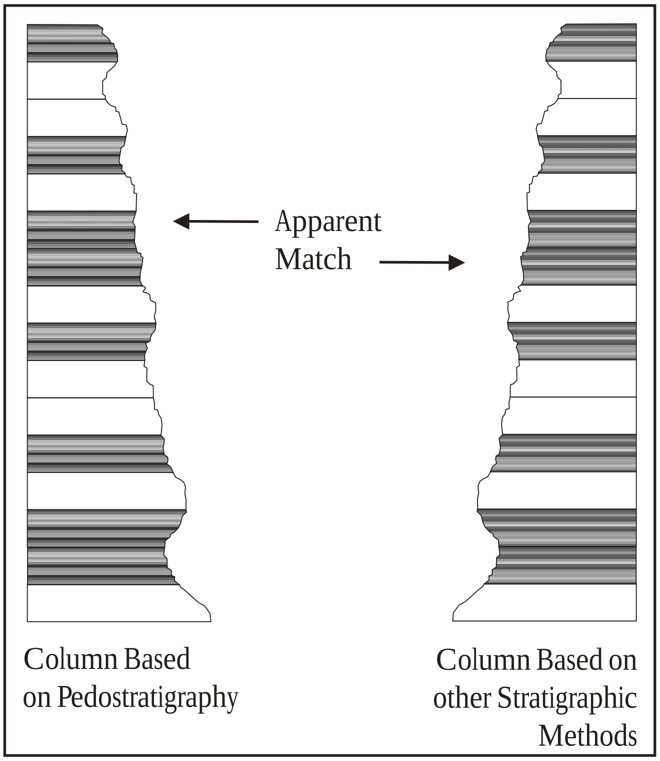

Figure 7. Apparent stratigraphic match which is not unique. In this illustration, pedostratigraphy appears to provide a perfect fit with other stratigraphic methods. However, because the correspondence is not unique, this may be coincidental or contrived.

2000). Some stratigraphic methods are actually historical rather than scientific or mix the two (Klevberg, 2000a).

For those not acquainted with stratigraphy, an example or two may be useful. One of us, while employed in the geology department of a major metals mine, was the field geologist for an extensive core drilling project to better delineate the geology of the mine area. A model had been developed already through several stages of drilling, and this model predicted locations of the diatreme hosting the ore, barren country rock, and dikes. The thickness, number, and location of these dikes proved different as a result of the new drilling data. The model was therefore refined. Theoretically a very accurate stratigraphic column could be developed by drilling every couple of meters in every direction, but the cost would be astronomical. Stratigraphy therefore fills the gap by synthesizing the available field data to form a predictive model. This then forms the basis for developing a new drilling program, and the cycle is repeated to the extent it is economically warranted (the mine model was an example of lithodemic stratigraphy, since these were not stratiform rocks, but it can be thought of as a local stratigraphic section or column). On another site, near the Canadian border in Montana, an electrical resistivity survey was conducted prior to drilling several shallow borings. The geophysicist conducting the survey interpreted the results as showing a plume of oil in the subsurface. Drilling showed very limited oil; what the resistivity survey had encountered was actually a sand-claystone contact. The geophysical data were the differences in resistivity. Without lithologic control from the borings, they could not be related to the site geology. However, the sequence of the strata developed using these two independent methods matched. The stratigraphy for the area between the drill holes could then be inferred with considerable confidence from the resistivity data that had previously been misinterpreted as showing a plume of oil.

One often hears arguments about "independent lines of evidence" establishing a certain age-dating or stratigraphic scheme. Such lines of "evidence" are immediately suspect when mixed questions are involved. Often, they are simply examples of the reinforcement syndrome (Klevberg, 2000b, p. 95; Oard, 1997, p. 11; Thompson and Berglund, 1976), a psychological phenomenon wherein researchers increasingly attempt–and possibly succeed–in finding data to support a popular new hypothesis in a kind of bandwagon effect until the hypothesis is simply assumed by the scientific mainstream. As described elsewhere, pedostratigraphy (stratigraphic correlation based on paleopedology) is not a strictly *scientific* approach to stratigraphy, whatever other merits it may have (Klevberg, 2000a). So what of the "agreement" between various methods? There are several possibilities:

- Assuming that the paleopedologic interpretation is right, and it is in agreement with magnetostratigraphy, assumed evolutionary succession ("biostratigraphy"), etc., then it would tend to support the EGP interpretation. However, this support is very weak if the correspondence is not *unique*, as has been demonstrated elsewhere relative to cyclothems (Zeller, 1964) and eustatic curves (Miall, 1992). Although the apparent correspondence between the stratigraphic sequence determined by one method and another method may be impressive, one must be careful to determine that this is not a cyclic pattern or the result of researcher bias. Correspondence may be fortuitous or contrived. This is illustrated by Figure 7. Cyclothems, repetitious sequences, properties that do not follow lithologic boundaries, and correlations with limited exposure and significant lateral facies changes can be especially problematic. If, for example, data from many sources all show alternating, meter-thick beds of sandstone and claystone that are virtually indistinguishable from similar beds above and below, nearly any shift of two meters up or down will make any two boring logs match. No one would find this convincing. But, a pattern such as that in Figure 7 could easily fool a geologist into thinking the stratigraphic relations of the rocks had been determined, while the columns derived from different methods or sets of data are really shifted relative to each

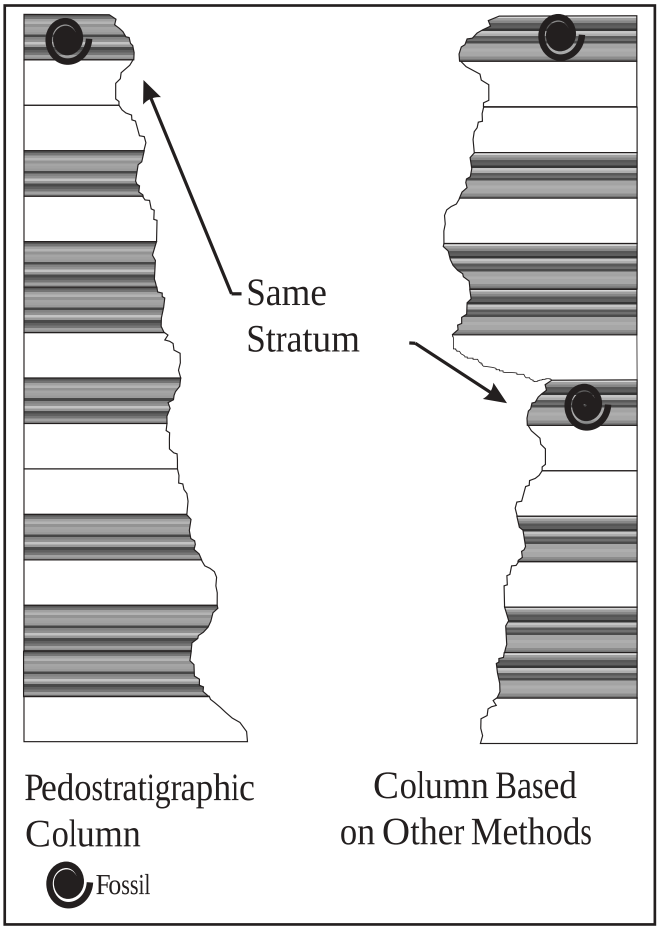

Figure 8. Mistaken stratigraphic correlation of cyclic strata. Illustration of nonunique stratigraphic sequences with false apparent correspondence between stratigraphic methods.

other. Pedostratigraphy may produce a sequence that appears identical to one determined using geophysical methods (e.g. resistivity or remanent magnetization), yet this sequence may be repetitious and correlations between methods fallacious, as illustrated by Figure 8.

- Assuming that the paleopedologic sequence is right, and it is in agreement with other stratigraphic methods, but the time required to form the sequence differs from the accepted EGP interpretation using other stratigraphic and "dating" methods, then the likelihood that the timescales of the other methods also need revision appears high. This is illustrated by Figure 9. Unfortunately, radiometric "dating" (methods which are historical and unscientific) are often used to *force* the data from other methods to "agree:" introducing hiatuses, overthrusts, paraconformities, etc., instead of assembling the individual types of data independently. Many EGP stratigraphers force everything, including radiometric "dates," to fit into the supposed fossil succession. Any fossil succession that may exist and any veracity radiometric dates may have are impossible to evaluate when other stratigraphic methods (including strictly scientific ones) are ignored or abused in this way.

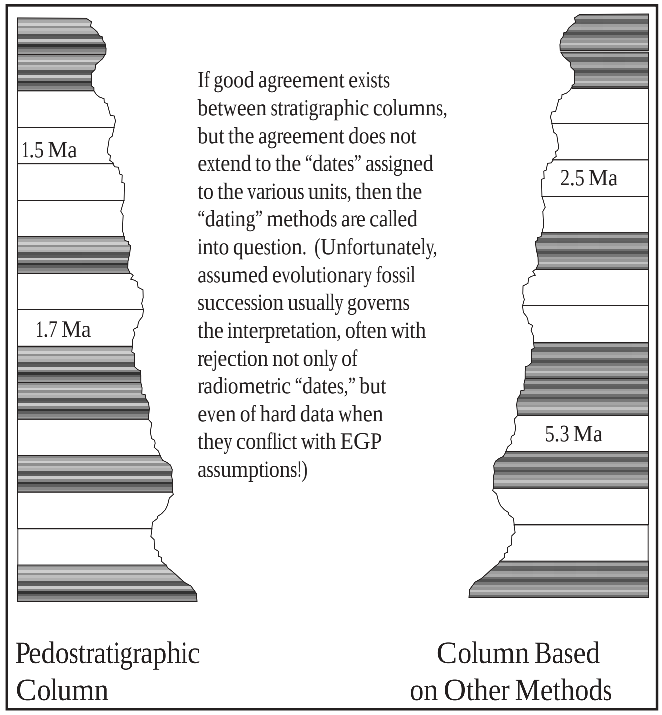

Figure 9. Matching stratigraphic columns with discordant "dates."

- If the sequence of strata is quite complicated or nearly random, agreement between a local stratigraphic column developed using paleopedology and a sequence developed using another stratigraphic method would tend to enhance confidence in the interpretation. (Stratigraphic correlation of nonstratiform materials can be quite difficult, and we will limit our illustrations here to stratiform earth materials.) This is illustrated by Figure 10. If the paleopedologic interpretation is wrong, and a sequence of strata represents a number of geologic events different from the paleopedologic scenario, then the alleged correspondence between pedostratigraphy and biostratigraphy or magnetostratigraphy is also wrong. This casts doubt on these other methods, especially if the correspondence between methods appears strong at the time one is discredited. This is illustrated by Figure 11.
- If the paleopedologic interpretation is doubtful, and the correspondence with other methods is clearly not a unique solution, then no mutual support between methods can be adduced, however convincing they may appear superficially. This is illustrated by Figure 12.
- If the paleopedologic interpretation conflicts with correlations based on other methods, at least one of the methods is invalid. This applies to any two stratigraphic (along with "absolute dating") methods. This is illustrated by Figure 13.

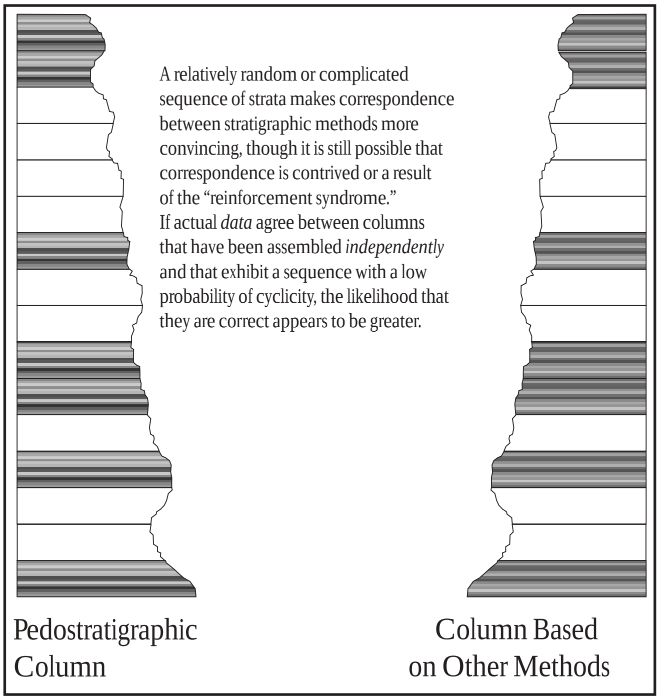

Figure 10. Convincing correspondence between stratigraphic methods.

- To provide a truly meaningful comparison, the pedostratigraphic column must be developed *independently* of the other methods and then compared with the results obtained using these other methods. Unless this is carefully observed, bias can be expected and the results dismissed as another example of the reinforcement syndrome. In general, uniformitarians specifically *avoid* using pedostratigraphy independently of the other stratigraphic methods, though some warn of the need for quantitative data and care in avoiding this pitfall (Birkeland, 1984, p. 339).

When DGP assumptions are substituted for EGP assumptions, conclusions can differ markedly. For example, suppose an EGP researcher believes ninety paleosols are represented in the wall of a canyon. Although unable to disprove the paleosol interpretation, field evidence may suggest that two-thirds of the "paleosols" are better explained by energetic geologic processes. If the average time required for a soil in the paleopedologic sequence to form was 150 years (and negligible time for the geologic events), the resulting total time for formation of the sequence would have been 4,500 years. This is several orders of magnitude less than the EGP scenario, yet the DGP results are in good agreement with historically observed rates of pedogenesis. Obviously, this is a gross simplification and only intended to be illustrative; each site warrants a careful, detailed investigation.

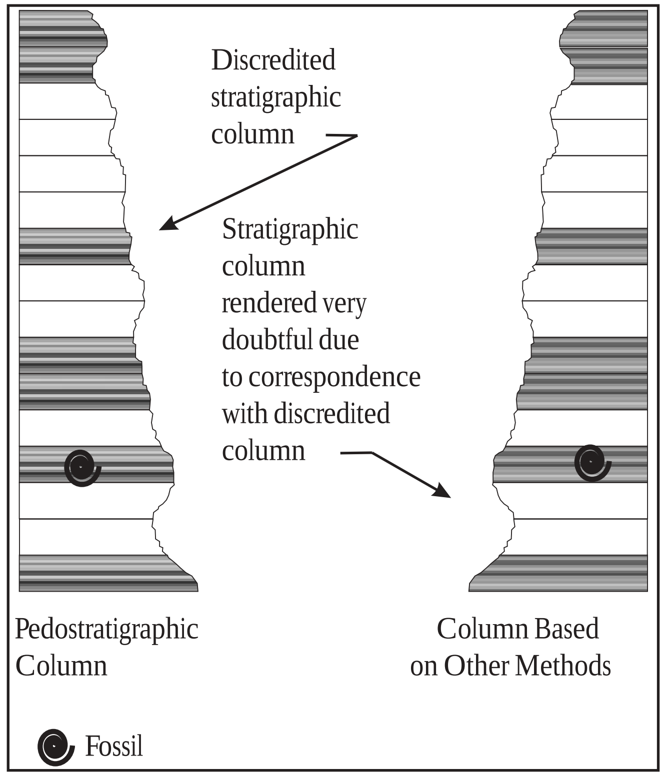

Figure 11. Discredited column with good correspondence to other methods.

Conclusions

The field of paleopedology is a mixed question domain. All of its results are speculative, and interpretations are highly dependent on researcher bias. Alternative explanations for apparent pedogenic features are abundant and often superior. Paleosols are not inimical to the DGP, but the expectations and interpretations of antithetical paradigms certainly lead in very different directions. This is especially true in the expected abundance and rate of formation of paleosols. Care must be exercised by researchers in this field to separate scientific data from historical data and to separate data from interpretation. Data acquisition must be as complete as practical and distinct from inference. Even then, the resulting interpretation is essentially tentative and must be identified as speculation. Speculative paleosols lead to speculative successions of paleosols, speculative pedostratigraphic columns, and speculative paleogeographic and paleoclimatologic reconstructions. Since these pedostratigraphic columns must be viewed with great skepticism, apparent agreement between "independent" stratigraphic methods must be approached with even greater skepticism, and one must beware of the possible influence of the reinforcement syndrome. Due to ubiquitous EGP bias, it may well be that many paleosols exist only in the mind of the beholder.

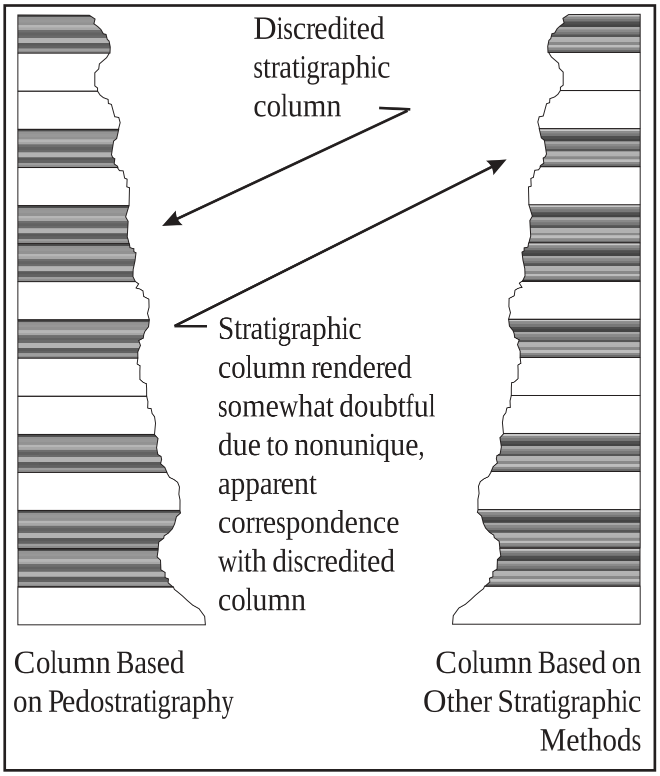

Figure 12. Doubtful correspondence with doubtful column.

Glossary

albic horizon: said of an eluvial soil horizon containing at least 85 percent material exhibiting a color determined largely by the primary sand and silt particles rather than particle coatings, implying that clay and free iron oxides have been removed from the materials or that the oxides have been segregated to such an extent that the colors largely reflect the natural mineral color of the sand and silt particles. Albic horizons usually occur beneath A horizons.

allochthonous: formed by transport to the location where it is now found rather than by growth in place.

autochthonous: formed *in situ* in approximately its present position rather than by transport from elsewhere.

DGP: the "diluvial geologic paradigm," a stereotype of the view that earth history has been dominated by catastrophic processes (principally the Deluge), a relatively short history as indicated by the Bible, and creation. Energy is the most important geologic variable.

diluvial: resulting from or pertaining to the Deluge, the global Flood cataclysm described in Genesis.

EGP: the "establishment geologic paradigm," a stereotype of the prevailing view that earth history has been dominated by gradual processes, immense amounts of time, and evolution. Time is the most important geologic variable.

glaebule: a particle within the soil matrix that is distinct from it due to composition, fabric, or some recognizable boundary that encloses it. It does not appear to have resulted from the soil-forming processes that produced the soil in which it is found.

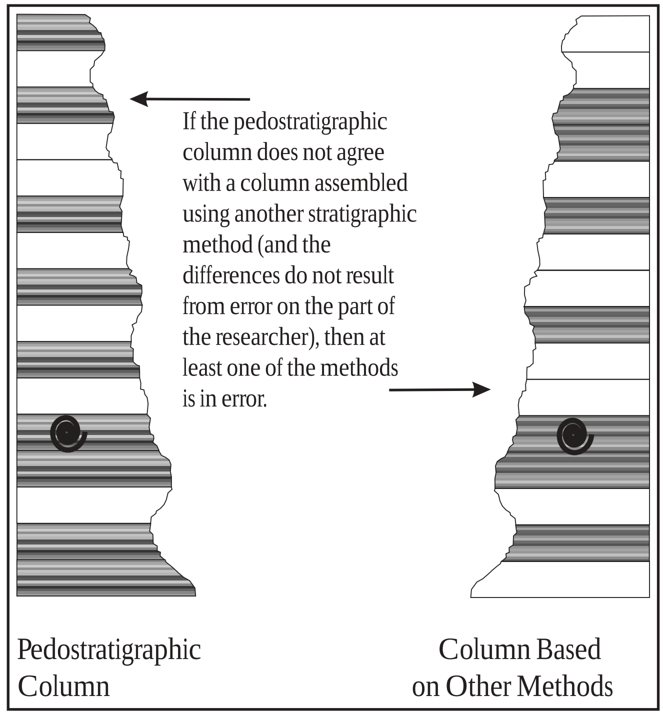

Figure 13. Lack of correlation between stratigraphic methods.

maturity: a term often used in the past to indicate the extent of soil development; however, this term is associated with discredited concepts and is not presently favored. The term "steady state" is preferred and refers to dynamic equilibrium of soil-forming processes with environmental factors (Klevberg and Bandy, 2003a; Lavkulich, 1969).

natural history: as used in this paper, *natural history* refers to the history of nature or earth history.

neocuvierist: a term loosely applied to neocatastrophists who envision large scale catastrophes and hold to periodicity (secular) or accord great importance to presumed postdiluvian catastrophes (creationist).

paleopedology: the study of paleosols.

solum: refers to the upper horizons of the soil where pedogenic processes occur; it overlies the C and R horizons (parent material).

spodic: said of a soil horizon characterized by accumulation of iron and aluminum sesquioxides, organic complexes and organic matter, and frequently found beneath an E horizon in forested terrain.

xeric: a moisture regime found in areas with a Mediterranean climate and characterized by moist, cool winters and warm, dry summers. The moisture, which falls during the winter when potential evapotranspiration is at a minimum, is particularly effective for leaching. In normal years the soil moisture control section is dry in all parts for 45 or more consecutive days in the four months following the summer solstice and moist in all parts for 45 or more consecutive days in the four months following the winter solstice.

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CRSQ: Creation Research Society Quarterly

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Book Review

Resurrecting Genesis by John R. Hadd
Dorrance Publishing Co., Pittsburgh, PA. 2002, 240 pages, $24

Author Hadd completed a career of Federal government police service. He has studied the creation-evolution debate for over three decades. This book is well written and attempts to "challenge … orthodox Darwinism without surrendering to fundamentalist creationism" (cover).

Four distinct approaches to origins and history are defined: materialistic evolution, theistic evolution, progressive creation, and young-earth creation (p. 103). Hadd lists three "problems" with the young-earth view as favored by the CRS (p. 103). First is the literal interpretation of Genesis 1. Second is the young age view itself, thousands of years instead of billions. Third is reliance on the Genesis Flood for reshaping the entire earth's surface. The book is somewhat confusing since Hadd thoroughly and correctly debunks radioisotope dating, a mainstay of old-earth thinking. He also describes in detail the tremendous tectonics which accompanied the Flood. An ark made of reeds is promoted as described by David Fasold (p. 79). It is unclear whether Hadd prefers a local or global flood.

The author holds to the progressive creation view. He believes that God orchestrated many animal/plant creations and extinctions over eons of time before mankind's appearance. The reason, Hadd says, was to provide mankind with object lessons (fossils) on the stewardship of life on earth (p. 66). This view is rather strange, that animal extinctions somehow teach the importance of life. In response, Hadd writes "No human being…has any place attempting to dictate strategy to the Creator" (p. 98). Hadd has simply been forced into this position of multiple animal extinctions by the progressive creation stance.

Much detail is given to cataclysmic events in earth earth history. These include interactions with other planets and the theories of catastrophists Isaac Vail, Immanuel Velikouvsky, and Donald Patten.

Several valuable appendices are provided. Ten pages are given to the Williamsburg Charter, a 1998 document which promotes religious liberty. Fifty pages are given to *Commentary* reprints of David Berlinski articles which challenge evolution and the big bang. Also included are 32 follow-up letters which appeared in Commentary, both for and against Berlinski

The reader may not agree with author Hadd's viewpoints but the information is nicely laid out and is challenging.

Don DeYoung
DBDeYoung@grace.edu