Earth-Science Reviews 89 (2008) 144–155

Contents lists available at ScienceDirect

Earth-Science Reviews

journal homepage: www.elsevier.com/locate/earscirev

Origins and implications of soil layering

Jonathan D. Phillips [a,*], Carsten Lorz [b]

[a] Tobacco Road Research Team, Department of Geography, University of Kentucky, Lexington, KY 40506-0027, USA
[b] Department of Geography, Dresden University of Technology, Helmholtzstr. 10, D-01062 Dresden, Germany

ARTICLE INFO

Article history:
Received 8 May 2007
Accepted 23 April 2008
Available online 7 May 2008

Keywords:
layering
horizonation
soils
regolith
pedogenesis
surficial deposits
geoarchaeology

ABSTRACT

Layering is common in soils, due to a variety of pedologic and geologic processes, and has important consequences for the interpretation of soils and landscapes. Layering can derive from original sedimentary layering; depositional upbuilding; episodic surface erosion, deposition, and stability; soil production by weathering; vertical or lateral translocation; bioturbation; and various combinations of these. Complex and polygenetic models incorporate both geogenic and pedogenic processes, and allow for physical and biological processes, as well as both vertical and horizontal movements. We review these conceptual frameworks and synthesize them into a vertical contrast model (VCM) for interpreting layered surficial materials. The VCM incorporates a variety of geologic and pedologic processes which may create, destroy, enhance, or obscure vertical contrasts. The model is illustrated via application to sites in the Ouachita Mountains, USA, and northwest Saxonian Lowlands, Germany. The examples illustrate the importance of a comprehensive pedogeomorphic interpretation of layering, since neither standard stratigraphic or top–down pedogenetic principles necessarily apply. The examples also show that the same process can, sometimes contemporaneously, both create and destroy vertical contrasts.

Contents

1. Introduction

1.1. Soil layering

Layering is widespread in soils, regoliths, and surficial sediments, and the subdivision of profiles, outcrops, and geological sections into

* Corresponding author.
E-mail address: jdp@uky.edu (J.D. Phillips).

0012-8252/$ – see front matter © 2008 Elsevier B.V. All rights reserved.
doi:10.1016/j.earscirev.2008.04.003

vertically differentiated zones (vertical organization) is fundamental to geological, pedological, ecological and archaeological analyses. Layering in soils and other surface materials can have numerous and complex origins, involving geological, pedological, hydrological, and biological processes and various combinations thereof. Earth scientists of different backgrounds, training, and predispositions often bring to the study of layered materials different conceptual models. The purpose of this review is to identify the major conceptual models applied to the study of layering in soils, and to show how a synthetic approach incorporating elements of several of these can be useful in interpreting soil layering. While soils are indeed our primary focus, we use the term soil layering in this paper as a general term for layering in surficial or exposed material in general, be they soils *per se* or other regolith materials.

Ruellan's (1971) discussion of historical aspects of the study of soil horizonation and layering draws a contrast between "allochthonists" who attribute great importance to erosion and deposition in creating vertical zonations in soils, and "autochthonists" who attribute the majority of horizon differentiation to pedological processes. Ollier and Pain (1996) recognized this schism and commented "…the regolith is a kind of no man's land. It is generally conceived as the loose, weathered, ill-defined rubbish near the earth's surface that nobody wants to deal with […] to a soil scientist it may be the parent material for a soil but is itself of no further interest…" (Ollier and Pain, 1996: 1). The contrasting approaches of geomorphologists, geologists, soil scientists, and engineers to the study of weathered mantles is reviewed by Ehlen (2005), who advocated an approach borrowing elements from each.

While some of the disparities in the approach to the study of (layering in) weathered mantles and sediments are perhaps inevitable byproducts of different research goals, institutional and historical factors may also play a role. Tandarich et al. (1994) discussed the informal assignment of the solum as the domain of pedologists, while lower parts of the regolith were considered the domain of Quaternary geologists. The very concept of solum or "true soil," and the pronouncement of this as the domain of soil science by politically and institutionally influential figures in the USA, played a major role in this flawed division (Johnson, 1994). The arbitrary distinction between a pedological upper and geological lower zone resulted in, among other things, different terminologies for the same profiles and features, and a divergence in research paradigms. The historical development of soil and weathering profile concepts in the U.S. and Europe is outlined by Tandarich et al. (2002).

The importance of interpreting surficial layering is apparent in pedology, and in other earth science subfields such as sedimentology, stratigraphy, soil geomorphology, and paleopedology (see, e.g., Ruhe, 1956, 1974; Johnson, 1990; Wright, 1992; Pain and Ollier, 1996; Kraus, 1999; Retallack, 1999; Kemp, 2001; Schaetzl and Anderson, 2006). Such interpretations are also important in geoarchaeology, as they have a critical bearing on the interpretation of cultural materials contained within the layers (e.g. Harris, 1979; Johnson, 1990, 1993; Balek, 2002; Van Nest, 2002). Assumptions about the nature and origin of soil layers can also impact assessments of element dispersal and distributions in soils (Lorz and Phillips, 2006; Kacprzak and Derkowski, 2007).

The application of standard geological stratigraphic principles to regoliths and weathering profiles can lead to numerous errors, as those principles do not apply to regoliths. Ollier and Pain (1996; Pain and Ollier, 1996) provide numerous examples, as well as a proposed set of principles for regolith stratigraphy. The uncritical application of pedological conceptual models without consideration of geological processes can similarly lead to errors (e.g. Arnold, 1968), as Paton et al. (1995) discuss and illustrate.

1.2. Definitions

Following both pedological and geological convention, we use the term layer (see Table 1) to refer to any more-or-less tabular body of unconsolidated material or rock roughly parallel to the land surface or the surface on which it (is presumed to have) formed, and which is more or less distinctly limited above and below. In pedology, the term horizon is generally understood to refer to layers which are the product of, or are substantially modified by, pedogenic processes (soil layer). The U.S. Soil Survey Manual (Soil Survey Division Staff, 1993) specifies that horizons are "… distinguishable from adjacent layers by a distinctive set of properties produced by the soil-forming processes," while the term layer is used if the differentiation is inherited, or if no interpretation is made as to whether the differentiation is inherited or pedogenic. Standard geologic terminology defines soil and pedologic horizons in a manner consistent with pedologists, but note that a "geologic horizon" is defined as an "interface indicative of a particular position in a stratigraphic sequence," and is thus not necessarily related to pedologic horizon concepts (Jackson and Bates, 1997).

Geological discontinuities denote abrupt changes in rock properties. In pedology, a lithological discontinuity in soils is a significant change in particle size distribution or mineralogy presumed to indicate a difference in the material in which the horizons formed and/or a significant difference in age (Soil Survey Division Staff, 1993; see also FAO, 2006: 46). Lithological discontinuities in soils are discussed at length by Schaetzel (1998), who surveys the theory and detection of pedological discontinuities and applies the methods to drumlins.

Stratigraphic terminology includes a hierarchy of terms for geogenic layers assumed to be derived from depositional processes, with laminae being the thinnest recognizable units of original deposition. Several laminae may constitute a bed, while a number of beds may be included in a stratum (Jackson and Bates, 1997). However, terms such as stratum, bed, lamination, and layer are often used in

Table 1
Summary of definitions discussed in Section 1.2, along with any presumption of pedological (pedogenic), or geological (geogenic) origin stated or implied in the definition

Term	Definition	Presumed formation
Layer(ing)	More-or-less tabular body of rock or unconsolidated material roughly parallel to surface on which it presumably formed; distinctly limited above and below. Layering is the vertical organisation of a soil or regolith profile	None
(Soil) Horizon	*Layer* which is the product of, or substantially modified by, pedological processes	Pedogenic
Lithological discontinuity	Significant change in particle size characteristics or mineralogy that indicates a difference in parent materials or age	Geogenic
Beds	Sedimentary layer composed of several *laminae*	Geogenic
Cover beds	Surface depositional layer(s) distinctly younger than the underlying material	Geogenic
Stratum	Sedimentary layer composed of several *beds*; pl. strata	Sedimentary deposition
Stratigraphic unit	*Strata* recognized as a unit with respect to any of the many characters, properties, or attributes that rocks might possess; e.g., chrono-, bio-, or lithostratigraphic units	Predominantly geogenic
Soil-stratigraphic unit	Soils with physical features and stratigraphic relations that permit consistent recognition and mapping	Pedogenic
Pedostratigraphic unit	Buried, traceable three-dimensional body consisting of one or more differentiated soil horizons	Pedogenic
Geosol	Mappable ancient land surface	Pedogenic
Regolith	All unconsolidated material overlying bedrock	None
Soil	That portion of the regolith which differs significantly from the parent material, primarily due to pedological processes	Pedogenic