Earth-Science Reviews 103 (2010) 122–134

Contents lists available at ScienceDirect

Earth-Science Reviews

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

Soil science applications in archaeological contexts: A review of key challenges

Helen Walkington *

Department of Anthropology and Geography, Oxford Brookes University, Gipsy Lane Campus, Headington, Oxford, OX3 0BP, UK

A R T I C L E I N F O

Article history:
Received 4 December 2008
Accepted 7 September 2010
Available online 17 September 2010

Keywords:
pedoarchaeology
soil processes
pedology
equifinality

A B S T R A C T

The recent emergence and application of Earth Science techniques, such as elemental analysis, to detect isotopes, biomarkers, trace and ultra trace metals, in combination with long established techniques like magnetic susceptibility and micromorphology, can allow fascinating insights into the analysis of soils at archaeological sites. Soil studies can reveal how humans in prehistory used the landscape and defined space through their activities. However, these new approaches do not wholly address persistent problems associated with making inferences about past human activity from soils. These challenges include: equifinality; distinguishing property–process relationships; identifying anthropogenic soil processes; the interdependency of the soil forming factors; and difficulties with soil dating. This paper reviews more than a decade of pedoarchaeological studies, structured around new approaches to addressing these challenges.

The paper outlines a staged framework which helps to create a systematic interpretation of soil processes and properties, and considers the impact of anthropic soil processes and properties in this context. This approach can be used as a guide to ensure that a rigorous and reproducible approach is taken to the study of soils at archaeological sites. In making this framework explicit, the paper finds that establishing property–process relationships in the soil is an essential precursor to reliable pedoarchaeological interpretation. It is argued that in the future, new applications developed in the Earth Sciences that aid our understanding of archaeological soil processes in three dimensions, will be able to contribute the most to addressing persistent challenges in pedoarchaeological interpretation.

Contents

* Tel.: +44 1865 483185; fax: +44 1865 483937.
E-mail address: hwalkington@brookes.ac.uk.

0012-8252/$ – see front matter © 2010 Elsevier B.V. All rights reserved.
doi:10.1016/j.earscirev.2010.09.002

1. Introduction

Despite the numerous opportunities which the study of soils at archaeological sites provide, as well as the wealth of scientific approaches available for soil analysis, there remain several persistent challenges associated with making inferences about past human activity from soils. The recent emergence and application of earth science techniques for the analysis of soils at archaeological sites has generated new levels of understanding of human activities and use of the landscape. Inductively coupled plasma atomic emission spectroscopy (ICP-AES) and inductively coupled plasma mass spectrometry (ICP-MS), can help to detect isotopes, lipids and biomarkers and trace and ultra trace metals. In combination with long established techniques like magnetic susceptibility, phosphate analysis and micromorphology, the information gained can allow fascinating insights into the analysis of soils at archaeological sites. Soil studies can reveal how humans in prehistory used the landscape and defined space through their activities. However, these new techniques do not wholly address several persistent problems associated with making inferences about past human activity from soils.

This paper begins by briefly describing soils and sediments and their differences. It considers frameworks for understanding soil development and outlines how paleosols can be regarded as archives. It goes on to review five major challenges when studying soils at archaeological sites. These challenges include equifinality; distinguishing property–process relationships; identifying anthropogenic soil processes; the interdependency of the soil forming factors; and difficulties with soil dating. Each challenge is exemplified using recent literature relating to a specific soil related theme, such as the anthropic origin of Terra preta soils from the Amazon, soil erosion in the eastern Mediterranean, evidence of cultivation and manuring land management practices in north west Europe, the identification of activity areas in Meso America, site integrity and bioturbation at sandy sites in the US. Finally the paper outlines the interpretive framework currently adopted in pedoarchaeology.

1.1. The soil–sediment continuum

Soils and sediments are composed of similar components, and form a continuum over the landscape. The point at which a sediment becomes a soil is related to the vertical patterning of properties, that cannot arise from sedimentation alone, created by in situ transformations at the earth's surface. Sediments comprise layered, unconsolidated materials of lithic or organic origin. They usually show stratigraphy, are paler and have a lower organic content than soils. Although they can show iron staining, they do not have the characteristic weathering horizons that are found in soils. Sediments tend to accumulate during phases of instability and can be deposited very rapidly (Waters, 1992; Rapp and Hill, 1998; Goldberg and Macphail, 2006).

Soil formation (pedogenesis) occurs in situ, to create a continuous layer with weathering horizons such that the chemical and textural composition changes in line with earth surface processes (Waters, 1992; Rapp and Hill, 1998; Goldberg and Macphail, 2006). Soils mature slowly, thereby developing a sequence of recognisable horizons which are genetically linked to each other. They form over whole landsurfaces during periods of landscape stability. They therefore develop catenary sequences due to differences in drainage and slope processes. Sediments may have pedogenic (soil forming) processes acting upon them, and this blurs the distinction. The possibility of interaction between sedimentary and pedogenic processes is further complicated by anthropogenic impact. Separating these three influences at archaeological sites can be challenging. In order to do so it is important to understand the fundamental characteristics of soils which have not been directly influenced by human activity.

1.2. Soil formation

Soils have traditionally been studied through the framework of the soil forming factors, i.e., climate, organisms (flora, fauna and humans), relief, parent material and time (Jenny, 1941). Soil development therefore follows a pathway related to the interaction of these factors in a geographical location. The relative importance of temperature and precipitation patterns; floral, faunal and human impact; topographic position and drainage; the rock or sediment in which the soil develops and the time it has been forming varies significantly. However, more recently there has been greater recognition in the literature of an approach termed 'dynamic denudation' (Johnson, 2002; Johnson et al., 2005a,b). This approach stresses the importance of biodynamic processes, particularly bioturbation. Bioturbation is crucial in developing soil thickness relationships, i.e., the upbuilding, deepening and removal process pathways of soil formation. Johnson et al. (2005a) argue that biodynamic processes contribute to soil formation to a much greater extent than previously thought. Related to the notion of soil deepening, Tanadarich et al. (2002) argue that there is a tension between the geological concept of soil depth (the full depth of weathering) and the shallower pedological concept (the solum) which traditionally addressed the needs of agriculture. Instead they use the concept of a 'pedoweathering profile' so that subsolum properties cannot be ignored. Indeed, by investigating the depth of just one soil process, clay translocation, Johnson et al. (2003) noted that illuvial clay can be deposited at great depths in the regolith and at the contact with bedrock. The pedoweathering profile concept takes into account such depths which traditional definitions of soil do not. The depth of burial of an archaeologically important soil can be instrumental in helping it to preserve information about the past, but other environmental factors related to climatic, biotic, topographic and parent material characteristics also influence the information that can be gleaned from ancient landsurfaces.

1.3. Paleosols

Despite a variety of definitions, paleosols still remain best defined as soils formed in landscapes of the past (Yaalon, 1986). Paleosols can be classified according to their state of preservation. Relict paleosols are those soils formed on pre-existing landscapes, under previous environmental conditions, but which have always remained at the surface. Because they have not been buried, they exhibit horizons or features from previous environments, over printed by modern processes. Their features are therefore polygenetic (Goldberg and Macphail, 2006). Buried paleosols are the most useful for archaeologists because they were formed on a landscape of the past but buried by younger sediment such as loess, coversand, till, alluvium (Catt, 1987) or even by anthropogenic activity, such as construction of earthworks (French, 2003). For some classifications, buried soils