Introduction

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This special issue of *Geoarchaeology*, along with an upcoming second issue (Volume 22, Number 4), brings together archaeologists and soil scientists from different parts of the world to explore the methodological challenges and intellectual rewards gained from soil science research in archaeology. The articles in these two issues, which derive from a symposium sponsored by the Society for Archaeological Sciences at the 2003 Annual Meeting of the Society for American Archaeology, provide a comprehensive overview of the latest advancements in the chemical study of anthrosols (soils modified by human activity). In doing so, these papers strengthen our framework for developing inferences about past human behavior, especially in contexts where little or no material evidence persists. The contributions in this issue explore advances in the pedoarchaeology of agriculture. The subsequent issue covers innovations in activity area analysis using soil chemistry.

It has long been recognized that physical, biological, and chemical properties of soils may be altered significantly as a direct result of human activities (see Tan, 1998). It is not surprising, then, that soil chemistry has played an important role in archaeological research for nearly a century. Much of the early work focused on the relationship between soil phosphate and ancient human settlement to identify archaeological sites. Today, however, archaeologists draw on more complex multielemental assessments of anthrosols to consider links between soil chemistry and a wide range of human behavior, including agricultural traditions, household activities, and ritual practices, among others. Generally, soil chemistry in archaeology considers three areas of study: detecting and dating prehistoric sites, reconstructing past agricultural practices, and determining the location and organization of ancient activity areas.

The first influential studies on archaeological soil chemistry were published in Europe during the 1920s and 1930s, and were concerned with the application of phosphate analysis for detecting archaeological sites. In generating soil maps for the Swedish Sugar Manufacturing Company, Arrhenius (1929, 1931) observed that soils from areas of medieval occupation contained elevated levels of phosphorus compared to unoccupied spaces. The archaeological importance of this observation relates to the unique manner in which humans interfere with phosphorus cycling in ecosystems and to the fact that this element is relatively inert once fixed in soil. Arrhenius's later studies (1955, 1963), along with those of Lorch (1940), Dauncey

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Geoarchaeology: An International Journal, Vol. 22, No. 3, 285–290 (2007)

(1952), and others (e.g., Lutz, 1951; Dietz, 1957; Mattingly and Williams, 1962; Gay, 1964; Schwarz, 1967; Provan, 1971, 1973; McCawley and MacKerrell, 1972; Proudfoot, 1976; Sjoberg, 1976; White, 1978) in the decades that followed, led to the development and application of a variety of field and laboratory techniques designed to detect soil phosphates with the aim of prospecting for archaeological sites. The influential work of Eidt (1973, 1977, 1984a, 1984b, 1985) and others (e.g., van der Merwe and Stein, 1972; Ahler, 1973; Shackley, 1975; Woods, 1975, 1977; Berlin et al., 1977; Barba and Bello, 1978) in the 1970s and 1980s contributed to important methodological advancements, including techniques employing chromatography and fractionation. A recent article by Holliday and Gartner (2007) provides a thorough overview of the various methods of soil P analysis in archaeology. Crowther (1997) addresses issues in sampling and surveying.

Working together over the past 10 years, archaeologists and soil scientists have refined these techniques and developed several alternatives. Today, archaeologists make use of qualitative field procedures for detecting phosphate signatures using commercial test kits, although some have begun to experiment with laboratory-based weak (or mild) acid-extraction and strong acid-digestion approaches using ICP-spectroscopy, which produces quantitative results (e.g., Cavanagh et al., 1988; Ball and Kelsay, 1992; Sandor, 1992; Dunning, 1993; Sánchez Vizcaíno et al., 1996; Sánchez Vizcaíno and Cañabate, 1999; Terry et al., 2000; Wells et al., 2000; Parnell, Terry, and Golden, 2001; Parnell, Terry, and Sheets, 2002). In addition, researchers have begun to examine the implications of elements other than phosphorus for site formation processes (e.g., Barba, 1986; Linderholm and Lundberg, 1994; Entwistle and Abrahams, 1997; Entwistle et al., 2000; Parnell, Terry, and Nelson, 2002; Wells, 2004).

Since the early 1960s, soil chemistry also has been employed in radiocarbon studies of soil organic matter and pedogenic carbonates to determine the chronological significance of archaeological deposits (e.g., Stein, 1984; Frink, 1992; Cherkinsky and Brovkin, 1993; Chichagova and Cherkinsky, 1993; Orlova and Panychev, 1993; Wang and Amundson, 1996). However, these approaches are not often applied to archaeological work because they are currently cost-prohibitive for the meager budgets of many research projects, although they have proven useful for studying long-term changes in ancient environments.

While soil chemistry and agricultural science share a long history, their application to archaeological domains of inquiry is a relatively recent phenomenon. One of the earliest studies was by Cowgill (1961; Cowgill and Hutchinson, 1966) in the mid-1960s, in which she and her colleagues employed soil chemical analysis of lake sediment cores in the Maya Lowlands of Central America to investigate the effects of intensive cultivation of the region's soils prior to the sixteenth century. They found that widespread cultivation accelerated soil erosion, which resulted in the accumulation of thick, clay-rich deposits in Petén lakes. Not long after this work, another study, by Provan (1971, 1973) in the early 1970s, applied chemical analyses to anthrosols from Bjellandsøynæ, an Early Iron Age farm site in Norway. By investigating exchangeable sodium, potassium, calcium, magnesium, organic carbon, total phosphorus, and total nitrogen, Provan observed that the distribution of brown podzols correlated with cultivated parcels of land, while iron-humus podzols signaled undisturbed soils (see Kristiansen, 2001, for an update on archaeological podzol analysis in Western Europe). These early studies were important because they not only provided archaeologists with a research design and methodology for identifying ancient cultivated landscapes and modeling their impacts on local environments, but they also demonstrated that elements other than phosphorus can be used to investigate the ways in which agricultural societies practiced cultivation.

Aside from these isolated cases, however, only since the mid-1970s has soil chemistry played a major role in archaeological research concerned with reconstructing prehistoric agriculture. At first, these studies were largely limited to research on enrichment and depletion of certain plant macronutrients—namely, phosphorus, nitrogen, and potassium—over time. More recently, however, soil chemistry has been incorporated into large, multidisciplinary projects that combine archaeological survey and excavation with physical and chemical analysis of sediments, palynology, and molluscan ecology (for reviews of some of these projects, see Holliday, 2004; Wells, 2006).

In addition to elemental detection, studies of stable carbon isotope ratios (i.e., $^{13}C/^{12}C$ ratios) have become particularly important to prehistoric agricultural studies because of the characteristic isotopic signatures of C_3 and C_4 plant groups. Corn, for example, is a C_4 plant that is enriched in ^{13}C relative to most other cultivated and wild plants. As a result, distinctive carbon isotope signals produced by ancient corn crop residues are preserved in the humic acid components of soil organic matter. Humus extracted from the horizons of soils that were likely used for agriculture is enriched in ^{13}C, indicating that corn was grown in these areas. These kinds of studies have been used to trace the spread of corn agriculture in the woodlands of North America and in the tropical forests of Central and South America (e.g., Boutton, 1996; Webb et al., 2004).

In the first article in this issue, Elizabeth A. Webb and colleagues describe an exciting new technique for detecting evidence for maize agriculture among the Classic (ca. A.D. 250–900) Maya, which applies stable carbon isotope analysis to soil organic matter fractions from Motul de San José, Guatemala. Similarly, the contribution by Kristofer D. Johnson and colleagues in this issue documents isotopic evidence for maize farming at Aguateca, a rapidly abandoned Maya center located to the south of Motul de San José. Due to generally poor preservation of organic remains in the wet tropical lowlands, traces of corn are rarely encountered in archaeological deposits. Even in investigations of soils directly associated with what are now recognized as intensive agrotechnologies, such as raised fields and hillslope terraces, evidence of maize pollen, phytoliths, or fossilized macrobotanical remains (kernels, cupules, cobs) are scarce. Instead, archaeologists have had to rely on secondary evidence for corn, such as the occurrence of traditional maize-processing implements (manos, metates) at habitation sites, or through chemical analysis of human skeletal remains.

Using stable isotope analysis, Webb and colleagues are able to distinguish between C_3 and C_4 plants in bulk soil organic matter and in humic acid fractions from a variety of upland soils, potentially identifying which soils were once used for prehispanic maize agriculture. Johnson and colleagues also find this distinction, but their evidence comes from upland soils, depression soils (*rehoyadas*), and wetland soils (*bajo*) adjacent to ancient settlement. These studies not only demonstrate the explanatory value of stable isotope studies for understanding ancient subsistence practices, but they also reveal the variability in agrotechnologies employed by the prehispanic Maya without relying on excavated data. A broader view of the physical and chemical properties of the soil resources around Motul de San José is presented by Christopher T. Jensen and colleagues. They provide the soil characteristics, taxonomic descriptions, and modern Itzá Maya soil classification of the profiles used by Webb and colleagues in their carbon isotope studies.

In contrast to the water-rich tropical lowlands of the Petén, Jonathan A. Sandor and colleagues present the results of their work on ancient agriculture in the arid region of the American Southwest where water is a major limiting resource for crop production. The authors combine indigenous knowledge of soils and resource management with experimental chemical studies to investigate eleventh-century rainfall runoff farming practices at Zuni Pueblo for understanding their effects on nutrient and hydrologic processes, maize productivity, and soil quality.

Together, the articles in this issue demonstrate some of the new ways in which geoarchaeology and soil chemistry are integrating to provide compelling arguments about past human subsistence practices. To continue advances along these lines, archaeologists should work more closely with local communities to develop and incorporate folk typologies of soilscapes (e.g., Sandor, 1992, this issue; Jensen et al., this issue), and then to compare these classifications with those generated using traditional soil taxonomies from the agricultural sciences. In addition, if the contributions to this issue are any indication, future work will benefit greatly from isotope studies as well as other chemical and physicochemical approaches.

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