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An archaeological foundation to soil sustainability

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For the '**SPECIAL ISSUE: Making Ground**', guest edited by Jonathan Gardner, Jeff Benjamin and Matt Edgeworth.

Abstract
Diverging from traditional archaeology, our research focuses on decomposition rather than preserved fragments of what people left behind. We are looking at the bulk of what constitutes archaeological deposits: soil. Comparing the thickness of soil where people have lived to thickness where there has been no human occupation shows greater accumulation, or soil formation, where humans have been active. These same soils are also often characterised by higher fertility than soils formed in the absence of humans. The implication is that the decay of what people throw away, leave behind, or bury forms soil. Yet, what we characterise as archaeological sites do not appear to be 'wastelands' because they have been altered by time. Given modern threats to soil security, we are applying what we are learning from wastelands of the past to change attitudes today—we need to embrace waste, trash, or rubbish as the soil of the future.

Keywords: soil, Maya, Belize, anthropic, waste

<1> Introduction – the waste of time

In keeping with the issue's theme, our interest is landscapes created from the deposition of waste. The landscapes we have studied, however (Graham et al. 2017; Macphail et al. 2017), and continue to study, are distinctive from a modern wasteland in two ways. The first is that our waste is so old that it is no longer recognizable as the discard from human occupation; it has instead become soil, a formation process that forces archaeologists to *dig* rather than to pick things up conveniently off a modern surface. The second is that the term 'waste' is somewhat inadequate. The landscapes we study indeed include what people have thrown away, such as household rubbish or industrial waste, but they also include abandoned buildings, roads, pavements, old fields or gardens, objects lost and never found, and not least, the buried dead. What many think of as natural soil—formed through the physical and

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chemical breakdown of parent materials such as bedrock (Evans et al., 2019) —can have an anthropogenic origin (Capra et al. 2015; Howard 2017). Our research emphasis, however, is not on humans intentionally generating soil, as the term 'anthropogenic' implies and which can be said of plaggen soils (Blume et al. 2004). Instead, our emphasis is on extending the concept of *soil parent materials* to include anything and everything that is human-altered or human-transported (Galbraith 2018) (as listed above) or human-generated (e.g., human waste). Archaeologists are acutely aware of the fact that everything around us will eventually decay or disintegrate. In the process, the products of decomposition contribute to the build-up of the earth around us, to the physical and chemical components of soil, and ultimately to a material which demonstrates signs of soil health (Harris *et al*., 2022).

<1> Soil formation and soil sustainability

Why is the connection between archaeological sites and soil formation important? Soils are generally considered a non-renewable resource because soils are said not to form on a timescale relevant for humans (Evans *et* al., 2020). We argue that humans have a critical role in soil formation if one considers archaeological timescales and the attendant decomposition of what humans produce and leave behind. If a significant portion of the soil of the Critical Zone (Critical Zone; Giardino and Houser 2015) – the earth's boundary layer or outer 'skin' where rock, soil, water, and organisms, including humans, interact (Blum et al. 2006)—derives from the detritus of human activity (or very old waste), it follows that the future of the planet's soils are endangered not only by the low priority societies give to soil in sustainability scenarios but also by attitudes toward modern waste and waste practices.

There are several factors that point to the fact that present-day use of soils is not sustainable. Average global crop yields are progressively decreasing, and insufficient nutrients are an agronomic problem in many areas (Foley et al. 337, 340). The ability of many cereal crops to deliver full yields has fallen in the past 30 years (Watts et al. 2019, Indicator 1.5). Degradation processes characterise the earth's soils (Nachshon 2021); in fact, soil degradation and depletion outstrip soil formation globally (Gibbs and Salmon 2015). Recent work led by Evans et al. (2020) has found that over 90% of conventionally managed soils are thinning, with 16% having lifespans of less than 100 years.

What can archaeology contribute to soil sustainability that has not heretofore been considered? For one thing, diachronic factors in modern studies of agricultural viability of soils and land use are not long-term. Additionally, in studies of urbanism and sustainability, the management of waste and products of decay (e.g., human burial, building debris) get far less attention than architectural design or energy use. When waste and rubbish are the focus of attention, 'solutions' emphasise recycling (as if recycled material will never be discarded) or burial in sealed landfill deposits so that decay will not take place. What archaeologists can contribute is (1) the perspective of time (Graham et al. 2021), and (2) that the detritus of human activity is the main mechanism by which resources are returned to (the) earth. By demonstrating the connection between the decomposition of the products of human activity and soil formation, we also aim to contribute to efforts to change conventional negative attitudes towards waste and decay to create a favourable environment for true soil sustainability by demonstrating the connection between the decomposition of the products of human activity and soil formation. Conceptually connecting what humans throw away or leave behind to the positive concept of resource

renewal adds to the argument that decay and disintegration should be considered culturally as well as ecologically productive (Bardini 2014; DeSilvey 2017).

<1> Research questions and approaches

Our overall concerns are: How does waste—what humans throw away or leave behind—influence or contribute to soil formation? What are the effects on soil thickness and soil nutrient capacity? To address these questions, we must ask: What are the long-term decompositional processes, how do they operate, and how do they influence the character of modern surface and sub-surface soils? Our methods entail two different kinds of investigation. On the one hand, we employ archaeological methods to determine what humans left behind and the activities that generated the deposits. On the other, we turn to soil science to determine the chemistry, mineralogy and organic components of the deposits and their contribution to the sediment/soil profile as soil parent materials.

Our field study sites, Lamanai and Marco Gonzalez (see summaries in Graham and Howie 2021; Graham et al. 2017) are in Belize (Figure 1).

Insert Figure 1 about here.

Lamanai was a Maya urban centre for two millennia, and Marco Gonzalez, on Ambergris Caye, was a coastal commercial and manufacturing hub that was part of Lamanai's urban sphere of economic and socio-cultural interaction (Figure 2). Both sites are characterized for most of their long histories by dense populations and intensive activities, particularly circum-peninsular trade and commerce.

Insert Figure 2 about here.

Our Lamanai focus is both land use and the long-term use of mineral-based construction materials (AZOm) in urban environments (Figure 3); mineral-based construction materials are most familiar to us today as cements. The 'disadvantage' to Lamanai is that its extensive built environment makes it difficult to pinpoint areas that have not been intensively altered by humans, and hence baseline (natural) conditions are problematic to establish. In addition, Lamanai's late chronology and occupation (British colonial, 20th century) need more archaeological study in order to establish soil formation rates.

Insert Figure 3 about here.

Marco Gonzalez has a more modest built environment than Lamanai, but over 2,000 years of occupation remains concentrated at the southern tip of the caye. There are small, nearby islands with the same underlying geology of Cretaceous and Tertiary limestones but minimal to no evidence of human alteration that enable us to isolate and assess natural (baseline) conditions and processes. The Colson Point sites in central coastal Belize (Graham 1994) provide a similar opportunity, although with different soil parent materials via the geology of the Maya Mountains. These sites provide distinct cases not only to explore human/waste/soil relationships but to develop a methodology tracking decompositional processes over time.

Maya sites may not first come to mind when one thinks of processes of soil formation that have applicability to soil security (McBratney et al. 2014). Precolumbian Maya cities and settlements, however, illustrate the importance to soil security of people's engagement

with soil (Vis et al. 2023a, b). Lamanai and Marco Gonzalez are characterized by the presence of long and continuous sequences, from Preclassic (Lamanai, 1,600 B.C., Ambergris Caye, ca. 400 B.C.) to modern times. Given the archaeological work that has been carried out at the sites, we have good chronological control to assist in calculating soil formation rates (Figure 4). By this we mean that we can distinguish remains (decompositional products) representing successive activities over time and can date the activities archaeologically, usually to within 200 years or less.

Insert Figure 4 about here.

<1> Results so far

We have been able to identify a Maya Dark Earth on Ambergris Caye (Macphail et al. 2017) but unlike Amazonian Dark Earths (Arroyo-Kalin 2014), there is no evidence so far for intentional improvement of soils. Instead, the changes in fertility and the accumulation of deposits seem to reflect unintentional behaviour—the detritus of living, working, and dying. Work carried out between 2013 and 2016, sponsored by the Leverhulme Trust (Graham et al. 2017, Macphail et al. 2017, Turner et al. 2021) enabled us to provide evidence that the topsoil incorporated components from earlier occupations, particularly from the disintegration of pottery used to contain brine in salt processing and the fuel used to heat the brine and drive off water to produce salt cakes. Topsoil nutrient capacity was higher than expected in what otherwise would be a mangrove wetland. Recent research in 2023 suggests that dark earth layers may have developed in earlier periods, but these phenomena warrant further study.

Initial research in Life Cycle Analysis (Duncan 2019) was carried out, an approach that is used today to measure environmental impact. For LCA to be achieved, we discovered that we needed more data on the total amount of human-generated/human transported deposits at the site, and this effort would require a considerably greater degree of excavation than we were able to accomplish at the time. Some key processes were identified, however, such as the long-term impact of lime production, which acted as a contaminant during the period of manufacture but in time contributed key nutrients to the soil profile (Duncan and Graham 2023). Salt production in the 7th and 8th centuries A.D. used large amounts of wood from mangrove species as a fuel source; the high demand for wood fuel would have likely degraded the local environment. In time, however, the extensive amount of wood charcoal contributed carbon to the soil. The fragile ceramic containers used in salt production, tempered with quartz from the Maya Mountains, deteriorated easily and contributed quartz to the soil.

Although excavations at Lamanai began in 1974 (Pendergast 1981) and have continued until 2019 (Graham 2011; Graham and Howie 2021), land use soil studies only began in 2022. Preliminary results from a reconnaissance carried out in 2022 by Glanville-Wallis indicate that differences in soil development at Lamanai appear to be driven by processes related to topography (slope position) and moisture status, as well as human activity and land use. Human activity includes not only material inputs from different land uses but also alteration of site topography. Investigations so far suggest that much of the topography in the epicentres of the site (the central precincts changed over time) results from past Maya land use; the extent to which this extends into peri-urban areas is currently under investigation.

<1> Future work

Although initial work demonstrates that Precolumbian and pre-modern activities contributed materials to the soil formation process, it remains for us to work out the details concerning the full range of decompositional components resulting from the materials deposited during each time period; the chemistry, mineralogy or organic composition of these components, as well as their relative impact; the role of bioturbation; and the overall timing involved in the formation of the modern topsoil.

Future work has several aims. A priority is integrating results of archaeologically oriented soil micromorphology—which details components of cultural deposits invisible to the naked eye, as well as initial processes of decomposition—with soil science analyses that are carried out according to soil science protocols and, at least in the first stages, remain 'blind' to cultural categories. A key goal is to develop a methodology—applicable in a range of disciplines—that facilitates assessments of the long-term impacts of human activities under urban conditions today (Evans et al. 2021).

The role of ecosystem engineers is a key factor in soil formation, and we have begun with a focus on the land crab, *Cardisoma guanhumi*, ubiquitous at Marco Gonzalez and in coastal locations generally in Belize (Glanville-Wallis 2015). Soil fauna and microfauna play key roles in soil formation and in an increase in soil nutrient capacity (Carter et al. 2007), and we plan to expand research to include other invertebrates and fungi, with a focus on the long-term effects of human burial on soil microecology (Pawlett et al. 2019). Our cited published papers have detailed environmental change, but also, rather surprisingly, Precolumbian mercury contamination, for which an investigative strategy has been developed (Turner et al. 2021). We would like to build on previous LCA studies. This would require considerable funding to support extensive excavation, which we have not yet been able to acquire. In the interim, however, the goal of developing a methodology that integrates cultural assessments of deposits with studies aimed at clarifying pedogenesis will provide an essential tool in any further strategies for LCA. Non-wood macrobotanical analysis, as well as wood charcoal identification, was carried out under the Leverhulme project (Duncan 2019) and will continue. In addition to the early (Preclassic) apparent import of maize and nance (*Byrsonima crassifolia*) at Marco Gonzalez, plant remains should reveal the stage at which it became possible to grow crops. Vegetables and fruit trees are today grown on the island in association with sites of Precolumbian occupation; locals also transport soils from the archaeological sites to their gardens.

Concomitant with and superseding our scientifically oriented goals is our aim of improving and deepening people's engagement with soil (Salazar et al. 2020). Our first step is to add a new dimension to an understanding of soil origins. Soil is generally assumed, as noted above, to be a finite resource (Pozza and Field 2020) that can be "modified" by humans. An archaeological perspective introduces the idea that what humans build, destroy, manufacture, discard, bury, excrete, lose, or throw away eventually decomposes and becomes soil. This means that engagement with soil involves re-thinking human attitudes not only towards the soil we can see around us but also towards the discarded materials that will in time become soil. 'Waste' is not the ideal term to cover material that is connected solely by falling into disuse (buildings or roads), or by being discarded (rubbish) or by being buried (bodies), or simply by slipping from everyday consciousness; but no

adequate unifying (or connotatively positive) term exists in the English vocabulary. 'Remains' places significance on what was once whole with the focus—as in traditional archaeology—on the past. We aim to shift awareness to include what, in time, becomes of remains. We strive to direct attention to the decay of the material world associated with human behaviour and to how awareness of the importance of decay can inform people's engagement with soil.

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Captions

Figure 1.
Map of northern Belize during the Spanish colonial period showing the sites of Lamanai and Marco Gonzalez. (Drawn by Debora Trein and Emil Huston)

Figure 2.
Belize Maya chronology.

From AD 1981 to the present	Independence
AD 1964–1981	Self-governing British Colony
AD 1862–1964	British Crown Colony
AD 1787–1862	British Settlement
AD 1660s–1787	British occupation of the coast
AD 1641–1700 AD 1544–1641	Spanish colonial period
AD 1492–1544	Terminal Postclassic – Early colonial period
AD 1350–1492	Late Postclassic
AD 1200/1250–1350	Middle Postclassic
AD 962–1200/1250	Early Postclassic
AD 773–962 (898–1025)**	Terminal Classic
AD 735–773 (656–891)	Late Late Classic
AD 624 (588-659)–735 (601–870)	Early Late Classic
AD 500–600	Middle Classic (Provisional)
AD 250–500	Early Classic
AD 150–250	Late facet of the Terminal Preclassic or 'Protoclassic'
100 BC–AD 150	Early facet of the Terminal Preclassic
400–100 BC	Late Preclassic
600–400 BC	Late facet of the Middle Preclassic
900–600 BC	Early facet of the Middle Preclassic
1500–900 BC	Early Preclassic

Figure 3.
Reconstruction drawing of the High Temple at Lamanai, ca. 100 B.C. The High Temple, at 33m, is a good example of the intensive use of mineral-based materials (limestone, plaster, mortar) in construction. (Drawing by H. Stanley Loten for Lamanai Archaeological Project)

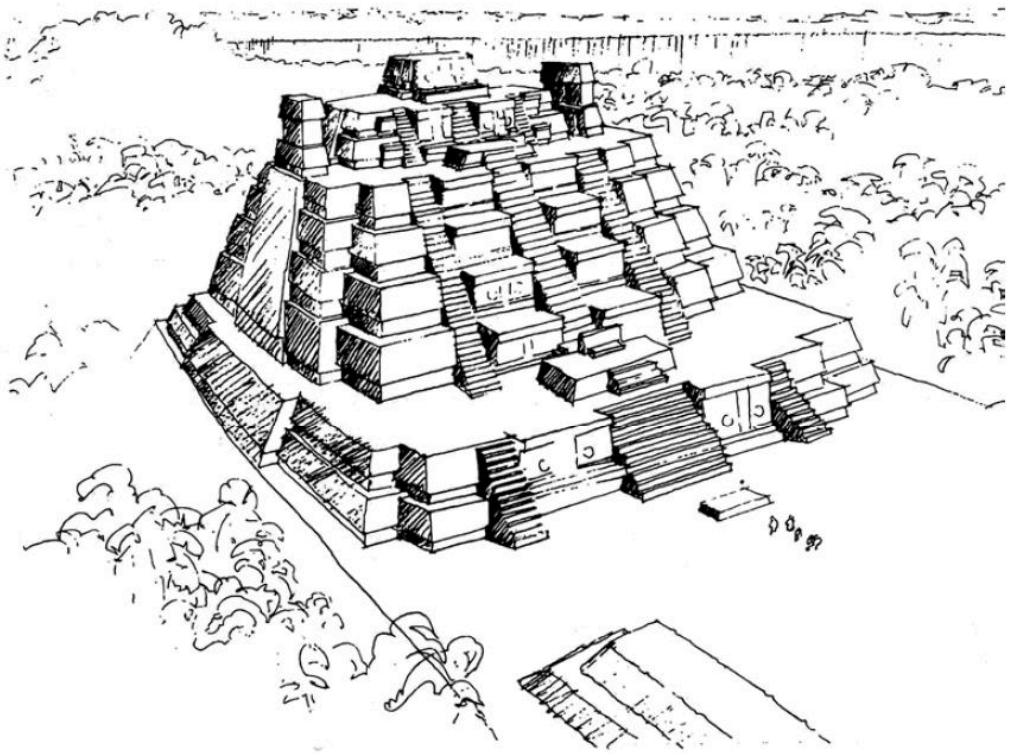

Figure 4.
One of the test pits at Marco Gonzalez showing the depositional sequence and upper-level Dark Earth. (Photo by permission of the Marco Gonzalez Archaeology Project)

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