



## Burnt lime production and the Pre-Columbian Maya socio-economy: A case study from the northern Yucatán



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### ABSTRACT

Burnt lime has been crucial for architectural, dietary, and other purposes in Maya society since as far back as 1100 BCE. The recent identification of a series of pit-kilns used for lime production in the Puuc region of the northern Yucatán Peninsula allows for an unprecedented investigation of the socio-economic organization of the Pre-Columbian lime industry. This article reports on the importance of burnt lime to Maya society and presents the results of spatial analyses of the pit-kilns in relation to other archaeological and environmental features. The distribution of the lime production features indicate that the Pre-Columbian lime industry was decentralized and organized at the small corporate group level. Some of these groups likely incorporated limestone extraction and processing into a broader multi-crafting subsistence strategy. Those small corporate groups that did not produce their own lime would have had to acquire it from producing groups through an intra-community exchange system. Spatial analyses also indicate that lime production locations reflect a desire to limit both pre- and post-production material transportation efforts. The study provides a model for investigating the production and distribution of a perishable craft good that can be used for examining perishable goods in ancient societies beyond Mesoamerica. The small-scale, decentralized lime production organization identified in the northern Maya lowlands can now be compared with systems of production and exchange of perishable goods in other pre-modern societies around the world.

### 1. Introduction

Burnt lime was used for construction, sanitary, dietary and other purposes by the Pre-Columbian Maya. The ubiquity of its use, as well as the large quantities of labor and raw materials involved, would have made lime production an important socio-economic endeavor throughout the Maya area. However, the ephemeral nature of both the material and its manufacturing locations has limited investigations of Pre-Columbian lime production. The recent identification of a series of lime pit-kilns in the Puuc region of the northern Yucatán Peninsula (Fig. 1) (Gallareta Negrón et al., 2015) provides the opportunity to investigate the socio-economic organization of the Pre-Columbian burnt lime industry. This article discusses the local organization of lime production at the site of Kiuc through a focus on spatial analyses of lime pit-kilns in relation to environmental and other archaeological features. The distribution of the pit-kilns throughout the Kiuc community indicates that burnt lime was most likely manufactured by

small-scale producers within a decentralized framework. The identification of this small-scale organization framework in the northern Maya lowlands introduces a model that can be compared with socio-economic production frameworks previously developed for societies throughout the pre-modern world.

The critical importance of burnt lime is not a feature peculiar to the Maya civilization. Societies across the globe have made and used burnt lime for a host of dietary, architectural, and other purposes for millennia. The earliest evidence for the production of burnt lime in the world yet discovered comes from Levantine Epi-Paleolithic Geometric Kebaran period sites (~12,000 BCE) in the form of lime-based plasters and mortars (Goren and Goring-Morris, 2008). While our understanding of the socio-economic systems underlying and structuring these earliest examples of lime production are hindered by their tremendous time-depth, studies of lime production organization from later Old World societies have benefitted from complementary documentary resources. For instance, archaeologists have access to a contemporary

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Fig. 1. An example of an annular structure located on the southwestern periphery of the Kiuic site center.

Roman manual for constructing and using lime kilns (Cato, 1998), as well as evidence of the Roman army centralizing lime production through its own large-scale kilns at places like Iversheim, Germany (Dix, 1979; Jackson et al., 1973). This type of in-depth understanding of the technologies and socio-economic circumstances surrounding lime production in some Old World societies has been relatively restricted in the Maya area until now. The lime pit-kilns identified in the northern Maya lowlands provide evidence for the independent development of similar production techniques and exchange mechanisms in Mesoamerica to pre-modern Old World societies with which the Maya had no contact.

The earliest evidence for architectural lime in Mesoamerica dates to approximately the 14th century BCE in Oaxaca (Marcus, 1989:163) and ca. 1100 BCE in the Maya area specifically (Hammond and Gerhardt, 1990:464). However, it is likely that scattered incidents of lime production occurred earlier. Architectural and decorative lime-based products were constant features of Maya sites from the Middle Preclassic up through the Spanish conquest. The burnt lime industry may have been especially significant in the Bolonchén district of the Puuc region where archaeologists have noted an especially high concentration of Pre-Columbian masonry architecture during the Late and Terminal Classic periods (Gallareta Negrón et al., 2015:1–4; Ringle, 2006). Several studies have investigated the potential environmental impacts of widespread lime production based on consumption estimates (e.g., Abrams and Rue, 1988; Hansen et al., 2002; Russell and Dahlin, 2007; Schreiner, 2002; Seligson et al., 2017a; Wernecke, 2008), but a lack of identifiable manufacturing locations has limited investigations of the economic importance of lime.

The identification of the Pre-Columbian pit-kilns at Kiuic allows for the first comprehensive investigation of lime production's role within the socio-economy of an ancient Maya community. The findings provide a basis for comparing Pre-Columbian Maya lime production organization with other pre-modern societies around the world. The lime kilns are distributed throughout Kiuic, but have their highest concentrations on the outskirts of the site core. This pattern likely reflects an attempt to balance the labor required for assembling the raw materials, including the wood fuel and grade of limestone most suitable for making burnt lime, and then transporting the burnt lime to the highest concentration of users in the site's nuclear zone. Spatial analyses indicate that just under 50 percent of both elite and non-elite small corporate groups had access to lime kilns and likely would have produced their own burnt lime. The half of Kiuic's small corporate groups that did not produce their own lime would have had to acquire it from the half that did, likely through some form of market exchange network. The findings presented here provide a model for addressing the role of this significant industry within socio-economies elsewhere in the Maya area, as well as for addressing the role of perishable craft goods in pre-modern socio-economies beyond the Maya area.

## 2. The importance of burnt lime in Maya society

Burnt lime is produced by heating calcareous material (limestone or marine shell in the Maya area) to at least 800 °C for at least 20 h in dry atmospheric conditions (Abrams, 1987; Russell and Dahlin, 2007; Schreiner, 2002:13; Seligson et al., 2017a,b). Carbon dioxide is released, carbonates decompose, and the raw calcium carbonate ( $\text{CaCO}_3$ ) is transformed into calcium oxide (CaO) or quicklime, a caustic material that resembles pure white pieces of limestone. Water is added to the quicklime, which causes it to crumble into a powder and stabilizes it, producing burnt lime, or calcium hydroxide ( $\text{Ca(OH)}_2$ ). The burnt lime is then used for a wide range of purposes, chief among them: architectural construction, *nixtamalization* (maize preparation), and sanitation.

Architectural lime products include plaster, stucco, and mortar, which are created by mixing water and aggregates with the burnt lime. The longer that the burnt lime is left to sit and mature before being used to make architectural products, the better it will hold and the less likely it will crack (Russell and Dahlin, 2007:409; Schreiner, 2002; Villaseñor Alonso, 2010:152–153). These products release water and absorb carbon dioxide as they dry to reform into calcium carbonate. Since at least as far back as 1100 BCE (Hammond and Gerhardt, 1990), the Maya have used lime products in the construction of residential and public architecture. Large amounts of lime mortar were used to construct stone-vaulted elite residences, as well as to hold temple-pyramids and palaces together. Although they would have used less architectural lime, non-elites would still have needed lime mortar to shore up the perishable wooden walls of their residences within their limestone foundations, as well as a lime-wash to cover the outsides of wattle and daub structures (Villaseñor Alonso, 2010:64). Lime-plastered plaza floors provide a much more sanitary surface on which to carry out daily activities than the soil of the forest floor. The introduction of such paved surfaces would have been crucial for maintaining a certain degree of hygiene as population centers began to grow (Barba Pingarrón, 2013:21; Riquelme et al., 2012:625; Villaseñor Alonso, 2010:67).

In addition to its importance for architectural purposes, burnt lime is integral to the Mesoamerican diet for enhancing the nutrition of maize. The *nixtamalization* process, by which maize is soaked in lime-infused water, releases certain b-vitamins such as niacin that otherwise would not be able to be absorbed by the human body (Barba Pingarrón, 2013:27–28). The development of this process may have even played a crucial role in allowing maize to become the staple crop of the Maya area and Mesoamerica more broadly. The *nixtamalization* process, and thus burnt lime, continues to be integral to the Maya diet today. In addition to its architectural, sanitary, and dietary significance, burnt lime likely served agricultural (Al-Bashaireh, 2008:72; Dunning, 1991; Villaseñor Alonso, 2009:43) and food storage purposes as well (Smyth, 1990:54). The Pre-Columbian Maya coated the surfaces of their bark-paper codices with lime plaster in order to provide smoother, more durable writing surfaces (Escalante Gonzalbo, 1999; Villaseñor Alonso, 2009:43). The importance of burnt lime transcends socio-economic disparities and continues to play a crucial role in so many aspects of daily Maya life to this day. This study sheds light on a production process that is rarely documented and/or documentable, but that would have played a central role in all Pre-Columbian Maya socio-economies.

## 3. The Puuc region and Kiuic

The Puuc region is a distinctive topographic and archaeological sub-region of the northern Maya lowlands that straddles the Mexican states of Yucatán and Campeche (Fig. 2). It is characterized by thousands of low hills, deep agricultural soils, and the complete absence of surface water. The Puuc is bordered on the northeast by the Sierrita de Ticul escarpment that runs southeast from the Pre-Columbian site of Oxkintok. Large archaeological sites including Uxmal, Nohpat, Kabah, and Yaxhom are located to the west of the Sierrita in the triangular,

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