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Invited review

Ancient Maya impacts on the Earth's surface: An Early Anthropocene analog?

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ABSTRACT

The measure of the "Mayacene," a microcosm of the Early Anthropocene that occurred from *c.* 3000 to 1000 BP, comes from multiple Late Quaternary paleoenvironmental records. We synthesized the evidence for Maya impacts on climate, vegetation, hydrology and the lithosphere, from studies of soils, lakes, floodplains, wetlands and other ecosystems. Maya civilization had likely altered local to regional ecosystems and hydrology by the Preclassic Period (3000-1700 BP), but these impacts waned by 1000 BP. They altered ecosystems with vast urban and rural infrastructure that included thousands of reservoirs, wetland fields and canals, terraces, field ridges, and temples. Although there is abundant evidence that indicates the Maya altered their forests, even at the large urban complex of Tikal as much as 40% of the forest remained intact through the Classic period. Existing forests are still influenced by ancient Maya forest gardening, particularly by the large expanses of ancient stone structures, terraces, and wetland fields that form their substrates. A few studies suggest deforestation and other land uses probably also warmed and dried regional climate by the Classic Period (1700-1100 BP). A much larger body of research documents the Maya impacts on hydrology, in the form of dams, reservoirs, canals, eroded soils and urban design for runoff. Another metric of the "Mayacene" are paleosols, which contain chemical evidence for human occupation, revealed by high phosphorus concentrations and carbon isotope ratios of C_4 species like maize in the C_3–dominated tropical forest ecosystem. Paleosol sequences exhibit "Maya Clays," a facies that reflects a glut of rapidly eroded sediments that overlie pre-Maya paleosols. This stratigraphy is conspicuous in many dated soil profiles and marks the large-scale Maya transformation of the landscape in the Preclassic and Classic periods. Some of these also have increased phosphorous and carbon isotope evidence of C_4 species. We synthesize and provide new evidence of Maya-period soil strata that show elevated carbon isotope ratios ($\delta^{13}C$), indicating the presence of C_4 species in typical agricultural sites. This is often the case in ancient Maya wetland systems, which also have abundant evidence for the presence of several other economic plant species. The "Mayacene" of c. 3000 to 1000 BP was thus a patchwork of cities, villages, roads, urban heat islands, intensive and extensive farmsteads, forests and orchards. Today, forests and wetlands cover much of the Maya area but like so many places, these are now under the onslaught of the deforestation, draining, and plowing of the present Anthropocene.

1. Introduction

Since Crutzen and Stoermer (2000) coined the term "Anthropocene," studies using the term have proliferated. Indeed, the term is now widespread in the mass media and across academic

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disciplines, with at least three journals (*The Anthropocene*, *The Anthropocene Review*, and *Elementa: Science of the Anthropocene)* and three Museum exhibits, planned and underway (Scott Wing, pers.com.). The US National Research Council (NRC) has recognized that one of their 'grand challenges' is to understand the nature of earth surface evolution in the Anthropocene (Chin et al., 2013; NRC, 2010). Multiple disciplines are addressing the issue. Both scientists and the broader public are aware that humans are having profound effects on Earth, but to quantify the scale and rate at which human impacts are altering the planet, we must know about background conditions and the chronology of change. One aspect of the Anthropocene discussion has been its timing, i.e. when did the period of large-scale human impact begin? This discussion has many precedents, from G.P Marsh's (1864) *Man in Nature*, to Carl Sauer et al.'s symposium in 1955 that led to *Man's Role in Changing the Face of the Earth* (Thomas, 1956), to B.L. Turner et al.'s (1993) *The Earth Transformed by Human Action,* to *The Americas before and after* 1492 (Butzer, 1992). Today, the concept of the Anthropocene transcends human impacts on Earth surfaces to include planet-changing greenhouse gases especially since the start of the Industrial Revolution (Ruddiman, 2013).

One expression of the 'Early Anthropocene' is in Central America, where the ancient Maya had profound impact on a globally important tropical forest (Figs. 1 and 13). Here we focus on the "Mayacene" or Maya Early Anthropocene and on a reckoning of environmental changes caused by ancient Maya Civilization from

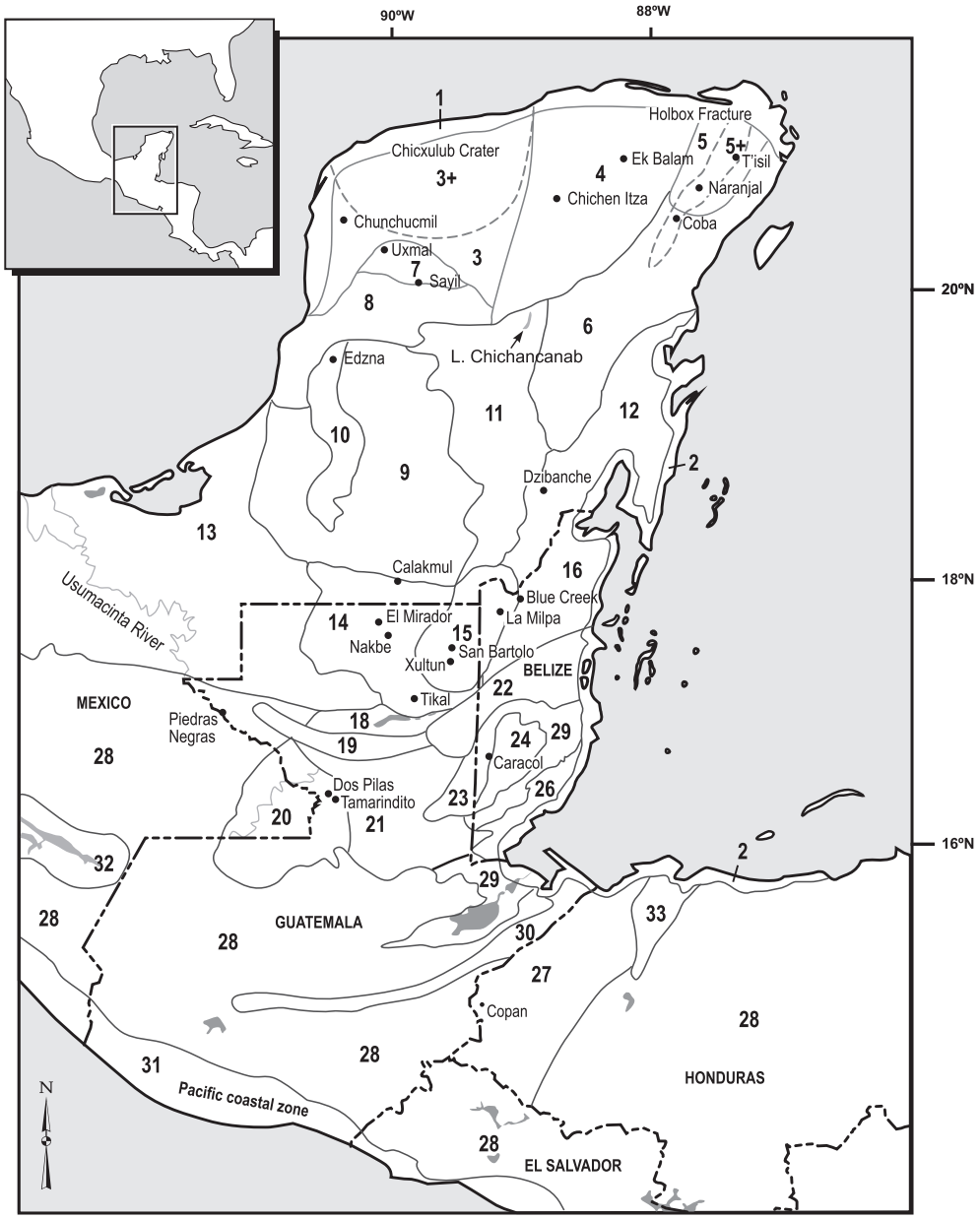

Fig. 1. Map of the Maya Lowlands showing physiographic sub-regions and sites mentioned in the text. (Numbers refer to sub-regions: *1 North Coast; 2 Caribbean Reef and Eastern* Coastal Margin; *3 Northwest* Karst Plain; *3 + Chicxulub* impact feature; *4 Northeast* Karst Plain; *5 Yalahau; 5 + Holbox Fracture; 6 Coba-* Okop; *7 Puuc-Santa Elena; 8 Puuc-Bolonchen Hills; 9 Central Hills; 10 Edzna*-Silvituk Trough; *11 Quintana* Roo Depression; *12 Uaymil; 13 Río Candelaria-Río San* Pedro; *14 Peten Karst Plateau* and Mirador Basin; *15 Three* Rivers Horst and Graben; *16 Rio Hondo; 17 Lacandon* Fold; *18 Peten Itza Fracture; 19 Libertad Anticline; 20 Río* de la Pasión; *21 Dolores; 22 Belize River Valley; 23 Vaca Plateau; 24 Maya* Mountains; *25 Hummingbird* Karst; *26 Karstic Piedmont; 27 Ulúa and Copán Valleys; 28 Highland Ranges and Valleys; 29 Sedimentary Fringe and Drainage of Maya Mountains; 30 Motagua Valley; 31 Pacific Coast; 32 Chiapas, Grijalva River; 33 Ulúa Delta.* (After Dunning et al., 1998; Dunning and Beach, 2010).