Catastrophic Volcanism and its Implication for Agriculture in the Maya Lowlands

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1. Introduction

This study investigates the potential importance of ash fall to our understanding of pedogenesis in the Maya Lowlands and, subsequently, for Maya agriculture and history. The widespread presence of volcanic ash in ancient Maya ceramics has led to suggestions that volcanic ash periodically fell across the lowlands (e.g. Ford and Glicken 1987; Ford and Rose 1995), but geoarchaeological data documenting regular ash fall has been lacking. Our discovery of the potential importance of ash fall in this region was made during geochemical analyses of well-dated excavated and extracted cores from reservoirs and natural depressions at the Maya ruins of Tikal, Guatemala. This discovery demonstrated that the sediments are derived chiefly from soil erosion and aeolian deposition from catastrophic volcanic events, which spanned the pre-habitation Late Pleistocene through to the Late Holocene, including the Preclassic through Post Conquest periods of Maya history (Dunning et al. 2015; Lentz et al. 2014, 2015; Scarborough et al. 2012; Tankersley et al., 2011, 2015). A previous study identified volcanic materials in soils from various parts of the Yucatan Peninsula, but did not seek to determine their origin (Bautista et al. 2011). Aeolian dust of African origin has also been identified in soils on the Yucatan (Cabadas et al. 2010; Bautista et al. 2011). To determine if ash from catastrophic volcanic events occurred in soils widely across the Maya Lowlands, we tested additional samples from widely geographically distributed archaeological sites in the Maya Lowlands, from northern Guatemala to Yucatan State, Mexico. We further posit that volcanic ash contributions were critical for maintaining soil fertility levels, especially in the southern Maya Lowlands and, thus, potentially linked to the sustainability of ancient Maya agriculture and its ability to support escalating populations in the Late Classic period (CE 550-800; see Table 1).

2. Maya Lowland Study Sites

Sediment samples were obtained from two soil pits in the Bajo La Justa, a large karst depression lying some 25 km southeast of Tikal, two soil pits from karst depressions near the ancient Maya site of La Milpa in northwest Belize, and a small depression near the ruins of Xcoch, Yucatan, Mexico (Fig. 1). Dunning collected these samples as part of three earlier projects (Dunning et al., 2003; Dunning et al., 2006; Dunning et al., 2014). These sampling locations were chosen initially as part of paleoenvironmental analyses conducted in association with archaeological projects examining human-environment interactions. The trenches were carried to bedrock or regolith and varied in depth from 80 to 230 cm. Soils were stored and initially processed in sterile conditions at the University of Cincinnati, Department of Geography soils laboratory.

2.1 Far West Bajo, La Milpa

Samples from La Milpa BH-09 and BH-10 were obtained in 1998 excavations in the Far West Bajo, a 2 sq. km. karst depression situated about 2.2 km west of the main plaza of the ancient Maya city of La Milpa, Belize. BH-09 was a trench excavated in a “typical” section of the flat bajo floor in Arbusto/Tintal forest (Dunning et al., 2003). This forest is dominated by *Haematoxylon campechianum*, a tree adapted to severe moisture extremes, and various stunted woody tree and grass species (Flores and Carvejal, 1994). The profile is fairly representative of many regional bajo soils, with a clear buried dark soil surface (unit 5: Ab horizon). Portions of the buried soil preserved thin bands of sapric organic matter with a conventional radiocarbon date of 1840 ± 40 yrs BP or a 2-sigma calibrated age range (CALIB 7.1) of AD 15-110 (Beta-121443). Pollen within the organic matter included *Nymphaea* (water lily) and *Typha* (cattail),

aquatic species no longer found within this bajo and indicating the former presence of a shallow lake or perennial wetland. Aggrading clayey sediments infilled the bajo sealing the Ab horizon. The predominance of smectite in these sediments coupled with increasing hydrologic extremes brought on by deforestation led to the development of a Vertisol soil characterized by high amounts of shrink-swell activity and the distortion of all horizons. Shrinking and swelling likely decreased after reforestation.

La Milpa BH-10 was a trench excavated in the floor of a small aguada (seasonal pond) within the Far West Bajo near La Milpa, Belize. Unit 5 is consistent with a shallow water deposit. Capillary deposits of gypsum are found in underlying horizons, most particularly in Unit 7, and are likely coeval with the drying of the aguada and bajo over time (Dunning et al., 2003)

2.2 Bajo La Justa

Bajo La Justa is a sprawling depression covering some 80 sq. km north of Lake Yaxha, Peten, Guatemala (Dunning et al., 2006). The samples La Justa Arbusto and La Justa Corozo were collected in soil pits excavated in the bajo floor in 1999 in two locations about 4.5 km north of the ancient Maya city of Yaxha. The Arbusto Pit was excavated on flat terrain where vegetation was typical Arbusto/Tintal forest like that at La Milpa BH-09 (see above), and the underlying soil is a similar Vertisol. The Corozo Pit was excavated on moderately sloping terrain mantled in forest dominated by Corozo Palm (*Attalea cohune*), a forest type typically associated with disturbed land (Brokaw and Mallory 1993; Dunning et al. 2003). The soil is a Vertisol similar to that in the Arbusto pit and in BH-09 (Dunning et al., 2006).

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88 2.3 Xcoch Zacate Savanna

89 The Xcoch Zacate pit was excavated in a 1.2 sq. km. karst depression lying about 500 m north of
90 the Great Pyramid at Xcoch, Yucatan, Mexico (Dunning et al., 2014). This depression is
91 currently covered largely in Guinea Grass, known locally as Zacate (*Megathyrsus maximus*).
92 Soil exposed in the excavation is an Alfisol (locally known as *kancab*) typical of similar
93 depressions in northern Yucatan. This location was included because it lies far to the north of the
94 other places included in the study within an area believed to receive eolian dust inputs from the
95 Sahara and from North America (Muhs et al., 2007, 2015; Das et al., 2011; Bautista et al. 2011).

96

97 3. Methods

98 3.1 XRD

99 Powder X-ray diffraction was used to identify the relative percent mineral composition of 36
100 sediment samples obtained from profile excavations in the Maya Lowlands. Soil strata were
101 defined on the basis of changes in Munsell soil color, particle size analysis, and sedimentary
102 boundaries. Samples were prepared for XRD analysis following the methodology described by
103 Tankersley et al. (2011, 2015).

104 The relative percentage of minerals was calculated by first totaling the counts per second
105 (cps) for each sample. The sum of all peaks (cps) for individual minerals was then divided by the
106 total cps per sample. Finally, dividing the total cps per mineral by the total cps per sample and

107 multiplying the sum times 100 provided the relative percent of each mineral (Table 2)(Fisher and
108 Underwood 1995; Milawski 2013).

110 **3.2 *Microscopy***

111 Heavy liquids were used to isolate volcanogenic crystalline minerals from Maya Lowland
112 sediments. Isolated crystals were identified under high magnification (>600x) with a Leica
113 MZ12 stereomicroscope and an Environmental Scanning Electron Microscope (ESEM).

115 **3.3 *XRF***

116 Whole rock X-ray Fluorescence Spectrometry (XRF) was used to determine the trace element
117 concentration of degraded volcanic ash from 36 samples from the Maya Lowlands. A Rigaku
118 3070 X-ray Fluorescence spectrometer was used to determine the intensity of the trace elements
119 Nb, Ti, Y, and Zr. Samples were prepared following the methods described by Tankersley et al.
120 (2011, 2015). Intensity data were converted to parts per million (ppm) using bivariate and
121 multiple variable regressions applied to United States Geological Survey, National Institute of
122 Standards, and Japan Geological Survey rock standards.

4. Results

4.1 Mineral Composition

As at Tikal, the minerals calcite, kaolinite, quartz, and smectite were found in sediments from La Milpa, La Justa Arbusto, La Justa Corozo, and Xcoch Zacate (Fig. 2). Calcite was the most abundant mineral (0-98%) and characterized by XRD peaks at 3.88Å, 3.38Å, 3.06Å, 3.03 Å, 2.50Å, 2.25Å, 2.29Å, 1.92Å, and 1.88Å. Smectite, the second most abundant mineral (0-96%), was characterized by XRD peaks at 15.63Å, 12.52-15.46Å, 5.98Å, and 4.50Å. The third most abundant mineral, quartz (0-60%), was characterized by XRD peaks at 4.20-4.25Å and 3.31-3.34Å. XRD peaks at 7.14-7.40Å and 3.53-3.56Å characterized kaolinite. XRD peaks at 14Å, 7Å, 4.72Å and 3.53Å characterized chlorite. Zeolite was also identified in two reservoirs (i.e., Corriental and Palace) at Tikal. The Maya may have added it to purify drinking water (Tankersley et al., 2015). As at Tikal, chlorite was identified at Xcoch Zacate in Mexico. Although Bajo La Justa is some 25 km southeast of Tikal, the sediments have comparable volcanogenic compositions suggesting that both sites were buried by the same catastrophic volcanic events. Chlorite, kaolinite, smectite, and first quartz are consistent with weathered volcanic ash deposited as aeolian minerals (Grim and Güven, 1978). They likely originated from andesitic, dacitic, and rhyolitic pyroclasts (Huff, 2008; Huff et al. 1999; Huff et al., 2000).

4.2 Zircons

Zircons commonly occur in felsic, granitic, and ultrapotassic volcanic ash. Zircons from the Maya Lowland soil samples appear as elongated dipyramidal tetragonal crystals about 250 µm in length with fluid inclusions (Fig. 3). Zircons can withstand extreme changes in heat and pressure

without compromising their original composition and are direct evidence of catastrophic volcanic events (Bindeman, 2006).

4.3 Trace Element Composition

The log of the Zr/TiO₂ ratio and the log of the Nb/Y ratio for sediments from the Maya Lowlands were compared to those from Tikal and to the composition of volcanic ash from catastrophic volcanic events in Guatemala, Mexico, and El Salvador (Table 3, Fig. 4). The trace element composition of sediments from Tikal and Xcoch Zacate is comparable to the trace element composition of Guatemalan and Mexican volcanic ash (Fig. 4). The trace element composition of sediments from La Justa Arbusto, La Justa Corozo, and La Milpa is comparable to the trace element composition of Guatemalan, Mexican, and Salvadoran volcanoes (Fig. 4).

5. Discussion

Geochemical and microscopic analyses of sediment samples from La Milpa (Far West Bajo BH-09 and BH10 pits), Belize, Bajo La Justa (Arbusto and Corozo pits), Guatemala, Tikal, Guatemala, and Xcoch (Zacate pit), Yucatan, Mexico demonstrate that a significant portion of the soil across the Maya Lowlands originated as weathered ash from repeated explosive catastrophic volcanic events. Ash fall occurred during the Maya occupation of the region and provided a mechanism for renewing soil fertility by increasing the nutrients, maintaining permeability and porosity, and replacing mineral material lost to erosion on sloping lands. Ash fall on this region today originates from strong eruptions of Guatemalan volcanoes such as

Fuego, Pacaya, Santa Maria, and Santiaguito, and from more distant explosive events from volcanoes such as El Chichón in northwestern Chiapas, Mexico (Gill 2001; Nooren et al., 2009). Between 28 March and 4 April 1982, the greater Maya Lowlands were blanketed by several centimeters of ash from El Chichón, and within a few months the ash degraded and enriched the soil (Espíndola et al., 2000; Gill 2001; Tankersley et al., 2011, 2015).

Sediments and soils in natural depressions such as *bajos* represent geologic material that has likely accumulated through the Quaternary. While age-appropriate stratification may be present, many of these soils such as those in the Bajo La Justa and around La Milpa are Vertisols, subject to considerable vertical mixing as the result of smectite-driven argilloturbation. Hence, volcanogenic material in these soils and sediments likely is from a wide age range. However, sediments and soils dating to the time of Maya occupation can often be identified because of the burial of pre-Maya or early Maya period soils under in-washing sediments generated by anthropogenic forest clearance and associated soil erosion. Since most of our samples were collected from above or within these buried soils we are confident that much of the volcanogenic material identified in these samples dates to the time of Maya occupation or shortly before. Further, the reservoir sediments from Tikal indicate that volcanic ejecta was deposited during the time of Maya occupation.

To varying degrees across time and space, ancient agricultural practices degraded the regional soilscape (Beach et al., 2006; Anselmetti et al., 2007). In addition to erosion, soils suffered from nutrient depletion associated with forest removal, an ecological change that produced cascading effects (Lawrence et al., 2007; Das et al., 2011; Dunning et al., 2012; Turner and Sabloff 2012). The soils of the Maya Lowlands are generally fertile, but notoriously low phosphorus. Locally, most available P is held in the biomass, but subject to recharge from

191 aeolian contributions (Das et al. 2012). These contributions may be in the form or local capture
192 of wood ash from burning forest, or from long-distance dust – or volcanic ash. However, as
193 forest is progressively removed from a location, the capture of dust is proportionally diminished
194 leading to decreasing P levels in the soil. Thus, as agriculture was intensified across the Maya
195 Lowlands, P levels in regional soils would have steadily declined. Declining soil fertility would
196 have had cascading effects. Yields would have declined necessitating clearance of more forest if
197 available. Plant health would have declined making crops more vulnerable to diseases.
198 Declining soil fertility would also increase vulnerability to field invasion by weedy species, most
199 notably of bracken fern (*Pteridium aquilinum* spp.), an aggressive plant that thrives in nutrient-
200 poor soil and which is noted for invading over-cropped fields in the southern Maya Lowlands
201 and for being difficult to remove once established (Pérez-Salicrup 2004; Dunning and Beach
202 2010). Thus, ironically, while the high-base-status soils and tropical climate of the Maya
203 Lowlands were favorable for cultivating maize and supporting high population densities,
204 population growth led to the incremental reduction of forest for construction material, fuel, and
205 farm land which would have created a risk spiral within the region, especially when coupled with
206 other environmental and cultural risk factors (Dunning et al. 2012; Turner and Sabloff 2012).
207 However, the regular, if unpredictable input of new mineral parent material from volcanic
208 deposition would have helped offset degradation.

209 For the Maya, whose agricultural system largely depended on local food production
210 within urban centers and their hinterlands, maintaining soil productivity was critical (Dunning at
211 al., 1998; Tourtellot, 1993; Scarborough et al., 2012). Soil renewal from volcanic ash would also
212 have been threatened by the decline of tree cover because less ash would be trapped and held on
213 upland soil surfaces, where much agricultural production was focused, with more ash carried into

depressions (Scarborough et al., 2012; Dunning et al., 2012, 2015; Lentz et al. 2014, 2015). Declining soil fertility would in turn have decreased the renewal of the forest itself, compromising vital fuel, construction and other resources on which the Maya depended. By the 8th century AD, population at urban centers such as Tikal were large enough to severely press agricultural and forest management systems, placing them at the edge of sustainability; declining soil productivity would have further stressed these systems (Lentz et al. 2015).

In the Late Classic period, some 30-40% of ceramics in the southern Maya Lowlands were manufactured with volcanic ash temper, encompassing both elite and commoner wares (Ford and Glicken 1987; Ford and Rose 1995). Ash is a far superior temper compared to grit derived from local limestone because of its ability to withstand much higher firing temperatures. Conservatively, some 1400 m³/yr of ash was employed in the creation of ceramics in the southern lowlands in the Late Classic, a quantity too large to have been transported 150 km overland from its nearest source in the volcanic highlands in a culture lacking beast of burden or wheeled vehicles (Ford and Glicken 1987). The collection and storage of ash after periodic eruptions is a more likely source of the ash. Ford and Rose (1985) suggest that the apparent greater prevalence of ash temper in the Late Classic may have been due to a greater frequency of volcanic eruptions during this period; greatly reduced use of ash in the Postclassic ceramics of the Peten Lakes region might indicate fewer eruptions. While the frequency of volcanic eruptions and the spatial and temporal pattern of ash temper use have not yet been properly quantified, the suggestion of greater eruptive frequency during the Late Classic also has implications beyond the availability of ash temper. More frequent eruptions in the Late Classic would also have helped sustain soil fertility and potentially fueled unprecedented population growth.

237 In the Late Classic, Maya agriculture and ceramic production were especially dependent
238 upon volcanic ash. Annual shifts in the Intertropical Convergence Zone (ITCZ) created highly
239 seasonal wind patterns and rainfall (Dunning et al., 1998). The ITCZ sits over the Yucatan
240 Peninsula with Trade Winds and Easterly Waves predominating during the wet season (i.e., June
241 through November). This situation would have effectively blocked ash fall from reaching the
242 Maya Lowlands. However, volcanic ash could have been more readily carried over the region
243 during the dry season (i.e., December through May) when the southward shift of the ITCZ brings
244 intermittent westerly and southerly winds (Giddings and Soto, 2003). Surface winds remain more
245 easterly on the northern half of the Yucatan Peninsula, especially on the coasts, but seasonal
246 shifts are more pronounced farther south and further inland, such as in the Peten District of
247 northern Guatemala. The potential distribution of ash from south to north is abetted when
248 eruptions send particulates into the upper Troposphere and lower Stratosphere where Hadley Cell
249 convection currents are moving air masses northward such as occurred with the March-April
250 1982 eruption of El Chichon (Gill 2001).

251 Maya water management systems constructed for the capturing and storing of rainwater
252 were subject to fouling from volcanic ash falls (Tankersley et al., 2011). This situation would
253 have been exacerbated in the Maya Lowlands when periods of aridity increased in frequency and
254 severity (Douglas et al., 2015; Dunning et al., 2012; Hodell et al., 1995). The number of days
255 when catastrophic volcanic events impacted the Maya Lowlands during drought years would
256 have increased with the failed or weakened development of the ITCZ (Haug et al., 2001).

257 Critically, drought years likely occurred when the ancient reservoirs, and the cities that
258 depended on them, were most vulnerable to water contamination from volcanic ash (Dunning et
259 al., 2012). Despite the occasional fouling of reservoirs, the overall impact of airborne ash

deposition from regionally active volcanoes was to provide ceramic production with raw materials as well as to enrich and stabilize agricultural soils; both of these benefits helped support population growth and social longevity for the Late Classic Maya.

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Figure 1. The geographic location of archaeological sites (stars) in the Maya Lowland and major volcanoes (after Milawski, 2013; Tankersley et al. 2015).

Figure 2. XRD analysis of sediments from Tikal, Bajo La Justa, La Milpa, and Xcoch (after Milawski, 2013; Tankersley et al. 2015).

Figure 3. Environmental scanning electron micrograph (ESEM) of a zircon crystal recovered from La Milpa (after Milawski, 2013; Tankersley et al. 2015).

Figure 4. The trace element content of sediment samples from Bajo La Justa, La Milpa, Xcoch, Tikal, and tephras from Mexico, Guatemala, and El Salvador.

Table 1. Major archaeological cultural periods in the Maya Lowland.

Major Period	Sub-period	Date Range
PaleoIndian		Pre-7,000 BCE
Archaic		7,000–2,200 BCE
Preclassic		2,200 BC–250 CE
	Early Preclassic	2,200–1000 BCE
	Middle Preclassic	1000–400 BCE
	Late Preclassic	400 BCE–100 CE
	Terminal Preclassic	100–250 CE
Classic		250–900 CE
	Early Classic	250–550 CE
	Late Classic	550–800 CE
	Terminal Classic	800–950 CE
Postclassic		950–1500 CE
	Early Postclassic	950–1250 CE
	Late Postclassic	1250–1500 CE

Table 2. Relative percent composition of Maya Lowland sediments based on powder X-ray diffraction (XRD) analysis. AMS radiocarbon dating suggests ash falls at Tikal were frequent throughout the late Pleistocene and Holocene (Tankersley et al. 2015).

Site	Provenience	Calcite (%)	Chlorite (%)	Kaolinite ^a (%)	Smectite ^a (%)	Quartz ^a (%)	Zeolite ^a (%)
Bajo La Justa	Airbusto Pit	0	0	10	68	22	0
Bajo La Justa	Corozo Pit (Range)	0-45	0	0-19	15-54	10-27	0
LaMilpa	BH 09 Unit 5	0	0	10	36	50	0
LaMilpa	BH 09 Units 1-4 (Range)	0	0	14-19	44-61	25-28	0
LaMilpa	BH 10 Unit 3	0	0	19	21	60	0
LaMilpa	BH 10 Unit 4	0	0	17	47	36	0
LaMilpa	BH 10 Unit 5	0	0	19	61	20	0
LaMilpa	BH 10 Unit 6	0	0	37	54	9	0
LaMilpa	BH 10 Unit 7	0	0	40	53	7	0
LaMilpa	BH 10 Unit 8	0	0	42	51	7	0
LaMilpa	BH 10 Unit 9	0	0	0	96	4	0
LaMilpa	BH 10 Unit 10	0	0	8	92	0	0
LaMilpa	BH 10 Unit 12	0	0	11	77	12	0
LaMilpa	BH 10 (Range)	0	0	0-42	21-96	0-60	0
Xcoch Zacate	Pit 2 Unit 1	44	16 ^d	16 ^d	8	32	0

Xcoch Zacate	Pit 2 Unit 2	61	13 ^d	13 ^d	9	17	0
Xcoch Zacate	Pit 2 Unit 3	63	9 ^d	9 ^d	16	12	0
Xcoch Zacate	Pit 2 Unit 4	55	20 ^d	20 ^d	15	10	0
Xcoch Zacate	Pit 2 (Range)	44-63	9-20 ^d	9-20 ^d	8-16	10-32	0
Tikal	(Range)	0-98	0-10	0-11	0-77	0-37	0-74

a. Volcanogenic mineral.

b. Zeolite peak co-occurs with smectite on the X-ray diffractogram. Both minerals result from the weathering of volcanic glass.

c. Natrolite is a zeolite found in amygdaloidal basalt and related igneous rock cavities.

d. Mixed chlorite/kaolinite layer.

Table 3. Trace element composition of volcanogenic sediments from the Maya Lowland and comparative volcanic sources.

Maya Site	Location	Ti	Zr	Nb	Y
Bajo La Justa	Arbusto Pit	1.03	21.12	0.87	1.57
Bajo La Justa	Arbusto Pit	1.06	20.51	0.91	1.32
Bajo La Justa	Arbusto Pit	1.10	20.90	0.86	1.03
Bajo La Justa	Arbusto Pit	1.07	21.06	0.87	1.78
Bajo La Justa	Arbusto Pit	0.89	13.28	0.85	3.13
Bajo La Justa	Corozo Pit	0.90	17.24	0.66	1.12
Bajo La Justa	Corozo Pit	0.94	16.74	0.72	1.27
Bajo La Justa	Corozo Pit	0.94	15.66	0.70	0.52
Bajo La Justa	Corozo Pit	0.60	8.54	1.31	12.44
Bajo La Justa	Corozo Pit	0.42	6.78	0.70	3.58
Bajo La Justa	Corozo Pit	1.02	14.86	0.88	0.82
Bajo La Justa Mean		0.91	16.06	0.85	2.60
La Milpa	BH-9	1.13	28.11	1.00	1.04
La Milpa	BH-9	1.22	25.72	1.03	1.02
La Milpa	BH-9	1.18	24.29	0.99	1.34
La Milpa	BH-9	1.16	0.96	0.78	25.49
La Milpa	BH-9	1.18	0.99	1.07	24.32
La Milpa	BH-9	1.06	1.01	2.06	22.53
La Milpa	BH-10	0.64	0.52	0.95	15.27
La Milpa	BH-10	0.88	0.76	1.21	15.88
La Milpa	BH-10	0.42	0.38	0.37	6.86
La Milpa	BH-10	0.34	0.47	4.01	3.83
La Milpa	BH-10	0.21	0.21	0.16	6.47
La Milpa	D-9	1.01	0.94	2.04	13.80
La Milpa	D-9	0.87	0.77	1.60	11.75
La Milpa	D-9	0.91	0.85	1.30	12.62
La Milpa	D-9	1.09	0.93	1.51	14.94
La Milpa Mean		0.89	5.80	1.34	11.81
Xcoch	Pit 2	0.95	0.82	1.50	10.60
Xcoch	Pit 2	0.87	0.82	1.46	10.31
Xcoch	Pit 2	0.64	0.62	1.16	8.06
Xcoch	Pit 2	1.16	1.11	1.97	13.63
Xcoch Mean		0.91	0.84	1.52	10.65
Tikal	Corriental	0.20	146	10	38
Tikal	Corriental	0.18	131	10	35
Tikal	Corriental	0.40	123	9	33
Tikal	Corriental	0.27	110	9	30
Tikal	Corriental	0.33	126	10	31
Tikal	Perdido	0.45	211	15	33
Tikal	Perdido	0.45	214	16	36

Tikal	Perdido	0.43	214	15	38
Tikal	Perdido	0.40	202	14	36
Tikal	Perdido	0.40	198	15	37
Tikal Mean		0.35	167.50	12.30	34.70
Mexico Mean		0.68	153	12.7	23.9
Guatemala Mean		0.68	132	7.3	17.9
El Salvador Mean		0.79	108	2.32	21.3