

# High-precision radiocarbon dating of political collapse and dynastic origins at the Maya site of Ceibal, Guatemala

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The lowland Maya site of Ceibal, Guatemala, had a long history of occupation, spanning from the Middle Preclassic Period through the Terminal Classic (1000 BC to AD 950). The Ceibal-Petexbatun Archaeological Project has been conducting archaeological investigations at this site since 2005 and has obtained 154 radiocarbon dates, which represent the largest collection of radiocarbon assays from a single Maya site. The Bayesian analysis of these dates, combined with a detailed study of ceramics, allowed us to develop a high-precision chronology for Ceibal. Through this chronology, we traced the trajectories of the Preclassic collapse around AD 150–300 and the Classic collapse around AD 800–950, revealing similar patterns in the two cases. Social instability started with the intensification of warfare around 75 BC and AD 735, respectively, followed by the fall of multiple centers across the Maya lowlands around AD 150 and 810. The population of Ceibal persisted for some time in both cases, but the center eventually experienced major decline around AD 300 and 900. Despite these similarities in their diachronic trajectories, the outcomes of these collapses were different, with the former associated with the development of dynasties centered on divine rulership and the latter leading to their downfalls. The Ceibal dynasty emerged during the period of low population after the Preclassic collapse, suggesting that this dynasty was placed under the influence from, or by the direct intervention of, an external power.

Maya archaeology | political collapse | dynastic origins | radiocarbon dating | Bayesian statistics

The processes of growth and decline of centralized polities represent a critical question in archaeological research. Particularly important moments of political changes in lowland Maya society include the decline of multiple centers at the end of the Preclassic Period (around AD 150–300), the emergence of historically documented dynasties at various centers at the end of the Preclassic Period and during the Early Classic Period (AD 200–600), and the abandonment of many settlements at the end of the Classic Period (around AD 800–950). The Classic collapse has long been an important issue in Maya archaeology (1–6). Scholars have presented various theories of its causes, including internal social problems, warfare, environmental degradation, and foreign invasions, although recent debates have focused on the effects of droughts (7–12). Scholars have more recently begun to address the Preclassic collapse, proposing droughts, the filling of lakes with eroded soils, and the intensification of warfare as its potential causes (13–15). The dynasties of some Classic-Period Maya centers appear to have originated in the period slightly before or around the Preclassic collapse, complicating our understanding of social dynamics during this era. The following Early Classic Period witnessed the emergence of more dynasties.

To understand how these episodes of political disintegration and centralization took place, we need to trace their processes through a refined chronology. Coarse chronologies tend to make these processes appear gradual by masking short-term changes. A higher-

resolution chronology may reveal a sequence of rapid transformations that are comprised within what appears to be a slow, gradual transition. Such a detailed understanding can provide critical insights into the nature of the social changes. Our intensive archaeological investigations at the center of Ceibal, Guatemala, have produced 154 radiocarbon dates, which represent the largest set of radiocarbon assays ever collected at a Maya site. Combined with a detailed ceramic sequence, this dataset presents an unprecedented opportunity to examine these critical periods of social change in the Maya area.

## Ceibal

Ceibal (also spelled Seibal) is the largest site located in the Pasión region of the southwestern Maya lowlands (Fig. 1). The site is known for having one of the earliest ceramic complexes in the Maya lowlands, dating to 1000 BC, and for its late florescence amid the Classic collapse. Ceibal was originally investigated from 1964 through 1968 by the landmark expedition of the Harvard Project (HP) (16–18). The ceramic chronology established by Sabloff as part of this project provided a solid basis, on which we developed our current study. Located in the Pasión region, Aguateca was studied from 1990 through 2005 by T.I., D.T., and K.A., providing 11 radiocarbon dates. Bachand excavated Punta de Chimino as part of the Aguateca Project and obtained 11 radiocarbon assays (19–21). We began to work at Ceibal as the Ceibal-Petexbatun Archaeological Project (CPAP) in 2005. Whereas our excavations originally focused on its ceremonial core, Group A, to document early buildings, we expanded our scope to examine a later elite complex, Group D, and the peripheral settlement (Fig. 2). The 154

## Significance

Tracing political change through refined chronologies is a critical step for the study of social dynamics. Whereas coarse chronologies can give an impression of gradual change, better temporal control may reveal multiple episodes of rapid disruption comprised in that span. Precise dating through radiocarbon determinations and ceramic studies is particularly important for the study of the Preclassic collapse, which lacks calendrical dates recorded in texts. The high-precision chronology of Ceibal revealed waves of decline over the course of the Preclassic and Classic collapses in a temporal resolution that was not possible before. The emerging understanding of similarities and differences in the two cases of collapse provides an important basis for evaluating the vulnerability and resilience of Maya political systems.

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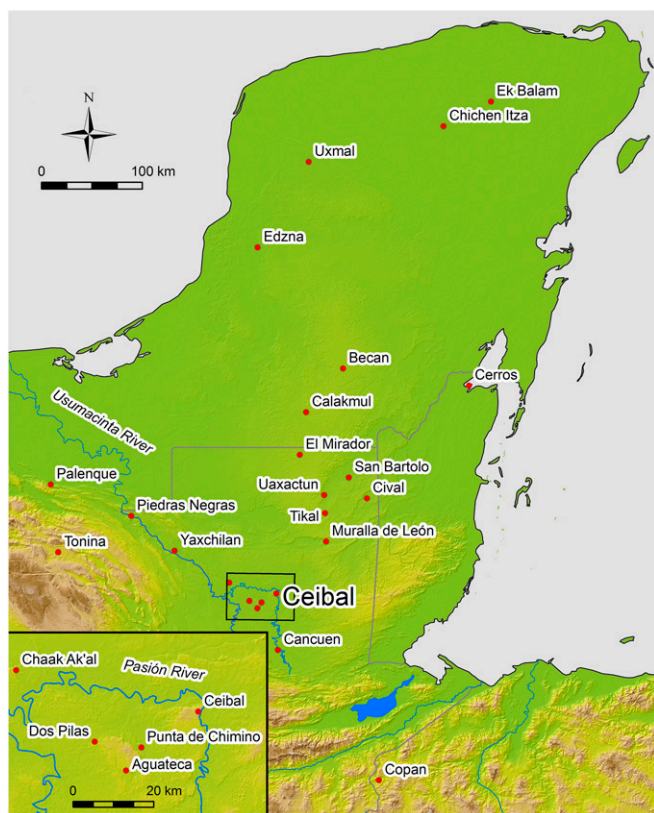


Fig. 1. Map of the Maya lowlands with a close-up of the Pasión region.

radiocarbon dates obtained by the CPAP include samples from the ceremonial cores and the outlying residential zone, as well as 9 assays from the minor center of Caobal excavated by Munson (22–25).

At Maya sites with long occupation, such as Ceibal, old deposits were often reused for fills of later constructions, and thus many layers commonly contained old pieces of charcoal. To reduce problems of stratigraphic mixing, we collected carbon samples mainly from primary contexts, such as on-floor burned layers, burials, caches, and shallow middens. When such contexts were not available, we also took samples from construction fills but focused mainly on those containing materials moved from short-period deposits, such as transferred middens and dumps.

## Analysis

We developed Bayesian models of our radiocarbon dates by combining information on stratigraphic sequences and ceramic phases. For the Classic Period, we also incorporated calendrical dates. In the analysis of the radiocarbon dates, identifying stratigraphically mixed carbon samples and old wood was a critical step (26, 27). The Oxcal program version 4.2 facilitated this process through the statistical identification of outliers and visual representations of probability distributions (28–30). The resulting refined calibrated dates helped us improve our ceramic chronology (Figs. 3 and 4, Figs. S1–S3, *SI Text*, Tables S1 and S2, and *Datasets S1* and *S2*). Our ceramic analysis showed that the original chronology developed by Sabloff was sound and solid. With detailed stratigraphic information from CPAP excavations and radiocarbon dates, we subdivided Sabloff's phases into shorter facets and established two new phases: Xate for the Terminal Preclassic (75 BC to AD 175) and Samat for the Postclassic (AD 1000–1200). The study of the Classic collapse through radiocarbon dating was challenging because calibrated radiocarbon dates from AD 700–950 typically had wide ranges of uncertainty resulting from a flat

section and large bends in the calibration curve for this time period. In examining this problematic period, we relied primarily on textual information from inscriptions to identify precise timings of political changes (31, 32). We have reported the results of our chronological study for the Middle Preclassic Period (1000–350 BC) in previous publications (23, 24). This article primarily addresses the Late and Terminal Preclassic (350 BC to AD 175) and Classic (AD 175–950) Periods.

To examine social trajectories, scholars have commonly estimated population levels with data obtained through survey, surface collection, and test excavations (33). Settlement investigations by Tourtellot during the HP provided important data in this regard (34). Nonetheless, surface collection and small test excavations typically produce a limited quantity of artifacts per tested site and may lack strict control of stratigraphy and contexts. The resulting chronological information tends to be coarse. Our study emphasized deep stratigraphic excavations, in which most lots (units of contextual control) were assigned to specific facets of our high-resolution chronology. The frequencies of lots and ceramics dating to specific temporal spans should approximate the intensity of construction and economic activity during those periods. To examine diachronic trends, we calculated values adjusted for the different lengths of periods, which we called time-weighted lot indices (TWLIs) and time-weighted ceramic indices (TWCIs) (Fig. 5 and *SI Text*). We should note potential biases in these data. For example, the large values for the Real and Escoba phases resulted partly from our excavation strategies emphasizing early constructions in Group A. Likewise, the TWLIs for the Bayal phase were somewhat inflated because we often subdivided a final occupation layer into more than one lot. Thus, TWLIs and TWCIs do not translate directly into regional population levels, but they reflect general diachronic trends and help us identify moments of marked increase and decline in construction and economic activity. Combined with Tourtellot's data on regional demographic estimates, our study traced social changes at a temporal resolution that was not possible before.

## Results

The first signs of social problems leading to the Preclassic collapse at Ceibal emerged at the beginning of the Xate phase, around 75 BC. Our study confirmed the observation by the HP researchers that the population of Ceibal declined significantly from the Cantutse phase to the Xate phase (Sabloff originally called them the Early and Late Cantutse phases, respectively) (18, 34). Xate ceramics at Ceibal corresponded to what Brady et al. defined as Protoclassic 1 ceramics for the Maya lowlands in general, which were characterized by pseudo-Usulután decorations with parallel wavy lines and nubbin, conical, or hemispherical tetrapods (35). Besides these diagnostic traits, many Cantutse ceramic types continued into the following period, making the identification of Xate occupation challenging. Tourtellot's calculation of a 74% population drop may have underestimated Xate occupation, but TWLIs and TWCIs also decreased drastically during the Xate 1 facet, suggesting that the decline in activity was real. An important change during this period was the establishment of Group D on a defensible hill surrounded by steep gullies and an escarpment. Although some residential groups in the periphery of Group D may have started during the Cantutse phase, as indicated by the HP archaeologists, our excavations demonstrated that the initial constructions of the ceremonial core of Group D dated to the Xate 1 facet. It is likely that the decline of Ceibal around 75 BC was related to the intensification of warfare in the region.

Activity levels in Group D and the outlying residential zone remained fairly constant from the Xate 1 to Xate 2 facet. The higher TWLI and TWCI of the Xate 2 facet in Group A resulted mostly from a large number of ritual caches deposited there. The



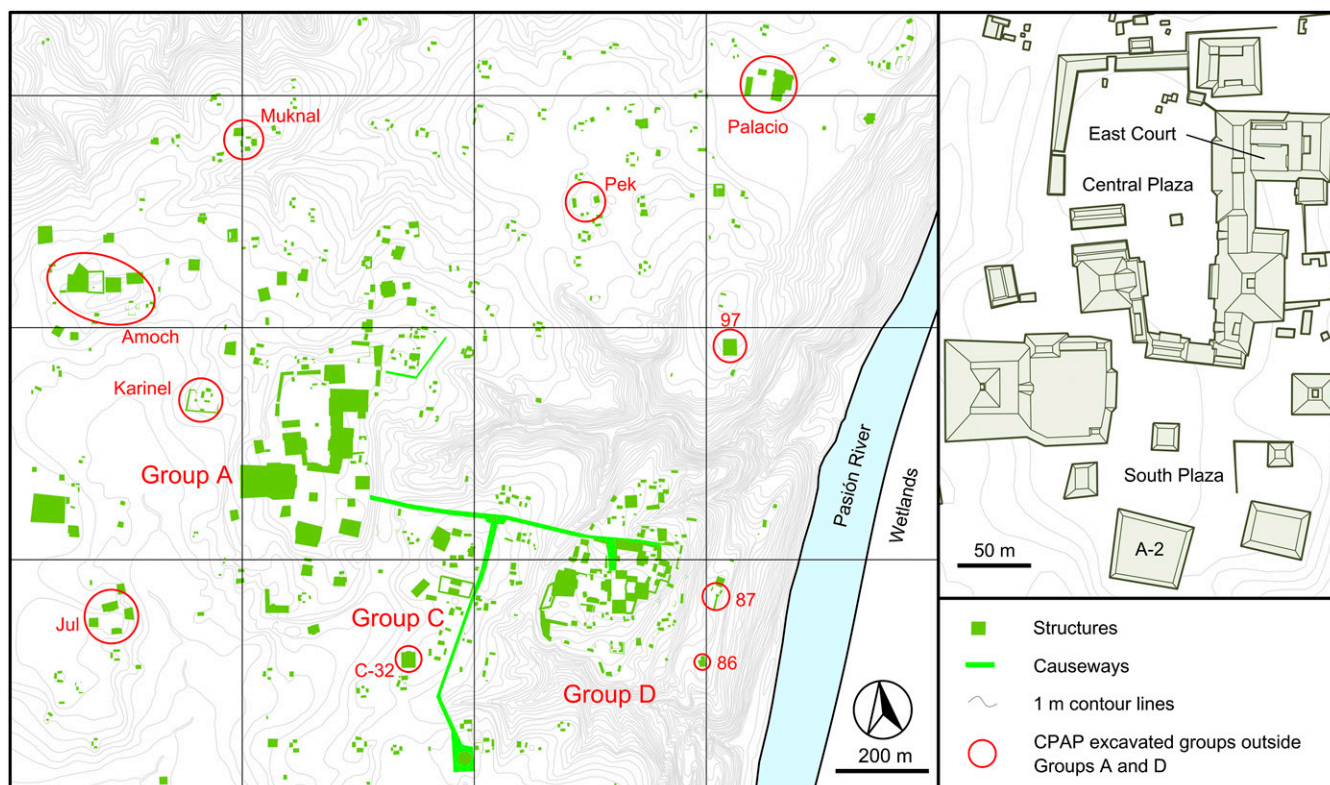


Fig. 2. Map of Ceibal with a close-up of Group A.

TWLI and TWCI declined significantly during the Xate 3 facet (AD 125–175), particularly in Group D and the residential zone. The values of this period for Group A are again inflated by numerous ritual deposits, although a similar decline in construction likely occurred in Group A as well. Group D and the residential zone regained some vigor during the Junco 1 facet (AD 175–300), which corresponded to Brady et al.'s Protoclassic 2 phase (35), characterized by Ixcario Polychrome and bulbous mammiform tetrapods. Tourtellot recorded a considerable number of Junco loci and suggested the continuity of Junco occupation from the Preclassic Period. We suspect that a substantial portion of the Junco occupation identified by the HP researchers dated more specifically to the Junco 1 facet. All of the studied areas, however, experienced a drastic decline at the end of this period, around AD 300. Some scholars have suggested that the ceramic types of the Preclassic Period continued to be produced during the Early Classic Period in the southwestern lowlands and that the assignments of these ceramics to the Preclassic resulted in significant underrepresentations of Early Classic populations (36, 37). Our ceramic study, however, showed that these ceramics could be confidently separated, and the Early Classic population decline was real. Many parts of Group D and the residential zone were deserted, and some minor temples in outlying areas were intentionally buried with black soils (34). Only a small population remained at Ceibal during the Junco 2 facet (AD 300–400).

The population level of Ceibal remained low throughout the Junco 2, 3, and 4 facets (AD 300–600). Remarkably, the Ceibal dynasty appears to have been established during this dark age of the center. The Ceibal Hieroglyphic Stairway, dedicated in AD 751, retrospectively mentions an early ruler possessing the Ceibal emblem glyph (dynastic title), who was active in AD 415 (38, 39). The reign of this individual at the beginning of the Junco 3 facet may have represented the origins of the Ceibal dynasty, although the inscription does not specify him as the dynastic founder. Excavations in Platform A-2 and the East Court of Group A, as well as the Karinel Group located

near Group A, uncovered Junco 3 ceramics, which closely resemble those from central Petén, including Dos Arroyos Polychrome and Balanza Black vessels with basal flanges, as well as a small number of Teotihuacan-inspired tripod vases. It is probable that the Ceibal dynasty was established under influence from, or through the direct intervention of, central Petén groups, possibly the growing center of Tikal. Notably, the largest concentration of Junco 3 ceramics was found in Platform A-2 located on the southern side of the South Plaza, which was likely a focus of elite activity during this period. This location may have mimicked the position of the Tikal royal place, the South Acropolis.

The HP researchers suggested that Ceibal was virtually abandoned during the sixth century, which made scholars wonder how the line of this early ruler connected to the Late Classic dynasty of Ceibal (40). Our research identified Junco 4 occupation dating to this assumed period of abandonment, which indicates that there was some continuity in the population of Ceibal, albeit diminished, from the Junco phase to the Late Classic Tepejilote phase. Tikal's influence over the Pasión region appears to have ceased after its defeat in AD 562 (41), but the Ceibal dynasty may have persisted.

After rapid population growth during the Tepejilote 1 facet (AD 600–700), the Classic-Period decline of Ceibal started with its defeat by the Dos Pilas-Aguateca dynasty in AD 735, during the Tepejilote 2 facet (AD 700–750). Construction and economic activity dropped significantly during the following Tepejilote 3 facet (AD 750–810). An illegitimate ruler named Ajaw Bot, who did not use the Ceibal emblem glyph, appears to have placed his palace in the defensible location of Group D, probably as a response to the intensification of warfare during this period (42). The number of bifacial points, possibly used as weapons, also increased significantly (43). The reign of Ajaw Bot ended shortly after the dedication of his last monuments in AD 800, and Ceibal underwent a hiatus in monument erection until AD 849. Excavations

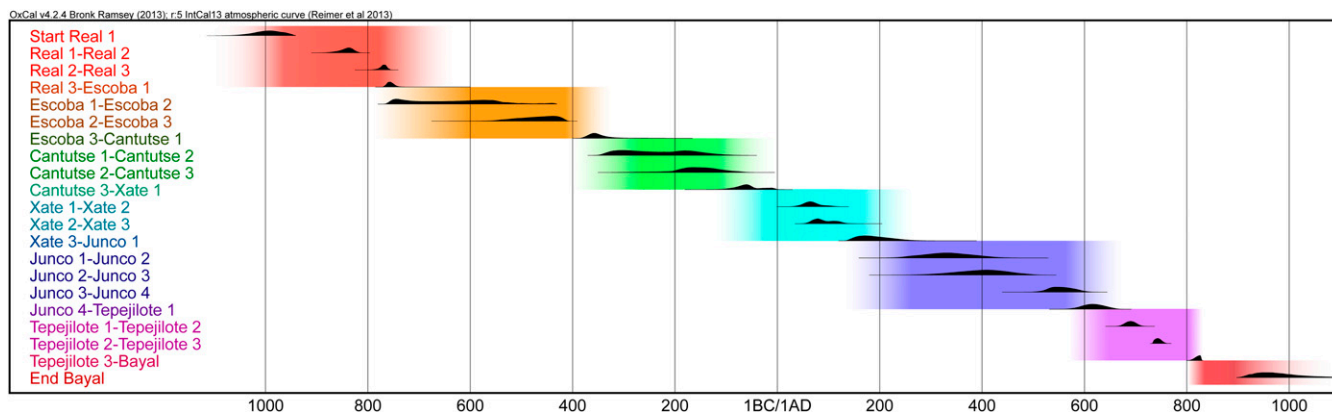


Fig. 3. Results of Bayesian analysis showing the probability distributions of phase boundaries.

at Group D by Bazy demonstrated that many buildings were ritually destroyed, most likely at the end of Ajaw Bot's rule (44). The relatively high TWLI and TWCI of Group D for the Tepejilote 3 facet resulted from Bazy's excavation strategy targeting these termination deposits.

We were not able to subdivide the Bayal phase (AD 810–950), and thus the TWLI and TWCI for this period were not refined enough to trace the social trend associated with this political disruption. Nonetheless, investigations by the HP and CPAP indicate that a considerable number of peripheral groups were abandoned or exhibited little activity during the Bayal phase, which possibly reflects the social effects of Ajaw Bot's fall. The arrival of a new ruler holding the Ceibal emblem glyph in AD 829, whose name may be read as Wat'ul K'atel, heralded a revival of Ceibal during the Bayal phase (45). This political regime, however, collapsed soon after AD 889, the last date recorded on monuments. The royal palace located in the East Court and some temples in Group A were destroyed, and Ceibal was completely abandoned (46).

## Discussion

Whereas the Classic collapse has a long history of study, aided by rich hieroglyphic records, the understanding of the Preclassic collapse is more limited. In this regard, our high-resolution chronology provides particularly important information on the latter. The trajectory of the Preclassic collapse at Ceibal exhibits a notable resemblance with that of the Classic collapse, with multiple waves of decline followed by short episodes of limited recovery. In both cases, the first signs of social problems appear to have been related to the intensification of warfare. Probable fortifications dating to the Late or Terminal Preclassic Period are found at other Maya sites, including El Mirador, Becan, Edzna, Cerros, Murralla de León, Cival, Chaak Ak'al, and multiple hilltop sites along the Upper Usumacinta River (47–55). Although it is not clear whether other Maya communities experienced decline during their Xate 1-corresponding periods, the construction of Group D in a defensible location at Ceibal was probably part of the growing social instability throughout the Maya lowlands around this time. The process of the Classic collapse in the Pasión region also began with the escalation of violent conflicts. Following the defeat of Ceibal in AD 735, Dos Pilas was also vanquished in AD 761 (56, 57). Then, a series of defensive walls were constructed at Dos Pilas and Aguateca, and Group D again became the center of elite occupation (58, 59). Violent encounters appear to have increased in other parts of the Maya lowlands as well (10).

In both the Preclassic and Classic collapses, early signs of decline were followed by a wave of drastic political disintegration throughout the Maya lowlands. In the former period, the major center of El Mirador and other Maya communities declined around

AD 150–175. The fall of El Mirador appears to have occurred during, or at the end of, the Xate 3-corresponding period, that is, the Protoclassic 1 phase, because of the presence of ceramics with pseudo-Usulután decorations and tetrapods and the absence of Ixcánrio Polychrome and bulbous mammiform supports in abandonment layers at El Mirador (60). Similarly, during the Classic collapse a major wave of political disintegration occurred around AD 810, which affected many centers over a wide area. Social impacts were particularly profound in the southwestern

Period	Long Count	Dates	Ceibal (Inomata)	Ceibal (Sabloff)	Uaxactun	Tikal	El Mirador
Postclassic	11.0	1200					
	10.10	1100	Samat	Post-Bayal		Caban	
Classic	10.0	1000					
	9.0	900	Bayal	Bayal	3	Eznab	
	8.0	800	3	Transition			
	7.0	700	2	Tepejilote	Tepeu 2	Imix	Lac Na
Early	6.0	600	1		1	Ik	
	5.0	500	4		3	3B	
	4.0	400	3	Junco	Tzakol 2	Manik 3A	Acropolis
	3.0	300	2			2	
Protoclassic	2.0	200	1		1	1	
	1.0	100	3				
	0.0	AD	2	Late		Cimi	Paixbancito
	BC	100	1	Cantutse	Chicanel	Cauac	
Preclassic	7.10	200	3	Early		Chuen	Cascabel
	6.0	600	2				
	5.0	500	1				
	4.0	400	3	Escoba	Mamom	Tzec	Late
Middle	3.0	300	2				Ox
	2.0	200	1				Middle
	1.0	100	3	Real	Eb	Late Eb	Early
	0.0	AD	2			Late	
	BC	100	1			Early Eb	
	200	200				Early	

Fig. 4. Chronological chart showing the ceramic phases of Ceibal and other Maya sites.

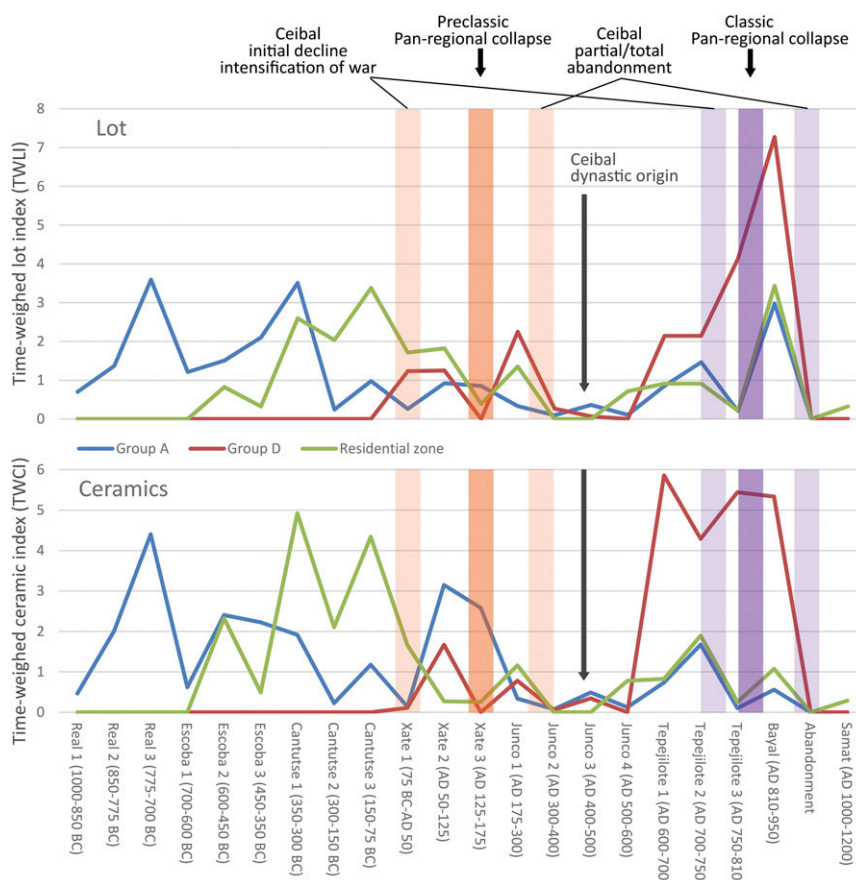


Fig. 5. TWLIs and TWCIs, approximating the intensities of construction and economic activity through time (SI Text and Tables S3–S4).

lowlands, where Aguateca, Cancuen, Yaxchilan, Piedras Negras, and Palenque declined or were abandoned in a short period (61, 62). The fall of Ajaw Bot at Ceibal was most likely tied to this regional process. Centers in other parts of the southern lowlands, such as Tikal, Calakmul, Tonina, and Copan, experienced somewhat more gradual decline or a hiatus in monument erection, although signs of political problems were not so clear in the northern lowlands (63). These major waves of political disintegration in both the Preclassic and Classic collapses may have corresponded with prolonged droughts, which may have exacerbated deteriorating social conditions (6, 12, 14, 15).

Processes following the wave of major collapse during the Preclassic and Classic Periods appear to have varied in different regions. At Ceibal, the decline around AD 300 was the most profound in the course of the Preclassic collapse. The Belizean site of Cerros may also have been abandoned around AD 300, following a major decline in population and construction around AD 150–175 (64, 65). It is not clear how widespread the wave of collapse around AD 300 was in other areas. In the central lowlands, dynastic rule solidified during this period. In the case of the Classic collapse, the ninth century witnessed political recovery at a limited number of southern lowland centers, including Ceibal, Tonina, Tikal, and Calakmul, and the prosperity of northern communities, including Uxmal, other Puuc centers, Chichen Itza, and Ek Balam. Many of these centers declined around AD 900–950, and only Chichen Itza continued as a powerful center for another century or so (66).

An intriguing question is the relation between the Preclassic collapse and the origins of Maya dynasties. Although the initial development of rulership can be traced back at least to the Late Preclassic Period, as suggested by the San Bartolo murals, it was

around the first century AD that historically recorded dynasties and royal tombs emerged at Tikal and possibly at other centers in the central lowlands (63, 67). These early dynasties probably predated and survived the major wave of collapse around AD 150–175. Centers in the peripheral zones of the Maya lowlands likely had some forms of political centralization during the Preclassic Period, but the historically known dynasties of these regions, such as Ceibal, Yaxchilan, Piedras Negras, Palenque, and Copan, appear to have originated during the fourth and fifth centuries, in some cases through connections with the developed dynasties of the central lowlands. Tikal, in particular, appears to have spread its political influence to Ceibal and other parts of the Pasión region, whose population levels continued to be low in the wake of the Preclassic collapse (41).

The Preclassic and Classic collapse exhibited tantalizing similarities in their diachronic patterns with multiple waves of political disruption, but they differed significantly in terms of the resulting forms of political organization. Whereas the former was tied to the development of dynasties with divine rulership, the latter led to the decline of this political system toward more decentralized organization and a stronger reliance on seaborne trade (5). Further analysis of these processes based on high-resolution chronologies should provide important insights into the vulnerability and resilience of these political systems.

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