Household Quarry-Reservoirs at the Ancient Maya Site of Yaxnohcah, Mexico

Jeffrey L Brewer and Christopher Carr

In this study, we present new data from the ancient Maya site of Yaxnohcah in southern Mexico. These data, which are drawn from lidar-based GIS analysis, field inspection, and the excavation of two small, closed depressions, suggest that many of this site's features served a dual function. Quarrying to extract construction materials left behind closed depressions that were then sealed to create household reservoirs. We classify these water-storage features as quarry-reservoirs. The ubiquity of these small quarry-reservoirs represented an important community water source outside the sphere of direct elite control.

Keywords: ancient Maya, water management, lidar

En este estudio, presentamos nuevos datos del antiguo sitio maya de Yaxnohcah en el sur de México. Los datos extraídos del análisis SIG basado en lidar, la inspección de campo y la excavación de dos pequeñas depresiones cerradas sugieren que muchos de estos elementos cumplían una doble función. Las canteras para extraer materiales de construcción dejaron de lado las depresiones cerradas que luego fueron selladas para crear depósitos domésticos. Clasificamos estos elementos de almacenamiento de agua como canteras-embalses. La ubicuidad de estas pequeñas canteras-embalses representaba una importante fuente de agua para la comunidad fuera de la esfera de control directo de la élite.

Palabras clave: Maya antiguo, administración del agua, lidar

Research combining lidar analysis, field inspection, and excavation at the ancient Maya site of Yaxnohcah in southern Mexico has revealed the multifunctional nature of small topographical depressions. Initially quarried for limestone, these features were then sealed and used as small water reservoirs. We classify these water-storage features as quarry-reservoirs.

Yaxnohcah is located in the Central Karstic Uplands of the Yucatán Peninsula, approximately 15 km southeast of Calakmul (Figure 1). Building on previous work by Šprajc (2008), the Proyecto Arqueológico Yaxnohcah was initiated in 2011 and has analyzed lidar data, conducted ground survey, and excavated numerous residential and water features across the expansive site area (see Reese-Taylor et al. [2016] for lidar details).

A six-month dry season necessitated the development of multiple levels of water storage by the ancient Maya. These storage features range from well-studied, large, central-precinct reservoirs to individual household water jars (Brewer 2018; Scarborough and Gallopin 1991; Weiss-Krejci and Sabbas 2002). In addition, depressions of varying sizes that originated as either natural karstic sinkholes or as anthropogenically quarried cavities often were sealed to retain water (Dunning et al. 2015; Horowitz et al. 2021). These small water-storage features may have been individually or communally controlled "household tanks," providing for the needs of individual homesteads or a group of residences (e.g., a plaza group). They were often located in residential areas removed from the urban core. We used lidar to map the location of candidate depressions and to guide us to those locations for field inspection and excavation. Expanding our previous study of small depressions (Brewer et al. 2017), we excavated two

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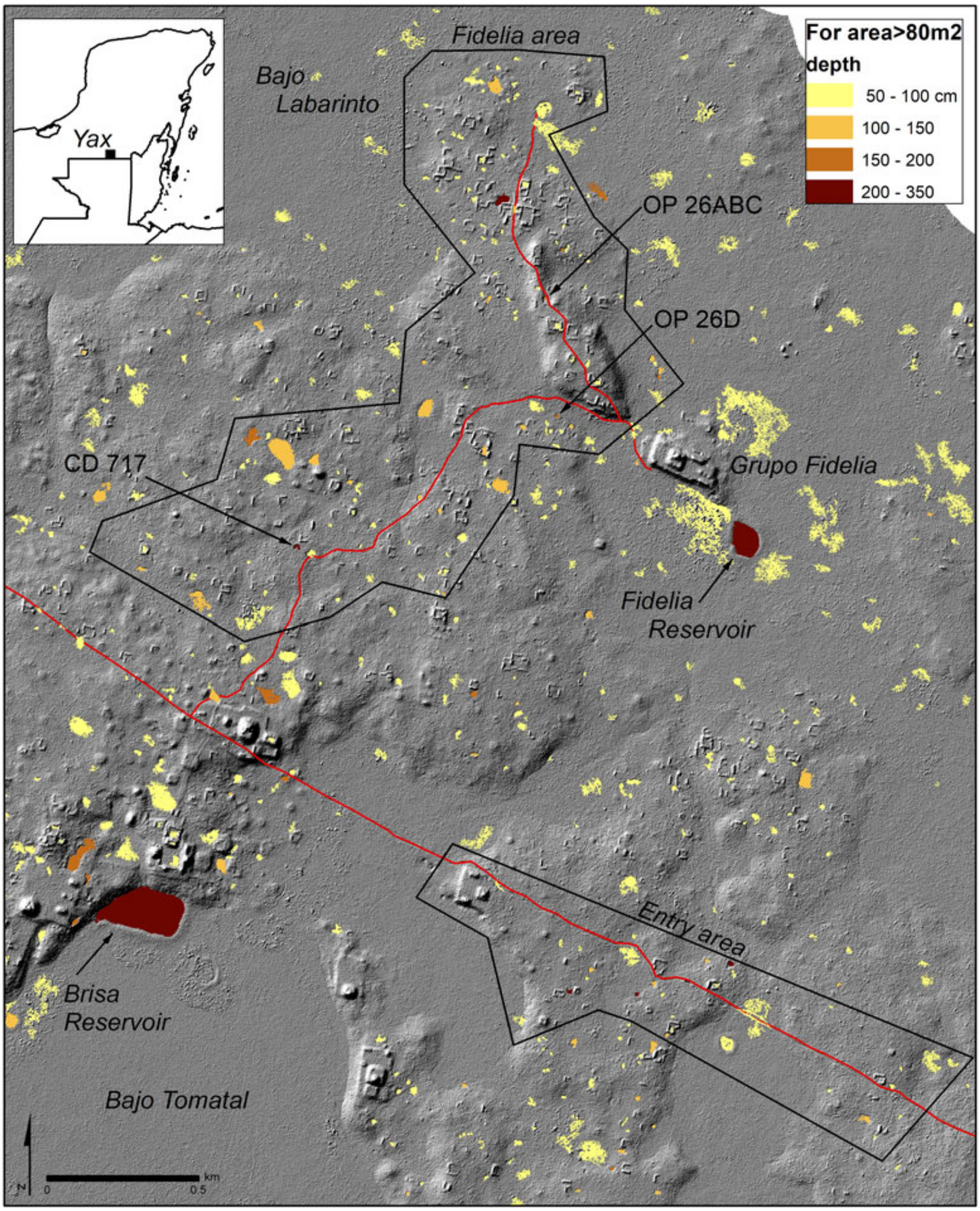

Figure 1. Lidar-derived hillshade image showing our two study areas. Coded by depth are the computer-identified closed depressions (CD) with surface area >80 m^2 and depth >50 cm (n = 494)—the household reservoir candidates. For comparison, two central-precinct reservoirs are indicated by arrows. Note CD 717, our reference quarry. Inset: Yaxnohcah location. Map by authors. (Color online)

closed depressions in non-elite residential areas during our third field season at Yaxnohcah (Brewer and Carr 2019).

We automated the analysis process to facilitate our search of the 24 km^2 lidar area for low spots where water could collect (closed depressions). This allowed us to focus on depressions that were difficult to identify by visual examination of lidar images and hard to locate through field inspection. The process used the ArcGIS hydrology "fill" tool, following Doctor and Young (2013). This automated process

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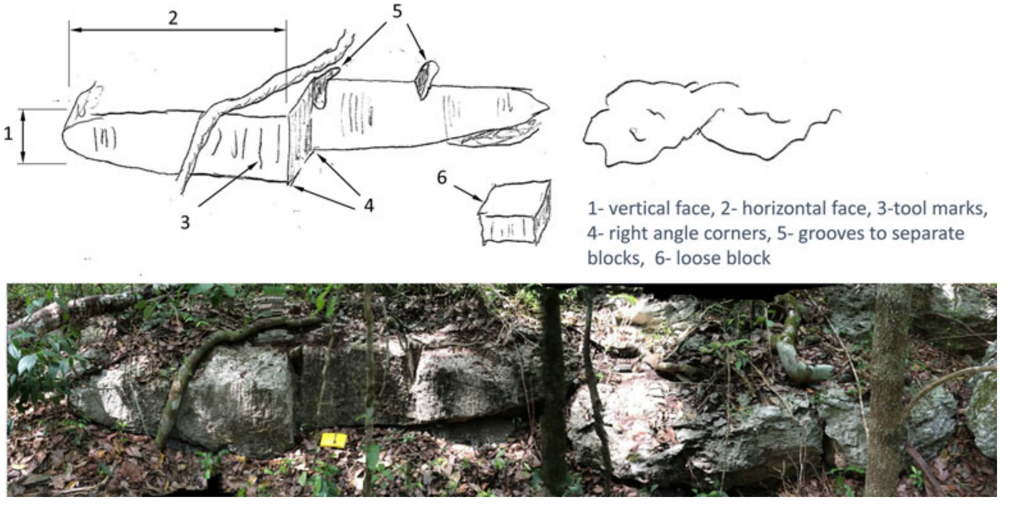

Figure 2. Elements used to identify a limestone quarry. This is one wall of CD 717 (depth = 2.0 m, surface area = 227 m^2). Photo by authors. (Color online)

takes the difference between the initial and filled raster data and groups clusters of filled pixels into polygons (the closed depressions). Standard GIS tools were used to assign a maximum depth and surface area to each depression. We selected our candidate list of depressions based on (a somewhat arbitrary) lidar-derived depth greater than 1 m and a surface area greater than 80 m^2.

Field Inspection of Candidate Closed Depressions

We inspected 66 closed depressions from two areas that are accessible by established project roads, selecting two for excavation based on their surface dimensions, proximity to residential structures, and general accessibility within the project area (Figure 1). Twenty-eight of the depressions from these two areas had lidar-derived depths greater than 1 m and a surface area greater than 80 m^2. As we moved from place to place, we opportunistically assessed an additional 38 depressions (depths less than 1 m). We characterized the closed depressions as displaying evidence of quarrying ($n = 48$; Figure 2), displaying no evidence of quarrying ($n = 8$), or "other" ($n = 10$). The "other" category encompasses five depressions with ambiguous evidence of quarrying; three formed by post-abandonment rockfall plaza groups; and two whose enclosing berm was not visible, leading to them being mischaracterized in the field as not being "closed." We further separated the closed depressions into three groups based on topographic position: those located in lowland *bajos* (solution pockets with a characteristic flat and level floor); those in upland area *bajos*, called pocket *bajos*; and those in upland areas outside of pocket *bajos*, which we call "upland non-*bajo*" (Table 1). Significantly, all 45 upland non-*bajo* depressions showed evidence of quarrying.

A review of the dimensions of the field-inspected upland non-*bajo* closed depressions suggests the parameters of what the site's

Table 1. Number and Size of Closed Depressions (CD).

	Lowland *Bajo*	Pocket *Bajo* (in upland)	Upland Non-*Bajo*	Total
CD-quarry count	0	3	45	48
CD-no quarry count	6	2	0	8
Median surface area	199 m^2	1,650 m^2	105 m^2	
Median distance to structure	102 m	40 m	31 m	

Note: All upland non-bajo CDs displayed evidence of quarrying, are small, and are close to structures.

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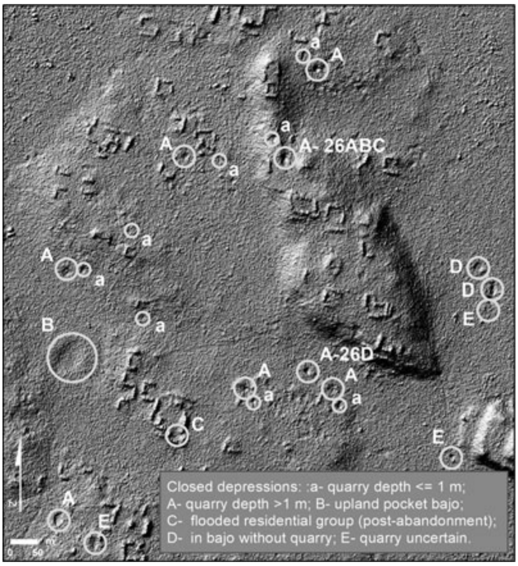

Figure 3. Hillshade image of part of our study area with closed depressions identified by the computer model, field inspected, and excavated (A-26ABC and A-26D). This small residential area (0.9 km^2) contains the 16 CD-quarry, which we suggest, based on its similarity to the two excavated depressions, is likely a reservoir under construction.

residents considered to be a "right-sized" household reservoir. We found 20 depressions with a lidar-derived surface area less than 100 m^2 (minimum size: 18 m^2), 18 from 100 to 200 m^2, and 7 from 200 to the maximum of 290 m^2. The smallest closed depressions may represent quarries that were in use at the time of site abandonment. Although the majority of these depressions are less than 200 m^2 in surface area, we hypothesize that the desired finished feature may be more in line with the maximum surface area—perhaps 200–300 m^2—based on the residents' desire for a reservoir large enough to provide for household needs while not taking up excessive living space. The distance between quarry-reservoirs and the nearest residential structures ranges from 3 to 87 m (median: 31 m), suggesting a strong spatial linkage between quarry and residence. The "signature" of a quarry-reservoir—a household water tank—is a small, roundish feature displaying quarry marks and located in the uplands near a residential structure.

Excavations of Candidate Closed Depressions

Operation 26ABC

This closed depression is located roughly 700 m northwest of Grupo Fidelia (Figure 3). The exposed rock face around the depression (Figure 4) exhibits cut marks that meet our definition of a quarry, including grooves in the rock that would have generated quarry rubble.

Based on dating of the recovered pottery sherds—$n = 4{,}602$; 49% identifiable (Table 2; Walker 2016)—the quarry-reservoir sequence started with a Preclassic period quarry, which was then leveled and sealed with a clay layer topped with a tamped sascab surface to create a watertight seal. Above this sealed Terminal

Figure 4. A typical closed depression of household-reservoir size (Operation 26ABC, backfilled post-excavation). Photo by authors. (Color online)

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Table 2. Yaxnohcah Ceramic Chronology.

Period	Date Range	Maya Ceramic Sphere	Yaxnohcah Complex
Postclassic	AD 1000–1450	None	LUCH
Late Classic	AD 840–1000	Tepeu III	XIKINCHE'
	AD 650–850	Tepeu II	LATE TUX
	AD 550–650	Tepeu I	EARLY TUX
Early Classic	AD 200–550	Tzakol	KIWI'
Late Preclassic	200 BC–AD 200	Chicanel	WOB
	400–200 BC		CHAY
Middle Preclassic	650–400 BC	Mamom	UM
	800–650 BC.	Pre-Mamom	LATE MACAL
	1000–800 BC		EARLY MACAL
Preceramic	1250–1000 BC	None	Unnamed

Source: Based on Walker (2016).

Table 3. Lidar-Derived Attributes of the Two Excavated Closed Depressions.

Operation	Maximum Depth (m)	Surface Area (m^2)	Watershed Area (m^2)	Distance to Structure (m)
26ABC	1.8	98	579	20
26D	1.8	133	272	41

Preclassic (200 BC–AD 200) to Early Classic (AD 200–550) period floor is a layer of quarry rubble consisting of extremely fine sandy clay, gravel, and cobbles located beneath the extremely degraded, virtually unrecognizable remains of a second, thinner-sealed Middle Classic (AD 550–650) surface (Figures 5 and 6). This floor is visible in the profile as a recognizable soil boundary separating the darker organic humus and sediment layer from the top of the lighter-gray sandy clay and gravel-cobble mixture. We also identified a third, uppermost surface corresponding to the Late or Terminal Classic (AD 650–1000). This floor was located beneath a layer of in-washed colluvium, which was separated from the underlying Middle Classic surface by another layer of quarry rubble. Within each rubble layer, we encountered numerous fragments of degraded plaster and stucco material that would have sealed these surfaces. A lack of water damage (no rounded, eroded edges) in the ceramic material suggests well-sealed plaster surfaces with little water exposure. Sherds represented just 0.5% by volume of the excavated material, negating the depression's use as a midden.

The dates, the presence of three distinct floors, and the nature of the quarry rubble all support the conclusion that the quarry-reservoir experienced an extensive period of use during which the initial limestone extraction occurred; this was followed by three episodes of quarrying that left rubble that was then sealed with a floor. These dates are supported by ^{14}C dates from Operation 26A, which range from the Late Preclassic (1990 ± 30 BP [ICA-0919; wood charcoal; no isotopic fractionation correction]) through Late Classic periods (580 ± 30 BP [ICA-0916; wood charcoal; no isotopic fractionation correction]).

Operation 26D

This closed depression likely also functioned as a water-storage feature. Its shape, depth, surface area, and partially exposed limestone quarry-like straight edges conform to our working profile of a quarry-reservoir (Table 3). We encountered a compacted, dark-gray clay layer that began approximately 50 cm below the ground surface. This layer may represent the heavily degraded remains of a thick, tamped clay sealant (Figure 7). Beneath this layer, we excavated through a less compact clay-and-gravel matrix that lay above what appeared to be a sealed clay-and-sascab lining overlying the base of the depression. Larger cobbles found at this depth likely would have served to level the uneven bedrock base of the depression before it was packed with this dense clay-mixed seal.

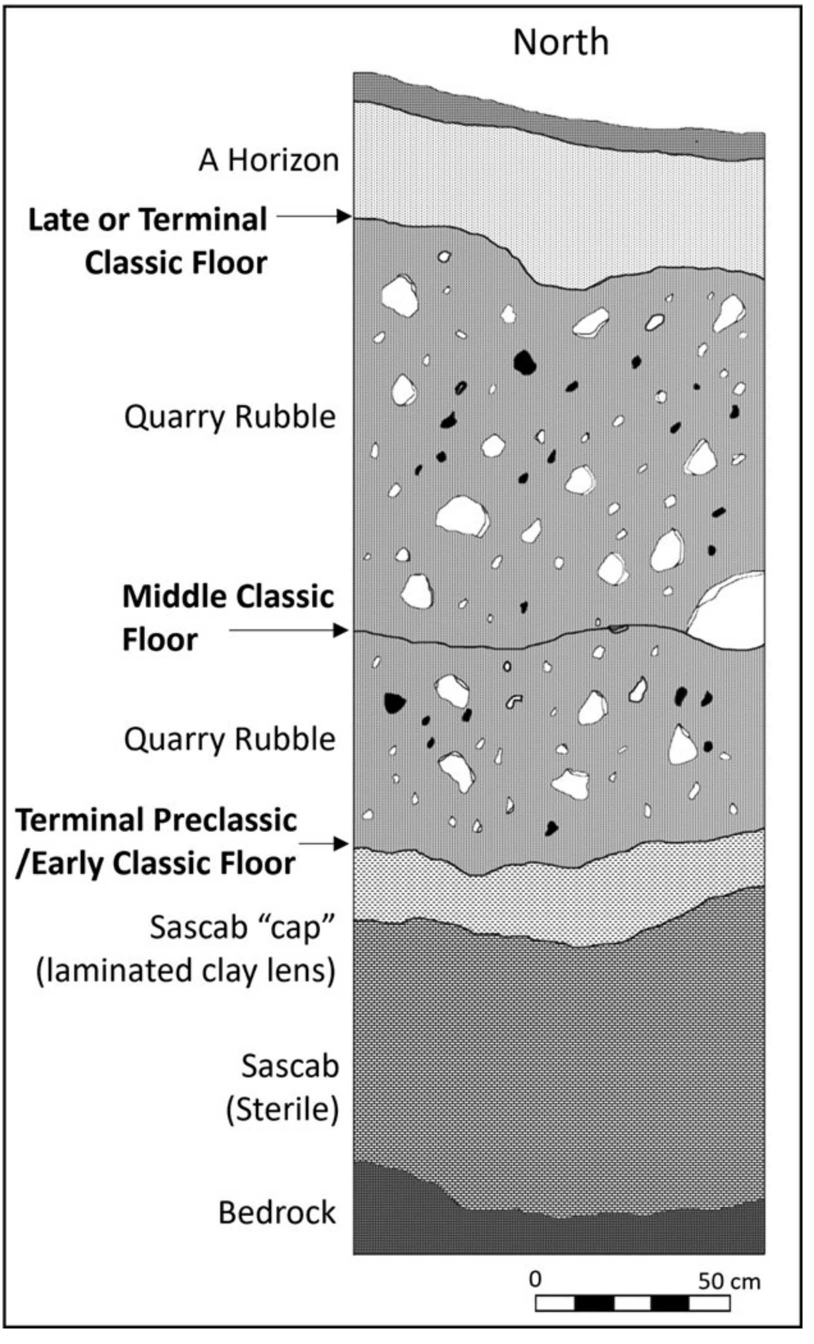

Figure 5. Operation 26A north profile showing three exposed floors.

This operation recovered little cultural material, likely because this depression was more distant from structures in the area. Of the 88 ceramic sherds collected, only 26 were able to be typed and dated. These were associated with the Late Classic phase of occupation (AD 550–850) and were all recovered from the bottom two lots (Operations 26D-5 and 26D-6) of the unit. Based on this limited evidence and the nature of the sealing method used in the depression, this

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Figure 6. Exposed Middle Classic period floor from Operation 26A. Photo by authors. (Color online)

feature may represent a comparatively low-tech Late Classic reservoir. The tamped clay floor corresponds to other Preclassic and Classic period aguadas excavated elsewhere in the Maya Lowlands (Akpinar Ferrand et al. 2012; Scarborough et al. 2012) and to sealed surfaces encountered in small, closed depressions investigated over prior seasons at Yaxnohcah (Brewer 2018; Brewer and Carr 2019).

Discussion

The creation and use of small depressions for water management have been demonstrated to be a temporally and spatially widespread practice

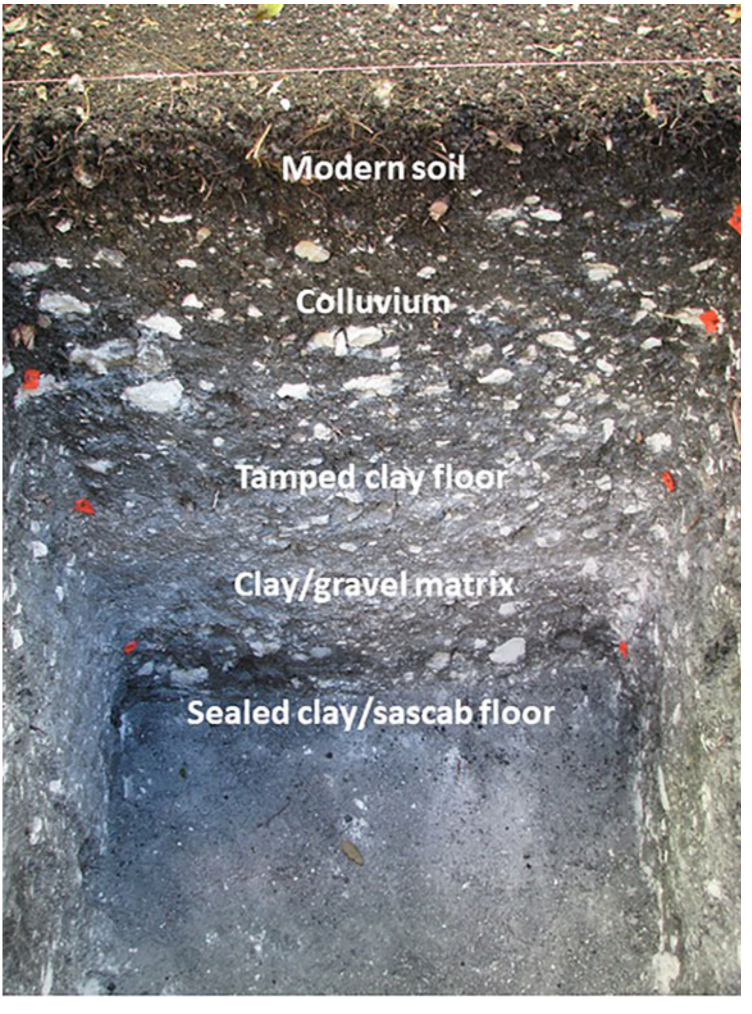

Figure 7. Operation 26D west profile showing two floors of varying construction. Photo by authors. (Color online)

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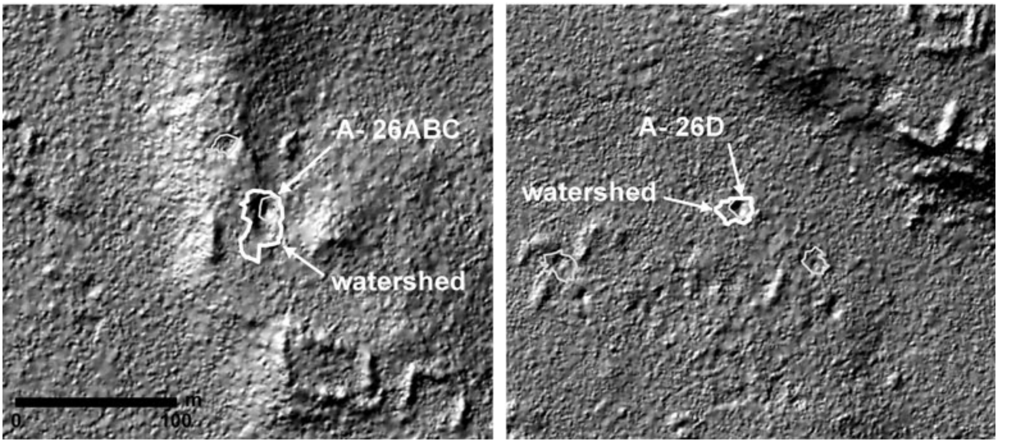

Figure 8. Lidar-defined watersheds of two investigated depressions.

beginning in the Preclassic period (Brewer 2018; Chase 2016; Weiss-Krejci and Sabbas 2002). Similarly, the extraction of limestone was continually done throughout the Lowlands, because the ancient Maya builders made use of the karst geology of their physical landscape to construct the structures and monuments that characterized their settlements and cities. Taken together, the frequency, distribution, and physical characteristics of these landscape features indicate that, in some cases, depressions were created by quarrying in a circular pattern for limestone blocks before then being sealed to serve as water reservoirs. The multiple floors and intermediate rubble suggest that, after their initial uses as a quarry and a reservoir, the quarry was reopened. We hypothesize that the subsequent quarries were expanded horizontally rather than vertically by removing limestone blocks from the edges of the quarry. This method required less labor than chiseling and levering the blocks up from the base of the quarry. In contrast with the dryer northern Yucatán Peninsula, the lidar shows that the watersheds of the closed depressions do not include the adjacent structures and plazas (Figure 8).

Other studies (cf. Brewer et al. 2017; Ruane 2015; Smyth et al. 2017) have suggested that quarried pits were used as reservoirs, but extensive, focused archaeological excavation and quantitative analysis are necessary to determine the exact scale and use of these features. Our scheme for classifying and identifying these features in the lidar imagery not only expedited our field inspection and excavation strategy at Yaxnohcah but also established a template for expanded analyses of human–environment relations, including water management, at the landscape scale. Our data show that quarry-reservoirs served as communal nodes for resource extraction, collection, storage, and distribution for more than a millennium—a critical period in Maya history during which expanding urban populations necessitated significant investments in capital improvements to meet the needs of a growing population.

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Data Availability Statement. Lidar collected for archaeological purposes in Mexico is administered by the Instituto Nacional de Antropología e Historia in accordance with permitting regulations. Project data may be requested from Kathryn Reese-Taylor and Armando Anaya Hernández, directors of the Yaxnohcah Archaeological Project.

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