Pre-Hispanic and Colonial Flood Plain Destabilization in the Texcoco Region and Lower Teotihuacan Valley, Mexico

Carlos E. Cordova*

Department of Geography, Oklahoma State University, Stillwater, OK 74078, USA

Correspondence
*Corresponding author;
E-mail: carlos.cordova@okstate.edu

Received
21 February 2015
Revised
14 July 2015
Accepted
27 August 2015

Scientific editing by Arlene M. Rosen

Published online in Wiley Online Library
(wileyonlinelibrary.com).

doi 10.1002/gea.21550

Stratigraphic sequences in the flood plains of the eastern Basin of Mexico reveal episodes of intense flooding in the past 3000 years, represented by the deposition of alluvial units C, D, and E, and their respective soil horizons. Unit C correlates with the initial growth of population and clearance of vegetation in the piedmont during the Formative period, followed by a stable period ca. 200 B.C. to A.D. 800 represented by a dark A-horizon (soil S3). Unit D is associated with land use changes in the Late Classic and Early Toltec periods, sometime between approximately A.D. 800 and 1100. A relatively stable period occurred during the Toltec and Aztec periods, marked by an A-horizon (soil S4). Unit E represents rapid sedimentation that occurred during the Spanish Colonial period. Previous research in this area suggests that flood plain destabilization in the Early Colonial period occurred as a result of rapid abandonment of terraces, check dams, and settlements in the watersheds of the main rivers. It is possible that the previous period of stabilization (unit D) was influenced by the abandonment of previously managed environments. In the three rapid sedimentation phases, it is possible that climatic fluctuations played an indirect role, if at all. © 2016 Wiley Periodicals, Inc.

INTRODUCTION

Controversy over the process of land degradation in the Americas before and after the European exchange has been one of the topics of discussion among archaeologists, geographers, and historians in the second half of the 20th century. By the end of the century, new studies on the evolution of the Amerindian and European landscapes shed new light on the complexity of processes involved in land degradation in pre-Hispanic and post-Conquest times, hence demystifying the Pristine Myth, or the idea that natives lived in complete harmony with their environment (Butzer, 1992; Denevan, 1992; Whitmore & Turner, 1992). High population concentrations and intensive forms of agriculture in many parts of the pre-Columbian Americas indicate that the landscape before the Spanish conquest was deeply transformed (Butzer, 1995). The Basin of Mexico (Figure 1) is one of those areas of the continent that at different times held high concentrations of population and different forms of intensive agriculture in pre-Columbian times (Sanders et al., 1979).

Because of its documented settlement history, straddling urban and rural environments, the Texcoco region, located east of former Lake Texcoco, represents a microcosm of pre-Hispanic and post-Conquest land transformation of the Basin of Mexico and in general of the highlands of Central Mexico. Being the homeland of King Nezahualcoyotl (reigning from 1429 to 1472), who was also a poet and engineer, the land was known for a series of irrigation and soil retention projects and laws regarding the use of the rural landscape (Palerm & Wolf, 1954; Alva-Iztilxóchitl, 1977). Some of Nezahualcoyotl's creative works are still to be seen in the region, most notably the aqueducts and gardens, as is the case of the Tezcutzingo Hill, located on the piedmont just west of the town of Texcoco, and the irrigated gardens of *ahuehuete* trees (*Taxodium mucronatum*) near the lake shore, now Parque El Contador (Figure 2).

The complex agricultural transformation of the Texcocan landscape is expressed through vestiges of agricultural installations, such as terraces, canals, and dams, and in changes visible in soil profiles and alluvial stratigraphic units. Combined, these pieces of evidence are a

Figure 1 Location of the study area (Texcoco region) in the context of the Late Aztec period geography of the Basin of Mexico. Source of background map: Wikimedia Commons.

geoarchaeological testimony of periods of landscape and instability, characterized by intense soil erosion, alluvial sedimentation, and channel incision (Cordova, 1997; Cordova & Parsons, 1997). One can appreciate that in the last phase of intense erosion, which occurred during the Spanish Colonial period, large amounts of sediments removed from the piedmont made their way into the flood plains (Figure 3). Similarly, earlier periods of erosion and sedimentation can be traced back and forth between soils and occupations in the piedmont and the stratigraphy of the flood plains. Thus, this study uses a geoarchaeological archive (geomorphic, stratigraphic, archaeological, and historical) to discuss the relations between geomorphic stability, climatic shifts, and pre-Hispanic and post-Conquest settlement history.

STUDY AREA

The study area roughly comprises the core region of the Aztec-allied Acolhua Kingdom (or Texcocan Kingdom)

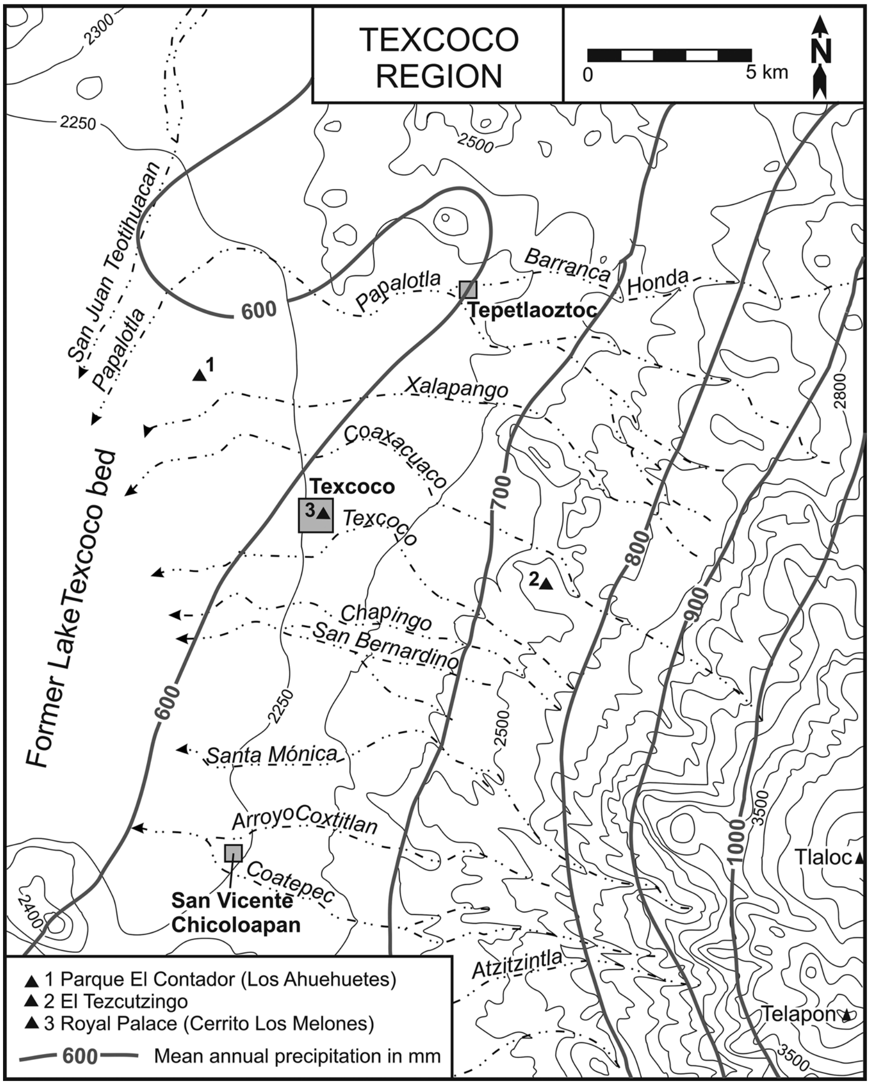

Figure 2 The study area, topography, hydrology, and mean annual precipitation.

at the time of the Spanish Conquest (1519–1521). Its capital was the city of Texcoco, where remains of the royal palace have been recently excavated at the Cerrito de los Melones site in the west-central part of the city (Figure 2). Although traditionally outside the Texcoco region, the southern end of the San Juan Teotihuacan River Valley is included in the study area.

The study area encompasses five physiographic units: mountains, piedmont, hills, alluvial plain, and lake bed. The mountains constitute the northern end of the Sierra Nevada (Figure 2). The highest elevations are the summits of two major volcanoes, Tlaloc (4120 m) and Telapon (4060 m). The mountains in general are formed by andesitic and dacitic lavas and pyroclasts of Pliocene and Pleistocene age (Vázquez-Sánchez & Jaimes-Palomera, 1989).

The piedmont is composed of a series of volcanic deposits including lavas, lahars, ash flows, and mudflows of the middle-to-late Pleistocene Tlaloc Formation (Vázquez-Sánchez & Jaimes-Palomera, 1989). One of the most distinctive characteristics of the Quaternary stratigraphy and soils of the piedmont is the presence of *tepetates*, or indurated layers in the subsoil, whose origins have been debated, but include volcanic tuff originally deposited at high temperatures, or any volcanic pyroclastic deposit that has undergone diagenesis and/or pedogenic induration with silica (Nimlos & Ortíz-Solorio, 1987; Zebrowski, 1992; Poetsch, 2004). Soils on tepetates are the most vulnerable to erosion because of the poor hydrological characteristics of the hard and impermeable layer (Nimlos & Ortíz-Solorio, 1987). Intense erosion in the past has created badlands in which erosional

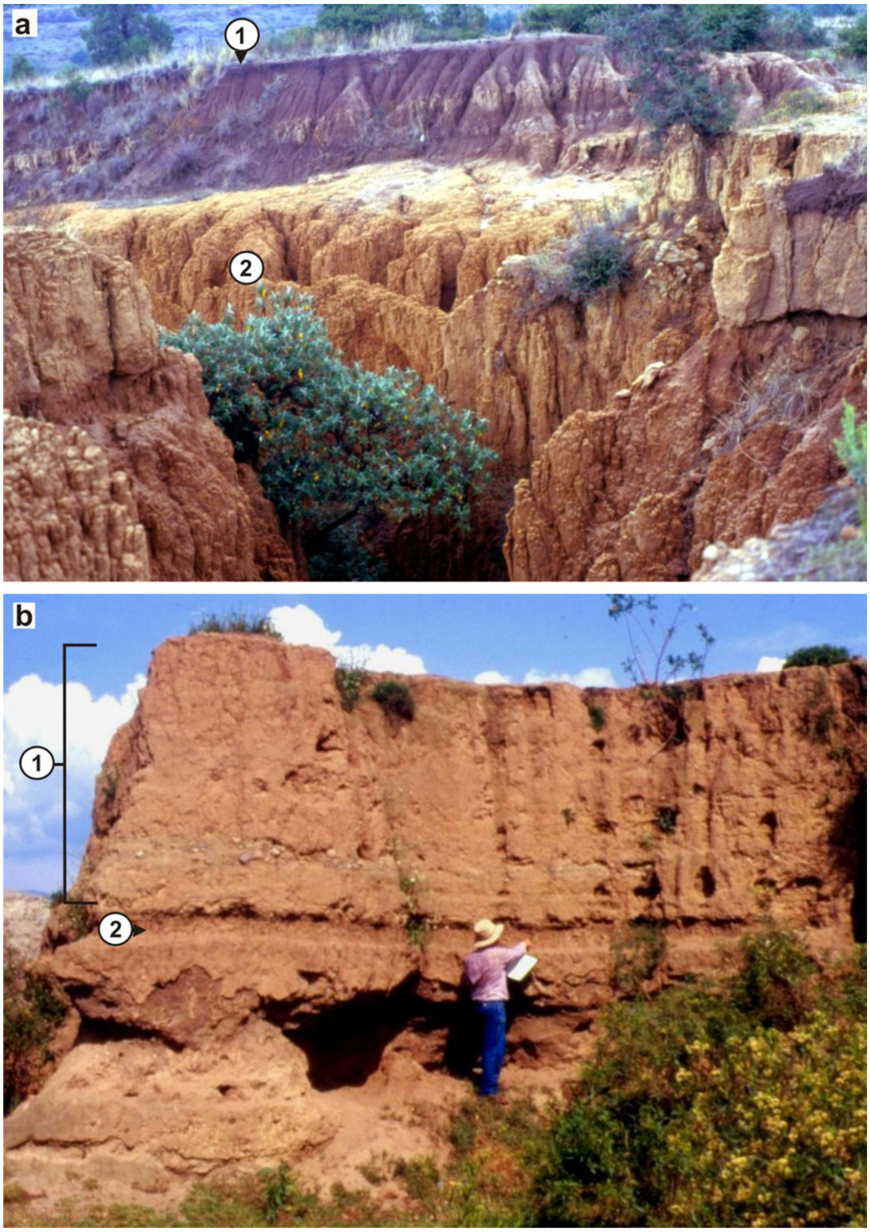

Figure 3 Parallel developments between piedmont erosion and lowland sedimentation. (a) Remains of a former soil containing Late Aztec–Early Colonial (16th century) occupations (1) and lands eroded down to the tepetate (2); (b) Sedimentation of overbank flood deposits and crevasse splays (1) burying a wetland soil dated to the 16th century (2).

pedestals and pinnacles are testimonies to ancient surfaces (Figure 3a). Additionally, vertical erosion of the main streams has dissected the piedomont, forming deep ravines (locally called *barrancas*). Other parts of the piedmont are formed of a series of pyroclastic flows, lahars, and alluvial fans, which have been described by Huddart and González (2006) in the piedmont southeast of Texcoco and west of the town of San Vicente Chicoloapan (Figure 2). These are the distal parts of pyroclastic flow fans associated with the volcanic activity of large volcanoes of the Sierra Nevada (Vázquez-Sánchez & Jaimes-Palomera, 1989).

The hills are isolated volcanic structures roughly within the elevation range of the piedmont, and include Cerro Patlachique in the north, Cerro La Purificación in the central part of the piedmont, and Cerro Chimalhuacan in the south comprising a variety of lavas from mafic to felsic rocks. The plain contains packages of alluvium underlain by volcanic ash, lahars, mudflows, and lacustrine deposits dating back deep into the Pleistocene (Huddart & González, 2006; González et al., 2014). The lacustrine plain, whose lowest elevation is about 2240 m, corresponds to the bed of former Lake Texcoco.

Climate in the study region is temperate with over 90% of the rain falling between May and October (Sanders, Parsons, & Santley, 1979; García, 1981). Due to orographic and rain-shadow effects, mean annual precipitation is distributed along an altitudinal gradient (Figure 2). Likewise, mean annual temperatures decrease with elevation (Figure 2). Temperatures in most of the region tend to be isothermal (less than 5% difference between maximum and minimum monthly means) (García, 1981). Frosts occur between October and March, and snow events are not uncommon at the highest elevations during winter.

The main rivers of the study area drain the western slopes of the Sierra Nevada. In the piedmont, the main streams and their tributaries flow along deeply incised valleys in the piedmont and spread onto broad alluvial fans in the plains, and then into former deltaic plains along the lakeshore. Today, however, the streams in the alluvial plains have been channelized (and straightened) and flow into a broad playa-like salty plain in the former bed of Lake Texcoco, where water accumulates in ponds and evaporates (Figure 2). The San Juan Teotihuacan River does not originate in the Sierra Nevada, but in the mountains surrounding the Teotihuacan Valley. It flows into the Texcoco plain from the north and empties into the former bed of Lake Texcoco.

The natural or original vegetation distribution pattern is arranged in altitudinal belts. The highest belt, occupying the summits, consists of tufted grass communities and isolated pine trees. The next belt down is the conifer forest, which is dominated by pine, but with representation of other conifers (e.g., fir), and broadleaf trees (e.g., alder). At lower elevation, this belt transitions into an oak-pine and oak forest (Rzedowski, 1975). Below the oak-pine level is the piedmont, which today is occupied by cropland, eroded areas of tepetate, and areas reforested with pine and eucalyptus. But remnants of oaks scattered through the piedmont suggest that the area may have been covered with oaks, or a mixture of oaks and grasses. The hills are covered by xerophytic scrub, but their original vegetation before agricultural clearings is unknown. In some of the highest parts of the Sierra de Patlachique, there are oak stands, which presumably are remnants of a woodland or forest of oak. Halophytic vegetation, mainly grasses and chenopods, and aquatic vegetation are still found in some areas of the former lakebed. The original vegetation of the plains is unknown. However, practically all the plain has been modified and replaced with crops, pastures, or areas occupied by ruderal plants.

METHODS

This study is based primarily on the stratigraphy of recent alluvial deposits exposed in the walls of brickyard pits and cut bank exposures in incised flood plains. Because both brickyards and cut banks were limited to only a few flood plains, this study focuses on the flood plains of the lowest reaches of the San Juan Teotihuacan, the lower and middle reaches of the Papalotla River and its tributary Barranca Honda, and the Coatepec-Arroyo Coxtitlan rivers (Figure 4). In two locations on the edge of the piedmont, stratigraphic units were described in gravel pits. Observations were also made on the geomorphology of the Texcoco River, southwest of the city of Texcoco as additional information to the regional geomorphic dynamics. Fieldwork and laboratory work was carried out during the years 1993–1996.

Stratigraphy and Geomorphic Approach

This study encompasses 27 stratigraphic sections in alluvial settings. Stratigraphic sequences were divided into zones (using Roman numerals), which correspond to distinctive alluvial deposits and soil horizons. The stratigraphic zones were grouped into stratigraphic units and soil horizons. The stratigraphic units were correlated with other sections in the basin and with other basins, and grouped into allostratigraphic units designated with capital letters A, B, C, D, and E, from oldest to youngest. In some cases, where there were interruptions or periods of erosion within the same units, subdivisions were created (e.g., B1 and B2 for unit B). Buried soil horizons were designated with a letter S and a number, S1, S2, S3, and S4, from oldest to youngest, and with subdivisions represented by numbers in parentheses (e.g., S2(1) and S2(2)). Based on the radiocarbon age determination and associated ceramics (see next section), the stratigraphic units and their associated soils were arranged in the frame of the regional cultural periods (Figure 5).

Because most streams in the Basin of Mexico have been channelized and straightened, there are no local modern analogs to most of the flood plain sedimentation that occurred in the past. Therefore, the relation between sections and geomorphology is difficult to assess. Thus, the interpretation of ancient depositional environments in the Texcocan flood plains rests on the alluvial architecture model, which considers the three-dimensional array of alluvial facies and landforms (Miall, 1985). Although this model was originally designed by geologists for the

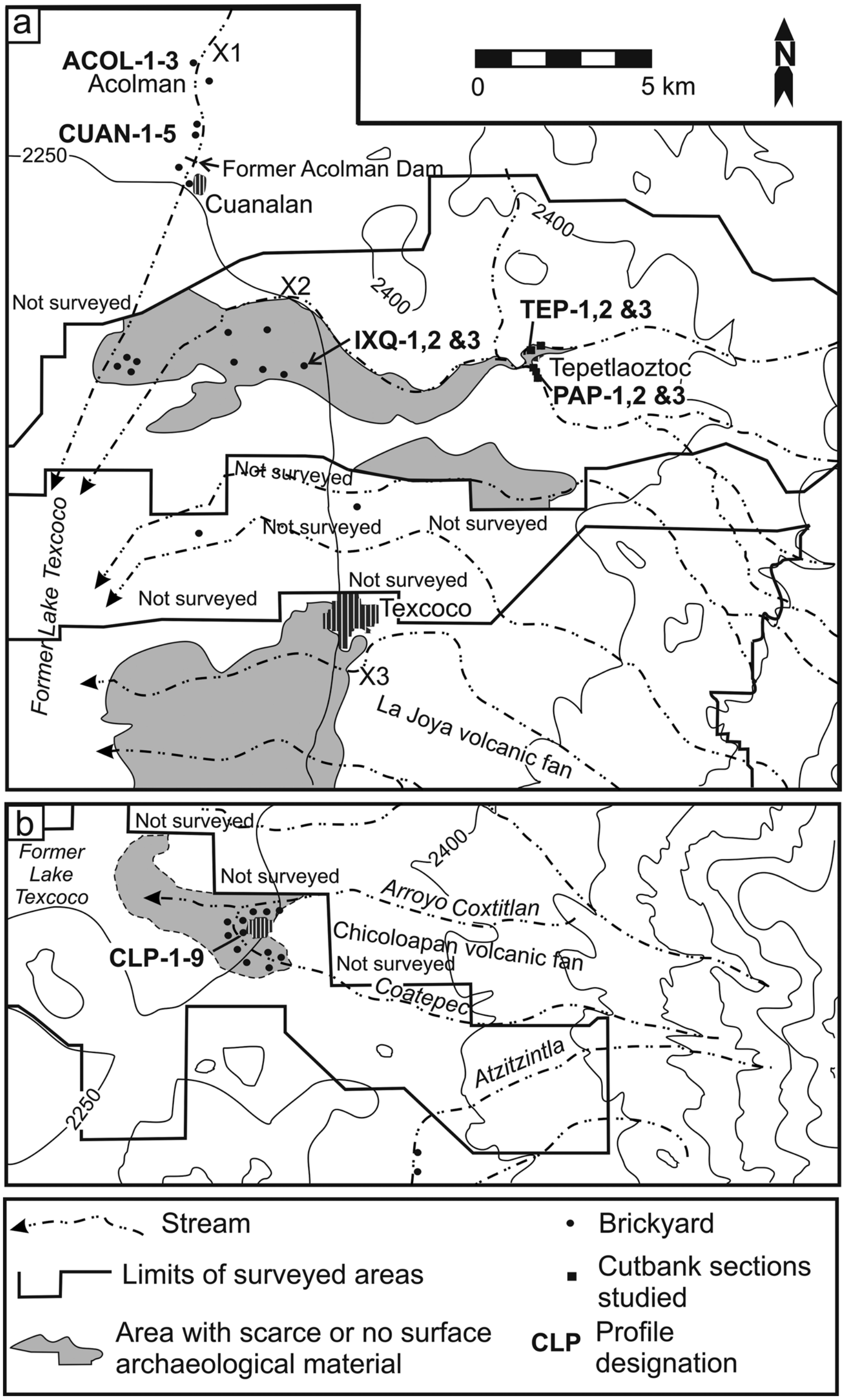

Figure 4 Modern river channels in relation to areas with no pre-Hispanic archaeological material on the surface. Locations of studied sections are indicated. X1, X2, and X3 are specific locations mentioned in text.

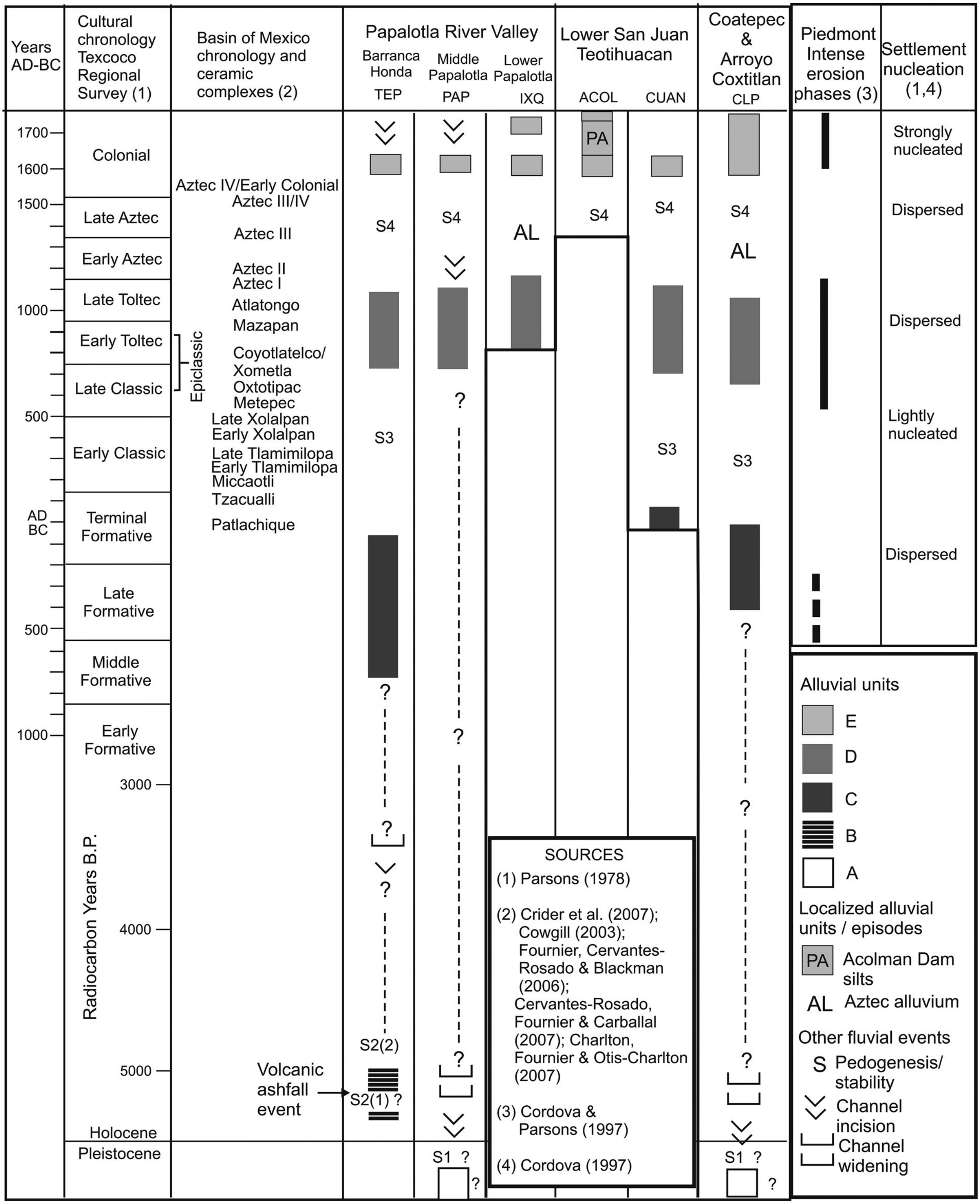

Figure 5 Chronology of alluvial allostratigraphic units and soil horizons in the context of the cultural periodization of the Basin of Mexico. Cultural periodization is based on Parsons (1971). Piedmont erosional phases are based on Cordova and Parsons (1997).

Table I Calibrated radiocarbon ages from alluvial sections.

Lab Number	Depth (cm)	Material Dated and Method	Locality[a] and Stratigraphic Unit	^{13}C-Corrected Age (^{14}C yr B.P.)	2-Sigma Calibrated Age A.D./B.C.[b]
OS-3476	150	Charcoal AMS	ACOL-1-III	145 ± 25	A.D. 1670 (0.82) A.D. 1890
OS-3477	218	Charcoal AMS	CUAN-3-V	355 ± 30	A.D. 1450 (1.00) A.D. 1640
OS-3478	280	Charcoal AMS	TEP-3-V	2070 ± 54	200 B.C. (1.00) A.D. 20
OS-3479	200	Charcoal AMS	PAP-4-IV	575 ± 30	A.D. 1290 (1.00) A.D. 1420
OS-3481	495	Charcoal AMS	CUAN-4-XI	1240 ± 30	A.D. 680 (1.00) A.D. 880
OS-3482	225	Charcoal AMS	PAP-1-IV	350 ± 30	A.D. 1450 (1.00) A.D. 1640
OS-3483	185	Charcoal AMS	CLP-3-V	365 ± 55	A.D. 1440 (1.00) A.D. 1640
Tx-7780	200	Charcoal Standard	CLP-1-III	219 ± 50	A.D. 1510 (0.09) A.D. 1590
					A.D. 1620 (0.84) A.D. 1890
Tx-7781	175-180	Soil humate Standard	TEP-1-V	5313 ± 51	4330 B.C. (0.07) 4280 B.C.
					4250 B.C. (0.93) 4000 B.C.
Tx-8094	100	Charcoal Standard	TEP-1-IIIb	3933 ± 15	2900 B.C. (1.00) 2000 B.C.
Tx-8021	224	Charcoal Standard	CLP-3-VI	2033 ± 96	400 B.C. (1.00) A.D. 200

[a]See Figure 4 for localities.
[b]All ages were calibrated using the curve: OxCal v2. 18 cub r.4 sd:12 prob [chron] (Stuiver et al., 1993).

interpretation of sedimentary environments in rocks, it is based on modern environments, which makes it functional in Quaternary alluvial contexts.

Dating and Ceramic Chronology

The age of units and soils was ascertained through associated ceramics and ^{14}C assays obtained primarily from charcoal in some instances from organic matter in soils and ceramic styles associated with surfaces buried by alluvial sediments. Radiocarbon age determinations included standard and AMS. Corrected radiocarbon ages and their calibrated ages are reported by section number and zone in Table I.

The use of ceramic styles in this study is even more important than radiocarbon assays because of the relatively recent ages of most studied deposits and the abundance of occupation surfaces buried under alluvium. Although ceramic-style chronologies can be a problem in areas where a seriation is not determined, in the Basin of Mexico, chronologies have been worked out sufficiently more than any other part of Mexico, particularly when it comes to the Postclassic (Cervantes-Rosado, Fournier, & Carballal, 2007), which is the most used here. The regional chronology is based primarily on the work by Parsons (1971), Hodge and Minc (1991), and modifications associated with certain style types, particularly those of Late Classic (Crider et al., 2007; Cowgill, 2013), and Late Aztec and Colonial age (Charlton, Fournier, & Otis-Charlton, 2007), as well as numerous studies cited in these works. The cultural periods used throughout this study abide by the chronology proposed by Parsons (1971), and only in certain cases other equivalent periods (e.g., Epiclassic) are used. To make sense of the cultural periods, ceramic styles, with respect to allostratigraphic units and soil horizons, the cultural and alluvial chronology has been paired in one single diagram (Figure 5).

Additional Information

Information on the distribution of archaeological sites was obtained from surveys published by Parsons (1971) and from the original survey maps and notes in the archives of the Museum of Anthropology at the University of Michigan in Ann Arbor. This information was vital for understanding the cultural landscape associated with geomorphic features. Landscape changes that occurred in historical times were corroborated using old maps and associated documents obtained mainly from the Archivo General de la Nación, in Mexico City (Cordova, 1997). Mapping was aided by aerial photographs and 1:50,000 topographic, soils, and geological maps from the Instituto Nacional de Geografía e Informática (INEGI) in Mexico City.

The timing of flood plain sedimentation and erosion developments was correlated with climatic data generated through regional tree-ring studies and historical data on events such as droughts and periods of excessive rain. This does not mean that the geomorphic changes in the flood plains are necessarily correlated with climatic shifts in the region. The purpose of mentioning climatic events is to put the geomorphic and population changes discussed here in a climatic context.

RESULTS

Alluvial Architecture and the Archaeological Record

The archaeological surveys of Texcoco carried out in the late 1960s and early 1970s reported areas of the Texcocan plains as empty of surface material (Parsons, 1971). These areas with no surface archaeology at the time of the surveys were cultivated fields, but in the 1980s and 1990s, as agriculture declined and urbanization expanded, mining for brickmaking became widespread. Thus, a number of brickyard pits were opened in areas where alluvial fine-grained sediment and sand could be found in one place, exposing archaeological occupations of different ages buried under suites of alluvium. In fact, the areas with no surface archaeology were areas of recent sediment that buried soils and occupations bearing Aztec IV and Colonial ceramics (Figure 3b).

The distribution of areas with no archaeological surface materials in the plains shows some recurrent patterns (Figure 4). First, most of the areas with no surface archaeological material are in the lower flood plains of the streams and the deltas; second, brickyard pits are located primarily in these areas; and third, the modern river channels, some of which have been re-directed or rectified, circumvent areas of former flood plain sedimentation. This is the case of the San Juan Teotihuacan north of the former Acolman Dam (at location X1), the Lower Papalotla north of San Pablo Ixquititlan (X2), and the Texcoco River southwest of the city of Texcoco (X3) (Figure 4a).

The five basic depositional environments found in the alluvial plains of the study area are channel, channel margin (lateral accretion), overbank (vertical accretion), overbank splay, and valley margin. Each of these depositional environments encompasses a set of lithofacies (Table II), each defined by textural characteristics and sedimentary structures (Table III).

Based on the distribution of the five basic depositional environments and their lithofacies, the relation between the alluvial architectural elements in the stratigraphy can be represented in two model diagrams that correspond to each of the flood plain types identified in the valleys of the study region (Figures 6, 7). Type-1 is a convex flood plain that eventually grades into a deltaic plain at the lakeshore and is characterized by nonincised channels with levees (Figure 6). The flood plains of the Lower San Juan Teotihuacan, the Lower Papalotla, the Coatepec River and the Arroyo Coxtitlan, all of which are located on the plains of the study area, have Type-1 flood plains (Figure 4a–b). In this type of flood plain, most of the exposures were studied in brickyard pits, since channel erosion has never exposed sediments. Brickyards tend to be on either side of the channel convexity

Table II Architectural elements and characteristics of the alluvial environments in the studied stratigraphic sections.

Element and Symbol	Depositional Environment	Lithofacies Assemblage Code (Miall, 1985)	Typical Example by Section and Zone
Channels CH	Channel lag deposits (Chl)	Gm, Gt	CLP-4-IV CUAN-3-IV CLP-1-IIIb
	Channel Transitory deposits (Cht)	Gt, Sl, Fm	CUAN-4-VI (a-b) CLP-1-V
Channel margins or lateral accretion deposits LA	Riverbank deposits (LAr)	Sp, Sh	CLP-6-V PAP-4-IV
Overbank fines or vertical accretion deposits OF	Backswamp/ dam/slack water deposits (OFs)	Fsc, Fcf	ACOL-1-IV CLP-1-1-IV
	Floods (OFf)	Fl, Fsc	CUAN-4-II IXQ-2-II
	Mudflows/mud drapes (OFm)	Fm	TEP-2-IV PAP-2-I
Overbank splays OS	Splays (OSc)	Sl	ACOL-1-III CLP-5-II
Valley margin VM	Colluvial deposits (VMc)	Poorly sorted deposits	CLP-9-I
	Mud flows (VMc)	Fm and poorly sorted deposits	TEP-2-IV
Other deposits	Ashfall	NA	TEP-1-V
	Artificial	NA	IXQ-2-VI

Table III Alluvial facies in the sedimentary deposits of this study according to the classification by Miall (1985).

Facies Code	Lithofacies	Sedimentary Structures	Interpretation
Gm	Massive or crudely bedded gravel	Horizontal bedding, imbrication	Longitudinal bars, lag deposits, sieve deposits
Gt	Gravel, stratified	Trough cross-beds	Minor channel fills
Sp	Sand, medium to very coarse, may be pebbly	Solitary or grouped planar cross-beds	Linguoid, transverse bars, sand waves (lower flow regime)
Sh	Sand, very fine to very coarse. may be pebbly	Horizontal lamination, parting, or streaming lineation	Planar bed flow (lower and upper flow regime)
Sl	Sand, fine	Low angle (<10°) cross-beds	Scour fills, crevasse splays, antidunes
Fl	Sand, silt, mud	Fine lamination, very small ripples	Overbank or waning flood deposits
Fsc	Silt, mud	Laminated to massive	Backswamp deposits
Fcf	Mud	Massive, with freshwater mollusks	Backswamp pond deposits
Fm	Mud, silt	Massive, desiccation cracks	Overbank or drape deposits

where sediment is finer and sand and gravel lenses exist (Figure 6a).

Type-2 is a narrow, concave flood plain characterized by vertical sediment accretion and repeated channel incision events (Figure 7). The flood plains of the Barranca Honda and the Middle Papalotla River, which are in the lower piedmont, have Type-2 flood plains (Figure 4a). Sediment exposures in these flood plains occur in cut banks on the erosional side of incised meanders. Brickyard pits are practically absent; although it is not

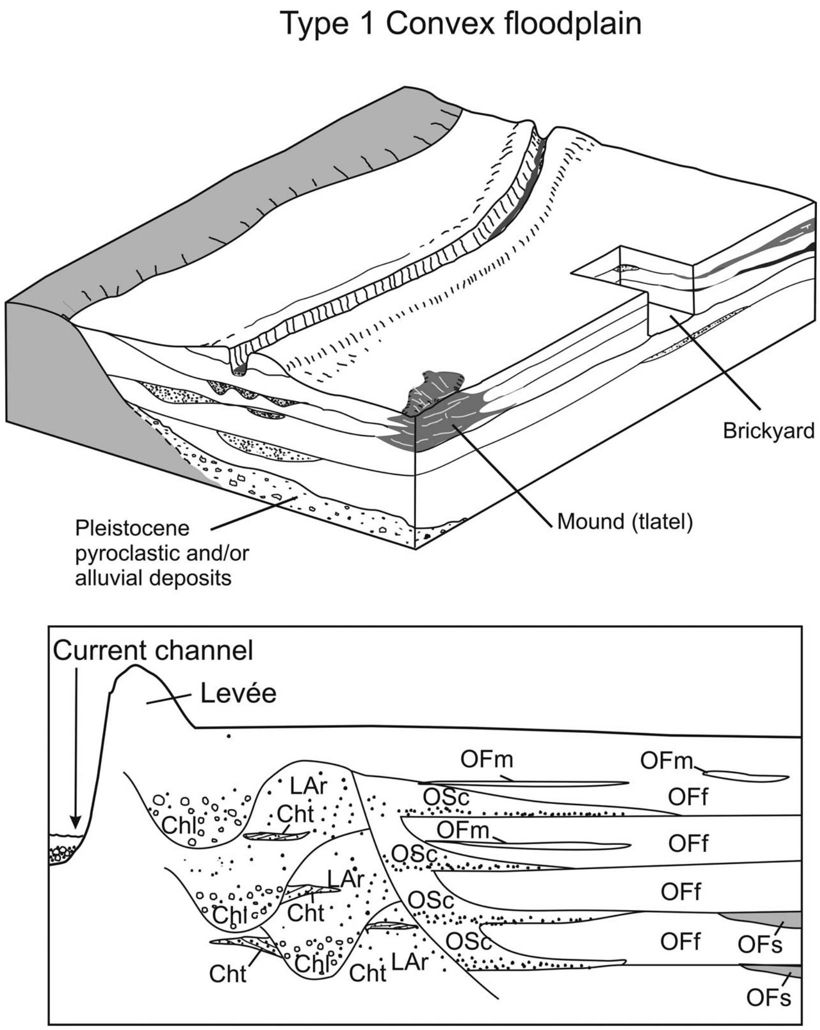

Figure 6 Type-1 flood plain model. (a) General alluvial architecture; (b) sedimentary environments. For abbreviations, see Table II.

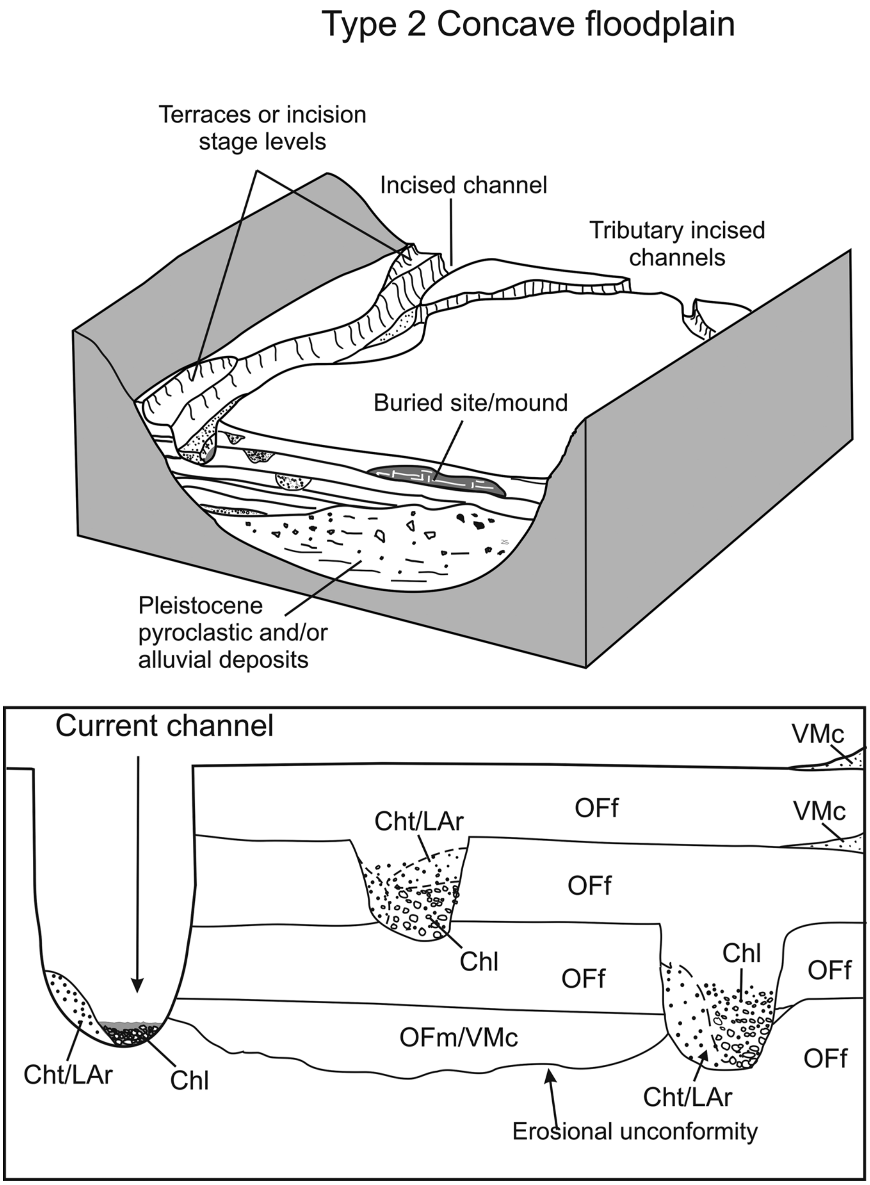

Figure 7 Type-2 flood plain model. (a) General alluvial architecture; (2) sedimentary environments. For abbreviations, see Table II.

uncommon for sediment to be mined from cut banks. It is important to point out that all rivers in the lower piedmont have Type-2 flood plains, which transit to Type-1 once they enter the low gradient areas of the Texcocan plain.

Differences in alluvial architecture are related to the distribution and abundance of depositional facies. In Type-1 flood plains, the convexity created by the channel often marks the transition between the lateral accretion facies (LAr), vertical accretion overbank (OFf), and crevasse splay (OSc) facies (Figure 6b). The reason most brickyards expose these facies is that the preferred raw materials for brickmaking are a mixture of silt-loam deposits of overbank deposits and backswamps (OFf) to which the coarse sand of the crevasse splay (OSc) is added as temper. However, other sedimentary facies used in brickmaking include the backswamp (OFs) and mudflows (OFm) facies, which are rather rare. The depositional facies found in Type-2 flood plains are essentially channel (Chl), point bar (Cht), and overbank (OFf) (Figure 7b). Levee facies (LAr) and backswamp facies (OFs) have never been identified in the streams of this study. Overbank splays (OSc) are rare and often associated with gravel lenses embedded in some overbank deposits.

Archaeological occupations in both flood plain types are often found associated with soil horizons either as part of the soil matrix itself, or in constructions that include floors and walls and, in a few cases, burials. In some instances, occupations of these surfaces are characterized by promontories of cultural deposits referred to as *tlatel* (from the Nahuatl *tlaltelli*, or mound). In a few cases, the outwash deposits of some of these tlatels interdigitate with alluvial deposits (Figure 6a). It is apparent that the tlatels are settlements that grew as the area around them were flooded, as it is shown in some of the stratigraphic sequences of this study.

Description of Stratigraphic Units by Area

The lower San Juan Teotihuacan flood plain

The studied sections on the lower San Juan Teotihuacan River are located in the Acolman and Cunalan areas (Figure 4a). In between the two areas lie the remains of the Colonial-age Acolman Dam. The studied sections can be divided into those behind the dam (ACOL-1, 2, and 3, and CUAN-1 and 2) and downstream from the dam (CUAN-3, 4, and 5) (Figure 8). The location of the former dam is the narrowest section of the pass between

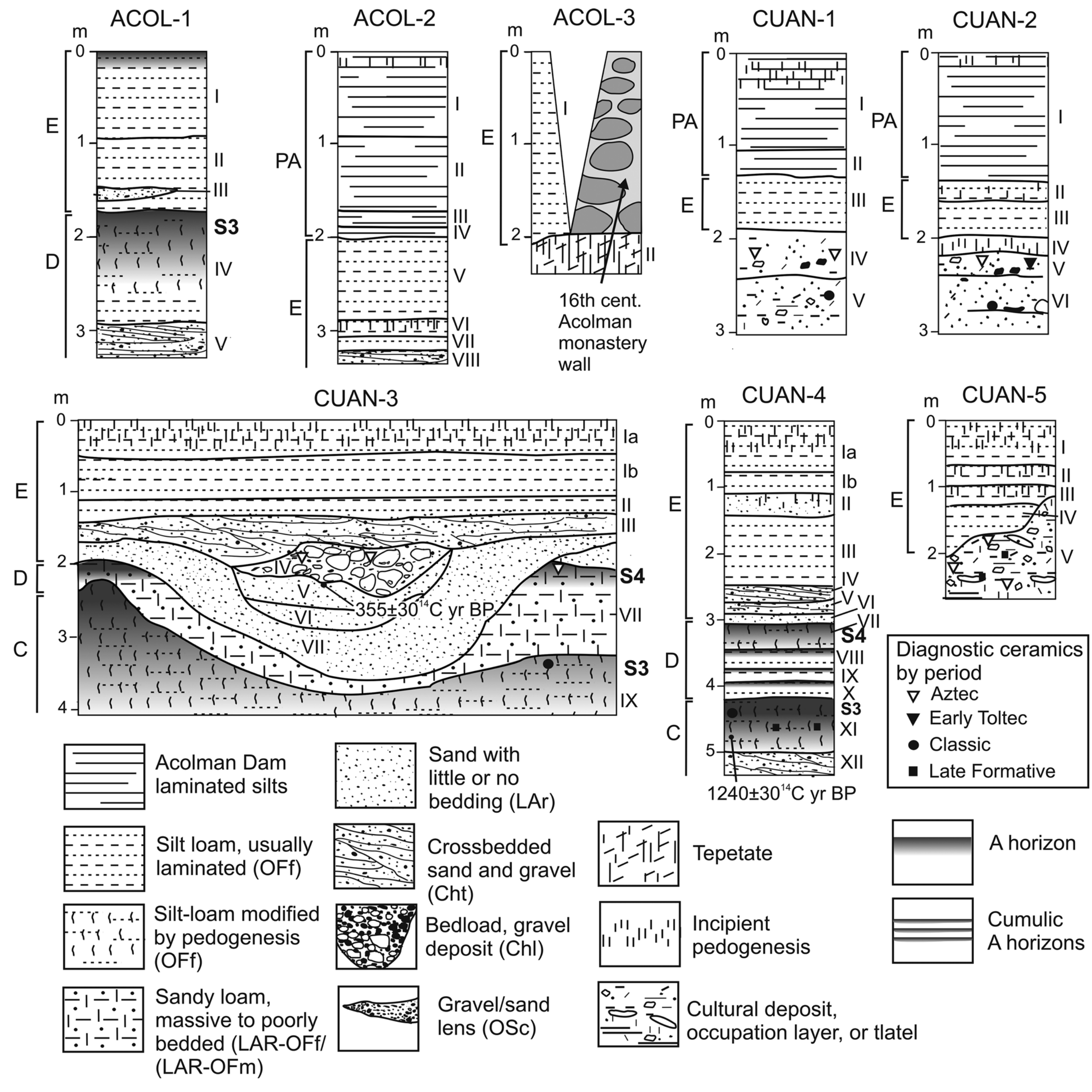

Figure 8 Lower San Juan Teotihuacan flood plain sections at the Acolman (ACOL) and Cuanalan (CUAN) areas.

the Teotihuacan Valley and the Texcoco lacustrine plain (Figure 4a).

The Acolman dam was a flawed engineering project initiated between 1604 and 1629 (Gamio, 1922). The purpose of the dam was to control the flow of water into the remnants of Lake Texcoco, which at that time flooded Mexico City after excessive rain episodes. However, the dam caused the waters of the San Juan River to recede, inundating fields in the southern part of the Teotihuacan Valley and forming a lake as early as 1608 (Gamio, 1922). Several floods ensued, particularly those of 1629 (Boyer-Everett, 1973) and 1645 (Gamio, 1922). The most disastrous floods took place in 1762, and are depicted in a historical document (Archivo General de la Nación, Bienes Nacionales, 1762), the floods led to the abandonment of the Acolman monastery. In the 20th century, sediments from around the front of the monastery were removed and the building re-opened as a museum. In some places, the fine-grained overbank sediments of this flood can reach up to 2 m over the foundations of buildings as shown in section ACOL-3 (Figure 8). The façade of the monastery's church still bears the scars of corrosion by salt contained in the sediments, which is a testimony of how deep the flood sediment was (Cordova, 1997: 310–311). The sediments that accumulated behind the dam are exposed in brickyard pits where silty clay and horizontally laminated silts are interbedded with crevasse splay deposits (sections ACOL-1, 2, and 3) (Figure 8).

Downstream from the former Acolman dam, section CUAN-3 exposes a channel that cuts through overbank deposits of unit D and through soil horizon S4 (Figure 8). It is assumed that this was the main channel of the San Juan Teotihuacan River prior to the construction of the dam. Although a radiocarbon date indicates a date older than the 15th century, the sediments of the channel are interdigitated with sediments of unit E dated to the Colonial period in other exposures. About 100 m downstream from the ruins of the dam, sections CUAN-4 and CUAN-5 expose a more complete sequence of overbank facies. In section CUAN-4, unit D (zones X to VII) buries an occupation surface with Epiclassic Coyotlatelco-style ceramics, which is consistent with the radiocarbon age of 1240 ± 30 ^{14}C B.P. (A.D. 680–880, 2-sigma calibrated). In the same sections, unit E (zones VI to I) comprises a series of overbank splays and fines that correlate with the deposits that buried the channel in section CUAN-3. The deposits of unit E become finer to the east where they cover an Aztec mound (tlatel), as shown in section CUAN-5 (Figure 8).

Barranca Honda and Papalotla River

The Papalotla River basin has been divided, for the purposes of this study, into three areas, the middle and lower courses of the Papalotla River (referred to as Middle and Lower Papalotla, respectively) and a segment of its tributary Barranca Honda (Figure 4). The middle Papalotla and the Barranca Honda correspond to Type-2 flood plains. The lower Papalotla corresponds to a Type-1 flood plain.

Barranca Honda crosses the north side of the town center of Tepetlaoztoc, founded at this location in the late 16th century. The original Aztec location of Tepetlaoztoc (Site Tx-A-24) is on the adjacent slopes of the valley (Figure 9a–b). It is a dispersed settlement with numerous slope terraces and check-dams structures (Parsons, 1971; Williams, 1994). The Middle Papalotla cuts through another Aztec site (Tx-A-40), which is partially eroded by the stream. Two erosional events in the flood plain of the Middle Papalotla are evident in the form of fluvial terraces T1 and T2 (Figure 9c). Lateral erosion and channel incision associated with terrace T2 exposed part of a tlatel bearing mostly Late Aztec ceramics (Figure 10).

The TEP sections (Figure 10) exhibit a sequence of fine overbank deposits with soil horizons developed in units B, C, D, and E. Unit B is subdivided into two members by a white volcanic ash layer. Below the ash layer, subunit B1 is a silty deposit with an organic soil horizon S2(1), which is a dark, organic soil that could be interpreted as a wetland soil (cienega-type soil). The organics of this soil horizon produced a date of 5313 ± 50 ^{14}C B.P., which marks the maximum age for the volcanic ashfall event. Age and the white, fine-grain nature of this volcanic ash suggest that in the regional tephrochronology of the Basin of Mexico, it may correspond to the *Pómez Marcadora Superior* (PMS), dated 4250 ± 110 in a core from Tlapacoya by García-Bárcena (1986), or the *Pómez de Grano Fino* (PGF) dated 4880 ± 120 in a core from Lake Chalco by Bradbury (1989). However, both locations are in the Chalco Basin, far south from the Barranca Honda. Above the ash is subunit B2, which is a poorly sorted deposit with fragments of the underlying ash. It can be interpreted as a mudflow that occurred shortly after the deposition of the volcanic ash. On top of this deposit soil horizon S2(2) developed, although it has been eroded in all, except section TEP-2 (Figure 10).

Overlying soil horizon S2(2) is a sequence containing units C, D, and E, and soil horizons S_3 and S_4. However, the white volcanic ash layer does not appear in section TEP-3 or in any of the other sections in the area. In section TEP-1, the lower of two dates from unit C is 3933 ± 50 ^{14}C B.P. The accumulation of unit C may be the result of destabilization of the slopes that was caused by clearing of vegetation due to agricultural expansion in the Formative period. Subsequently, unit C reflects pulses of sedimentation in the form of overbank silt-loam deposits forming cumulic soils and is capped by a more developed

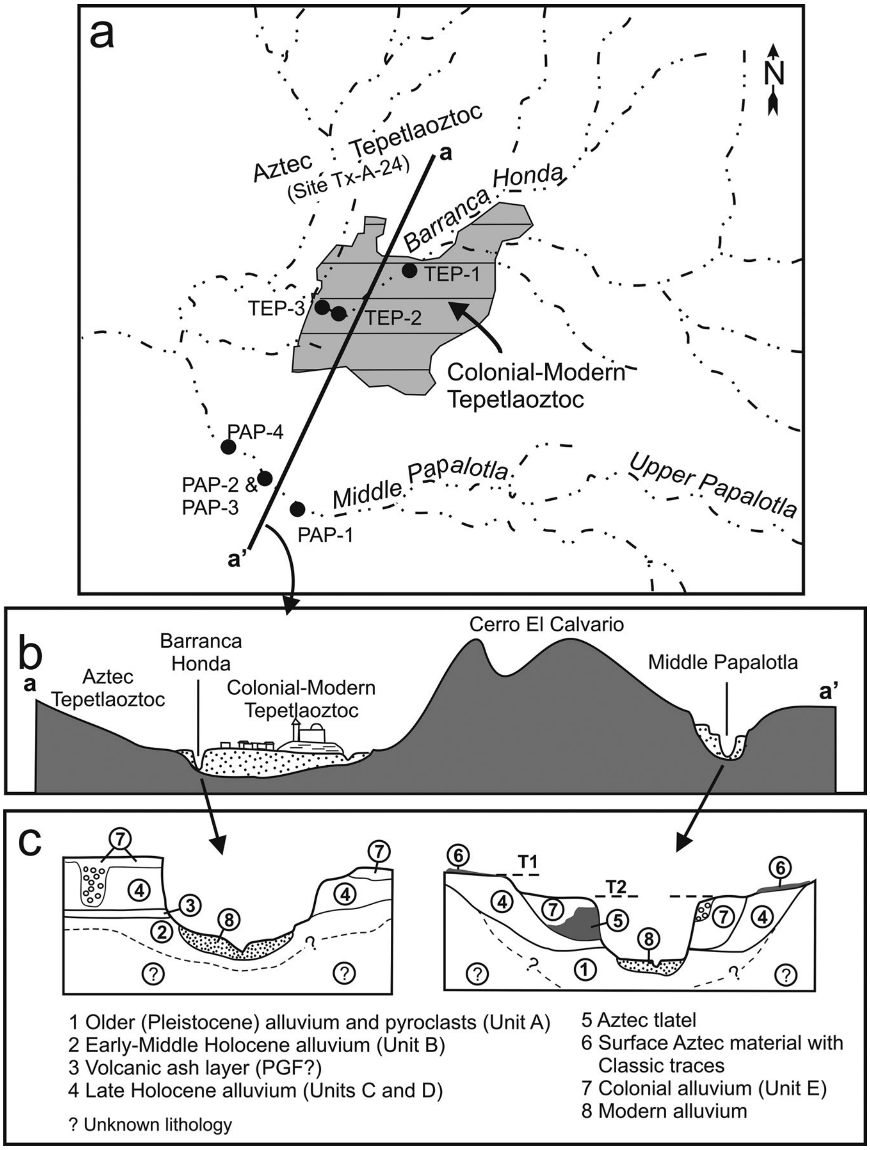

Figure 9 Geomorphological contexts of Barranca Honda and Middle Papalotla River sections. (a) General area; (b) transects across the valleys; (c) transects across the streams.

A-horizon. Unit D is an overbank silt-loam deposit similar to unit C, but lighter in color and with less cumulic soil development. Unit E is a distinctive massive silt deposit, corresponding mainly to overbank deposition with occasional channels incising older units, as shown in section TEP-1 (Figure 10).

The alluvial units along the Middle Papalotla are distributed into two terraces (Figure 9c): T1 contains units A and D, and T2 contains unit E. The PAP sections show the same alluvial units, with the exception of units B and C, which might have been completely eroded or never deposited. Unit A is exposed at the bottom of section PAP-4 and appears to be a braided channel deposit (Figure 10). The deposit contains pedogenic carbonate, which suggests perhaps a Pleistocene age. Elsewhere along the stream similar older deposits including lahars, pyroclastic flows and alluvium have similar pedogenic carbonates. Units D and E buried several occupation levels, including part of a tlatel. The alluvium with Late Aztec material might be due to the degradation of the tlatel or to intentional filling of the channel with trash before the building of the tlatel (PAP-3, Figure 10).

In the Lower Papalotla flood plain, the studied sections are located in an abandoned brickyard near the town of San Pablo Ixquititlan (Figure 11). The stratigraphy in the exposed parts of the brickyard pit shows the continuous

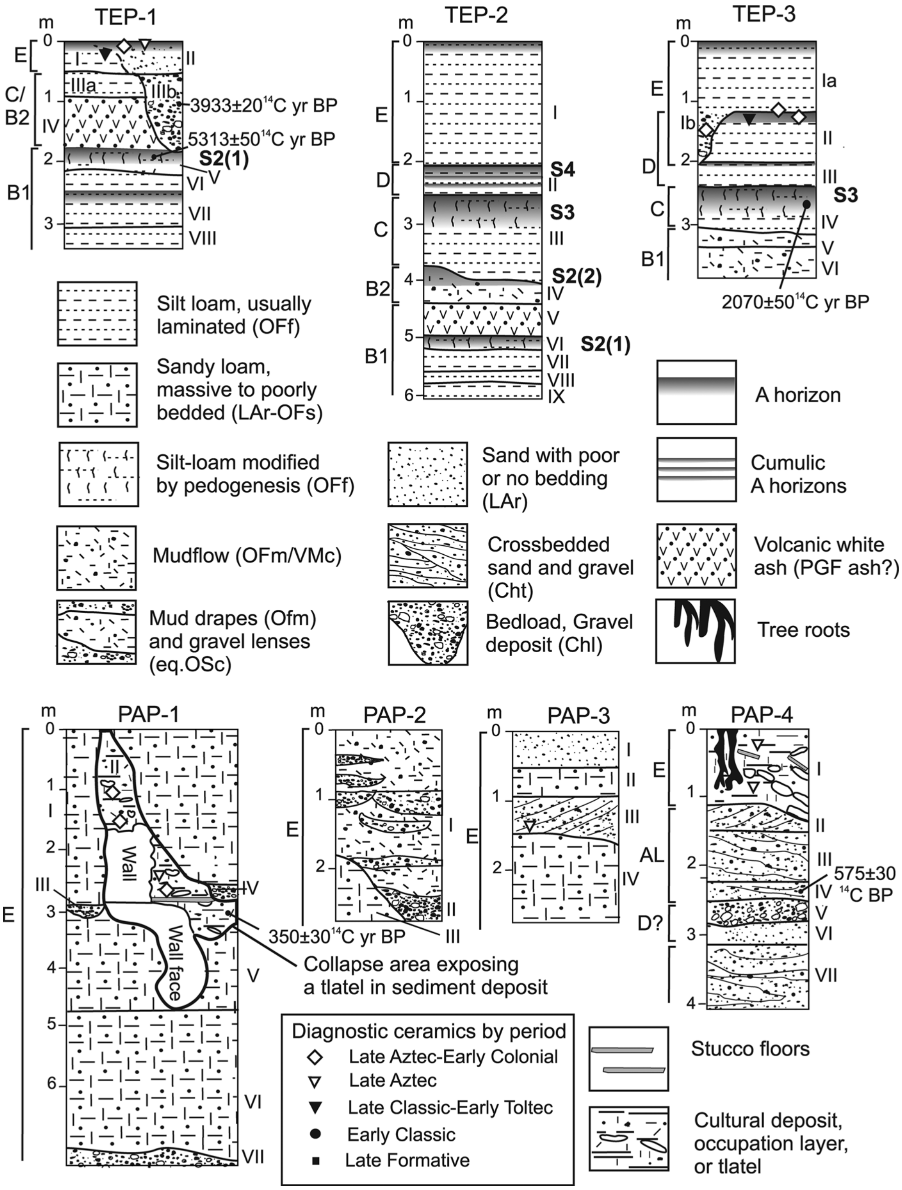

Figure 10 Barranca Honda (TEP) and Middle Papalotla (PAP) flood plain sections.

deposition of overbank silt-loam, with mud drapes interdigitated with cultural deposits associated with a tlatel (Figure 11). The diagnostic ceramic complexes in the tlatel range from Late Classic/Early Toltec to Colonial. Radiometric dating was not possible due to the lack of datable material. The top 3 m of alluvium corresponds to unit E, although the age of the cultural materials also agree with an Aztec-period date.

To the north of the brickyard pit, a linear ridge marks the levees of a former main channel (Figure 11). This ridge, apparent in aerial photographs, has been identified with a channel represented in Colonial maps (Cordova, 1997: 335–337). The modern channel of the lower Papalotla is located to the north, where it follows a canal bordered by artificial earthen levees (location X2, Figure 4a).

The foundations of the abandoned church stand on the tlatel that contains Late Aztec ceramics (Figure 11). Flooding may have been the main reason for the abandonment of the church, since 80 cm of alluvial deposits of unit E abut its foundations. Colonial maps and documents suggest that floods in the 18th century forced the abandonment of the church (Cordova, 1997: 338).

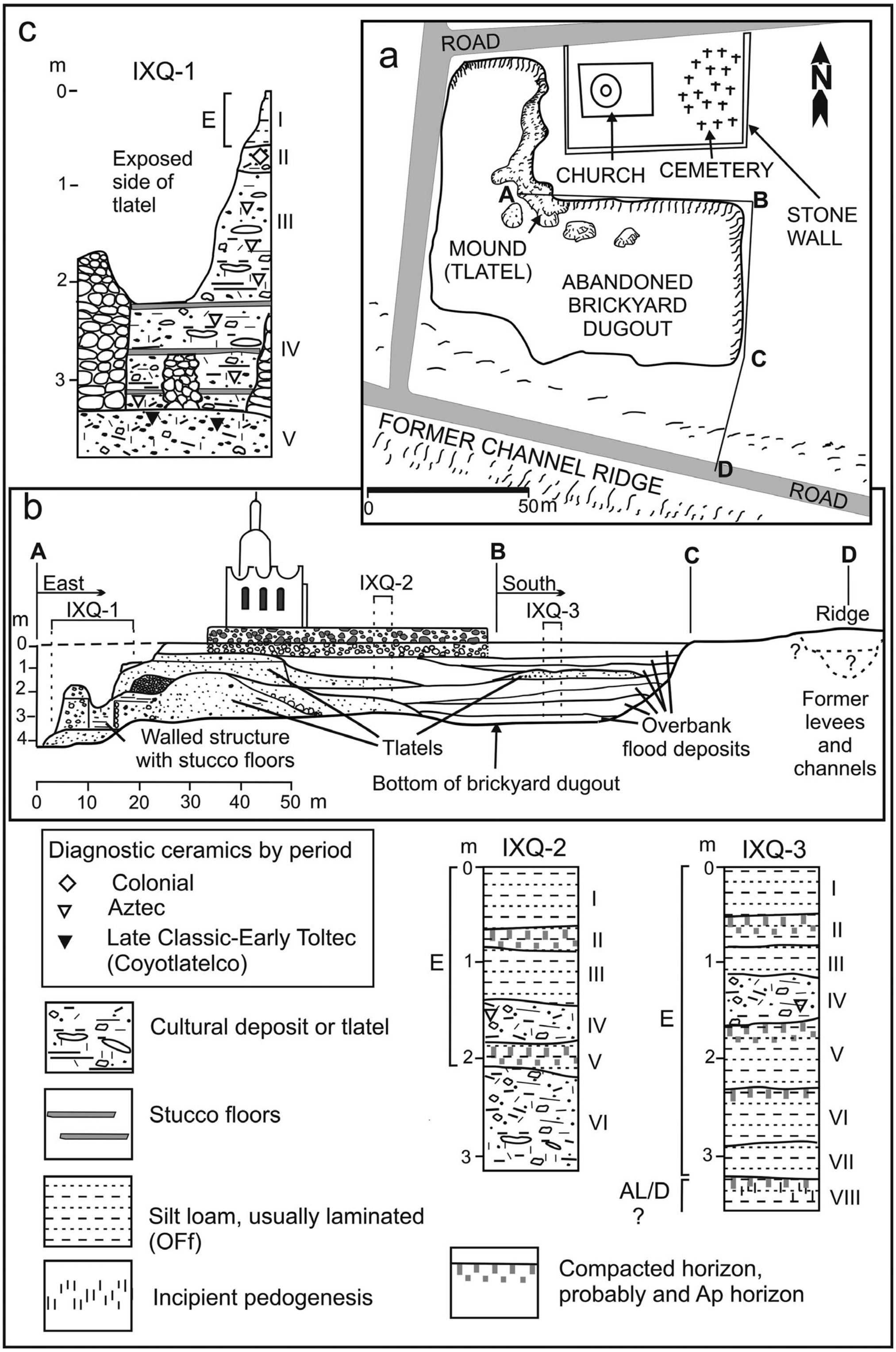

Figure 11 Lower Papalotla flood plain sections (IXQ). (a) General area; (b) section across the area; and (c) profile sections.

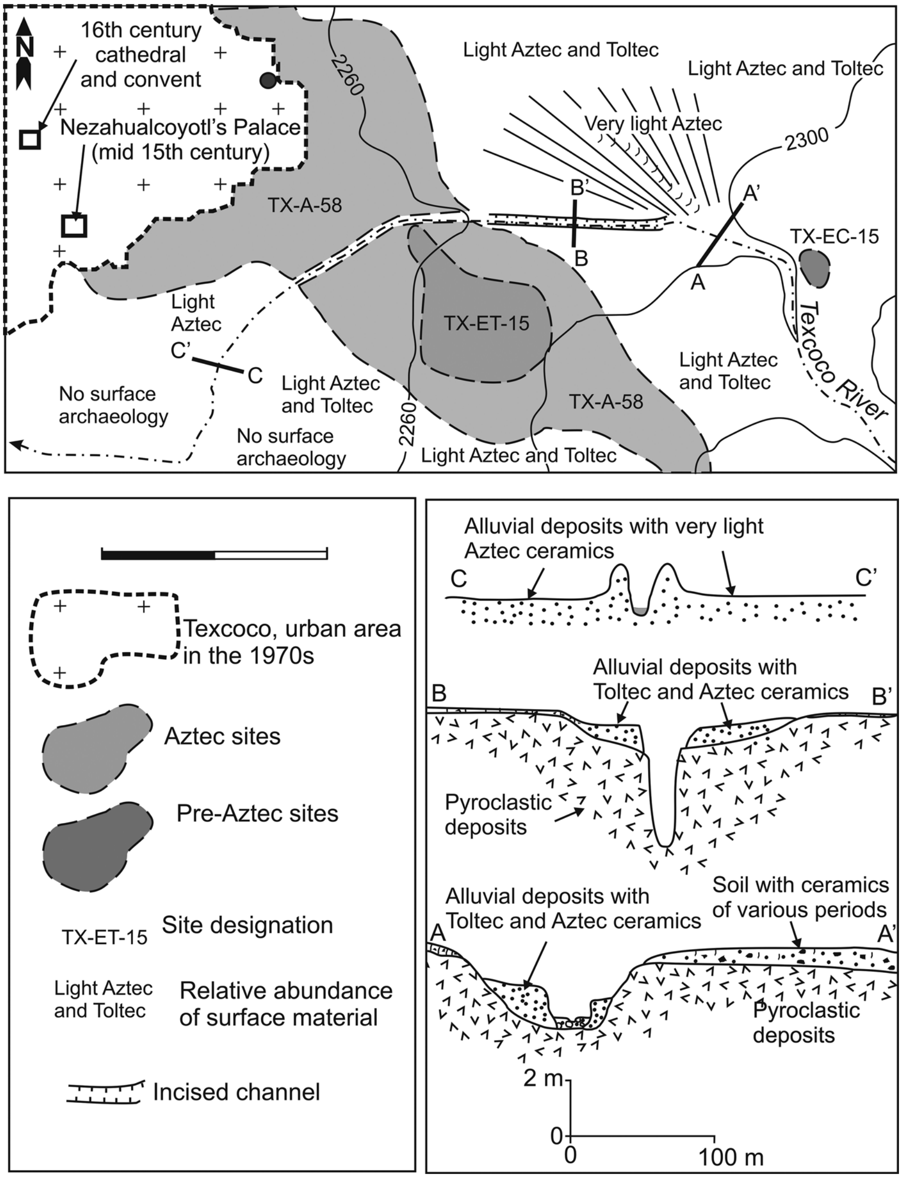

Figure 12 Geomorphological and cultural contexts of the lower Texcoco River.

The Texcoco city area

The main river in the center of the study area is the Texcoco River, whose channel surrounds the city of Texcoco on its southern side (Figure 12a). Along this reach, the Texcoco River displays an abrupt transition from Type-2 to Type-1 flood plain marked by a deeply incised straight channel (section B-B′ in Figure 12b). The upper and middle course of this river in the focus area is a barranca cutting through a series of pyroclastic flow deposits that constitute the distal part of a massive volcanic fan (Figures 2, 4a). North of this barranca, shallow pits expose layers of sand, subangular gravel, and fragments of reworked pottery of various ages. The convex topography of this surface suggests that this may have been some sort of alluvial fan system associated with an older channel flowing northwest (Figure 12a).

The lower course makes a sharp bend south, which may suggest that it could have already been flowing in this direction in Aztec times, perhaps purposely diverted by King Nezahualcoyotl to prevent flooding of the city and his palace. The levees of the river from the base of the piedmont to the lacustrine plain are artificial, as suggested by their height and stratigraphy, but it is not possible to date their construction.

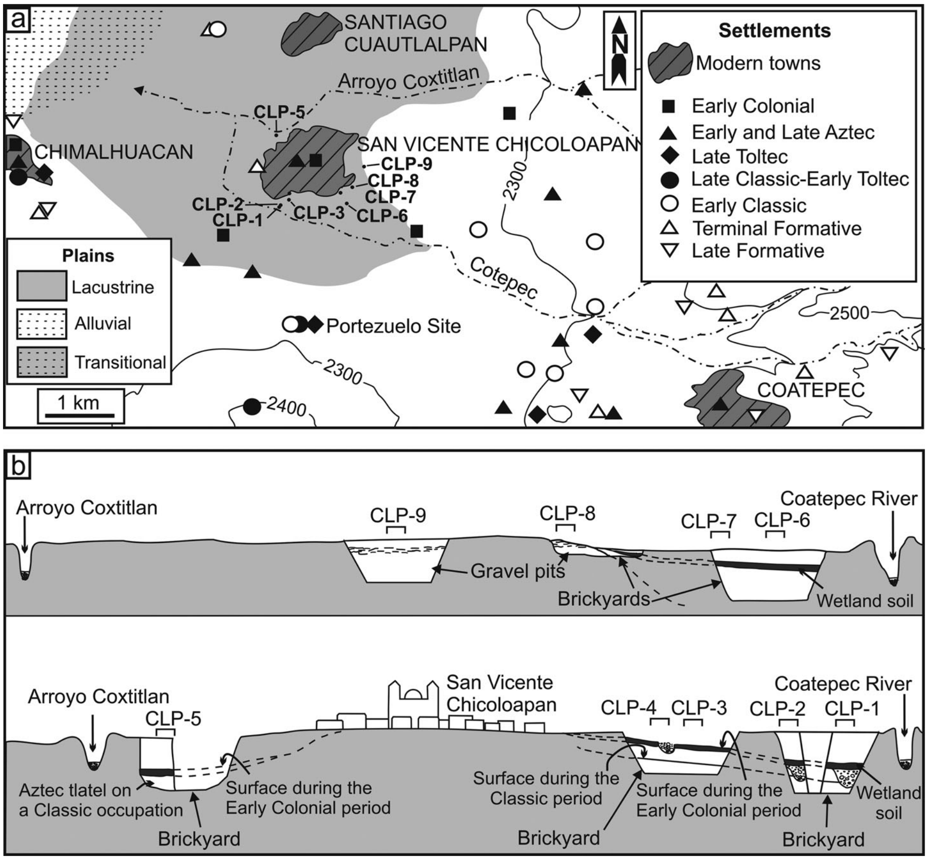

Figure 13 The geographic and archaeological context of the Coatepec-Arroyo Coxtitlan flood plains with the locations of sections. (a) General view; (b) sections across the landscape around San Vicente Chicoloapan.

South of Texcoco, Parsons' (1971) archaeological surveys reported almost no surface material (area of C-C′ transect; Figure 12). Unfortunately, no brickyards were dug in this area. Interestingly, locals refer to this area as having no good material for brickmaking. The soil is sandier than on the other flood plains studied, most likely because of the availability of coarse material in the lower part of the volcanic fan. The lack of surface archaeological material of Prehispanic periods suggests that Colonial-time sedimentation was intense in this area (Figure 4a, location X3).

The Coatepec and Arroyo Coxtitlan flood plains

In the southern part of the Texcocan plain, the Coatepec and Arroyo Coxtitlan Rivers merge west of the town of San Vicente Chicoloapan (Figure 13a). At their merging location, the two rivers form Type-1 flood plains, and similar to other parts of the Texcocan alluvial plain, the archaeological surveys reported a large area with no surface archaeological material (Figure 5b). All the studied sections are located in brickyard pits (Figure 13b), where units A, C, D, and E, and soil horizons S1, S3, S4, and modern soil are exposed (Figure 14).

Unit A corresponds to a buried Pleistocene terrace north of San Vicente Chicoloapan. This unit comprises alluvial fan-like reworked volcanics and a calcrete (K horizon). The calcrete and other pedogenic structures are part of soil S1, exposed only at CLP-9 (Figure 14). It is possible that the foundations of the modern town of San Vicente Chicoloapan sit on a preexisting natural rise, and a flood-safe surface, formed by unit A, but none of the exposures were deep enough to confirm it. Unit A is a distal part of the old volcanic fan. However, a study of stratigraphic sections exposed in quarries to the east of San Vicente Chicoloapan shows a complex of Pleistocene sedimentary sequences of pyroclastic and deltaic deposits of Late Pleistocene age (Huddart & Gonzále, 2006).

Unit C in this area is limited in extent and disturbed by occupation bearing Late Formative and Classic pottery, but units D and E are more prominent and exposed in most brickyard pits. Unit D is formed mainly by overbank, backswamp, and channel facies capped always by ceramics with Aztec styles. In lower areas, the Aztec period is

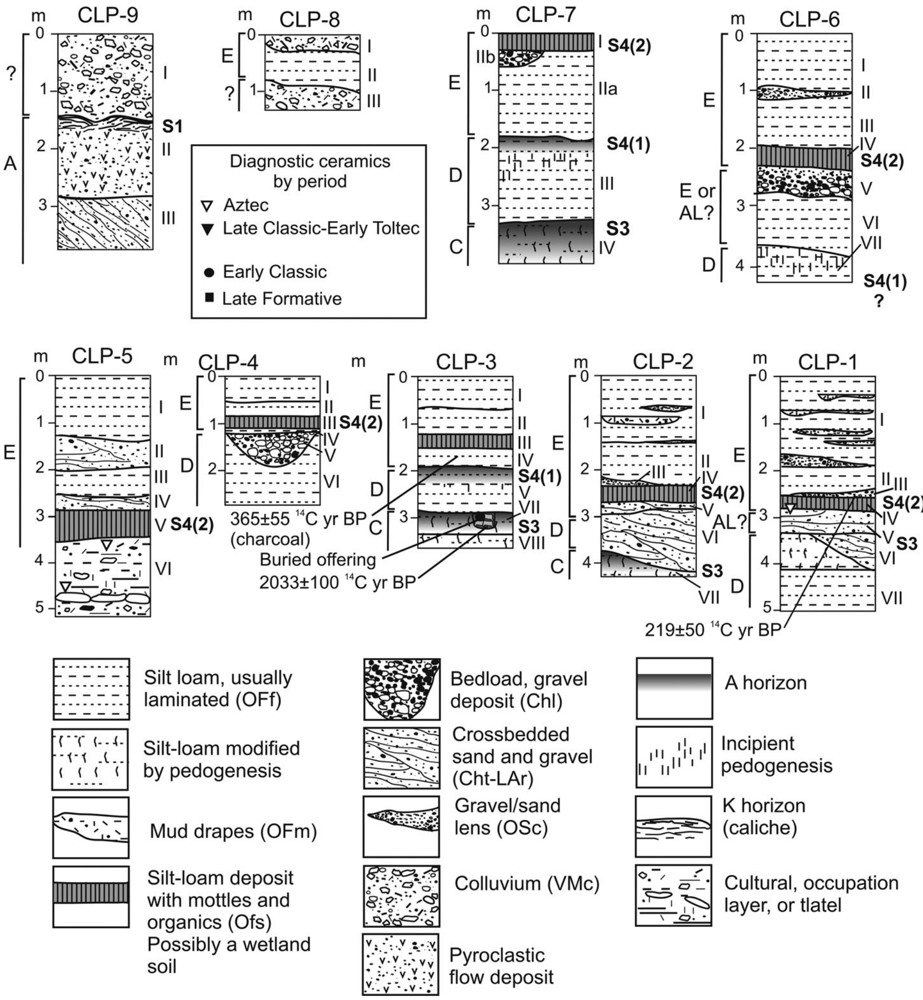

Figure 14 Studied stratigraphic sections of the Coatepec-Arroyo Coxtitlan area (CLP). See Figure 13 for location and broader stratigraphic context.

marked by a silt-loam wetland soil suggesting perhaps a seasonal or permanent backswamp. This soil is equivalent to soil S4 and has a mixture of Aztec ceramic types, including early Colonial Aztec IV ceramics (Figure 3b). There is a reference to a wetland in one of the colonial documents of the region, the *Relación Geográfica de Coatepec*, and in an accompanying map dated ca. 1579 (Acuña, 1985), which depicts a spring represented by water and a bird, and farther south of it a blue area labeled as *laguna*, a term that can be translated as a wetland. Burying this wetland soil is a thick sediment accumulation of unit E (Figure 3b).

Interestingly, the aforementioned map dated ca. 1579 does not show the river channels, but a series of wetlands, which suggests that perhaps the stream flowed elsewhere or across the wetlands. The changes brought about by the Colonial floods with the subsequent deposition of unit E may have caused a change in the flood plain landscape and the channelization of the streams. There is no historical reference as to when the two streams were channelized. However, a map attached to a land litigation document dated 1747 (Centro de Información del Archivo General de la Nación, 1979: Illustration 1151) shows that the channels had already acquired their present configuration.

DISCUSSION

Alluvial Sedimentation and Settlement Chronologies

Flood plain dynamics depend on several controls, some of which are directly or indirectly related to geology, climate, and land use, which is why their response varies from basin to basin (Schumm, Harvey, & Watson, 1984; Waters, 1991). Therefore, it is not always possible to expect direct correlations of events between alluvial basins in the same geographic area. However, in a review of regional alluvial records in Central Mexico, Borejsza and Frederick (2010) found that alluvial developments show similarities between basins in the preagricultural period, presumably driven by regional climatic changes. But during the agricultural period, land use and settlement changes superseded climatic shifts and each small basin had its own fluvial development. This statement is true in the study area when it comes to basin size, but arguable in streams of similar size that drain similar geomorphic areas.

In the studied streams, basin size and order seem to be similar between the Papalotla-Barranca Honda and Coatepec-Arroyo Coxtitlan fluvial systems (Figure 4). Additionally, they have similar settlement histories as revealed by the survey maps published by Parsons (1971). Thus, the recurrence of sequences displaying units C, D, and E in all three basins studied seems to have similar patterns. In contrast to the fluvial characteristics of these three basins, the San Juan Teotihuacan River drains a larger basin with somehow different lithological and altitudinal characteristics and different settlement history, influenced in particular by the large settlement of Teotihuacan. But despite these differences, the Cuanalan sections (CUAN sections) present patterns with similar depositional sequences to the other flood plain localities of this study, particularly in terms of the sequencing of units C, D, and E. Interestingly, this part of the lower Teotihuacan Valley has a settlement pattern history similar to the Texcoco region, judging by the map published by Sanders, Parsons, & Santley (1979). The Acolman sections, on the other hand, are somewhat different because of the poor visibility of lower units, caused in part by the massive accumulation of silts of unit E. It is possible that the recurrence of sedimentation patterns across the region is due to similarities in settlement history and land use, a recurrent phenomenon that may extend beyond the Texcoco region.

Some correlations are even possible between the studied sections and those in other areas of the eastern part of the Basin of Mexico (Figure 1). Thus, in the alluvial plains in the Teotihuacan Valley, north of the study area, McClung de Tapia et al. (2005) identified instability and stability that seem correlative with those identified in the Texcocan alluvial sequences. Subsequent studies identified development of a late Holocene dark soil developed on alluvium (Rivera-Uria et al., 2007; Solleiro-Rebolledo et al., 2011; Sánchez-Pérez et al., 2013. This dark soil known as SP1 (Solleiro-Rebolledo et al., 2011) or Black San Pablo Soil (BSPS) (Sánchez-Pérez et al., 2013) produced dates somewhat similar to those of unit C and soil horizon S3 of sections in the Cuanalan (CUAN), Tepetlaoztoc (TEP), and Chicoloapan (CLP) areas, which range between 3000 and 1500 years B.P. (Figure 5). Dates of the SP1/BSPS in the Teotihuacan Valley extend along a lengthier time span, but they concentrate in the period 400 B.C. to A.D. 650 (cal. 2350–1300 B.P.) (Sánchez-Pérez et al., 2013).

The presence of soil SP1/BSPP in the Teotihuacan Valley, and S3 in Texcoco, suggests that a period of slow and steady sediment accumulation characterized most of the flood plains during times corresponding to the Terminal Formative and Early Classic (Figure 5). This relatively stable dynamics in the flood plains becomes interrupted by the alluvial deposition of unit D, but it is not clear if units D and E are present in the Teotihuacan Valley.

Although periods of geomorphic instability have been attributed to times after the Early Classic Period (e.g., McClung de Tapia et al., 2005; Solleiro-Rebolledo et al., 2011; González-Arqueros et al., 2013), no substantial alluvial deposits correlative with units D and E in Texcoco have been reported in the Teotihuacan valley. However, an alluvial deposit of Colonial age at Rancho Esquitlán reported by Charlton (1972) may be correlative with unit E.

South of the study area, in the Chalco Region, Frederick (1996) reports alluvial sedimentation dated to the Middle and Late Formative period, but no soil horizon that could be correlative with soil horizon S3 is reported. It looks as if the relatively stable or steadily accumulating period of unit C and its soil horizon is missing in Chalco. Instead, it seems that alluvial deposition is rapid and in some cases catastrophic.

An alluvial event correlative of unit D in the Chalco alluvial records by Frederick (1996) is also missing. Instead, massive deposition occurring in the Colonial period suggests that the destabilization that caused the deposition of unit E in Texcoco has a correlative stratigraphic unit in Chalco. Although reported in small streams, the sizeable sedimentation occurs in the Amecameca River Delta, where sediments cover lacustrine deposits including Late Aztec chinampa beds (Frederick, 1996; Hodge, Cordova, & Frederick, 1996).

Alluvial events between Chalco and Texcoco are difficult to correlate because of the size and nature of the fluvial basin. Sedimentation in the Chalco region is greatly influenced by the Amecameca River, which has a large basin and drains an area geologically and geomorphologically different from those of the Texcocan streams. Furthermore, land-use history is different given the different and rather younger volcanic terrain surrounding the Chalco Basin. Nonetheless, like in Texcoco, widespread abandonment of terraced slopes due to the epidemics and the congregations of the 16th century may have caused destabilization.

Beyond the Basin of Mexico, records from El Bajío region, Tlaxcala, Michoacán, and Oaxaca suggest different timing of events, perhaps also because of differences in settlement land use changes (Borejsza & Frederick, 2010; Mueller, Joyce, & Borejsza, 2012). Their different topography, geology, and land-use histories make direct correlation of fluvial events with Texcoco difficult.

Flood Plain Stability, Settlement history, and Climatic influences

Stability in alluvial systems is often measured in terms of soil formation in contrast to sedimentation and channel erosion (Ferring 1992; Mandel & Bettis, 2001). In most cases, flood plain stability is measured by the rate of organic accumulation, or the formation of A-horizons, which are indicative of a paucity of sedimentation and erosion. Stability and instability are evident in the Texcocan flood plain sections as sequences of allostratigraphic units (A, B, C, D, and E) and their respective soil horizons (S2, S3, S4, and the modern soil). However, although this model sounds simple, the question of how climate and land use interact together to stabilize or destabilize a fluvial system is a difficult one to address.

In theoretical terms, flood plain stability would depend on climatic fluctuations. But in the case of central Mexico, since farming became an important activity, links between fluvial changes and climatic fluctuations are difficult to establish (Borejsza & Frederick, 2010). Therefore, any histories of flood plain stability–instability processes in the streams of the Basin of Mexico should be linked to regional and local settlement and land-use histories.

Stream destabilization and rapid sedimentation following initial clearing of forests by an ever-expanding farming population in the Formative led to sedimentation in various areas of the Mexican highlands (Borejsza & Frederick, 2010; Mueller, Joyce, & Borejsza 2012; Borejsza, Frederick, & Lesure, 2011). In the Texcocan flood plains, this process is represented by the development of unit C. Subsequent slope stabilization, whether due to better management of slopes, favorable climatic conditions, or a combination of both, led to the stabilization of the flood plains that allowed the formation of soil S_3 and settlement in an area previously frequently flooded.

Subsequent periods of alluviation (i.e., units D and E) and channel incision can be linked to the more complex phenomena of rapid population increase followed by abandonment, which suggests that population dynamics stability might be a factor to consider beyond climatic changes. Nevertheless, it is important to look at the climatic background to flood plain stabilization because in some cases climatic shifts may have an indirect role or in other cases a direct role in triggering certain geomorphic phenomena.

In Central Mexico, the only high-resolution climatic records for the Late Holocene come from tree-ring analyses, some of which are complemented by historical references in Aztec codices and Spanish Colonial documents (O'Hara and Metcalfe, 1997). The composite record shows a series of drought periods, often referred to as megadroughts. One of the best known in Mesoamerica are those of the Late Classic, which allegedly caused the unstable conditions that brought down the Teotihuacan dominance as well as other cultures of Mesoamerica (Haug et al., 2003). Reconstructed June PDSI (Palmer Drought Severity Index) values from tree rings point to a drought in the period A.D. 897–922 (Stahle et al., 2011), but this cannot be linked to the collapse of Teotihuacan because the dates place the decline of the city around A.D. 550 (Beramendi-Orosco et al., 2009). However, it is possible to think that the A.D. 897–922 drought may have influenced the destabilization that created the accumulation unit D in the Texcocan flood plains, but there is no direct proof of that. Instead, as discussed below, settlement history provides a more direct clue to the destabilization of slopes and flood plains.

The chronological resolution for unit D is poor and based on one single radiocarbon date at CUAN-4, layer XI (A.D. 680–880; Table I), or the layer below this unit. Elsewhere, the bottom of unit D is associated with the Coyotlatelco ceramic style, which is dated to the Late Classic (and more specifically with the so-called Epiclassic) with dates in the Basin of Mexico ranging between A.D. 600/650–850/950 (Fournier et al., 2006). The top of the unit, or more specifically soil horizon S4, is associated with ceramics of the Toltec and Aztec periods, usually referred to Aztec I, II, and III (Figure 5). This suggests that unit D occurred in a relatively short time sometime between the Late Classic and Early Toltec periods (Figure 5). Coincidentally, based on the Texcoco survey data, Parsons (1978) identified the Late Classic and Early Toltec as the periods with lowest number of settlements, with only half the number of sites for the Early Classic. Furthermore, the few sites of the Late Classic and Early Toltec are highly nucleated with vast unoccupied areas (Parsons 1978). These data suggest that site abandonment, particularly in the piedmont, might be associated with the destabilization of slopes and subsequent sediment accumulation in the flood plains.

The implications for this abandonment of rural areas, as experienced in the piedmont later in the Early Colonial period, could have had serious consequences for slope instability, given that terraces, check-dams, and other structures in the area were abandoned and highly vulnerable to soil erosion. As suggested by archaeological surveys

(Parsons, 1971) and later geoarcheological work (Cordova, 1997; Cordova & Parsons, 1997), there is little evidence of terraces dated to pre-Aztec period. Some terraces of Late Aztec age sites contain Early Classic ceramics (Cordova & Parsons, 1997). Therefore, there is the possibility that Late Aztec farmers rebuilt the remains of terraces of former periods (e.g., Formative and Classic).

The influence of climatic events on geomorphic stability in Texcoco is not clear, since no direct link is evident between droughts and settlement dynamics, or droughts and flood plain stabilization. In the Late Aztec period, the so-called Aztec drought, which in terms of June PDSI data encompasses the period 1378–1406, is one of the most prominent megadroughts of the past 2000 years (Stahle et al., 2011). Another prominent, though short, drought of the Aztec period is the one associated with the famine of the 1-Rabbit year in the Aztec Calendar (i.e., 1454) (Therrell, Stahle, & Acuna-Soto, 2004). Needless to say, the droughts of the 1400s seem to have no effect on destabilizing the economic and social systems of rural settlement in Texcoco. In fact, the Late Aztec period (1350–1519) is the time when the major expansion of settlements, waterworks, and reclamation projects occurs in Texcoco (Parsons, 1971; Cordova & Parsons, 1997). During the same period, construction of terraces to cultivate marginal areas on the slopes increases productivity through a complex system that involved state and local functionaries and family households (Evans 1993).

Furthermore, no sign of widespread alluvial sedimentation or channel incision is apparent in the Texcocan alluvial records during the Early and Late Aztec Periods. The so-called Aztec alluvium is only scattered channel deposit with Aztec pottery, which might even be part of lower unit E (Figure 5). The possibility that the Aztec alluvium is a unit assigned to the early Colonial period lies in the fact that most of the pottery in it is Aztec III, which is a style that in rural areas expands across a relatively long period from the late 1300 to the mid-1500s (Charlton, Fournier, & Otis-Charlton, 2007).

The 16th-century droughts occurred in the early part of the Colonial period, beginning with the 1514–1539 megadrought and were followed by a series of shorter droughts between 1540 and 1625, during which the epidemics that decimated the population occurred (Acuna-Soto et al., 2002). Those who survived the epidemics were congregated in nucleated settlements through a colonial policy known as *Congregaciones* (Gibson, 1964). This policy meant the abandonment of lands in most of the piedmont (Cordova, 1997). Because of lack of maintenance, the walls of dams and terraces broke easily, creating high-energy torrents and providing sediments that would flow down the streams (Cordova & Parsons, 1997). A comparable slope and stream stabilization is documented in the Tlaxcala region, where similar population dynamics changes took place in the 16th century (Borejsza, 2013).

To make matters worse for slope and stream destabilization, vacant areas of the depopulated rural territories were given as land grants to Spanish and Mestizos for grazing. This change in land use took a tremendous toll on the highly vulnerable soils of the piedmont, particularly during the excessive precipitation events that occurred in the early 1600s, especially the so-called *Gran Inundación* (Great Flood) of 1629–1633 (Boyer-Everett, 1973). During this early phase of unit E deposition, sediments removed during these events constitute most of the alluvial deposits classified here as unit E. This unstable phase caused sedimentation and channel avulsion in Type-1 flood plains (lower San Juan Teotihuacan, lower Papalotla, and Coatepec-Arroyo Coxtitlan), and sedimentation and channel incision in the Type-2 flood plains (Barranca Honda and Middle Papalotla).

The latest phase of sedimentation of unit E occurred in the 1770 and 1780s when dry years followed by excessive rains produced large amount of sediments (Cordova, 1997). It is one of these events that rendered the Acolman dam useless, and why it was subsequently destroyed. In subsequent years, flooding was reduced in part because of works such as the building of dams, controlling channels, and building of earthen levees along the stream channels. Today, once again, the region is in a geomorphically stable period. No major drought has been recorded for the past 250 years, but the stability is also in part due to land management measures. It is important to remember that the 18th and 19th centuries were the time when most of the work of the *desagüe* (drainage of the lakes) and management of flood control took place under the colonial administration (Junta Directiva del Desagüe, 1902). Despite the known climatic crises of the late 18th and early 19th century (see Endfield, 2012), the Texcoco region seems not to have had the environmental crises that afflicted the region in the early Colonial period.

Finally, it is important to point out that geomorphic instability during the Colonial period is a common process recorded in several parts of central Mexico. Originally, however, this phase was attributed to the devastating effects of the introduction of sheep (Melville 1990, 1994), which later has been denied on the grounds that the landscape had already been damaged (Whitmore & Turner 1992; O'Hara et al., 1993; Butzer & Butzer 1993, 1997). Further studies in the Texcoco region (Cordova, 1997; Cordova & Parsons, 1997), Tlaxcala (Borejsza, 2013), the Mixteca Alta (Perez-Rodriguez & Anderson, 2013) and the Pátzcuaro Basin (Fisher et al., 2003; Fisher, 2005) relate destabilization to the abandonment of terraces and other structures to retain soil and water. This happened in tandem with the effects of newly introduced land-use practices by the Spanish among other causes (Endfield, 2012). Although not the main point of discussion here, this example shows that in this part of the world, population change, particularly decline, seems to be more detrimental than population increase in triggering soil erosion (Fisher et al., 2003). The case of the Late Aztec period shows that despite adverse climatic events, the land was kept intact because of high population levels and organization, which translated into several works (terraces, canals, dams, and others). These systems had to be maintained by farmers. Once epidemics decimated the Indian population and the congregations moved the survivors to nucleated settlements, terraces and dams broke up creating high mobilization of sediments on a landscape already vulnerable to erosion.

CONCLUSIONS

The history of alluvial sedimentation in the Texcocan flood plains during the late Holocene is characterized by responses mainly to shifts in settlement and land use. At least in two instances rural settlement abandonment and settlement nucleation created unstable slopes with consequences for sedimentation and channel changes downstream. At least in the past, climatic shifts played a secondary role, although perhaps droughts and periods of intense rain contributed to triggering thresholds that led to geomorphic instability.

During the agricultural period, the initial destabilization of the Texcocan fluvial systems seems to be related to the expansion of the farming population on slopes in the Formative period, which in the Texcocan flood plains is represented by the deposition of unit C. The relatively stable period that ensued is evidenced by the formation of organic soil horizon S3, and construction of living structures on the flood plain during the Late Formative and Early Classic periods.

Subsequent destabilization of the fluvial systems occurred sometime in the Late Classic or Early Toltec, as evidenced by the deposition of unit E, which buried soil horizon S3. The Texcoco archaeological survey showed that the Late Classic is characterized by depopulation of the Texcocan piedmont and subsequent settlement nucleation. Therefore, it is hypothesized that the abandonment of structures in the landscape aided slope destabilization and soil erosion led to the mobilization of sediments that formed unit D in the flood plains. The stable period that followed this event is characterized by the development of organic soil horizon S4 on sediments of unit D. This period also saw intense occupation and settlement building in the flood plains, as evidenced by numerous settlements of Late Toltec and Early and Late Aztec periods. Despite population increase and severe droughts during the Late Toltec and Early and Late Aztec phases, no fluvial destabilization is apparent in the sedimentary record of the Texcocan flood plains. In the Texcocan piedmont, this led to the reclamation of formerly eroded areas of tepetate with the implementation of terraces and check-dams, which were constantly maintained with farmers living in each land plot (Cordova & Parsons, 1997). Nonetheless, the rapid and drastic settlement changes that occurred during the early colonial period led to depopulation of intensively managed lands (e.g., terraces, dams, canals, etc.), which culminated in the destabilization of slopes, flooding, and deposition of sediments of unit E. A new period of geomorphic stability in the flood plains began at the end of the 18th century, lasting to the present as the rural population levels have recovered and water management works have been implemented.

I am very thankful to Karl Butzer and Charles Frederick for advice and guidance in this research, and to archaeologists Luis Morett-Alatorre, Lorena Gámez-Eternod, and the late Dr. Mary Hodge for their assistance in the identification and dating of the archaeological materials and support in the field. I am also grateful to Professor Jeff Parsons (University of Michigan) for granting access to his field notes and maps of the Texcoco Archaeological Survey and his useful guidance in this research. I am also grateful to Eduardo Fernández de Arteaga, Manuel Figueroa Maheng, and Gabriel Legorreta for their assistance in field work. I am thankful to the anonymous reviewers for their valuable suggestions to improve this paper.

This research was funded by the NSF Dissertation Improvement Grant SBR-9304967. Additional support for field research was provided by the Instituto de Geografía at the National Autonomous University of Mexico and the Museum of Agriculture at the Autonomous University of Chapingo in Texcoco. My thanks go also to the National Oceanic AMS facility of the Woods Oceanographic Institution in Massachusetts, and to Sam Valastro of the former University of Texas Radiocarbon Laboratory and to the kind support with the radiocarbon dating.

REFERENCES

Acuña, R. (1985). Relaciones geográficas del siglo XVI: México, Vol. 1. Mexico City: Universidad Nacional Autónoma de México.

Acuna-Soto, R., Sthale, D.W., Cleaveland, M.K., & Therrell, M.D. (2002). Megadrought and megadeath in 16th century Mexico. Revista Biomédica, 13, 289–292.

Alva-Iztilxóchitl, F. (1977). Obras Históricas II. In E. O'Gorman (Ed.). Mexico City: Universidad Nacional Autónoma de México.

Archivo General de la Nación (1762). Section: Bienes Nacionales, document number 1887. Unpublished document with a map.

Beramendi-Orosco, L.E., Gonzalez-Hernandez, G., Urrutia-Fucugauchi, J., Manzanilla, L.R., Soler-Arechalde, A.M., Goguitchaishvili, A., & Jarboe, N. (2009). High-resolution chronology for the Mesoamerican urban center of Teotihuacan derived from Bayesian statistics of radiocarbon and archaeological data. Quaternary Research, 71, 99–107.

Borejsza, A. (2013). Village and field abandonment in post-Conquest Tlaxcala: A geoarchaeological perspective. Anthropocene, 3, 9–23.

Borejsza, A., & Frederick, C.D. (2010). Fluvial response to Holocene climate change in low-order streams of central Mexico. Journal of Quaternary Science, 25, 762–781.

Borejsza, A., Frederick, C.D., & Lesure, R.G. (2011). Swidden agriculture in the *tierra fria*? Evidence from sedimentary records in Tlaxcala. Ancient Mesoamerica, 22, 91–106.

Boyer-Everett, R.E. (1973). La Gran Inundación: Vida y Sociedad en la Ciudad de México, 1629–1638. Mexico City: SEP Setentas.

Bradbury, J.P. (1989). Late Quaternary lacustrine palaeoenvironments in the Cuenca de México. Quaternary Science Reviews, 8, 75–100.

Butzer, K.W. (1992). The Americas before and after 1942: An introduction to current geographical research. Annals of the Association of American Geographers, 82, 345–368.

Butzer, K.W. (1995). No Eden in the New World. Nature, 362, 16–17.

Butzer, K.W., & Butzer, E.K. (1993). The sixteenth century environment of the central Mexican Bajío. Archival reconstruction from Colonial land grants and the question of ecological impact. In K. Mathewson (Ed.), Culture, Form and Place (pp. 89–124). Baton Rouge, LA: Louisiana University Press.

Butzer, K.W., & Butzer, E.K. (1997). The "natural" vegetation in the Mexican Bajío: Archival documentation of a sixteenth century savanna environment. Quaternary International, 43/44, 161–172.

Centro de Información del Archivo General de la Nación (1979). Catálogo de Ilustraciones, Vol. 3. Mexico City: Archivo General de la Nación.

Cervantes-Rosado, J. Fournier, P., & Carballal, M. (2007). La Ceramica del Posclasico en la Cuenca de Mexico. In B. L. Merino-Carrión & A. García-Cook (Eds.), La Producción Alfarera en el México Antiguo (Vol. 5, pp. 277–320). Mexico City: Instituto Nacional de Antropología e Historia.

Charlton, T.H. (1972). Post-conquest developments in the Teotihuacan Valley, Mexico: Part I, Excavations. Iowa City, IA: Office of the State Archaeologist.

Charlton, T.H., Fournier, P., & Otis-Charlton, C.L. (2007). La cerámica del periodo colonial temprano en la Cuenca de México: Permanencia y cambio. In B. L. Merino-Carrión & A. García-Cook (Eds.), La Producción Alfarera en el México Antiguo (Vol. 5, pp. 429–496). Mexico City: Instituto Nacional de Antropología e Historia.

Cordova, C.E. (1997). Landscape transformation in Aztec and Spanish Colonial Texcoco, Mexico. Unpublished doctoral dissertation. Austin, TX: University of Texas.

Cordova, C.E., & Parsons, J. (1997). Geoarchaeology of an Aztec Dispersed Village on the Texcoco Piedmont of Central Mexico. Geoarchaeology: An International Journal, 12, 177–210.

Cowgill, G.L. (2013). Possible migrations and shifting identities in the Central Mexican Epiclassic. Ancient Mesoamerica, 24, 131–149

Crider, D, Nichols, L., Neff, H., & Glascock, M.D. (2007). In the aftermath of Teotihuacan: Epiclassic pottery production and distribution in the Teotihuacan Valley, Mexico. Latin American Antiquity, 18, 123–143.

Denevan, W.M. (1992). The Pristine Myth: the landscape of the Americas in 1942. Annals of the Association of American Geographers, 82, 369–385.

Endfield, G.H. (2012). The resilience and adaptive capacity of social-environmental systems in colonial Mexico. Proceedings of the National Academy of Sciences, 109, 3676–3681.

Evans, S.T. (1993). Aztec household and village administration. In R.S. Santley & K.G. Hirth (Eds.), Prehispanic domestic units in western Mesoamerica: Studies of the household, compound and residence (pp. 173–189). Boca Raton, FL: CRC Press.

Ferring, C.R. (1992). Alluvial pedology and geoarchaeological research. In V.T. Holliday (Ed.), Soils in archaeology (pp. 1–39). Washington, DC: Smithsonian Institution Press.

Fisher, C.T. (2005). Demographic and landscape change in the Lake Pátzcuaro Basin, Mexico: Abandoning the garden. American Anthropologist, 107, 87–95.

Fisher, C.T., Pollard, H.P., Israde-Alcántara, I., Garduño-Monroy, V.H., & Banerjee, S.K. (2003). A reexamination of human-induced environmental change within the Lake Pátzcuaro Basin, Michoacán, Mexico. Proceedings of the National Academy of Sciences, 100, 4957–4962.

Fournier, P.G., Cervantes-Rosado, J., & Blackman, J. (2006). Mito y realidad del estilo Epiclásico Coyotlatelco. In L.S. Valverde (Ed.), El fenomeno Coyotlatelco en el centro de México: Tiempo, espacio y significado. Memoria del Primer Seminario-Taller sobre Problematicas Regionales (pp. 41–68). Mexico City: Instituto Nacional de Antropología e Historia.

Frederick, C.D. (1996). Landscape change and human settlement in the southeastern Basin of Mexico. Unpublished report, University of Houston, Clear Lake, TX.

Gamio, M. (1922). La Población del Valle de Teotihuacan, Vol. 2. Mexico City: Secretaría de Agricultura y Fomento.

García, E. (1981). Modificaciones al Sistema de Classification de Koeppen (para adaptarlo a las condiciones de la República Mexicana). Mexico City: Universidad Nacional Autónoma de Mexico.

García-Bárcena, J. (1986). Algunos aspectos cronológicos. In J.L. Lorenzo & L. Mirambell (Eds.), Tlapacoya: 35000 años de historia en el lago de Chalco. Colección Científica, Serie Prehistoria (Vol. 115, pp. 219–224). Mexico City: Instituto Nacional de Antropología e Historia, México.

Gibson, C. (1964). The Aztecs under Spanish rule: A history of the Indians of the Valley of Mexico 1519–1810. Stanford, CA: Stanford University Press.

González, S., Huddart, D., Israde Alcántara, I., Domínguez Vázquez, G., & Bischoff, J. (2014). Tocuila mammoths, Basin of Mexico: Late Pleistocene-Early Holocene stratigraphy and the geological context of the bone accumulation. Quaternary Science Reviews, 96, 222–239.

González-Arqueros, M.L., Vázquez-Selem, L., Gama-Castro, J.E., McClung de.Tapia, E., & Sedov, S. (2013). History of pedogenesis and geomorphic processes in the Valley of Teotihuacán, Mexico: Micromorphological evidence from a soil catena. Spanish Journal of Soil Science, 3, 201–216.

Haug, G.H., Gunther, D., Peterson, L.C., Sigman, D.M., Hughen, K.A., & Aeschlimann, B. (2003). Climate and the collapse of Mayan Civilization. Science, 299, 1731–1735.

Hodge, M. G., & Minc, L. D. (1991). Aztec-period ceramic distribution and exchange systems. Unpublished report, National Science Foundation for Grant # BNS-8704177.

Hodge, M.G., Cordova, C.E., & Frederick, C. (1996). Los asentamientos prehispánicos y el medio cambiante del sureste de la Cuenca de Mexico. In A. Tortolero-Villaseñor (Ed.), Medio Ambiente, Agricultura e Industria en la Cuenca de Mexico: Varios Siglos de Transformaciones (pp. 49–68). Mexico City: Centre d'Études Mexicaines et Cetraméricaines.

Huddart, D., & González, S. (2006). A review of environmental change in the Basin of Mexico. In J.C. Jiménez-López, S. González, J.A. Pompa y Padilla, & F. Ortiz-Pedraza (Eds.), El Hombre Temprano en América y sus Implicaciones en el Poblamiento de la Cuenca de México (pp. 77–105). Mexico City: Instituto Nacional de Antropología e Historia.

Junta Directiva del D. (1902). Memoria Histórica, Técnica y Administrativa del Desagüe del Valle de México, 1499–1900, Vol. 1. Mexico City: Tipografía de la Oficina Impresora de Estampillas.

Mandel, R.D., & Bettis II, E.A. (2001). Use and analysis of soils by archaeologists and geoscientists: A North American perspective. In V.T. Holliday, C.R. Ferring, & P. Goldberg (Eds.), Earth sciences and archaeology (pp. 173–204). New York: Kluwer/Plenum Academic.

McClung de Tapia, E., Rubio, I.D., Castro, J.G., Solleiro, E., & Sedov, S. (2005). Radiocarbon dates from soil profiles in the Teotihuacan Valley, Mexico: Indicators of geomorphological processes. Radiocarbon, 47, 159–175.

Melville, E.G.K. (1990). Environmental and social change in the Valle del Mezquital, Mexico. Comparative Studies in Society and History, 32, 24–53.

Melville, E.G.K. (1994). A plague of sheep: Environmental consequences of the conquest of Mexico. Cambridge, UK: Cambridge University Press.

Miall, A.D. 1985. Architectural-element analysis: A new method of facies analysis applied to fluvial deposits. Earth-Science Reviews, 22, 261–308.

Mueller, R.G., Joyce, A.A., & Borejsza, A. (2012). Alluvial archives of the Nochixtlan valley, Oaxaca, Mexico: Age and significance for reconstructions of environmental change. Palaeogeography, Palaeoclimatology, Palaeoecology, 321, 121–136.

Nimlos, T. M., & Ortíz-Solorio, C. (1987). Tepetate and soil erosion in the Valley of Mexico. Journal of Soil and Water Conservation, 42, 43–60.

O'Hara, S.L., & Metcalfe, S.E. (1997). The climate of Mexico since the Aztec period. Quaternary International, 43–44, 25–31.

O'Hara, S.L., Street-Perrott, F.A., & Burt, T.P. (1993). Accelerated soil erosion around a Mexican highland lake caused by Pre-Hispanic agriculture. Nature, 362, 48–51.

Palerm, A., & E. Wolf. (1954). El desarrollo del área clave del imperio texcocano. Revista Mexicana de Estudios Antropológicos, 14, 337–350.

Parsons, J.R. (1971). Prehispanic settlement patterns in the Texcoco Region, Mexico. Memoirs of the Museum of Anthropology, Vol. 3. Ann Arbor, MI: University of Michigan.

Perez-Rodriguez, V., & Anderson, K.C. (2013). Terracing in the Mixteca Alta, Mexico. Cycles of resilience of an ancient land-use strategy. Human Ecology, 41, 335–349.

Poetsch, T. (2004). Forms and dynamics of silica gel in a tuff-dominated soil complex: Results of micromorphological studies in the Central Highlands of Mexico. Revista Mexicana de Ciencias Geológicas, 21, 195–201.

Rivera-Uria, M.Y., Sedov, S., Solleiro-Rebolledo, E., Pérez-Pérez, J., McClung, E., González, A., & Gama-Castro, J. (2007). Degradación ambiental en el valle Teotihuacan: evidencias geológicas y paleopedológicas. Boletín de la Sociedad Geológica Mexicana, 59, 203–217.

Rzedowski, J. (1975). Flora y Vegetación en la Cuenca del Valle de México, In Memoria de las Obras del Sistema del Drenaje Profundo del Distrito Federal, (Vol. 1, pp. 79–134). Mexico City: Talleres Gráficos de la Nación, México.

Sánchez-Pérez, S., Solleiro-Rebolledo, E., Sedov, S., McClung-Tapia, E., Golyeva, A., Prado, B., & Ibarra-Morales, E. (2013). The Black San Pablo Paleosol of the Teotihuacan Valley, Mexico: Pedogenesis, fertility, and use in ancient agricultural and urban systems. Geoarchaeology, 28, 249–267.

Sanders, W.T., Parsons, J.R., & Santley, R.S. (1979). The Basin of Mexico: Ecological processes in the evolution of a civilization. New York: Academic Press.

Schumm, S.A., Harvey, M.D., & Watson, C. C. (1984). Incised channels: Morphology, dynamics and control. Chelsea, MI: Water Resources Publications.

Solleiro-Rebolledo, E., Sycheva, S., Sedov, S., McClung de Tapia, E., Rivera-Uria, Y., Salcido Berkovich, C., & Kuznetsova, A. (2011). Fluvial processes and paleopedogenesis in Teotihuacán Valley, Mexico: Responses to the late Quaternary environmental changes. Quaternary International, 233, 40–52.

Stahle, D.W., Villanueva Diaz, W.J., Burnette, D.J., Paredes, J., Heim, R.R., Fye, F.K., Acuna-Soto, R., Therrell, M.D., Cleaveland, M.D., & Stahle, D.K. (2011). Major Mesoamerican droughts of the past millennium. Geophysical Research Letters, 38, 1–4.

Stuiver, M., Long, A., Kra, R., & Devine, J.M. (Eds). (1993). Calibration 1993. Radiocarbon, 35, 1–244.

Therrell, M.D., Stahle, D.W., & Acuna-Soto R. (2004). Aztec drought and "the curse of One Rabbit. Bulletin of the American Meteorological Society, 85, 1263–1272.

Vázquez-Sánchez, E., & Jaimes-Palomera R. (1989). Geología de la Cuenca de México. Geofísica Internacional, 28, 133–190.

Waters, M. (1991). The geoarchaeology of Gullies and Arroyos in Southern Arizona. Journal of Field Archaeology, 18, 141–159.

Whitmore, T.M., & Turner, B.L. (1992). Landscape of cultivation in Mesoamerica on the Eve of the Conquest. Annals of the Association of American Geographers, 82, 402–425.

Williams, B. (1994). The archaeological signature of local level polities in Tepetlaoztoc. In M.G. Hodge & M.E. Smith (Eds.), Economies and polities in the Aztec realm (pp. 73–87). Albany, NY: State University of New York at Albany.

Zebrowski, C., (1992). Suelos volcánicos endurecidos en América Latina. Terra, 10, 15–23.

