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Invited review

Bridging the theoretical divide in Holocene landscape studies: social and ecological approaches to ancient Oaxacan landscapes

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A B S T R A C T

In this article we discuss two theoretical approaches to landscape studies in archaeology: the ecological and social/symbolic. We suggest that an integrated approach can provide a more effective means through which archaeologists and earth scientists can model the complex interplay between people and the environment. Our perspective views peoples' engagements with the landscape as simultaneously ecological and social, material and symbolic. To illustrate this synthetic approach we discuss our research from the highland and lowland regions of the Mexican state of Oaxaca using archaeological, ethnographic, ethnohistorical, paleoecological, and geomorphological data. In highland Oaxaca we examine the ways in which political and religious principles were embedded in the landscape as well as the social, symbolic, and material dimensions of anthropogenic landscape change during the Formative period. For the coastal lowlands, we discuss the social and ecological implications of the transition to sedentism and the effects of anthropogenic landscape change during the Formative period. We also examine the interplay between politics and land use during the Classic and Postclassic periods.

1. Introduction

In this paper we consider recent approaches to the dynamic interplay between humans and the natural environment. We identify two broad archaeological approaches to human–environment interaction – ecological and social/symbolic – that have increasingly coalesced around the concept of landscape. The ecological and social/symbolic approaches differ in the ways in which they conceptualize landscape and its relationship to people as well as in their data sources, methodologies, and interdisciplinary collaborations. We argue that to effectively address human–environment interaction these two approaches must be bridged through interdisciplinary collaborations between archaeologists and earth scientists that recognize the inseparability of the material, social, and symbolic dimensions of landscapes.

We draw upon our own research in the coastal lowlands and highlands of Oaxaca, Mexico to elucidate these issues. Like much of the research in landscape archaeology, our research in Oaxaca has tended to fall either within the ecological (Joyce and Mueller, 1992, 1997; Goman et al., 2005, 2010, in press; Mueller et al., 2012, in press) or social/symbolic (Joyce, 2004, 2006, 2009a, 2009b) theoretical poles, although the fact that we have carried out both types of studies suggests the potential for a synthetic approach. In this article we provide two attempts to bridge the theoretical divide in landscape archaeology. The first deals with the inseparability of the material and symbolic dimensions of landscape in the highland valleys that constitute the Río Verde's upper drainage basin. The second example summarizes our research on the history of landscape change in the Verde's lower valley on the Pacific coast of Oaxaca that emphasizes the social and political dimensions of ecological change. Both examples represent preliminary attempts at a synthetic approach to landscape and should be considered as exploratory.

1.1. Landscape archaeology

Over the past 20 years landscape archaeology has emerged as a major theoretical focus in Americanist archaeology (Binford, 1982; Earle and Preucel, 1987; Ashmore and Knapp, 1999; Redman, 1999; Anschuetz et al., 2001; Fisher and Feinman, 2005; Falconer and Redman, 2009). Within landscape archaeology, two theoretical traditions can be defined: one is ecological and has largely focused on the material dimensions of human landscapes, while the other emphasizes social, symbolic, and political dimensions of landscape

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(Joyce, 2009a). Admittedly, this is a broad characterization and each approach includes a diversity of perspectives along with areas of common interest (Crumley, 1994; Ashmore, 2002, 2003).

The ecological approach to landscape archaeology developed out of early settlement pattern research pioneered by Willey (1953, 1956) and the ecological interests of the New Archaeology beginning in the 1960s (e.g., Binford, 1962, 1968; Flannery, 1965, 1968; Butzer, 1971). The ecological approach has focused on the complex ways in which human populations interact with their biophysical environments, including how environmental variables across landscapes affect subsistence, settlement, economy, and social organization and in turn how human populations impact the environment (e.g., Adams and Nissen, 1972; Sanders et al., 1979; Binford, 1982; Joyce and Mueller, 1997; Billman and Feinman, 1999; Redman, 1999; Bawden and Reycraft, 2000; Whitmore and Turner, 2001; Goman et al., 2005). Ecological researchers also consider responses to environmental problems like volcanic eruptions (Sheets, 1999, 2002; Gutiérrez, 2011; Oppenheimer, 2011) and El Niño events (Moore, 1991; Van Buren, 2001). The ecological approach has been closely tied to cultural evolutionary perspectives such that ecological relations are often seen as being a component of the evolution of cultures toward greater complexity (e.g., Flannery, 1972; Sanders et al., 1979; Algaze, 2001). Most researchers take an adaptationist perspective with an emphasis on how populations adapt as a unit to the environment often as components of ecosystems (Butzer, 1982, 1996; Redman, 1999). Variation in how people within social groups might view and/or interact with the environment is rarely considered except in ethnoarchaeological and ethnohistorical cases where historical records or living people are the focus of study (e.g., Kirkby, 1973; Sanders et al., 1979; Parsons and Parsons, 1990; Sanders, 1992; Parsons, 2001). The main cross-disciplinary links of the ecological approach in landscape archaeology have been with ecology, geology, and geography. These linkages are reflected in interdisciplinary research within the ecological tradition where archaeologists, palynologists, geologists, paleobotanists, and other "paleo-specialists" collaborate to examine human ecology in the past. Within anthropology, the ecological approach has been most closely aligned with neoevolutionary and systems ecology approaches in cultural anthropology (e.g., White, 1949; Sahlins and Service, 1960; Rappaport, 1984). Ecological research on ancient landscapes utilizes techniques drawn from the earth sciences (e.g., sediment cores; isotopic studies of bone, shell, and soils; remote sensing) coupled with settlement and subsistence research in archaeology.

Like the ecological approach, the social/symbolic tradition has its roots in settlement research and the early New Archaeology. The social/symbolic tradition, however, emerged as a result of perceived limitations of the ecological approach and was influenced by European and especially British postprocessual archaeologists (Deetz, 1990; Ashmore and Knapp, 1999; Anschuetz et al., 2001; Ashmore, 2002). The social/symbolic approach has focused on the social, political, and symbolic dimensions of landscapes, including aspects of both the "built" and "natural" environment. Central research questions include the cultural construction of ritual landscapes (Stein and Lekson, 1992; Brady and Ashmore, 1999; Snead and Preucel, 1999; Koontz et al., 2001), the sacred geography of built ceremonial places (Ashmore, 1991; Sugiyama, 1993; Joyce, 2000), the relationship between landscape and identity (Helms, 1988; Gillespie, 1991; Snead, 1995; Stark et al., 1995), and historical transformations of landscapes often related to changing political relations (Crumley and Marquardt, 1987; Yentsch, 1996; Ashmore, 2002; Joyce, 2006, 2009b). In addition, most researchers have moved away from the holistic and functionalist aspects of ecosystems ecology that view human groups as unified components of ecosystems. Instead, negotiation, struggle, and conflict as well as cooperation among people based on social differences such as class, gender, ethnicity, and occupation are considered in understanding people's symbolic and material relations to landscapes (Tilley, 1994; Brady and Ashmore, 1999; Joyce et al., 2001; Robin, 2002). The main cross-disciplinary inspirations of the symbolic approach are with history as well as symbolic and political approaches in cultural anthropology and geography. Although research on social/symbolic dimensions of landscape can involve collaborations with earth scientists, there is often a reliance on text-based, iconographic, and ethnographic evidence and approaches in addition to archaeology to address issues of meaning associated with past landscapes.

While there has been an increasing exchange of ideas on landscape studies (Ashmore and Sabloff, 2002; Ashmore, 2003), there continues to be a significant divide in the research interests, cross-disciplinary interactions, and theoretical orientations of scholars pursuing landscape archaeology. The social/symbolic tradition has tended to focus on the ways in which beliefs involving ritual, ideology, and identity construct landscapes, while the ecological approach has emphasized material relations involving land use, subsistence, human impact, and the effects of environmental change on economic relations. The lack of engagement across this theoretical divide is in part due to theoretical tensions between the ecosystems ecology and cultural evolutionary leanings of many in the ecological tradition and the rejection of these perspectives by many archaeologists on the social/symbolic side of the spectrum who favor practice-based and more cultural and historically orientated approaches. Yet in biological and human ecology, scholars long ago rejected the holism and functionalism of systems ecology and have increasingly considered the importance of social and political relations in human–environment interaction (Colinvaux, 1973; Vayda and McCay, 1975; Orlove, 1980; Simberloff, 1980; Vayda, 1986; Greenberg and Park, 1994; Robbins, 2004). Despite the potential for studies that bridge the ecological and social/symbolic divide, few researchers have considered the connection between the symbolic dimensions of landscape and material relations involving production, landscape degradation, labor, settlement, and demography (McAnany, 1995; Brady and Ashmore, 1999; Dunning et al., 1999; Freidel and Shaw, 2000; Sheets, 2009). Such a perspective would view landscapes as products of both how people engage with and conceptualize the environment and their place in it as well as the physical properties of climate, physiography, ecology, etc.

This relational view of landscape has been explored by archaeologists, cultural anthropologists and other social scientists as part of a suite of recent approaches labeled materiality theory (Miller, 2005; Tilley et al., 2006). Drawing on the work of scholars like Ingold (1995), Pred (1990) and de Certeau (1984), landscape can be seen not as a neutral, external backdrop to human activity as in the ecological approach or a symbolic ordering of space as in much of the social/symbolic research, but instead as a process emanating from people's engagements with the world, simultaneously symbolic and material. This is what Ingold (1995) has termed a "dwelling perspective" (also see Hutson, 2010). This perspective also draws attention to temporality, the recognition that the landscape is constituted as an enduring record of the history of human relations with the world at multiple temporal scales. The traces of these past relations, again both material and symbolic, are visible in the landscapes that we encounter in the present. Present day landscapes therefore represent a palimpsest of past dwellings and the present is always conditioned by previous symbolic, social, and material engagements with the world (see Fisher and Feinman, 2005; Fisher, 2009). A dwelling perspective therefore requires a multi-scalar approach that integrates short-term and local processes with long-term, regional ones and these processes should be viewed as simultaneously social, political, symbolic, material, geological, and ecological.

2. Bridging the theoretical divide in ancient Oaxaca

2.1. Regional setting

The Río Verde is one of the largest rivers on the Pacific coast of Mesoamerica in terms of both drainage area and discharge (Tamayo, 1964; Rodrigo Alvarez, 1983; Fig. 1). The upper drainage basin of the Verde consists largely of the Valley of Oaxaca and the Nochixtlán Valley. The Valley of Oaxaca lies at an elevation of 1500–1700 m above sea level, while the Nochixtlán Valley varies from 2000 to 2500 m. Mean annual temperature in the highland valleys is about 16° to 20 °C and average annual rainfall varies from about 600 to 1000 mm. Precipitation in both the highlands and lowlands is strongly seasonal marking the movement of the Intertropical Convergence Zone during the wet season between June and September. Vegetation in the highland valleys prior to land clearance for agriculture is poorly known; however, thousands of years of cultivation have left many highland regions as eroded badlands (Fig. 2) covered with prehispanic agricultural and residential terracing (Fig. 3). Archaeological research over the last 120 years (e.g., Saville, 1899; Seller, 1904; Caso, 1935, 1938; Caso et al., 1967; Flannery and Marcus, 1983; Spores, 1984; Winter, 1989; Kowalewski et al., 2009; Joyce, 2010) has shown that both the Oaxaca and Nochixtlán valleys gave rise to sedentary communities in the Early Formative (4120–2755 cal B.P.) with initial complex societies emerging by the Middle Formative (2755–2350 cal B.P.). Regional polities with their political seats at early urban centers like Monte Albán, Cerro Jazmín, and Yucuita developed by the Late Formative (2350–2065 cal B.P.).

The Río Verde descends from the Sierra Madre del Sur in a deep canyon until it emerges onto its broad coastal floodplain about 30 km from the Pacific Ocean. The coastal climate is hot and humid with mean temperatures ranging from 25° to 28 °C and mean annual rainfall between 1000 and 2000 mm near sea level (Rodríguez et al., 1989). In the coastal lowlands, semi-deciduous tropical forest once dominated but has been replaced by agricultural fields and most recently commercial cash crops, particularly tropical fruit orchards (Joyce, 1991a; Goman et al., 2010). Archaeological research in the lower Río Verde Valley began in the 1950s (DeCicco and Brockington, 1956) and the region has more recently been the focus of a long-term interdisciplinary project (Joyce, 1991a, 1991b, 1994, 2008, 2010, in press; Joyce and Mueller, 1992; Joyce et al., 1998, 2001; Workinger, 2002; King, 2003; Barber, 2005; Goman et al., 2005, 2010, in press; Levine, 2007; Joyce and Barber, 2011; Hepp, 2011). The research shows that early horticulture dates to the Late Archaic period with sedentism possibly developing by the initial Early Formative. A small city that was the political seat of a regional polity emerged at Río Viejo by the Terminal Formative (2065–1620 cal B.P.).

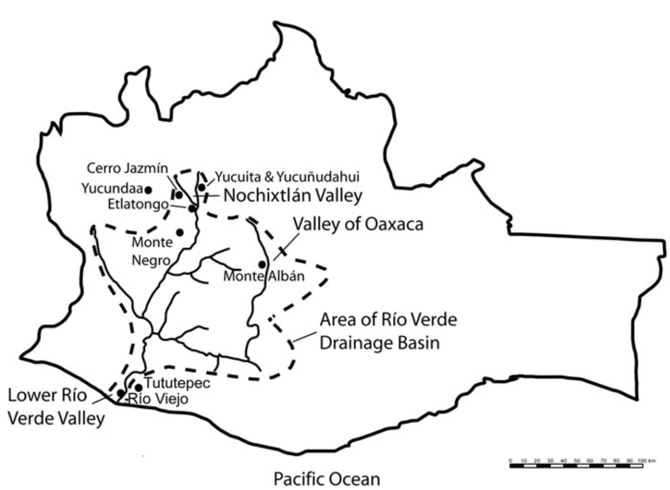

Fig. 1. Map of Oaxaca showing the Río Verde drainage basin with sites and regions mentioned in the text.

3. Sacred landscapes of highland Oaxaca: agriculture, politics and the divine

In the Río Verde's upper drainage basin in the highlands of Oaxaca there are archaeological, ethnohistoric, and ethnographic data that leave no doubt as to the inseparability of the symbolic and material dimensions of landscape. Using evidence largely taken from the Mixteca Alta region of western Oaxaca, which includes the Nochixtlán Valley, one can see the indivisibility of the material and symbolic in indigenous engagements with the landscape. These regions are inhabited by Mixtec speaking peoples and have been the focus of research that offers important insights into the ways in which ancient and modern Mixtecs engage(d) with the landscape (Spores, 1969, 1984; Kirkby, 1972; Monaghan, 1995; Terraciano, 2001; Pérez Rodríguez, 2006; Kowalewski et al., 2009; Pérez Rodríguez et al., 2011; Mueller et al., 2012).

The Mixteca Alta today, as well as in the prehispanic past, is a region where people's lives depend on the land. Over the last several millennia of the prehispanic era the region supported dozens of urban centers that were the political seats of complex polities (Winter, 1994; Balkansky, 1998; Balkansky et al., 2004; Blomster, 2004; Kowalewski et al., 2009; Joyce, 2010; Pérez Rodríguez et al., 2011). Populations of the largest of these ancient cities, such as Cerro Jazmín, Yucundaa, and Yucuñudahui probably numbered over ten thousand. The agricultural systems that supported urban societies focused on maize, beans and squash and relied on sophisticated terrace systems to maintain yields and control erosion in this mountainous land. Interdisciplinary research has shown that despite the development of soil conservation technologies, agriculture had complex and at times destructive effects on the landscape (Spores, 1969; Joyce and Mueller, 1997; Rincón Mautner, 1999; Pérez Rodríguez et al., 2011; Mueller et al., 2012).

Yet to focus only on economy and ecology misses much of the dynamism of human–environment relations in the Mixteca. For prehispanic peoples as well as many Mixtecs today, what we consider the natural world – earth, rain, sun, wind, maize, etc. – was inseparable from the world of people, deities, and ancestors (Monaghan, 1990, 1995; López Austin and López Luján, 1996; Hamann, 2002; Urcid, 2005; Sellen, 2011). At the time of the Spanish Conquest Mixtecs and other Mesoamerican peoples believed that a vital force animated all "living" things; these religious concepts continue to be part of the beliefs of modern indigenous people throughout Oaxaca such as Zapotec and Chatino speaking peoples in addition to Mixtecs (Greenberg, 1981; Marcus, 1983; Monaghan, 1995, 2009; Terraciano, 2001; de la Cruz, 2007). For Mixtecs this force was called *ini* or *yii*, which can be translated as "wind," "heat," and "heart." Animate objects include not just people, plants, and animals but also time and the sacred calendar, rivers, rain, light, mountains, wind, earthquakes, and clouds as well as a range of divine beings. Earth, mountains, and rivers are therefore not considered parts of a physical environment separate from humans, but have agency and are connected with people and deities via the sacred life force (Fig. 4A). There are numerous deities associated with Rain, Earth, and Wind and each deity represents

Fig. 2. Erosion in the Nochixtlán Valley (photo: R. Mueller, used with permission).

a different embodiment or "face" of the earth and can be associated with a diverse array of landscape features and objects such as different bends in a river or Precolumbian figurines found in farm fields (Monaghan, 2009). In late prehispanic times one of the principal deities was a local example of the pan-Mesoamerican rain god termed *Dzahui* in Mixtec. The rain god lived in sacred caves treated as shrines and referred to as "rain houses" and had many "faces" including that of "rain people" who appear as lightning bolts, and multicolored "rain serpents" that fly through the sky bringing rain (Monaghan, 1995, 2009). "Rain people" also included priests who performed offerings, prayers, and sacrifices to petition the gods for rain.

For the Mixtecs, both ancient and modern, there is a fundamental connection between agriculture, earth, rain, and the divine that exemplifies the inseparability of the material and symbolic dimensions of landscape. A key part of the Mixtec creation story recounted by Mixtecs today and recorded in a series of prehispanic screenfold books, or codices, describe the origins of agriculture (Monaghan, 1990; Jansen and Pérez Jiménez, 2007). The origins of agriculture and the Mixtec way of life are depicted as the culmination of a "War of Heaven" where gods and nobles fought against rock-skinned earth deities and rain descending cloud deities (Monaghan, 1990, Hamann, 2002; Fig. 4B). The war was resolved through the establishment of a covenant with the powerful deities of earth and sky that allowed people to practice agriculture. The covenant was necessary because the turning of the soil and the harvesting and consumption of maize, the daughter of the earth and rain, caused the deities great pain. In return for being allowed to practice agriculture, the deities require that humans sacrifice their bodies in death, going into the earth where they are

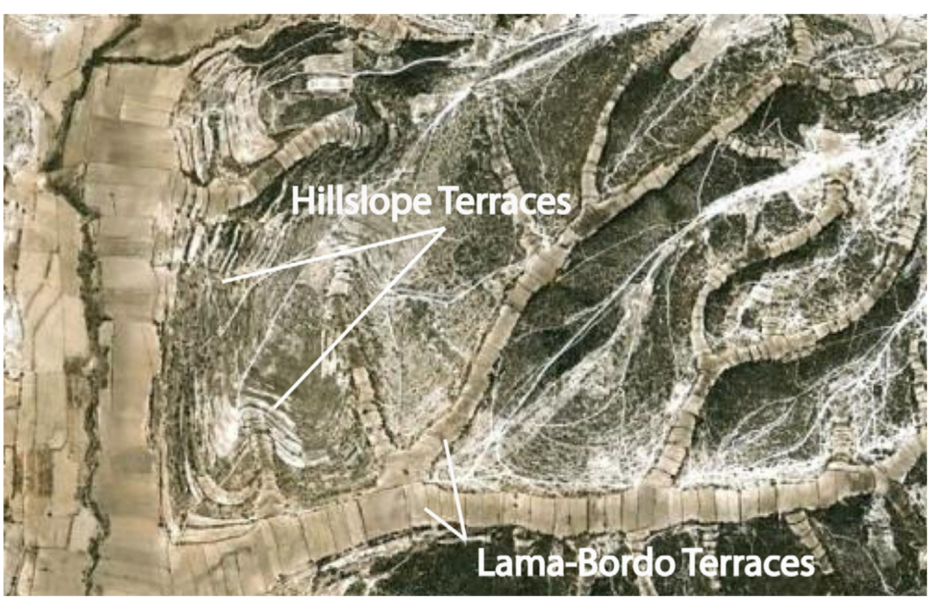

Fig. 3. Google Earth image of hillslope and cross-channel (locally called lama-bordo) terraces in the Nochixtlán Valley ((c) Google 2012; (c) 2012 Cnes/Spot image; (c) 2012 INEGI; Image (c) 2012 Digital Global).

A

B

Fig. 4. Scenes from the Mixtec codices. A. Yucuñudahui or the Hill of the Rain God from the *Codex Nuttall*. B. Scene of the War of Heaven from the *Codex Nuttall* (after Codex Zouche Nuttall, 1987).

assimilated by the gods. The modern Mixtecs of the town of Nuyoo studied by Monaghan (1995) describe this covenant by saying, "we eat the earth and the earth eats us." Following the establishment of the covenant, the current world began with the first sunrise of the new era and the founding of the major ruling houses of the Mixteca Alta.

Mixtec creation stories as well as those of other indigenous Mesoamerican peoples therefore describe the fundamental relationship between people and the divine, including the earth, rain, and sky as a sacred covenant that established relations of debt and merit between humans and the gods, with sacrifice as a fundamental condition of human existence (Monaghan, 1990, 2009). At the time of the Spanish Conquest there were a variety of religious practitioners who were responsible for carrying out sacrifices and other rituals designed to contact deities and ancestors and petition them for fertility and prosperity. Priests were responsible for sheltering, honoring, and "feeding" or making sacrificial offerings to the deities that invoked the sacred covenant (Marcus, 1983; Spores, 1984; Terraciano, 2001; Zeitlin, 2005). People also made offerings to the earth in the form of ceramic vessels, figurines, and food to petition the gods for agricultural fertility and well-being.

Mixtecs dwelt in a sacred landscape and the sustenance that they drew from the earth was not only economic, but spiritual. Many places on the landscape were considered sacred and were locations of ritual activities. For example, sacred mountaintops were associated with rain and the cosmic creation (Hamann, 2002), while springs and caves were portals to the underworld where sacrifices and offerings were made to gods and ancestors (Fig. 5A; Fitzsimmons, 2005; Rincón Mautner, 2005). Buildings, like houses, palaces, and temples were ritually animated with the vital force through dedicatory ceremonies (Marcus, 1983; Terraciano, 2001; Jansen and Pérez Jiménez, 2007). Many buildings were also equated with natural places. Temples built on pyramids were seen as sacred mountains of creation. Ballcourts, tombs, and sunken patios were equated with caves. Whole communities like Apoala and Achiutla were religious centers. Even ancient ruins were recognized as places of creation where ancestors resided (Hamann, 2002, 2008).

Although these notions of the sacred landscape may seem esoteric, they had real material consequences for the lives of people. For example, the relationship between sacrifice and agricultural fertility was fundamental to political relations in the Mixteca and throughout Mesoamerica, especially the unequal flow of material resources between elites and commoners. This was because nobles occupied a special place in relation to religious belief and practice, especially the sacred covenant and the acts of sacrifice that it required (Joyce, 2000; Hamann, 2002; Sellen, 2011). The most powerful ritual specialists were nobles. Human and autosacrifice performed by and on the bodies of the nobility were the most potent form of sacrifice. Nobles therefore acted as intermediaries between people and the divine forces and beings that controlled the cosmos. Sacrifice was a kind of social contract between commoners and nobles (Joyce, 2000; Monaghan, 2009). In addition to the various types of blood sacrifice, many offerings in the form of goods and labor given by commoners to the nobility were conceived of not as tribute, but as sacrifice (Monaghan, 2009). In return for sacrificial offerings, priests, rulers, and other nobles enacted the most potent forms of sacrifice that invoked the covenant, opened up contact with the divine, and provided for human and natural fertility.

The sacred covenant therefore was a key aspect of prehispanic ideologies since it established and reinforced both the hierarchical relationship between people and deities as well as that between commoners and nobles. The covenant established reciprocal ritual, political, and material obligations between nobles and commoners that nevertheless legitimated the privileged position of the nobility and mobilized goods and labor to the elite. Archaeological evidence suggests, however, that the ideological aspects of the sacred covenant could also become a source of conflict within ancient Oaxacan societies and at times may have contributed to the collapse of rulers and ruling institutions (Joyce, 2000, 2008, 2009b; Joyce et al., 2001; Joyce and Weller, 2006; Barber and Joyce, 2007; Hamann, 2008). Relations between prehispanic Mixtecs and the land were therefore more than material and economic. To miss this interconnection between the material and symbolic dimensions of landscape for ancient Mixtecs is to miss a major aspect of their human–environment relations.

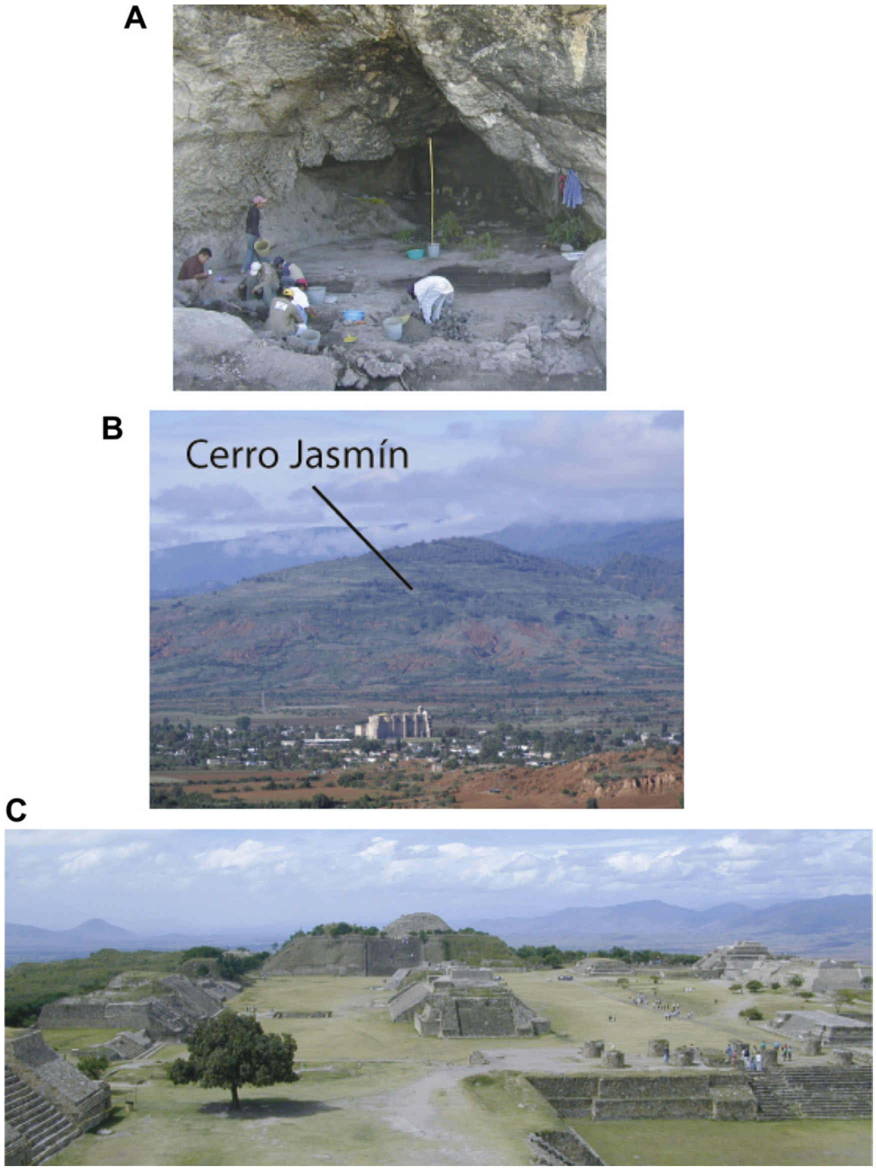

Fig. 5. Landscape features of Oaxaca. A. Cueva del Diablo (Devil Cave), a sacred cave in the Valley of Oaxaca where sacrificial offerings are still made by indigenous Zapotecs. B. The Terminal Formative mountaintop city of Cerro Jasmín in the northwestern Nochixtlán Valley. C. The Main Plaza of Monte Albán (photos: A. Joyce).

The inseparability of the material and symbolic dimensions of landscape are evident at the end of the Formative period in the Mixteca Alta. During the Late Formative from 2350 to 2065 cal B.P. a major transformation in political organization, settlement, and land use occurred in the Mixteca Alta and throughout much of Oaxaca as people left their communities, homes, ancestors, and agricultural fields to found early urban centers (Blanton, 1978; Spores, 1983; Winter, 1989; Marcus and Flannery, 1996; Balkansky, 1998; Blanton et al., 1999; Balkansky et al., 2004; Kowalewski et al., 2009; Joyce, 2010; Pérez Rodríguez et al., 2011). The best known of these early cities was Monte Albán in the Valley of Oaxaca, but dozens of others arose including Monte Negro, Cerro Jazmín, Etlatongo, and Yucuita in the Nochixtlán Valley. Urban centers, especially in the highlands, were located on hilltops (Fig. 5B) and there was an overall shift in settlement into the piedmont (Kowaleski et al., 1989, 2009). The movement of people into higher elevations in these erodible landscapes had significant implications for land use and agriculture. The evidence suggests a major expansion in the use of hillslope and cross-channel terraces (Balkansky, 1998; Balkansky et al., 2004; Kowalewski et al., 2009; Pérez Rodríguez et al., 2011), although based on current evidence it is impossible to assess the proportion of agricultural versus residential terracing. Since our geomorphological investigations do not suggest a significant change in erosion at this time, it seems likely that terraces were effective in controlling erosion (Mueller et al., 2012).

Urbanization was at least in part a result of interpolity conflict, although the nature and scale of warfare are debated (e.g., Zeitlin and Joyce, 1999; Flannery and Marcus, 2003; Joyce, 2003, 2011; Spencer, 2007; Workinger and Joyce, 2009; Sherman et al., 2010). Beyond warfare, however, there is abundant evidence that changes in religion and politics were implicated in the urban transition (Spores, 1983, 1984; Joyce and Winter, 1996; Blanton et al., 1999; Joyce, 2000, 2010). Evidence from all of the early cities that have been investigated archaeologically show that they were religious and political centers as well as demographic ones. Much of the initial constructions at these sites involved the building of ceremonial precincts including monumental structures for ritual performances and political administration (Winter, 1989; Acosta and Romero, 1992; Balkansky et al., 2004; Blomster, 2004; Joyce, 2010; Pérez Rodríguez et al., 2011) such as the Main Plaza at Monte Albán (Fig. 5C). The residences of elites were spatially associated with ceremonial precincts and the evidence indicates that religious belief legitimated new and more centralized forms of political authority. The archaeological record shows that these sites were the centers of novel political and religious institutions, including new deities, hieroglyphic writing, and ritual practices such as human sacrifice (Winter, 1989; Blanton et al., 1999; Joyce, 2000, 2010). Iconography from the ceremonial precincts of several urban centers indicates that they were viewed as sacred mountains of creation and sustenance (Fig. 6), a common theme in later prehispanic times (Joyce, 2000, 2010; Gámez, 2002; Urcid, 2005).

The archaeological record of early urbanism in Oaxaca shows that considerations of cultural meanings, symbolism, and practice add a crucial dimension to research on environment, settlement, and land use. This includes the ways in which aspects of landscape can act as important religious and political symbols such as the association of early cities with sacred mountains whose control by elites legitimated political authority (Joyce, 2000, 2010; Gámez, 2002). Religious and political principles were in turn objectified and made salient in the material aspects of the sacred caves, farm fields, mountains of creation, and ceremonial centers which people encountered on a daily basis. Likewise, anthropogenic impacts on the environment can be linked to religious and political changes as occurred at the end of the Formative in the Mixtec highlands. People relocated to hilltop urban centers due to increased warfare, which itself had a significant religious component (Workinger and Joyce, 2009; Joyce, 2011), and as a result of new religious and political movements. The shift in settlement to highly erodible piedmont settings required an increasing reliance on terrace technologies to support both residences and control agricultural erosion. Population growth and the diversion of labor provided as tribute to the nobility for the construction of monumental buildings and for warfare in turn likely also drove agricultural intensification as people were drawn away from farming. Finally, notions of sacred landscape were means through which the identities of nobles and commoners as well as residents of cities and hinterland communities were increasingly differentiated (Joyce, 2000, 2010). The divergent political interests represented in the art, architecture and activities carried out in ceremonial centers also fostered alternative views of landscape that would eventually contribute to social

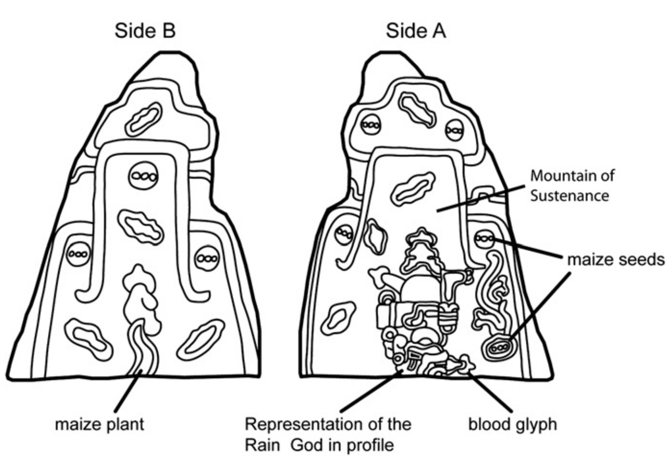

Fig. 6. Yucuita Monument 1 depicting a person in the guise of the Rain god with blood issuing from the mouth as in autosacrifice. Above the personage is a representation of Glyph J, symbolizing maize, along with what may be an image of a mountain of sustenance with depictions of maize at various stages of growth from seeds to mature plants (drawing courtesy of Javier Urcid).

Table 1
Lower Río Verde Valley Chronology.

Period	Uncalibrated Dates	Calibrated Dates
Early Formative	1800–850 B.C.	4120–2900 cal B.P.
Early Middle Formative	850–700 B.C.	2900–2755 cal B.P.
Late Middle Formative	700–400 B.C.	2755–2350 cal B.P.
Late Formative	400–150 B.C.	2350–2065 cal B.P.
Early Terminal Formative	150 B.C.–A.D. 100	2065–1820 cal B.P.
Late Terminal Formative	A.D. 100–250	1820–1620 cal B.P.
Early Classic	A.D. 250–500	1620–1330 cal B.P.
Late Classic	A.D. 500–800	1330–1060 cal B.P.
Early Postclassic	A.D. 800–1100	1060–740 cal B.P.
Late Postclassic	A.D. 1100–1522	740–428 cal B.P.

Oaxacan archaeologists have traditionally used uncalibrated dates when reporting the age range of ceramic phases. The calibrated dates were converted using OxCal 4.1 (Bronk Ramsey, 2009). In this article we use the median of the calibrated radiocarbon ages. The median age is preferred over traditional intercept-based methods as these are overly sensitive to minor changes in the mean of the radiocarbon date (Telford et al., 2004).

tensions and conflict within indigenous Oaxacan society (Joyce et al., 2001; Joyce, 2009a, 2009b; Lind and Urcid, 2010).

4. Landscape history of the lower Río Verde Valley, Oaxaca

Our second example from ancient Oaxaca reminds us that recognition of the social, political, and symbolic side of landscape does not mean that we can ignore ecology. Ecology and broader concerns with resource availability, economics, land use, demography and settlement patterns matter, although these more traditionally materialist concerns are inseparable from social, political, and cultural relations. An interest in ecology and its relationship to social and political change is the focus of our interdisciplinary research in the lower Río Verde Valley, which has traced human–environment interaction through the Middle to Late Holocene (Table 1 provides the regional chronology for the lower Río Verde Valley). We have designed our research to produce a multi-scalar view of human–environment relations. Such a multi-scalar approach requires that researchers collect paleoenvironmental and archaeological data on similar spatial and temporal scales. This research necessitates interdisciplinary collaborations to understand the history of relations among complex variables like geology, climate, hydrology, vegetation, soils, fauna, human settlement patterns, demography, economy, sociopolitical dynamics, and the cultural construction of landscape (see Russell, 1997; van der Leeuw and Redman, 2002). Quaternary paleoecologists need to address environmental change at much finer spatial and temporal scales and to better integrate their evidence with research on the human dimension of landscapes (e.g., Beach et al., 2002; Davies and Tipping, 2004; Kirch et al., 2004; Overland and O'Connell, 2008). High resolution spatial and longitudinal analyses of multi-proxy data in conjunction with the archaeological record provide an opportunity to develop a more comprehensive understanding of landscape that bridges the ecological and social/symbolic divide.

In the lower Verde region (Fig. 7), interdisciplinary research has comprised archaeological, geomorphological, and paleoecological studies. Archaeological research has included excavations at 18 sites, including horizontal and/or block excavations at 6 sites (Joyce, 1991a, 1991b; Joyce et al., 1998; Workinger, 2002; King, 2003; Barber, 2005; Levine, 2007; Joyce and Levine, 2009; Joyce and Barber, 2011). We have also carried out a full-coverage, regional survey over 152 km^2 to provide data on settlement and land use change through time (Joyce et al., 2001). Subsistence studies have included archaeofaunal and archaeobotanical analyses along with human bone chemistry (Joyce, 1991b; Fernández, 2004; Taylor

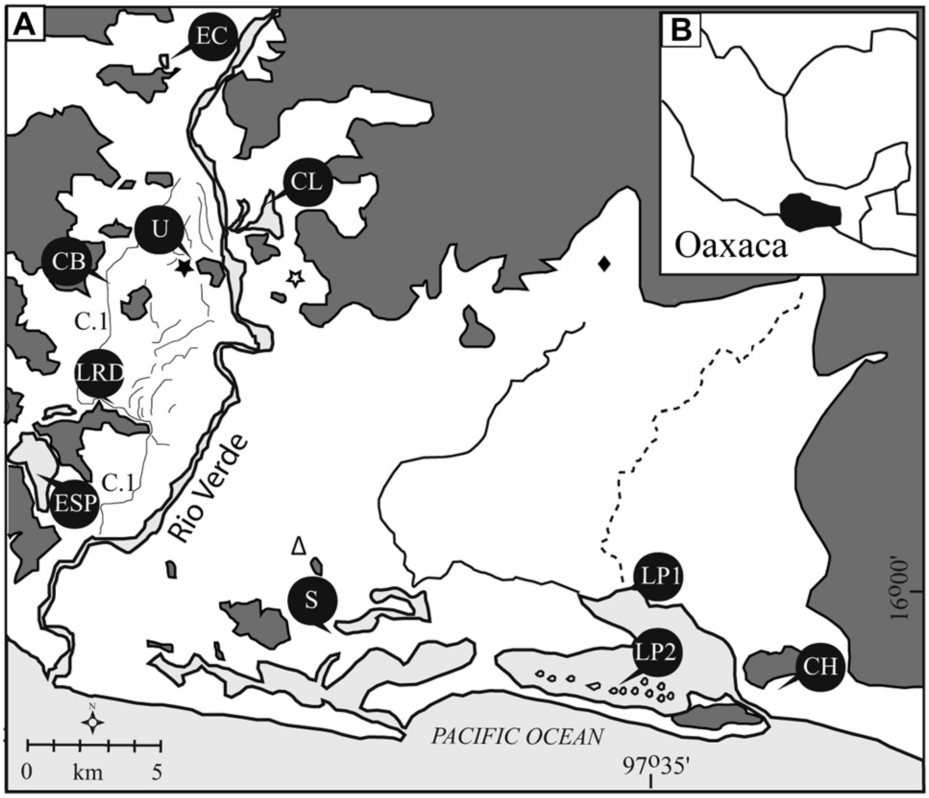

Fig. 7. Map of the location of paleoecological and key archaeological sites in the lower Río Verde Valley. Key to sites: CB = Charco Barro, CH = Cerro Hermosa, CL = Charco Lavado, EC = El Charquito, ESP = Espejo, S = Salinas, LP = Laguna Pastoría sites 1 and 2, LRD = Loma Reyes and U = U2 feature at Río Viejo. The black star indicates the location of Rio Viejo; the open star the location of San Marquitos; the open triangle indicates the location of La Consentida and the black diamond the location of Tututepec. Inset B shows the location of the state of Oaxaca in Mexico.

et al., 2009). Changes in floodplain and coastal land forms have been investigated through geomorphological and paleoecological studies based on a regional coring project that has provided insights on how environmental changes affected settlement and subsistence (Mueller, 1991; Joyce and Mueller, 1992; Goman et al., 2005, 2010, in press; Mueller et al., in press).

A multi-scalar perspective necessitated a change in our paleoecological research strategy from typical approaches (Goman et al., 2010). Spatial patterning in vegetation and land use within the Holocene is usually addressed at the global to regional scale with synthesis of individual site data following decades of work by research teams (e.g., Webb et al., 1993; Jackson et al., 1997; Williams et al., 2004; Shuman et al., 2005). Although long-term, regional records are important for discerning broad patterns in environmental and land use change, human decision making involving land use, subsistence, labor allocation, etc. occur at much finer spatial and temporal scales. In the lower Río Verde multiproxy paleoecological data are available at high temporal resolution from several floodplain sites that vary in size and ecological setting within the region (Goman et al., 2010). Further, our paleoecological data network within the Río Verde floodplain is expanding with analysis either completed or in progress at a further 4 sites (Goman et al., 2010, 2011, 2012). In the coastal zone two estuarine sediment cores provided critical information as to changes in coastal morphology and early horticulture and agriculture in the region (Goman et al., 2005, in press). We have expanded our coastal coverage to include a further 2 sites, although these sites are awaiting analysis.

Data analysis includes magnetic susceptibility, pollen, micro and macroscopic charcoal, phytolith, and carbon isotopes. The macroscopic charcoal record is used as a proxy for local fire history (Whitlock and Larsen, 2001). Fire is not a natural component of the local ecology; however fire is omnipresent in the modern landscape as it is used to clear brush for land clearance for agriculture and for removal of the prior season's crop stalks. The use of fire in agricultural field preparation in the region has likely occurred since domesticates were first introduced (Goman et al., 2010, in press). Stable carbon isotopes are analyzed to provide an indication of the C3 to C4 ratio as they can be used as a proxy for forest clearance and crop cultivation (Lane et al., 2004). Figs. 8 and 9 show a synopsis of macroscopic charcoal and carbon isotope data collected to date from the region.

Particularly important are three records (Charco Barro, Loma Reyes, and the Río Viejo U2 feature), which provide highly localized data (Figs. 7–9; Goman et al., 2010). Loma Reyes is an infilled meander scar of an ancestral Río Verde channel, designated C.1 (Fig. 10). A large prehispanic platform is located close to the auger site. Archaeological survey of the surface as well as test excavations indicate that the site was initially occupied during the Late/Terminal Formative (2350–1620 cal B.P.), grew to its largest extent during the Early Classic (1620–1330 cal B.P.), and saw continued use through the Late Postclassic (740–505 cal B.P.; Joyce et al., 2009). Approximately 5 m of sediments were obtained from the site via auguring. Unfortunately, the top 3 m of samples, covering the Late Classic to modern period were rendered useless because of label provenience loss; the record thus encompasses the Late Formative to Early Classic. Charco Barro is an extant oxbow pond also associated with channel C.1. A ~2.5 m long sediment core was obtained from the pond. This record encompasses the past 1500 years commencing with the latter part of the Early Classic.

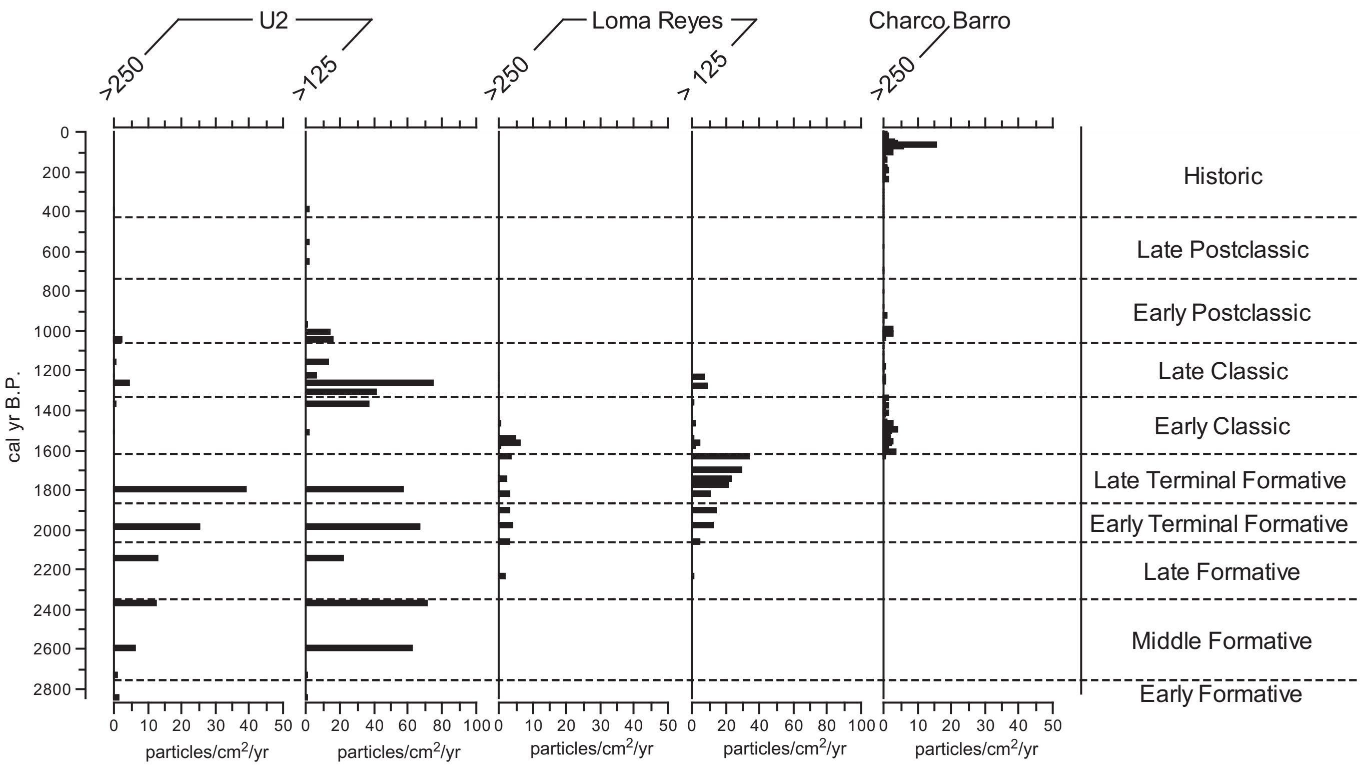

Fig. 8. Macroscopic charcoal records from the floodplain sites of Charco Barro and Loma Reyes (Goman et al., 2010) and U2 (the chronology for this site is tentative).

Multiproxy data from three vertically spaced auger samples extracted from an artificial depression associated with a large u-shaped residential platform designated Mound 2 at the site of Río Viejo have previously been detailed (the u-shaped feature is hereafter referred to as U2; Goman et al., 2010). Several similar features are present at Río Viejo and at other large sites in the region. They typically range in size from 1 to 2 ha and can be up to 4 m below the associated platform and at least 1 m below the level

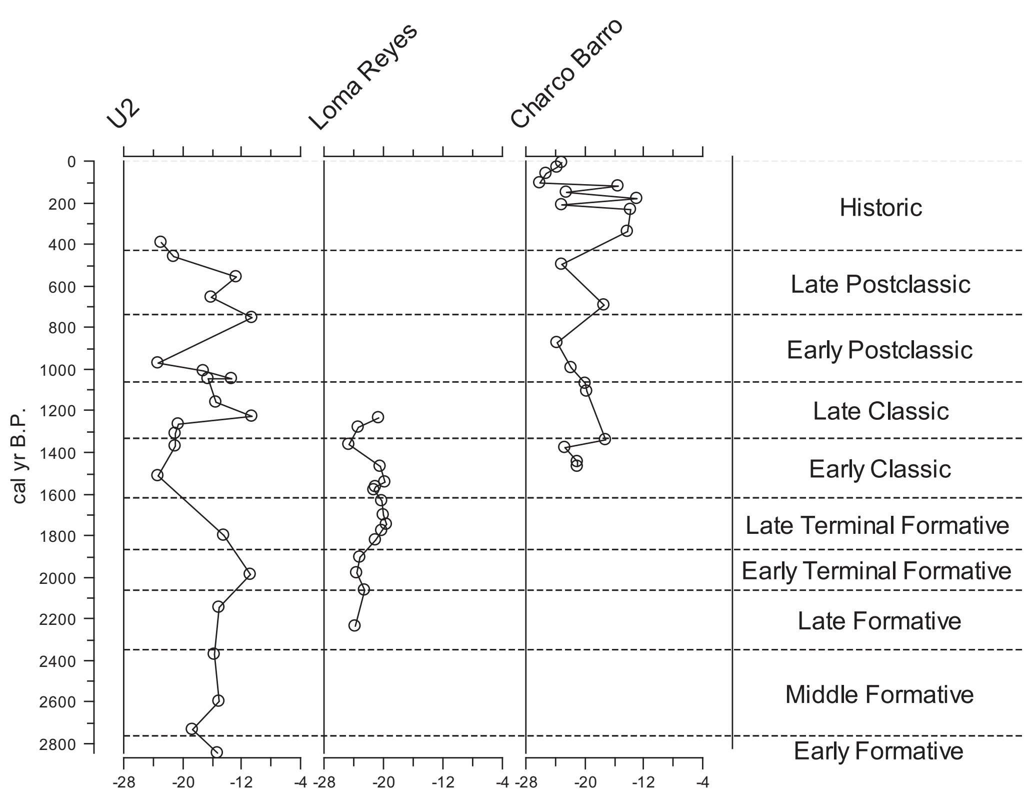

Fig. 9. Carbon isotopic records from the floodplain sites of Charco Barro and Loma Reyes (Goman et al., 2010) and U2 (the chronology for this site is tentative).

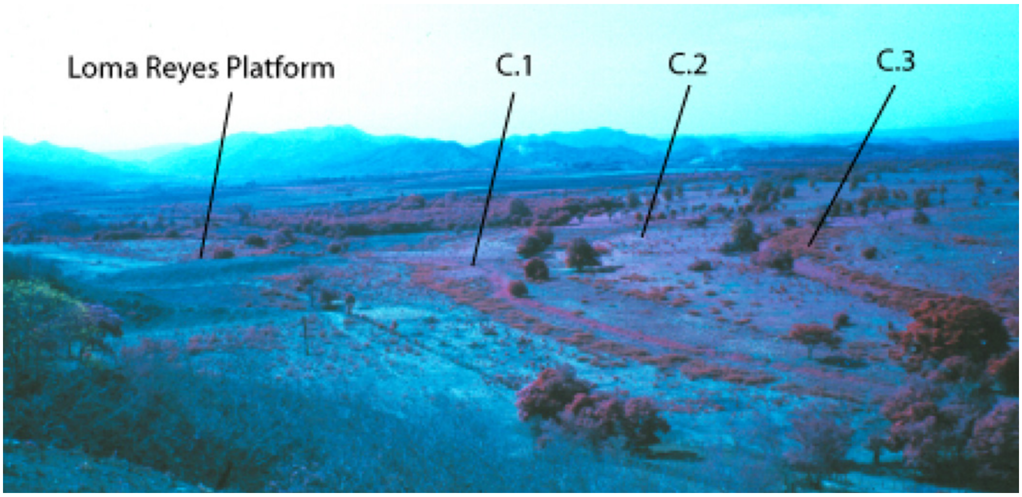

Fig. 10. False infrared photograph of the abandoned channels and prehispanic platform at Loma Reyes (photo: A. Joyce).

of the floodplain (Fig. 11). The purpose of the depressions is not known but is hypothesized to have been a water-control feature. Here we present a full record from the site that extends from a depth of ~60–350 cm. One radiocarbon date currently provides the chronology for the site. An age of 1990 cal BP (AA 93097; 2037 ± 34 ^{14}C B.P.) was obtained from an auger sample with a depth range of 278–289 cm. The remaining chronology is based upon the assumption of consistent sedimentation rates (which may likely be erroneous; see Section 4.3) and ceramics found in the augur samples (Goman et al., 2011). Further radiocarbon samples are pending.

4.1. The transition to sedentism and agriculture in the lower valley

The earliest evidence for a human presence in the lower Río Verde Valley comes from the paleoecological record and, as in several other regions (e.g., Rue, 1989; Jones, 1994; Goman and Byrne, 1998; Leyden, 2002; Horn, 2006), predates the earliest available archaeological evidence. Pollen, charred grass cuticles, panicoid phytoliths and high levels of microscopic charcoal in a sediment core from Laguna Pastoría, a coastal estuary, suggest land clearance at approximately 4800 cal B.P. by people practicing a limited form of horticulture (Fig. 12). These people were probably experimenting with the cultivation of early domesticates, while largely relying on wild resources (Goman et al., in press). Horticultural activity in the region was brief and a significant hiatus followed until what appears to be more intensive agricultural activity by about 2500 years ago, when the coastal zone and particularly the floodplain region abutting the lower Río Verde became the focus for permanent occupation (Joyce, 2005; Goman et al., 2010, in press).

The earliest archaeological site in the region is La Consentida located on the coastal plain approximately 2 km from the modern-day estuary system. La Consentida covers 4.5 ha and is dominated by a large platform rising approximately 5 m above the surrounding plain (Joyce, 1991a; Hepp, 2011; Personal communication 2012; Winter, n.d.). The excavations suggest there were both residential and ceremonial structures built on the platform. Carbon samples for AMS dating were taken from two hearths and from a possible earthen floor. The samples returned dates ranging from 3858 to 3479 cal B.P., making La Consentida one of the earliest well-dated sites of the Mesoamerican Formative period. All of the AMS dates pertain to the earliest phase of occupation at La Consentida, which marked the initial period of platform construction.

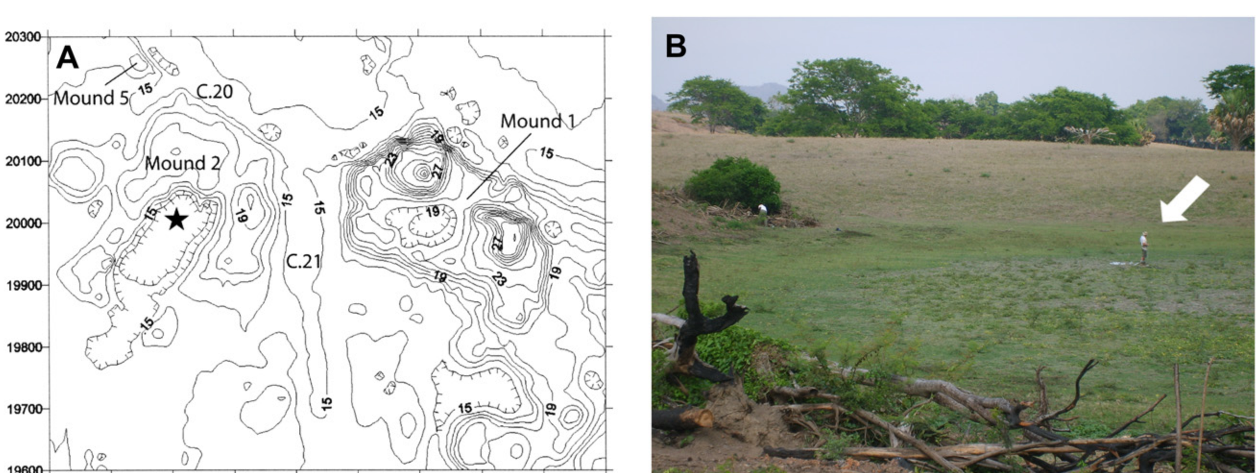

Fig. 11. A. Contour map of the "U" feature at Mound 2, Rio Viejo (C.20 = Abandoned Channel 20; C.21 = Abandoned Channel 21). B. Photo of the U2 feature. The auger site is located near the individual shown by the white arrow. Image taken from the western arm of the U feature looking northeast (photo: M. Goman).

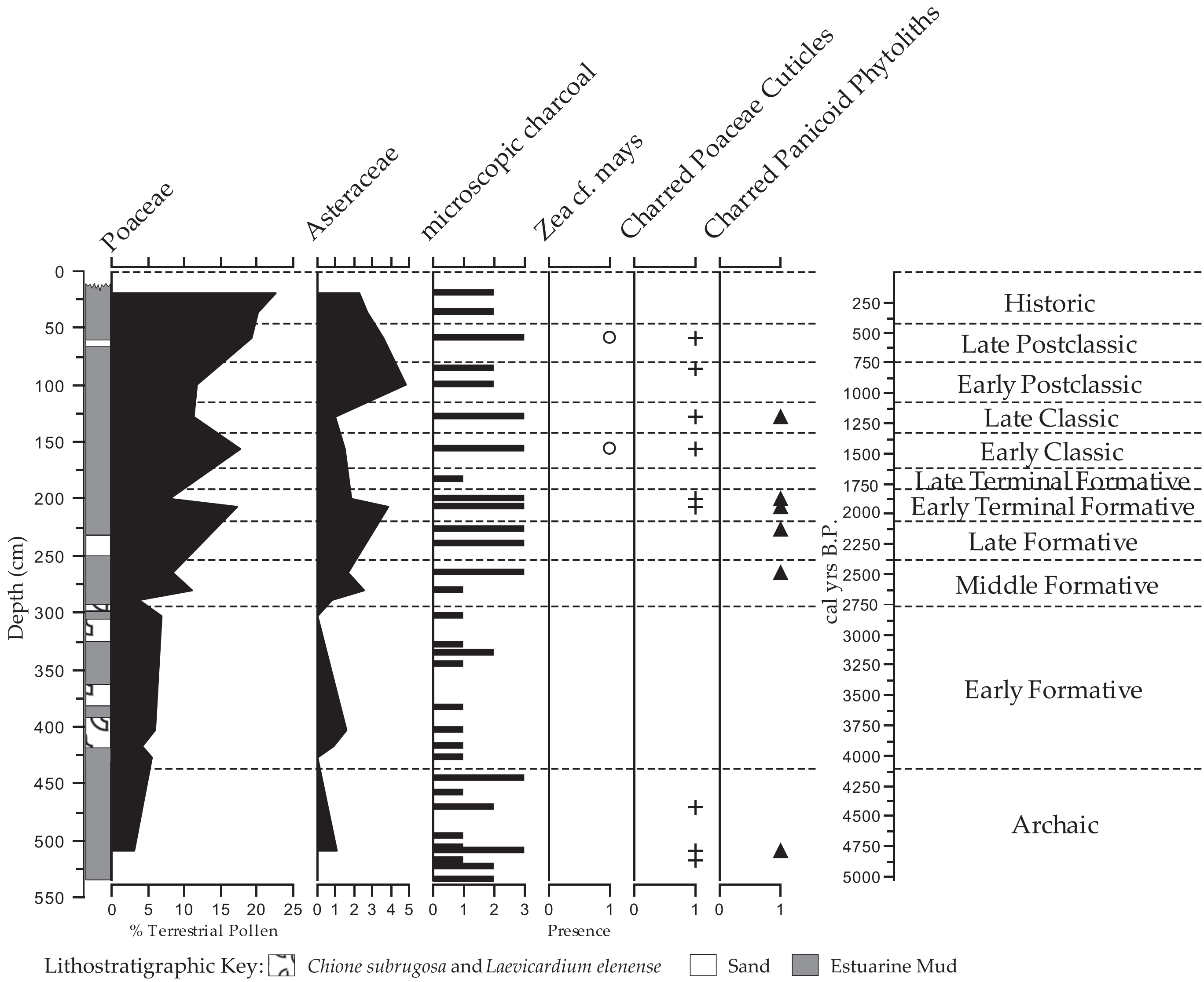

Fig. 12. Data from Laguna Pastoría Core 1 (LP1), showing lithostratigraphy, weedy pollen taxa (Poaceae and Asteraceae), microscopic charcoal, maize pollen and charred grass cuticles and phytoliths.

The AMS dates place La Consentida in the early part of the Early Formative period. The initial phase of occupation at La Consentida is comparable in age to the Barra and Madre Vieja phases (3850–3650 cal B.P.) on the Pacific coast of Chiapas and Guatemala (Blake et al., 1995; Love, 2007) as well as the Espiridión phase in the Valley of Oaxaca (Flannery and Marcus, 1994) and the Purrón phase in the Tehuacán Valley (MacNeish et al., 1970). Evidence from coastal Chiapas and Guatemala is limited, however, until after 3650 cal B.P. The initial Early Formative is defined by the presence of the earliest ceramic vessels in Mesoamerica. Until recently, it was argued that this period also saw the first clear evidence for sedentary communities and agricultural economies in Mesoamerica (MacNeish et al., 1972; Stark, 1981; Marcus and Flannery, 1996). Initial social complexity developed shortly thereafter at least in parts of the southern Pacific coast of Mesoamerica, if not elsewhere (Clark and Blake, 1994; Clark, 2004).

Recent evidence has complicated arguments concerning the relationship between agriculture, sedentism, and social complexity, however. Macrobotanical and microbotanical remains of maize and other early domesticates have been found at sites in the southern Pacific coast (Feddema, 1993; Rosenswig, 2006; Lesure, 2009) and there is evidence for land clearance from some pollen cores (Neff et al., 2006). Evidence from human bone chemistry and ground stone tools, however, have led many archaeologists to question whether agricultural economies developed until after ca 2950 cal B.P. (Blake et al., 1992; Chisholm and Blake, 2006; Rosenswig, 2006; Lesure, 2009). Initial Early Formative subsistence instead appears to have involved a diverse array of foodstuffs focused on estuarine resources and domesticates produced by long-fallow horticulture. Rather than agricultural economies involving a dependence on domesticated plants, the evidence suggests that wild resources constituted the most important dietary staples. Cultivation of domesticates gradually increased through the Early Formative with economies becoming largely agricultural by the Middle Formative. In the lower Río Verde Valley, paleoecological indicators of land clearance disappear by the Early Formative in the sediment core from Laguna Pastoría, suggesting that people living at La Consentida practiced limited forms of horticulture.

Likewise, researchers have questioned whether sedentism developed in many parts of the southern Pacific coast until after 3650 B.P. (Rosenswig, 2006; Lesure, 2009). At La Joya, on the Gulf coast, Arnold (1999) has argued that sedentism may not have appeared until the Late Formative. Explanations for early sedentism have tended to focus on the emergence of a sufficiently stable resource base to allow for permanent occupations along with the development of technologies necessary to exploit these resources (Coe and Flannery, 1967; MacNeish, 1971; Stark, 1981; Marcus and Flannery, 1996). Traditionally, maize based agriculture was seen as the key resource allowing for sedentary life, but data from the Soconusco region on the Pacific coast of southern Mexico and Guatemala indicate that estuarine resources may have been more critical (Neff et al., 2006; Lesure, 2009). The transition to a dependency on maize-based agriculture therefore may have been a result, rather than a cause of sedentism.

The creation of resource concentrations sufficient to allow for sedentism was undoubtedly an important factor in village origins. We suspect, however, that changes in social relations and in relations between people and the landscape were also needed to make sedentism and agriculture possible (see Bender, 1978; Hodder, 1990, 2006; Ingold, 1995; Bradley, 1998; Kuijt, 2000; Jones, 2002; Hodder and Meskell, 2010). That is, people do not necessarily congregate in villages once the distribution and availability of resources on the landscape allow for sedentism. Village life requires new relations among people and with the landscape that may only have been developed long after environmental conditions made sedentism economically feasible. Archaeologists in the Old World have argued that initial sedentism in Southwest Asia may have resulted from people congregating at ritual centers, which became the milieu within which new social and economic relations were worked out (Mithen, 2003; Hodder, 2010). The more intensive exploitation of wild resources around these centers would have led to domestication and eventually dependence on agriculture. Likewise, a commitment to agriculture requires transformations in conceptions of space with more fixed notions of land use and of time with the extended temporal scale required for agricultural planning (e.g., planting cycles and fallow periods; Bradley, 1998). For example, archaeologists argue that the spread of more intensive forms of mixed farming in Western Europe was delayed until people's attitudes toward the landscape had changed (Hodder, 1990; Bradley, 1998; Jones, 2002). Innovations in ritual practices, especially the construction of stone and earthwork monuments, are implicated in these changing perceptions of space, time, and landscape (Bradley, 1998; Hodder, 2010). As argued by Jones (2002), "Monuments evoke an altered conception of both time and place; they embody an alteration of the natural world, and their construction involves the creation of a new kind of place in the landscape which, by their very nature, they endure."

In Mesoamerica, the timing of initial sedentism, agriculture, and the construction of monumental public buildings have been difficult to untangle and the evidence from the initial Early Formative in most regions, including the lower Verde, is limited. We wish to raise the possibility, however, that earthen platform construction in Mesoamerica, at least in part for ritual purposes, may have been a material manifestation of changing perceptions of time and space that contributed to the transition to sedentism and agriculture. Platforms like the one at La Consentida created fixed places on the land that endured. Hepp's (2011, Personal communication 2012) discovery of burials interred within the La Consentida platform suggests that the performance of mortuary ceremonies and the emplacement of the dead could have objectified a shared history and identity as descendants of the ancestors who were interred therein. McAnany (1995) has argued that the interment of ancestors was crucial for establishing a community's claims to land in ancient Mesoamerica. Enduring places like the La Consentida platform reflect long-term commitments to particular places on the landscape. Such commitments to place and the new conceptions of time and space that they imply are implicated in the transition to sedentary lifestyles and the more intensive land use practices associated with the transition from horticulture to agriculture.

Elsewhere in Mesoamerica, particularly in the Gulf coast lowlands and the Pacific coast of Chiapas, early evidence for the domestication of maize at ca 6500–7000 cal B.P. was associated with productive estuarine settings (Pope et al., 2001; Pohl et al., 2007; Kennett et al., 2010) that likely could have supported larger populations than indicated archaeologically. Instead of these productive habitats triggering population growth and aggregation, the archaeological record does not indicate the development of sedentism until after 4000 cal B.P., which was within a few hundred years of initial mound building and the creation of ceremonial centers. As discussed above, a dependence on domesticates may not emerge until after 3000 cal B.P. These data suggest that changing views and relations with the landscape as objectified by mounded architecture may have been important in the development of sedentism and agriculture throughout Mesoamerica.

4.2. Ecology and society in the Formative period

Our interdisciplinary research along the Río Verde drainage basin shows that once agriculture was established, it resulted in complex and unintended effects, both social and ecological, on a variety of temporal and spatial scales. Geomorphological and pedological research in the upper drainage basin of the Río Verde indicate that early land clearance for agriculture, and perhaps earlier horticultural practices, contributed to erosion that had significant environmental and social effects both locally and in the lower reaches of the river over 150 km downstream (Joyce and Mueller, 1992, 1997; Mueller et al., 2012, in press). While our fieldwork has examined exposed sequences in the Ejutla and Oaxaca valleys, we have concentrated our efforts on the Nochixtlán Valley where stream incision has exposed thick sequences of Holocene aged alluvium (Mueller et al., 2012).

Six cycles of aggradation followed by incision episodes are present within the Nochixtlán Valley and span the Pleistocene to the present time. These fill packages exemplify the effects of hillslope erosion (Joyce and Mueller, 1992, 1997; Mueller et al., 2012). Fill cycle 2, which persisted from about 3700 to 900 cal B.P., is perhaps the most significant in terms of anthropogenic erosion. The onset of Fill Cycle 2 coincides roughly with the period of initial sedentism and agriculture in the Nochixtlán Valley and it continues through the later Formative and Classic periods, when several hilltop urban centers dominated the region (Spores, 1984; Winter, 1994; Blomster, 2004; Kowalewski et al., 2009). The proclivity for early sedentary communities and later urban centers to occupy upland slopes would have resulted in land clearance of hill slopes with gradients that promoted soil erosion. The exploitation of such slopes and intensification of their use as cultivation and fuel wood needs intensified, likely resulted in extensive gullying, creating a positive feedback that increased drainage density, sediment delivery and peaks in discharge to the main stream channel (Joyce and Mueller, 1997; Mueller et al., 2012). The association of thousands of hillslope and cross-channel terraces (locally termed lama-bordo terraces; Figs. 3 and 13) with Formative and Classic-period sites has led archaeologists to suggest that early agriculturalists in the area were actively attempting to mitigate the impact of erosion (Spores, 1969; Kowalewski et al., 2009). The dating of terraces through surface survey, however, has proven to be unreliable (Borejsza et al., 2008). In Nochixtlán, more reliable associations are provided by ancient cross-channel terraces exposed in incised drainages in stratigraphic positions dating to the Formative, Classic, and Postclassic periods based on dated paleosol sequences (Pérez

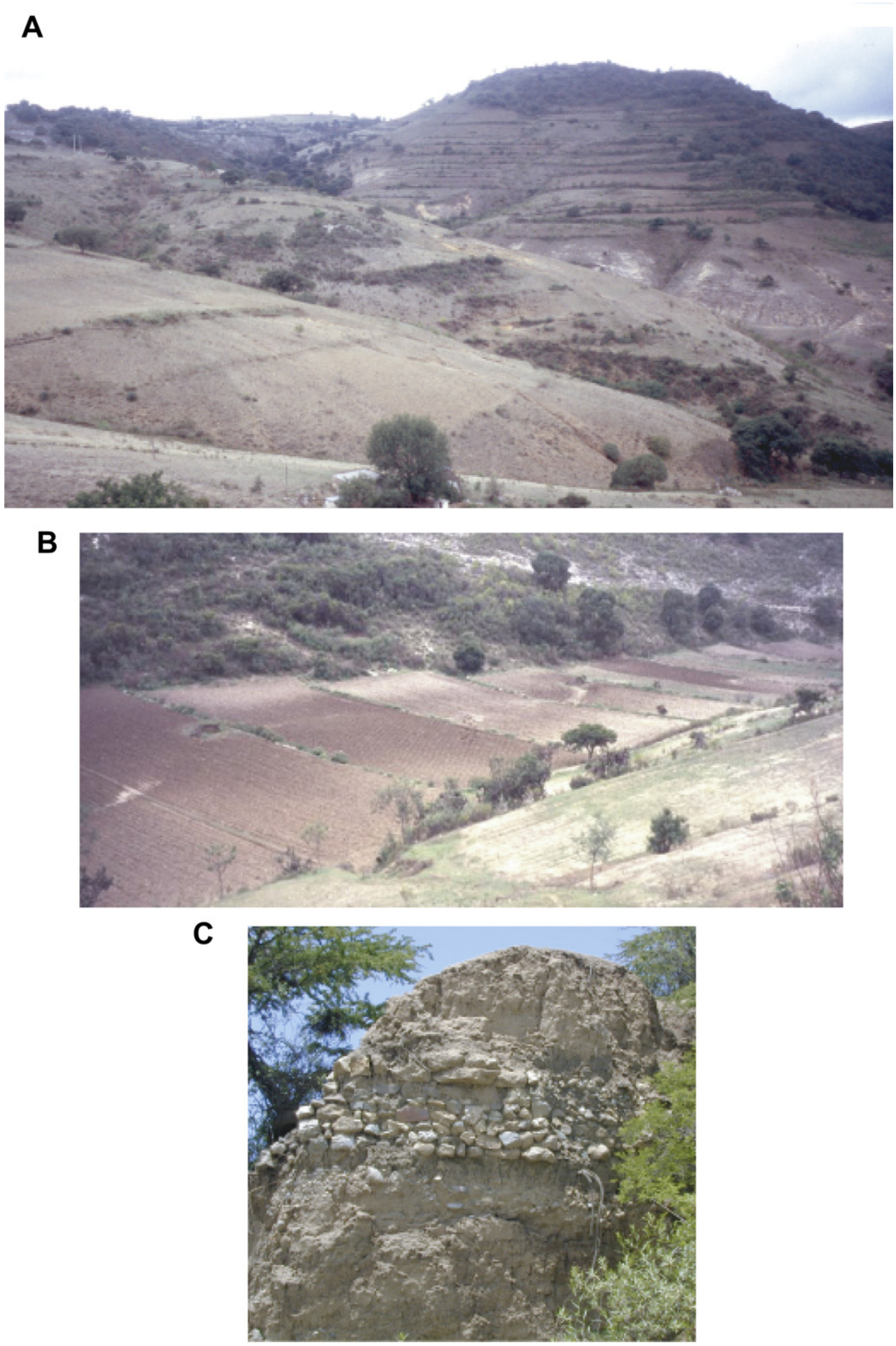

Fig. 13. Terraces in the Nochixtlán Valley: A. Ancient hillslope terraces. B. Modern cross-channel (lama-bordo) terraces. C. An ancient cross-channel terrace exposed in a river cut (photos: R. Mueller, used with permission).

Rodríguez et al., 2011; Leigh et al., 2012; Mueller et al., 2012). The earliest terrace that we have identified in the region was a cross-channel terrace exposed in an incised river and was associated with a paleosol dating to 3040 cal B.P. (Mueller et al., 2012, Fig. 13C).

We hypothesize that the sediment and runoff mobilized within the upper drainage basin of the Río Verde, particularly associated with Fill Cycle 2 in Nochixtlán, resulted in higher rates of alluviation and flooding in the lower valley (Joyce and Mueller, 1992; Mueller et al., 2012, in press). Sediment storage in the middle part of the drainage basin is negligible as the river runs through deeply incised, narrow, steep canyons in the Sierra Made del Sur. Deposition of sediment exported from the highlands can only occur once the Río Verde passes through the Sierra Madre del Sur and enters the coastal plain (Joyce and Mueller, 1992, 1997; Mueller et al., in press). Higher discharge and sediment supply would combine to cause the deposition of larger-grained alluvium and increase the severity of rainy season flooding. Under these conditions, the agriculturally productive floodplain of the lower Río Verde would have expanded. The extent of these changes ultimately resulted in a shift from more meandering to more braided river conditions. Extensive geomorphic and subsurface probing of the modern floodplain indicates that the switch from a meandering to braided stream was in progress by 3500 cal B.P. and the current braided river depositional regime was in place between 2400 and 2100 cal B.P. (Joyce and Mueller, 1992, 1997; Mueller et al., in press).

Evidence for changes in coastal geomorphology that relate to increases in sediment flow through the Río Verde is archived in sediment cores obtained from Laguna Pastoría. The record is best exemplified by core 1 from Laguna Pastoría (LP1). Here, low energy mud facies are interrupted by abruptly constrained shell hash layers which contain both deep water mollusks (*Laevicicardium elenense*) and intertidal ones (*Chione subrugosa*) reflecting high energy depositional events (Goman et al., 2005, Fig. 12). The energy source for the commingling of these species, which prefer vastly different habitats for survival, is hypothesized to be hurricane storm surges that forced deep water shells into a shallow bay that was open to the sea. Numerous shell hash layers exist prior to ~2300 cal B.P.; however, at this time a thick sand layer was deposited. The only mollusks found within the sediments that overlay the sand deposit are *Chione* found in growth position (as determined from the location of the paleosinal scar). The stratigraphy obtained from the lagoonal sediments suggests that by ~2300 cal B.P. a bay barrier comprised of sand discharged into the Pacific by the Río Verde had formed, effectively enclosing an open bay and resulting in the development of the ecologically rich estuarine system that persists today (Contreras, 1988; Torres-Moye et al., 1993; Goman et al., 2005, in press). One subsequent storm deposit occurs at LP1 following the formation of the bay barrier and this is composed of sand. Sea-level is estimated to have stabilized significantly earlier than our evidence for barrier formation, suggesting that factors other than sea level were involved in barrier formation (Curray et al., 1969; Atwater et al., 1977; Voorhies, 2004). The implications of these data are that the bay barrier was not present during the Archaic and Early Formative as the river lacked the sediment load to construct it (Goman et al., 2005).

The expansion of the floodplain and the formation of the estuaries would have increased the productivity of many of the most important subsistence resources in the region. Maize grown on the floodplain as well as estuarine resources such as fish, shellfish, and waterfowl are r-selected resources, which have been identified as important in the development of complex societies (Hayden, 1990, 1995; Clark and Blake, 1994). R-selected resources are characterized by rates of replacement and population densities that make them difficult to overexploit given the technologies and populations of the Formative period. Although, Kennett et al. (2008) working in the adjacent state of Guerrero have found evidence for changes in mollusk and fish populations from the Late Archaic to Late Formative Periods which are likely due to overexploitation. These resources create the types of "intensifiable habitats" that allow for resource surpluses and the expansion of population that are necessary for escalating competition by incipient elites during the development of social complexity. Clark and Blake (1994) do not assert that intensifiable habitats were the sole cause of social complexity, but these resources appear to have been an important material component.

Archaeological and paleoecological research shows that population in the lower Río Verde Valley increased following the environmental changes triggered by highland erosion. Prior to ca 2755 cal B.P., the lower Verde supported only small populations (Joyce, 2005, 2010). Only three Early Formative period sites have been discovered in the region and they total 7 ha. The numerous archaeological and sedimentological excavations in the floodplain and piedmont, along with the survey and reconnaissance results, suggest that the small number of Early/Middle Formative sites is not simply the result of sampling bias or alluvial burial. Deep test excavations to archaeological sterile deposits at five sites in the floodplain have failed to recover ceramics earlier than the late Middle Formative period (Joyce, 1991a; Barber, 2005, 2009). Survey in the piedmont where sites would not have been affected by alluvial burial, has also failed to recover Early Formative sites (Joyce et al., 2004).

Regional archaeological data demonstrate a major demographic expansion beginning in the Middle Formative from 2755 to 2350 cal B.P. Regional population continued to increase through the remainder of the Formative with the occupational area in the survey zone reaching 699 ha by 1620 cal B.P. During the Terminal Formative (2065–1620 cal BP), an urban center emerged at Río Viejo on the floodplain west of the river. The site grew to cover 225 ha. The power of the rulers of Río Viejo is indicated by the scale of labor mobilization required to build the city's massive central acropolis, with an estimated Terminal Formative construction volume of 455,050 m^3 and maximum elevation above the floodplain of at least 17 m (Joyce and Barber, 2011, Fig. 14). Mortuary and residential evidence from multiple sites in the region indicate that social inequality increased though the later part of the Formative period (Joyce, 1991a, 1991b, 1994, 2005, 2010; Barber, 2005).

We attribute most of the social changes at the end of the Formative to social and cultural factors (Workinger, 2002; Barber,

Fig. 14. The acropolis at Río Viejo (photo: A. Joyce).

2005; Joyce, 2005, 2008, 2010, in press; Barber and Joyce, 2007). The increase in environmental productivity and the creation of intensifiable habitats, however, would have supported population growth and the generation of surpluses in both resources and labor. In addition, a growing body of evidence indicates that people altered their subsistence practices to more intensively focus on maize-based agriculture and estuarine resources.

Pollen, phytolith, and charcoal evidence from sediment cores and auger drives in estuaries, freshwater ponds and cultural features in the region indicate the resumption of maize-based agriculture on the floodplain by the Middle Formative (Goman et al., in press). Macroscopic charcoal and carbon isotopic data (Figs. 8 and 9; Goman et al., 2010, 2011) from the auger samples in the U2 feature at Río Viejo show agricultural activity, presumably maize cultivation, during the Middle Formative period as shown by the high charcoal concentrations and enriched carbon isotope ratios. Activity continues at U2 and begins at Loma Reyes, located approximately 5 km to the south–southwest of Río Viejo during the Late Formative. Macrobotanical remains of maize are found in midden deposits in Late Formative and later sites (Woodard, 1991). A recent stable carbon isotope study of human teeth, primarily from the Late/Terminal Formative, shows a significant increase in the consumption of C_4 pathway plants over this period, which in the region consisted primarily of maize (Taylor et al., 2009). These data indicate an increasing reliance on maize at the end of the Formative as the agricultural fertility of the floodplain improved.

Archaeofaunal analyses suggest a greater reliance on estuarine resources at the end of the Formative. Faunal remains show an increase in the proportion of estuarine shellfish in midden deposits from the Middle Formative to the Early Classic period (Fernández, 2004). Midden samples from floodplain sites show that estuarine fish were an important source of high quality protein by the Late Formative. By the Early Classic period, shellfish largely replace fish. Analyses of Ba/Sr ratios from human long bones show that marine/estuarine resources were significantly greater in the diets of coastal people relative to a highland control sample (Joyce, 1991b). Not surprisingly, evidence for the greatest consumption of marine/estuarine resources comes from the site of Barra Quebrada on the bay barrier adjacent to the estuary system. Although people in the region exploited estuarine resources, the archaeological and bone chemistry data indicate that the focus of subsistence was agricultural. Animals exploited from the estuaries, however, may have provided an important source of high quality protein. A biocultural study of Terminal Formative period skeletal remains suggests that coastal populations enjoyed a mixed diet, rich in carbohydrates, iron, and protein that resulted in an overall pattern of good health (Melmed, 2006).

Although the data indicate that Formative period environmental change in the lower Río Verde Valley had a largely positive impact on human populations, there are indications that increased severity of flooding during the Formative period may have created problems for people living on the floodplain. High-energy overbank deposits have been noted in Late Formative stratigraphy from floodplain sites (Joyce, 1991a). At Río Viejo, we also noted frequent incidents of raising and rebuilding the level of houses after 2400 cal B.P. (Joyce, 1991a; Workinger and Joyce, 1999). We suspect that the construction of massive residential platforms at many floodplain sites was probably in part a response to increasing rainy season flooding and the need to elevate residences above floodwaters during years of severe inundations. These platforms constituted a form of landscape capital (Erickson, 1999; Fisher, 2005), which required major labor investments to construct, but provided benefits to succeeding generations. Today, many communities in the region continue to occupy these ancient platforms. The environmental changes of the Formative period therefore provided both risks and benefits to people in the lower Río Verde Valley.

4.3. Politics and land use in the Classic and Postclassic periods

The major floodplain and coastal environmental changes that occurred during the Formative period are followed by minor landscape changes in the Classic and Postclassic periods, with primarily local shifts in the lower Río Verde's channel position (Mueller et al., in press). However, the archaeological record indicates that dramatic shifts in settlement and land use occurred during this time. The most marked changes involved shifts in settlement between the floodplain and piedmont regions that were the result of major political upheavals (Joyce et al., 2001, 2004; Joyce, 2008, 2010; Goman et al., 2010).

The Classic period (1620–1060 cal B.P.) opens with the collapse of the Río Viejo polity that had dominated the region during the Terminal Formative (Barber and Joyce, 2007; Joyce, 2008, 2010; Joyce and Barber, 2011). The causes of the political collapse are not clear, although internal political conflict and/or conquest by the powerful central Mexican polity of Teotihuacan are possibilities. Conflict is suggested by evidence of burning and the abandonment of Río Viejo's civic-ceremonial center on the site's acropolis. Unusually high frequencies of obsidian imported from Pachuca in the Basin of Mexico during the Early Classic period raises the possibility that Teotihuacan may have been involved in Río Viejo's decline. Variance in public buildings, mortuary patterns, and ceremonial caches among sites also suggests that Río Viejo's rulers were unable to impose overarching political ideas, institutions, and practices on people within the region, suggesting the possibility of internal unrest (Barber and Joyce, 2007; Joyce, 2008). The Early Classic period is a time of political fragmentation and settlement shifts into the piedmont perhaps for defensive reasons (Joyce, 2005). By the Late Classic (1330–1060 cal B.P.), Río Viejo once again became the regional political seat and settlement moved down out of the piedmont and back to the floodplain. At ca 1060 cal B.P., the Río Viejo polity again collapsed as did complex polities throughout Mesoamerica. Piedmont locations became the emphasis for settlement; this time however, the focus was on land to the east of the river.

The paleoecological data provide a fine-grained model of how major changes in settlement recorded in the archaeological record affected patterns of land use (Goman et al., 2010: Figs. 7–9). Macroscopic charcoal levels dramatically drop off to negligible amounts during the late Terminal Formative in the U2 feature at Río Viejo, although we suspect this corresponds to the Early Classic when Río Viejo lost over half its population following the collapse of the Terminal Formative polity (refinement of the U2 chronology is underway with several radiocarbon samples pending). The decline in burning activity is also associated with a dramatic drop in carbon isotopic levels with a move toward C3-type inputs as ecological succession toward woody plants occurred. Pottery sherds are present throughout most of the auger samples at U2 below a depth of 167 cm; notable exceptions are depths between 214 and 257 cm which correlate to the Early Classic.

At Loma Reyes on the western edge of the floodplain, late Terminal Formative agricultural activity from burning as well as carbon isotopic concentrations are significant and suggest that this portion of the floodplain was possibly an important food source for Río Viejo prior to its demographic decline (Figs. 8 and 9). At the end of the Terminal Formative, the paleoecological record at Loma Reyes indicates a dramatic decrease in burning. Although the size of Loma Reyes increases considerably at this time, the location of settlement moves from the floodplain near the paleoecological sampling site to a ridge to the west, which could account for the decline in evidence of local burning.

With the collapse of Río Viejo and subsequent political fragmentation during the Early Classic, settlement moves into the piedmont west of the river (Joyce, 1999, 2005; Joyce et al., 2009). During this period the only significant evidence we have for land clearance for agriculture is at Charco Barro (unfortunately, the earliest recovered sediments only date to this time so we cannot comment on early land use near the site). Unlike the records from U2 and Loma Reyes, the record from Charco Barro indicates that there was significant burning of agricultural fields in the proximity of the pond at this time. Evidence for burning continues into the Late Classic at Charco Barro, although the amount of macroscopic charcoal is less than the previous period, and the record also shows enrichment in stable carbon isotope ratios. During the Late Classic we also see evidence for agricultural burning at Río Viejo (U2) with macroscopic charcoal concentrations in the 125 micron range returning to Terminal Formative levels. The carbon isotope ratios at U2 are also highly enriched. Río Viejo saw a renaissance as the regional political seat during the Late Classic and the site reached its maximum extent of 250 ha so that the expansion of agriculture around the community would be expected. Unfortunately, our record at Loma Reyes is artificially terminated; however the samples that we do have for this time frame indicate that once again the western floodplain region was a focus of agricultural burning and the dominance of C4 type plants (Figs. 8 and 9).

Río Viejo's reemergence as a political center ended by about 1060 cal BP when the polity collapsed once again. During the Early Postclassic settlement moved back toward the piedmont, especially on the east side of the river (Joyce et al., 2001). The site of San Marquitos in the low piedmont grew from less than 10 ha to 190 ha at this time. By the beginning of the Late Postclassic at ca 740 cal B.P. archaeological evidence as well as indigenous histories recorded in three of the prehispanic codices show that Mixtec speaking peoples from the Oaxacan highlands migrated into the region (Joyce et al., 2004; Levine, 2007, 2011). The codical histories link the movement of Mixtecs into the lower Río Verde region to the actions of the famous ruler, Lord 8 Deer "Jaguar Claw," who is shown founding the powerful Late Postclassic imperial center of Tututepec in the foothills above the floodplain (Fig. 15). The arrival of Mixtecs is also related to a major shift in settlement from the low piedmont to higher elevations with the near abandonment of the floodplain west of the river. During the Late Postclassic, settlement at Tututepec reached 22 km^2 constituting 94% of the occupational area recorded in the regional full-coverage survey (Fig. 16). Early colonial records as well as the codices recount that the city came to dominate an empire extending over an estimated 25,000 km^2 (Spores, 1993; Joyce et al., 2004). The reason for the shift in settlement into the foothills above the valley may have been for defensive purposes, since Tututepec fought wars with many polities in surrounding regions, or simply because the highland peoples that founded Tututepec preferred living in the mountains. The near abandonment of the west side of the floodplain is more curious (Joyce et al., 2004). Since Tututepec was carrying out an active agenda of military expansion, the river may have served as a defensive barrier from threats to the west. Alternatively, population increases during the Late Postclassic period could have resulted in movement off of the floodplain to permit more intensive agriculture.

The abandonment of the floodplain sites west of the river is reflected in the two records that we have for this time period (Figs. 8 and 9). At U2 charcoal concentrations become negligible to absent and carbon isotope ratios shift to less enriched ratios; while at Charco Barro, an initial peak in charcoal concentration at the beginning of the Early Postclassic is quickly replaced by minimal charcoal inputs to the oxbow and low carbon isotopic ratios. Significant agricultural activity at Charco Barro did not resume until the colonial and Mexican periods. The paleoecological data therefore indicate that the western floodplain was not actively used for farming during the Late Postclassic, which begs the question as to where the population was growing its food supplies. A possible location for agricultural field systems during the Postclassic lies to the east of the river. In contrast to the floodplain sites, palynological data from the estuarine site of Laguna Pastoría indicate agricultural activity occurring in the region north of the estuary from the Middle Formative until the Spanish Conquest (Fig. 12). Although, the record has low temporal resolution, it shows a significant decline in pollen of weedy taxa associated with agricultural fields beginning toward the end of the early Terminal Formative and continuing until the end of the Late Classic; agricultural activity did not completely cease however, as charred grass cuticles and charred panicoid phytoliths are present in samples throughout the period (Goman et al., in press). Pollen from the Poaceae and Asteraceae families, however, are of a much greater importance in the Postclassic periods and charred grass cuticles and pollen of *Zea* cf. *mays* are also present. This possibly indicates either sustained

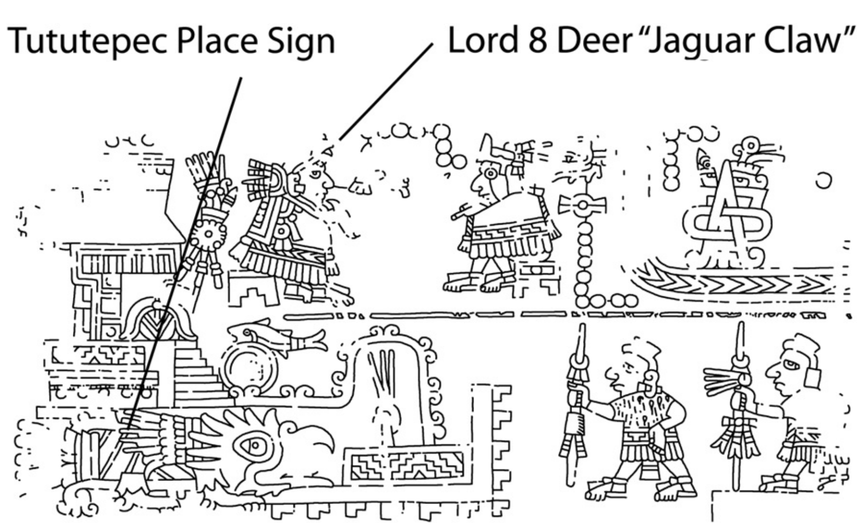

Fig. 15. The founding of Tututepec by Lord 8 Deer "Jaguar Claw" in the year A.D. 1083 as depicted in the *Codex Colombino-Becker*, codex page 5 (after Codex Colombino, 1892).

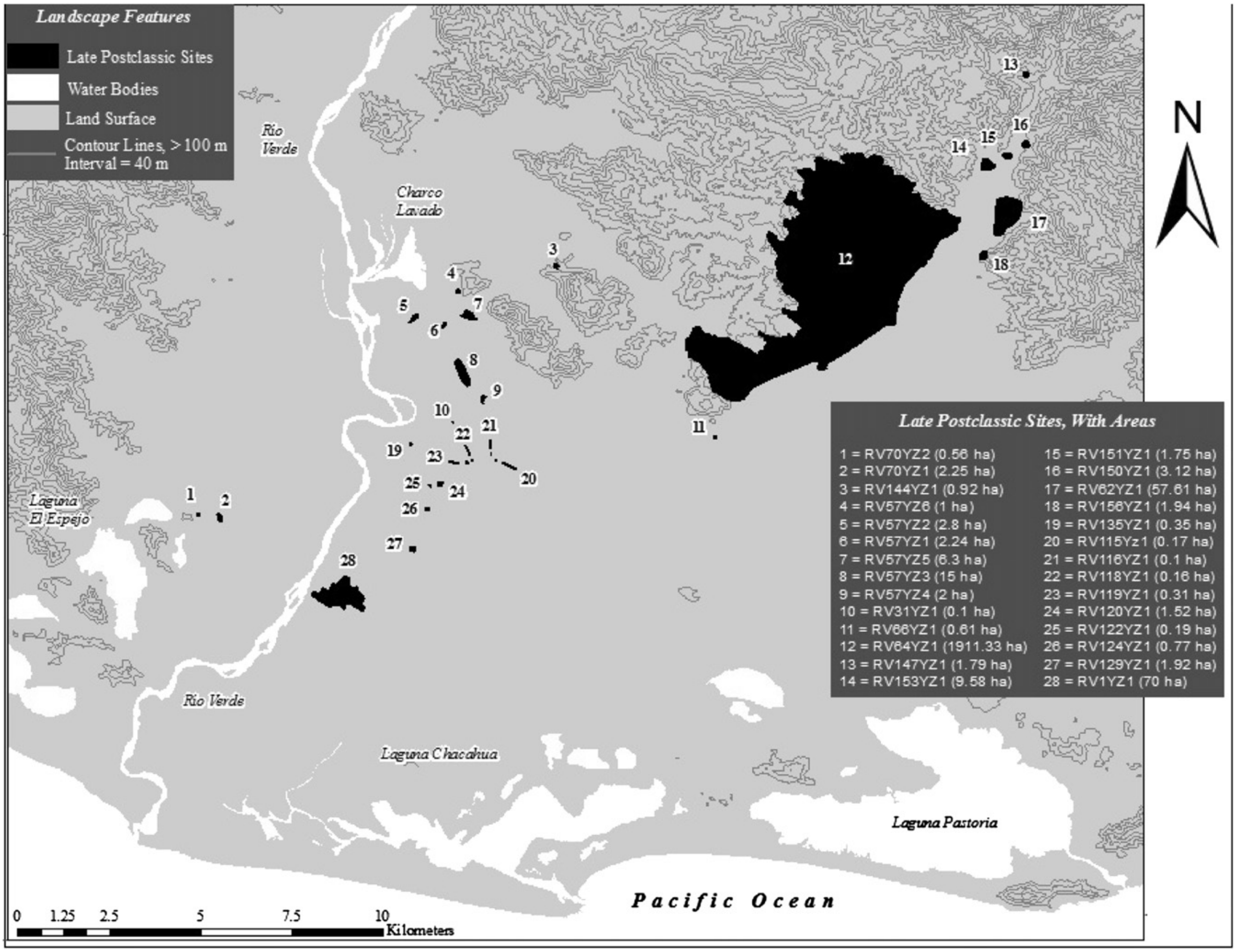

Fig. 16. Late Postclassic settlement in the lower Río Verde Valley showing the site of Tututepec and the near abandonment of the west side of the river (drawn by J. Hedgepeth).

agricultural activity or more intense activity on the east side of the river closer to Tututepec. The overall absence of agricultural activity west of the river, coupled with the evidence for agriculture from Laguna Pastoría suggests that when the population concentrated at Tututepec during the Late Postclassic, the focus of agricultural activity also shifted to the east side of the river. This hypothesis is currently speculative; future analysis of additional sediment cores obtained from sites east of the river should clarify our understanding.

5. Conclusions

In conclusion, in this article we have argued for a synthesis of the ecological and social/symbolic approaches to landscape studies in archaeology and paleoecology. Such a synthesis would acknowledge that peoples' relations with the environment are always culturally mediated. As in the examples discussed from the Mixtec region of Oaxaca, the symbolism of landscape always embodies important political, religious, and more broadly social dimensions along with ecological and economic ones. For example, the movement of people in the highlands to hilltop urban centers in the Late Formative was simultaneously political, religious, ecological, and economic. The symbolism of the sacred mountain, which was part of what drew people into the piedmont, was inseparable from the material consequences of the construction of terraces and the intensification of agriculture that the changes in settlement patterns necessitated. In turn, landscape features like caves, mountains, and monumental architecture manifest political and religious ideas in materially prominent and powerful ways. Ideological and sacred principles were made salient and durable through their expression in visible and ever present features of the landscape.

Land use changes in the highlands had far-reaching and unintended consequences due to the acceleration of erosion that accumulated as Fill Cycle 2 in the Nochixtlán Valley and which was carried down the drainage basin to the coastal lowlands. The expansion of the floodplain and the acceleration of bay barrier formation that ensued in the lowlands by ca 2300 cal B.P. would have increased the productivity of important subsistence resources, including maize as well as estuarine fish, shellfish, and waterfowl. Subsistence data indeed indicate that people in the region increasingly consumed these resources during the latter part of the Formative period, which may have contributed to the rapid increase in regional population at this time. The paleoecological record of the lower valley also shows how political processes can impact the environment. During the Classic and Postclassic periods in the lower valley, environmental change was largely driven by local political events such as the collapse of the Río Viejo polity at ca 1620 cal B.P. and again at 1060 cal B.P. as well as the arrival of highland Mixtecs and the establishment of Tututepec in the foothills at ca 850 cal B.P. These major political transformations triggered changes in settlement and land use that affected patterns of land clearance and vegetation within the region. Again, without considering political as well as economic and environmental variables, we would be missing a major component of the history of landscape change in the lower Río Verde Valley.

The ability to consider the social and especially the symbolic dimensions of landscape in ancient Oaxaca benefit from the availability of a rich and detailed textual record, including prehispanic codices and early colonial documents authored by both Native Americans and Europeans. These documents provide direct evidence for indigenous views of landscape during the prehispanic and early colonial periods, including indigenous geographies and views of the sacred landscape (e.g., Pohl and Byland, 1990; Byland and Pohl, 1994; Terraciano, 2001; Hamann, 2002; Pohl, 2004; Jansen and Pérez Jiménez, 2007; Trogdon, 2010). Ethnographic research can augment the textual evidence, although it must be used with caution given the changes in indigenous culture that have occurred over the last several centuries (Monaghan, 1990, 1995; see Wylie, 1985 and Stahl, 1993 for a discussion of the critical use of ethnohistoric and ethnographic evidence for analogy building in archaeology). In areas of the world that lack such records, it is more challenging to infer aspects of the symbolic dimensions of landscape particularly with the level of detail possible in places like ancient Oaxaca (however see Bradley, 1998, 2000; Barrett, 1999; Buikstra and Charles, 1999; Van Dyke, 2007; Whittlesey, 2009). Ethnohistoric and ethnographic sources can also provide useful insights into the ecological dimensions of landscape such as agricultural techniques and technologies (Kirkby, 1973; Flannery, 1983; Parsons and Parsons, 1990; Sanders, 1992).

Our research in Oaxaca has begun to explore ways in which the theoretical divide in Holocene landscape studies can be bridged. There are also many potential avenues of future research that could strengthen our models and explore other aspects of human–environment relations in Oaxaca's prehispanic past. For example, the prehispanic and early colonial documents on which we rely to infer ancient views of landscape were largely authored by indigenous and Spanish elites. These documents therefore provide a view of the symbolism of landscape that is strongly biased toward elite perspectives. Additional ethnohistoric research on early colonial records dealing with land rights and disputes would help to balance this perspective as would ethnographic work in indigenous communities focused on the ways in which common people view the land.

One of the most challenging problems in human paleoecology is to demonstrate causal relations between people and environmental change. Archaeologists are often seduced by evidence of climate change or landscape degradation that provide plausible explanations for societal collapse or other major cultural changes. Yet it has long been recognized that correlations between environmental and cultural change do not alone make for robust causal arguments (e.g., Vayda and Rappaport, 1968). In the lower Verde there is strong evidence for both dramatic environmental and cultural changes during the Formative period. Future research needs to better demonstrate the ways in which cultural changes were the result of the expansion of the floodplain and the creation of estuaries, rather than due to strictly social processes. The clearest indication of the effects of environmental change is the dietary evidence, especially bone chemistry, which suggests the increasing use of maize and estuarine resources at the end of the Formative. These data could be strengthened through additional sampling as well as archaeological studies of settlement, land use, and domestic economy designed to evaluate the degree to which people in the region were affected by the ecological changes. Likewise, in the Oaxacan highlands, more intensive, systematic geological research would allow for the quantification of Holocene erosion rates and allow for a more precise unraveling of the causes of landscape change during the later Holocene.

Many of the subtle changes in land use and vegetation in the lower Río Verde Valley would not have been evident if we relied solely on regional-scale records of landscape change such as sediment cores extracted from large basins like Laguna Pastoría. Instead we have taken a multi-scalar approach that integrates archaeological, geological, and paleoecological data at a variety of spatial and temporal scales. Paleoecological research in the lower valley would be strengthened by additional sampling of both large estuaries and lakes that preserve regional-scale records as well as the infilled oxbow ponds and artificial depressions like the U2 feature at Río Viejo that preserve local records of ecological change. Through such a multi-scalar paleoecological approach along with a theoretical perspective that considers both the ecological and social/symbolic dimensions of landscape we hope to be able to provide a more comprehensive and balanced view of landscape in ancient Oaxaca and beyond.

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Appendix A. Supplementary data

Supplementary data related to this article can be found at http://dx.doi.org/10.1016/j.quascirev.2012.08.003.

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