CHAPTER 20

GEOMORPHOLOGY AND STRATIGRAPHY

Jonathan B. Mabry
Desert Archaeology, Inc.

The alluvial deposits exposed in trenches at the Clearwater site, AZ BB:13:6 (ASM), during the Rio Nuevo Archaeology project can be related to alluvial deposits identified in several previous trenches excavated in the Holocene floodplain of the Santa Cruz River, on the western side of the present channel below A-Mountain (Ahlstrom et al. 1994; Freeman 1996, 1997a, 1997b, 1999; Katzer 1987). The locations of the alluvial exposures discussed here are shown in Figure 20.1. The deposits documented in previous exposures were correlated at a general level by Freeman (1997b). Mabry (1999) subsequently developed a more detailed, but still preliminary model of the stratigraphy of the floodplain west of the river to compare it with the alluvial stratigraphy identified east of the present channel at the East Bank site, AZ BB:13:535 (ASM). The new exposures of alluvium and additional radiocarbon dates reported here allow refinement of the stratigraphic model of the Holocene terrace (T2 in McKittrick 1988) at the base of A-Mountain. This chapter provides a synthesis and interpretation of the information currently available.

GEOMORPHOLOGY

Geomorphic processes in the area of the Santa Cruz River floodplain in downtown Tucson are strongly influenced by geology, topography, and valley geometry. Except during intervals when the channel is a continuous arroyo in this reach—as it is currently—a barrier of volcanic bedrock, of which A-Mountain is the only visible portion, forces the underground flow of the river to the surface (Betancourt and Turner 1990). At this location, the river is also constricted between alluvial fans derived from the Tucson Mountains to the west and Pleistocene-aged terraces to the east. Throughout the Holocene, these conditions have typically led to sediment storage and a high water table south of A-Mountain, and, north of it, a steeply downsloping floodplain dominated by sediment transport (Parker 1995). During Holocene intervals of floodplain aggradation, the gradient of the floodplain slope downstream of A-Mountain gradually increased until it became susceptible to channel incision.

These characteristics have made this a locus of multiple cycles of channel incision throughout the Holocene, with the most recent downcutting occurring during the 1890s (Cooke and Reeves 1976). During the last incision cycle, the channel reached a layer of indurated Pleistocene sediments. Since then, it has been widening during floods, leading governmental agencies to stabilize the banks with concrete in several reaches during the 1980s and 1990s. Within the wide channel, small terraces have formed, including the T1 terrace in McKittrick (1988). Vegetation is currently increasing in the channel bottom, trapping sediments and promoting channel filling.

Previous studies of exposures of alluvium in the middle Santa Cruz Valley (the portion within the Tucson Basin) have identified earlier cycles of channel cutting and filling, with at least six major cycles during the last 5,000 years (Freeman 1996, 1997a, 1997b, 1998, 1999, 2000a, 2000b; Gregory and Barr 1999; Haynes and Huckell 1985, 1986; Huckell 1998; Huckleberry 2006; Katzer 1987, 1989; Mabry 1999; Nials 2006; Stafford 1987; Waters 1987, 1988). The 265 radiocarbon dates reported in these studies, in addition to the 36 dates reported here, provide the most detailed alluvial chronology in the Greater Southwest to date, particularly for the last 4,000 years (in uncalibrated radiocarbon years before present, expressed here as ^{14}C years b.p.).

These radiocarbon dates, along with temporally diagnostic artifact types, bracket the ages of identified alluvial deposits and indicate a pattern of long intervals of deposition interrupted by relatively brief intervals of channel entrenchment. These channels filled rapidly (within 100 years or so), and their fills contain similar sediment sequences. Coarse sands and gravels in the lower levels generally fine upward to silts and clays in the higher levels. The uppermost sediments filling paleochannels are often thick clays that were deposited in wet meadows (*ciénegas* in Spanish) created by high water tables (Hendrickson and Minckley 1984). Haynes and Huckell (1986:26-27) provided what is still the most concise description of the typical sediment sequences within the channel fills and the associated geomorphic processes:

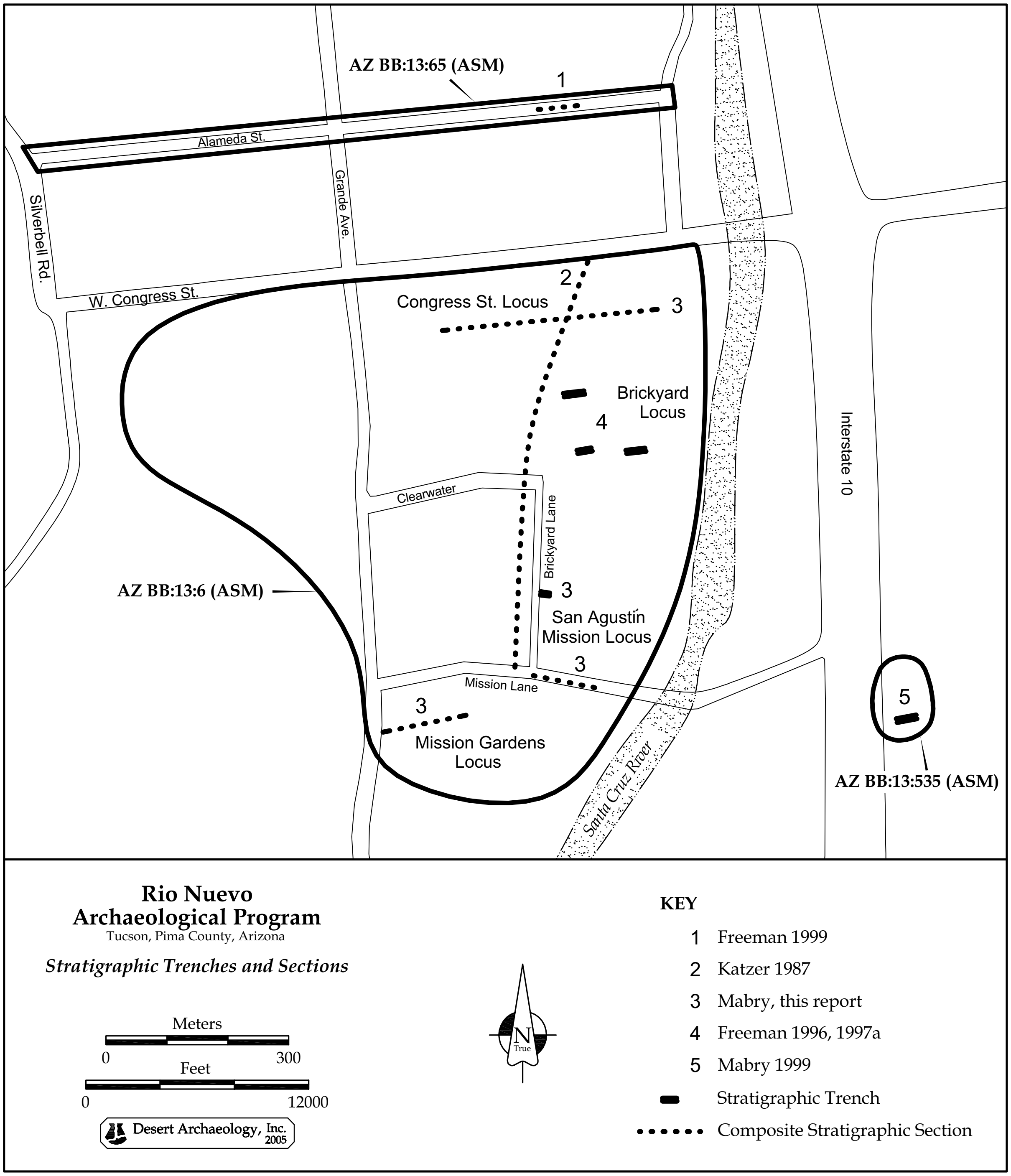

Figure 20.1. Locations of described alluvial exposures at the Clearwater site, AZ BB:13:6 (ASM), and nearby sites.

The depositional units are similar, consisting of basal sands and gravels of fluvial origin similar to the present bed load. These are overlain by multiple layers of relatively thin, somewhat organic, clayey sands or silty clays separated by varying thicknesses of silty sands, all grading laterally to less well sorted slopewash alluvium that in some cases could probably be traced to segments of adjacent alluvial fans . . . The clayeyer [sic] layers, occupying the relatively flat, low-gradient portions of the floodplain, are actually lenses that pinch out laterally, indicating that they are the fine-grained facies winnowed from the more coarse-grained facies along the margins of the floodplain and upstream. In places where the zone of saturation intersects the surface, or where spring water seeps

> onto the floodplain, cienegas, or wet meadows, occur. Anytime the floodplain is not actively aggrading or being eroded, soil development takes place as vegetation grows and helps stabilize the surface by a combination of root growth, reducing the velocity of overflowing water, and trapping sediment. The top of each major depositional unit, where adequately preserved, has a soil indicating a longer period of pedogenesis and stability than any of the soils buried within the units, but the time of stability and soil development must be relatively short compared to the time of aggradation.

The sequence of Holocene alluvium at the base of A-Mountain also contains numerous flood deposits. Some flood sediments are thin bands of silt, representing slackwater deposits that settled out of slow-moving or ponded water during floods of minor and moderate magnitudes, while others are massive sandy deposits, more than a meter thick, representing channel deposits laid rapidly by fast-moving water during major flood events. Still others are sands several meters in thickness that show bedding. These represent multiple high-magnitude floods closely spaced in time. The alluvial sequence shows that the last 4,000 years have been predominated by regular overbank floods depositing silts and rapidly building the floodplain. The thick cienega clays, representing long intervals of low-energy deposition, also contain multiple thin bands of silt and sand representing frequent minor flood events.

Alluvial Units

The current Holocene alluvial chronology of the A-Mountain reach of the Santa Cruz River floodplain is based on 36 radiocarbon dates presented in Tables 20.1 and 20.2 (this total does not include five dates rejected as unreliable, shown in parentheses). The alluvial units identified in trench exposures in various locations on the western and eastern sides of the current river channel are correlated in Table 20.3. Twelve distinct units represent the entire 11,000-^{14}C-year span of the Holocene and are designated here for the first time. The ages of the units younger than about 4,000 ^{14}C years are estimated from associated radiocarbon dates and temporally diagnostic artifacts. The ages of older units are estimated through correlations with radiocarbon-dated units in other reaches. The alluvial units in the A-Mountain reach and their estimated timespans fit well (consistently within 100 years) with the estimated beginning and ending dates of the units identified for the entire middle Santa Cruz Valley by Haynes and Huckell (1986). However, the correlations suggested here may be revised with additional information.

Unit 1

The oldest alluvial deposits identified in the A-Mountain reach are cross-bedded gravels and sands with manganese staining 4-5 m below the present ground surface on the eastern side of the river at the East Bank site (Units XVI-XIV, in ascending and temporal order; Mabry 1999). These represent braiding channels of the river during an interval of rapid flow, probably dating to the terminal Pleistocene and early Holocene, sometime between 11,000 and 8,000 ^{14}C years b.p. No equivalents of these deposits have been identified on the western side of the river at the Clearwater site. However, similar deposits thought to date to this time frame have been documented to the south (upstream) at the San Xavier Bridge site, AZ BB:13:14 (ASM) (Waters 1987), and in Airport Wash (Units A1-3 in Haynes and Huckell 1986). Braiding channel deposits possibly of this age have also been identified downstream at the Santa Cruz Bend site, AZ AA:12:746 (Unit 1a in Huckell 1998). Alternatively, this unit may date to the early portion of the middle Holocene, possibly during some interval between 8000 and 6000 ^{14}C years b.p.

Unit 2

At the East Bank site, Unit 1 channel deposits are overlain by 2 m of sands, sandy silts, and clayey silts (Units XIII-IX in Mabry 1999), representing three cycles of overbank deposition preceded and followed by deposition of colluvium derived from the next highest terrace to the east—the final Late Pleistocene Jaynes terrace of Smith (1938). Lenses of colluvium are also present in these predominately overbank deposits. Numerous calcium carbonate filaments and areas of heavy manganese staining indicate high groundwater levels after deposition, but in the distant past. No equivalents of these deposits have been identified on the western side of the river at Clearwater, or in any other reach in the middle Santa Cruz Valley. These deposits are estimated to date to the late portion of the middle Holocene (6000-5000 ^{14}C years b.p.?), an interval during which channel deposition or high-energy overbank deposition was also occurring at the downstream at the Santa Cruz Bend; Las Capas, AZ AA:12:111 (ASM); and Los Morteros, AZ AA:12:57 (ASM), sites (Huckell 1998; Katzer 1989; Nials 2006), while channel cutting and widening was occurring upstream at San Xavier Bridge (Waters 1987).

Unit 3

The next higher unit at the East Bank site is composed of two silty clays deposited by overbank floods and modified by pedogenesis and bioturbation (Units

Table 20.1. Radiocarbon dates from the Clearwater site, AZ BB:13:6 (ASM), by stratum.

Stratum/Context	Material	Uncalibrated Radiocarbon Age b.p.	$^{13}C/^{12}C$ Ratio	Calibrated Age Range (1-sigma)	Sample Number	Reference
Top of Stratum 504, Congress Street Locus						
Pit structure, F. 516	Juniper charcoal	3800±40	-25.0	2290-2150 B.C.	Beta-157018	This report
Intramural pit, F. 580.01	Maize	3690±40	-10.9	2140-2020 B.C.	Beta-175842	This report
Pit structure, F. 581	Charcoal	3680±40	-25.3	2130-2010 B.C.	Beta-175843	This report
Intramural pit, F. 580.01	Maize	3650±40	-10.4	2120-1950 B.C.	Beta-160381	This report
Pit structure, F. 3359	Charcoal	3620±40	-24.8	2030-1920 B.C.	Beta-175844	This report
Top of Stratum 503, Congress Street Locus						
Pit, F. 572	Mesquite charcoal	3280±40	-24.5	1610-1510 B.C.	Beta-190713	This report
Pit, F. 630	Annual plant	3220±40	-8.3	1520-1440 B.C.	Beta-193150	This report
Stratum 502, Brickyard Locus						
"Big house," F. 9357.01	Maize	2620±40	-10.5	820-790 B.C.	Beta-193151	This report
Intramural pit, F. 1040.04	Charcoal	2600±50	-23.2	810-780 B.C.	Beta-90227	Diehl 1997
Intramural pit, F. 1006.02	Maize	2580±60	-8.7	805-770 B.C.	Beta-90225	Diehl 1997
Pit structure, F. 3323	Maize	2530±50	-9.9	790-550 B.C.	Beta-193148	This report
Intramural pit, F. 175.01	Maize	2520±40	-10.5	790-540 B.C.	Beta-85405	Diehl 1996
Pit, F. 1014	Mesquite	2510±50	-26.5	785-525 B.C.	Beta-92620	Diehl 1997
Intramural pit, F. 1006.03	Maize	2500±60	-10.0	785-505 B.C.	Beta-90226	Diehl 1997
Intramural pit, F. 3325.01	Maize	2500±50	-10.6	780-520 B.C.	Beta-193149	This report
Intramural pit, F. 1040.02	Mesquite	2500±50	-23.8	780-515 B.C.	Beta-90231	Diehl 1997
Pit structure, F. 371/370	Mesquite	2480±50	-24.0	775-425 B.C.	Beta-92622	Diehl 1997
Canal, F. 141	Maize	2470±40	-9.2	770-430 B.C.	Beta-160379	This report
Pit, F. 1023	Mesquite	2440±60	-24.9	760-405 B.C.	Beta-92618	Diehl 1997
Pit, F. 1020	Mesquite	2440±60	-23.5	760-405 B.C.	Beta-92621	Diehl 1997
Pit structure, F. 370/371	Maize	2430±60	-9.5	760-400 B.C.	Beta-92619	Diehl 1997
Pit, F. 1029	Maize	2420±50	-10.8	745-400 B.C.	Beta-90229	Diehl 1997
Pit, F. 1016	Maize	2390±50	-11.3	505-395 B.C.	Beta-90228	Diehl 1997
Pit, F. 1009	Mesquite	2390±70	-23.9	525-390 B.C.	Beta-92617	Diehl 1997
Pit, F. 1032	Mesquite	2250±50	-23.3	380-205 B.C.	Beta-90231	Diehl 1997
Canal, F. 139	Charcoal	2140±40	-21.4	200-110 B.C.	Beta-160378	This report
"Big house," F. 9357	Maize	(2010±40)	-11.4	50 B.C.-A.D. 40	Beta-190717	This report
Pit structure, F. 3293	Mesquite	(770±140)	-25.0	A.D. 1160-1310	Beta-193147	This report
Stratum 502, San Agustín Mission Locus						
Pit structure	Maize	2450±75	-16.9	765-405 B.C.	AA-6638	Mabry 1999
Intramural pit, F. 65.01	Maize	2430±50	-10.9	760-410 B.C.	Beta-193152	This report
Pit structure	Maize	2395±60	-9.9	755-395 B.C.	AA-6637	Mabry 1999
Pit structure	Maize	2390±65	-10.6	755-395 B.C.	AA-6636	Mabry 1999
Pit structure	Maize (?)	2360±60	-22.5	480-390 B.C.	AA-6639	Mabry 1999
Top of Stratum 502, San Agustín Mission Locus						
Pit structure, F. 15	Maize	1650±40	-10.5	A.D. 380-430	Beta-190710	This report
Pit structure, F. 28	Mesquite	(450±40)	-21.0	A.D. 1430-1460	Beta-190712	This report
Pit, F. 178	Capsicum	(100±40)	-25.7	A.D. 1680-1950	Beta-190711	This report
Top of Stratum 502, Mission Gardens Locus						
Pit structure, F. 3014	Maize	1760±40	-11.7	A.D. 230-450	Beta-193146	This report
Pit structure, F. 3038.02	Columnar-celled seed coat	1600±40	-25.3	A.D. 410-530	Beta-190715	This report

Table 20.2. Relevant radiocarbon dates from sites near the Clearwater site, AZ BB:13:6 (ASM), by alluvial unit.

Stratum/Context	Material	Uncalibrated Radiocarbon Age b.p.	$^{13}C/^{12}C$ Ratio	Calibrated Age Range (1-sigma)	Sample Number	Reference
Subunit 4b: Alameda Street Locus [Unit 2 at AZ BB:13:65 (ASM)]						
Charcoal lens	Unidentified charcoal	3650±60	?	2130-1940 B.C.	Beta-85537	Freeman 1999
Subunit 5d: East Bank Site [Upper Unit IV at AZ BB:13:535 (ASM)]						
Pit, Feature 67	Mesquite charcoal	2420±80	-25.0	760-400 B.C.	Beta-119021	Mabry 1999

VIII and VII in Mabry 1999). The lower paleosol averages approximately 30 cm in thickness, and the upper paleosol is about 50 cm thick in most places. These units, referred to here as Units 3a and 3b, represent intervals of overbank deposition, interrupted by periods of floodplain stability and surface weathering, that may correlate with cycles of incision of the main river channel. Temporally, this unit appears to correlate with the Unit B1 colluvium deposited along the edge of the river channel (Unit B1) in the upstream reach south of San Xavier, with associated radiocarbon dates ranging between 4850 and 3980 ^{14}C years b.p., and containing Middle Archaic sites (Haynes and Huckell 1986).

Unit 4

Unit 4 represents an interval of rapid deposition, beginning with flood sands or near-channel sands (4a), then shifting to overbank silts and clays (4b). Associated radiocarbon dates bracket the total timespan of Unit 4 between about 4000 and 3000 ^{14}C years b.p. This unit is approximately equivalent to Unit B2 in Haynes and Huckell (1986), which was initiated by a cycle of channel cutting documented in other reaches of the middle Santa Cruz floodplain. No equivalent channel has been identified at the base of A-Mountain, although erosion of the top of Unit 3 may be related to local channel entrenchment.

Subunit 4a. On the western side of the current river channel, south of Congress Street, strata 504 and 503 (both within Unit 4a) are coarse, sandy deposits laid down by high-velocity water flows in and near the channel. The surface of Stratum 504, the earliest deposit in this unit, is not level. It forms a low, gently sloping ridge trending southwest-northeast (Figure 20.2). The southeastern side slopes more steeply than the northwestern side. The orientation, distribution, and size of this deposit suggest it formed subaqueously, as a channel-margin or current-margin bar during a relatively large flood event. Trenches did not extend to the bottom of the deposit; therefore, the presence of an actual channel incised into the floodplain is speculative. The channel (or current) appears to have been meandering, and the Stratum 504 ridge appears to have been deposited as a bar-like feature on the outside of the meander. This postulated origin would explain the elevated nature of the surface and the steeper southeastern side, as well as the coarse nature of the sediments. The sandy sediments are highly oxidized, with an orange color. Cultural features excavated into the top of this unit provided five radiocarbon dates ranging between 3800 and 3620 ^{14}C years b.p., including two dates on maize of 3690±40 and 3650±40 ^{14}C years b.p. (Chapter 19, this report).

The sediments of the overlying Stratum 503 are almost identical to Stratum 504, except they are not oxidized and have been modified by moderate pedogenesis. Stratum 503 is relatively thin and appears to be thickest over the Stratum 504 crest, draping over the ridge and thinning toward its margins (see Figure 20.2). The contact between strata 503 and 504 is easily recognized, but appears to have been "blurred" by postdepositional bioturbation processes. There are no indications of significant pedogenesis on Stratum 504 prior to Stratum 503 deposition, although the presence of cultural features and artifacts on the surface of Stratum 504 implies that it was exposed for a period of time. Cultural features originating in Stratum 503 provided two radiocarbon dates of 3280±40 and 3220±40 ^{14}C years b.p., the latter on annual plant remains (see Chapter 19).

The lack of pedogenesis on top of Stratum 504 indicates the hiatus between depositions of strata 504 and 503 was relatively short, while the radiocarbon dates associated with Stratum 503 cultural features indicate they were dug into its surface several centuries after its deposition. In addition to the lack of pedogenesis on Stratum 504, the absence of subaerial erosional features (rills, dunes, and so forth) and the absence of eolian sorting of the sandy Stratum 504 deposits all support the scenario that Stratum 503 was deposited subaqueously, not long after the deposition of Stratum 504. This would explain the morphology and texture of Stratum 503 sediments. Water

Table 20.3. Concordance table for identified alluvial units in the Santa Cruz River floodplain at the base of A-Mountain.

Locations of Exposures						**A-Mountain Holocene Alluvial Units and Estimated Timespans (Uncalibrated ^{14}C Years b.p.)**	Middle Santa Cruz Valley Units (Haynes and Huckell 1986)
Western Side, AZ BB:13:6 (ASM) , and AZ BB:13:65 (ASM)					Eastern Side, AZ BB:13:535 (ASM)		
Alameda Street (Freeman 1999)	Congress Street (This report)	Brickyard (Freeman 1997a)	San Agustín Mission (This report)	Mission Gardens (This report)	East Bank (Mabry 1999)		
Present channel	Present channel	Present channel	Present channel	Present channel	Present channel	**9 100-present**	E
6, Historic plowzone	498, Cienega/Plowzone	4. Historic fills	497, Plowzone	499, Upper (soil)	IA, Upper (overbank silts)	**8 200-100**	D
	499, Cienega	5, Upper channel fill	*truncated*	499, Lower (silts)	IA, Lower (overbank silts)	**7b 900-200**	C3
5, Channel fill	500, Channel fill	5, Lower channel fill	*by*	500, Flood sands	IB, Flood sands	**7a 1000-900**	C3
	501, Upper (cienega)	3, Upper (cienega)	*plowzone*	501, Flood silt and irrigation clay	II, Upper (cienega)	**6c 1100-1000**	C2
4, Overbank silts	501, Middle (overbank silts)	3, Middle channel fill	501, Soil	*disconformity*	II, Lower (overbank silts)	**6b 1800-1100**	C2
	501, Lower (channel gravels)	3, Lower channel fill	501, Flood sands		III, Flood sands	**6a 2000-1800**	C2
3, Upper (cienega)	502, Upper (cienega)	2, Upper (cienega)	502, Upper (cienega)	502, Upper (cienega)	IV, Upper (cienega)	**5d 2400-2000**	C1
			502, Middle (flood)	502, Middle (flood)		**5c ca. 2400**	C1
	502, Lower (cienega)	1, Upper soils	502, Lower (cienega)	502, Lower (cienega)	IV, Lower (cienega)	**5b 2800-2400**	C1
3, Lower (channel fill)		2, Lower (channel fill)				**5a 3000-2800**	C1
2, Overbank silts	505, Overbank silts	1, Overbank silts	503, Flood sands		V, Overbank silts	**4b 3700-3000**	B2
1, Multiple channels	504-503, Flood bar		505, Flood sands		VI, Flood sands	**4a 4000-3700**	B2
					VIII-VII, Soils	**3a-b 5000-4000**	B1
					XIII-IX, Silts and colluvium	**2 Middle Holocene**	
					XVI-XIV, Braiding channels	**1 Early Holocene-terminal Pleistocene**	A

Note: **Bold** text indicates alluvial units and timespans referred to in this report.

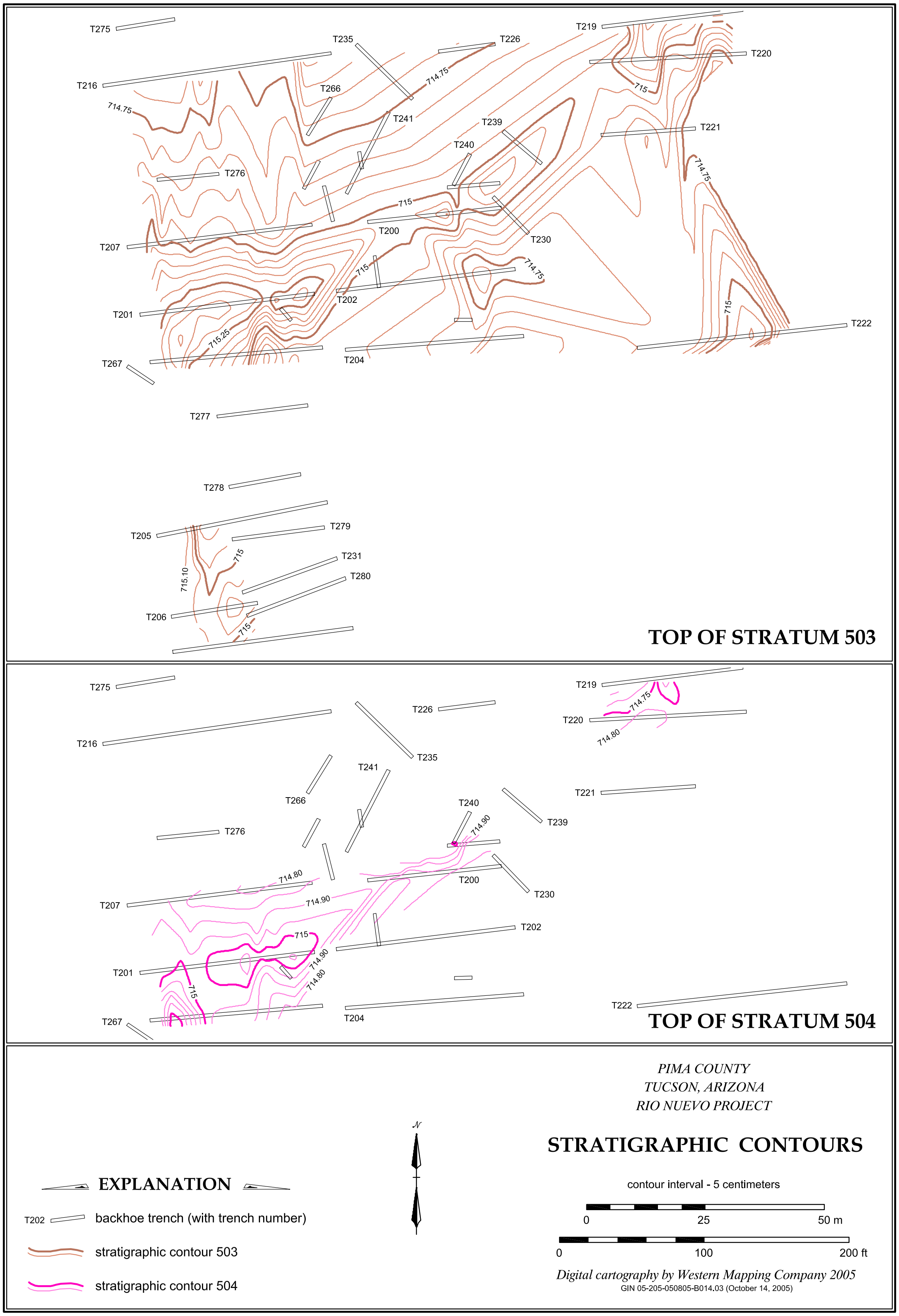

Figure 20.2. Topographies of the tops of Stratum 503 and Stratum 504 at the Congress Street locus, the Clearwater site, AZ BB:13:6 (ASM).

flowing over a vegetated floodplain (including during a flood) would deposit sediments more rapidly over the Stratum 504 ridge due to shallower conditions there, as occurs in the formation of natural levees.

Equivalent alluvial units exposed in other nearby locations include channels and sandy flood deposits. In a trench along Alameda Street, on the western side of the river north of the Clearwater site, several small channels are represented in a coarse-grained unit near the present entrenched channel (Unit 1 in Freeman 1999). At the San Agustín Mission locus, Unit 505 is a thick deposit of coarse sediments representing a number of closely spaced, very large floods. On the eastern side of the present river channel, Unit VI at the East Bank site is composed of coarse sediments representing near-channel deposits or floods (Mabry 1999).

Subunit 4b. At the Congress Street locus, Stratum 505 overlies the slopes of the Stratum 504 ridge, but not the Stratum 503 sediments capping the ridge. Stratum 505 is a thick deposit of overbank silts with numerous clay lenses throughout. There are no associated radiocarbon dates or cultural remains. However, the radiocarbon dates associated with the overlying Stratum 502 indicate Stratum 505 was deposited prior to 2600 ^{14}C years b.p., by which time up to 0.5 m of cienega clay had already been deposited (see below). The timespan of deposition of Stratum 505 at Congress Street is therefore estimated to be about 3700-3000 ^{14}C years b.p., the same as that of the lower portion of Unit B2 in Haynes and Huckell (1986).

These temporal and stratigraphic relationships indicate that the Stratum 503 paleosol remained exposed on a ridge above the floodplain surface between approximately 3700 and 3200 ^{14}C years b.p., while Stratum 505 was accumulating around the paleosol. Pollen evidence (Chapter 15, this report) indicates a high water table and high soil moisture levels during the occupation on Stratum 503 at about 3200 ^{14}C years b.p., a reconstruction further supported by the presence of Canal 152 in the top of this stratum (see Chapter 19).

Overbank silts (Unit 2 in Freeman 1999) were also deposited near Alameda Street during the Stratum 505 deposition, with a sample of wood charcoal from a charcoal lens in the lower portion yielding a radiocarbon date of 3650±60 ^{14}C years b.p. At the Brickyard locus, the lower overbank silts (Unit 1 in Freeman 1997a) are modified by pedogenesis. The equivalent unit at the San Agustín Mission locus is a sandy in-channel or near-channel deposit (Unit 503). These units correlate with a unit of overbank silts modified by moderate pedogenesis on the eastern side of the river (Unit V in Mabry 1999).

Unit 5

The deposition of Unit 5 followed a cycle of channel cutting near 3000 ^{14}C years b.p. The lower fill of this channel is a medium-to-coarse sand, with lenses of fine gravel, as documented between Congress Street and Mission Lane by Katzer (1987). Overlying this coarse material, the upper fill of the channel is a 1.5- to 2.0-m-thick, dark, clayey deposit with strong ped structure and thin lenses of silt and sand throughout. This is the cienega deposit in Ahlstrom et al. (1994) and Katzer (1987), upper Unit 2 in Freeman (1997a), and Unit 502 at the Congress Street locus. On the western side of the present channel, this cienega clay extends from at least Alameda Street to Mission Lane, and overlies both the Stratum 503 paleosol and Stratum 505 overbank silts at Congress Street. The top of this cienega clay is modified by pedogenesis.

A combination of radiocarbon dating, contexts of archaeological remains, and estimated sedimentation rates bracket the total timespan of Unit 5 between about 3000 and 2000 ^{14}C years b.p., partially overlapping the estimated timespan of 2500-2000 ^{14}C years b.p. for Unit C1 in Haynes and Huckell (1986). The coarse lower channel fill is designated as Subunit 5a (circa 3000-2800 ^{14}C years b.p.). Subunit 5b is the lower portion of the cienega deposit. A flood silt in the middle of the cienega deposit is designated Subunit 5c. The upper portion of the cienega deposit is Subunit 5d. The flood deposit 5c (estimated to have occurred circa 2400 ^{14}C years b.p.) represents the boundary between 5b below (circa 2800-2400 ^{14}C years b.p.), and 5d above (circa 2400-2000 ^{14}C years b.p.).

Subunit 5a. At the Brickyard locus, the Unit 5 channel (Unit 2 channel in Freeman 1997a) cuts the Unit 4b deposit of overbank silts (Unit 1 in Freeman 1997a). At Alameda Street, what is probably the same channel (Unit 3 channel in Freeman 1999) cuts into the top of the Unit 5 overbank silts (Unit 2 in Freeman 1999). This cycle of channel cutting appears to correlate with channel cutting near 3000 ^{14}C years b.p., evident upstream at Locality 1 in the Martinez Hill reach (Huckleberry 2006), and downstream at Santa Cruz Bend (Huckell 1998) and Los Pozos, AZ AA:12:91 (ASM) (Freeman 1998). The lower channel fill of Subunit 5a correlates with rapid channel deposition between about 3100 and 2900 ^{14}C years b.p., at Valley Farms, AZ AA:12:736 (ASM), downstream (Freeman 2000b).

Subunit 5b. At the Brickyard locus, the uppermost paleosol in Unit 1 (Freeman 1997a) contains Early Cienega phase (circa 2800-2400 calendar years B.P.) features that have provided radiocarbon dates between 2620 and 2390 ^{14}C years b.p. (Diehl 1997; see also Chapter 19). Toward the west, north, and south, this uppermost paleosol transitions laterally to the lower part of the Stratum 502 cienega clay (Unit 5b), and is overlain by the upper portion of Stratum 502 (Unit 5d). At the San Agustín Mission locus, the middle of the Stratum 502 cienega clay contains Cienega phase features radiocarbon dated between 2395 and 2360 ^{14}C years b.p. (Elson and Doelle 1987; dates reported in Mabry 1998a:Table 1.3). On the eastern side of the present channel at the East Bank site, the contact between Unit V overbank silts and the overlying Unit IV cienega clay is modified by pedogenesis, but is gradational; these units may represent lower and upper portions of the same deposit rather than distinct strata (Mabry 1999). Early Cienega phase features originate at this contact and just above it.

Subunit 5c. The Cienega phase features at the San Agustín Mission locus originate on a surface that was subsequently covered by a thin, sandy silt layer deposited by a flood of minor to moderate magnitude, bracketed near 2400-2350 ^{14}C years b.p. by the ages of cultural features in underlying and overlying units. What is thought to be the same flood deposit was also visible in the middle of the Stratum 502 cienega clay at the Mission Gardens locus.

Subunit 5d. The top of Subunit 5d, representing a continuation of cienega conditions over a large area, can be dated to about 2000 ^{14}C years b.p., based on the oldest cultural materials on it. Late Cienega phase (circa 2400-1950 calendar years B.P.) cultural features are dug into the top of the Stratum 502 cienega deposit at the San Agustín Mission locus; a canal radiocarbon dated to roughly 2100 ^{14}C years b.p. is in the upper part of the Stratum 502 cienega clay at the Brickyard locus (this report), and sherds of the Agua Caliente phase (circa 1950-1450 calendar years B.P.) are in the upper portion of an equivalent cienega clay unit at Alameda Street (Unit 3 in Freeman 1999). At the East Bank site, Unit IV grades from silty clay to clayey silt (becoming a cienega deposit) westward toward the present channel. One of the Late Cienega phase features originating in the upper portion of this unit provided a radiocarbon date of 2420±80 ^{14}C years b.p. (Mabry 1999).

Unit 6

Deposition of Unit 6 followed a cycle of downcutting near 2000 ^{14}C years b.p. The channel fill grades upward from coarse channel gravels and sands (Subunit 6a), to overbank silts (Subunit 6b), to a cienega deposit (Subunit 6c). Associated radiocarbon dates and temporally diagnostic ceramic types bracket the total timespan of deposition of Unit 6 between about 2000 and 1000 ^{14}C years b.p., equivalent to Unit C2 in Haynes and Huckell (1986).

Subunit 6a. At Congress Street, the Stratum 501 channel cuts the Stratum 502 cienega clay. At the Brickyard locus, the Unit 3 channel cuts the cienega clay in the upper part of Unit 2 (Freeman 1997a). At the San Agustín Mission locus, the Stratum 502 cienega clay is overlain by an in-channel or near-channel sand deposit (Unit 501). The intervals of Subunits 6a and 6b are represented by an erosional surface at the Mission Gardens. On the eastern side of the present channel, a laminated deposit of sandy in-channel or near-channel sediments (Unit III) tops the cienega deposit in the upper part of Unit IV (Mabry 1999). Channel deposition following entrenchment probably lasted no longer than a couple of centuries, and the estimated timespan of Subunit 6a is circa 2000-1800 ^{14}C years b.p.

Subunit 6b. Filling of the lower part of the Unit 6 channel with coarse sediments was followed by overbank deposition of finer sediments. Overbank silts of Unit 4 overlie the Unit 3 cienega clay at Alameda Street (Freeman 1999). At Congress Street, the middle channel fill of Stratum 501 is composed of bands of silts and clays. During this interval, a weak soil formed in the upper part of Unit 501 at the San Agustín Mission locus. At the Mission Gardens locus, Agua Caliente phase cultural features radiocarbon dated to 1760±40 and 1600±40 ^{14}C years b.p. were excavated into the eroded top of the Stratum 502 cienega deposit during a hiatus in deposition at that location. The corresponding lower part of Unit II on the eastern side of the present channel is a clayey silt deposited by overbank floods and containing cultural features of the Cañada del Oro phase (circa 1250-1150 calendar years B.P.) (Mabry 1999).

Subunit 6c. The upper part of the Unit 6 channel fill at Congress Street (this report) and at the Brickyard locus (upper Unit 3 in Freeman 1997a) is a 30- to 50-cm-thick cienega clay displaying weak pedogenesis. At the Brickyard locus, pottery sherds of the Early and Middle Rincon subphases (circa 1050-900 calendar years B.P.) are contained in this cienega deposit (Freeman 1997a). Canal 146, containing pottery sherds of the Late Rincon and Tanque Verde phases (circa 900-700 ^{14}C years b.p.), is cut into the top of it. At the San Agustín Mission locus, Canal 137 was probably excavated during the interval of Subunit 6c, but the top of the canal and the surrounding alluvial sediments deposited during this interval are truncated by the historic plowzone. At the Mission Gardens locus, a flood silt was deposited after Canal 200 was excavated, followed by deposition of a thin sheet of clay that probably derived from the irrigation water delivered by this canal. Forming the upper part of Unit 2 on the eastern side of the present channel is a cienega clay displaying weak pedogenesis (Mabry 1999). Hohokam cultural features dating to the Middle Rincon subphase (circa 1000-900 calendar years B.P.) are contained in this cienega deposit, and cultural features of the Late Rincon subphase (circa 900-850 calendar years B.P.) intrude the top of it (Mabry 1999).

Unit 7

Deposition of Unit 7 follows a cycle of channel cutting near 1000 ^{14}C years b.p., equivalent to the channel-cutting cycle near that time in several other reaches of the middle Santa Cruz Valley (Unit C3 channel in Haynes and Huckell 1986). Associated radiocarbon dates and temporally diagnostic ceramic types bracket the total timespan of deposition of Unit 7 from about 1000 ^{14}C years b.p. to sometime between 300 and 200 calendar years B.P., equivalent to Unit C3 in Haynes and Huckell (1986).

Subunit 7a. At Alameda Street, the small Unit 5 channel cut into the top of the Unit 4 overbank silts. Freeman (1999) suggests this channel may be the ditch excavated at Saint Mary's Road in 1888, which became the initial locus of arroyo headcutting the following year (Betancourt and Turner 1990). However, at Congress Street, a similar-sized (7-8 m wide), sand-filled channel (Stratum 500) cut through the cienega clay in the upper portion of Stratum 501, and a sequence of two Hohokam canals (Features 146 and 154) containing sherds of the Late Rincon and Tanque Verde phases (circa 900-700 calendar years B.P.) were subsequently excavated within this sand-filled channel.

At Alameda Street, Freeman (1999:Figure 2.3) identified two historic canals in the top of the Unit 5 channel fill. The historic-era Canal D (Feature 180) documented by Freeman (1996) at the Brickyard locus was also excavated into a sandy channel deposit containing pottery sherds of the Early and Middle Rincon subphases (circa 1050-900 calendar years B.P.). These stratigraphic relationships and associated datable artifacts indicate the channel cutting occurred near 1000 calendar years B.P. The channel deposition represented by Subunit 7a is bracketed between about 1000 and 900 calendar years B.P. by the ages of cultural features contained in the underlying and overlying units (see above and below).

The corresponding unit at the Mission Gardens is a massive deposit of flood sands (Stratum 500) that filled Canal 200 and terminated its use. At the San Agustín Mission locus, historic plowing truncated the sediments deposited during this interval, but the flood deposit that filled the upper portion of Canal 137 may correlate with the flood sands at the Mission Gardens. These flood deposits on the western side of the present river channel correlate with the Unit IB flood sands on the eastern side (Mabry 1999).

Subunit 7b. The top of the Unit 7 channel fill (upper Stratum 499) at Congress Street is a cienega clay. This deposit formed during the use of Canal 149, draping down into the canal profile. The sediments filling this canal contained a variety of Classic period sherds, including Tanque Verde Red-on-brown, Sells Red, and corrugated wares, bracketing its age between about 850 and 700 calendar years B.P. A flood sand filled Canal 149 and terminated its use. Canal 151 also appears to have been excavated through the upper Stratum 501 cienega clay during this interval. The Subunit 7b cienega is equivalent to the upper channel fills of Unit 5 at both Alameda Street and the Brickyard locus (Freeman 1997a, 1999). The corresponding sediments at the San Agustín Mission locus are truncated by historic plowing. During this interval, overbank silts (Stratum 499) were deposited at the Mission Gardens locus.

Protohistoric period canals 201, 204, 205, and 207—dating between about 500 and 300 calendar years B.P. (and possibly as late as 200 calendar years B.P.)—originated within the upper part of this unit. On the eastern side of the present river channel, the lower part of the overbank silts of Unit IA were deposited; this unit contains cultural features of the Late Rincon subphase (circa 900-850 calendar years B.P.) (Mabry 1999). Spanish period remains at the San Agustín Mission lie on top of Unit 7b, indicating deposition of this unit stopped by 200 years ago. The ages of these archaeological features, and the ages of the underlying and overlying units, bracket the age of Subunit 7b between about 900 and 200 calendar years B.P.

Unit 8

Although no equivalent channel has been identified in the area at the base of A-Mountain, deposition of Unit 8 follows a cycle of channel cutting sometime between 500 and 200 calendar years B.P. in several other reaches of the middle Santa Cruz Valley (Unit D channel in Haynes and Huckell 1986). Waters and Haynes (2001) place this channel-cutting episode near 500 years ago, but do not present the basis of this dating. The presence of Protohistoric canals within Unit 7b at the Mission Gardens seems to indicate the Unit 8 channel cutting occurred sometime between 300 and 200 calendar years B.P., while the Spanish period remains of the San Agustín Mission on top of Subunit 7b and contained in Unit 8 sediments indicate Unit 8 began accumulating approximately 200 years ago. At the Mission Gardens and Congress Street loci, Unit 8 contains Spanish, Mexican, and American Territorial period artifacts, features, and canals. These associated cultural remains suggest a timespan of about 200-100 calendar years B.P. for Unit 8, of which the upper portion has been truncated by historic plowing.

At Congress Street, following a period of soil formation in the upper part of the flood sand that filled the Hohokam canal Feature 149, historic canal Feature 155 was excavated along the depression of the prehistoric canal. A cienega clay contemporaneous with this historic canal extends toward the present river channel. West of Canal 155, the historic plowzone truncates the upper portions of sediments and canals dating to this interval. Nevertheless, it is apparent that historic canal Feature 147 was excavated along the same alignment as Hohokam Canals 146 and 154, intruding their upper fills. Canal Feature 138, shown on an 1862 map as the "Acequia Madre Primera," was also excavated during this interval.

At the Mission Gardens locus, the top of the Unit 7b silts are modified by weak pedogenesis and partly truncated by the historic plowzone. The plowzone also truncated Unit 8 deposits at Alameda Street (Freeman 1999), while this unit contains cultural fills dating to the nineteenth and twentieth centuries at the Brickyard locus (Freeman 1997a). East of the present channel, the upper part of Unit IA contains historic-era trash and is disturbed by modern construction activities; its top forms the present ground surface.

Unit 9

The most recent cycle of channel cutting at the end of the nineteenth century is well documented by local newspapers and photographers (Betancourt and Turner 1990). A ditch was excavated at St. Mary's Road in 1888 to intercept the river's underflow to increase the water supply to agricultural fields to the north. The following year, this ditch became the locus of arroyo headcutting during a large summer flood. Large floods also occurred during the summers of 1890 and 1891, and the arroyo starting at Hugh's ditch extended upstream (southward) along the Acequia Madre. The river channel downcut to the water table lowered by previous years of drought and overgrazing. By 1891, the arroyo had extended south of A-Mountain. This headcut coalesced with another downcut segment near the San Xavier Mission by 1910, resulting in the continuous incised channel through Tucson that is visible today.

Summary

This new model of the alluvial sequence for the Santa Cruz River's former floodplain at the base of A-Mountain allows a number of observations, conclusions, and correlations. The estimated beginning and ending dates of the alluvial units in this reach correlate well (within 100 years or less) with those generalized by Haynes and Huckell (1986) for the entire middle Santa Cruz Valley. Probable early and middle Holocene deposits are currently identified only on the eastern side of the present river channel, while the western-side sequence has the best dating control, starting about 3700 ^{14}C years b.p. Figure 20.3 is a graphic summary of the alluvial sequence model developed here.

The sequence shows five (or possibly six) cycles of channel cutting and filling over the last 4,000 years, with each unit of channel fill sediments fining upward. The last four cycles ended with intervals of cienega conditions, indicating high water tables, across most of this reach circa 2600-2000 and 1100-1000 ^{14}C years b.p., and also circa 800-700, and 150-100 calendar years B.P. There were occasional lags in the onset of cienega conditions between loci up to a century in duration, and the depositions of cienega clays were sometimes very localized (see Table 20.3).

The presence of cienegas during the Hohokam Classic period and the late nineteenth-century are documented in this area for the first time (both at the Congress Street locus). Rapid channel deposition from floods occurred between 4000 and 3700 ^{14}C years b.p., and for short intervals following channel downcutting near 2600, 2000, and 1000 ^{14}C years b.p. Flood events of moderate magnitude are represented by silt and sand deposits dated near 2400, 1150, and 700 ^{14}C years b.p., and historical records document another roughly 110 years ago. The high magnitude flood in A.D. 1983 is not represented by sediments in this location.

A narrative interpretation of the alluvial sequence at A-Mountain starts during the early Holocene, between about 11,000 and 8000 ^{14}C years b.p., when braiding channels deposited sands and gravels over a wide area. During the late middle Holocene, between about 6000 and 5000 ^{14}C years b.p., overbank floods and local slopewash deposited silts and colluvium, respectively. Deposition of overbank silts between circa 5000 and 4000 ^{14}C years b.p. was interrupted by two intervals of weathering and soil formation. During the first alluvial cycle of the late Holocene, frequent flooding deposited in-channel and near-channel sands between about 4000 and 3700 ^{14}C years b.p., followed by deposition of overbank silts until channel cutting occurred near 3000 ^{14}C years b.p. Rapid filling of this channel with sands and gravels was followed by clay deposition in an extensive cienega between about 2800 and 2000 ^{14}C years b.p., indicating a higher water table during that long interval.

Channel cutting near 2000 ^{14}C years b.p. initiated the next alluvial cycle. Between about 2000 and 1100

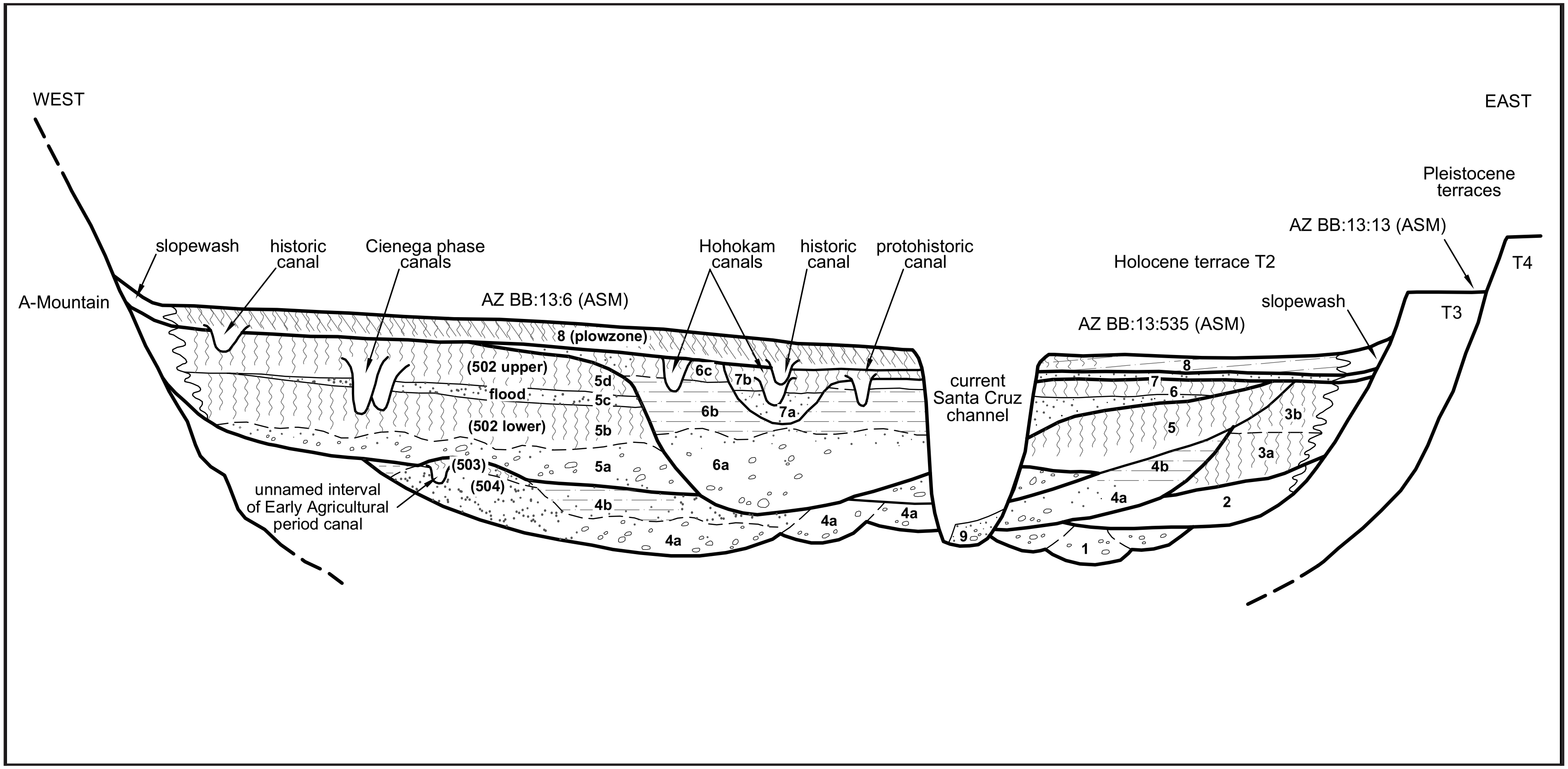

Figure 20.3. Composite geologic cross section of the A-Mountain reach of the Santa Cruz River floodplain.

^{14}C years b.p., this channel filled first with coarse sediments and then overbank silts. This cycle ended with a rise in the water table and deposition of an extensive cienega clay between about 1100 and 1000 ^{14}C years b.p., when the next channel-cutting event occurred. Between roughly 1,000 and 200 years ago, this channel filled with sediments that fined upward over time, with a smaller cienega forming near Congress Street between approximately 800 and 700 years ago. The next alluvial cycle (marked by a channel-cutting event in most other reaches) deposited silts and cienega clays between about 200 and 100 years ago, while the stable floodplain surface in the Mission Gardens locus experienced weathering and limited soil formation. Between 1889 and 1891, following a period of drought and falling water table, the most recent downcutting event created an entrenched channel through what is now downtown Tucson—the channel that is visible today.

The ages of cultural occupations and canals are bracketed by the radiocarbon-dated timespans of the alluvial units that contain, underlie, and overlie them. Cultural occupations generally correlate with intervals of floodplain stability or slow aggradation from regular, low-energy overbank floods. Construction and operation of canals tend to correlate more specifically with intervals of high water tables and cienega conditions. During the mid- to late nineteenth century, two canals were dug along the same alignments as Hohokam canals built at least 500 years earlier. The depressions of the prehistoric canals were not likely to have been still visible during the Mexican or early American Territorial periods. Rather, different vegetation probably grew in the better-drained canal fills, making their alignments visible. It was advantageous to dig new canals along the earlier canal alignments, because it was easier to dig in the sandy sediments filling the prehistoric canals than in the heavy clay sediments predominating in the Congress Street area at that time.

LOCAL PATTERNS

Many of the alluvial processes and resulting depositional units identified in the A-Mountain reach have correlates in the 11 other radiocarbon-dated alluvial sequences in the middle Santa Cruz Valley, from south of Martinez Hill to the northern end of the Tucson Mountains (Figure 20.4). The estimated timespans and associated alluvial processes of the alluvial units identified in those localities are summarized in Figure 20.5. For each sequence, the number of radiocarbon dates providing the chronological framework is shown below its column. Temporal boundaries of units are shown with solid or dashed lines, according to the level of confidence in the dating. The localities are grouped by the four reaches of the river through the Tucson Basin, as defined by Nials (2006), and from left to right, are shown in their order from upstream (south) to downstream (north).

One important spatial pattern among the dated alluvial sequences is the presence of middle Holocene (7500-5000 ^{14}C years b.p.?) deposits at the East Bank site and most of the downstream localities. These are generally coarse or poorly sorted deposits representing in-channel or near-channel deposition during floods, high-energy overbank floods, or local slopewash (colluviation) during rain events. Upstream, erosion and channel widening either predominated throughout the middle Holocene, or occurred during the late portion of the middle Holocene, removing any sediments deposited earlier during that interval.

Between approximately 5500 and 4000 ^{14}C years b.p. at A-Mountain and some downstream locations, overbank deposition was interrupted by one or more intervals of soil formation, representing stable floodplain surfaces and local channel entrenchment. In other locations, this interval was characterized by rapid, high-energy overbank and channel deposition and local slopewash.

Following a widespread cycle of downcutting near 4000 ^{14}C years b.p., rapid overbank deposition began in most reaches by 3700 ^{14}C years b.p., implying the channel had filled by that time. Cienega conditions between approximately 3700 and 2800 b.p. near the mouth of Julian Wash between Martinez Hill and A-Mountain (Locality 4 in Huckleberry 2006) overlapped intervals of cienega conditions near 2600 ^{14}C years b.p. in the upstream Continental Reach (Haynes and Huckell 1986; Waters 1987), between about 3500 and 3300 ^{14}C years b.p. at Los Pozos (Nials 2006), between about 2800 and 2500 ^{14}C years b.p. at Las Capas (Nials 2006), between about 3200 and 3100 ^{14}C years b.p. at Valley Farms (Freeman 2000b), and prior to about 2500 ^{14}C years b.p. at Los Morteros, Locus 1 (Katzer 1989). These cienega deposits indicate high water tables and unentrenched channel segments in those locations.

Deposition of overbank and cienega sediments was interrupted by intervals of floodplain stability and soil formation at Los Pozos between about 3400 and 3300 ^{14}C years b.p., and in several locations between roughly 3200 and 3000 ^{14}C years b.p., and again between about 2700 and 2500 ^{14}C years b.p. These soils imply local channel entrenchment. About 3000 ^{14}C years b.p., channel cutting occurred at A-Mountain and other locations in the A-Mountain reach (Santa Cruz Bend and Los Pozos).

There was valley-wide channel cutting between approximately 2600 and 2500 ^{14}C years b.p., followed by channel filling and then overbank deposition. A high water table sustained a cienega at the base of A-Mountain between roughly 2800 and 2000 ^{14}C years

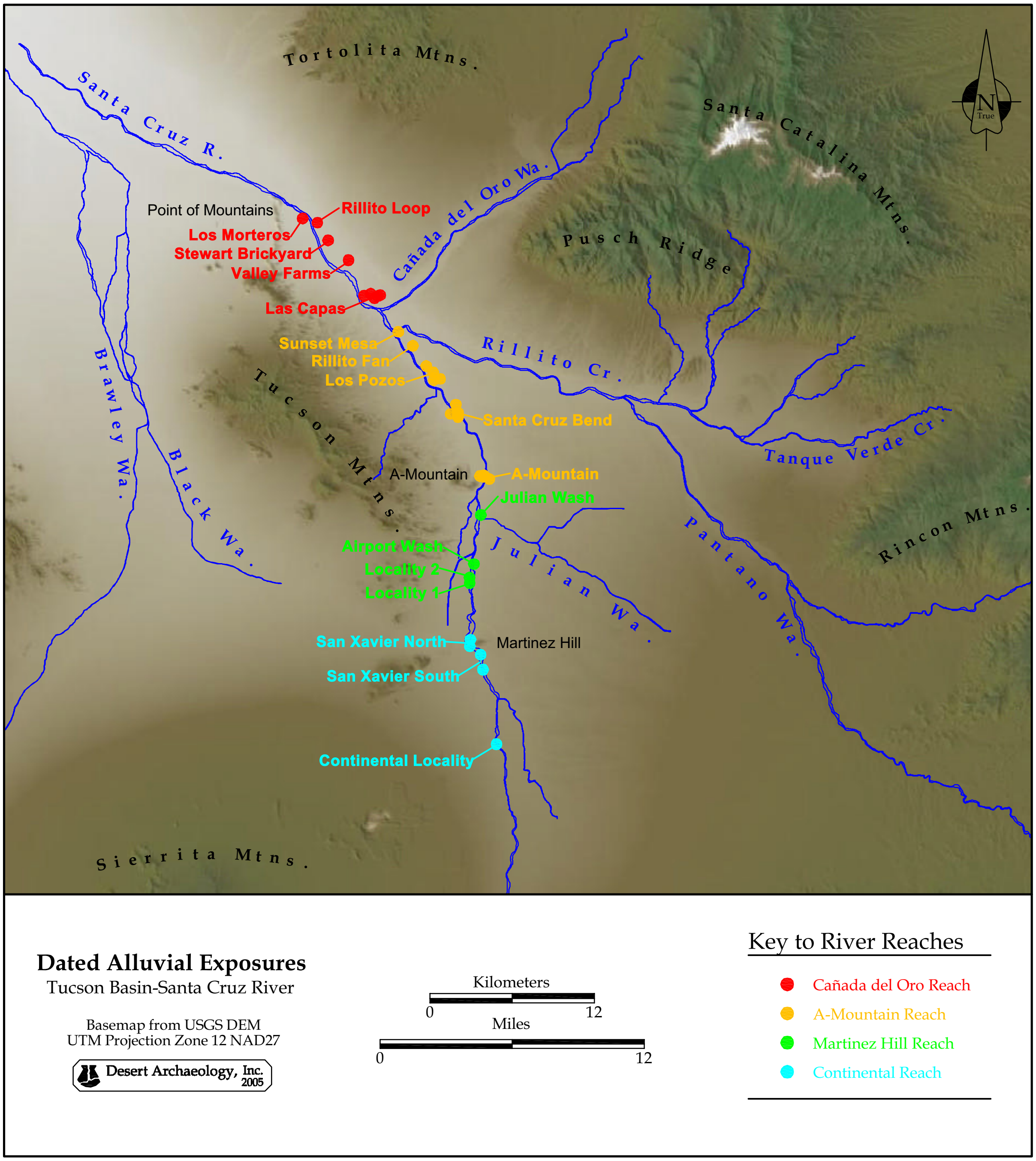

Figure 20.4. Locations of described and dated alluvial exposures in the Santa Cruz River floodplain.

b.p. (this report), during the latter part of that interval at Los Pozos (Freeman 1998), and during an interval prior to 2000 ^{14}C years b.p. in the Continental reach (Haynes and Huckell 1986; Waters 1987). A soil formed in several locations before 2000 ^{14}C years b.p.

A nearly valley-wide channel-cutting cycle occurred about 2000 ^{14}C years b.p. Overbank deposition resumed after this channel filled rapidly. Soils formed in several locations between about 1200 and 1000 ^{14}C years b.p. High water tables and cienega conditions occurred circa 1100-1000 ^{14}C years b.p. in the A-Mountain reach (this report) and in Locality 1 between Martinez Hill and A-Mountain (Huckleberry 2006).

Another nearly valley-wide downcutting cycle occurred about 1000 calendar years B.P.; dunes formed south of San Xavier between roughly 1000

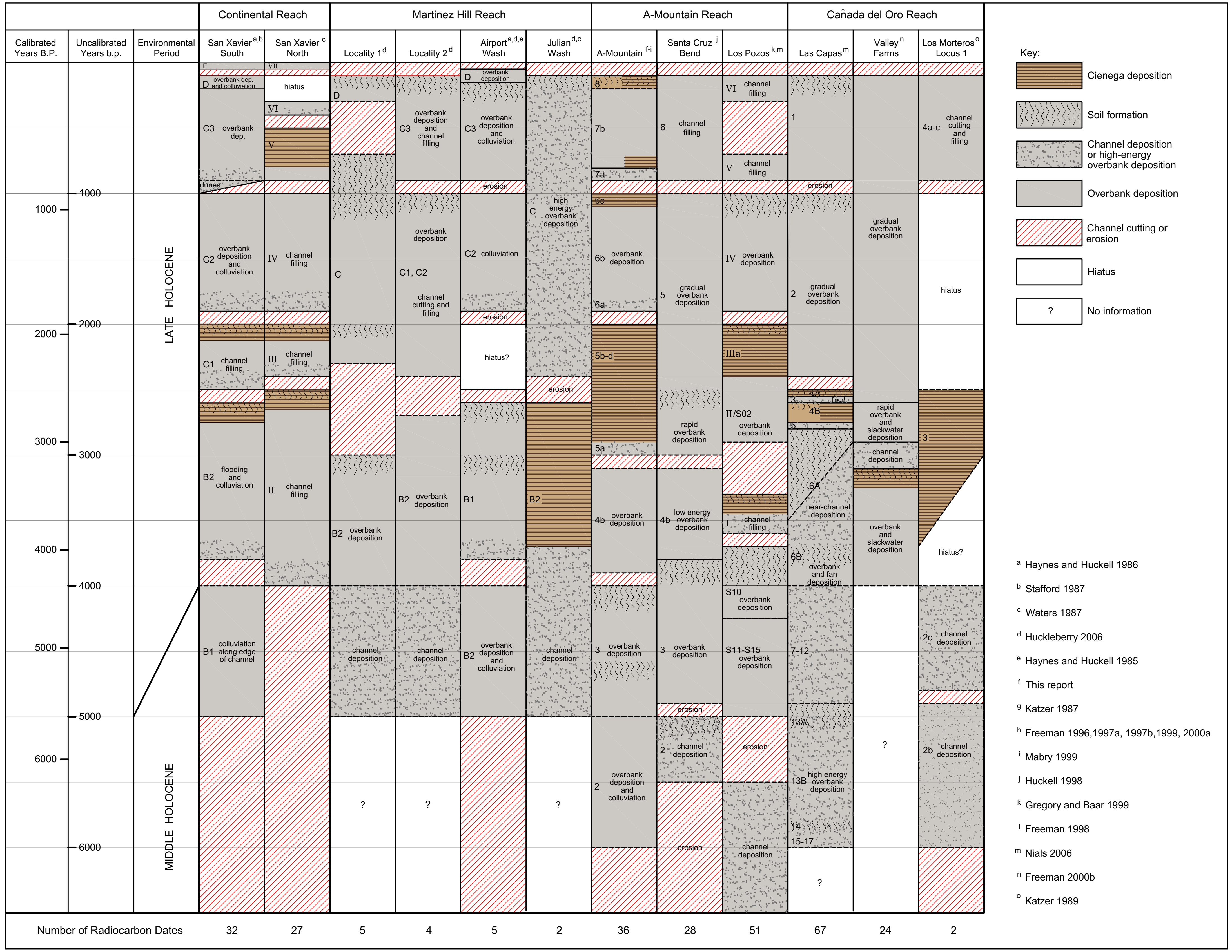

Figure 20.5. Correlations of the alluvial sequences of various reaches of the Santa Cruz River within the Tucson Basin.

and 900 calendar years B.P. (Huckell and Haynes 1986). Overbank deposition resumed after the channel had filled. Cienega conditions are indicated at A-Mountain circa 800-700 calendar years B.P. (this report), and near San Xavier circa 700-500 calendar years B.P. (Waters 1987).

Within the last 500 years, each reach of the river has experienced one or two cycles of channel cutting, including the most recent valley-wide channel downcutting at the end of the nineteenth century. Preceding that event, cienega conditions occurred circa 200/150-100 calendar years B.P. at A-Mountain and in Huckleberry's (2006) Locality 1. In several other locations, soils formed between approximately 300 and 100 ^{14}C years b.p.

As interpreted here, the middle and late Holocene sequence is divided into several valley-wide alluvial cycles that began with intervals of widespread channel downcutting. These largely correspond with the alluvial cycles defined by Nials (2006; see also Gregory and Nials 2005). However, the estimated timespans of some cycles have been adjusted with new data, and Nials' Cycle 3 (circa 4000-1975 ^{14}C years b.p.) is subdivided by the almost valley-wide downcutting event near 2500 ^{14}C years b.p.

Differences among the reaches in the middle Santa Cruz Valley—such as channel downcutting or soil formation occurring in some reaches simultaneous with aggradation in other reaches—is expected along an arid-land, discontinuous ephemeral stream such as the Santa Cruz River (Bull 1997). Sediment storage and transport will also temporally lag between upstream and downstream reaches of the main channel, and between tributaries and the main channel (Patton and Schumm 1981). However, there appear to have been a number of valley-wide, near-simultaneous changes in alluvial processes (see also Waters and Haynes 2001). Major transitions in the older portions of the sequences, representing long-term changes in alluvial regimes, occurred between 8000-7500, 5500-5000, and 4000-3700 ^{14}C years b.p.

Between three and six cycles of channel cutting and filling are documented in most reaches over the last 4,000 years, with widespread but brief episodes (lasting a century or less) of erosion and channel cutting occurring near 4000, 2500, 2000, and 1000 ^{14}C years b.p., and most recently about 110 years ago. The A-Mountain reach became entrenched near 3000 ^{14}C years b.p., and several locations were entrenched some 500 years ago. Intervals of floodplain stability and soil formation centered near 3700, 3000, 2500, 2000, 1000, and 200 ^{14}C years b.p. are documented in multiple reaches, correlating with intervals of channel entrenchment.

Regional Patterns

At a larger scale of comparison, the middle Santa Cruz Valley sequence generally fits with a number of regional trends in Southwestern alluvial sequences. Figure 20.6 illustrates the age ranges, based on qualitative archaeological and absolute radiocarbon dating, of selected Holocene valley alluvial fills in southern Arizona and in other parts of the Greater Southwest. Dark bar segments indicate documented timespans of deposits, while the gaps between the bars represent interruptions in deposition and/or erosion. The numbers of associated radiocarbon dates are shown below each example. For the middle Santa Cruz Valley, the unit designations of Haynes and Huckell (1986) are provided. The quality and precision of dating varies considerably among sequences; however, some general patterns seem clear.

Throughout the Southwest, deposition of coarse channel gravels predominated in the late (deglacial) Wisconsin (14,000-11,000 b.p.). During the early Holocene, between 11,000 and 8000/7500 ^{14}C years b.p., mostly fine-grained alluvium was deposited by overbank floods. A widespread hiatus in deposition and/or erosion starting between 8000 and 7500 ^{14}C years b.p. was followed by channel deposition, high-energy overbank deposition, and slopewash beginning at different times between 6500 and 5000 ^{14}C years b.p. and lasting until about 4000-3700 ^{14}C years b.p. One or more soils also developed during this interval, indicating sustained periods of floodplain stability. A long period of rapid deposition of fine-grained alluvium and slope wash sediments between about 4000/3700 and 2500 ^{14}C years b.p., followed by steady deposition at a slower rate until about 1000 ^{14}C years b.p., is recorded in many valleys.

Many Southwestern alluvial sequences were interrupted by cycles of channel downcutting or widening near approximately 2000 and 1000 ^{14}C years b.p., including the middle Santa Cruz River (Haynes and Huckell 1986; Waters 1987), the middle Gila River (Huckleberry 1995; Waters and Ravesloot 2000), the Upper San Pedro River (Haynes 1987; Waters and Haynes 2001), and Cienega Creek (Eddy and Cooley 1983) in southern Arizona. In the same region, Whitewater Draw also downcut near roughly 1000 ^{14}C years b.p. (Waters 1985, 1986b). Since about 1000 ^{14}C years b.p., most Southwestern valleys have experienced one or two additional cut-and-fill cycles. Many Southwestern arroyos are currently filling with channel deposits and colluvium.

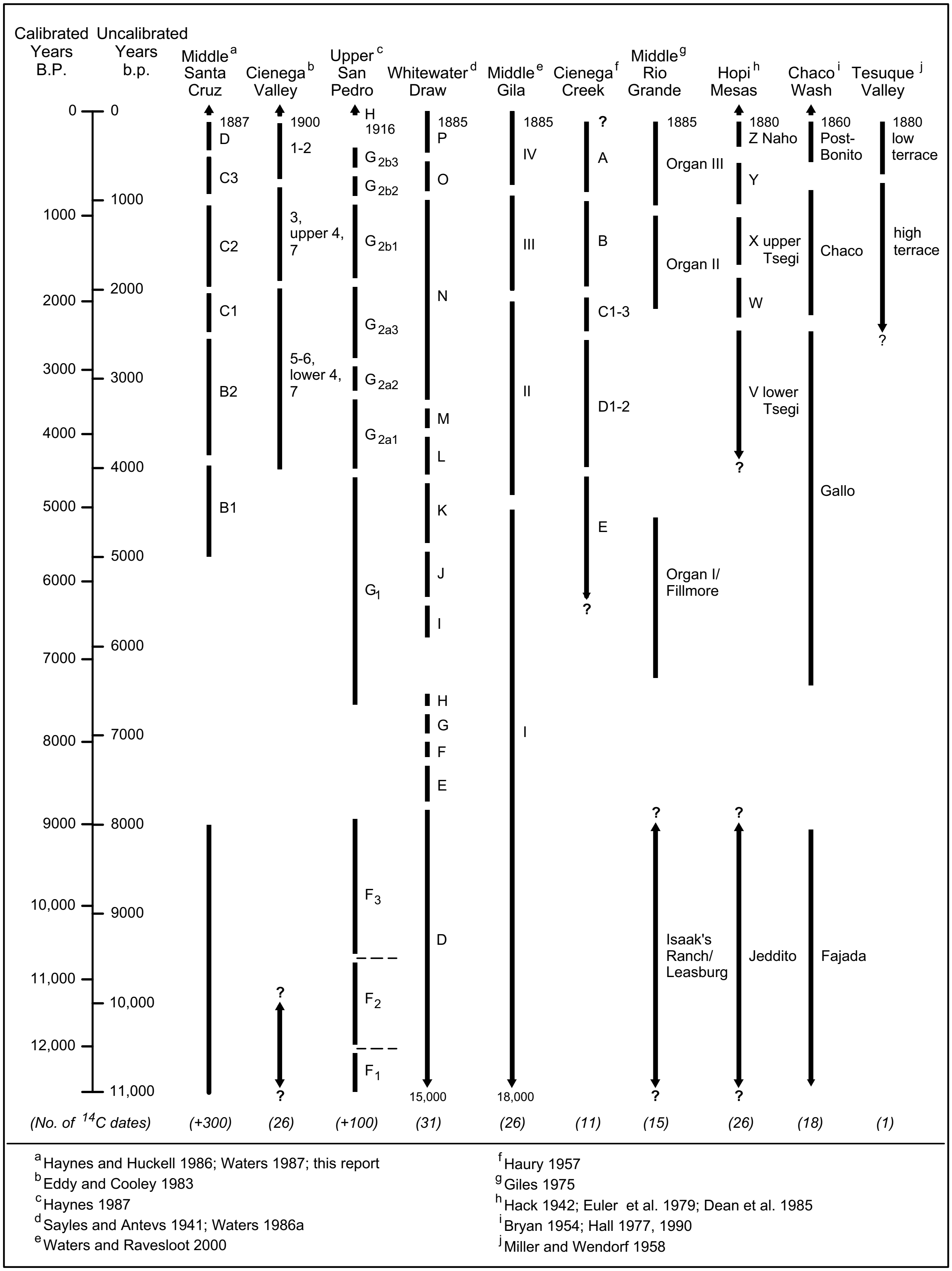

Figure 20.6. Age ranges of Holocene valley alluvial fills in the Greater Southwest, based on radiocarbon and archaeological dating.

CAUSES AND TIMINGS OF FLOODPLAIN AGGRADATION AND EROSION

What were the likely causes of shifts between long intervals of floodplain aggradation and the much shorter intervals of erosion in the middle Santa Cruz Valley? Haynes and Huckell (1986) suggested that climatic shifts were largely responsible for the multiple late Holocene cut-and-fill cycles, but pointed out that the fluctuating level of the water table played an important role in the historic entrenchment of the Santa Cruz floodplain, and probably also influenced the timings of cutting and filling during prehistory. Huckell (1996, 1998) attributed the documented pattern of rapid aggradation of late Holocene alluvium in the Santa Cruz Valley and other valleys of southeastern Arizona to climatically related changes in runoff and sediment yield from the slopes of the mountains and piedmonts bounding the river valleys.

Waters (1987, 1991), citing the threshold-equilibrium model of Schumm (1973, 1977), argued that intrinsic geomorphic thresholds were more important than such external factors. Noting that the increased frequency of cutting and filling in the Santa Cruz floodplain during the late Holocene correlates with rapid vertical aggradation (up to 7 m in places), Waters (1987) hypothesized that the gradients of certain channel reaches steepened to the point where a critical threshold of slope was exceeded, increasing their susceptibility to incision. Entrenchments of these unstable reaches of the floodplain could have been triggered by flooding related to both short-term climatic anomalies, including the El Niño effect (see also Waters and Haynes 2001), and also longer-duration climatic states. Aggradation resumed after short intervals of floodplain incision.

Freeman (1997b, 2000a) drew attention to the role of topographic controls on the separate responses of different reaches of the Santa Cruz River to intrinsic geomorphic factors. She noted that the near-surface bedrock at A-Mountain creates a location favorable to sediment storage, and the narrow distance between the mountain on the west and Pleistocene terraces on the east increased the water velocity and sediment load capacity during floods. Although Freeman (1997b, 2000a) did not discuss it, a similar subsurface bedrock barrier and lateral constriction occurs between Martinez Hill and Black Mountain, and has the same effects on the San Xavier reaches. Cooke and Reeves (1976) documented that, historically, headcutting initiated at the steep areas of the Santa Cruz floodplain immediately downstream from these subsurface barriers and the marshy sediment traps they created on the upstream sides.

Waters (1987) also raised the possibility that, like historic-era farmers in the late nineteenth century, prehistoric farmers may have unwittingly created loci of entrenchment by constructing irrigation ditches. He has suggested that the nonsynchronous entrenchment of the San Xavier reaches (during the Early Rincon phase) and Cienega Creek (during the Late Rincon phase) rules out a climatic perturbation as the cause, and points to the role of human activities (Waters 1991).

Mabry (1999) argued that the lack of synchronicity between the Santa Cruz River and Cienega Creek (see Eddy and Cooley 1983), a major tributary, is to be expected due to the complex response a fluvial system undergoes to reach a new equilibrium after crossing a geomorphic threshold (Schumm 1973, 1977). Temporary sediment storage causes a time-lag between deposition in upper and lower parts of fluvial systems, and there is also a time-lag between erosion in main trunks and in their tributaries as headward cutting occurs (Patton and Schumm 1981). The result is that a fluvial system is often simultaneously downcutting in one reach and aggrading in another. This effect is even more pronounced in watersheds where surface flows and entrenchment are discontinuous, as was the case for the historic Santa Cruz River (Betancourt and Turner 1990; Cooke and Reeves 1976). It also explains the differences between the alluvial sequences of the different reaches of the Santa Cruz River considered here. Channel cutting in one or more reaches correlated, at times, with soil formation, colluviation, or overbank deposition in other reaches, while channel filling sometimes correlated with overbank deposition elsewhere.

More recently, Waters and Haynes (2001) emphasized the general synchronicity of arroyo-cutting (channel-entrenchment) events in the Santa Cruz and San Pedro valleys of southern Arizona during the last 4000 ^{14}C years b.p. They noted that four of six regional arroyo-cutting events coincide with wet periods documented by other types of paleoenvironmental records, and inferred that these wet intervals are related to the El Niño-Southern Oscillation (ENSO) pattern. Similarly, they suggested that the apparent hiatus in arroyo-cutting cycles between the early and late Holocene is due to a lower intensity and frequency of ENSO events during the middle Holocene (see Fontugne et al. 1999; Keefer et al. 1998; Rodbell et al. 1999). In their broader interpretation, all the synchronous arroyo-cutting events during the late Holocene are the result of dry-wet climatic cycles (Waters and Haynes 2001). In each case, a preceding period of dry conditions lowered water tables and reduced the vegetation covers that protected the desert valleys from erosion. Flooding subsequently resulting from a period of increased precipitation triggered arroyo-cutting.

In the Greater Southwest, a link has been proposed between frequent El Niño conditions, increased tropical and frontal storms (and cutoff low-pressure systems), and high-magnitude floods capable of entrenching floodplains. Parker (1995) has suggested that periods of channel filling along the Santa Cruz River correlate with periods dominated by monsoonal precipitation, as monsoon storms are localized, and the floods they cause can transport sediments only short distances. In contrast, the high-magnitude, scouring floods caused by tropical and frontal storms have the necessary power to connect discontinuously entrenched reaches into a single, continuously entrenched channel (Parker 1995).

In a study of historical weather data and flood measurements spanning most of the twentieth century, Webb and Betancourt (1992) found a correlation between El Niño events and high-magnitude floods along the Santa Cruz River. Studies of paleoflood deposits across the Southwest have also shown that, over the last 5000 ^{14}C years b.p., the frequency of high-magnitude floods increased during intervals of frequent El Niño events (Ely et al. 1993). Depositional evidence of 251 paleofloods along 19 rivers in Arizona and southern Utah indicate extreme floods were most frequent between 4800 and 3600 ^{14}C years b.p., near 1000 ^{14}C years b.p., and after 500 ^{14}C years b.p., with a peak during the late 1800s and early 1900s. Extreme floods were relatively infrequent from 3600-2200 and 800-600 ^{14}C years b.p.

The hypothesis that cycles of channel downcutting in the middle Santa Cruz Valley correlate with intervals of increased frequency of El Niño conditions has been developed further by Gregory and Nials (2005). They note studies indicating that, in the Greater Southwest, El Niño conditions typically result in reduced monsoonal precipitation (Webb and Betancourt 1992) and increased precipitation from fall and winter storms (Andrade and Sellars 1988), resulting in increased streamflow and probability of floods (Cayan and Webb 1992; Ely et al. 1993). Comparing trends in atmospheric carbon isotope ratios over the last 20,000 years with an 8,000-year bristlecone pine tree-ring chronology from southeastern California, they argue that variability in El Niño frequency is related to variability in solar activity and present a detailed model of the effects on the Santa Cruz River and its floodplain (Gregory and Nials 2005).

Emerging from these studies is a general model of alluvial regimes, flood frequencies, and downcutting cycles being related to shifts between summer-dominant (monsoonal) precipitation, more balanced summer and winter precipitation, and frequent El Niño conditions. For example, the predominance of channel deposition and localized slopewash deposition in the middle Santa Cruz Valley between about 5000 and 4000 ^{14}C years b.p. may have been due to increased monsoonal rainfall during that interval, as interpreted from southern Arizona pollen data (Martin 1963; see also Mehringer et al. 1967) and packrat midden data (Van Devender 1987, 1990).

The long interval of rapid overbank deposition and higher water tables, starting between 4000 and 3700 ^{14}C years b.p., and lasting until about 2500 ^{14}C years b.p., may represent an interval of more balanced summer-winter precipitation and increased effective moisture in southern Arizona, as indicated by higher lake levels (Waters 1989), dune stability (Waters 1986a), and plant taxa in packrat middens (Van Devender 1987, 1990). However, such correlations need to be tested with paleoenvironmental data that allow these different precipitation patterns to be distinguished. Likewise, the hypothesis that Holocene cycles of channel entrenchment in the Santa Cruz River watershed correlate with intervals of frequent El Niño conditions (Gregory and Nials 2005; Waters and Haynes 2001) needs testing through comparison of: (1) historical weather data; (2) paleoenvironmental records that can distinguish relatively wet falls and winters; and (3) the detailed alluvial chronology described here.

In summary, these various models all have some empirical support, and the timings of floodplain incisions during the Holocene have likely been determined by local geomorphic thresholds, topographic controls, and human impacts. However, the long-term trends in floodplain aggradation, channel cutting, and other alluvial processes in the Santa Cruz watershed correlate relatively well with those in other basins in the Southwest, and are probably related to long-term climate shifts (including the frequency of El Niño events and the fluctuating strength of the monsoonal pattern) and concomitant changes in vegetation, surface runoff, water table levels, and sediment supplies.

SITE LOCATIONS, SEDIMENT CONTEXTS, AND PRESERVATION CONDITIONS

Throughout prehistoric and historic times, the Santa Cruz River was the main focus of settlement in the Tucson Basin. Most of the known prehistoric sites in the basin are on Pleistocene terraces overlooking the Holocene floodplain and buried in the floodplain itself. In the A-Mountain reach, the remains of prehistoric occupations have been found in the floodplain at depths between 20 cm and 400 cm below the present ground surface. They generally correlate with buried soil horizons representing periods of relative stability of the floodplain and, to a lesser extent, with overbank deposits representing aggradation. Historic remains are generally limited to the upper 50 cm. The identified prehistoric and historic-era canals generally correlate with soil surfaces and cienega clays.

While rapid accumulation of alluvium has preserved a 4,100-year sequence of cultural remains in the A-Mountain reach, the alternate wetting and drying of sediments has accelerated oxidation of organic materials. This has led to poor preservation of pollen and uncarbonized plant parts and animal bones, thereby skewing the archaeological record toward artifacts made of unperishable materials and carbonized organic remains. It is also very likely that the multiple cycles of channel cutting during the Holocene have removed a significant portion of the archaeological record.

The possible presence of middle Holocene deposits in the A-Mountain reach (at least on the eastern side of the present channel) is important because deposits of such age are very rare throughout the Southwest (see Figure 20.4), and because it means that middle Holocene cultural remains could be preserved in some locations in this reach. If they are found, remains of this age would be highly significant because archaeological sites definitely dating between 7600 and 4900 ^{14}C years b.p. (circa 6400-3700 B.C. calibrated) have not yet been found in southern Arizona (Mabry 1998b). Any information about cultural activities during that interval characterized by generally less favorable climate and erosion of the landscape would fill a prominent gap in current knowledge of southern Arizona prehistory.

ALLUVIAL PROCESSES AND CULTURAL ACTIVITIES

The documented intervals of prehistoric occupation in the A-Mountain reach of the Santa Cruz River correlate with intervals of relatively mesic climate, a high water table, perennial soil moisture, and floodplain stability or aggradation. For humans, this set of conditions meant a reliable water supply, a high concentration of edible wild plants and game, and the right conditions for water-table farming, flood farming, and irrigated farming (Bryan 1941; Huckell 1996).

The correlation of canals with soils and cienega clays in this area suggests the ideal conditions for irrigation included a stable or slowly aggrading unentrenched floodplain and a high water table. During periods characterized by these conditions, water could be conveyed by gravity, canals silted up less rapidly (thus requiring cleaning less frequently), and canals were blown out by floods less often. In addition to diverting surface flows of the river, canals that were dug into cienega surfaces could also intercept high water tables, thereby conveying water even in seasons (or longer intervals) when there were no surface flows. While the heavy, constantly saturated, and somewhat saline cienega clays were probably not cultivated, the canals could have directed water to agricultural fields located on the coarser, better-drained sediments on the margins of cienegas.

However, the floodplain in the A-Mountain reach was probably abandoned temporarily by human groups whenever the river channel was incising. Channel entrenchment implies a lowered water table and more difficult access to a drinking supply, a decrease in wild food resources in the riparian zone, a reduced frequency and regularity of overbank floods necessary for floodwater farming, and stranding of canal intakes for irrigated agriculture. Incision cycles usually lasted a century or less, according to the dating information from the alluvial fills (Haynes and Huckell 1986). This suggests that, while floodplain entrenchment was a recurrent problem for inhabitants of this reach of the valley, conditions became favorable again after only a few generations.

Current dating information from archaeological contexts indicates generally continuous human occupation of the A-Mountain reach over the last 4,100 years, with interruptions generally being shorter than can be demonstrated with current dating techniques. The only apparent long-term break in occupation during the late Holocene was between about 3200 and 2600 ^{14}C years b.p., an interval approximately equivalent to the San Pedro phase (circa 3200-2800 calendar years B.P.), for which archaeological remains have not yet been documented in this part of the Santa Cruz floodplain. However, this gap in the archaeological record is probably only a sampling problem, and San Pedro phase cultural remains will likely be documented by future archaeological investigations in this area of the floodplain, on the older terraces above the floodplain, or on nearby Tumamoc Hill. The floodplain area immediately upstream of A-Mountain, where the subsurface barrier of bedrock forces groundwater upward, would have been one of the last oases in the middle Santa Cruz Valley during periods of dry climate. It is therefore likely that human occupation is more continuous in this location than in most other areas of the floodplain.

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