A Recalibrated Chronological Framework for Texas Archaeology–Geoarchaeology

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A RECALIBRATED CHRONOLOGICAL FRAMEWORK FOR TEXAS

ARCHAEOLOGY–GEOARCHAEOLOGY

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DEDICATION

Those who have come before whose research and insights we benefit greatly from and to those who will follow that will continue the work and correct our mistakes. This thesis is also dedicated to Freda Gibson (my first real teacher), my wife Susan (who has been my biggest supporter), and my study buddy Baxter (who we miss terribly).

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ABSTRACT

A RECALIBRATED CHRONOLOGICAL FRAMEWORK FOR TEXAS

ARCHAEOLOGY–GEOARCHAEOLOGY

By

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December 2010

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Radiocarbon assays from select archaeological-geoarchaeological research projects within Texas river basins were compiled and recalibrated using the same calibration curve (i.e., INTCAL09). Chronometric data from investigations within the Nueces, San Antonio, Colorado, Brazos, and Trinity River basins were uniformly calibrated to construct a consistent chronological framework. Once calibrated, the analogous chronometric data were then used to compare drainage basins, paleoenvironmental data, and cultural chronologies across Texas and the region. These comparisons revealed four periods (Synchronous Events I–IV) in the Holocene that occurred simultaneously within all of the examined drainage basins. Synchronous Event I dating to 8,750–8,250 cal yr BP (~6800–6300 BC), Synchronous Event II dating to 7,000–6,250 cal yr BP (~5050–4300 BC), and Synchronous Event III 5,250–5,000 cal yr BP (~3300–3050 BC) are apparent periods of instability. While Synchronous Event IV occurs at 1,000–750 cal yr BP (~AD 950–1200) represents a period of stability. These events may be attributed to previously identified widespread climatic changes and seemingly coincide with several transitions in the archaeological record.

CHAPTER 1

Introduction-Setting

This study regards the construction of a recalibrated radiocarbon baseline from select archaeological-geoarchaeological research projects in Texas. The compilation of the chronometric data was the result of an extensive archival review that focused on previous research from sites containing deep, intact alluvial stratigraphy, which encompassed the Late Pleistocene–Holocene. Subsequently, select radiocarbon assays from previous investigations were compiled and recalibrated using the same calibration curve (i.e., INTCAL09). The uniform calibration of the radiocarbon assays provided a consistent chronological framework that can be used to compare drainage basins, paleoenvironmental data, and cultural chronologies across Texas.

There are several interrelated research objectives for the current study. The primary objective is to recalibrate radiocarbon data from previous archaeological-geoarchaeological investigations within select Texas drainage basins (Figure 1.1). The recalibration of these data will provide a chronological baseline for the comparison of Texas drainage basins and cultural components contained therein. Further, this chronological baseline will enable the evaluation of the depositional histories of Texas drainage basins for characterizing the integrity of each basin at various times. This study also compares the depositional histories of the selected drainages within a basin to each other (i.e., intra-basinal) and with other drainages in Texas and the region (i.e., inter-

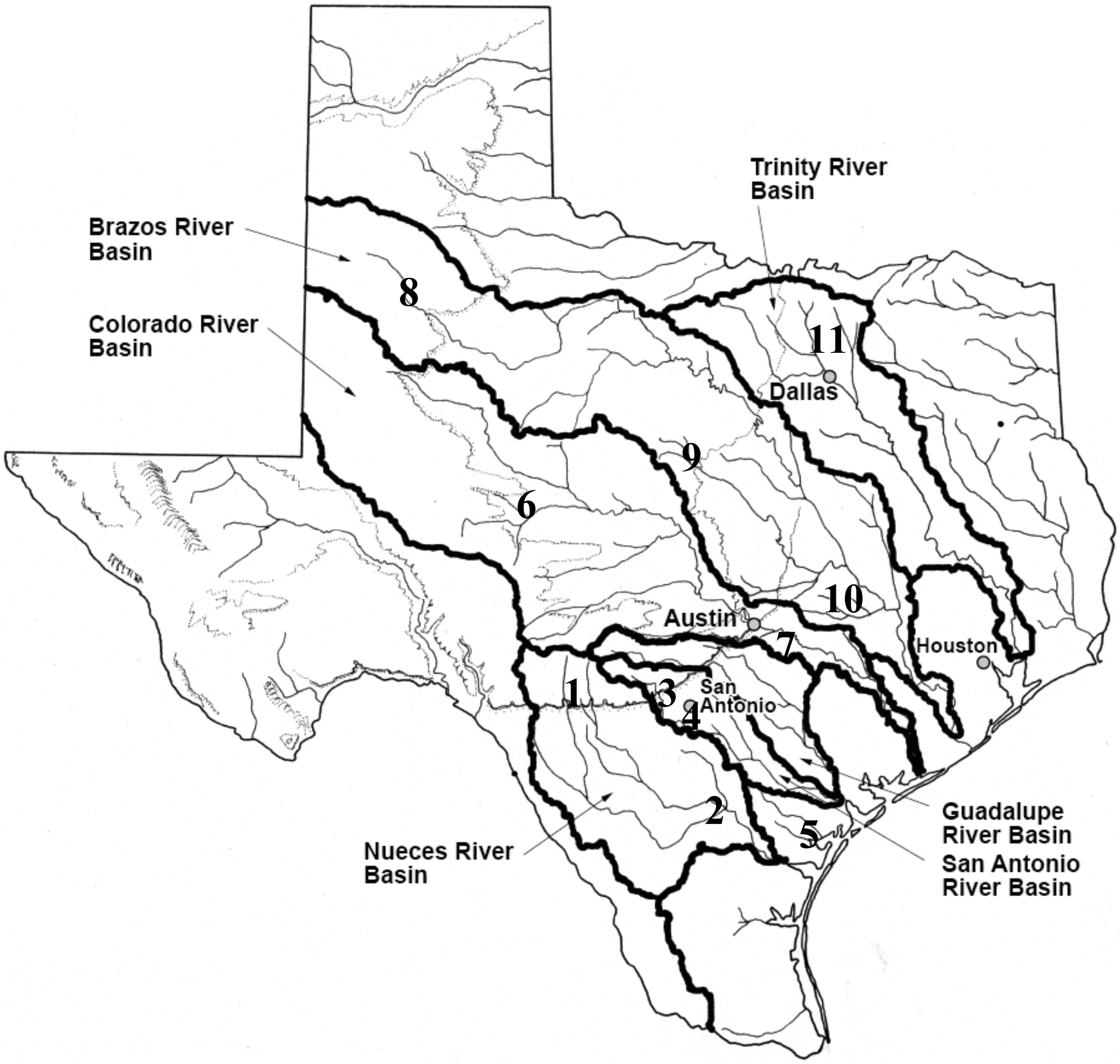


Figure 1.1 Overview of Texas River Basins with Examined Study Areas.
1) Woodrow Heard, 2) Choke Canyon Reservoir, 3) Jonas Terrace, 4) Richard Beene, 5) Copano Bay, 6) San Angelo, 7) Lower Extent Colorado River, 8) Lubbock Lake, 9) Fort Hood, 10) A&M-College Station, and 11) Upper Trinity River Basin.

basinal) in an effort to discern similarities. Observed patterns within this study are then correlated with external mechanisms (e.g., climate and eustatic effects), which may have contributed to these occurrences. Finally, the depositional patterns of the basins are compared with the archaeological record in Texas to demonstrate a correlation.

This chapter includes a review of the geology of the selected Texas drainage basins. Chapter 2 reviews of the Methods and Background for this study. Subsequent to this is a discussion of the selected drainage basins of this study, beginning with the Nueces River Basin (Chapter 3), the Guadalupe-San Antonio River basin (Chapter 4), the Colorado River basin (Chapter 5), the Brazos River basin (Chapter 6), and concludes with the Trinity River basin (Chapter 7). Each drainage basin chapter briefly reviews previous investigations conducted within the basin.

The radiocarbon datasets selected for recalibration because they satisfied three primary criteria (assays of charcoal, assays 'corrected' for isotopic fractionation, and those assays in good stratigraphic context). Additionally, selected datasets have been utilized by other researchers for characterizing the depositional and/or paleoenvironmental history of these study areas. These data from widely accepted studies were recalibrated in part to demonstrate the implications for recalibrating chronometric data. There are numerous previous investigations with chronometric data scattered within drainage basins that were not selected for recalibration. Those datasets were omitted because either they 1) did not meet the predefined criteria, 2) had been recently calibrated, 3) had a sparse chronometric dataset, or 4) a combination of these factors. Several of the recalibrated datasets within this study do suffer from some of these concerns, but were included out of necessity.

Chapter 8 consolidates and reviews the results from all of the basins and discusses the identification of geomorphic patterns and possible correlations derived from the calibrated chronological baseline. Chapter 9 summarizes the conclusions from the recalibrated basins and interpretations that developed during its course, as well as reviewing several study areas and topics for future research and investigation.

Geology

With some exceptions, the surface geology of the selected drainage basins in Texas typically cross progressively younger geological deposits as they trend toward their terminus at the Gulf of Mexico. The geology of the High Plains region, which contains the headwaters of the Colorado and Brazos River basins include erosionally softer sedimentary Tertiary and Quaternary deposits before descending into significantly older Lower Cretaceous (Colorado River basin) or Permian deposits (Brazos River basin) in North-central Texas (Spearing 1991). The sedimentary Permian-aged deposits crossed by the Brazos River basin and portions of the Colorado River basin include soft beds of shale, sandstone, and gypsum. The Trinity River basin joins these basins as they cross lower and upper Cretaceous-aged deposits of limestone, sandstone, marl, and shale (Ferring 2001; Spearing 1991; Williams 2004). The Colorado and Brazos River basins enter into the Edwards Plateau region while the Trinity River basin exits the Cretaceous-age surface geology and enters Paleocene deposits of fine grained mixed clastic including clay, silt, and sand (USGS 2010). Within the Edwards Plateau, the Brazos and Colorado River basins are joined by the headwaters of the Guadalupe-San Antonio and Nueces River basins. The southern and eastern edges of the Edwards Plateau are indicated by the Balcones escarpment formed by a fault zone (Spearing 1991). Uplift along the Balcones

Fault has subsequently caused the edges of the Edwards Plateau to erode away along waterways that form flat-topped hills with stair-stepped tiers clearly demarcating its separation from the Coastal Plains. Below the Cretaceous age geology of the Plateau, the Colorado, Brazos, Guadalupe-San Antonio, and Nueces River basins enter the broad Tertiary and Quaternary age deposits of the Coastal Plains. The nearly level Coastal Plains consist of progressively younger beds from the Tertiary and Quaternary composed of sandstone, siltstone, and mudstone, while the drainages throughout the basin largely contain Holocene age deposits of clay, silt, sand, and gravel.

The implications of the respective geology for each of the basins regard the development of their channels. Notably, Ferring (1994:150, 2001) argues that the underlying bedrock lithology influences the Trinity River basin. Specifically, the resilience of the surface geology to erosion affects the evolution of the upper basin landforms and consequently the vegetation. The limestone bedrock in the western portion of the Trinity River basin erodes into calcareous soil supporting a prairie environment while bedrock composed of noncarbonate deposits (e.g., sandstone and shale) erode into non-calcareous soils that supports a mixed forest environment (Ferring 1994:150). A corollary of this is the vegetation of a region influences the rate of erosion and sediment budget for the drainage (Figure 1.2). Ferring (1994:150) proposes that areas with non-calcareous soils are more susceptible to erosion with the implication being possibly poor conditions for the preservation of cultural deposits. Similarly, the drainage basins that cross the Edwards Plateau, in particular the Colorado River basin, cross limestone of varying resistance, thin marls, shale, and chalk (Abbott 1994:359–360).

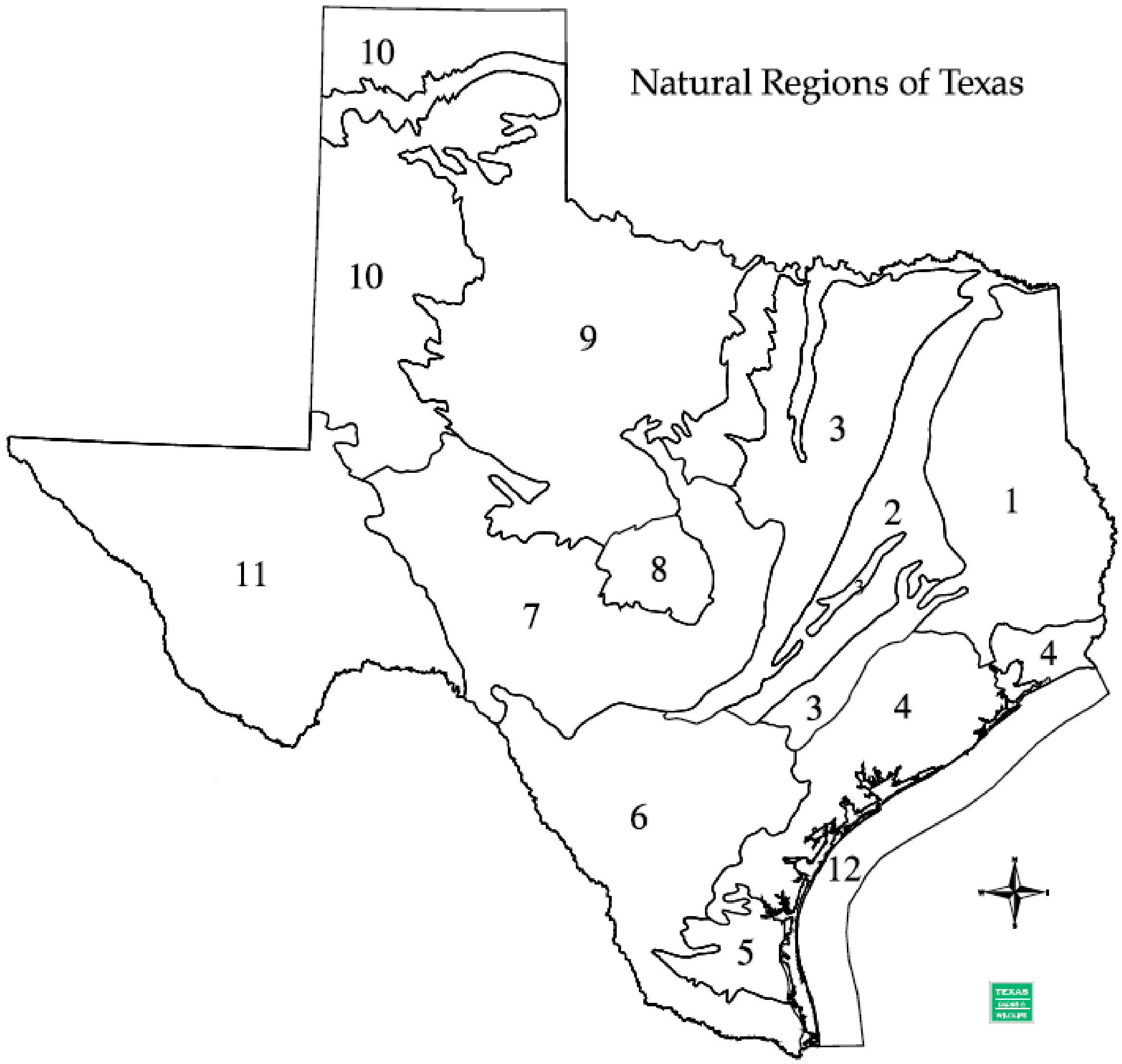


Figure 1.2 Overview of Natural Regions of Texas: 1) Piney Woods, 2) Oak Woods & Prairies, 3) Blackland Prairie, 4) Gulf Coast Prairies & Marshes, 5) Coastal Sand Plain, 6) South Texas Brush Country, 7) Edwards Plateau, 8) Llano Uplift, 9) Rolling Plains, 10) High Plains, 11) Trans Pecos, and 12) Marine Environment (adapted from TPWD 2009).

Once the drainage basins enter the Coastal Plain, the deposits become progressively younger and composed of sandstone, siltstone, and mudstone while the drainages throughout the basins largely contains localized deposits of Holocene age clay, silt, sand, and gravel. Simply put, as the drainage basins transition from the more resistant limestone to the less resilient bedrock lithology of the nearly level Coastal Plains, the drainages convert from smaller bedrock incised channels with low-moderate sinuousity to larger floodplain channels with high sinuosity (Thoms and Mandel 2007). Thus, the lower drainage basins have higher potential for well-preserved, stratigraphically isolated cultural deposits. Consequently, the quantity and integrity of alluvial deposits within a drainage largely depends upon the portion of a basin (e.g., upper, middle, or lower extent) within which it is located.

CHAPTER 2

Methods and Principles

Radiocarbon Research

Previous researchers have expertly and thoroughly addressed the history and application of radiocarbon analysis (e.g., Libby 1955; Lowe and Walker 1997; Taylor 1987, 1997, 2009). Briefly however, few discoveries have had such a profound impact on archaeology as that of the process of radiocarbon (^{14}C) dating (Ramsey 2008:249). Since radiocarbon's discovery by Willard Libby in the late 1940s, researchers could now scarcely imagine conducting archaeological research without it (Bowman 1990; Huntley 1985; Libby 1955; Taylor 1987, 1997, 2009). The introduction of radiocarbon analyses provided absolute dates for archaeological deposits in contrast to the gross approximation of relative dating from methods like stratigraphy. A chronological framework could now be constructed with a foundation accepted by almost all researchers. Further, the temporal information derived from radiocarbon analysis allowed comparisons to other sites, regions, or countries. Whereas, the relative dating supplied by stratigraphic provenience was only applicable to an immediate area or region. The ramifications of the process on the field of archaeology were substantial and widespread.

There are two analysis methods for the measurement of ^{14}C, the original conventional method and the more recent Accelerator Mass Spectrometry (AMS) (Bowman 1990:12; Lowe and Walker 1997:241). At its simplest, the conventional method consists of counting the remaining electrons of a weighted sample to determine the ^{14}C rate of emission (Bowman 1990:12). By contrast, the AMS method 'accelerates' particles in a sample in order to compare the proportion of ^{14}C atoms to the atoms identified in the ^{13}C and ^{12}C in the sample (Bowman 1990:12; Lowe and Walker 1997:241). Both methods effectively provide a similar output, which (most importantly) can be converted to a chronological measurement. In this study, a predominance of the selected samples utilized conventional methods and a distinction is made when AMS methods were used.

The principle behind radiocarbon dating is that one of the isotopes of carbon (^{14}C), a naturally occurring element in all living organisms, has a prolonged rate of decay that can be measured (Banning 2000; Bowman 1990; Christen 1994; Hedman 2007; Libby 1955). Libby determined that once an organism dies its remains stop accumulating ^{14}C and the radioactive decay of ^{14}C could be determined, which he calculated had a half-life of 5568 $\pm$ 3 0 years (Banning 2000; Bowman 1990; Libby 1955). Although, subsequent research has refined the ^{14}C half-life to be 5730 $\pm$ 30 years, laboratories continue to use Libby's calculation (e.g., 5568 $\pm$ 30 years) to prevent confusion (Banning 2000; Bowman 1990; Christen 1994; Libby 1955; Lowe and Walker 1997; Stuiver and Polach 1977). One of Libby's assumptions was that a constant amount of ^{14}C has entered the atmosphere throughout time and that this exchange has been evenly distributed (Christen 1994; Taylor 1987, 1997, 2009). However, researchers have since determined that the amount of ^{14}C has extensively fluctuated globally and throughout time. To account for these atmospheric ^{14}C variations (sometimes called the de Vries effect) among other key assumptions of Libby's determined to be incorrect, a suite of operating parameters were adopted (Stuiver and Polach 1977). Some of the parameters include researchers using the aforementioned 5568 + 30 year half-life, using A. D. 1950 as the beginning point of before present (BP), and a recognition of isotopic fractionation effects whereby ^{14}C samples must be 'normalized' to a baseline of δ ^{13}C value of -25.0$^{0}/_{00}$ (Hua 2009; Mook and Waterbolk 1985; Stuiver and Polach 1977; Taylor 1997:67–68). In short, a system of calibration must be implemented to identify the ^{14}C discrepancies in order to use them in a chronological application (Ramsey 2008:260).

Another common error with the ^{14}C dating process is the misinterpretation of the results by researchers (Banning 2000). One often-occurring mistake is equating of ^{14}C result with a calendar age by archaeological researchers. The ^{14}C result is not a calendar date, but rather, a ratio of isotopes (Bartlein et al. 1995; Blockley et al. 2007; McCormac and Baillie 1993; Lowe and Walker 1997:243; Mock and Bartlein 1995; Ramsey 2008, 2009:337; Stuiver and Suess 1966). When this disparity occurs, the researcher often rejects, misuses, and/or incorrectly reports the results, which may lead to a misinterpretation that cascades throughout their research. Considering that the use and reporting of ^{14}C results (calibrated and conventional) differ throughout North American and European journals, it is small wonder that these errors and misconceptions occur (Taylor 1997:68–69).

The incorporation of dendrochronology (tree-ring dating) with radiocarbon analysis has been the most effective calibration method, which has been an instrument of calibration has only occurred since the late 1950s (Taylor 1997). One method of this process uses the known age provided by tree rings and then processes them through radiocarbon analysis typically dating the tree rings in decadal or bidecadel year increments (Lowe and Walker 1997; Nash 1999; Taylor 1997; Walker 2005). The result of such analyses from around the world has been the refinement and extension of the calibration curve (Klein et al. 1982). Although researchers have identified these atmospheric variations, they have also determined that the extent of the discrepancies is more widespread and occasionally more pronounced than previously recognized.

This ^{14}C calibration curve is continually being supplemented and refined from collected data and since 1981 published in various journals (e.g., *Radiocarbon*) and on the internet (Banning 2000:268). One particular group, the IntCal Working Group (IWG), comprised of international scientists from a variety of disciplines, is developing an internationally agreed-upon calibration curve (Blackwell and Buck 2008:227). This international curve (IntCal) is frequently updated and presented for the use of researchers (e.g., Reimer et al. 2009). Recent calibration curves have been produced in 1998 (IntCal98), 2004 (IntCal04), and most recently in 2009 (IntCal09). Of primary relevance, with the introduction of each of these calibration curves, the radiocarbon datasets that had been previously calibrated using earlier calibration curves (e.g., IntCal98) are not fully comparable with the most recent calibration curve. Consequently, the ^{14}C data that had been previously calibrated needs 'adjustment', sometimes significantly to be correlated with more recent ^{14}C data. The most dramatic alterations to ^{14}C data regard those assays that date to roughly 7,000 ^{14}C BP or older, where calibration data previously has been more sparse.

Due to these abundant deviations of the ^{14}C fluctuations, numerous techniques have been developed for the calibration, interpretation, and presentation of the results (e.g., Acabado 2009; Blackwell et al. 2006; McCormac et al. 1993; Michael and Klein 1979; Ralph et al. 1973; Steier et al. 2001; Talma and Vogel 1993; Taylor et al. 1996;

Wohlfarth 1996). One process includes calibration software (e.g., OxCal, Bcal, and Calib), which interprets the conventional ^{14}C data with a probability distribution (Banning 2000; Ramsey 1995, 1998, 2001, 2008, 2009). In essence, the calibration software plots the ^{14}C dating results onto the calibration curve and then characterizes the probability of the interpreted outcome. There are more than a half dozen software packages, but the one used for this study is OxCal Version 4.1.6, which can incorporate Bayesian statistics into the characterization of the dating results.

Bayesian Statistics

Broadly defined, Bayesian statistics enables a researcher to incorporate data from the calibration curve with new data (e.g., ^{14}C results) as well as accounting for prior information (e.g., stratigraphy) to suggest the most probable outcome (Bayliss and Ramsey 2004; Blackwell and Buck 2008; Buck et al. 1991; Buck et al. 1992; Buck et al. 1994; Buck et al. 1996, Buck et al. 2004; Buck 2004; Christen 1994; Heaton et al. 2009; Ramsey 2009; Sharon 2001). The technique uses Baye's theorem that expresses the uncertainty of an event or set of parameters occurring before and subsequent to the results of an analysis (Buck 2004; Buck et al. 1996; Christen 1994). Put another way, the Bayesian analysis of ^{14}C calibration data considers all possibilities of the outcome (prior) with the measured data (likelihood), and then determines the probability of those results occurring (Ramsey 2009). A prior probability is inferred from relative dates (e.g., stratigraphy) and then compared with the likelihood probability that is interpreted from the absolute dates (e.g., ^{14}C dates), which culminates in the determination of the posterior probability.

When comparing multiple events simultaneously, the large number of individual combinations that are considered for each outcome (iteration) can become infinite. To aid in these analyses by calibration software, a sampling algorithm such as the Metropolis-Hastings or equivalent is typically used (Ramsey 2009). Metropolis-Hastings is an algorithm of the Markov chain Monte Carlo (MCMC) method, which randomly examines each event across a defined distribution gradually increasing the confidence of the result (Breyer 2009; Heaton et al. 2009; Ramsey 2009). Further, the implementation of MCMC allows for the inclusion of the uncertainty of multiple factors that can allow for the comparison of points as well as their deviations on the curve (Buck and Blackwell 2004:1101; Everitt 2002; Upton and Cook 2006).

In summary, the analysis and interpretation of ^{14}C results requires calibration due to extensive atmospheric ^{14}C variations that have been recognized. The calibration of the ^{14}C dates, whether individually or in multiple sets, are plotted on an internationally agreed upon calibration curve (currently IntCal09), which is continually updated and periodically published. Due to these refinements, the results of previous ^{14}C analyses, even though calibrated, require adjustment. In addition, numerous software packages are used for the calibration of the ^{14}C results that use some form of Bayesian statistics to characterize the results most accurately. For the calibration and comparison of multiple events, the Bayesian analysis commonly utilizes MCMC sampling algorithms (e.g., Gibbs Sampler and Metropolis-Hastings) for the most appropriate outcome (Ramsey 2009).

Methods

Several additional concepts and definitions warrant discussion and clarification. A brief review of relevant components pertaining to this study follows and, when appropriate, a more detailed discussion is provided in later chapters. There were three main criteria used for selecting the radiocarbon assays for this recalibration study. Namely, 1) assays of charcoal were given priority over other dated materials; 2) samples that have been previously 'corrected' for isotopic fractionation, and finally; 3) datasets composed of samples in good stratigraphic context.

Previous investigators have noted that bulk humate (both sediment and soil) tends to date inconsistently, sometimes drastically older (approximately 1,000–1,500 years) than comparable charcoal samples (Abbott 1994:375; Fowler et al. 1986; Grimm et al. 2009; Mandel et al. 2007:50; Matthews 1985; Martin and Johnson 1994; Nordt 1992:9–10; Wang et al. 1996). One reason proposed for this phenomenon is attributed to mean residence time (MRT) of the soil sample. Simply put, the MRT of the bulk humate is a weighted average of the organic components within the sample (Lowe and Walker 1997: 247–248; Schaetzl and Anderson 2005). Thus, any radiocarbon analyses of bulk humate samples may encompass a suite of organic matter that could provide an imprecise measurement beyond use. For this study, bulk humate samples from previous investigations have been avoided as much as possible. Only when charcoal samples were not available for an important allostratigraphic unit (e.g., Jackson alluvium in Fort Hood) were bulk humate samples used. Although, these data from bulk humate samples are included in summary table they have not been included in recalibration exercise unless essential.

Radiocarbon years (^{14}C) are not calendar years, but rather a measurement of remaining ^{14}C isotopes (McCormac and Baillie 1993; Lowe and Walker 1997:243; Ramsey 2009:337; Stuiver and Suess 1966; Taylor 1997:68). Thus, the ^{14}C years must be converted to a calendrical format (i.e., calibrated) (Mook and Waterbolk 1985:20; Van der Plicht and Hogg 2006:238). Regarding the issue of isotopic fractionation (i.e., $\delta\ ^{13}C$ value of $-25.0\,^{0}/_{00}$), all samples selected for this study have been adjusted for fractionation by the initial investigators and represent the 'corrected' value. Similarly, several assays reviewed and calibrated within this study were derived from marine shell. Researchers have long recognized a discrepancy between radiocarbon dates from terrestrial samples and shell from a marine environment. This difference (reservoir effect) differs by as much as 400 radiocarbon years from their terrestrial equivalent and must be corrected (Stuiver and Braziunas 1993). Those shell assays reviewed from previous investigations for this study were not corrected or undetermined to have been corrected for this reservoir effect. Likewise, the current study did not correct for the reservoir effect when calibrating shell assays. This study has also adopted the nomenclature of Nordt (1992) and the journal *American Antiquity* for distinguishing between uncalibrated radiocarbon and calibrated radiocarbon results. Specifically, in this study uncalibrated radiocarbon years are reported as '**^{14}C yr BP**' while calibrated radiocarbon samples are indicated as '**cal yr BP**'.

Regarding the third criteria of context, previous investigations that had conducted extensive radiocarbon analyses of depositional stratigraphy (e.g., allostratigraphic units) were almost exclusively selected. The term allostratigraphic unit used herein follows the definition indicated by the North American Commission on Stratigraphic Nomenclature (NACSN). Briefly, this refers to a mappable body of sedimentary rock bounded by a discontinuity (NACSN 2005:1578). In this study the use of allostratigraphic unit is appropriate because it provides a recognizable system for characterizing fluvial deposits of previous investigations reviewed here (Jacobson et al. 2003:36–37). However, the nomenclature of the initial researchers has been adopted when available. The purpose of selecting datasets in this context is to provide additional information (e.g., the prior) for Bayesian analyses and provide for the previously mentioned phase model and sequential setting to get the most probable statistical outcome. Further, the recalibration and characterization of allostratigraphic units of one study area ideally can be contrasted with the results of other allostratigraphic units in other basins. The objective of this ^{14}C recalibration is to uniformly calibrate and present the results to produce a consistent chronological framework. Once ^{14}C results are on the same baseline, they can to be used by researchers for regional comparisons and refinement of cultural chronologies. Additionally, the depositional history of select Texas drainage basins as well as the chronology of cultural activities can be reevaluated.

For the calibration and comparison of multiple events from previous investigations, the current study used the OxCal v4.1.6 program, which utilizes the MCMC Metropolis-Hastings sampling algorithm, a collaborative component of Bayesian analyses (Ramsey 2009). For specific OxCal v4.1.6 operations, the calibration curve utilized IntCal09 and the analyses were primarily conducted using default settings. However, output was set at both 68.2% (1σ) and 95.4% (2 σ) and rounded to the nearest decade for a minimum of 30,000 iterations, but frequently went over 3 million iterations. Due to the nature of the samples selected for recalibration (i.e., multiple samples) a calibration model was utilized. Specifically, these analyses focused on previous investigations with radiocarbon samples collected from recognized horizons in a stratigraphic setting. Using these criteria, analyses were conducted under the assumption that horizons at lower elevations will be older than shallower samples (i.e., Law of Superposition). When recalibrating the suites of radiocarbon assays for this study they were grouped in the stratigraphic horizon identified (when available) by the previous investigator. Consequently, the analyses were conducted in OxCal using the phase model under the Sequential setting. This setting allows for sets of radiocarbon samples to be grouped in a particular sequence (i.e., stratigraphic) and contrasted both within the group and against other groups (Ramsey 2009). Further, the Sequential setting operates under the assumption that another group (e.g., horizon) cannot be temporally contiguous or overlapping (Ramsey 2009). Ultimately, the intent of using this suite of techniques is to derive as much information as possible from previous research, compare the results with an equivalent metric, and, to substantiate or update previous interpretations when necessary.

CHAPTER 3

Synthesis of Geoarchaeological Investigations Nueces River Basin

The Nueces River basin of Texas is relatively small basin (16,800 square miles), which composes a significant portion of South-Central Texas (Durbin 1999; Weddle 2010). With the exception of its headwaters, the Nueces River basin is south of the Edwards Plateau (Figure 3.1). It crosses the South Texas Plains then the Gulf Prairies and Marshes before entering Nueces Bay in San Patricio and Nueces Counties. Upon exiting the Plateau, waterways cross the coastward-sloping Coastal Plains and become gradually more sinuous. Some of the prominent tributary drainages contributing to the roughly 315-mile-long (500 km) Nueces River include the West Nueces, Sabinal, Frio, Dry Frio, Atascosa, and Leona rivers as well as Indian, Seco, Hondo, Verde, San Miguel, and Hackberry creeks (NRA 2010; Weddle 2010).

Three drainages form the main trunks of this basin with the other tributaries dendritically draining into these waterways (Figure 3.1). The primary trunk, the Nueces River, drains the western portions of the basin beginning in Edwards County and crossing Uvalde, Zavala, Dimmit, La Salle, McMullen, Live Oak, Nueces, and San Patricio Counties. Within Live Oak County, the Nueces River converges with the other two main basin trunks, the Frio and Atascosa rivers. The Frio River, begins at a spring in Real County where it trends southward, is joined by the Sabinal River in Uvalde County, and meets its confluence with the Nueces River 250 miles (400 km) from its source

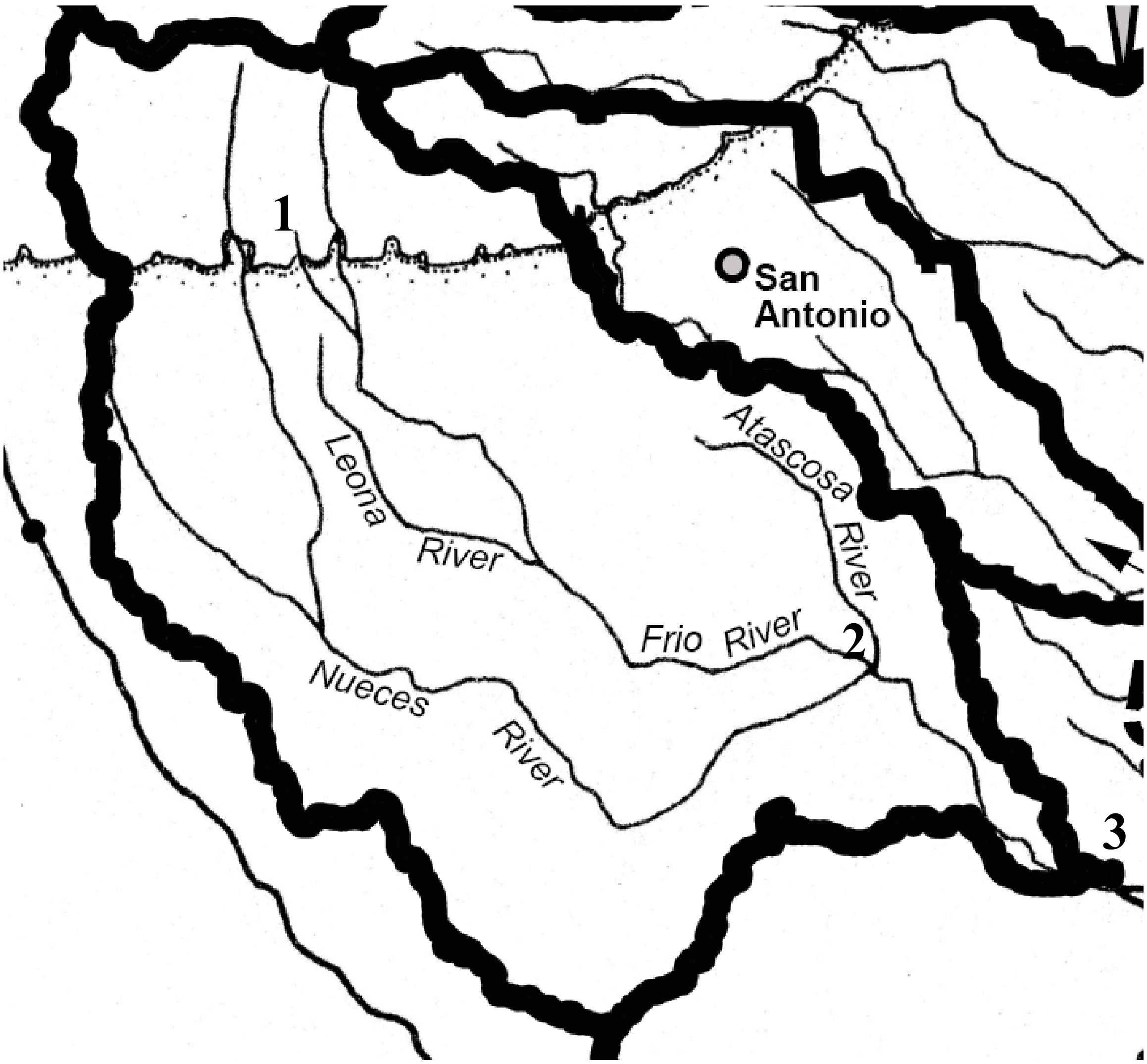


Figure 3.1 Nueces River Basin: 1) Woodrow Heard, 2) Choke Canyon Reservoir, and 3) Paine 1991 study area.

(Texas Parks and Wildlife Department 2009). The third main waterway is Atascosa River, a seasonal drainage, which begins as two minor branches (North and West Prongs) in Bexar and Medina Counties, respectively. The Atascosa River runs south-southeast along the eastern margins of the basin prior to converging with the Frio River in Live Oak County.

Previous Investigations

Archaeological investigations, particularly in the Edwards Plateau region, have been conducted within the Nueces River basin since the 1930s (Sayles 1935). However, only a select few have conducted a serious examination of the geomorphic history within the basin (Table 3.1). The investigations that incorporated geology and archaeology occurred relatively early with Mear's (1953) master thesis work along the Sabinal River. Since that time, roughly a dozen geoarchaeological investigations have been carried out, but most of these were typically assessing site integrity or had a similarly narrow focus (e.g., Brown et al. 1982; Scott and Fox 1982; Taylor and Highley 1995).

One investigation of particular relevance occurred in the early 1980s at the northern extent of the Nueces River Basin occurred at the Woodrow Heard site (41UV88) on the Dry Frio River in northern Uvalde County (Figure 3.1). Although not extensive, a component of this research involved a deliberate geoarchaeological investigation of the Dry Frio River valley around the site and included a geomorphic assessment with a series of radiocarbon analyses (Decker et al. 2000).

One of the larger, more comprehensive archaeological investigations in South Texas was undertaken in the 1970s at Choke Canyon Reservoir situated on the lower reaches of the Frio River in Live Oak and McMullen Counties (Figure 3.1).

Table 3.1 Previous Geoarchaeological Investigations in the Nueces River Basin

Drainage Extent	Drainage	Resource	Project-Site(s)	Geoarchaeologist or Researcher	Chronometric Data*
Lower	Nueces River	Johnson 1933, Price 1933, Weeks 1933, 1945	Coastal region	E. Johnson, W. Price, and A. Weeks	Relative
Upper	Sabinal River	Mear 1953, 1990,1995, 1998	Sabinal River Valley; thesis, articles	Charles Mear	Relative; some uncorrected 14c
Upper	Nueces River	Gustavson 1978	Nueces River; article	Thomas Gustavson	Relative
Lower	Frio River	Brown et al. 1982; Hall et al. 1982; Scott and Fox 1982	Choke Canyon Reservoir; 41LK31, 41LK32, 41LK67, and 41LK202; CRM report	Russell Bunker (vol. 5)	Relative; sparse 14c
Lower	Hackberry Creek-Atascosa/Frio River	Taylor and Highley 1995	Loma Sandia (41LK28); TxDOT Report	Vance T. Holliday	Relative; Uncorrected, uncalibrated 14c
Lower	Nueces River	Baskin and Cornish 1989; Cornish and Baskin 1995	Lower Nueces River sedimentation; article	F. G. Cornish and J. A. Baskin	Very sparse 14c
Lower	Nueces River	Ricklis 1988, 1993; Ricklis and Blum 1997; Ricklis and Cox 1998	McKinzie Site (41NU221), 41NU266, 41NU268, White's Point sites; article	Robert Ricklis	14c shell; Relative
Lower	Nueces River	Durbin 1999	Late quaternary geomorphic change to lower Nueces River; Dissertation	James M. Durbin	TL; OSL; Relative
Upper	Dry Frio River	Decker, Black, and Gustavson 2000	Woodrow Heard (41UV88); TxDOT Report	Thomas Gustavson	Relative; calibrated 14c
Lower	Nueces River	Simms 2005	Late quaternary coastal shelf evolution of Nueces River; Dissertation	Alexander Simms	Corrected, calibrated 14c

[shaded] indicates study selected for calibration

* TL=thermoluminescence, OSL=optically stimulated luminescence

The investigations, utilizing a broad spectrum of multi-disciplinary approaches consisted of survey, testing, and data recovery of a number of archaeological sites (Hall 2010). Despite significant research contributions, the chronometric data for these multi-year investigations was severely limited.

In the late 1980s, research was conducted regarding sedimentation of the Nueces River during the Late Quaternary (Figure 3.1). These investigations, conducted on the lower extent of the Nueces River, identified four terraces (Angelita, Fort Lipantitla, Bluntzer, and Corpus Christi) in addition to the modern floodplain (Baskin and Cornish 1989; Cornish and Baskin 1995:193). These researchers identified several allostratigraphic units that they correlated to the Holocene. These units include the Cayamon Creek Allomember 1 (CCA-1) associated with the Terminal Pleistocene/Early Holocene, Cayamon Creek Allomember 2 (CCA-2) Middle to Late Holocene, and the Cayamon Creek Allomember 3 (CCA-3) Recent (Cornish and Baskin 1995).

Beginning in the mid 1980s, investigations were conducted at the McKinzie Site (41NU221) along the Nueces River overlooking Nueces Bay (Figure 3.1). This research was compared to results from 22 other archaeological sites in similar settings at Baffin Bay, Copano Bay, Guadalupe Bay, and Lavaca Bay (Ricklis 1988, 2004; Ricklis and Blum 1997; Ricklis and Cox 1998). Situated in upland settings, the sites all had stratified shell middens that provided 80 radiocarbon assays (Ricklis and Blum 1997).

Also in the lower extent of the basin, a more recent geomorphic investigation along the Nueces River at the Gulf of Mexico was the doctoral research by Durbin (1999). The research examined the responses of the Nueces River to changes in the climate and fluctuations in sea level using new research and previous investigations

(Durbin 1999). Encompassing the last 120,000 years, a component of this research investigated the proposal that rising sea levels instigated valley aggradation while conversely dropping sea levels caused valley incision (Durbin 1999).

Geomorphic/Alluvial History

The result of these geoarchaeological investigations is a set of Late Quaternary stratigraphic records within the Nueces River basin (Figure 3.2). These are discussed geographically, beginning at the upper (northern) extent of the basin and then downstream to the lower extent of the basin to the Nueces Bay.

Upper- Dry Frio River (Woodrow Heard site)

The investigations at the Woodrow Heard site (41UV88) provided chronometric data for the Dry Frio River and the basin (Figure 3.1). This research provided thirty radiocarbon samples, predominantly composed of charcoal (n=23) and fourteen of these samples, including two derived from humate, were used to establish a geomorphic chronology of the valley (Gustavson 2000:114–123).

The geoarchaeological analysis at Woodrow Heard identified two stratigraphic units (Units I and II) composing the Dry Frio River terrace (Decker et al. 2000:114–117). The base of Unit I was not observed during investigations, but the observed stratigraphy consisted of a series of fining upward deposits beginning with gravels (Figure 3.3). The chronometric data from Unit I indicated deposition prior to 8,000 ^{14}C yr BP (Decker et al. 2000:117). Subsequent to this, but prior to roughly 6,400 ^{14}C yr BP, the drainage migrated laterally and began to deposit Unit II (Decker et al. 2000:117). In addition, a disconformity separates the two stratigraphic units, suggesting a period of erosion. Unit II consists of four internal deposits (Units IIa–IId) from oldest to youngest, respectively

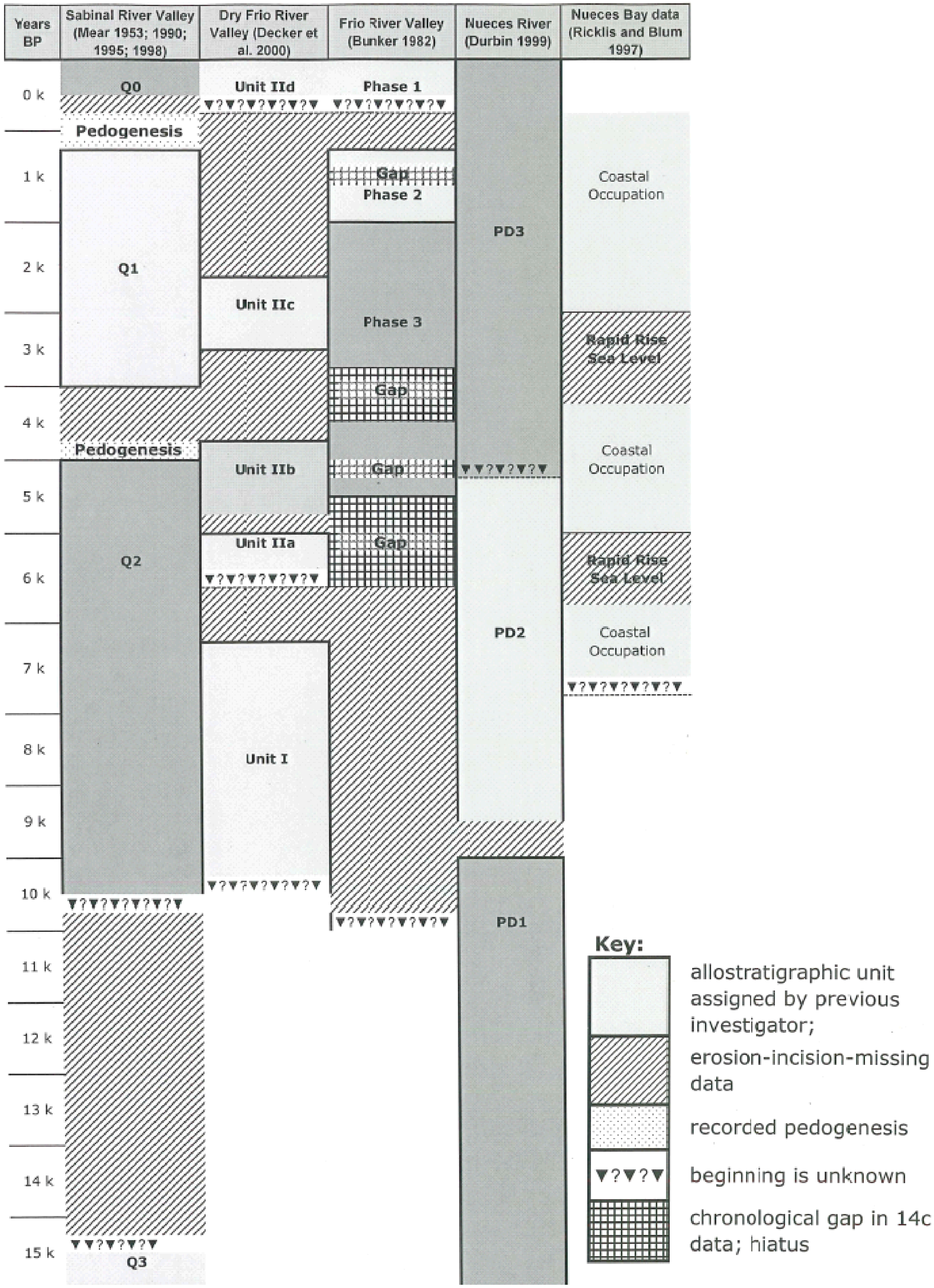


Figure 3.2 Initial Depositional History Nueces River Basin.

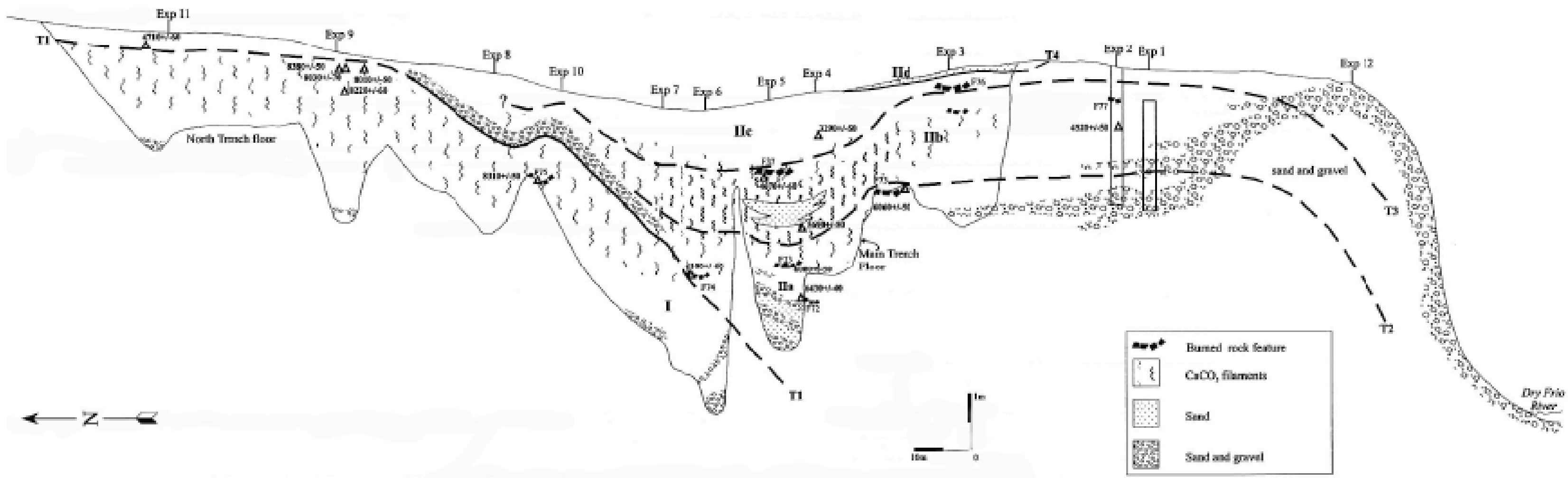


Figure 3.3 Profile of Woodrow Heard Stratigraphy (adapted from Decker et al. 2000: Figure 54).

(Figure 3.2). Each of these units was recognized by slight differences in parent material. The radiocarbon data indicate that Unit IIa was deposited between 6,400–6,000 ^{14}C yr BP, Unit IIb was deposited between 5,650–4,710 ^{14}C yr BP, and Unit IIc was deposited sometime after 3,270 ^{14}C yr BP (Decker et al. 2000:117–124). No chronometric data was available for Unit IId.

Lower- Choke Canyon

The Choke Canyon project in Live Oak and McMullen Counties was one of the largest projects conducted within the basin. Unfortunately, the chronometric data was severely limited. During Phase I investigations at the Possum Hollow Site (41LK201), over 70 radiocarbon samples were collected, but only seven were processed (Highley 1986). Similarly, on the Gates-Rowell Site (41LK31/32), only three radiocarbon samples were measured (Scott and Fox 1982:34). In contrast, the Phase II investigations of Choke Canyon Reservoir faired better chronometrically. Forty-three (MASCA corrected) radiocarbon samples (wood charcoal) collected from seven prehistoric sites were submitted for analyses (Hall et al. 1986).

Several notable results from the Choke Canyon project stand out. The first is that there were several gaps in the radiocarbon dates. The most prominent gaps occurred between 5,780–4,790 ^{14}C yr BP, 4,610–4,130 ^{14}C yr BP, 3,810–3,360 ^{14}C yr BP, and 1,800–1,520 ^{14}C yr BP (Hall et al. 1986:585–588). The researchers attributed the gaps to possible sampling bias, preservation, human settlement pattern discontinuities, or a combination of these factors (Hall et al. 1986:587). Regarding the chronological assessment of the Frio River valley stratigraphy, the researchers identified that this was an area needing future research (Hall et al. 1986:590). Even though the Choke Canyon investigations comprised the largest group of radiocarbon assays in Southern Texas and a geomorphic study was undertaken (i.e., Bunker 1982), radiocarbon dating of the depositional history of the Dry Frio River was not a research focus.

Bunker (1982) did recognize four terraces (1–4) in the Frio River Valley encompassing modern to Pleistocene in age (Figure 3.2). Other, older, terraces were observed in the valley, but these were characterized as discontinuous and isolated (Bunker 1982:499). No chronometric data was indicated for Terrace 4, but Bunker (1982:501) infers that it is Pleistocene in age. The third terrace (Terrace 3), containing most of the Choke Canyon Reservoir archaeological sites, began construction sometime before 5,330 ^{14}C yr BP and was characterized by extensive lateral migration eroding older deposits and bearing a coarse bedload until roughly 2,280 ^{14}C yr BP (Bunker 1982:514–515). Sometime after 2,280 ^{14}C yr BP, the Frio River straightened, incised and began construction of the second terrace. Terrace 2 was described as having a decrease in overbank flooding episodes with more stability (Bunker 1982:515). No chronometric data were available for determining the end of Terrace 2 construction and beginning of Terrace 1. However, Bunker (1982:511) suggests that sometime after 2,000 ^{14}C yr BP, the Frio River incised isolating Terrace 2 and forming the modern floodplain (Terrace 1).

Near the coast, Durbin (1999) identified Pleistocene Deweyville allostratigraphic units and Holocene Post-Deweyville (PD) allostratigraphic units (Figure 3.2). The Pleistocene Deweyville units consisted of High Deweyville (HD), Middle Deweyville (MD), and Low Deweyville (LD) and were dated using Thermoluminescence (TL) and Optically Stimulated Luminescence (OSL) methods. The more recent Post-Deweyville

(PD) unit was recognized as Terminal Pleistocene/Early Holocene (PD1), Middle to Late Holocene (PD2), and Recent (PD3) (Durbin 1995:119– 131). Durbin (1999:124) did correlate PD1 to the Cayamon Creek Allomember 1 (CCA-1) identified by Cornish and Baskin (1995). Similarly, units PD2 and PD3 correlate with CCA-2 and CCA-3, respectively. Unfortunately, the chronometric data for the Holocene PD units was limited to two OSL dates from Durbin's study (1999:118–124) and a single radiocarbon sample from another investigation by Cornish and Baskin (1995).

Durbin (1999) concluded that climate and sea level (eustatic) fluctuations affect valley deposits. However, sea level affects were not as pronounced, possibly to less than 40–100 km from the coast, as previous researchers had proposed (Durbin 1999:149–150; Etheridge et al. 1998). Further, the Pleistocene Deweyville units were deposited under cooler and moister conditions than the Holocene when sea levels were lower. Consequently, the Deweyville units had elevated flow regimes producing larger meanders and coarser bed loads with each unit incising into previous, units resulting in stair-stepped terraces (Durbin 1999:180–183). In contrast, the Terminal Pleistocene to Holocene PD units were constructed under the transition to progressively more arid and warmer climates and rising sea levels. These conditions decreased the flow regime and increased the amounts of sediment contribution through erosion causing gradual vertical aggradation with each unit covering the preceding one (Durbin 1999:180–183). Thus, the stratigraphy of the PD units is well-defined allostratigraphic units (Durbin 1999:182–183). Unfortunately, due to the paucity of chronometric data for the PD units, the chronology of these units is poorly defined.

Near to Durbin's research were the investigations conducted in Nueces Bay by Ricklis (2004) examining shell middens on upland sites overlooking coastal estuaries. Among several important observations, this work is helpful to correlate sea level rise with prehistoric occupation along the coast (Ricklis 2004; Ricklis and Blum 1997; Ricklis and Cox 1998). Two occupation hiatuses were observed between 6,800–5,900 ^{14}C yr BP and 4,200–3,000 ^{14}C yr BP and correspond to higher sea levels (Ricklis 2004:175–177; Ricklis and Blum 1997:299–300).

Calibration Results

For a variety of reasons, only the suite of assays from the Woodrow Heard site at the northern extent of the basin met this study's calibration criteria (e.g., stratigraphic control and δ ^{13}C corrected). Although the chronometric data from Ricklis' (2004) investigations do not meet the criteria for this study, his dates have been recalibrated due to its broad implications for the Nueces River basin and the coast in general. Despite the limited dataset, the calibration of select radiocarbon samples from the Woodrow Heard site and Ricklis' research proved beneficial and informative (Table 3.2). This is particularly true of the Woodrow Heard assays. Specifically, the stratigraphic history of the Dry Frio River may, in actuality, be more reflective of basin changes affected by climate.

The calibration of Unit I at the Woodrow Heard site revealed that this horizon was constructed prior to 9,480 cal yr BP and ended after 8,810 cal yr BP. Following the construction of Unit I an apparent period of lateral migration southward occurred between 8,810–7,420 cal yr BP when the oldest date of Unit IIa occurs. Beginning prior to 7,420 cal yr BP, Unit IIa was deposited until after 6,880 cal yr BP.

Table 3.2 Radiocarbon Data from Nueces River Basin

Locality	Sample#	13c Adjusted 14c yr BP	Dev +/-	Depth (m)	δ 13 c	Material sampled	Initial 68.2%	Initial 95.4%	IntCal09 68.2%	IntCal09 95.4%
Upper Extent of Nueces River basin										
Dry Frio River Woodrow Heard-Geological Unit I										
Area A; Near Feat 14, Level 10	CAMS-14500	8400	50		-26.1	Indeterminate wood	8430-8430		9480-9310	9510-9280
Area D; Feature 75	Beta-112979	8330	50		-25.8	Indeterminate	8360-8260		9430-9280	9470-9140
Area A; S6/W2, Level 12	CAMS-14501	8250	60		-26.9	Indeterminate wood	8280-8160		9380-9120	9410-9030
Area A; S6/W2, Level 8	CAMS-9057	***8030*****	***70***		-26.5	Sotol/yucca leaf base	9000-7960		9030-8790	9130-8660
Area A; S6/W0 Level 10	CAMS-14496	8010	50		-25.2	Live Oak wood type	8060-7960		9010-8810	9030-8720
Dry Frio River Woodrow Heard-Geological Unit IIa										
Area D; Feature 72	Beta-112976	6430	40		-25.2	Indeterminate	6480-6380		7420-7310	7430-7270
Area D; Feature 74	Beta-112978	6110	60		-25.7	Indeterminate	6160-6040		7160-6910	7170-6850
Area D; Feature 73	Beta-112977	6090	50		-25.5	Indeterminate	6130-6030		7150-6890	7160-6850
Area D; Feature 71	Beta-112974	6080	50		-25.9	Live Oak wood	6110-6010		7150-6880	7160-6800
Dry Frio River Woodrow Heard-Geological Unit IIb										
Area D; between Features 37 and 73	Beta-112981	5650	50		-22.6	Humate	5740-5640		6480-6320	6530-6300
Area A; near Feature 18	CAMS-9054	***4710*****	***60***		*	Juniper wood	4770-4650		5580-5320	5590-5310
Area D; Feature 49	CAMS-9063	***4670*****	***60***		-22.1	Sotol/yucca leaf base	4730-4610		5470-5310	5590-5300
Area C; S74/W2 Level 9	CAMS-9060	***4520*****	***50***		*	Live Oak wood	4570-4470		5310-5080	5440-4990
Dry Frio River Woodrow Heard-Geological Unit IIc										
Area D; 60cm above Feature 37	Beta-112980	3270	50		-23.8	Humate	3340-3240		3570-3440	3630-3390
Middle Extent Nueces River basin										

Table 3.2 Radiocarbon Data from Nueces River Basin

Frio River Choke Canyon Radiocarbon Phase II assays-Horizon 4										
41LK51 N998 E982	TX-4690	6360	90	98.4-98.3		wood	7380-7060		7420-7160	7440-7000
41LK51 N998 E982	TX-4691	5860	80	98.4-98.3		wood	6400		6780-6560	6890-6480
41LK201 N500 E996	TX-4673	2520	70	97.75-97.65		wood	2670-2610		2760-2610	2780-2500
41LK201 N500 E996-997	TX-4672	2710	60	97.85-97.75		wood	2790-2770		2860-2750	2950-2740
Frio River Choke Canyon Radiocarbon Phase II assays-Horizon 3										
41LK201 N491 E1043	TX-4665	2450	60	97.65-97.55		wood	2430		2450-2350	2560-2330
41MC296 N1023 E986-987	TX-4669	2090	70	98.90-98.80		wood	1920-1900		2150-1950	2310-1890
41MC296 N1023 E986-987	TX-4681	1860	60	98.90-98.80		wood	1790		1870-1720	1930-1620
41MC296 N1023 E986-987	TX-4679	2020	70	99.00-98.90		wood	1920-1900		2060-1880	2160-1820
41MC296 N1023 E986-987	TX-4680	1440	80	99.00-98.80		wood	1360		1520-1300	1550-1260
Frio River Choke Canyon Radiocarbon Phase II assays-Horizon 2										
41MC29 N997 E1013	TX-4688	2320	70	99.30-99.20		wood	2360			
41MC29 N997 E1013	TX-4689	2060	80	99.30-99.20		wood	2010-1940			
41MC296 N1022-1024 E985-987	TX-4687	1110	60	99.20-99.10		wood	1040		1040-930	1150-790
41MC296 N1022-1024 E985-987	TX-4685	780	60	99.30-99.20		wood	750-730		770-670	910-650
41MC296 N1025-1027 E997-999	TX-4686	750	70	99.30-99.20		wood	720		770-650	910-560
Frio River Choke Canyon Radiocarbon Phase II assays-Horizon 1										
41MC296 N1024 E989	TX-4684	320	50	99.50-99.40		wood	440-360		460-340	490-310
41MC296 N1025-1027 E997-999	TX-4683	290	50	99.50-99.40		wood	430-340		460-350	480-300
41MC296 N1022-1023 E985-987-989	TX-4682	450	60	99.40-99.30		wood	520		490-330	520-310
41MC296 N1023-1024 E985-987	TX-4677	430	80	Surf-99.40		wood	520		480-330	510-310
41MC296 N1024 E985	TX-4678	330	60	Surf-99.40		wood	430		470-330	490-310

Table 3.2 Radiocarbon Data from Nueces River Basin

41LK201 N497-499-500 E997-998	TX-4667	360	50	99.15-99.05		wood	480-450		470-330	500-310
41LK201 N507-508 E1013	TX4668	320	60	99.20-99.10		wood	440-360		460-340	490-310
Lower Extent Nueces River basin										
Ricklis and Blum 1997 Shell midden Sea Level Dataset										
41NU281	Beta-80018	6600	60			oyster	7525-7390		7560-7430	7580-7420
41SP153	TX-7024	6550	120			scallop	7509-7299		7570-7320	7660-7250
41NU266	Beta-80015	6500	60			oyster	7395-7290		7470-7320	7560-7280
41NU266	Beta-53647	6430	50			oyster	7381-7237		7420-7320	7430-7260
41NU266	Beta-80009	6390	60			oyster	7371-7216		7420-7260	7430-7170
41NU266	Beta-80014	6380	50			oyster	7360-7215		7420-7260	7430-7170
41NU266	Beta-80007	6270	70			oyster	7220-7035		7280-7020	7420-6980
41SP153	TX-7082	6210	90			oyster	7189-7010		7250-7000	7320-6880
41SP153	Beta-57043	6110	80			oyster	7167-6857		7160-6890	7250-6750
41SP136	TX-7302	6070	110			oyster	7159-6798		7160-6780	7250-6670
41NU266	Beta-53073	5980	70			oyster	6888-6737		6910-6730	7000-6660
41NU281	Beta-80017	5050	50			Rangia flex.	5895-5730		5900-5740	5910-5660
41SP153	TX-7308	4990	70			oyster	5888-5650		5890-5640	5900-5600
41JK24	Beta-57912	4940	70			oyster	5736-5638		5740-5600	5900-5580
41NU266	Beta-53072	4900	70			oyster	5716-5589		5720-5580	5720-5580
41NU221	TX-5264	5030	90			Rangia flex.	5919-5654		5900-5660	5890-5470
41NU221	TX-5263	4850	90			Rangia flex.	5724-5474		5710-5710	5860-5320
41NU221	TX-5265	4810	90			Rangia flex.	5647-5336		5650-5330	5730-5320
41NU184	TX-5303	4790	70			Rangia flex.	5633-5336		5600-5330	5650-5320
41SP156	TX-7081	4750	90			oyster	5592-5325		5590-5320	5660-5300
41NU281	Beta-80019	4750	50			Rangia flex.	5581-5332		5590-5330	5590-5320
41SP153	TX-7083	4500	70			oyster	5298-4991		5300-5040	5440-4880
41SP15	TX-6963	4430	70			scallop	5257-4875		5280-4870	5290-4860
41NU266	Beta-53198	4430	70			Human bone	5243-4873		5280-4870	5290-4860
41SP148	TX-7307	4080	270			Charcoal	4986-4229		4960-4150	5440-3860
41NU266	Beta-80006	4380	60			Rangia flex.	5036-4863		5040-4860	5280-4840
41NU267	Beta-80013	4370	50			oyster	4986-4862		5030-4860	5270-4830
41SP153	TX-7309	4080	270			Charcoal	4962-4229		4960-4150	5440-3860
41NU268	Beta-80009	4260	70			Rangia flex.	4865-4636		4960-4640	5040-4570

Table 3.2 Radiocarbon Data from Nueces River Basin

41SP156	TX-6881	4210	70			scallop	4859-4614		4850-4620	4950-4520
41SP1534	TX-7310	4190	90			scallop	4861-4568		4850-4580	4960-4440
41SP120	TX-7311	3970	80			quahog	4533-4353		4530-4290	4810-4150
41SP177	Beta-47105	2840	60			oyster	3156-2873		3070-2860	3160-2790
41NU266	Beta-80005	2990	60			oyster	3258-3069		3320-3070	3350-2990
41CL2	UGA-6152	2611	89			oyster	2837-2611		2850-2510	2920-2360
41AS3	TX-5664	2610	60			quahog	2773-2740		2840-2540	2860-2490
41CL3	Beta-77687	2610	60			oyster	2764-2727		2840-2540	2860-2490
41NU267	Beta-80012	2580	50			oyster	2752-2716		2770-2540	2790-2480
41JK35	Beta-57915	2479	70			Rangia cun.	2736-2357		2720-2460	2730-2360
41CL3	Beta-77686	2450	60			oyster	2713-2355		2700-2360	2720-2350
41SP136	TX-7303	2230	60			oyster	2340-2155		2330-2150	2350-2060
41CL3	Beta-77685	2160	60			oyster	2303-2051		2310-2060	2330-2000
41CL74	UGA-6151	2006	86			Rangia cun.	2060-1873		2110-1870	2300-1730
41NU268	Beta-80008	1910	60			Rangia cun.	1891-1752		1930-1740	2300-1730
41CL2	UGA-6151***	1756	88			oyster	1818-1559		1810-1560	1890-1410
41CL3	Beta-77684	1810	60			oyster	1816-1626		1830-1630	1710-1410
41SP153	TX-7084	1760	70			oyster	1816-1749		1780-1560	1870-1520
41JK24	Beta-57911	1720	60			oyster	1812-1551		1700-1550	1820-1510
41SP43	TX-5891	1850	70			quahog	1873-1711		1880-1710	1950-1600
41SP43	TX-5893	1660	70			quahog	1689-1515		1700-1420	1730-1390
41SP43	TX-6062	1659	60			quahog	1682-1514		1690-1420	1710-1410
41NU266	Beta-80016	1670	50			Rangia cun.	1611-1522		1690-1520	1710-1410
41SP43	TX-5892	1580	70			scallop	1546-1395		1540-1390	1690-1320
41CL3	Beta-77683	1640	60			oyster	1569-1418		1610-1410	1700-1400
41SP149	TX-7304	1440	70			Rangia cun.	1407-1296		1400-1290	1520-1190
41SP120	TX-7313	1370	60			scallop	1338-1270		1350-1180	1390-1170
41SP120	TX-7312	1180	70			whelk	1217-974		1180-980	1270-960
41SP43	TX-523	1220	50			scallop	1235-1067		1240-1070	1280-1010
41SP43	TX-521	1220	50			scallop	1235-1067		1240-1070	1280-1010
41SP43	TX-522	1110	40			scallop	1062-970		1060-970	1170-930
41SP120	TX-6924	1160	50			oyster	1161-996		1170-980	1240-960
41SP120	TX-6926	1030	70			quahog	990-919		1060-800	1170-770
41SP120	TX-6919	1020	70			scallop	982-915		1060-790	1080-740
41SP120	TX-6925	980	70			whelk	960-793		960-790	1060-730

Table 3.2 Radiocarbon Data from Nueces River Basin

41SP120	TX-7305	910	60			scallop	926-741		920-770	940-690
41SP120	TX-7306	910	70			quahog	928-738		920-760	940-690
41RF21	TX-6127	760	130			Bison bone	790-576		900-560	930-530
41RF21	TX-6125	790	70			Bison bone	768-675		780-660	910-560

*standard value of -25.0 assumed by previous investigators

**radiocarbon date not listed on original table

***duplicate sample number in original text

The Dry Frio River again migrated southward between 6,880–6,480 cal yr BP when the oldest Unit IIb sample is indicated. Of note, this date is derived from a humate sample (Beta-112981) and may not accurately reflect the age of the genesis of Unit IIb (e.g., Grimm et al. 2009; Matthews 1985). Another reason for doubting the accuracy is comparing this date to the other Unit IIb results where the humate sample is distinctly out of sync with the others (Figure 3.4). Regardless, Unit IIb definitely was being deposited by 5,580 cal yr BP and continued until sometime after 5,080 cal yr BP when the drainage again migrated southward. The lateral migration appears to have occurred between 5,080–3,570 cal yr BP when the oldest date for Unit IIc is indicated. Unfortunately, only one sample (Beta-112980) is available for Unit IIc, which is a humate sample and none for the overlying Unit IId.

Comparing the initial Woodrow Heard radiocarbon calibration results to the recalibration of this study demonstrates some significant differences. The most apparent changes are exhibited in the older assays of the site, particularly in Unit I (Figure 3.5). The recalibration results push the ages of Unit I and Unit IIa back about 1,000 years.

To a lesser degree the age of Unit IIb has been pushed back about 750 years older than the initial calibration (Figure 3.5). Although there was a shift in the recalibration of Unit IIc, the magnitude of this shift is marginal.

The observed change from the initial Woodrow Heard calibrations to the current study is expected. Simply put, the majority of recent improvements to the radiocarbon calibration curve are applied to the older end of the curve where calibration data (i.e., dendrochronology) are sparser. Thus, most adjustments of a recalibration will typically

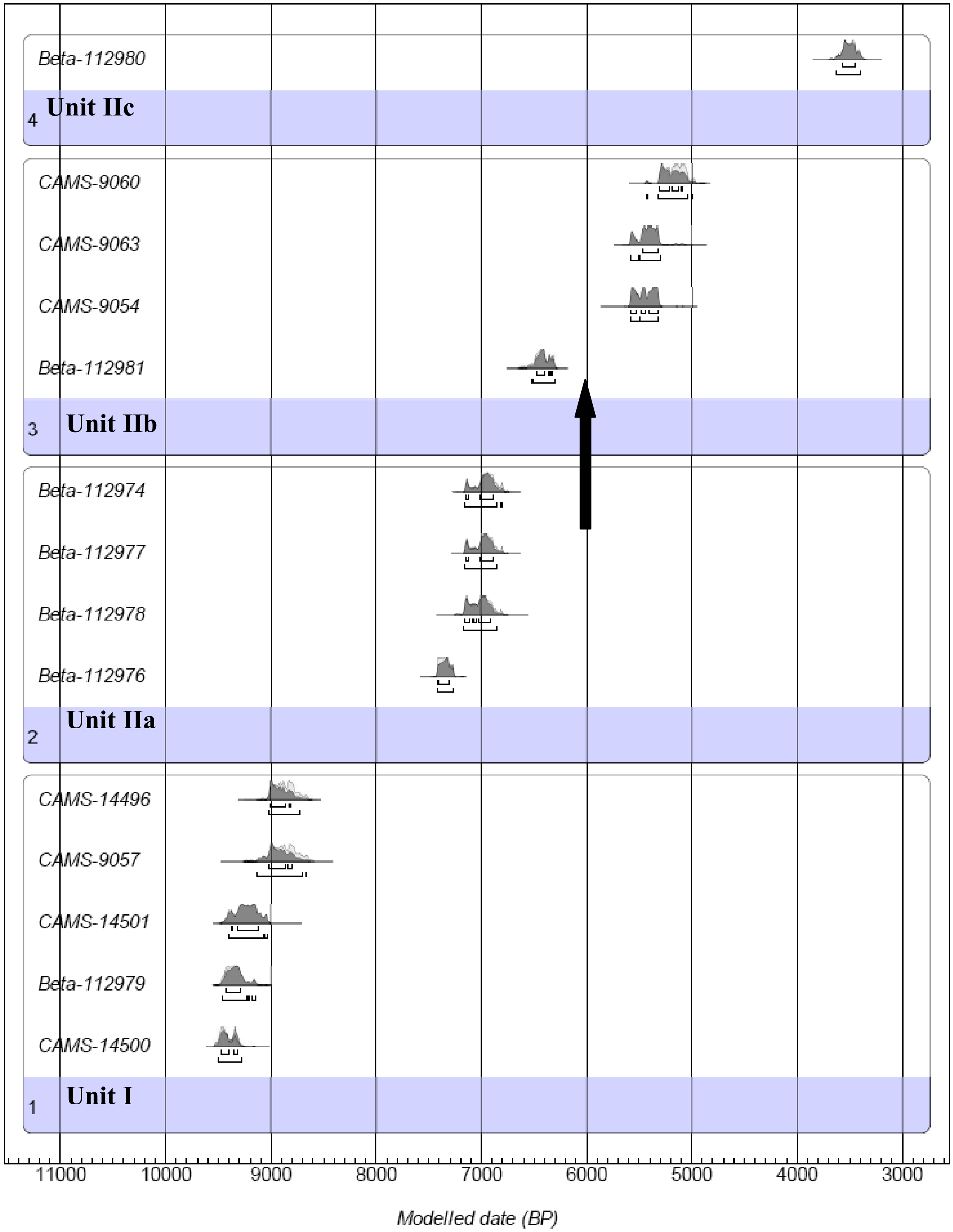


Figure 3.4 Calibration Plot of Woodrow Heard radiocarbon assays; arrow indicates anomalous assay.

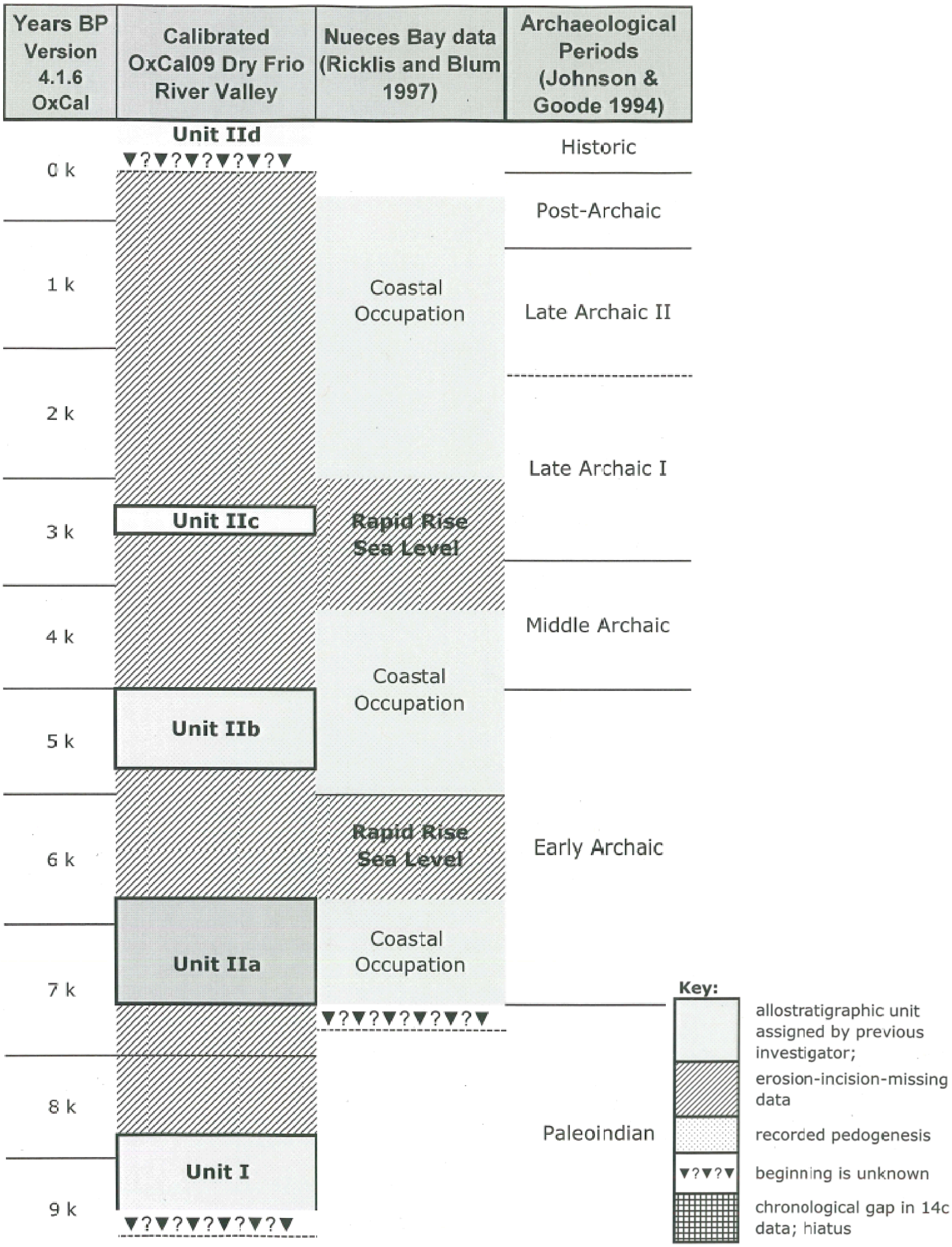


Figure 3.5 Calibrated Depositional History Nueces River Basin.

be exhibited in the older assays of a study. Such was the case of the recalibration of the Woodrow Heard radiocarbon assays.

A final observation regarding the recalibration of the Woodrow Heard assays is the use of the MCMC analysis. The implementation of MCMC is most useful when radiocarbon results in stratigraphic context overlap temporally. Due to the sizable chronological gaps between each of the stratigraphically defined Woodrow Heard geological units, the application of MCMC did not measurably refine the recalibration results. Therefore, the MCMC analysis of the Woodrow Heard assays was not informative.

As previously mentioned, the recalibration of Ricklis' dataset was also conducted for this study. These assays were reexamined in order to determine if the two occupational hiatuses identified by Ricklis would be altered using the most recent calibration data. The cultural hiatuses, identified by gaps in the radiocarbon results, were recognized to have occurred between 6,800–5,900 ^{14}C yr BP and 4,200–3,000 ^{14}C yr BP (Ricklis 2004; Ricklis and Blum 1997; Ricklis and Cox 1998). These chronometric data were composed of a combination of oyster, scallop, *Rangia flex.*, Quahog, and wood charcoal from 23 coastal archaeological sites (Ricklis and Blum 1997; Table I). Interestingly, the results of the recalibration of these data are very similar to the initial calibration (Table 3.2). Although there are some slight variations between the two calibrations, there are no appreciable differences. Therefore, the timing of the previously identified occupation hiatuses and corollary rapid sea level transgressions still appears to have occurred at 6,800–5,900 ^{14}C yr BP and 4,200–3,000 ^{14}C yr BP.

The results of these recalibrated Nueces River basin study areas are examined further, contrasted with other recalibrated analyses, and correlated with extrinsic factors in Chapter 8.

CHAPTER 4

Recalibrated Geoarchaeological Framework within the Guadalupe-San Antonio River Basins

The Guadalupe and San Antonio River basins encompass a significant portion of South-Central Texas (Figure 4.1). Both basins begin in the Edwards Plateau and extend from the southern margins of the Plateau southeastward across the coastal plain before emptying into the Gulf of Mexico. The roughly 252 mile (405 km) Guadalupe River and 180 mile (290 km) San Antonio River drain a combined 10, 250 mile^2 (26,545 km^2) basin area (Donecker 2010; Smyrl 2010). The Edwards Plateau contains a complex system of interrelated aquifers, springs, and rivers. The most prominent of these is the Edwards Aquifer, a large subterranean reservoir underlying the Hill Country in which water filters through porous Lower Cretaceous limestone directly above resistant pre-Cretaceous formations (Edwards Aquifer 2009). As such, this groundwater discharge provides excellent water sources supplying springs, creeks, and rivers. In addition to the Guadalupe River, the most prominent contributors in the basin include the Comal and San Marcos rivers followed by the Blanco River, Coleto Creek, and Sandies Creek. About seven miles north of its terminus at the coastal San Antonio Bay near Tivoli, Texas, the San Antonio River empties into the Guadalupe River.

For the San Antonio River, some of the prominent drainages include the Medina River as well as Cibolo, Leon, Salado, San Pedro, Marcelinas, Culebra, Ecleto, and Medio creeks. Three drainages compose the main trunks of the San Antonio River basin

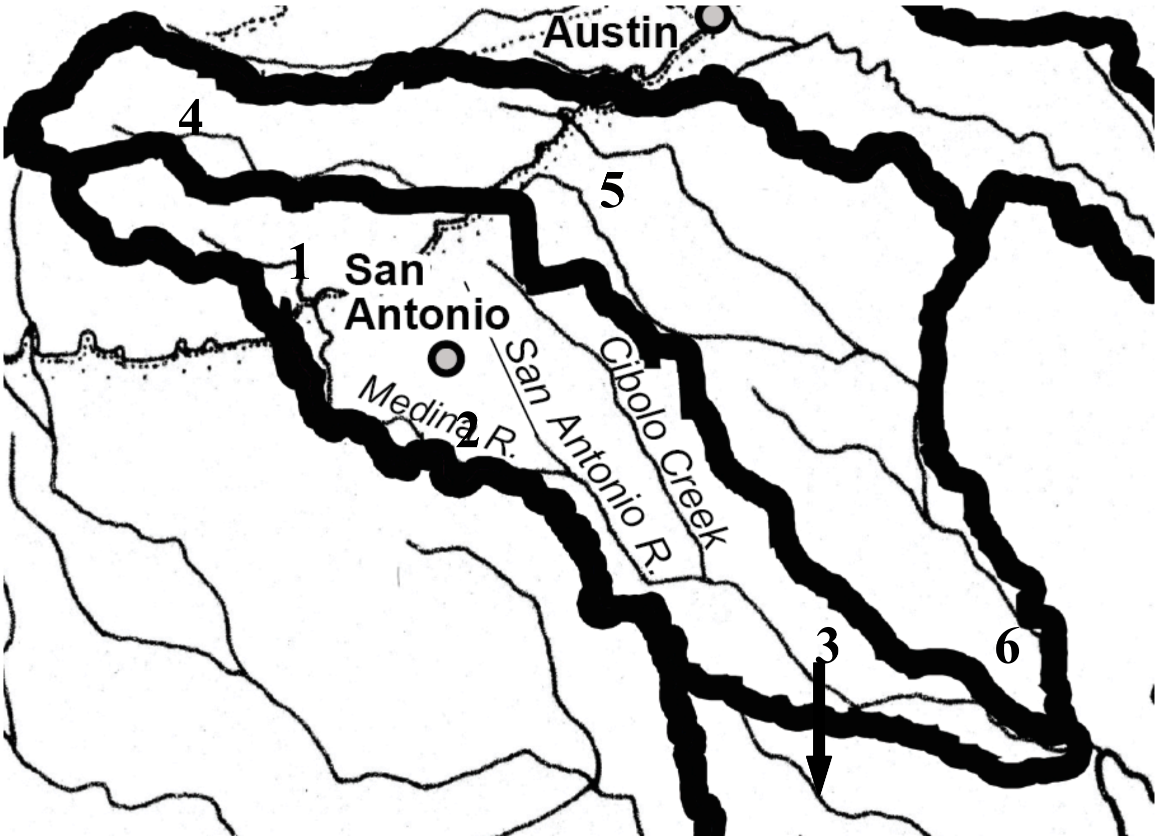


Figure 4.1 Overview of Guadalupe-San Antonio River Basins: 1) Jonas Terrace site, 2) Richard Beene site, 3) Copano Bay study area, 4) Gatlin site, 5) San Marcos study area, and 6) McNeill Ranch site.

with the other tributaries dendritically spread around and draining into one of the three trunk waterways.

The primary trunk is the San Antonio River that runs roughly down the middle of the basin through Bexar, Wilson, Karnes, Goliad, and Refugio Counties. Within Refugio County the San Antonio River converges and drains into the Guadalupe River, which in turn empties into the San Antonio Bay and then the Gulf of Mexico. The second trunk is the Medina River, a perennial waterway that begins at a spring in the Edwards Plateau county of Bandera where it trends southeastward for about 116 miles along the southern margins of the basin before draining into the San Antonio River. The third main waterway is Cibolo Creek, a seasonal drainage, which begins at a spring in Kendall County and runs south-southeast roughly 96 miles along the northern margins of the basin prior to converging with the San Antonio River in Wilson County.

Previous Investigations

Within the Guadalupe River Basin, the earliest notable investigations with a geoarchaeological component is at Berger Bluff (41GD30) occurring in the 1970s (Brown 2006). Within the San Antonio River basin, the earliest noteworthy geoarchaeological investigation occurred in the 1980s (Table 4.1). Since that time about a dozen significant geoarchaeological investigations have been carried out in the Guadalupe and San Antonio River Basins. The following review of the Guadalupe and San Antonio River basins encompasses some of the more prominent investigations associated with geomorphic examinations, beginning in the upper reaches of each basin and continuing downstream to the gulf.

Table 4.1 Previous Geoarchaeological Investigations in the Guadalupe-San Antonio River Basins

Basin Extent	Drainage	Resource	Project-Site(s)	Geoarchaeologist or Researcher	Chronometric Data
Guadalupe River Basin					
Lower	Coleto Creek	Brown 2006	Berger Bluff Site (41GD30) dissertation	K. Brown	14c; relative
Upper	Upland	Toomey 1993; Toomey et al. 1993	Hall's cave; articles and dissertation	Rickard Toomey	14c
Middle	San Marcos River	Ringstaff 2000	41HY165 Thesis	C. Ringstaff	limited 14c; relative
Middle	Blanco-San Marcos Rivers	Schroeder and Oksanen 2002	Armstrong Site (41CW54)	E. Schroeder	14c; relative
Upper	Upland	Cooke et al. 2003; Cooke 2005, Cooke et al. 2007	**Hall's cave** Edwards Plateau articles and dissertation	Mary Cooke	Relative, AMS
Lower	Guadalupe River	Aiuvalasit 2006, 2007	McNeill-Gonzales Site (41VT141) thesis and article	M. Aiuvalasit	OSL; Relative
Upper	Guadalupe River	Houk et al. 2008	Gatlin site (41KR621) CRM report	J. Abbott and C. Frederick	14c; relative
Middle	San Marcos River	Oksanen 2008	Icehouse site (41HY161) thesis	E. Oksanen	14c (AMS); relative
Middle	San Marcos River	Nickels and Bousman 2010	San Marcos Springs site (41HY160) CRM report	L. Nordt and B. Bousman	14c (AMS); relative
San Antonio-Medina River Basin					
Middle	Salado Creek	Black and McGraw 1985	Panther Springs site (41BX228) CRM report	Glen L. Evans	14c; relative
Lower	Aransas River; Copano Bay	Paine 1991; Prewitt and Paine 1987	Swan Lake site (41AS16) dissertation and article	Jefferey Paine	14c (mostly shell); relative; temporally diagnostic artifacts
Upper	South Fork San Geronimo Creek	Johnson 1995; Johnson and Goode 1994	Jonas Terrace Site (41ME29) CRM report	Leroy Johnson	14c; relative
Middle	Leon Creek	Tennis and Hard 1995	Archaeological Survey Upper Leon Creek Terraces (41BX47); CRM report	L. Nordt	Relative
Middle	Leon Creek	Tennis 1996	Upper Leon Creek Terraces (41BX47) CRM report	L. Nordt	uncorrected 14c; relative

Table 4.1 Previous Geoarchaeological Investigations in the Guadalupe-San Antonio River Basins

Middle	Medio Creek	Houk and Nickels 1997	Lackland Airforce Base (41BX1070, 41BX1076, 41BX1088, 41BX1090, 41BX1091, 41BX1102, 41BX1103, and 41BX1114) CRM report	L. Nordt	14c; relative
Middle	Salado and Panther Springs Creeks	Black, Karbula, Frederick, and Mear 1998	Wurzbach Parkway Number-6 Site (41BX947, 41BX948, 41BX996, 41BX1062, and 41BX1603) CRM report	C. Frederick and C. Mear	14c; relative
Middle	San Antonio River	Houk, Miller, Meadows, and Ringstaff 1999	Brackenridge Park 41BX323 CRM report	L. Nordt	
Middle	Cibolo Creek	Hudler 2000	Dissertation	D. Hudler	no radiocarbon
Middle	Culebra Creek	Nickels, Bousman, Leach, and Cargill 2001	Culebra Creek Site (41BX126) CRM report	L. Nordt and C. Frederick	14c; relative
Middle	San Antonio River	Thoms 2001	41BX1239 CRM report	S. Christopher Caran, David Kuehn, and Rolfe Mandel	Relative
Middle	Medina River	Nordt, Boutton, Jacob, and Mandel 2002	Richard Beene article (41BX831)	L. Nordt, T. Boutton, J. Jacob, and R. Mandel	14c; relative
Middle	Salado and Panther Springs Creeks	Weston 2003	Walker Ranch 41BX1271	Russell Greaves	Relative
Middle	Leon Creek	Collins, Hudler, and Black 2003	Pavo Real (41BX52) CRM report	Charles Johnson and Michael Collins	14c; relative
Middle	San Antonio River	Osburn and Kuehn 2006	Blue Wings SAWS 41BX1623 CRM report	David Kuehn	Relative
Middle	Medina River	Thoms and Mandel 2007	Richard Beene Report (41BX831)	R. Mandel, J. Jacob, and L. Nordt	14c
Middle	San Antonio River	Osburn, Frederick, and Ward 2007	Missions Reach 41BX254, 41BX256, 41BX1621, and 41BX1628 CRM report	C. Frederick	14c; relative
Middle	San Antonio River	Lawrence, Carpenter, Bousman, Miller, Bement, and Lowe 2007	41BX1239 CRM report	B. Bousman	14c; Relative

(shaded) indicates study selected for calibration

* TL=thermoluminescence, OSL=optically stimulated luminescence, relative (stratigraphy-temporally diagnostic artifacts)

Guadalupe River Basin

In the 2000s, archaeological excavations were conducted by SWCA at the Gatlin site (41KR621) located in the upper extent of the Guadalupe River in eastern Kerr County (Houk et al. 2008). This stratified archaeological site contained cultural activities from the Archaic to Late Prehistoric. One aspect of the site investigations of particular relevance was to characterize the Guadalupe River deposits at different locations (Abbott 2008; Frederick 2008). Specifically, the Gatlin site's location in the Edwards Plateau was contrasted with the deposition of the river off the Edwards Plateau along the margins of the Balcones Escarpment (Abbott 2008).

Although not situated in a drainage setting, Hall's Cave is significant to this study because of the extensive paleoenvironmental investigations and chronometric analyses. Hall's Cave is located at the northern extent of the Guadalupe Basin and the deposits within the Central Texas cave have been a subject of several informative studies (Cooke et al. 2003; Cooke 2005; Cooke et al. 2007; Toomey 1993).

In the late 1990s through the 2000s, a series of investigations were conducted at several archaeological sites (e.g., 41HY160, 41HY161 and 41HY165) along the San Marcos River in San Marcos, Texas. These investigations were conducted by Texas State University Archaeological Field Schools and the Center for Archaeological Studies (CAS) associated with the Aquarena Center at the confluence of Sink Creek and the San Marcos River (Nickels and Bousman 2010; Oksanen 2008; Ringstaff 2000). A component of these investigations included a geoarchaeological examination of the sites with some chronometric analyses. The research identified stratified deposits extending back to the Late Pleistocene and over 11,000 years of cultural activity.

Further downstream the San Marcos River near its confluence with the Blanco River investigations were conducted in the late 1990s at the Armstrong Site (41CW54). The Armstrong Site is situated on a relict channel of the San Marcos River and was investigated by Paul Price and Associates (Schroeder and Oksanen 2002). Work at this stratified site included a geomorphic assessment of the site's stratigraphy coupled with chronometric analyses.

At the lower extent of the Guadalupe Basin in Victoria County, investigations were conducted at the McNeill-Gonzales site (41VT141) in the early 2000s. This site is located in the Coastal Plains and situated on a terrace of the Guadalupe River with deposits extending into the Late Pleistocene (Aiuvalasit 2006, 2007). A primary component of the research consisted of a geoarchaeological analysis of the site to characterize and date the site and drainage stratigraphy.

In 1979, multi-year archaeological investigations began at the Berger Bluff site (41GD30) by the Center for Archaeological Research (CAR). This work was associated with the construction of the Coleto Creek Reservoir. This site is about 9.5 miles (15.3 km) west of Victoria and situated on a high bluff overlooking Coleto Creek a tributary of the Guadalupe River (Figure 4.1). These investigations focused on the geomorphology of the Coleto Creek valley, which included a robust chronometric sampling strategy in order to characterize the geochronology of the site and drainage (Brown 2006).

San Antonio River Basin

In the mid 1980s and early 1990s, archaeological excavations were conducted at the Jonas Terrace site (41ME29) in northeastern Medina County (Johnson 1995; Johnson and Goode 1994). The site is situated on the South Fork of the San Geronimo Creek, a tributary of the Medina River and contains deposits dating back to the early Holocene. One of the many research avenues undertaken at the site was to date the stratigraphy of the terrace and site as well as reexamine the climates of the Holocene of the eastern Edwards Plateau. Of particular relevance, the researchers compiled a dataset of chronometric data from previous Central Texas investigations and calibrated them to a comparable scale.

In 1991 and 1995, archaeological investigations were carried out for the Applewhite Reservoir project located on the Medina River, a tributary of the San Antonio River (Thoms and Mandel 2007). This project included the excavation at the Richard Beene Site (41BX831), which is located southwest of San Antonio situated on an alluvial terrace (Applewhite Terrace) of the Medina River (Figure 4.1). A significant component of these investigations focused on the geomorphology of the Medina River valley, including a robust chronometric sampling strategy to characterize the geochronology of the site and drainage (Mandel et al. 2007). As such, these investigations at this unprecedented site containing over 7 m of Pleistocene-Holocene alluvial deposits were the first serious and most extensive consideration of Late Quaternary depositional history in the San Antonio River basin.

In the late 1980s, investigations were conducted along the coast at the Swan Site (41AS16) and the Copano Bay area (Paine 1991; Prewitt and Paine 1987). The site is located on the adjacent Aransas River, technically outside of the San Antonio River basin, but the implications of the research are germane to this examination. Of particular relevance, Paine (1991) examined the valley fill near the site to determine changes in sea level and climate over the last 100,000 years. Although this research primarily used offshore bore samples for radiocarbon analyses, several assays were conducted from the Swan Site coupled with temporally diagnostic artifacts.

Geomorphic/Alluvial History

The depositional history of the San Antonio River basin is composed of a representative selection of several of the aforementioned investigations (Figure 4.2). These selections each have a reasonably extensive, stratified dataset that embodies the various extents (i.e., upper, middle, and lower) of the basins. These interpreted stratigraphic records are arranged geographically beginning at the upper (northern) extent of the basin upstream of the Balcones Escarpment. The middle extent includes the drainage sections from the Balcones Escarpment to the Gulf Prairies and Marshes region. The lower extent of the basin covers the Gulf Prairies and Marshes to the Gulf of Mexico (see Figure 1.2). The selections include the Jonas Terrace site (41ME29) for the upper basin, Richard Beene site (41BX831) for the middle, and the Copano Bay area with the Swan Lake site (41AS16) for the lower extent (Figure 4.2).

Upper Extent San Antonio River Basin

The research at Jonas Terrace was not the most geomorphically focused, but did comprehensively evaluate the site's stratigraphy, enabling a depositional comparison. One focus of research regarded levels of phosphate by horizon with the inference that low amounts of phosphate were implied with fast aggradation while high phosphate quantities inferred slow aggradation (Johnson 1995:29–30). Similarly, the presence and quantities

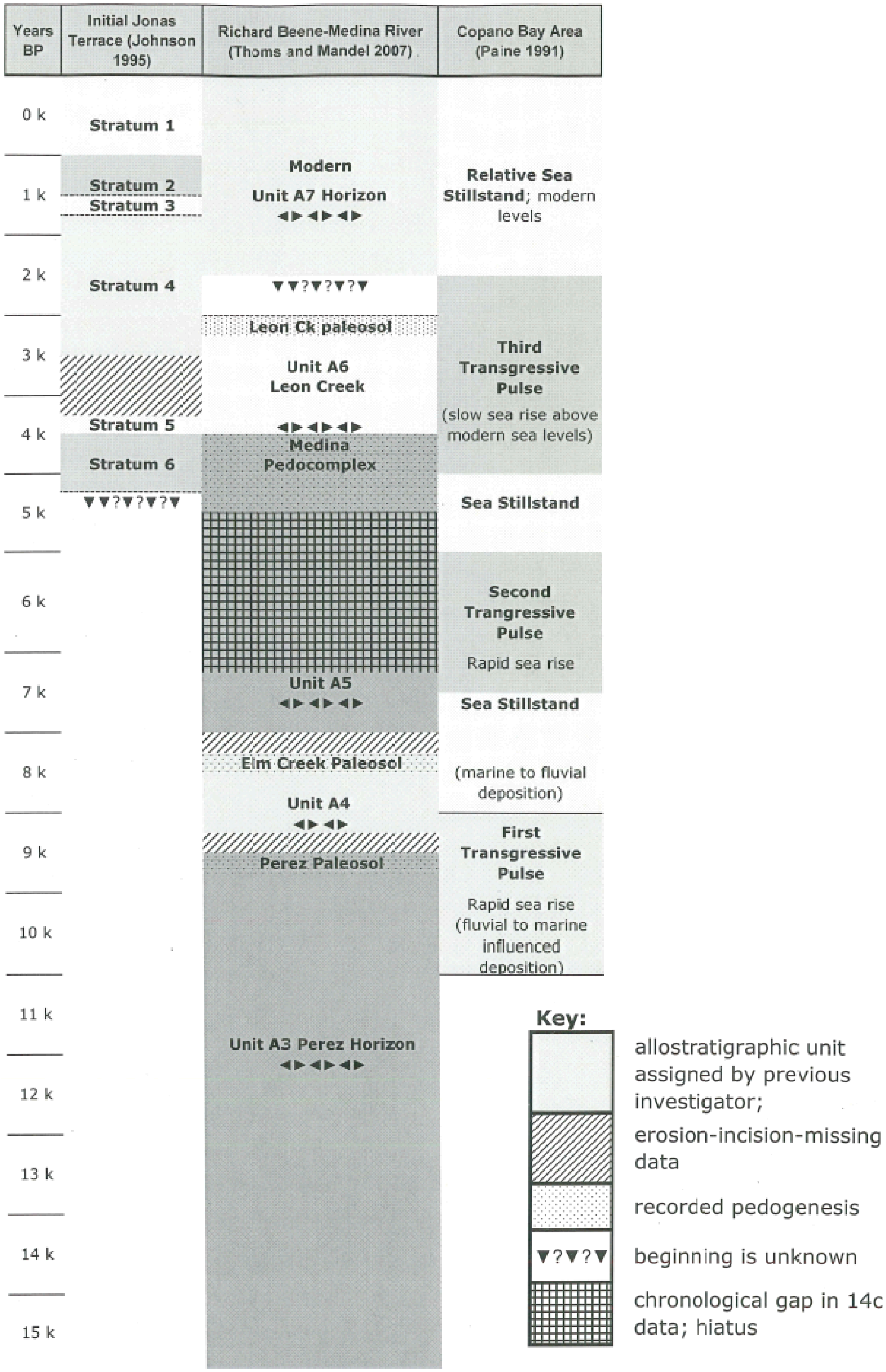


Figure 4.2 Initial Depositional History San Antonio River Basin.

of various snail species (e.g., *Rabdotus mooreanus* and *Oligyra orbiculata*) were interpreted to correspond with various environments. The researchers identified six strata (i.e., Strata 1–6) at the site all containing cultural materials (Johnson 1995:30–32). The following stratigraphic description was primarily derived from the researcher's description of Unit 23 (Figure 4.3).

The lowermost of the site deposits is Stratum 6, which rested unconformably on bedrock and characterized as alluvial sediments with fluctuating amounts of phosphate and a dominant presence of *Oligyra orbiculata* (Johnson 1995:30–32). Based on these data, Johnson (1995:30–31) interpreted Stratum 6 as having slow aggradation with vegetation cover that was deposited prior to ~5,280 cal yr BP (3330 BC) and ending sometime after ~4,770 cal yr BP (2820 BC) with an erosive event. The overlying Stratum 5 is composed of a thin horizon of colluvial deposits exhibiting low phosphate amounts and an increase in *Rabdotus mooreanus* (i.e., Prairie Rabdotus) snail species. The researchers infer a relatively quick aggradation with a more open vegetation cover for Stratum 5. This horizon has one radiocarbon date indicating an age of 4,400–4,230 cal yr BP (2450–2280 BC). The deposition of the overlying Stratum 4 occurred sometime prior to ~3,460–3,260 cal yr BP (1510–1310 BC) and continued at least until ~2,350 cal yr BP (400 BC). The *terminus post quem* for Stratum 4 is tentative in that the researchers recovered an assay (Beta-62339) from atop a burned rock midden upon the surface of Stratum 4, which dates to a more recent ~1,170 cal yr BP (AD 780). In contrast, the previously mentioned date of ~2,350 yr BP (400 BC) is derived from within Stratum 4 and is seemingly more reflective of the horizon's *terminus post quem* (Figure 4.3). Regardless, Stratum 4 is characterized as containing high phosphate amounts with a

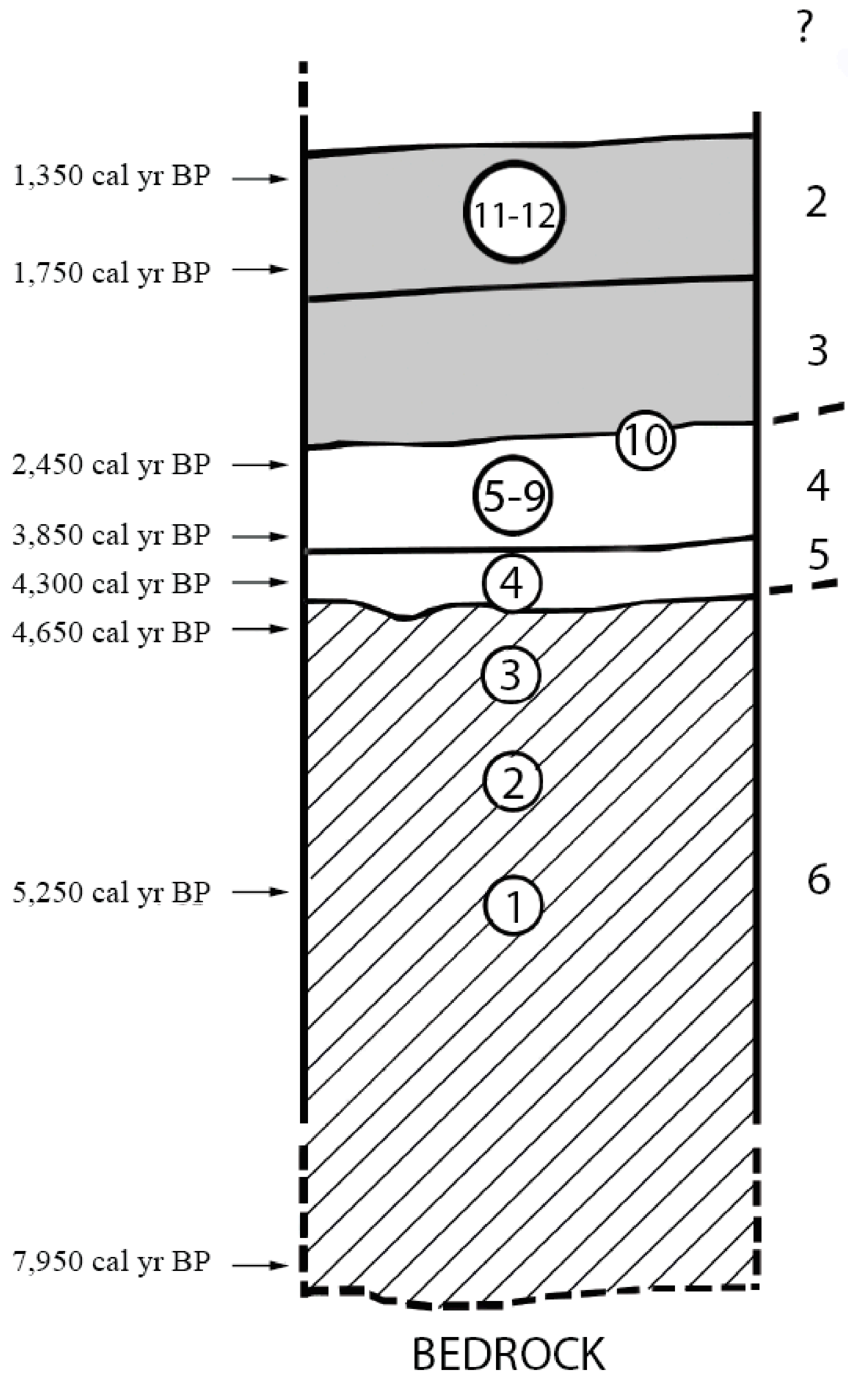


Figure 4.3 Idealized Profile of Jonas Terrace site (41ME29), strata are numbered along right side of profile while sample numbers (1–12) are within profile (adapted from Johnson and Goode 1994: Figure 3).

continued dominance of *Rabdotus mooreanus* and a notable abundance of cultural materials (Johnson 1995:31). These data imply a slower aggradation for Stratum 4 with a continuation of more open vegetation cover.

No chronometric data are available for Stratum 3; this horizon is described as exhibiting a decrease in phosphates, a replacement of *Rabdotus mooreanus* with *Oligyra orbiculata* snail species, and a noticeable decrease in cultural materials. Johnson (1995:31) interprets these data as reflecting a return of tree cover and the fast aggradation of Stratum 3.

The overlying alluvial horizon Stratum 2 began aggrading prior to 1,870 cal BP (AD 80), which notably precedes the aforementioned troublesome assay (Beta-62339) of Stratum 4. Stratum 2 is described as similar to that of the underlying Stratum 3 with low amounts of phosphate and cultural materials, but with a general drop in snail quantities (Johnson 1995:31). This horizon also may have had a relatively fast aggradation that appears to have ended sometime after 1,280 cal BP (AD 670).

The surface layer Stratum 1 is characterized as a partially disturbed horizon of colluvial-alluvial deposits with a slight increase in *Rabdotus mooreanus* and cultural materials. Stratum 1 has one radiocarbon date indicating an age of 1,060–920 cal yr BP (AD 890–1030).

The researchers propose that the environment during the time of Stratum 6 was cooler and moister than present until the approximate terminus of the horizon. The climate steadily became more arid and warmer (i.e., xeric) until peaking around 3,850 cal yr BP (1900 BC) sometime prior to the deposition of Stratum 4. From this apex, the climate became cooler and moister reaching comparable levels of today around the beginning of Stratum 3 (Johnson 1995). It bears repeating that the Stratum 4 /Stratum 3 boundary is tentative considering Stratum 3 has no chronometric data while the *terminus post quem* for Stratum 4 is the problematic assay (Beta-62339). Nevertheless, the environment is interpreted to continue to cool reaching a relative nadir around 1,950 cal yr BP (AD 0) and returning to conditions similar to today near the terminus of Stratum 2. During the deposition of Stratum 1, the climate is interpreted to have become increasingly warmer and arid reaching a peak around 750 cal yr BP (AD 1200) before becoming cooler and more mesic.

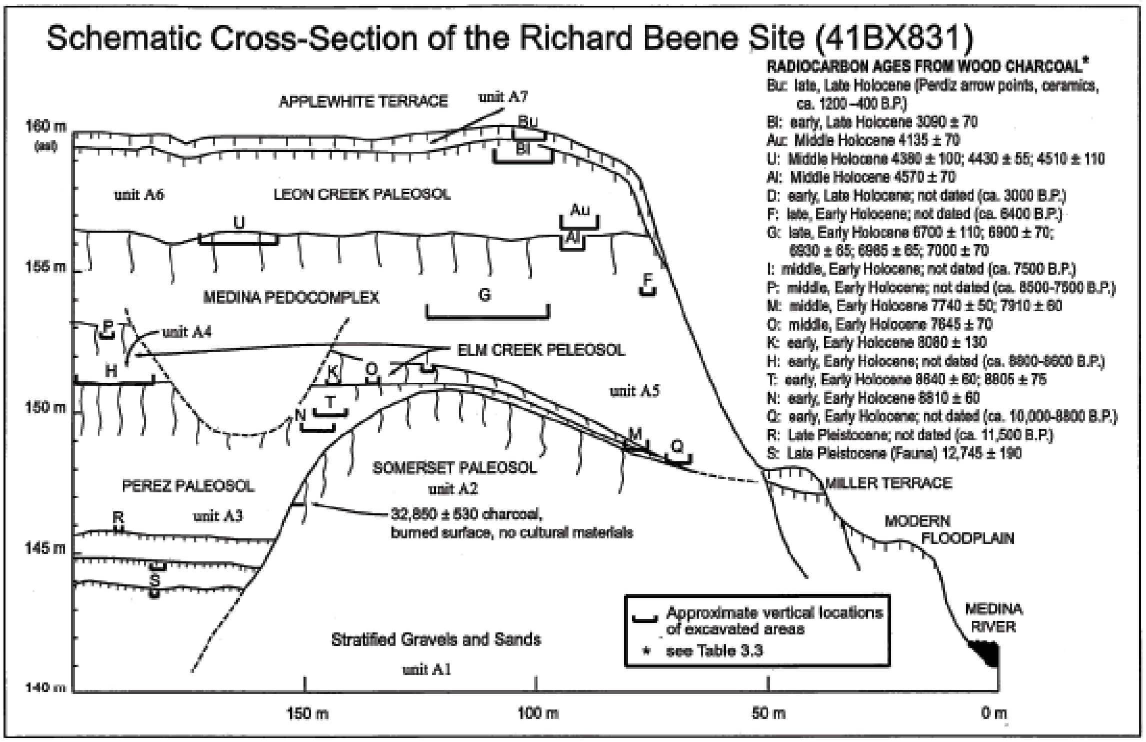
Middle Extent San Antonio River Basin

One of the most intensive geoarchaeological investigations was that conducted at the Richard Beene site in southern Bexar County (Figure 4.1). The site is situated on the right bank of the Medina River and is located about 1.2 miles (2 km) upstream from the drainage's confluence with Leon Creek. The researchers identified five terrace landforms within the Medina River valley at this location that from oldest to youngest consist of the Walsh Terrace (T_4), the Leona Terrace (T_3), the Applewhite Terrace (T_2), the Miller Terrace (T_1), and the modern floodplain (Mandel et al. 2007). Similarly, seven depositional units (Units A1–A7) were recognized primarily related to the Applewhite Terrace (T_2), which contains the Richard Beene site and was the focus of the investigations (Figure 4.4).

Mandel and others (2007:35) interpreted Unit A1 as a coarse-grained depositional unit underlying the Applewhite Terrace, which has an unknown beginning but ceased aggrading before 33,000 ^{14}C yr BP, when Unit A2 is dated. The age of Unit A2 is based upon chronometric data indicating a beginning around 33,000 ^{14}C yr BP and continuing until 20,000 ^{14}C yr BP. Next, Unit A3 extends from the Late Pleistocene into the early Holocene starting around 20,000 ^{14}C yr BP and terminated deposition about 8,600 ^{14}C yr BP. Near the upper boundary of Unit A3, deposits are characterized as cumulic in which soil pedogenesis (Perez Paleosol) formed while alluvium was gradually added. This paleosol in Unit A3 contains the first evidence of cultural activities at the site, which are interpreted to reflect Early Archaic (Angostura) occupations. Also, the upper boundary of the Perez Paleosol exhibits truncation suggesting a discontinuous surface and erosion. Subsequent to this period of erosion, Unit A4 begins deposition containing another paleosol (Elm Creek paleosol). Unit A4 and the Elm Creek Paleosol within contains a few artifacts and extends from 8,600–7,000 ^{14}C yr BP before terminating. The Elm Creek Paleosol is capped with the depositional horizon Unit A5 (Medina Horizon).

The researchers indicate that Unit A5 received the most intensive stratigraphic analyses at the site and contains cultural materials from the Early and Middle Archaic occupations (Mandel et al. 2007:50–52). Among other observations, this unit is noted to have an increase in sand deposits that continued into the following Unit A6 (Leon Creek Horizon) and that may represent an increase in fluvial energy during this time. Further, the upper boundary of Unit A5 contains at least two buried soils that have welded together and have been designated the Medina Pedocomplex. The numerous chronometric assays within the Medina Pedocomplex date the span of Unit A5 to 7,000–4,400 ^{14}C yr BP before being overlain by Unit A6.

The following stratigraphic Unit A6 is noted to have a buried soil (Leon Creek Paleosol), which exhibits evidence of two types of development (Mandel et al. 2007:52–53). Specifically, pedogenesis seems to have started during an extended period of surface



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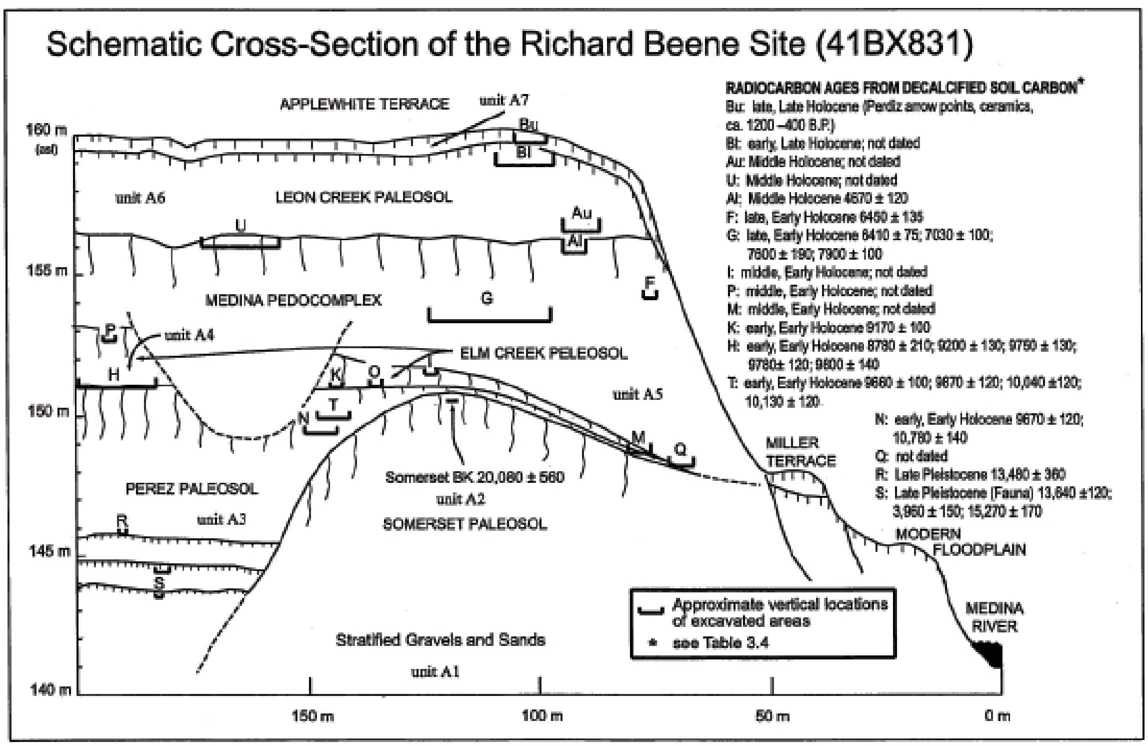


Figure 4.4 Cross-section at Richard Beene site on Medina River (adapted from Thoms and Mandel 2007: Figure 3.3).

stability in Unit A6 and again when aggradation renewed and cumulic development occurred. Although not overtly stated by the researchers, the period of stability may indicate a temporary change in environment during the interpreted span (i.e., 4,100–2,800 ^{14}C yr BP) of Unit A6.

The final stratigraphic unit studied on the Applewhite Terrace is Unit A7. This depositional unit is characterized as encompassing 2,800 ^{14}C yr BP to the present and exhibits evidence of a decrease in fluvial deposits, particularly from 1,200–400 ^{14}C yr BP. The researchers notably correlate the paucity of Late Prehistoric occupation features at the Richard Beene site to the slower deposition in Unit A7 whereby, they argue, created a palimpsest.

Lower Extent San Antonio-Nueces Coastal Basin

For the lower extent of the San Antonio Basin, research in the Copano Bay area was selected for review. Of note, the Swan site (41AS16) is located on the Aransas River, which is situated outside of the San Antonio River basin bounded on the opposite side by the Nueces River Basin (Figure 4.1). Regardless, the site and most importantly the geomorphic investigations in the Copano Bay area are adjacent to the San Antonio Basin and relevant to this study (Figure 4.5). Specifically, Paine (1991) used a variety of datasets (e.g., sea cores, trench profiles, archaeological investigations) to examine sea levels influenced by changes in the climate. Extending back over the last 100,000 years, the research dated these changes using previous research, new radiocarbon data, and temporally diagnostic artifacts (Paine 1991; Prewitt and Paine 1987).

Focusing on the Late Pleistocene-Holocene, Paine (1991) recognized two phases over the last 18,000 years. Broadly defined, the period from 18,000 to 5,000 years ago interpreted to be a transgressive phase of sea level rise followed by a relative sea level stillstand encompassing the last 5,000 years Paine (1991:57). Within these phases there are ‘pulses’ that represent transgressive sequences that alter from a dominance of fluvial, deltaic, or estuarine deposits (Paine 1991:60–61). During the Holocene, Paine (1991:61–64) recognizes three transgressive pulses of rising sea level occurring at 10,000–9,000 years ago, 7,500–6,000 years ago, and 5,000–4,000 years ago. Of note, mean sea levels (MSL) at these times were below modern levels as much as 27.5 m.

The first transgressive pulse (10,000–9,000 years ago) is interpreted to be a transition from fluvial (i.e., stream) to marine (i.e., sea) influenced deposition signifying a rapid rise in sea level. Paine (1991:61–64) indicates this pulse is followed by a transition from marine back to stream deposition at roughly 9,000–7,000 years ago suggesting a stillstand or possible drop in sea level. Subsequently, the second transgressive pulse represented by a transition from stream to marine deposition occurred around 7,500–6,000 years ago signifying another rise in sea level. The second transgressive pulse is followed by a transition from marine to stream deposition at roughly 6,000–5,000 years ago suggesting another stillstand. Around 5,000–4,000 years ago, the third transgressive pulse is suggested by a transition from stream to marine deposition interpreted to be a slow sea level rise. Interestingly, Paine (1991:170–171) interprets that sea levels at this time rose above present day levels by as much as 0.9 m beginning as early as 5,300 years ago and lasting until roughly 2,600 years ago. This third transgressive pulse ushers in a sea level stillstand, which covers the last 5,000 years.

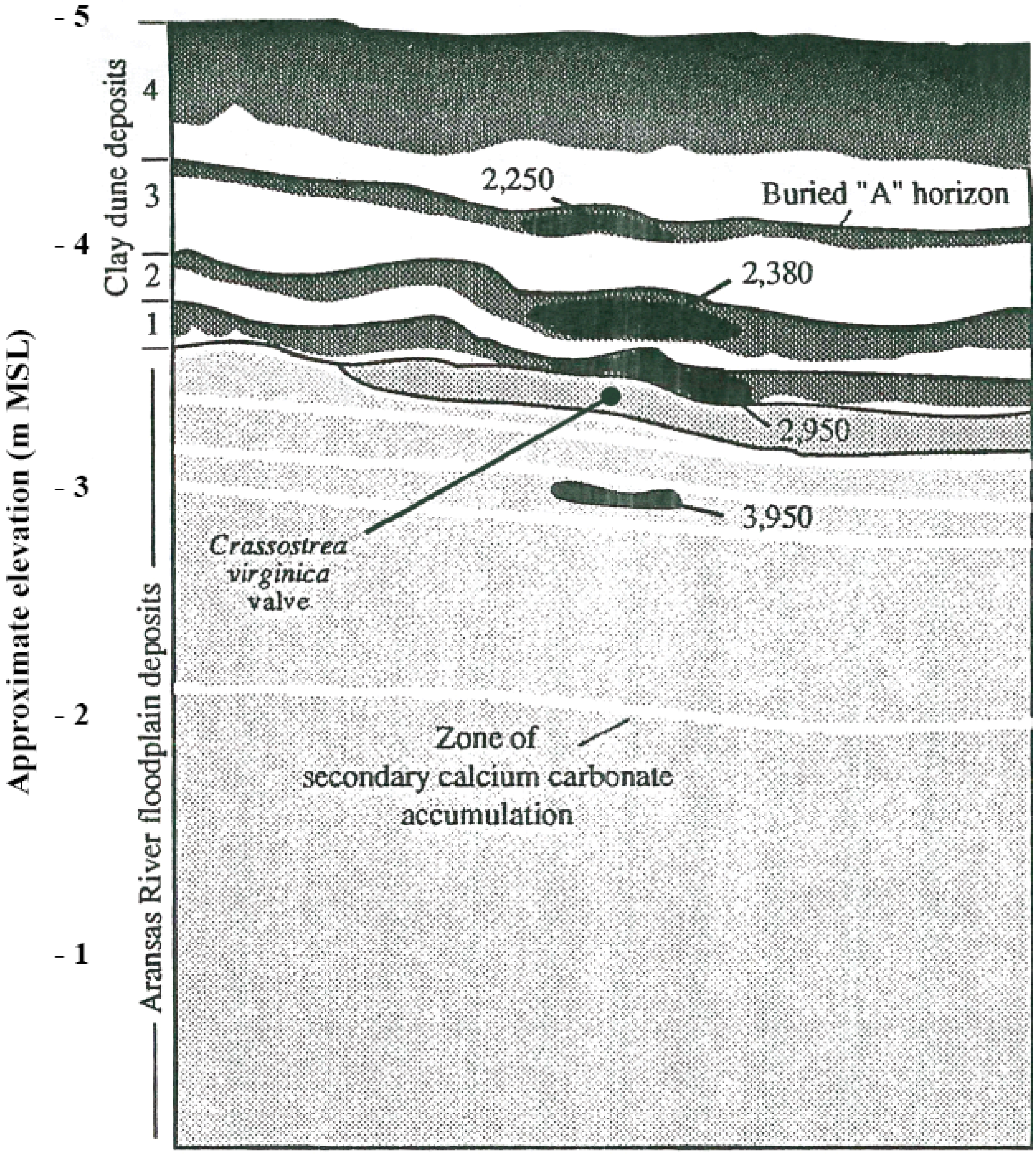


Figure 4.5 Profile of Swan Lake deposits (adapted from Paine 1991: Figure 42).

Calibration Results

The radiocarbon datasets for the previously reviewed Jonas Terrace site (41ME29), Richard Beene site (41BX831), and the Copano Bay area (e.g., 41AS16) were recalibrated (Table 4.2 and Figure 4.6). Beginning at the Jonas Terrace site on San Geronimo Creek of the San Antonio basin, the results are presented from this point in the upper limits of the basin followed by the Richard Beene results downstream and finally the chronometric data at Copano Bay area at the coast.

Upper Extent

Thirteen radiocarbon assays were selected from the Jonas Terrace assemblage, all derived from charcoal (Johnson 1995:Table 1). Generally, the recalibration of the assays did not dramatically alter the initial results (Johnson 1995). The most beneficial result of the current study was to increase the precision of the previous results. Beginning with Stratum 6 the oldest identified horizon, the recalibration indicates that deposition began sometime prior to 5,140 cal yr BP and continued subsequent to 4,680 cal yr BP. Sometime prior to 4,380 cal yr BP, the deposition of Stratum 6 ended and the overlying Stratum 5 began.

Stratum 5 is represented by one radiocarbon assay (i.e., Beta-62347) that suggests a terminated around 4,180 cal yr BP. In contrast, the overlying Stratum 4 is dated by six radiocarbon assays indicating deposition began prior to 3,420 cal yr BP and termination after 2,380 cal yr BP. As previously discussed, the *terminus post quem* for Stratum 4 is uncertain in that one of the six assays appears to be anomalous (Beta-62339), which is particularly apparent when examining the calibration plot for this dataset (Figure 4.7).

Table 4.2 Radiocarbon Data San Antonio-Medina River Basins

Locality	Sample#	13c Adjusted 14c yr BP	Dev +/-	Depth (m)	δ 13 c	Material sampled	Initial 68.2%	Initial 95.4%	IntCal09 68.2%	IntCal09 95.4%
Upper Extent San Antonio River Basin										
San Geronimo Creek (Jonas Terrace) Stratum 6-Johnson 1995 Table 1										
Date 1; Stratum 6	Beta-62340	4480	80		-25.8	Charcoal, buried stump	5280-5100, 5090-4990		5140-4890	5280-4850
Date 2; Stratum 6, Burned rock midden 25I	Beta-62343/CAM S-6503	4370	90		-26.9	Charcoal; AMS	5050-4840		5040-4860	5240-4740
Date 3; Stratum 6, Burned rock midden area 25F	Beta-62341/CAM S-6501	4180	60		-27	Charcoal; AMS	4770-4610		4840-4680	4870-4590
San Geronimo Creek (Jonas Terrace) Stratum 5-Johnson 1995 Table 1										
Date 4; Stratum 5, Burned rock midden area 25D	Beta-62347/CAM S-6506	3870	60		-27.7	Charcoal; AMS	4400-4230		4380-4180	4430-4100
San Geronimo Creek (Jonas Terrace) Stratum 4-Johnson 1995 Table 1										
Date 5; Stratum 4, Soil Column III, Burned rock midden area	Beta-62348/CAM S-6507	3140	80	0.4-0.5	-26.8	Charcoal; AMS, live oak wood	3460-3260		3420-3210	3520-3080
Date 6; Stratum 4, Soil Column IV, Burned rock midden area	Beta-62349/CAM S-6508	2600	70	0.3-0.4	-26	Charcoal; AMS, live oak wood	2780-2710, 2590-2500		2780-2540	2850-2430
Date 7; Stratum 4, South Block 3F	Beta-62338	2570	60		-25.8	Charcoal; AMS	2760-2710, 2630-2500		2740-2520	2780-2410
Date 8; Stratum 4, South Block 24H	Beta-62342/CAM S-6502	2400	70		-26.3	Charcoal; AMS	2710-2640, 2490-2340		2650-2370	2710-2310
Date 9; Stratum 4, South Block 23G	Beta-62346/CAM S-6505	2420	60		-28.3	Charcoal; AMS	2700-2640, 2490-2350		2660-2380	2710-2350
Date 10; Stratum 4, Soil Column IV, Burned rock midden area	Beta-62339/ETH-10478	1295	55	0-0.1	-26.5	Charcoal; AMS	1280-1170		1480-1330	1520-1320
San Geronimo Creek (Jonas Terrace) Stratum 2-Johnson 1995 Table 1										
Date 11; Stratum 2, Feat. 10, North Block 18C or 18D	Beta-11250	1830	110		-26.7	Charcoal	1870-1610		1380-1300	1450-1290

Table 4.2 Radiocarbon Data San Antonio-Medina River Basins

Date 12; Stratum 2, North Block 27C	Beta-26345/CAM S-6504	1430	60		-26.4	Charcoal; AMS	1360-1280		1360-1300	1410-1270
San Geronimo Creek (Jonas Terrace) Stratum 1-Johnson 1995 Table 1										
Date 13; Stratum 1, Feat. 1, South Block 87	Beta-75905/CAM S-15805	1060	70		-26.3	Charcoal	1100-920		1060-920	1170-810
Middle Extent of San Antonio River Basin										
Medina River-Richard Beene-Somerset Horizon Unit A2										
BHT 54; Somerset paleosol?	Beta-47528	32850	530	13	n/a	charcoal burned surface; AMS			37970-36650	38740-36450
Medina River-Richard Beene-Perez Horizon Unit A3										
Block S BHT 39; Upper Soil 7	Beta-47526	12745	190	15.74	n/a	charcoal, Feature 95; AMS		14270-15900	15290-14320	15890-14120
Block N; Perez paleosol	Beta-80974	8810	60	10.6	-24	charcoal		9940-9620	10070-9730	10150-9620
Block T; Perez paleosol	Beta-47527	8805	75	10.64	-25	charcoal isolated frags; AMS		9560-10150	10070-9710	10160-9590
Block T; Perez paleosol	Beta-80687	8640	60	10.55	-26	charcoal, Feature 106		9500-9890	9700-9550	9850-9530
Medina River-Richard Beene-Elm Creek Horizon Unit A4										
Block K; Elm ck paleosol?	Beta-44386	8080	130	10.65	-26	charcoal, Feature 64?		8600-9400	8920-8630	9120-8540
Block M; Elm ck paleosol?	Beta-78656	7910	60	11.68	-25.5	charcoal, Feature 80		8590-8890	8840-8620	8960-8560
Block M; Elm ck paleosol?	Beta-78657	7740	50	11.68	-25.4	charcoal, Feature 80		8410-8590	8580-8460	8610-8420
Block O; Elm ck paleosol?	Beta-47529	7645	70	9.08	n/a	charcoal, Feature 109; AMS		8220-8590	8550-8410	8590-8370
Medina River-Richard Beene-Lower Medina Horizon Unit A5										
Block G	Beta-47530	7000	70	6.45	n/a	charcoal, Feature 43		7680-7940	7910-7740	7950-7680
Block G	Beta-47523	6985	65	6.42	n/a	charcoal, tree burn		7590-7920	7900-7730	7940-7680
Block G	Beta-47525	6930	65	6.64	n/a	charcoal, Feature 44		7620-7930	7840-7690	7920-7640
Block G	Beta-47524	6900	70	6.42	n/a	charcoal, AMS Feature 30		7590-7920	7820-7670	7910-7610

Table 4.2 Radiocarbon Data San Antonio-Medina River Basins

Block G	AA-20400	6700	110	6.37	n/a	charcoal, AMS		7340-7790	7660-7480	7780-7400
Medina River-Richard Beene-Upper Medina Horizon Unit A5										
Lower Block A; top of Medina pedocomplex?	Beta-38700	4570	70	2.6	-26.3	charcoal, tree burn		4980-5470	5400-5090	5470-5000
Block U; Medina pedocomplex?	AA-20402	4510	110	3.59	n/a	charcoal		4860-5470	5330-5030	5500-4900
Block U; Medina pedocomplex?	GX-21746	4430	55	3.43	n/a	charcoal		4870-5290	5240-4970	5290-4880
Block U; Medina pedocomplex?	AA-20401	4380	100	3.43	n/a	isolated charcoal, AMS		4660-5310	5250-4940	5310-4860
Medina River- Richard Beene Leon Creek horizon Unit A6										
Block A; near base of Unit A6	Beta-43330	4135	70	2.5	-24.5	charcoal, tree burn		4450-4830	4720-4510	4810-4430
Leon ck paleosol	Beta-36702	3090	70	1.3-4	n/a	charcoal, Feature 1		3080-3470	3390-3220	3460-3100
Lower Extent										
Paine 1991; Table 5 Copano Bay-Egery Island MSA-1										
MSA-1:217, Egery Island	TX-6061	3950	100	2.17		Humate; floodplain	4529-4279		4500-4180	4700-4020
MSA-1:157, Egery Island	TX-6060	2950	60	1.57		humate; clay dune	3215-3004		3230-3020	3320-2950
MSA-1:133, Egery Island	TX-6059	2380	70	1.33		humate; clay dune	2701-2343		2670-2400	2710-2340
MSA-1:82, Egery Island	TX-6058	2250	70	0.82		humate; clay dune	2345-2152		2320-2150	2360-2060
Paine 1991; Table 5 Copano Bay-Egery Island MSA-5 Location										
MSA-5:33, Egery Island	TX-6103	4630	60	0.33		Chione shell	5451-5295		5466-5300	5581-5064
MSA-5:33, Egery Island	TX-6102	4580	90	0.33		mixed shell	5300-5055		5450-5050	5580-4970
*standard value of -25.0 assumed by previous investigators										
**radiocarbon date not listed on original table										
***duplicate sample number in original text										

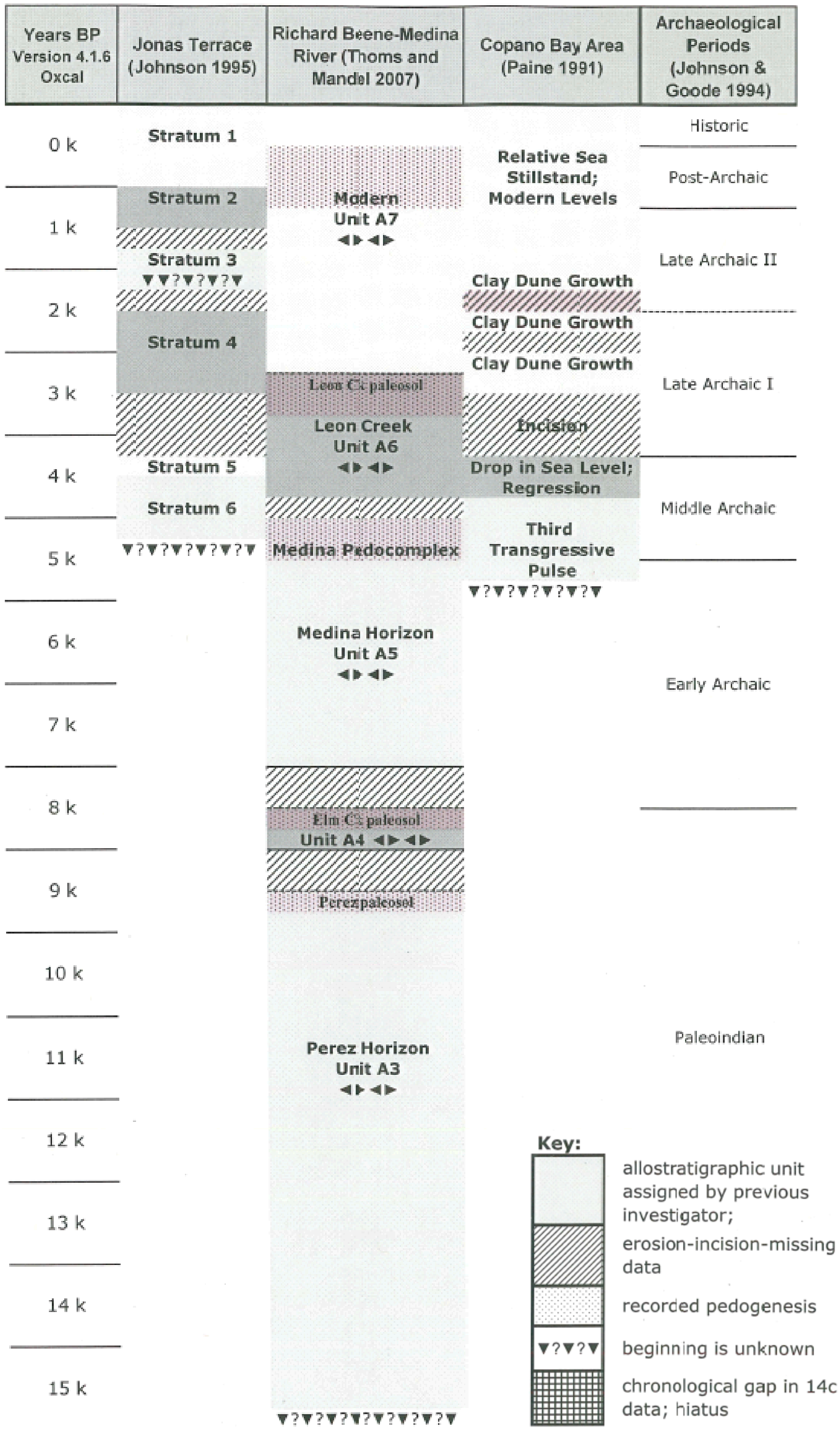


Figure 4.6 Calibrated Depositional History San Antonio River Basin.

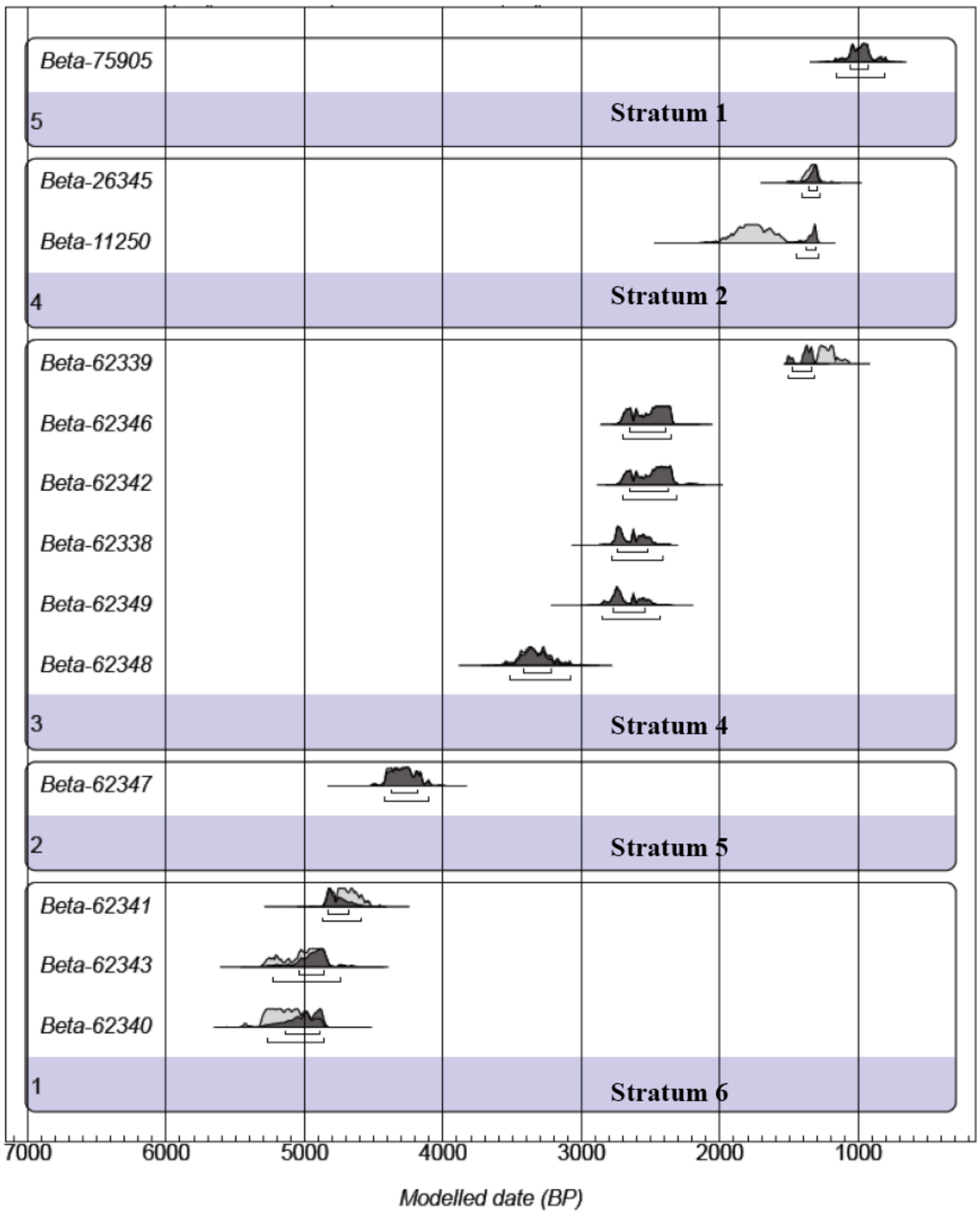


Figure 4.7 Calibration Plot of Jonas Terrace site (41ME29) radiocarbon assays.

Although the sample is derived from charcoal, its provenance is questionable (i.e., atop a burned rock midden upon the surface of Stratum 4). Consequently, for the purposes of this study the sample Beta-62339 has been rejected.

The next chronometric data is within Stratum 2 exhibits a beginning prior to 1,380 cal yr BP and termination subsequent to 1,300 cal yr BP. These data infer an approximate 1,000 year gap between Stratum 4 and Stratum 2, which includes the undated Stratum 3. The final horizon Stratum 1 has one radiocarbon assay that indicates a beginning prior to 1,060 cal yr BP and continues to the present.

A comparison of the initial and current calibrations does not exhibit any striking differences. The most apparent distinction regards the terminus of Stratum 4, but this is a result of rejecting sample Beta-62339 rather than adjustments from a more recent calibration curve. The omission of this sample effectively broadens the possible temporal range for Stratum 3 whereas the initial results implied a very brief Stratum 3. Similarly, the use of the MCMC analyses on this dataset did not markedly refine the results. However, it was instrumental in pointing out the anomalous radiocarbon sample.

Considering these recalibration results, Johnson's (1995) interpretations stand without any notable adjustments, particularly the environmental reconstruction. One exception may regard interpretations associated with Stratum 3. Specifically, the horizon was interpreted to be concurrent with a return of arboreal cover and rapid alluvial deposition, presumably a short-lived depositional horizon. If correct, the adjustment in timing to Stratum 3 in combination with a return in tree pollen correlates with a previously identified spike in arboreal pollen in Central Texas. Bousman (1998:212) interpreted a jump in arboreal canopy to have occurred around 2,000 ^{14}C yr BP. Similar to the low arboreal canopy interpreted for Strata 4 and 2 at Jonas Terrace, Bousman (1998:Figure 7) identified that the spike in arboreal canopy was preceded and followed by low arboreal pollen counts. Further, a comparison of the environment associated with each of the Jonas Terrace strata appear to correlate with that proposed by Bousman (1998:Figure 7). The sole exception is the spike of arboreal pollen around 3,500 ^{14}C yr BP, which is not identified at Jonas Terrace. However, this exception seemingly falls within the gap between Strata 5 and 4 (Figure 4.7). Although not conclusive, the data seems to reflect that the proposed environments are comparable particularly when considering the recalibration data.

Middle Extent

Nineteen radiocarbon assays were selected from the Richard Beene assemblage all derived from charcoal (Mandel et al. 2007: Table 3.4). The calibration of select radiocarbon samples from Richard Beene proved beneficial and, to varying degrees, the results generally pushed back the age of the previously reported assays.

Beginning with Unit A3 (Perez Horizon) at the Richard Beene site, the calibration revealed that this horizon was constructed prior to 15,290 cal yr BP and ended subsequent to 9,550 cal yr BP. Using other lines of evidence (e.g., soil carbon) in conjunction with charcoal, Mandel and others (2007:35–48) indicates that Unit A3 possibly began forming around 20,000 ^{14}C yr BP and ceased aggrading about 8,600 ^{14}C yr BP (Mandel et al. 2007:39–46). Further, this depositional unit contained cultural materials interpreted to represent Early Archaic occupations. The presence of the Perez Paleosol, which caps this horizon suggests that this depositional unit ended with a period of stability and seemingly followed by a period of erosion as evidenced by the disconformity separating it from the overlying Unit A4 (Mandel et al. 2007:Figure 3.10). This erosive event terminated prior to 8,920 cal yr BP as suggested by the oldest assay in Unit A4.

Unit A4 (Elm Creek Horizon) appears to have been relatively brief ending construction sometime after 8,410 cal yr BP, but also has a paleosol (Elm Creek Paleosol) suggestive of a period of prolonged stability (Mandel et al. 2007:48–49). Prior to 7,910 cal yr BP, Unit A5 (Medina Horizon) began deposition capping the underlying Unit A3 (Table 4.2). As previously mentioned, Mandel and others (2007:51) noted several buried soils welded together within this depositional unit identified as the Medina Pedocomplex. Four radiocarbon assays date the Medina Pedocomplex (i.e., Upper Medina Horizon) collected from the top of the horizon while five assays date the lower portions of the horizon (i.e., Lower Medina). The Medina Pedocomplex assays indicate that pedogenesis likely began around 5,400 cal yr BP continuing until sometime after 4,940 cal yr BP as indicated by the latest Unit A5 assay. Although the Medina Horizon extends from 7,910–4,940 cal yr BP, there is an apparent hiatus of about 2,000 years separating the Lower and Upper Medina portions (Figure 4.8). However, this gap may be attributed to differing sample elevations; the assays were collected from about 4 m vertical difference between the upper and lower sample sets.

Subsequent to Unit A5, the overlying Unit A6 (Leon Creek) began aggrading prior to 4,720 cal yr BP (Table 4.2). The Unit A6 Leon Creek Horizon extends from 4,720–3,220 cal yr BP and is capped by the (Leon Creek Paleosol), which again suggests a period of stability prior to the deposition of the Unit A7 (Modern Horizon) mantle. No chronometric assays are available for the final unit the Modern Horizon only Late

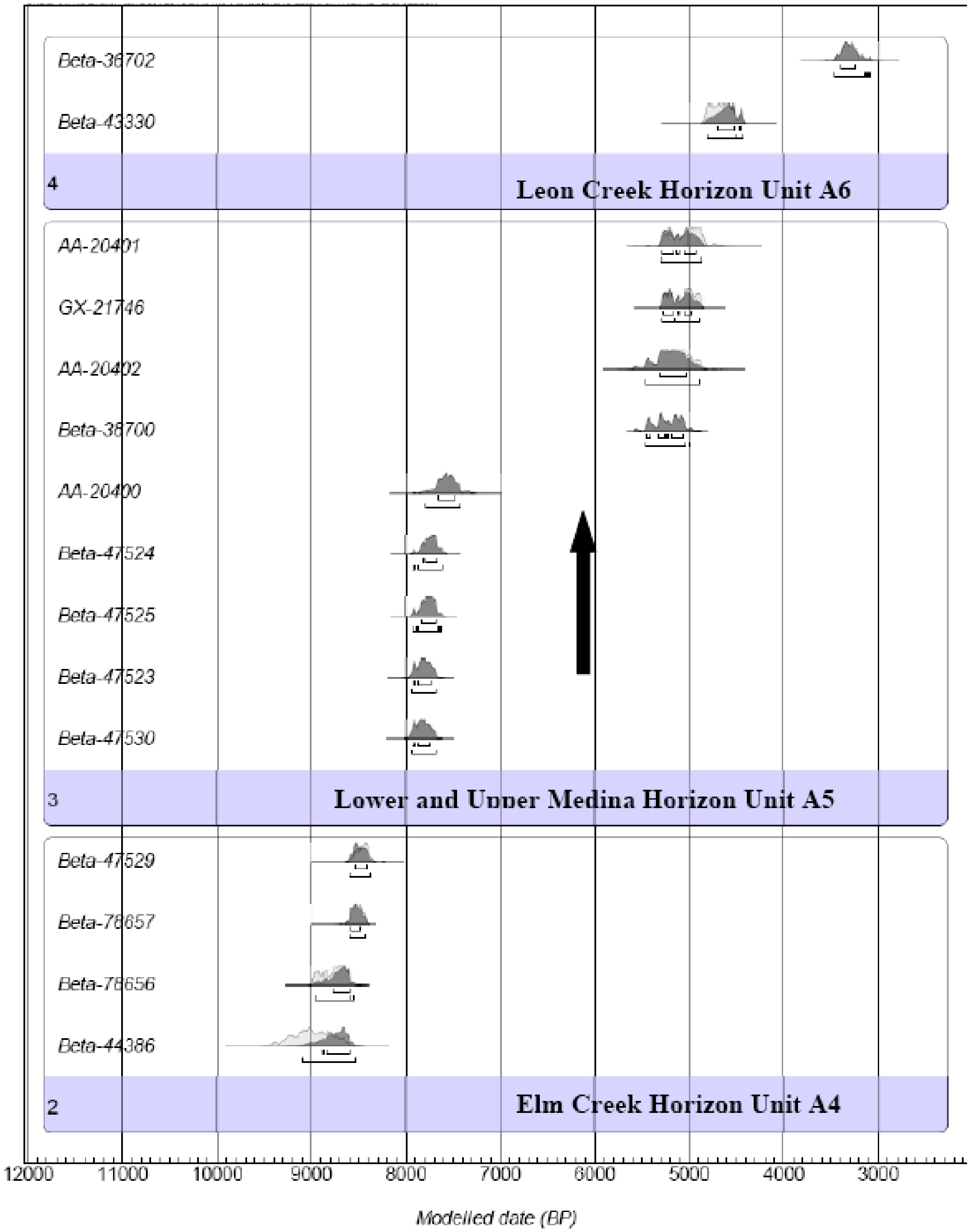


Figure 4.8 Select Calibration Plots of the Richard Beene site radiocarbon assays; arrow indicates hiatus period between Lower and Upper Medina Horizon.

Prehistoric artifacts. Thus, the researchers interpreted Unit A7 to extend from the end of Unit A6 to the present (Mandel et al. 2007:53).

Overall, several interesting findings were determined by contrasting the results of the initial calibration with those of the current recalibration study. First, the differences between the results of the two calibrations were not as pronounced as is typical (Table 4.5). The recalibration of the Richard Beene radiocarbon data trended very close to the initial results and occasionally skewed younger. The most evident adjustments involve the Unit A4 Elm Creek Horizon, which the calibration has shortened by roughly 700 years. To a lesser extent, the *terminus post quem* for both Unit A5 and Unit A6 horizons were identified to have occurred earlier than the initial calibration. The majority of these refinements are attributed to the implementation of the MCMC analysis of the recalibration results. The performance of the MCMC application appears to have been beneficial in that the largest refinements to the Richard Beene results were due to this statistical analysis.

Lower Extent

There are several issues with the radiocarbon dataset for the Copano Bay area. One issue regards the provenience information for the samples, only four of the ten radiocarbon assays could be placed into a stratigraphic context (Figure 4.5). Further, none of the assemblage is charcoal, but rather composed of soil humate and shell (Paine 1991:Table 5). With these limitations in mind, the samples were recalibrated due to the implications of their results. Specifically, Paine (1991:170–171) had interpreted these samples to represent distinct depositional events particularly in relation to the previously mentioned third transgressive pulse when sea level rose above present day levels by as much as 0.9 m. Therefore, the radiocarbon assays from the Copano Bay area were selectively chosen to determine how the recalibration of the assays would alter the initial interpretation.

Six radiocarbon assays were selected from the Copano Bay area assemblage all from Egery Island (Table 4.3). Four of the samples were in a stratified context (MSA-1) while the remaining two are indicated by Paine (1991:134) to date the sea level highstand. Of note, only the four stratified radiocarbon assays were subjected to the phase model and Bayesian analyses of OxCal (Figure 4.4). The remaining two 'unstratified' samples (i.e., TX-6102 and TX-6103) were each calibrated individually.

The results of the two 'unstratified' samples exhibit some parity. They both are from shell samples that indicate the third transgressive highstand began sometime prior to 5,466 cal yr BP and continued beyond 5,050 cal yr BP (Table 4.2). In contrast, the oldest stratified assay (TX-6061) is from a buried soil and is indicated to date to 4,500–4,180 cal yr BP. This horizon is associated with alluvial floodplain deposits, which Paine (1991:134) implies represents a drop in sea level (i.e., regression) had begun. A disconformity separates this horizon with the overlying clay horizon. This incision or erosional event occurred sometime between 4,180–3,230 cal yr BP indicated by sample (TX-6060) that dates a period of clay dune growth. This horizon signifying clay dune growth is one of four strata observed by Paine (1991:Figure 42). Each stratum of clay dune growth is separated by a disconformity with the fourth stratum composing the modern surface. The three periods of clay dune growth are calibrated to be 3,230–3,020 cal yr BP, 2,670–2,400 cal yr BP, and 2,320–2,150 cal yr BP.

CHAPTER 5

Recalibrated Geoarchaeological Framework within the Colorado River Basin of Texas

The Colorado River is the largest drainage contained entirely within Texas, which extends about 600 miles (965 km) and throughout its course drops in elevation about 3,400 feet from its headwaters in Dawson County to its terminus at the Gulf of Mexico at Matagorda, Texas south of Bay City (Comer and Kleiner 2010). The drainage trends almost exclusively southeast as it winds through the Southern High Plains into the Edwards Plateau where it runs through a bedrock confined valley before exiting the Balcones escarpment onto the relatively level Coastal plain (Blum 1992; Blum and Valastro 1994; Comer and Kleiner 2010). The Colorado River basin encompasses about 110, 000 km^2 (42,475 square miles) with approximately 92 percent of the drainage network portion situated north of the Balcones Escarpment. Using a drainage basin division recognized by Blum (1992:18), the Colorado River basin is divided into two parts consisting of an upper and lower extent demarcated at the Balcones Escarpment (Figure 5.1). Along its course, the Colorado River crosses a diverse assemblage of physiographic settings beginning in the Southern High Plains and drops into rolling prairies of the North Central Plains where it trends east-south eastward before turning southward to wind through series of canyons between the Central Texas Uplift (i.e., Llano Uplift) and the Edwards Plateau. The drainage abruptly emerges out of the Edwards Plateau at the Balcones Escarpment and crosses a narrow band of Blackland

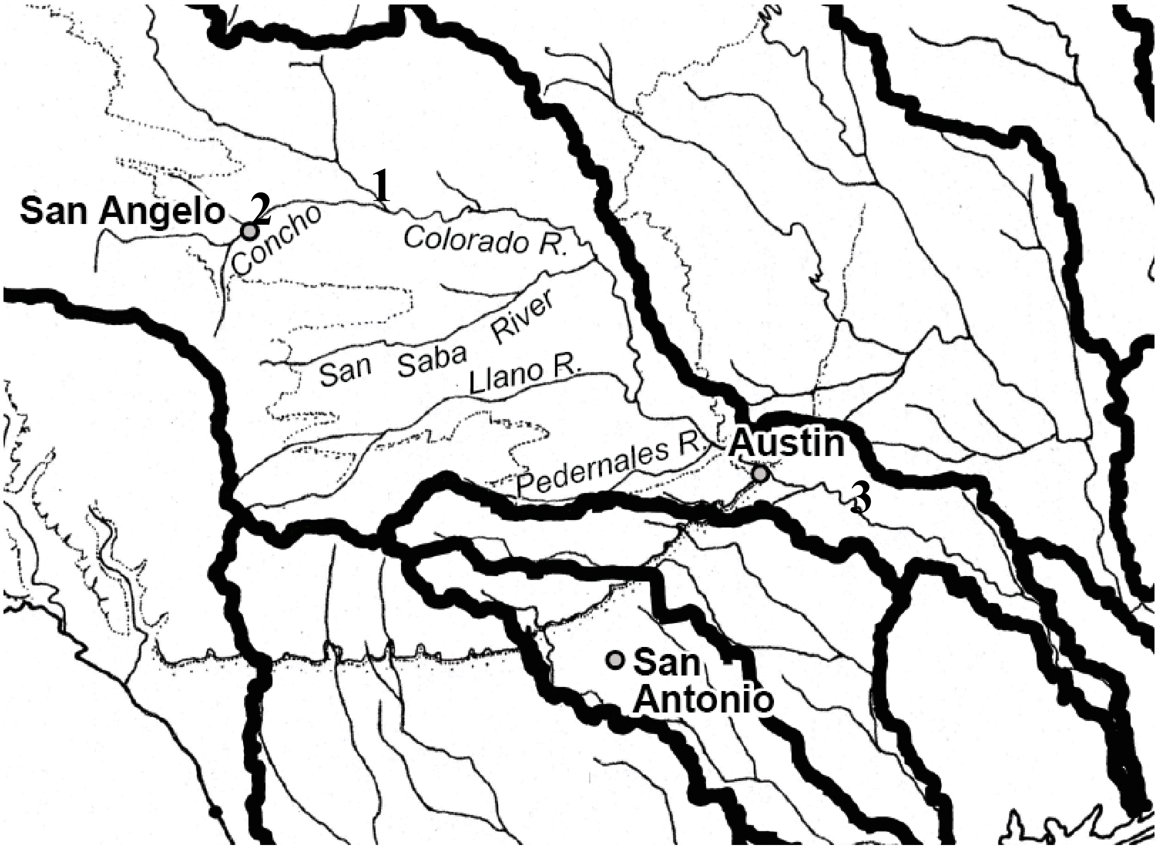


Figure 5.1 Overview of Colorado River Basin: 1) O. H. Ivie Reservoir, 2) San Angelo study area, and 3) Lower Colorado River study area.

Prairie before entering the interior Coastal Plain, and finally the Coastal Prairies and Marshes.

In the Upper Extent, the basin begins in a series of intermittent ephemeral draws that gradually converge to form the Colorado River. The principle tributaries in the Upper Extent include the Pedernales, Llano, San Saba, and Concho Rivers while the primary tributaries of the Lower Extent include Onion, Big Sandy, Sandy, Cedar, Alum, Pin Oak, and Caney Creeks. Similar to the adjacent Guadalupe River, the Colorado River as it exits the steeper Edwards Plateau and enters the relatively flat Coastal Plain, they convert from a smaller bedrock incised channel with low-moderate sinuousity to a larger floodplain with an increase in sinuosity.

Blum (1992:57–59) recognizes three components (i.e., gathering, transport, and deposition) of the basin in order to characterize the hydrology of the Colorado River basin. The gathering component encompasses the entire upper extent of the Colorado River basin and, as the name implies, collects the sediment from the network. The transport component moves the sediment from the Plateau downstream and extends across the interior Coastal Plain from the Balcones Escarpment downstream to roughly Columbus, Texas. Finally, the deposition component deposits the drainage's materials and roughly extends from Columbus, Texas to the coast.

Previous Investigations

The Colorado River basin is second only to the Brazos River basin for previous investigations (Table 5.1). Investigations have been conducted along the Colorado River basin for a little over 100 years, but the predominance of this research has been in the Lower Extent of the basin (Blum 1992; Blum and Valastro 1994). Since the

Table 5.1 Previous Geoarchaeological Investigations in the Colorado River Basin

Drainage Extent	Drainage	Resource	Project-Site(s)	Geoarchaeologist or Researcher	Chronometric Data
Upper	Clear Creek	Fiore 1976	Thesis; Burnet County	R. Fiore	Relative
Upper	Colorado River	Lintz, Treirweiller, Oglesby, O'Neill, Doering, and McFaul 1991	Mitchell County Reservoir	W. Doering and M. McFaul	14c
Upper	Colorado and Concho Rivers	Blum and Valastro, Jr. 1992	O. H. Ivie Reservoir research article	M. Blum and S. Valastro	uncorrected 14c; relative
Upper	Colorado and Concho Rivers	Lintz, Treirweiller, Oglesby, Blum, O'Neill, Holloway, Scott-Cummings, and Scurlock 1993	O. H. Ivie Reservoir	M. Blum and C. Lintz	uncorrected 14c; relative
Upper	North Concho River	Quigg and Peck 1995	Rush Site (41TG346)	J. Quigg and J. Peck	14c
Upper	Concho River	Quigg, Peck, Lintz, Treece, Frederick, Clem, Ellis, Schubert, and Abbott 1996	41TG307 and 41TG309	C. Frederick and J. Abbott	14c; relative
Upper	Middle Concho River	Mauldin and Nickels 2001; Nordt and Bousman 2001	Twin Buttes Reservoir Project (41TG378, 41TG379, and 41TG410)	L. Nordt and B. Bousman	14c; relative
Upper	Pedernales River	Blum 1987	Thesis	M. Blum	14c data; relative
Upper	Pedernales River	Blum and Valastro, Jr. 1989	Annals of American Geographers article	M. Blum	14c data; relative
Middle	Pedernales River	Blum, Toomey III, and Valastro, Jr. 1994	Article focused on paleoclimate change reflected in Texas drainages (Concho River, Pedernales River, Sabinal River, Cowhouse Creek, and Town Creek)	M. Blum, R. Toomey III, and S. Valastro Jr.	uncorrected 14c; relative

Table 5.1 Previous Georchaeological Investigations in the Colorado River Basin

Lower	Barton Creek, Onion Creek, Shoal Creek, and Bull Creek	Urbanec 1963	Austin area-Thesis	D. Urbanec	Relative
Lower	Colorado River	Weber 1968	Thesis	G. Weber	Relative
Lower		Tinkler 1971		K. Tinkler	Relative?
Lower	Colorado River	Wallis 1976	Thesis	J. C. Wallis	Relative
Lower	Colorado River	Mandel 1980	Thesis	R. Mandel	No 14c data; relative
Lower	Colorado River	Caran and Baker 1986		S. C. Caran and V. Baker	Relative?
Lower	Colorado River	Frederick 1987	Austin Mastodon Site-Thesis	C.Frederick	14c; relative
Lower	Middle Onion Creek	Ricklis and Collins 1994	Barton Site 41HY202 and Mustang Branch 41HY209	J. Abbott and M. Collins	14c; relative
Lower	Colorado River	Carpenter, Chavez, Miller, and Lawrence 2006	41BP627 McKinney Roughs Site	C.Crawford and C. Frederick	14c; relative
Lower	Colorado River	Baker and Penteado-Orellana 1977		V. Baker and M. Penteado-Orellana	Relative
Lower	Colorado River	Looney 1977	Bastrop and Fayette Counties-Thesis	R. Looney	Relative
Lower	Pin Oak Creek	Largent 1987	Pin Oak Creek site (41FY53) thesis	F. Largent Jr.	
Lower	Colorado River	Baker and Penteado-Orellana 1978		V. Baker and M. Penteado-Orellana	Relative
Lower	Colorado River	Blum 1992	Dissertation	M. Blum	14c; relative
Lower	Colorado River	Blum and Valastro, Jr. 1994	GSA article	M. Blum and S. Valastro	14c
Lower	Colorado River	Miller et al. 1996	MidTexas Pipeline	M. Waters and L. Nordt	Relative
Lower	Colorado River	Blum and Aslan 2006	article	M. Blum and A. Aslan	Relative
	indicates study selected for recalibration				

investigations prior to the 1950s lacked chronometric control, the characterization of the deposits used relative dating techniques. Furthermore, only within the last 30 years have there been concerted geomorphological investigations considering the effects of the drainages on the archaeological sites. Numerous investigations have been performed with some facet of geoarchaeology within the last few decades, but a majority of these was either too narrowly focused on site integrity or restricted to a specific time period (e.g., Brownlow 2004, Carpenter et al. 2006, Lintz et al. 1991, Ricklis and Collins 1994, Quigg and Peck 1995). Fortunately, several projects within the basin, associated with the construction of reservoirs, encompass deposits from the Late Pleistocene to the present and were extensively investigated regarding alluvial history of the basin. Beginning in the upper extent, a review of select projects within the basin will be conducted that will proceed downstream to the gulf.

The most comprehensive investigations within the Colorado River basin were conducted for the O. H. Ivie Reservoir at the confluence of the Concho and Colorado Rivers through the 1980s to early 1990s (Lintz et al. 1993). In part, these investigations extensively examined the alluvial deposits of the Colorado and Concho Rivers as well as several tributaries and generated a series of excellent research (e.g., Blum 1989, 1992; Blum et al. 1989, 1994; Blum and Valastro 1989, 1992). Unfortunately, out of the numerous radiocarbon assays from the O. H. Ivie investigations, only a select few (Tx-5770 and Tx-6293) were corrected for isotopic $\delta\ ^{13}C$ fractionation (Blum and Valastro 1992:428; Winans 2010). Therefore, a majority of the assays could not be included in the current recalibration study. Despite this impediment, Blum and others (1994) consider these dates as a minimum for each of the characterized deposits. Thus, the chronometric data will not be calibrated, but the interpretations of these researchers will be reviewed in more detail in the subsequent section.

Situated slightly upstream from the O. H. Ivie Reservoir investigations along the Concho River, archaeological research was conducted near San Angelo at sites 41TG307 and 41TG309 in the early 1990s for a wastewater alignment (Quigg et al. 1996). A component of this research was to characterize the alluvial deposits of the drainage (Frederick 1996:85–110). The deposits along the Concho River at these sites encompass the Holocene and were correlated to previous geoarchaeological work at the O. H. Ivie Reservoir. These investigations utilized relative and absolute dating techniques derived from charcoal, humate, and shell. Although sparse, a series of radiocarbon assays associated with the depositional history of the drainage were collected and corrected for isotopic $\delta\,^{13}C$ fractionation (Quigg et al. 1996: Table 12.2).

In the late 1980s, Blum (1987) conducted a series of investigations along the Pedernales River, a tributary of the Colorado River, in order to determine the alluvial history of the drainage. These investigations utilized relative dating techniques with a small suite (n=12) of radiocarbon assays (Blum 1987:69). However, no information was provided regarding if the assays were calibrated or corrected for isotopic $\delta\,^{13}C$ fractionation. Therefore, as with the O. H. Ivie data, the chronometric data for these investigations were not calibrated for this study, but the interpretations of Blum's research will be reviewed in more detail in the subsequent section.

In the lower extent of the Colorado Basin, downstream from the Balcones Escarpment more research relevant to the depositional history of the basin was conducted. Several previous investigators, in particular Blum (1992:81–102) provide an in depth review of this research. Most significant to the current study was Blum's (1992) research of the lower extent of the basin, which characterized the depositional history and environments of the Colorado River. These investigations utilized relative and absolute dating techniques and, most importantly, were corrected for isotopic $\delta\ ^{13}C$ fractionation.

Geomorphic/Alluvial History

The following review of the interpreted geomorphic/alluvial history of the Colorado River basin is based upon select summaries of previous research (Figure 5.2). For the upper extent of the basin, the research conducted along the Colorado and Concho Rivers for several reservoir projects and the Pedernales River on the Edward Plateau. The lower extent of the Colorado River basin is a distillation of the abundant investigations of the region and, particularly, Blum's (1992) Colorado River allostratigraphic research.

Upper Extent

This review of the upper extent of the Colorado River Basin is composed of three closely related projects. Two of these investigations were conducted along a portion of the Concho River and its confluence with the larger Colorado River, while the third is on the Pedernales River. The Pedernales River investigations were conducted within the Edwards Plateau while the other investigations occurred at the margins of the Plateau and the Southern High Plains.

Colorado and Concho Rivers

The largest project within the basin was conducted for the O. H. Ivie Reservoir project in Concho, Coleman, and Runnels Counties. The researchers recognized six

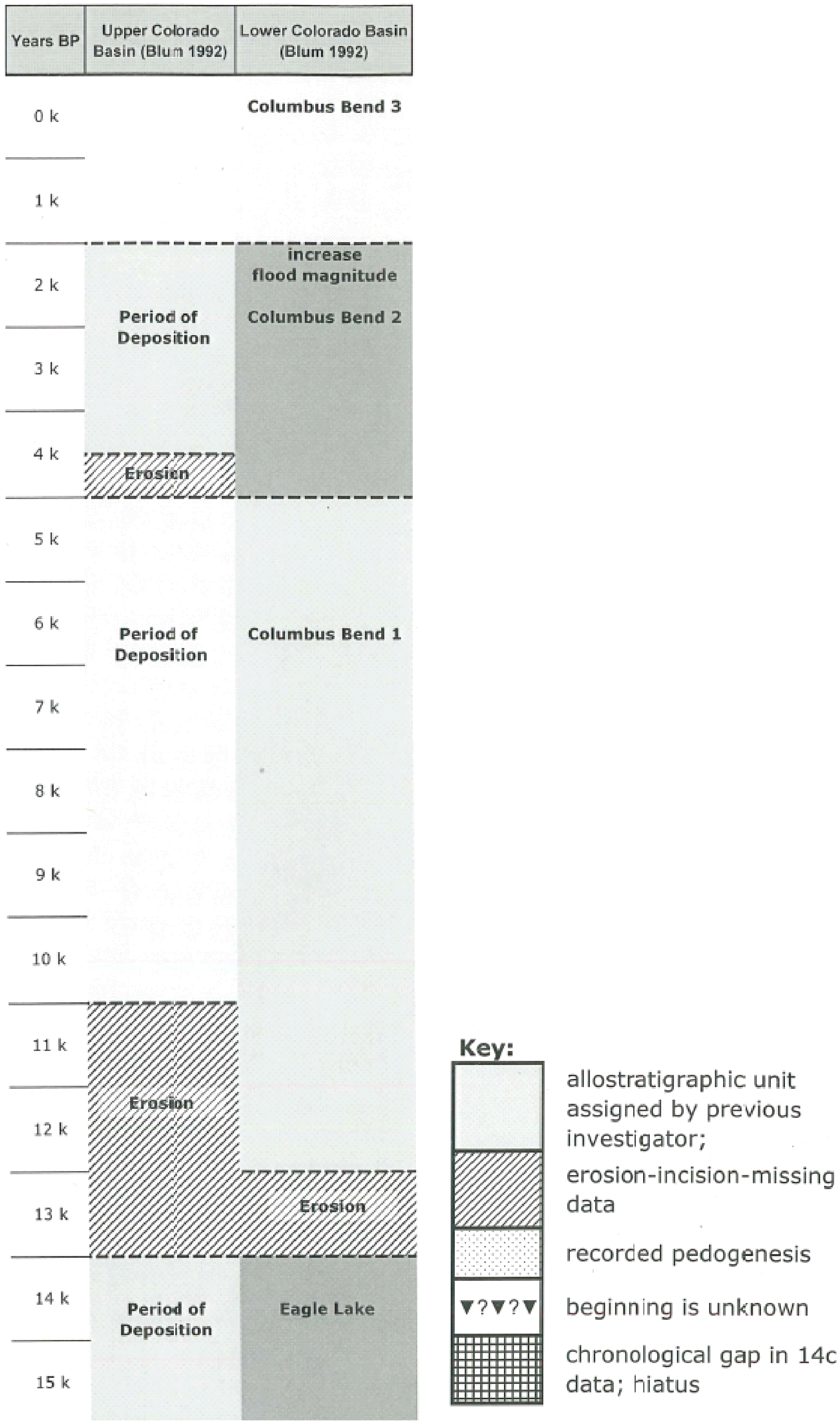


Figure 5.2 Initial Depositional History Colorado River Basin.

allostratigraphic units that extend from the Early-Middle Pleistocene until modern deposits (Blum and Lintz 1993; Blum et al. 1994; Blum and Valastro 1992). Regarding the Late Pleistocene to the Holocene, the Late Pleistocene has two terraces that were associated with this time described as roughly 12–14 and 16–18 m above the modern drainage channel (Blum and Valastro 1992:427). The more recent Late Pleistocene terrace exhibits some truncation from erosion and partially capped by eolian deposits. The only two assays (i.e., Tx-5770 and Tx-6293) from the O. H. Ivie dataset to be corrected for isotopic fractionation were derived from this terrace. These dates indicate the terrace was deposited prior to 11,430± 540 ^{14}C yr BP.

The next allostratigraphic unit is identified as the Early to Middle Holocene alluvium and described as situated roughly 6 m above the modern channel and ranges from 2–9 m thick (Blum and Valastro 1992:431). This stratigraphic unit was chronometrically dated with 25 assays that suggest it was deposited prior to 9,930^{14}C yr BP and continued until the drainage avulsed sometime after 5,000 ^{14}C yr BP (Blum and Valastro 1992:431). The researchers note that the terrace was stable for an extended period (possibly 3,000 years) allowing for soil pedogenesis until it was capped by the overlying Late Holocene allostratigraphic unit (Blum and Valastro 1992:431). The Late Holocene deposits are characterized as unconformably overlying the Early to Middle Holocene alluvium and are situated up to 5–6 m above the existing channel. Twenty-two radiocarbon assays suggest that this allostratigraphic unit was deposited between 4,600–1,000 ^{14}C yr BP (Blum and Valastro 1992:431–434). The final allostratigraphic unit is identified by the researchers as modern aligns the channel and chronometrically suggests deposition sometime prior to 840±70 ^{14}C yr BP (Blum and Valastro 1992:436). These radiocarbon assays were not corrected for isotopic $\delta^{13}C$ fractionation and were not calibrated for this study.

Concho River

In contrast, the investigations conducted upstream along the Concho River for the San Angelo wastewater alignment were not as extensive as that employed at the O. H. Ivie investigations. However, this research at sites 41TG307 and 41TG309 succinctly characterized the Concho drainage alluvial history. Frederick (1996) recognized through a series of backhoe trenches and cutbank exposures four alluvial deposits, which he interpreted to correlate with the O. H. Ivie data (Figures 5.3a and 5.3b). The oldest deposits were the Late Pleistocene alluvium only observed in a few locations situated beneath eolian or alluvial deposits (Frederick 1996:91–94). The Late Pleistocene deposit is described as sloping with an undulatory tread implying an erosional event subsequent to deposition. Next, the overlying alluvial deposits designated Early-Middle Holocene is characterized as unconformably situated on the Late Pleistocene deposits and having two distinct alluvial fills (Frederick 1996:91–94). Specifically, the Early-Middle Holocene deposits are composed of fine-grained overbank facies and a more coarse-grained pink colored sandy channel facies. The radiocarbon data for the overbank alluvium indicate deposition between 8,300–5,300 ^{14}C yr BP, which suggests the pink colored channel deposits accumulated between 10,000 and 8,300 ^{14}C yr BP (Frederick 1996; Frederick and Boutton 1996).

Situated above the Early-Middle Holocene unit are the Middle-Late Holocene deposits described as a mix of coarse (e.g., gravel and loamy sands) channel facies and fine-grained overbank facies (Frederick 1996:95–97). Based on three radiocarbon assays (i.e., Beta-69766, Beta-72273, and Beta-69770), the interpreted deposition of the Middle-

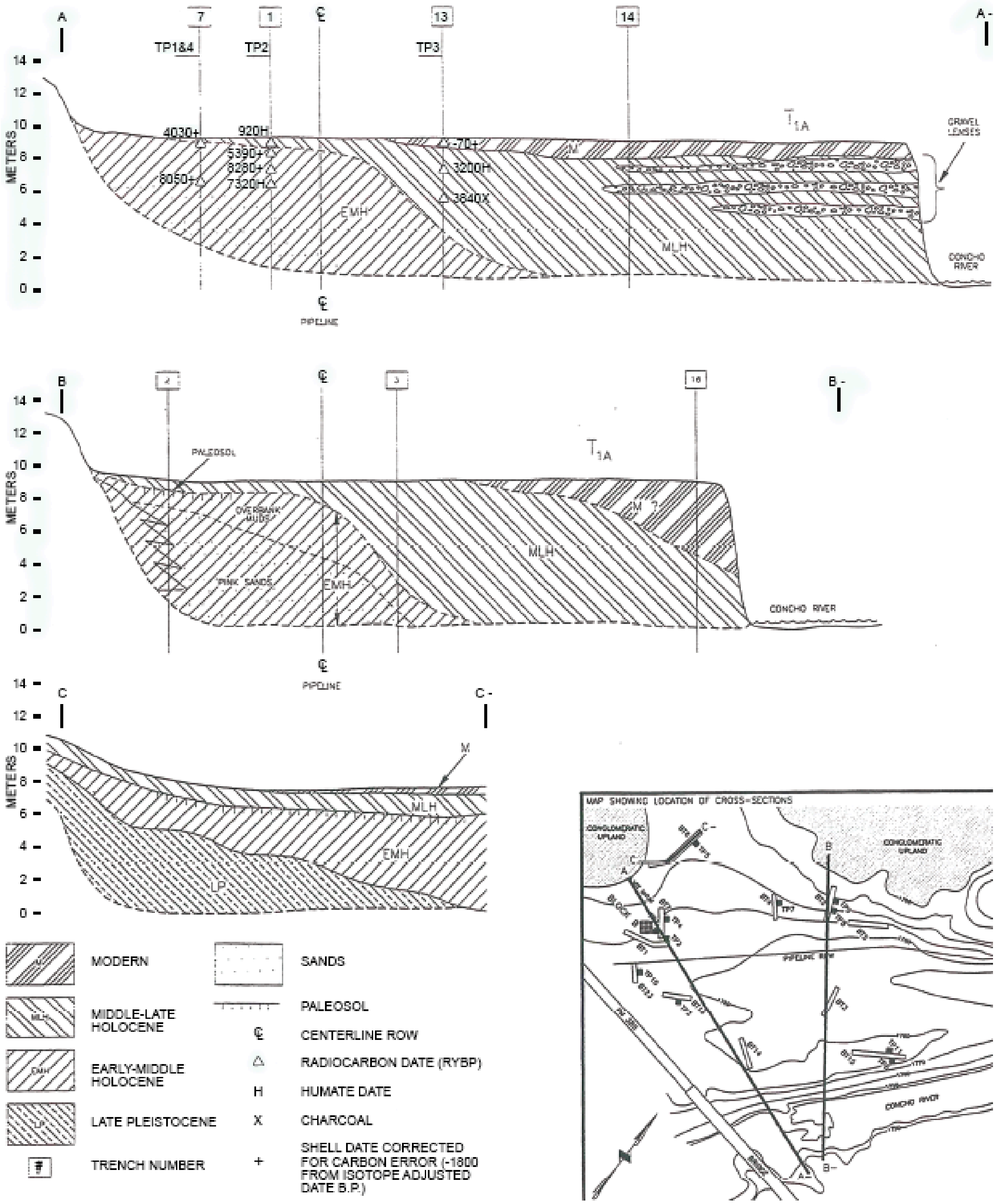


Figure 5.3a Profile of 41TG307 on Concho River (adapted from Quigg et al. 1996; Figure 5.2).

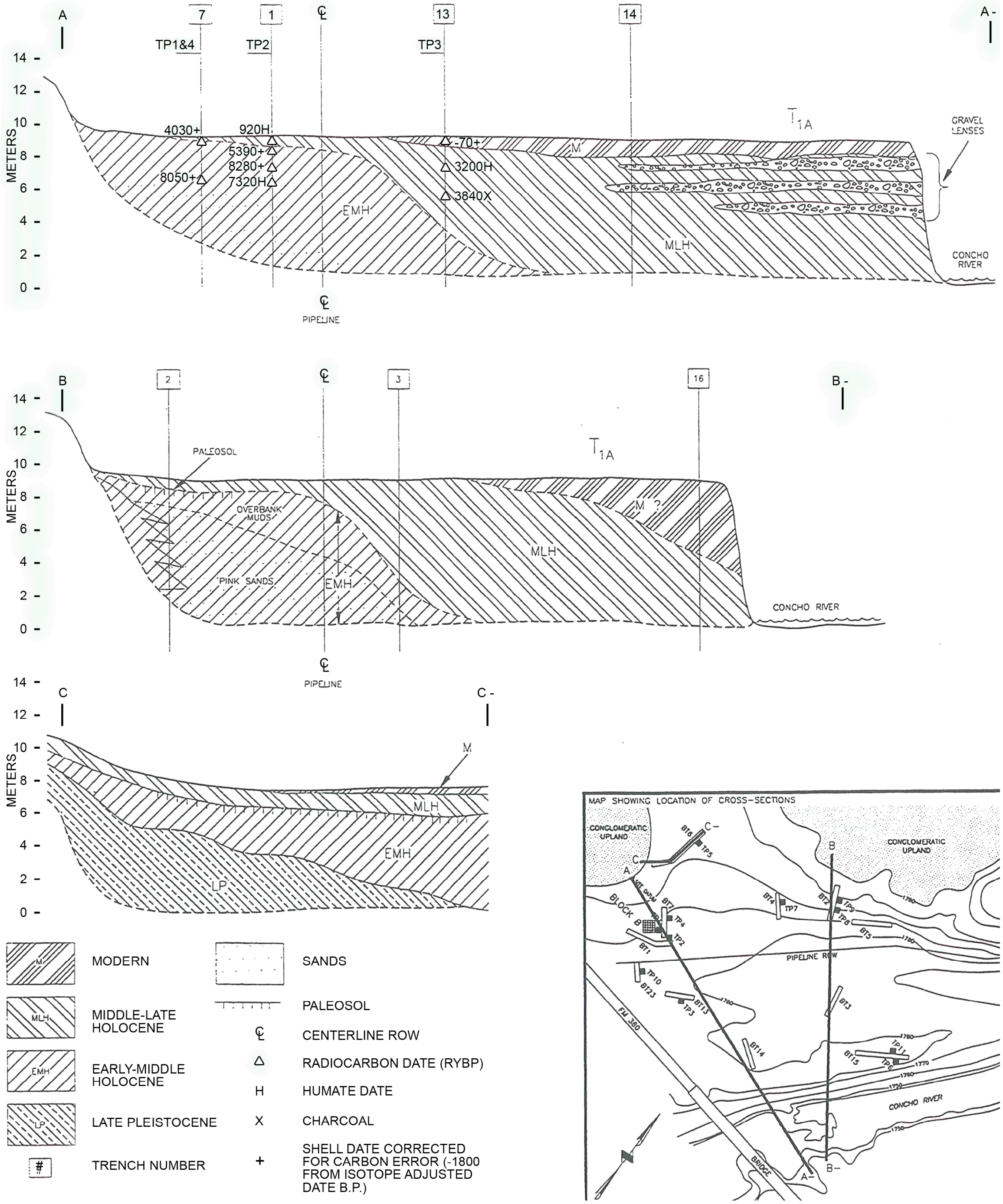


Figure 5.3b Profile of 41TG309 on Concho River (adapted from Quigg et al. 1996: Figure 5.3).

Late Holocene unit to roughly coincide with that proposed at the O. H. Ivie data. However, instead of terminating around 1,000 ^{14}C yr BP, the Middle-Late Holocene ends about 1,300 ^{14}C yr BP.

The most recent unit, the Modern alluvium was characterized as overbank, channel, and bar facies that composes the entire T_0 terrace as well as aprons the adjacent T_{1a} tread (Frederick 1996:97–100). Notably, Frederick (1996:99) indicates that the deposits of the modern alluvium situated over the Middle-Late Holocene unit are almost indistinguishable. Yet, a radiocarbon assay (Beta-70134) indicating a *terminus post quem* of 960 ^{14}C yr BP for the Middle-Late Holocene unit was collected (Frederick 1996: Figure 5.2, Table 12.2). This assay derived from humate was not reviewed in the Middle-Late Holocene unit discussion and was presumably rejected as being stratigraphically inconsistent. However, it may be correct and the allostratigraphic unit may actually be the Modern alluvium instead of the Middle-Late Holocene unit due to the difficulty of discerning the two deposits. Regardless, the Modern alluvium was interpreted to have been deposited between 1,200 ^{14}C yr BP to the present (Frederick 1996: 97–100).

Pedernales River

Located further downstream in the Colorado River basin along the Pedernales River, Blum (1987) investigated a series of drainage cutbanks centered around Fredericksburg, Texas (Figure 5.1). Of note, Blum (1987) did not calibrate the radiocarbon assay results processed at the Radiocarbon Laboratory at the University of Texas (Blum 1987:3). Considering the researcher lists the results with the assay's deviation, the assumption is made that results are uncorrected ^{14}C years that are reported. This research observed seven allostratigraphic units (Units A–G), which encompasses

Early Pleistocene to Modern deposits. Most relevant, Unit D is associated with the Late Pleistocene, Unit E with the Early Holocene, Unit F with the Late Holocene, and Unit G with Modern deposits. Unit D is characterized as a distinct terrace positioned 12–13 m above the modern channel composed of a fining upward of clast materials (gravels to clays). The radiocarbon assays for this unit indicated 17,260±230 ^{14}C yr BP and a very dubious 5,200±340 ^{14}C yr BP.

Next, the Early Holocene Unit E is described as variable with coarse, weakly cemented gravels-gravelly sands in some exposures and a predominance of finer-grained sediments capped with a weakly developed paleosol (Blum 1987: Figure 34). Based upon select radiocarbon assays and Pleistocene faunal remains (*Equus sp.*), the Unit E alluvium is interpreted to have been deposited between 11,000–7,000 ^{14}C yr BP (Blum 1987:88). Deposited unconformably upon Unit E is the Late Holocene Unit F that is characterized as possibly composed of up to 10 m of gravels and sand capped by a weakly developed soil (Blum 1987:91–93). The sparse chronometric data for this unit suggest deposition occurred at roughly 5,000–800 ^{14}C yr BP. The modern deposits, Unit G, are described as laterally confined with roughly 5 m of sand and gravels. Blum (1987:96) notes that a radiocarbon assay (Tx-5532) was collected from the base of Unit G indicating this allostratigraphic unit was deposited between 900 ^{14}C yr BP and the present. Overall, the depositional history outlined for the Pedernales River correlates with that proposed for the Colorado and Concho Rivers (O. H. Ivie and San Angelo) in the Upper Extent of the basin.

Summary Upper Extent

The researchers interpret the alluvial history of this section of the Colorado River basin to begin with a period of channel aggradation during the Late Pleistocene roughly coinciding with the Last Glacial Maximum. This period of floodplain construction was followed by a drainage avulsion and an extended phase of erosion around 14,000 ^{14}C yr BP, which deeply incised into bedrock. This erosion continued until the development of the Early-Middle Holocene floodplain between 11,000–5,000 ^{14}C yr BP followed by another erosive event concurrent with a period of stability that formed a soil capping the unit. The Middle-Late Holocene allostratigraphic unit began forming around 4,600 ^{14}C yr BP and continued until approximately 1,000 ^{14}C yr BP. This period ended with a drainage avulsion and an extended phase of erosion concurrent with a period of stability that formed a soil capping the unit. The modern phase of floodplain construction began roughly 800 years ago and continues to the present.

Lower Extent

As previously defined, the lower extent of the basin extends from the Balcones Escarpment downstream to the Gulf Coast. Undoubtedly, the most comprehensive investigations within this region were by Blum (1992). These investigations recognized four Members for the entire lower Colorado River basin, which encompassed the Late Pleistocene to modern times (Blum 1992; Blum and Törnqvist 2000; Blum and Valastro 1994). Blum (1992) examined a series of Colorado River profiles between Austin and Wharton, in part, to characterize the depositional history of the lower basin and correlate it with the upper, determine the chronology of these fluvial events, and examine the influence of climatic and eustatic effects on these fluvial events.

<u>Colorado River</u>

The four identified allostratigraphic members include the Eagle Lake alloformation of the Late Pleistocene and the Columbus Bend alloformation members 1–

3 encompassing the Late Pleistocene to Holocene (Figures 5.3a and 5.3b). The Eagle Lake alloformation is characterized as exhibiting varied facies depending upon position along the drainage (Blum 1992:149–165). In the section identified as transport within the basin (i.e., Interior Coastal Plain), the deposits are primarily gravelly clast materials while the section identified as the depositional (i.e., Coastal Prairies and Marshes) exhibits finer-grained clast materials. The Eagle Lake alloformation varies in thickness about 8–10 m with the base situated on bedrock about 6–8 m above the modern channel (Figures 5.4a and 5.4b). This alloformation was dated with a series of radiocarbon assays, which indicate that accumulation began prior to 20,000 ^{14}C yr BP and ended sometime after 14,000 ^{14}C yr BP (Blum 1992: Table 6.1).

The Columbus Bend allomembers 1–3 are three terrace landforms that compose the Columbus Bend alloformation (Blum 1992: Figure 6.15). The roughly 10–12 m thick Late Pleistocene-Early Holocene deposits of the Columbus Bend member 1 rests unconformably on bedrock and against the Eagle Lake alloformation. The Columbus Bend allomember 1 is described as comprising a variety of channel related deposits ranging from gravels to fine sands. Blum (1992:177–178) interprets the deposition of this allostratigraphic unit to have been predominantly attributed to lateral migration as overbank deposits suggested by thick deposits of finer clast materials were rare. The radiocarbon assays for the Columbus Bend member 1 indicate deposition occurred between 13,000–5,000 ^{14}C yr BP (Blum 1992: Table 6.2).

Inset against and overlapping the Columbus Bend member 1 is the Middle-Late Holocene Columbus Bend member 2. These deposits are typically over 12 m thick extending below modern water levels and characterized as having varied channel facies

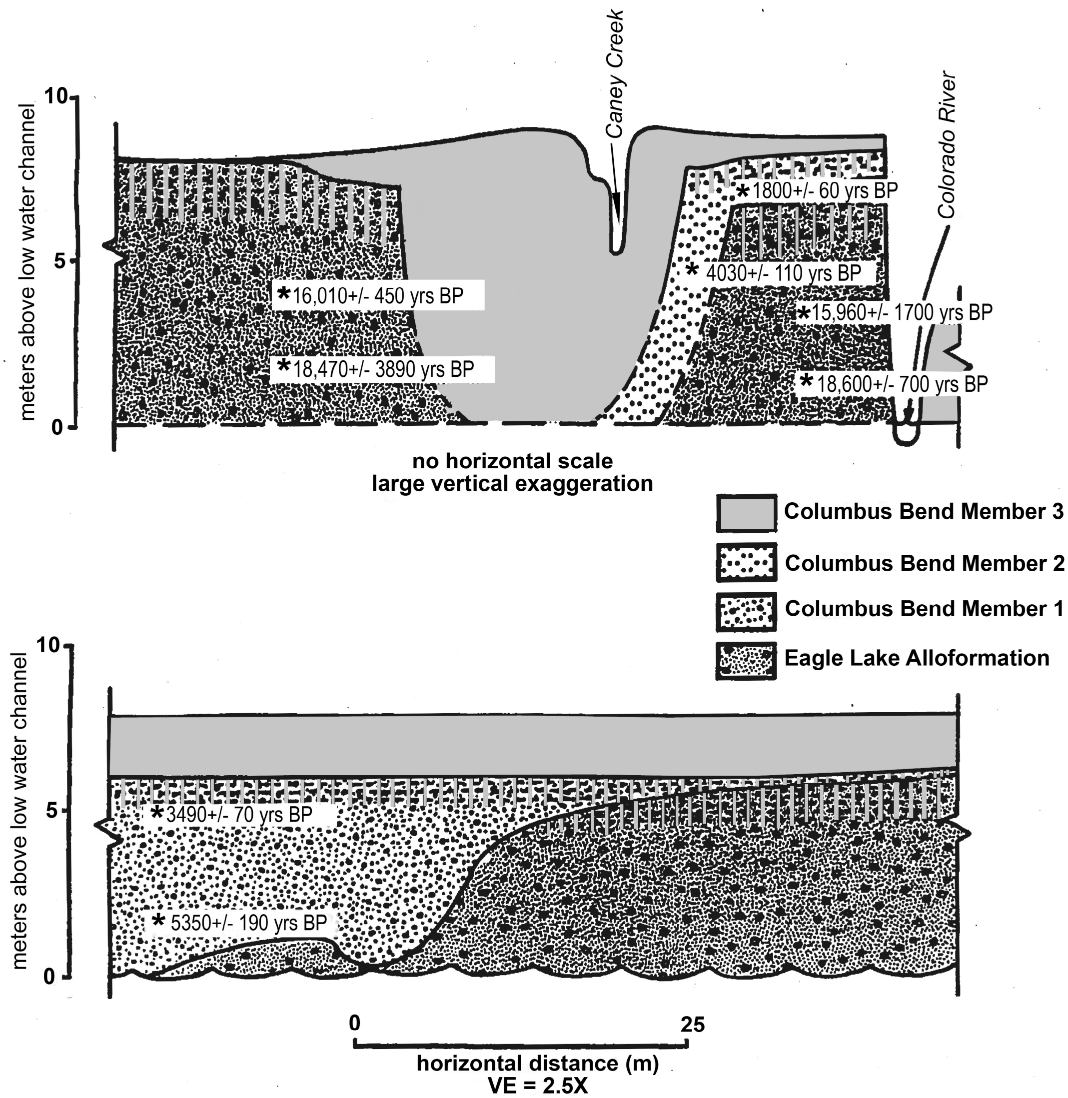


Figure 5.4a Idealized Cross-section of Colorado River Basin at the Eagle Lake locality (adapted from Blum 1992: Figure 6.5).

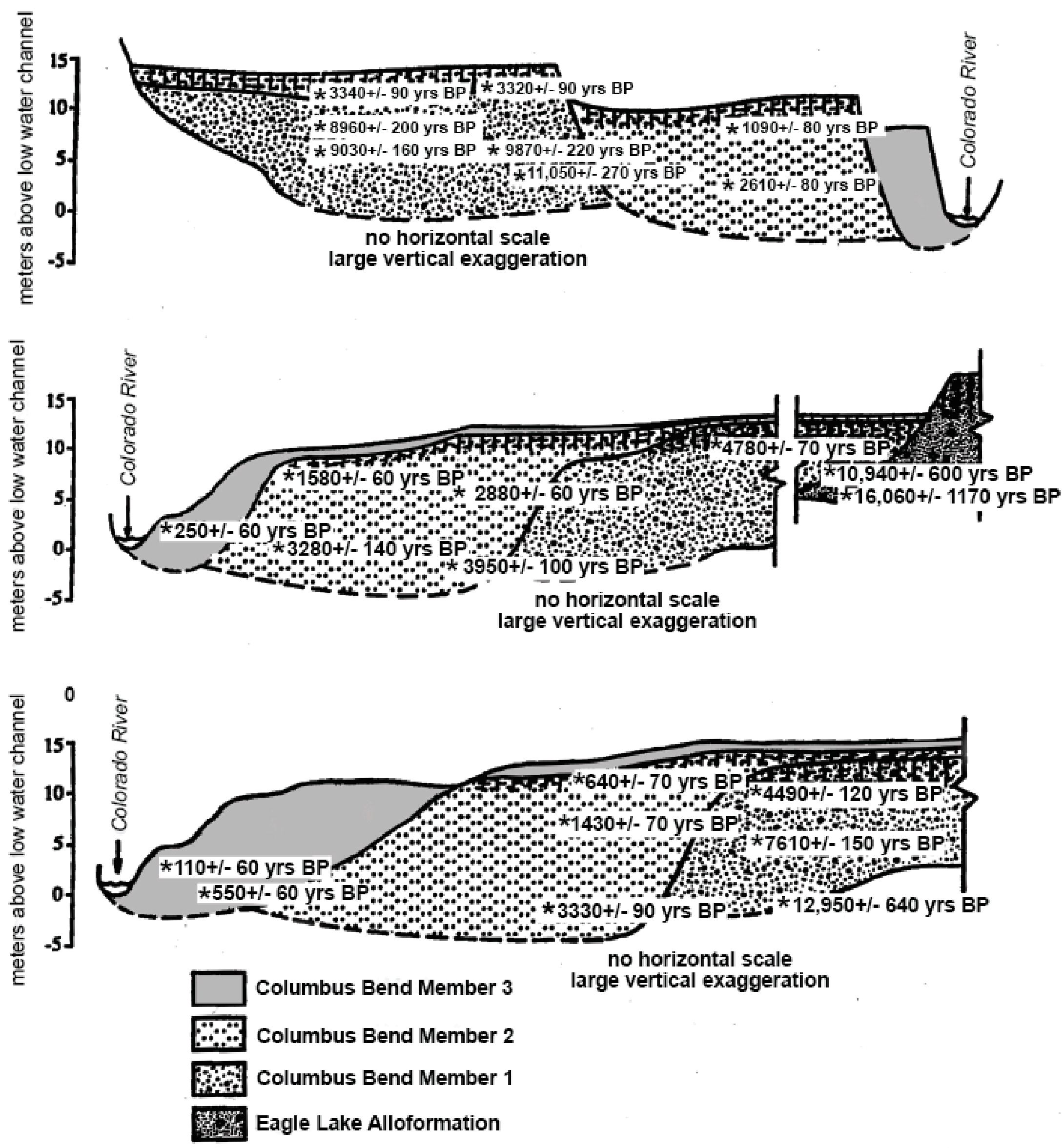


Figure 5.4b Idealized Cross-section of Columbus Bend Members 1–3 at the Austin, West Point, and Columbus locations (adapted from Blum 1992: Figure 6.15).

with a predominance of floodplain facies (Blum 1992:186). The Columbus Bend allomember 2 radiocarbon data suggest deposition occurred prior to 5,000 ^{14}C yr BP and continued until sometime after 1,000 ^{14}C yr BP.

Interestingly, Blum (1992:186–190) observes that the Columbus Bend member 2 seemingly had frequent episodes of high magnitude overbank flooding and ended with a period of stability, which formed a soil that capped the unit. Next, the Columbus Bend member 3 is unconformably inset against the Middle-Late Holocene Columbus Bend member 2 indicating some erosion of this older unit. The dramatic avulsion of the Colorado River that began the modern Columbus Bend member 3 is interpreted to have abandoned its initial course, the existing Caney Creek, and moved eastward to its modern course (Blum 1992:190–193). This avulsion occurred near Wharton, Texas with Caney Creek trending southeast containing the older allostratigraphic units and the Colorado River trending south-southwest containing the modern Columbus Bend member 3 both emptying into the gulf about 32 km (20 miles) apart.

The Columbus Bend member 3 is described as ranging from 1–10 m in thickness and collected radiocarbon assays suggest deposition between 600–100 ^{14}C yr BP. Of note, the assays for the Columbus Bend member 3 were the only samples derived from wood while the remaining assays were humate materials (Blum 1992: Tables 6.1–6.4). Finally, Blum (1992:193) only notes cultural deposits within the Columbus Bend member 3 consist only of historic artifacts. The other allostratigraphic units for the lower extent of the basin have no mention of cultural materials as being present.

Summary Lower Extent

The alluvial history proposed for the lower extent of the basin is similar to that indicated for the upper extent. Beginning at the Last Glacial Maximum, the Colorado

River had a period of extensive deposition between 20,000–14,000 ^{14}C yr BP (Blum 1992; Blum and Valastro 1994). This period of deposition was followed by an extended period of incision eroding underlying bedrock throughout the lower basin to its current levels. Beginning around 12,000 ^{14}C yr BP, the formation of the Columbus Bend alloformation units occurred. Columbus Bend member 1 deposition extended from roughly 12,000–5,000 ^{14}C yr BP followed by a reduction in flood magnitude beginning the deposition of Columbus Bend member 2 (Blum 1992; Blum and Valastro 1994: Figure 10). The reduction in flood magnitude allowed for pedogenesis to occur in the Columbus Bend member 1 unit, which continued until approximately 2,500 ^{14}C yr BP.

The Columbus Bend member 2 floodplain accumulated between 5,000–1,000 ^{14}C yr BP with an increase in flow regime occurring after 2,500 ^{14}C yr BP resulting in the burial of Columbus Bend member 1 (Blum 1992; Blum and Valastro 1994). Subsequent to 1,000 ^{14}C yr BP, the flood magnitude decreased abandoning the Columbus Bend member 2 and at the Caney Creek meanderbelt (Blum 1992; Blum and Valastro 1994).

The modern Columbus Bend member 3 accumulated within the last 600 years. Based on the general thickness of the units and the floodplain facies, Blum (1992:193–197) observes that the flow regime for the basin changed over time. Specifically, from the Late Pleistocene up to the Middle Holocene floodplain construction was predominantly lateral migrations while the latter half of the Holocene had a noticeable increase in overbank flooding (i.e., vertical accretion).

Calibration Results

Select assays of radiocarbon datasets for the previously reviewed Upper and Lower Extents of the Colorado River Basin were recalibrated. As previously mentioned, only two of the radiocarbon assays (Tx-5770 and Tx-6293) from the O. H. Ivie investigations were corrected for isotopic $\delta\ ^{13}C$ fractionation (Blum and Valastro 1992:428; Winans 2010). Similarly, the assays for Blum's (1987) investigations along the Pedernales River were not calibrated or corrected for isotopic $\delta\ ^{13}C$ fractionation. Consequently, neither the O. H. Ivie nor Pedernales River datasets were calibrated for this study. Fortunately, a series of radiocarbon assays from the investigations along the Concho River near San Angelo were corrected for isotopic $\delta\ ^{13}C$ fractionation (Quigg et al. 1996: Table 12.2). Although sparse, these data are used as a proxy for the upper extent of the Colorado River basin. In contrast, the dataset for the lower extent of the Colorado River basin is robust and adequately represents the depositional history of the basin.

Upper Extent

Five radiocarbon assays were selected from Quigg and others (1996: Table 12.2) chronometric assemblage derived from fluvial sediment (i.e., humate) and wood. These assays from charcoal and humus were selected due to their known stratigraphic context and association with three of the identified stratigraphic units (Figures 5.3a and 5.3b). Other assays were available, but rejected as these samples were derived from mussel shell. One assay represents the Early-Middle Holocene, three assays represent the Middle-Late Holocene, and one assay represents the Modern unit (Table 5.2). Notably, one assay (Beta-70134) was not included due to several troubling factors including its stratigraphic inconsistency as initial radiocarbon analysis indicated (Frederick 1996:97–100). Therefore, due to the questionable validity of this sample it was not included in the recalibration.

Table 5.2 Radiocarbon Data Colorado River Basin

Locality	Lab#	13c Adjusted 14c yr BP	Dev +/-	Depth (m)	δ 13 C	Material sampled	Initial 68.2%	Initial 95.4%	IntCal09 68.2%	IntCal09 95.4%
Eagle Lake Alloformation (Blum 1992: Table 6.1)										
Eagle Lake	Tx-7011***	18600	700	4	-25	fluvial sediment			22000-20290	22980-19610
Eagle Lake	Tx-7012	18380	3890	7.3	-31	fluvial sediment			21400-19170	22990-18070
West Point	Tx-7225	16180	1170	7	-17.9	fluvial sediment			20780-18990	21910-18130
Eagle Lake	Tx-7013	16090	450	3.9	-23.4	fluvial sediment			19960-18990	20440-18660
Eagle Lake	Tx-7010	15970	1700	1.9	-24.8	fluvial sediment			20960-18930	22270-17890
Eagle Lake	Tx-7011***	15900	810	1.9	-24.9	fluvial sediment			20280-18860	21210-18120
Columbus	Tx-7230	15610	1300	7.5	-25.2	fluvial sediment			20660-18790	21850-17810
Columbus Bend Member 1 (Blum 1992: Table 6.2)										
Columbus	Tx-7326	12970	640	10.5	-23.4	fluvial sediment			15820-14030	16720-13470
West Point	Tx-7224	10910	600	2.8	-26.7	fluvial sediment			13430-11940	14420-11220
Utley	Tx-7328	7970	630	5.5	-24.2	fluvial sediment			9800-8300	10770-7740
Columbus	Tx-6811	7730	150	5.2	-17.8	fluvial sediment			8790-8410	8980-8230
Eagle Lake	Tx-7323	5350	180	4.2	-20.7	fluvial sediment			6310-5930	6530-5730
West Point	Tx-7226	4960	70	1.5	-14.6	2Bkb horizon			5840-5630	5890-5590
Columbus	Tx-7325	4640	120	1.4	-15.5	3Bkb horizon			5560-5260	5640-5060
Columbus Bend Member 2 (Blum 1992:Table 6.3)										
Webberville	Tx-7232	4160	70	10.5m	-19.1	fluvial sediment			4760-4550	4830-4450
Eagle Lake	Tx-7008	4120	110	4.3m	-18.9	fluvial sediment			4750-4460	4840-4310
West Point	Tx-7220	4010	100	10.6m	-21.2	fluvial sediment			4650-4320	4800-4180
Webberville	Tx-7234	3640	60	7.5m	-19.7	fluvial sediment			4060-3880	4140-3780
Webberville	Tx-7233	3390	60	10.4m	-25.8	wood			3720-3560	3820-3480
Webberville	Tx-6809	3440	90	10m	-18.4	fluvial sediment			3830-3580	3950-3480
Columbus	Tx-6810	3440	90	10m	-18.4	fluvial sediment			3830-3580	3950-3480

Table 5.2 Radiocarbon Data Colorado River Basin

West Point	Tx-7222	3380	140	1.2m	-18.9	fluvial sediment			3820-3480	4020-3340
Webberville	Tx-7330	3250	90	5.5	-20.6	fluvial sediment			3590-3390	3700-3270
West Point	Tx-7221	2950	60	6	-20.1	fluvial sediment			3220-3010	3320-2930
Eagle Lake	Tx-7007	1870	60	1.1	-20.8	fluvial sediment			1880-1730	1950-1640
Webberville	Tx-7331	1900	60	1.5	-16.1	fluvial sediment			1910-1750	1980-1700
West Point	Tx-7223	1660	60	2	-20	fluvial sediment			1660-1460	1710-1410
Columbus	Tx-6812	1590	70	4.2	-14.8	fluvial sediment			1560-1400	1680-1340
Columbus	Tx-6813	820	70	0.3	-13.7	A horizon			890-720	920-680
Columbus Bend Member 3 (Blum 1992:Table 6.4)										
Columbus	Tx-7334	490	60	8.5	-28.5	wood			540-350	620-320
Columbus	Tx-7335	350	60	8	-26.4	wood			470-320	510-290
West Point	Tx-7321	190	60	6.2	-28.3	wood			290-100	420-0
Columbus	Tx-7227	70	60	5.5	-27.9	wood			260-60	280-0
Concho River Investigations (Quigg et al. 1996:Table 12.2)										
Early-Middle Holocene Horizon										
41TG307	Beta-70133	7320	120	2.9	-20.4	Humus/soil	5370 B.C.		8270-8010	8360-7890
Middle-Late Holocene Horizon										
41TG309	Beta-69769	4450	60	2.4	-18.5	Charcoal	2500 B.C.		5220-4940	5290-4870
41TG307	Beta-69766	3840	60	3	-25.8	Charred material	1890 B.C.		4370-4150	4420-4050
41TG307	Beta-72273	3200	60	1.9	-17.9	Humus/soil	1250 B.C.		3510-3370	3580-3290
Modern Holocene Horizon										
41TG309	Beta-69770	1230	60	4	-25.4	Charcoal	A.D. 720		123-1060	1280-980
41TG307	Beta-70134	920	60	0.5	-18.2	Humus/soil	A.D. 1030		910-780	960-720
*standard value of -25.0 assumed by previous investigators										
**radiocarbon date not listed on original table										
***duplicate sample number in original text										

The results of this recalibration indicate the *terminus ante quem* for the Early-Middle Holocene terrace is 8,270–8,010 cal yr BP (Table 5.2). The overlying Middle-Late Holocene unit suggests deposition began prior to 5,220 cal yr BP indicating the abandonment of the Early-Middle Holocene unit sometime in the intervening 2,790 years. The *terminus post quem* of the Middle-Late Holocene unit (i.e., assay Beta-72273) is 3,370 cal yr BP while the overlying modern unit began sometime prior to 1,230 cal yr BP. Therefore, the abandonment of the Middle-Late Holocene terrace and formation of the modern terrace occurred in the approximate 2,000-year interval.

Despite the obvious limitations of the dataset, the recalibration of the Concho River chronometric data is informative. Specifically, in regards to the Early-Middle Holocene deposits Frederick (1996:94) notes a horizon of pink colored channel deposits likely deposited between 10,000 and 8,300 yr BP. The recalibration of the data conforms with Frederick's (1996) initial interpretation, but may need to be pushed back in age considering the 8,270–8,010 cal yr BP result. Further, the deposition of the Middle-Late Horizon between 5,220–3,370 cal yr BP conforms with the interval of deposition proposed at O. H. Ivie and the Pedernales River. Similarly, the deposition of the modern deposits also concurs with that proposed by Frederick (1996:97–100).

Lower Extent

Nineteen radiocarbon assays were selected from the Blum's (1992) assemblage derived from fluvial sediment (i.e., humate) and wood. Admittedly, only three of the assays were from wood while the remaining 15 assays were from humate materials (Table 5.2). These 19 assays were selected for calibration because their stratigraphic position at their collection location at the Eagle Lake, Columbus, and West Point localities was identified (Blum 1992: Figures 6.6a, 6.15). More significantly, all of these samples were corrected for isotopic fractionation (Blum 1992: Tables 6.1, 6.2, and 6.3). Four assays are from the Eagle Lake Member, five assays are from the Columbus Bend Member 1, seven are from the Columbus Bend Member 2, and three are from Columbus Bend Member 3.

The results of the recalibration indicate that the Eagle Lake Member began deposition prior to 22,500 cal yr BP and terminated deposition sometime after 19,000 cal yr BP, which is immediately after the last glacial maximum at ~23,500 cal yr BP (Figure 5.5). The overlying Columbus Bend Member 1 has a *terminus ante quem* of 15,940 cal yr BP suggesting an approximate 3,000-year gap between the two members. This gap (19,000–15,940 cal yr BP) is interpreted to be a dramatic period of deep bedrock erosion-incision, which concurs with the disconformity separating the two units (Blum 1992, Blum and Valastro 1994).

The Columbus Bend Member 1 continued deposition until a soil capping these deposits began to develop between 5,550–5,210 cal yr BP suggesting a period of stability. This period of pedogenesis may indicate when the Colorado River decreased flow and began the deposition of the Columbus Bend Member 2. The *terminus ante quem* of the Columbus Bend Member 2 is 4,570 cal yr BP suggesting the floodplain abandonment of Columbus Bend Member 1 and erosion minimally occurred during the 640-year gap between Columbus Bend Members 1 and 2. During this time, the Colorado River is interpreted to have increased in flood magnitude and overtopped the Columbus Bend member 1 terrace and soil. Initially, this was argued to have occurred around 2,500 ^{14}C yr BP. Two radiocarbon assays (i.e., Tx-6533 and Tx-6534) indicating an age of

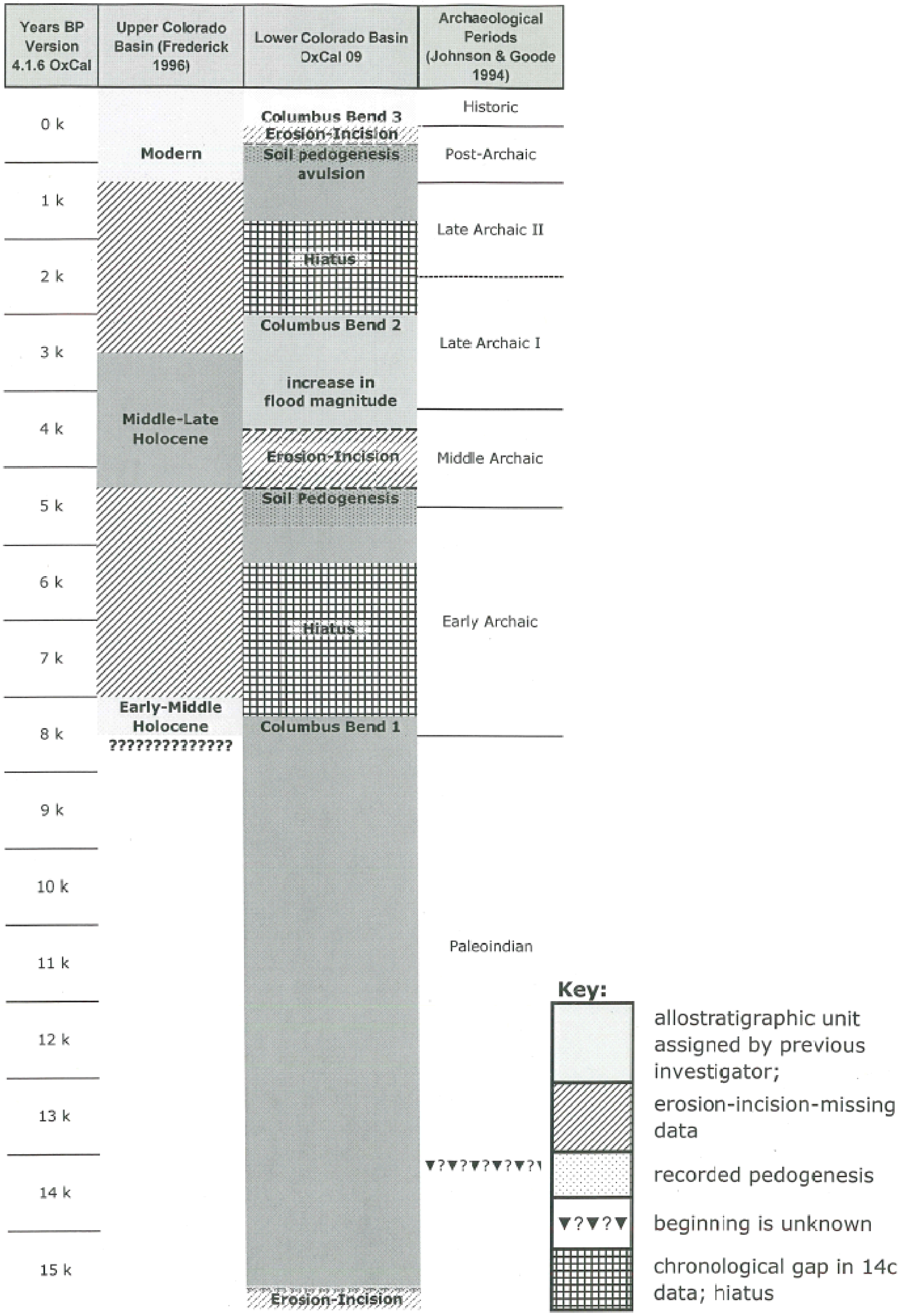


Figure 5.5 Calibrated Depositional History Colorado River Basin.

3340±90 and 3320±90 ^{14}C yr BP, respectively were collected from the Columbus Bend Member 2 veneer capping the soil (Figure 5.4b).

Unfortunately, these assays were not corrected for isotopic $\delta\ ^{13}$C fractionation. However, a radiocarbon assay (Tx-6810) of equivalent uncorrected radiocarbon age (i.e., 3330±90 ^{14}C yr BP) was corrected for fractionation and calibrated. This calibrated assay used as a proxy dated to 3830–3580 cal yr BP, which could be inferred to suggest that the increase in flood magnitude on the Colorado River occurred prior to this age (Table 5.2).

The Columbus Bend Member 2 continued deposition until roughly 900 cal yr BP when soil pedogenesis occurred between 890–710 cal yr BP. The overlying Columbus Bend Member 3 has a calibrated *terminus ante quem* of 540 cal yr BP suggesting an approximate 170-year gap between it and Columbus Bend Member 2. Again, the avulsion of the Colorado River, which abandoned the present day Caney Creek meander belt, may have taken place prior to the pedogenesis of the Columbus Bend Member 2 and before the deposition of the Columbus Bend Member 3, which continues up to the present.

The recalibration of the Lower Colorado River basin chronometric data when contrasting the initial investigation exhibits some notable trends. Typically, adjustments are limited to the older assays, but the recalibration of Blum's (1992) dataset exhibits shifts throughout all of the allostratigraphic members. These prevalent adjustments between the initial and recalibrated datasets are in no small part attributed to the fact that the initial ^{14}C assays were not calibrated. The most prominent adjustment occurs between the Eagle Lake and Columbus Bend 1 members (Figure 5.5). The Late Pleistocene Eagle Lake Member terminates sometime after 19,000 cal yr BP much older than previous interpreted. Similarly, the Columbus Bend Member 1 begins prior to 15,940 cal yr BP much earlier than initially proposed (i.e., ~13,000 ^{14}C yr BP). Also, the termination of Columbus Bend Member 1 occurred about 200–300 years earlier and followed by a gap of roughly 650 years before Columbus Bend Member 2 begins deposition.

The abandonment of the Columbus Bend Member 1 floodplain is interpreted to have been followed by a period of erosion, which seemingly occurred between 5,210–4,570 cal yr BP. The termination of Columbus Bend Member 2 has been shifted to end about 300 years more recently around 710 cal yr BP compared to the initial ~1,000 ^{14}C yr BP (Blum 1992, Blum and Valastro 1994). Finally, the beginning of Columbus Bend Member 3 occurred around 500 cal yr BP as opposed to ~1,000 ^{14}C yr BP separated by an approximate 200 year erosion after the abandonment of the Columbus Bend Member 2 floodplain.

Other observations during the recalibration of the lower extent of the Colorado River basin include several chronological gaps within the radiocarbon assays of Columbus Bend Members 1 and 2 (Figure 5.6). Two chronological gaps were observed in the Columbus Bend Member 1 between 11,940–8,790 cal yr BP and 8,410–5,840 cal yr BP and one recognized hiatus in Columbus Bend Member 2 between 3,010–1,660 cal yr BP. These lulls may be attributed to sampling rather than issues of geomorphic processes or preservation. To investigate this possibility an additional suite of radiocarbon assays from Blum's (1992) chronometric dataset were examined. Additional assays were gathered from Columbus Bend Members 1 and 2 regardless of whether their stratigraphic context could be determined and incorporated into the recalibration study. These data suggest that the 11,940–8,790 cal yr BP is the result of sampling as it

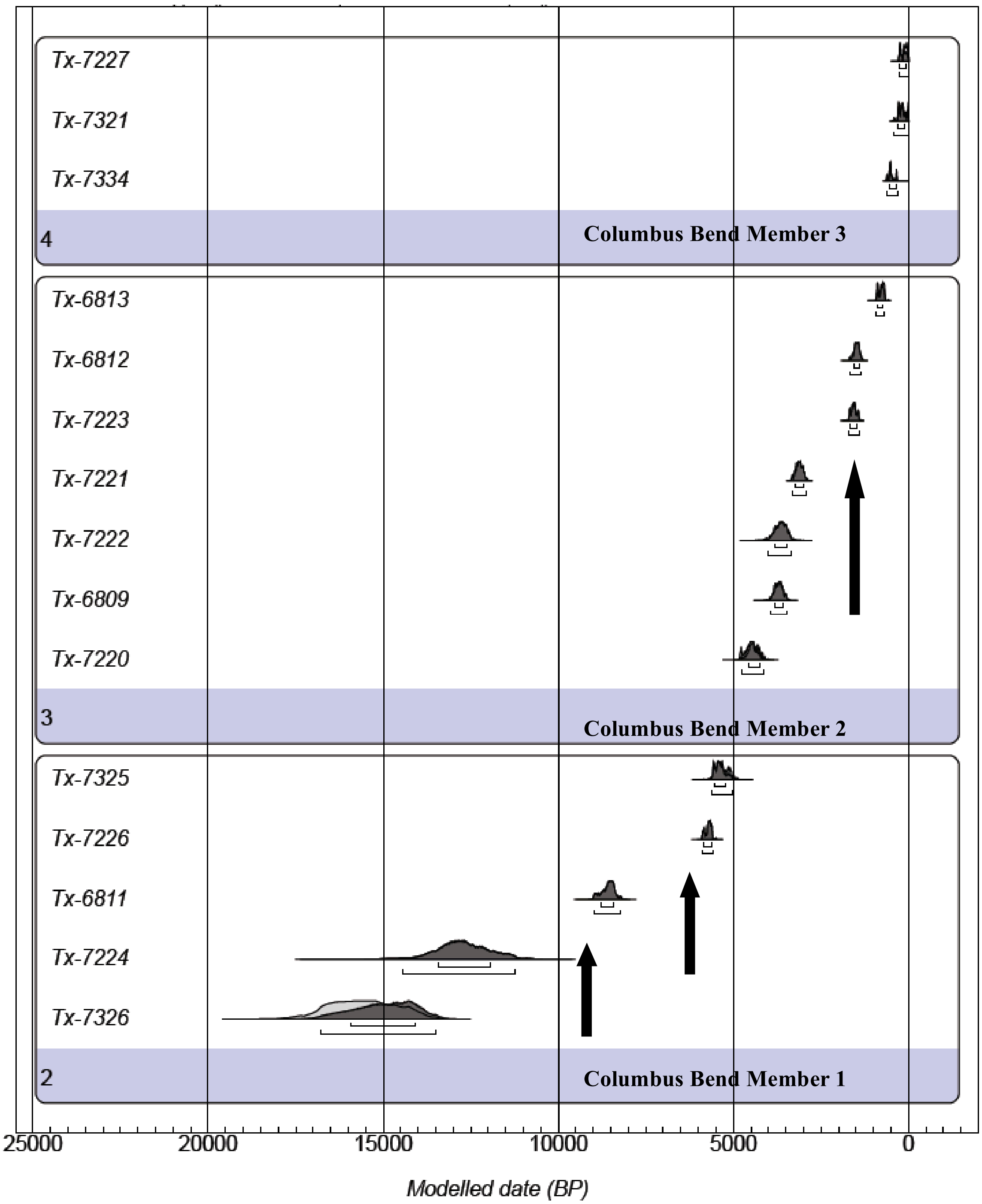


Figure 5.6 Select Calibration Plot of Lower Extent of Colorado River Basin; arrows indicate hiatus periods.

disappears with the introduction of the additional assays. However, the new data demonstrate that gaps at 8,410–6,310 cal yr BP and 3,010–1,880 cal yr BP remain. These chronologic lulls have narrowed down a little, but still suggest a hiatus in Columbus Bend Members 1 and 2. Again, the reason for these phenomena is undetermined if they are attributed to depositional processes, sampling, or a combination of these factors. Interestingly, these chronological gaps do correlate with similar lulls in other drainage basins. These temporal hiatuses, apparent correlations and possible causes are examined further and contrasted with other recalibrated analyses in Chapter 8.

CHAPTER 6

Recalibrated Geoarchaeological Framework within the Brazos River Basin of Texas

The Brazos River is the largest drainage within Texas extending about 1,200 miles (2,000 km) from its headwaters at Blackwater Draw in New Mexico to its terminus at the Gulf of Mexico at Freeport, Texas near Galveston (Figure 6.1). The Brazos River basin encompasses about 44,000 square miles (114, 000 km^2) and throughout its course drops in elevation about 4,600 feet (Epps 1973; Hendrickson 2010). The contributory network of drainages within the Brazos River is extensive. From upstream to downstream, several of the most significant contributing drainages of this large basin include Yellowhouse Draw, Blackwater Draw, Running Water Draw, Double Mountain Fork, Salt Fork, Clear Fork, Palo Pinto Creek, Bosque River, Leon River (with Henson Creek, Cowhouse Creek—Table Rock Creek—House Creek), Lampasas River, Little River (San Gabriel River—Brushy Creek and Salado Creek—Buttermilk Creek), Navasota River, and Oyster Creek. As a consequence of this vast network, the Brazos River and its tributaries crosses a diversity of physiographic settings between its genesis and conclusion. Trending south and east from its beginning in the High Plains, the basin crosses the Rolling Plains, the Cross Timbers and Prairies, across the alternating Blackland Prairies and Post Oak Savannah regions, and finally the Gulf Prairies and Marshes.

Previous Investigations

Possibly due to its size, the Brazos River basin is the most extensively investigated basin in Texas. As early as 1901, researchers have been evaluating and

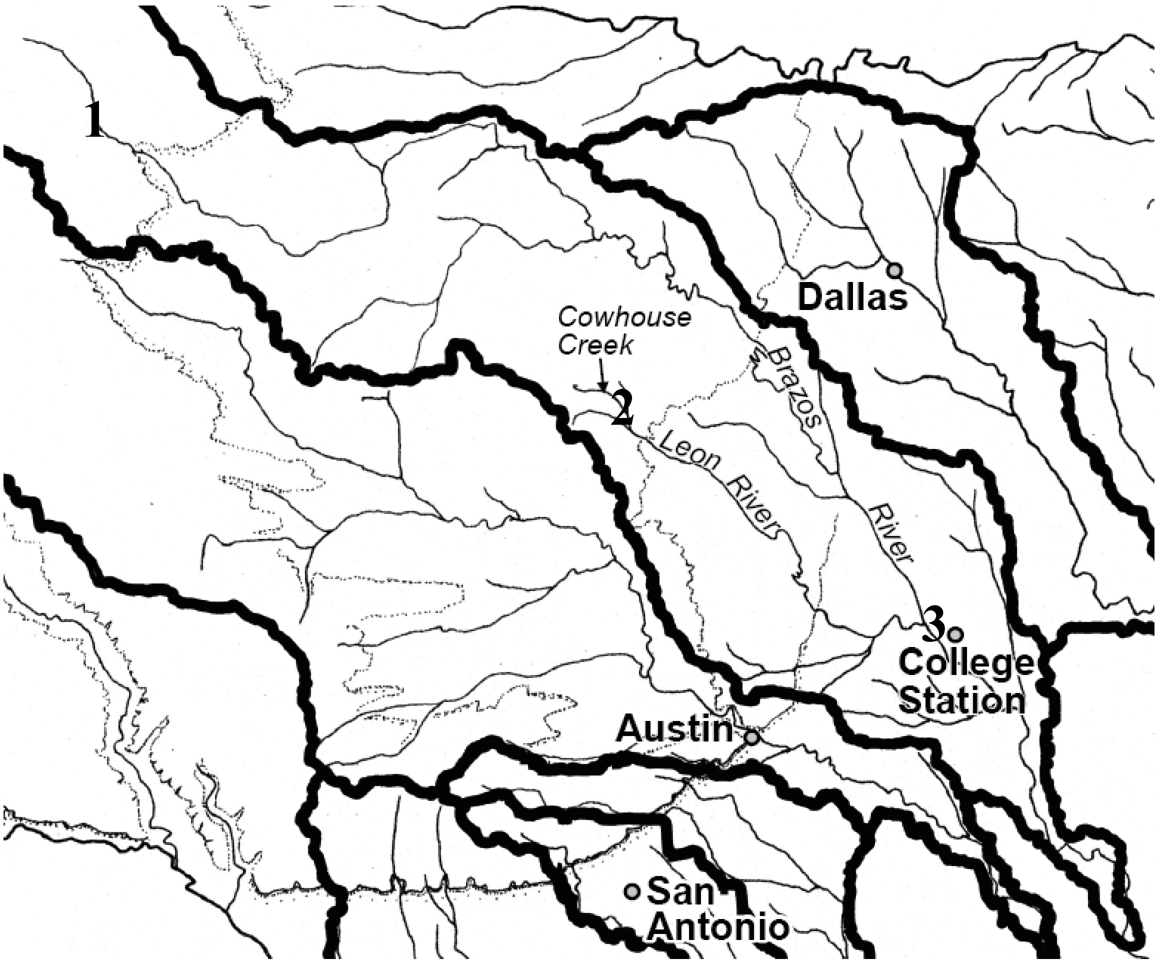


Figure 6.1 Overview of Brazos River Basin: 1) Lubbock Lake site, 2) Fort Hood, 3) and A&M study area.

documenting the basin, but the investigations prior to the 1950s lacked chronometric control (Hill 1901: 345—359). Subsequent to the introduction of ^{14}C analyses, relative temporal characterizations of drainage terrace deposits were then supplemented with absolute dating (Table 6.1). To be sure, there have been some substantial geomorphological investigations previously conducted, but a comparatively few of those truly considered the effects of the drainages on the archaeological sites. Within the Brazos River basin, the incorporation of geomorphic examinations into archaeological investigations (i.e., geoarchaeology) began early. These early concerted efforts employing archaeological geology occurred due to Early Man studies particularly at the Lubbock Lake site (41LU1) on a tributary of the Brazos River. Since that time, numerous significant geoarchaeological investigations have been carried out along the Brazos River and its tributaries. Although more investigations have been performed with some facet of geoarchaeology, but most of these were typically general reviews of the immediate site area focused primarily with site integrity or a similarly narrow focus (e.g., Alexander 2008; Gadus et al. 2006; Gibson 1997; Hilliard 1997; Pearl 1997).

The culmination of these previous geomorphic, geoarchaeological, and archaeological investigations are a collection of Late Quaternary stratigraphic history across the Brazos River basin. Several researchers have compiled a comprehensive review of the previous investigations in the upper extent (Holliday 2009, 2000, 1997; Mandel 1992:53–57), the middle extent (Nordt 1993, 1992), and the lower extent (Abbott 2000). Due to the broad geography of their coverage, the varied focus of those investigations and the span of time, only a select few of those research projects were selected for this study.

Table 6.1 Previous Georchaeological Investigations in the Brazos River Basin

Drainage Extent	Drainage	Resource(s)	Project-Site(s)	Geoarchaeologist or Researcher	Chronometric Data
Upper		Hill 1901		Robert Hill	Relative
Upper	Brazos River	Stricklin 1961		F. Stricklen	Relative
Upper	Yellowhouse Draw	Holliday 1985, 1988, 1995, 1997, 2000, 2009; Holliday and Johnson 1983, 1986, 1981; Holliday et al. 1983, 1985, 1999; Johnson and Holliday 1980; Stafford 1981,1983	Lubbock Lake site (41LU1)	V. Holliday, T. Stafford	14c; relatvie
Upper	Double Mountain Fork of Brazos River	Blum, Abbott, and Valastro 1992	Justiceburg Reservoir	Blum, Abbott, and Valastro	Radiocarbon
Upper	Clear Fork of the Brazos River	Mandel 1992	Southbend Reservoir	Rolfe Mandel	Radiocarbon
Upper		Ferring 1995b	Southern Plains	C. Reid Ferring	Radiocarbon
Middle	Brazos River-McLennan County	Bronaugh 1950	Thesis	R. Bronaugh	Relative
Middle	Brazos River	Epps 1973		L. W. Epps	Radiocarbon
Middle	North Bosque River	Brotherton 1978	Thesis	M. Brotherton	Relative
Middle	Brazos River	Nordt 1983	Thesis	L. Nordt	Relative
Middle	Brazos River	Woolly 1985	Thesis	B. Woolly	Relative
Middle	Brazos, Navasota, and Trinity Rivers	Nordt 1986	Article associated with 1983 thesis	L. Nordt	Relative
Middle	Aquilla Creek	Brown 1987	Aquilla Lake	Peter Patton	Relative
Middle	Leon River	Tharp 1988	Thesis	Tommy L. Tharp	Relative
Middle	Navasota River	Fields 1990	Jewett Mine-Charles Cox, Lambs Creek Knoll, and Buffalo Branch Sites	R. Fields, Bousman, et al	Radiocarbon
Middle	Navasota River	Fields, Klement, Bousman, Tomka, Gadus, and Howard 1991	Jewett Mine-Bottoms, Rena Branch, Moccasin Springs Sites	R. Fields, Bousman, et al	Radiocarbon
Middle	Cowhouse, Table Rock, and Henson Creeks	Nordt 1992	Ft. Hood	L. Nordt	Radiocarbon
Middle	Cowhouse, Table Rock, and Henson Creeks	Nordt 1993	Ft. Hood	L. Nordt	Radiocarbon
Middle	Cowhouse Creek	Nordt, Boutton, Hallmark, and Waters 1994	Ft. Hood	Nordt, Boutton, Hallmark, and Waters	Carbon isotopes; 14c
Middle	Henson Creek	Nordt 1995	Ft. Hood-Henson Creek	L. Nordt	Radiocarbon
Middle	Cowhouse Creek	Nordt 1996	Ft. Hood-Dissertation	L. Nordt	Stable C Isotopes

Table 6.1 Previous Georchaeological Investigations in the Brazos River Basin

Middle	Brazos River	Hilliard 1997	Waco Mammoth Site-Thesis	K. Lee Hilliard	Relative
Middle	Buttermilk Creek	Gibson 1997	Thesis	B. D. Gibson	Radiocarbon
Middle	Upper Lampasas	Pearl 1997	Thesis	F. Pearl	Radiocarbon
Middle	Cowhouse Creek	Nordt, Boutton, Hallmark, and Waters 1998	Ft. Hood-Pedogenic carbonate accumulations	Nordt, Hallmark, Wilding, and Boutton	Stable C Isotopes
Middle	Brushy Creek	Collins 1998	Wilson-Leonard (41WM235)	Bousman, Goldberg, Stafford, Collins	Radiocarbon and others
Middle	Owl Creek	Hilliard 2000	Ft. Hood GIS study	using L. Nordt data	Radiocarbon
Middle		Mehalchick, Kleinbach, Boyd, and Kibler 2000	Ft. Hood	L. Nordt	Radiocarbon
Middle	Little River	Mahoney and Tomka 2001; Nordt 2001b	41MM340 and 41MM341	L. Nordt	Radiocarbon
Middle	Brazos River	Prochnow 2001	Horn Shelter No. 2-Thesis	S. Prochnow	Radiocarbon
Middle	Brushy Creek	Abbott 2003	Blackland Prairie 41WM815	J. Abbott	Radiocarbon
Middle	Little River	Mahoney, Tomka, Mauldin, Shafer, Nordt, Greaves, and Galdeano 2003	41MM340	L. Nordt	Radiocarbon
Middle	Cowhouse Creek	Nordt 2004	Ft. Hood-Cowhouse Ck	L. Nordt	Radiocarbon
Middle	Cowhouse Creek	Campbell and Johnston 2004	Ft. Hood	using L. Nordt data	n/a
Middle	Brazos River	Gadus, Fields, and Kibler 2006	J. B. White Site (41MM341)	Karl Kibler ?	Radiocarbon
Middle	Brazos River	Bongino 2007	Waco Mammoth Site-Thesis	J. D. Bongino	Radiocarbon, OSL
Middle	Buttermilk Creek	Alexander 2008	Gault Site (41BL323)-Thesis	using L. Nordt data	Radiocarbon
Lower	Brazos River	Bernard, Major, Parrott, and Leblanc 1970	Bureau of Economic Geology	[illegible] B. S. Parrott, and R. J. [illegible]	Relative
Lower	Brazos-Coastal	Wilkinson and Basse 1978		Wilkinson and Basse	Radiocarbon
Lower	Brazos-Coastal	Aten 1983		L. Aten	Radiocarbon
Lower	Brazos River	Voellinger 1990	Thesis		Relative
Lower	Brazos River	Waters and Nordt 1995		M. Waters and L. Nordt	Radiocarbon
Lower	Brazos River	Miller 1995	MIDTEXAS pipeline	M. Waters and L. Nordt	Relative
Lower	Brazos River	Husain 1998		Syed Raziuddin Husain	Relative
Lower	Trinity-Coast	Abbott 2001	TxDOT Houston Area PALM	J. Abbott	corrected 14c; relative
Lower	Brazos River	Sylvia and Galloway 2006		D. Sylvia and W. Galloway	Thermoluminescence; Radiocarbon
Lower	Brazos River	Urista 2009	Vernor Mammoth Site-Thesis	Urista	Relative

(shaded) indicates study selected for recalibration

Using a modified basin divisions recognized by Epps (1973) and Nordt (1983), the Brazos River Basin is broken into three parts. Largely attributed to the underlying geology and physiography these sections consist of the Upper Extent, the Middle Extent, and the Lower Extent. Roughly outlined, the Upper Extent begins at Yellowhouse Draw (Lubbock Lake) in the High Plains and trends eastward off of the Llano Estacado across the Osage Plains until about the Parker and Hood County line. From this point, the Middle Extent trends south-southeast across the Cross Timbers and Blackland Prairie stopping just south of the margins of the Balcones Escarpment and the confluence of the Little and Brazos Rivers. At this point, the Lower Extent begins to cross the Gulf Prairies and Marshes of the Coastal Plain and runs southeastward until the Brazos River finally empties into the Gulf of Mexico near Freeport, Texas.

Upper Extent

One project conducted in the Upper Extent of the Brazos River Basin reexamined here is the Lubbock Lake investigations (Holliday 1997). In addition to the ^{14}C dating, this research of this project is relevant due to the extensive investigations of the Lubbock Lake site (41LU1) with the intent of characterizing the depositional history of the channels and surrounding landscape. The extensiveness and implications of the previous research at the Lubbock Lake site (41LU1) is not to be understated. The research at this locality is varied and prolific (e.g., Holliday 1985, 1988, 1995, 1997, 2000, 2009; Holliday and Johnson 1983, 1986, 1981; Holliday et al. 1983, 1985, 1999; Johnson and Holliday 1980; Stafford 1981,1983) and the following review does not intend to supersede previous research. Rather, this review is a compilation of previously identified stratigraphy and an examination of the chronometric analyses (Figure 6.2).

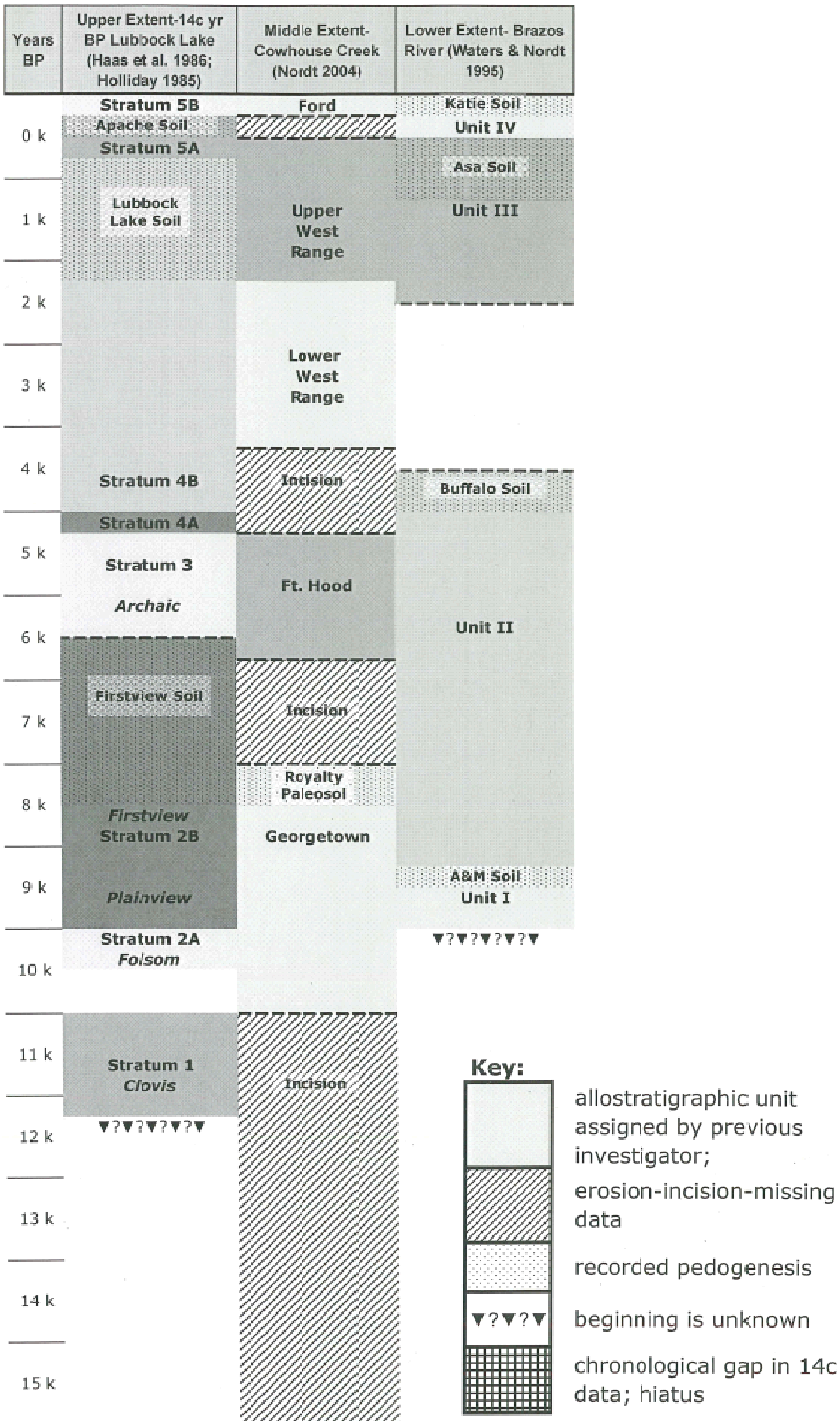


Figure 6.2 Initial Depositional History Brazos River Basin.

The Lubbock Lake site (41LU1) was first discovered in 1936 during excavations in the Yellowhouse Draw House for construction of a reservoir in Lubbock, Texas (Holliday 1997:76). These construction activities encountered evidence of Paleoindian occupations, which instigated investigations over subsequent decades. Various prominent researchers have comprehensively investigated the deposits at Lubbock Lake and along the Yellowhouse Draw drainage with some minor variations in interpretation. Generally, the stratigraphy at Lubbock Lake is characterized as having five primary strata (Strata 1–5) containing various internal horizons, and paleosols (Holliday 1997, 1985; Stafford 1981).

The oldest deposit recognized at Lubbock Lake is Stratum 1, which is described as alluvial deposits and possibly localized lacustrine deposits that contain Pleistocene fauna and Clovis cultural materials (Holliday 1985:1484–1486, 1997:78–83; Stafford 1981). Radiometric data for this stratum suggests it terminated sometime prior to 11,000 ^{14}C yr BP (Holliday 1985:1484). Above the first horizon is the complex Stratum 2 characterized as containing several internal horizons (Strata 2A, 2B, 2e, 2s, and 2F) composed of lacustrine, marsh, eolian, and possibly spring deposits and capped by the Firstview Soil, a paleosol (Figure 6.3). The horizons of Stratum 2 are interpreted to have been deposited roughly between 11,000–6,300 ^{14}C yr BP (Holliday 1985:1486–1487; Stafford 1981:552). The Firstview Soil is indicated to have developed approximately between 8,500–6,300 ^{14}C yr BP (Holliday 1985:1487). Situated above Stratum 2, is Stratum 3 recognized as having two distinct internal horizons with one composed of eolian deposits (3e) and a lacustrine deposit (3l) and capped by a buried soil identified as the Yellowhouse Soil (Holliday

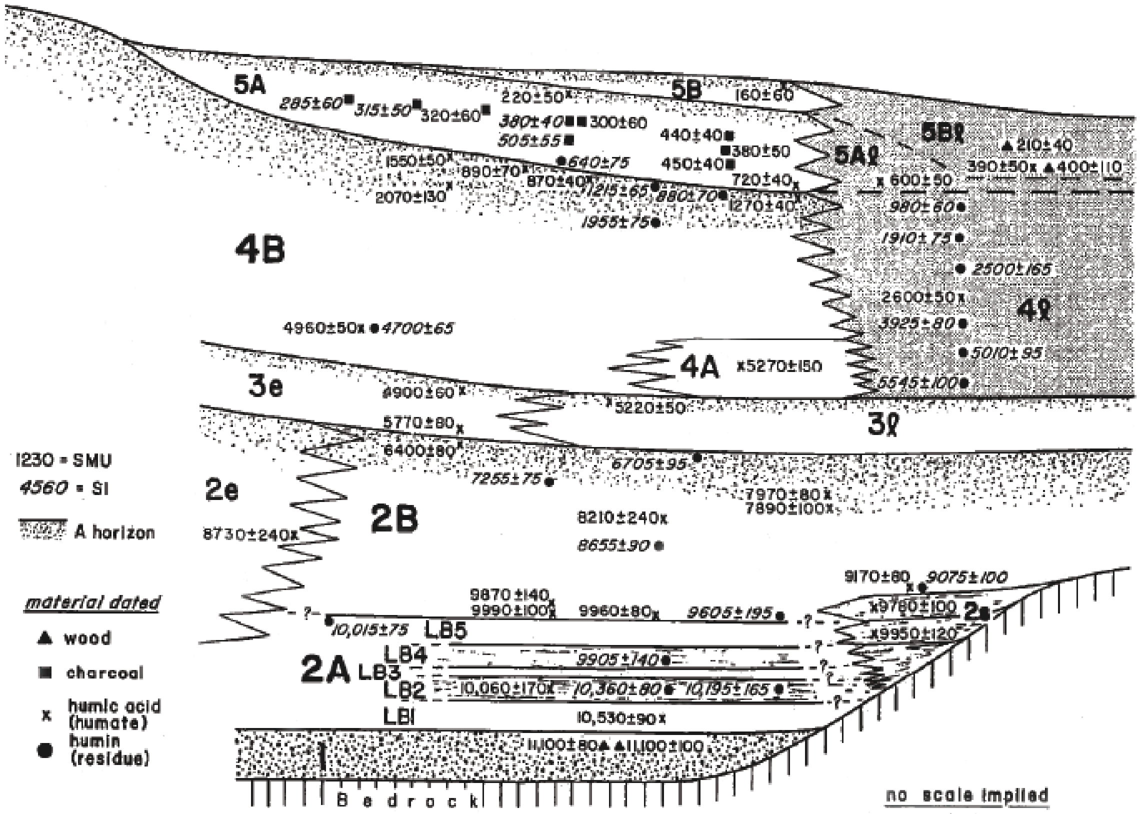


Figure 6.3 Idealized Profile of Lubbock Lake site (adapted from Haas et al. 1986: Figure 4).

1985:1487). Stratum 3 contains cultural materials from the Archaic period and is interpreted to have been deposited about 6,300 ^{14}C yr BP and capped by the overlying horizon about 5,500 ^{14}C yr BP (Holliday 1985:1488).

Unconformably overlying Stratum 3 is Stratum 4 composed of two internal horizons (i.e., Strata 4A and 4B) and capped by the Lubbock Lake Soil (Holliday 1985:1488–1489). The deposits of Strata 4A and 4B are described as spring and eolian deposits, respectively and contain cultural materials extending from the Middle Archaic to Late Prehistoric. Stratum 4 is interpreted to have been deposited between 5,500–4,500^{14}C yr BP followed by an extended period of stability represented by the Lubbock Lake Soil.

Subsequent to the extended period of stasis, the deposition of Stratum 5 began around 750 ^{14}C yr BP (Holliday 1985:1489). Stratum 5 is characterized as containing two internal horizons (Strata 5A and 5B) of lacustrine deposition each capped with the Apache and Singer soils, respectively. The Stratum 5 deposits contain Late Prehistoric to Historic cultural materials and continue up to modern times.

The general depositional sequence interpreted from these deposits argues that a period of incision occurred during the Late Pleistocene followed by the deposition of Stratum 1when the climate was wetter and cooler (Holliday 1985:1489–1492). A decrease in drainage discharge likely attributed to a reduction in moisture ushered in the lacustrine/marsh environment of Stratum 2. Researchers have varied interpretations for the cause of the impoundment of the Yellowhouse Draw at this time. Regardless of whether the static flow is from eolian deposits damming the channel (Holliday 1985, 1997; Holliday and Johnson 1983) or part of a natural pool (Stafford 1981, 1983) the

Yellowhouse Draw at this time was not flowing. The climate is interpreted to have become gradually warmer and drier in part attributed to eolian deposits at the end of Stratum 2 and throughout Strata 3 and 4 (Holliday 1985: Figure 7). The increasing presence of eolian deposits was interpreted to represent a decrease in vegetative cover and stasis to allow the development of the Yellowhouse Soil. A possible drought is interpreted to have occurred followed by a trend toward modern climatic conditions during Stratum 4. Some localized erosion (i.e., unconformity) is noted at the Strata 3 and 4 boundary that may reflect the return of some moisture and modern conditions. The modern climatic conditions are interpreted to have continued throughout Stratum 4 concurrent with the development of the Lubbock Lake Soil. The presence of colluvial slope wash in Stratum 5 may represent swings toward arid environments beginning about 1,000^{14}C yr BP.

Middle Extent

For a variety of reasons, the Middle Extent of the Brazos River Basin is the most extensively investigated region through geomorphological and geoarchaeological methods in Texas (Table 6.1). One factor is the prevalence of development within this portion of the basin, but most influential is the presence of the Fort Hood military reserve in Hood County. Archaeological and geoarchaeological research has been conducted for almost two decades within this military reserve. Various research within Fort Hood, which encompasses several significant tributaries of the Brazos River, has spawned numerous reports, articles, masters' theses, and doctoral dissertations (Campbell and Johnson 2004; Hilliard 2000; Mehalchick et al. 2000; Nordt 1992, 1993, 1995, 1996, 2004; Nordt et al. 1994; Nordt et al. 1998). This portion of the Brazos River Basin also contains two of Texas' more prominent prehistoric sites that have some exceptional stratigraphic records and have similarly influenced extensive research (Alexander 2008; Bousman 1998; Collins 1998; Gibson 1997; Goldberg and Holliday 1998). Specifically, Wilson-Leonard (41WM235) on Brushy Creek in Williamson County and the Gault Site (41BL323) on Buttermilk Creek in Bell County. The current research will consider select investigations conducted within Fort Hood on Cowhouse Creek.

Cowhouse Creek (Fort Hood)

Within Fort Hood, the geoarchaeological investigations have focused upon the Henson Creek, North Nolan Creek, Reese Creek, Cowhouse Creek and its tributaries Table Rock, Owl, and House Creeks and the Leon River, which they all eventually intercept. This research over the last two decades has gradually constructed a comprehensive depositional history for the region as well as systematically evaluated a diversity of settings and drainages ranging in size from upland tributaries to their associated lowland trunk channels.

The culmination of these previous investigations of the Fort Hood drainages has identified four late quaternary landforms (designated T_3 to T_0) that contain six allostratigraphic units (Nordt 1992, 1993, 1995, 2004). From oldest to most recent, Nordt (1992, 2004) recognizes the Pleistocene Reserve alluvium only observed on the Leon River, the middle-late Pleistocene Jackson alluvium, the early Holocene Georgetown alluvium, the middle Holocene Fort Hood alluvium, the late Holocene West Range alluvium, and the recent Ford alluvium (Figure 6.4). Further, the West Range unit is occasionally divided into Upper and Lower West Range units interpreted to be separated by an erosional disconformity (Nordt 1992, 2004). These investigations have also documented several buried soils (i.e., paleosols) within the drainages. Within Cowhouse

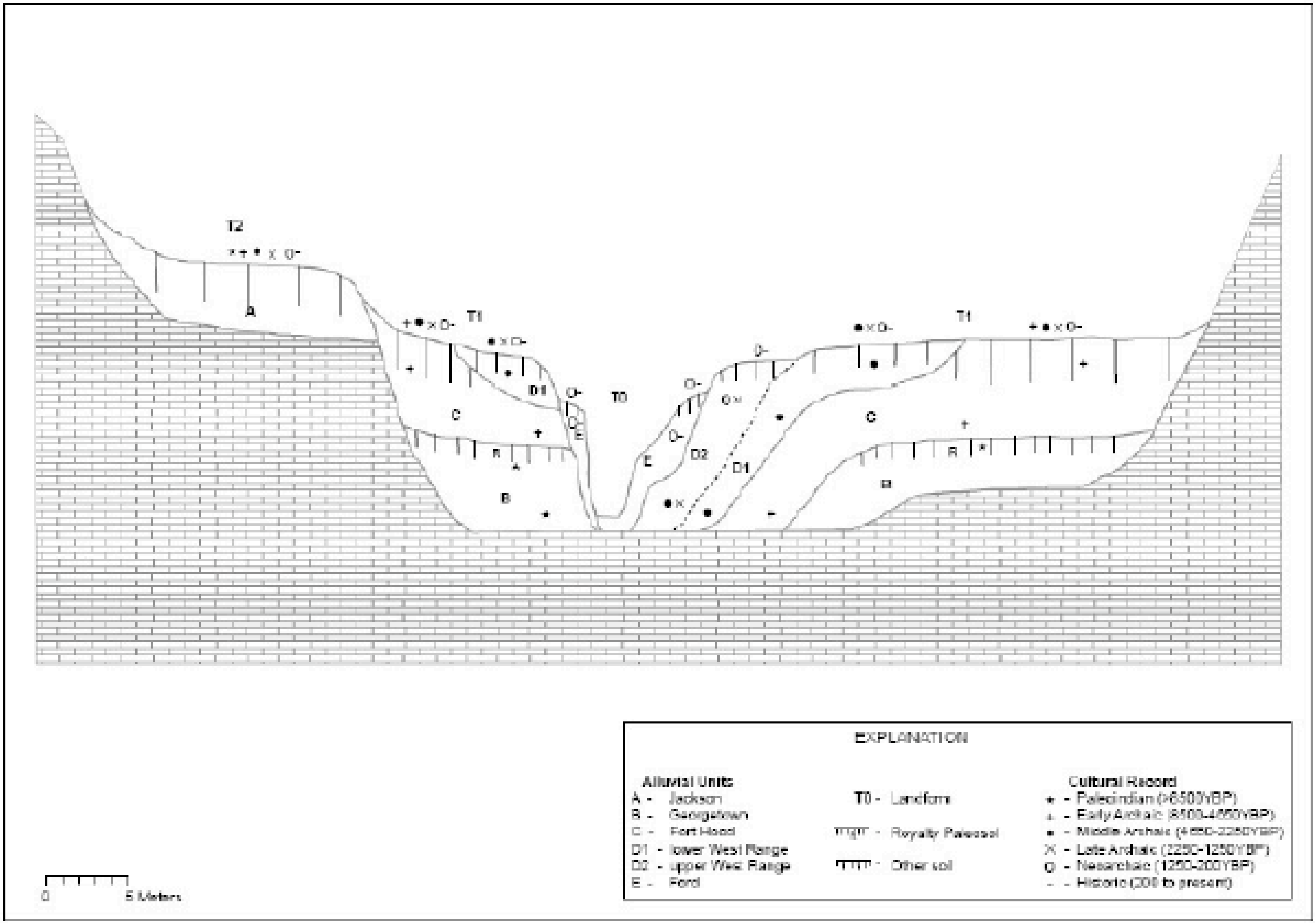


Figure 6.4 **Idealized Cross-section of Cowhouse Creek** (adapted from Nordt 1992: Figure 29)
29).

Creek and its tributaries, the Royalty Paleosol is recorded at the top of the Georgetown unit (Nordt 2004). Similarly, Henson Creek contains the Royalty Paleosol and the Tanktrail Paleosol at the top of the Upper West Range unit (Nordt 1995). The chronology of these stratigraphic units is derived from a series of ^{14}C analyses (Nordt 1992: Appendix J).

The oldest allostratigraphic unit identified in the Fort Hood study area is the Jackson alluvium identified resting on Glen Rose limestone and composes the T_2 terrace along the investigated drainages (Nordt 1992, 1993, 1995, 2004). The chronometric data for the Jackson alluvium is provided by a single bulk sediment humate sample roughly dating 15,000 ^{14}C yr BP indicating deposition occurred during the Late Pleistocene (Nordt 2004: Table 1). Nordt (2004:296–297) indicates that a period of incision-erosion occurred before the construction of the second allostratigraphic unit (Georgetown alluvium).

The Georgetown alluvium, which composes the T_1 terrace in the study area, is identified as early Holocene. Eight radiocarbon samples have been collected from this unit, but only two (Beta-63007 and GX-15762) are uncontaminated charcoal (Table 6.2). The remaining samples are from bulk soil humate and have not been used in this study. The two charcoal samples date to about 8,900 ^{14}C yr BP and 8,300^{14}C yr BP, respectively. Capping the Georgetown alluvium is the Royalty paleosol (Nordt 2004). Subsequent and possibly concurrent to the development of the Royalty paleosol, a dramatic decrease in hydrologic flow occurred particularly along Cowhouse Creek that partially eroded this paleosol (Nordt 2004:297).

Table 6.2 Radiocarbon Data for Brazos River Basin

Locality	Lab#	13c Adjusted 14c yr BP	Dev +/-	Depth (m)	δ 13 C	Material sampled	Initial 68.2%	Initial 95.4%	IntCal09 68.2%	IntCal09 95.4%
Upper Extent Brazos River Basin										
Yellowhouse Draw-Lubbock Lake site (41LU1) Stratum 1 (Haas et al. 1986:Table 1; Holliday et al. 1983, 1985)										
1, Area 2	SMU-548	11100	100			wood	9150 BC		13080-12850	13170-12740
1C	SMU-263	11100	80			wood			13080-12850	13170-12740
Yellowhouse Draw-Lubbock Lake site (41LU1) Stratum 2A (Haas et al. 1986:Table 1; Holliday et al. 1983, 1985)										
2ALB2, Area 6	SI-4976	10195	165			humin	8245 BC		12190-11740	12400-11560
2ALB4, Area 6	SI-4975	9905	140			humin	7955 BC		11950-11610	12080-11490
2ALB1, Area 2	SMU-285	10530	90			humic acid	8580 BC		12460-12140	12570-12050
2ALB2, Area 6	SI-3200	10360	80			humin	8410 BC		12330-12040	12450-11850
2ALB2, Area 3	SMU-251	10060	170			humic acid	8110 BC		12070-11670	12340-11520
2A, upper, Tr90	SI-3203	10015	75			humin, organic mud	8065 BC		11920-11600	11990-11480
Yellowhouse Draw-Lubbock Lake site (41LU1) Stratum 2B (Haas et al. 1986:Table 1; Holliday et al. 1983, 1985)										
2B, base, Area 6	SI-4974	9605	195			humin	7655 BC		11170-10660	11380-10390
2B, base, Area 6	SMU-828	9870	140			humic acid	7920 BC		11420-11110	11590-10810
2B, base, Area 5	SMU-829	9170	80			humic acid	7220 BC		10470-10260	10560-10210
2B, base, Area 5	SI-4179	9075	100			humin	7125 BC		10390-10070	10510-9910
2B, base, Area 6	SMU-728	9990	100			humic acid	8040 BC		11490-11270	11620-11220
2B, base, Area 2	SMU-275	9960	80			humic acid	8010 BC		11470-11270	11600-11230
2B, upper, Area 6	SI-4177	8655	90			humin, organic mud	6705 BC		9820-9560	10080-9500
2B, upper, Area 6	SMU-830	8210	240			humic acid	6260 BC		9420-8800	9760-8560
2B, upper, Area 3	SMU-302	7890	100			humic acid	5940 BC		8920-8600	9000-8470
2B, upper, Area 3	SMU-262	7970	80			humic acid	6020 BC		8960-8680	9030-8600
2B, upper, Tr90	SI-3204	7255	75			humin	5305 BC		8160-8000	8270-7950
2B, upper, Area 6	SI-4178	6705	95			humin	7880-7260 BP		7650-7490	7750-7430

Table 6.2 Radiocarbon Data for Brazos River Basin

2B, upper, Tr108	SMU-544	6400	80			humic acid	7555-7030 BP		7420-7270	7480-7180
Yellowhouse Draw-Lubbock Lake site (41LU1) Stratum 3 (Haas et al. 1986:Table 1; Holliday et al. 1983, 1985)										
3l, Tr49	SMU-1093	5220	50			A Horizon, humic acid	4325-3805 BC		6100-5930	6180-5910
3e, Tr108	SMU-545	5770	80			humic acid	6895-6375 BP		6630-6440	6720-6340
3e, Tr108	SMU-531	4900	60			A Horizon, humic acid	5830-5350 BP		5890-5830	5900-5740
Yellowhouse Draw-Lubbock Lake site (41LU1) Stratum 4A (Haas et al. 1986:Table 1; Holliday et al. 1983, 1985)										
4A, Tr116	SMU-1200	5270	150			humic acid	4420-3780 BC		5810-5720	5850-5660
Yellowhouse Draw-Lubbock Lake site (41LU1) Stratum 4B (Haas et al. 1986:Table 1; Holliday et al. 1983, 1985)										
4B, Tr108E	SMU-1191	2070	130			A Horizon, humic acid	4085-625 BP		2240-1900	2340-1740
4B, Tr108E	SMU-1177	1550	50			A Horizon, humic acid	1465-1365 BP, 1515-1415 BP		1510-1380	1550-1340
4B, Area 7	SMU-1090	1270	40			A Horizon, humic acid	1225-1145 BP, 1240-1160 BP, 1275-1195 BP, 1295-1215 BP		1260-1150	1290-1080
4B, Area 16	SMU-492	4960	50			humic acid	5845-5595 BP		5690-5610	5730-5590
4B, Area 16	SI-4171	4700	65			humin	5710-5500 BP		5550-5340	5580-5310
4B, Tr59	SI-4174	1955	75			A horizon, humin	2015-1835 BP, 1975-1815 BP		2000-1820	2110-1720
4B, Tr59	SI-3201	1215	65			A horizon, humin	1255-1115 BP		1230-1060	1280-980
4B, Tr108	SMU-651	890	70			A horizon, humic acid	870-710 BP		900-750	940-700
4B, Area 8	SI-4169	880	70			A horizon, humin	870-710 BP, 835-696 BP		900-750	930-700
4B, Tr108	SMU-534	870	40			A horizon, humic acid	835-735 BP, 810-710 BP		890-740	910-700
Yellowhouse Draw-Lubbock Lake site (41LU1) Stratum 5A (Haas et al. 1986:Table 1; Holliday et al. 1983, 1985)										
5A, Area 7	SMU-893	450	50	19		charcoal, GA7-5	550-470 BP		530-450	550-340
5A, Area 7	SMU-970	380	50	21		charcoal, GA7-5	525-425 BP		490-360	520-320
5A, Area 7	SMU-968	440	40	20		charcoal, GA7-5	560-460 BP		520-460	540-340
5A, Area 7	SMU-314	720	40	19		A Horizon, humic acid	720-620 BP		650-560	680-550
5A, Area 8	SI-3208	640	75	19		A horizon, humin	730-570 BP, 660-500 BP, 650-490 BP		610-540	660-510
5A, Area 8	SI-2701	505	55	20		charcoal	590-470 BP		560-500	630-450

Table 6.2 Radiocarbon Data for Brazos River Basin

5A, Area 8	SI-2700	380	40	20		charcoal	525-425 BP		490-360	510-320
5A, Area 19	SMU-546	320	60	21		charcoal	440-320 BP, 395-255 BP		470-350	500-360
5A, Area 14	SI-2704	315	50	21		charcoal	475-375 BP, 440-340 BP, 385-265 BP		460-350	500-300
5A, Area 8	SMU-345	300	60	21		charcoal	475-355 BP, 470-350 BP, 390-250 BP		460-350	500-300
5A, Area 15	SI-2703	285	60	21		charcoal	390-250 BP		460-350	500-290
5A, Tr108	SMU-555	220	50	22		A Horizon, humic acid	355-235 BP		430-300	470-270
5A, Area 7	I-208	160	90	23		bone, bison				
Yellowhouse Draw-Lubbock Lake site (41LU1) Stratum 5B (Haas et al. 1986:Table 1; Holliday et al. 1983, 1985)										
5B, Area 7	SMU-343	160	60			A Horizon, humic acid			230-30	300- -10
Middle Extent Brazos River Basin										
Ft Hood- Stratigraphic Unit A -Jackson Alluvium (Nordt 2004: Table 1)										
Cowhouse ck; CB10	Beta-38694	15270	260	2.9		Bulk sediment-humate			18680-18080	18960-17790
Ft Hood- Stratigraphic Unit B- Georgetown Alluvium (Nordt 2004: Table 1)										
Cowhouse ck; CB2	Beta-63007	8830	70	6.71		Charcoal-hearth			10100-9750	10170-9630
Ft Hood-Stratigraphic Unit C- Ft Hood Alluvium (Nordt 2004: Table 1)										
Cowhouse ck; CB6	Beta-37618	6850	90	6.25	-19.3	Charcoal-dispersed			7780-7600	7890-7520
Cowhouse Ck; CB15	Beta-46192	5820	110	6.84		Bulk sediment-humate-hearth			6770-6500	6910-6390
Cowhouse Ck; CB15	GX-15892	5740	300	3.79	-16.3	Charcoal-midden			6960-6290	7280-5990
Cowhouse Ck; CB12	Beta-37452	5210	230	1.62	-16.5	Charcoal-hearth			6350-5860	6620-5640
Ft Hood-Stratigraphic Unit D1- (Lower) West Range Alluvium (Nordt 2004: Table 1)										
Cowhouse Ck; CB9	TX-6705	4170	100	6	-18.5	Charcoal-dispersed			4790-4520	4890-4420
Cowhouse Ck; CB13a	TX-6704	3950	290	7.05	-18.5	Charcoal-dispersed			4680-3980	4980-3650
Cowhouse Ck; TR11	TX-6703	3010	110	2.3		Charcoal-hearth			3330-3030	3440-2900
Cowhouse Ck; CB13a	Beta-38173	2860	50	1.79		Charcoal-dispersed			3070-2910	3170-2860

Table 6.2 Radiocarbon Data for Brazos River Basin

Cowhouse Ck; CB17	Beta-37451	2720	110	1.47		Charcoal-hearth			3040-2790	3200-2700
Ft Hood-Stratigraphic Unit D2- (Upper) West Range Alluvium (Nordt 2004: Table 1)										
Cowhouse Ck; CB1	TX-6702	2380	150	8.3		Charcoal-dispersed			2430-2060	2620-1910
Cowhouse Ck; CB18	Beta-37156	1820	80	1.1		Charcoal-hearth			1850-1640	1930-1560
Cowhouse Ck; CB16	Beta-37450	1690	90	2.75	-19.2	Charcoal-hearth			1710-1480	1820-1390
Cowhouse Ck; CB14	Beta-38174	1500	60	5.71		Charcoal-dispersed			1490-1330	1530-1300
Cowhouse Ck; CB4	TX-6701	650	160	4.05		Charcoaol-hearth			830-580	940-510
Cowhouse Ck; CB13a	TX-6700	600	140	0.47	-20.3	Charcoal-hearth			750-570	900-500
Ft Hood-Stratigraphic Unit E- Ford Alluvium (Nordt 2004: Table 1)										
Cowhouse Ck; CB3	Beta-38177	390	60	3.14		wood			450-320	500-300
Cowhouse Ck; CB5	TX-6699	370	180	2	-19	Charcoal-dispersed			440-290	500-120
Cowhouse Ck; CB7	TX-6697	300	100	3.1		Charcoal-dispersed			440-290	490-150
Cowhouse Ck; TR18	Beta-37008	190	90	1.8		Charcoal-hearth			420-220	470-70
Lower Extent Brazos River Basin										
Allostratigraphic Unit I (Waters & Nordt 1995: Table 1)										
	SMU-1754	17730	130		-27.5	Wood			21450-20970	21500-20770
Buffalo Ranch-**A&M Soil**	A-7513	8465	100		-15	Soil	9544-9406	9635-9272	9550-9400	9660-9260
Hearth in **A&M Soil**	GX-15417	8390	330		-24.1	Charcoal	9516-9324	9585-9151	9570-9320	9830-9160
Allostratigraphic Unit II (Waters & Nordt 1995: Table 1)										
County Road Locality	A-7511	8145	75		-29.1	Wood	9148-8989	9265-8771	9200-8810	9270-8770
Hearth in County Road Locality	A-6401	6480	100		-26.1	Charcoal	7477-7301	7572-7244	7480-7290	7580-7170
Hearth in **Buffalo Soil**	A-7510	4185	55		-25.6	Charcoal	4836-4787,4763-4690,4677-4644	4851-4570	4840-4640	4860-4570
Allostratigraphic Unit III (Waters & Nordt 1995: Table 1)										
Log in **A&M soil**	GX-15415	2505	75		-27.1	Wood	2640-2459 (52.3%)	2731-2357	2650-2360	2740-2350
Charcoal at Berger Farm	A-7509	1405	145		-25.4	Charcoal	1520-1429 (19.9%), 1426-1261 (48.3%)	1626-1098	1520-1170	1620-980

Table 6.2 Radiocarbon Data for Brazos River Basin

Goodland Farm- **Asa Soil**	GX-15418	1320	170		-16.4	Soil	1301-1054	1415-916	1390-1010	1610-910
Hearth in **Asa soil**	A-6400	880	50		-26.1	Charcoal	910-854 (37.7%), 828-813 (7.9%), 799-755 (22.7%)	925-727	910-740	930-720
Allostatigraphic Unit IV (Waters & Nordt 1995: Table 1)										
Goodland Farm-log	GX-15416	530	70		-23.7	Wood	556-502	633-466	560-460	630-320
Debris/twigs Goodland Farm	GX-15422	430	70		-26.5	Wood	525-475	550-425	530-340	540-320
Goodland Farm-log	GX-15420	400	70		-25.5	Wood	504-438	520-365	520-330	530-320
Goodland Farm-log	GX-15419	315	70		-28.8	Wood	485-390	497-312	500-390	510-310
Debris/twigs Goodland Farm	GX-15421	270	70		-26.3	Wood	460-358 (58.0%), 319-296 (10.2%)	495-266	500-380	510-290

*standard value of -25.0 assumed by previous investigators

**radiocarbon date not listed on original table

***duplicate sample number in original text

After the brief erosional event, the Fort Hood alluvium began to be deposited upon the Georgetown alluvium (Nordt 2004). This alluvial unit composes the majority of the T_1 terrace and had 12 radiocarbon samples to provide chronometric data. Half of these samples were charcoal and primarily date to 6,900–4,700 ^{14}C yr BP. One sample (GX-15760) collected from the Leon River investigations dates to 8,600 ^{14}C yr BP, which temporally overlaps with the older Georgetown alluvium. The construction of the Fort Hood alluvium ended during another change in hydrologic flow coupled with an erosional event.

Above the Fort Hood alluvium on the T_1 terrace on Cowhouse Creek is the West Range alluvium unit. Frequently recognized as two separate units (upper and lower), this allostratigraphic unit has had the most radiocarbon samples (n=29) collected from it within the Fort Hood study area. Sixteen of these samples are derived from charcoal and primarily date from 4,200–600 ^{14}C yr BP. The division between the upper and lower West Range alluvium is interpreted to be a very brief erosional event and an increase in hydrologic flow occurring around 2,400 ^{14}C yr BP (Nordt 2004:297). Subsequent to that, the Upper West Range alluvium is indicated to have a coarser bed load from the increased flow. Capping the Upper West Range in some locations (Henson Creek) is a buried soil identified as the Tanktrail paleosol (Nordt 1995). Further, only the Upper West Range division was identified on Henson Creek, which occupied the T_0 landform and not the T_1 as identified on the larger Cowhouse Creek (Nordt 1995, 2004). The absence of the Lower West Range on Henson Creek is likely attributed to a complete removal from the brief erosional event around 2,400 ^{14}C yr BP (Nordt 1995:214). The West Range alluvium ended during another erosional event around 600 ^{14}C yr BP, which incised into underlying bedrock beginning the modern Cowhouse Creek floodplain (Nordt 2004:297).

Finally, above the West Range alluvium forming the modern Cowhouse Creek floodplain and current allostratigraphic unit is the Ford alluvium. This alluvial unit composes the T_0 terrace and has 12 radiocarbon samples to provide chronometric data. These samples, all derived from charcoal or wood, date from 700–200 ^{14}C yr BP However, using only those samples from the Cowhouse Creek drainage Nordt (2004) correlates the Ford alluvium to encompass 400 ^{14}C yr BP to the present.

Lower Extent

Numerous geomorphic examinations have been conducted along the Lower Extent of the Brazos River Basin. One of the most significant is Abbott's (2001) synthesis of regional geoarchaeology, which provides an exceptional review of previous research for the lower extent of the basin as well as the Gulf Coast. This research examined the Late Quaternary stratigraphy and various geomorphic processes of the Houston area. Further, Abbott (2001) cogently characterized the affects of the processes upon the cultural resources within this area and developed a model for evaluating the likelihood for the presence and integrity of archaeological resources. Although these investigations did have chronometric data, it was not a primary component of the research.

Similarly, most of the other geomorphic investigations in the lower basin have not undertaken extensive chronometric analysis (e.g., Husain 1998; Nordt 1983, 1986). One exception is a project conducted in the mid-1990s that did examine a suite of radiocarbon samples with the intent of characterizing the depositional history of the basin. The research conducted by Waters and Nordt (1995) compared allostratigraphic units they had identified in the Brazos River study area with other drainage basins in the region. The researchers investigated a 75 km segment of the Brazos River between the cities of Hammond and Navasota and west of College Station, Texas. These investigations involved the examination of numerous drainage profiles as well as documentation of six cutbank exposures and the collection of charcoal and bulk sediment samples for chronometric analyses.

<u>Brazos River (A & M Study area)</u>

The culmination of these investigations was the identification of a complex depositional history of the Brazos River that extended into the Late Pleistocene, which exhibited multiple allostratigraphic units (Figure 6.5). The researchers interpreted the stratigraphy in the examined floodplain to have five allostratigraphic units (i.e., Units I–V) bounded by erosional disconformities and buried soils (Waters and Nordt 1995:311–312). The chronometric analyses for this study consisted of 15 radiocarbon samples composed of wood and charcoal and two sediment humate samples (Waters and Nordt 1995:315). Although the researchers calibrated these radiocarbon results to calendar years, they reported the results in radiocarbon years.

The earliest allostratigraphic unit (Unit I) is situated upon Tertiary bedrock and had three radiocarbon samples (two wood and one bulk sediment humate) that ranged from approximately 18,000–8,400 ^{14}C yr BP (Waters and Nordt 1995:Table 1). Two of the radiocarbon samples were collected from a buried soil (A&M soil), which capped Unit I interpreted to be the *terminus post quem* for this allostratigraphic unit at roughly

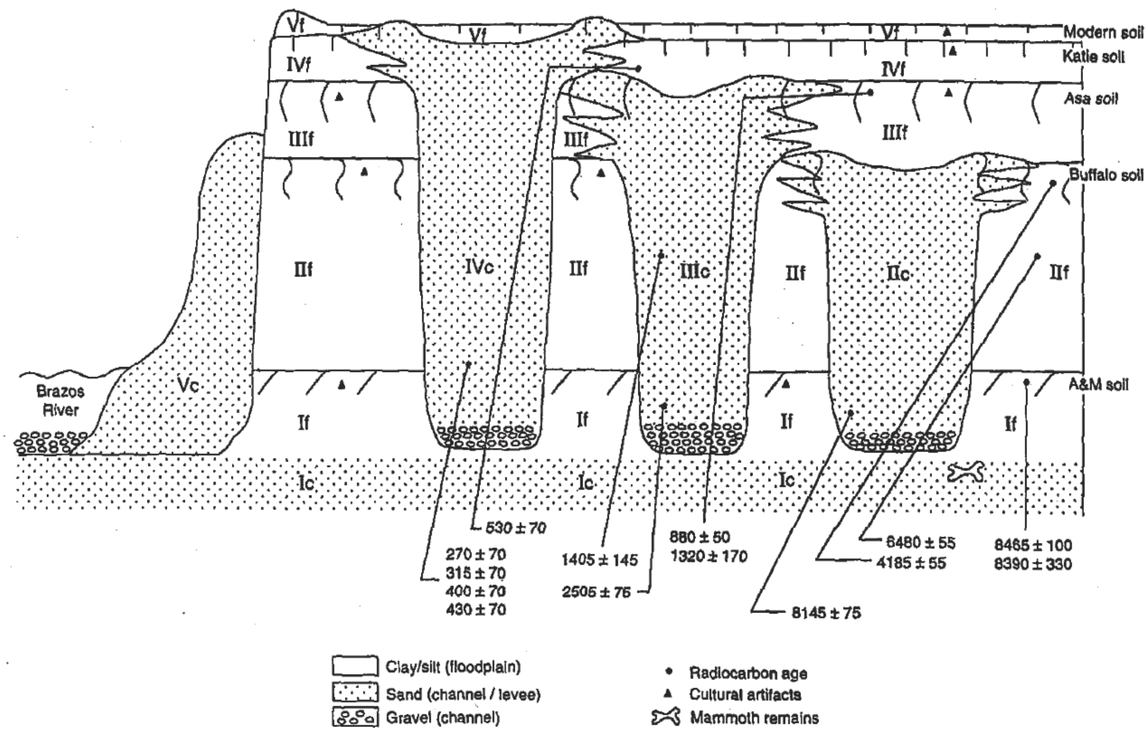


Figure 6.5 Idealized Cross-section of Brazos River at A&M study area (adapted from Waters and Nordt 1995: Figure 3).

8,400 ^{14}C yr BP. Notably, one of the samples (GX-15417) came from a cultural feature within the A&M paleosol, which caps Unit I (Waters and Nordt 1995:313).

The second allostratigraphic unit (Unit II) rests unconformably above Unit I suggesting a period of erosion between the end of Unit I and the beginning of Unit II (Waters and Nordt 1995:315–316). The researchers interpreted this break as a decrease in hydrologic discharge along the Brazos River citing a smaller channel and decrease in lateral movement of the drainage. Three radiocarbon samples were collected from Unit II ranging from 8,100–4,200 ^{14}C yr BP. One of the radiocarbon samples (i.e., AA-12579) was collected from a cultural feature within a buried soil (Buffalo soil) that caps Unit II and marks the *terminus post quem* for this unit at about 4,200 ^{14}C yr BP.

The third allostratigraphic unit (Unit III) is unconformably situated above Unit II, which in places has eroded the Buffalo soil (Waters and Nordt 1995:314–315). The researchers interpret this erosion as an avulsion event that terminated the stable period of the Buffalo soil and began Unit III. The chronological data for the third allostratigraphic unit consists of four samples that range from 2,500–900 ^{14}C yr BP. Unit III is capped by a buried soil (Asa soil) from which two radiocarbon samples were collected. One sample at the base of the Asa soil was a bulk soil sample (i.e., GX-15418) dating to roughly 1,300 ^{14}C yr BP while the second sample (i.e., A-6400) was collected from a cultural feature and marks the *terminus post quem* for Unit II at about 900 ^{14}C yr BP. Notably, temporally diagnostic artifacts were recognized at both the top and bottom of the Asa paleosol. Near the base, a Middle to Transitional Archaic Gary/Kent projectile point interpreted to range from 4,450–1,450 cal yr BP was observed while Late Prehistoric Scallorn and Perdiz artifacts interpreted to range from 1,250–450 cal yr BP were observed at the top of the Asa paleosol (Turner and Hester 1999). Simply put, the diagnostic artifacts provide a broad range of 4,450–450 cal yr BP for the Asa paleosol while the radiocarbon analyses indicate a much more refined range of 1,300–900 ^{14}C yr BP for the buried soil.

Overlying Unit III is the fourth allostratigraphic unit (Unit IV), which has five radiocarbon samples all from wood that roughly range from 530–300 ^{14}C yr BP (Waters and Nordt 1995: Table 1). Unit IV is also capped by a buried soil (Katie soil), which the authors describe as ‘weakly developed’ (Waters and Nordt 1995:315).

The final allostratigraphic unit is Unit V and represents the modern floodplain surface (Waters and Nordt 1995:315). This unit is characterized as a thin drape capping Unit IV and is interpreted to have began deposition approximately 300 years ago (Waters and Nordt 1995:315).

Overall, the authors briefly summarize the history of the Brazos River study area (Waters and Nordt 1995:316). Sometime in the Late Pleistocene around 18,000 ^{14}C yr BP, a large and widely migrating Brazos River deposited Unit I. By the beginning of the Holocene about 8,400 ^{14}C yr BP this unit had a period of stability, which developed the A&M soil. Between 8,400–8,100 ^{14}C yr BP, the Brazos River avulsed and decreased in hydrologic flow and began depositing Unit II. The deposition of this unit continued until roughly 4,200 ^{14}C yr BP when a period of stability occurred developing the Buffalo soil. Possibly lasting until 2,500 ^{14}C yr BP, the stability ended when the Brazos River avulsed again severely eroding the Buffalo soil and began depositing Unit III. The construction of Unit III continued until roughly 1,250 ^{14}C yr BP when the Brazos River entered a period of stability, which developed the Asa paleosol. At approximately 500 ^{14}C yr BP, the river avulsed again forming Unit IV that lasted until about 300 ^{14}C yr BP when the Katie paleosol developed. The modern unit (Unit V) began deposition at roughly 300 ^{14}C yr BP with the latest avulsion of the Brazos River forming the modern drainage channel.

Calibration Results

The radiocarbon datasets for the previously reviewed Upper, Middle, and Lower Extents of the Brazos River Basin were recalibrated. Beginning at the Lubbock Lake site on Yellowhouse Draw, the results are presented from this point in the upper limits of the basin followed by the Fort Hood chronometric results downstream and finally the chronometric data at College Station area. Undeniably, there are an abundance of previous investigations and radiocarbon datasets throughout the Brazos River Basin that could also have been recalibrated. However, these three datasets have been extensively used by other researchers to characterize the depositional history of the Brazos River basin. Further, each study has good stratigraphy that extends to the Late Pleistocene, has cultural deposits in almost all of the recognized stratigraphic units, and has a robust chronometric dataset.

Upper Extent

Forty-eight radiocarbon assays were selected from the Lubbock Lake (41LU1) assemblage derived from humic acid, humin, and charcoal (Haas et al. 1986:Table 1). The selected assays are part of a relatively straightforward profile, which exhibits the stratigraphic context of each of the samples in relation to each other. Consequently, with the vertical relationship and strata information, the recalibration of the samples can be examined and interpreted (Haas et al. 1986: Figure 4). Of note, the overwhelming majority of these radiocarbon assays are from humic acid or humin. Unfortunately, samples derived from charcoal were the minority in this assemblage. Therefore, due to reasons previously elaborated (e.g., mean residence time), the calibrated results for these samples may trend older than their true temporal context. However, these chronometric data do conform sequentially and associated temporally diagnostic artifacts do correlate with the respective strata.

The five stratigraphic units (Strata 1–5) at the Lubbock Lake site were categorized into eight phases based upon internal horizons within the strata. Specifically, the chronometric assays were grouped from oldest to youngest into Stratum 1, Stratum 2A, Stratum 2B, Stratum 3, Stratum 4A, Stratum 4B, Stratum 5A, and Stratum 5B. The two samples collected from the top of Stratum 1 calibrated to 13,080–12,850 cal yr BP.

The *terminus ante quem* for the overlying Stratum 2A calibrated to 12,460 cal yr BP suggesting a possible 390-year gap between the end of Stratum 1 and the beginning of Stratum 2. Interestingly, Stratum 1 is recorded to contain Clovis cultural materials while Stratum 2A contains a Folsom occupation (Haas et al. 1986: Figure 3). The *terminus post quem* of Stratum 2A is indicated to be about 11,600 cal yr BP while the base of Stratum 2B dates to roughly 11,490 cal yr BP suggesting a very brief gap (100 years) that falls within the margin of deviation. The brief (about 860 years) Stratum 2A contains Folsom deposits while Stratum 2B is recorded to have Plainview cultural materials at the lower portions and Firstview occupations near the top (Haas et al. 1986: Figure 3).

Stratum 2B is capped by a buried soil aptly titled the Firstview Soil (Haas et al. 1986; Holliday 1985). The assays from the Firstview Soil indicating the *terminus post quem* of Stratum 2B calibrate to 8,920–7,270 cal yr BP (Table 6.2). The three assays from the overlying Stratum 3 calibrates to 6,630–5,830 cal yr BP suggesting an approximate 670 year gap between Strata 2 and 3. Stratum 3 is capped by the Yellowhouse Soil characterized as weakly developed (Holliday 1985:1487). Two of the Stratum 3 assays (i.e., SMU-1093 and SMU-531) come from the Yellowhouse Soil calibrating to 6,100–5,830 cal yr BP almost encompassing the entire span of Stratum 3.

Interestingly, the overlying Stratum 4A calibrates to 5,810–5,720 cal yr BP suggesting a very brief gap between Strats 3 and 4, which is at variance with the observed stratigraphy. Specifically, Stratum 4A is recognized to unconformably rest upon Stratum 3 suggesting an erosive event belying the negligible gap between these strata (Holliday 1985:1488). Consequently, the accuracy of the dates for the Strata 3 and 4 transition should be accepted with prudence.

The calibrated *terminus ante quem* for Stratum 4B is 5,690–5,340 cal yr BP while the Lubbock Lake Soil assays capping Stratum 4B calibrate to 2,240–740 cal yr BP. These results suggest an approximate 3,100-year hiatus between the Lubbock Lake Soil and the base of Stratum 4B (Haas et al. 1986: Figure 4). This hiatus likely attributed more to sampling rather than deposition, but it is interesting that this gap falls within the enigmatic Middle Archaic archaeological period.

The overlying Stratum 5A has a calibrated *terminus ante quem* of 650–560 cal yr BP and is capped by the Apache Soil providing the *terminus post quem*, which dates to 430–300 cal yr BP (Figure 6.4; Table 6.2). Finally, the sole assay for Stratum 5B calibrates to 230–30 cal yr BP suggesting that it is decidedly modern.

Comparing the initial Lubbock Lake radiocarbon calibration results to the recalibration of this study demonstrates some significant differences (Figure 6.6). Notably, these shifts were to be expected considering the initial radiocarbon assays were

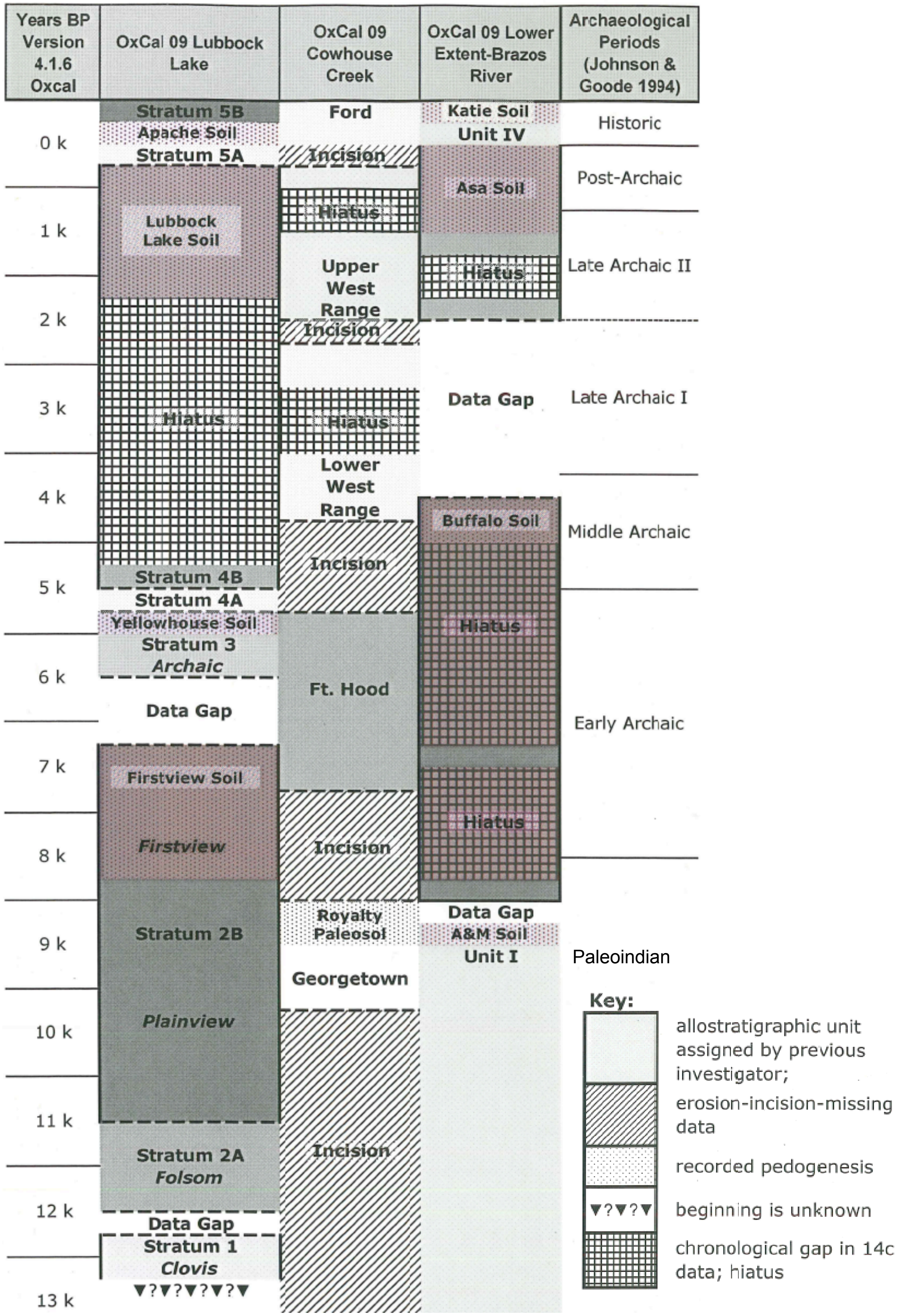


Figure 6.6 Calibrated Depositional History Brazos River Basin.

only partially calibrated. Specifically, assays older than 7,240 ^{14}C yr BP (i.e., preceding Stratum 3) were not initially calibrated (Holliday et al. 1983:170, 1985). Rather, the initial dates prior to Stratum 3 were to be considered 'minimum ages' for the respective assays (Holliday et al. 1983:171). Therefore, the older assays of the site (particularly in Strata 1 and 2) having been adjusted by more recent calibration data, do exhibit significant adjustment (Figure 6.6). The recalibration results push the ages of Stratum 1 back about 1,500 years and considerably shorten this unit. Similarly, Stratum 2 has also been pushed back to start approximately 12,500 cal yr BP. Further, the beginning of Stratum 4 has been shifted about 500 years older to begin about 5,800 cal yr BP. However, the Strata 3 and 4 transition rests on a disconformity and, as previously mentioned, the accuracy of the dates for the Strata 3 and 4 transition warrants caution. The comparison of the chronometric data for the remaining Lubbock Lake strata aligns exceptionally well. Although there are some refinements in the assays, these differences are negligible.

Another observation from the recalibration of the Lubbock Lake data regards the 'hiatus' in Stratum 4B. Specifically, an apparent 3,100-year gap in radiocarbon age reveals itself between the Lubbock Lake Soil and the base of Stratum 4B. None of the Stratum 4B chronometric data overlaps this time period. This temporal gap is probably more a result of sampling rather than depositional or geomorphic processes.

Middle Extent

Twenty-one radiocarbon assays from Cowhouse Creek and one from Tablerock Creek were selected from the investigations in Fort Hood derived from humate and charcoal to be calibrated (Nordt 1992, 2004: Table 1). The selected assays are overwhelmingly charcoal are from a good stratigraphic context, and compose an assemblage used to characterize the alluvial history of Cowhouse Creek and Fort Hood (Nordt 2004: Figures 5 and 6). As previously indicated, six allostratigraphic units have been identified within the Fort Hood study area, which from oldest to youngest include Jackson alluvium, Georgetown alluvium, Fort Hood alluvium, Lower West Range alluvium, Upper West Range alluvium, and the Ford alluvium.

The one sample collected from the Late Pleistocene Jackson alluvium calibrated to 18,680–18,080 cal yr BP (Table 6.2). This assay (Beta-38694) is the sole humate sample in this assemblage. Above the Jackson alluvium is the Georgetown allostratigraphic unit, which calibrated to 10,100–9,750 cal yr BP. The significant 7,980-year gap between the end of the Jackson alluvium and the beginning of the Georgetown alluvium correlates to a period of incision, which likely eroded significant deposits of the Jackson allostratigraphic unit (Nordt 2004). The Georgetown alluvium is capped by the Royalty paleosol, but none of the selected assays from Cowhouse Creek was from this buried soil. However, a charcoal assay (GX-15762) associated with the Royalty paleosol from Tablerock Creek was used as a proxy and calibrated indicating the buried soil dated to 9,410–9,120 cal yr BP (Nordt 1992). The four assays for the overlying Fort Hood alluvium calibrates to 7,780–5,860 cal yr BP. An approximate 1,300-year gap separates the Georgetown and Fort Hood units, which correlates to a period of incision. The *terminus ante quem* for the Lower West Range alluvium calibrates to 4,790 cal yr BP and terminates sometime after 2,790 cal yr BP.

The overlying Upper West Range calibrates to 2,430–570 cal yr BP indicating an approximate 400-year gap between the Upper and Lower West Range units. Of note, a hiatus is present in both these West Range units (Figure 6.7). In the Lower West Range, a 650-year hiatus occurs at one sigma deviation between 3,980–3,330 cal yr BP. Similarly, in the Upper West Range a 500-year hiatus occurs between 1,330–830 cal yr BP. At present, it is undetermined if these gaps are reflective of depositional processes, sampling, or a combination of these factors. However, the hiatus of the Lower West Range coincides with the aforementioned gap observed in Stratum 4B at Lubbock Lake (Haas et al. 1986; Holliday 1985). Regardless, the period of incision identified between the Lower and Upper West Range units appears to have occurred between 2,790–2,430 cal yr BP (Nordt 2004: Figure 6). Finally, overlying the Upper West Range unit is the Ford alluvium that calibrates to 450–220 cal yr BP. The identified period of incision between these units appears to have been brief (120 years) and occurred between 570–470 cal yr BP.

Some notable differences are apparent when contrasting the initial Cowhouse Creek at Fort Hood radiocarbon calibration results to the recalibration of this study. Typically, adjustments are limited to the older assays, but the recalibration of the Cowhouse Creek dataset exhibits shifts throughout all of the allostratigraphic units. The largest shift involved the Georgetown unit where the recalibration truncated the beginning and terminus of this unit (Table 6.2). Admittedly, the recalibration did utilize a radiocarbon assay (i.e., GX-15762) from a drainage (i.e., Tablerock Creek) other than Cowhouse Creek as a proxy to date the Royalty paleosol. However, the assay was derived from charcoal and conforms to the Cowhouse Creek chronology and is considered reliable. Another significant shift occurs in the Fort Hood unit, which has been pushed back about 700 years. The shift suggests that the Fort Hood unit is almost

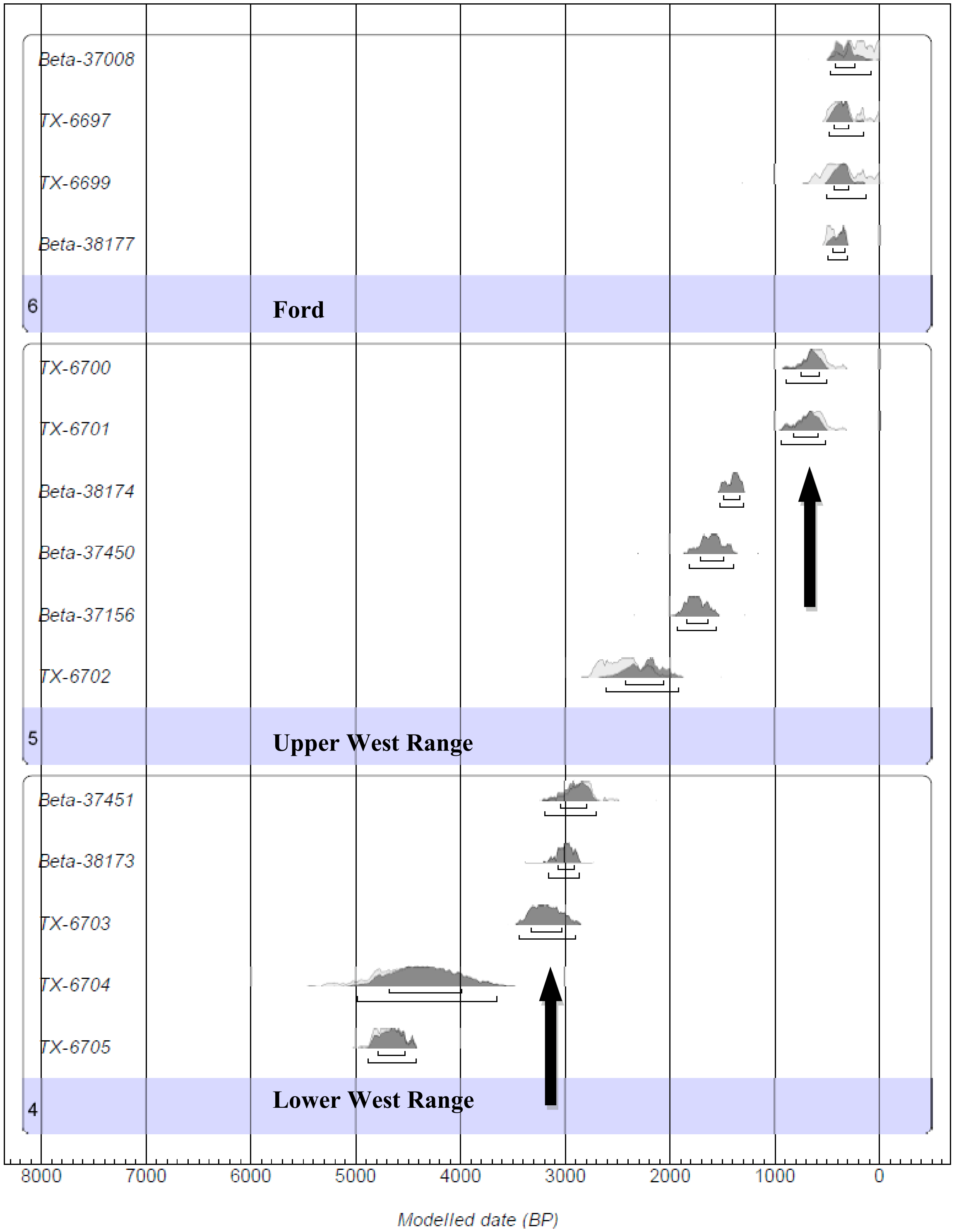


Figure 6.7 Select Calibration Plot of Cowhouse Creek assays; arrows illustrate hiatus periods.

entirely within the Early Archaic instead of spanning the Early and Middle Archaic periods. The beginning of the Lower West Range unit is shifted about 500 years to begin at roughly 4,800 cal yr BP. Interestingly, a 650-year gap in the radiocarbon assays (i.e., 3,980–3,330 cal yr BP) is revealed in the Lower West Range unit and a similar 500-year gap occurs in the Upper West Range.

Lower Extent

Fourteen radiocarbon assays from the investigations along the Brazos River west of College Station was selected for calibration (Table 6.2). Only two of the fourteen assays were derived from humate, the majority of the samples came from charcoal and wood. Also of note, Waters and Nordt (1995) encountered cultural features or artifacts within each of the buried soils at the College Station study area. Specifically, evidence was observed in the A&M soil of Unit I, the Unit II Buffalo soil, the Unit III Asa soil, and in the Katie soil of Unit IV. The presence of these cultural deposits provided data (i.e., hearth charcoal) from which to securely date each of the paleosols and by extension, periods of environmental stability.

Unfortunately, one of the three radiocarbon assays available for Unit I is derived from humate. However, the result of the calibration of the humate assay (i.e., A-7513) conforms with the charcoal radiocarbon result from Unit I and is considered reliable. Notably, Waters and Nordt (1995: Table I) provide an assay (SMU-1754) derived from wood reportedly in the Unit I channel facies, which is the *terminus ante quem* for this unit. The calibration of this assay dates to 21,450–20,970 cal yr BP with the next recalibration date is 9,570 cal yr BP. Considering Waters and Nordt (1995) do not indicate a disconformity between these two assays, the implications are that the erosive pre-Holocene event is not represented at this study area. Further, if the erosive event is not present then the enigmatic Pre-Clovis timeframe should be intact. However, there are multiple reasons that this assay (SMU-1754) should be regarded with caution. The assay was collected from a gravel pit on the edge of the floodplain and its vertical position to the other Unit I samples is not indicated. Therefore, this assay is interpreted with some prudence.

The calibration of the A&M soil that caps Unit I and provides the *terminus post quem* suggests that this unit ceased deposition sometime after 9,320 cal yr BP. The overlying Unit II began deposition prior to 9,200 cal yr BP indicating an extremely short (80 year) transition between the two units. The deposition of Unit II continued until the Middle Holocene ending sometime after 4,640 cal yr BP. The calibration of the Buffalo Soil that caps Unit II suggests a period of stability occurred prior to 4,840 cal yr BP. Notably, two gaps in the chronometric data of Unit II are evident within this unit. One gap exhibits a 1,300-year hiatus between 8,810–7,480 cal yr BP while the second 2,500-year gap occurs between 7,290–4,840 cal yr BP (Table 6.2 and Figure 6.6). These gaps are partially attributed to sampling since only three radiocarbon assays represent Unit II. Another possibility may be attributed to a base level rise in sea level (i.e., transgression). As previously mentioned in the Nueces River basin study, a rapid rise in sea level occurred along the Gulf at 6,800–5,900 cal yr BP and 4,200–3,000 cal yr BP (Ricklis and Blum 1997; Ricklis and Cox 1998).

Unconformably resting on Unit II is the third allostratigraphic unit (i.e., Unit III) (Figure 6.5). The recalibrated *terminus ante quem* for Unit III suggests deposition began prior to 2,650 cal yr BP when the Brazos River is interpreted to have avulsed and severely eroded the Buffalo soil of Unit II. The erosive event occurred sometime between 4,640–2,650 cal yr BP, which not coincidently squarely falls within the second sea level transgression (4,200–3,000 cal yr BP) identified by Ricklis and others (1997, 1998). The Asa Soil that caps Unit III provides the *terminus post quem* that suggests the Brazos River entered a period of stability prior to 1,390 cal BP and ends sometime after 740 cal yr BP. Finally, sometime prior to 560 cal yr BP an avulsion occurred that began the construction of Unit IV. The Brazos River entered a brief period of stability forming the Katie Soil around 300 cal yr BP followed by the most recent avulsion, which formed the modern channel (Unit V).

In aggregate, this depositional history of the Brazos River basin identified from the recalibration of previous research will be compared with those in other drainage basins and correlated with extrinsic factors in Chapter 8.

CHAPTER 7

Recalibrated Geoarchaeological Framework with the Trinity River Basin

The Trinity River is solely contained within Texas and is generally recognized to have an upper and lower extent (Gard 2010). The Upper Trinity River basin is situated in the North Central Plains region and encompasses the headwaters region of the basin bounded by the Brazos River basin to the south and the Red River basin to the north. The Trinity River basin is the only basin within this study that does not cross the Edwards Plateau. Instead, the Upper Trinity River is recognized to cross forested rolling topography with narrow stream channels with three main headwater branches, the Elm Fork, the West Fork, and the Clear Fork Rivers (Ferring 1991; Gard 2010). In contrast, the Lower Trinity River basin crosses the grass prairies of the Gulf Coastal Plain beginning just between Dallas, Texas and the Trinity's confluence with the Elm Fork River and trends southeastward to terminate at Trinity Bay on the coast (Figure 7.1). Overall, the basin encompasses a total 17, 969 mile^2 (46,500 km^2) area with the three Upper Trinity River branches averaging 114 miles (183 km) in length while the Lower Trinity River basin is about 260 miles (420 km) long (Ferring 1991; Gard 2010; Garvin 2008; Prikryl 1990). Some of the prominent contributory drainages in the Trinity River basin include Elm Fork, East Fork, West Fork, and Clear Fork Rivers. Less prominent tributaries include Ten Mile, Five Mile, White Rock, Keechi, Clear, Hickory, and Cedar creeks as well as Cedar Bayou. The easternmost tributary is the East Fork that is about 78 miles (125 km) long and extends through Grayson, Dallas, and Kaufman Counties. The central tributary drainage is the roughly 85 mile (137 km) long Elm Fork River,

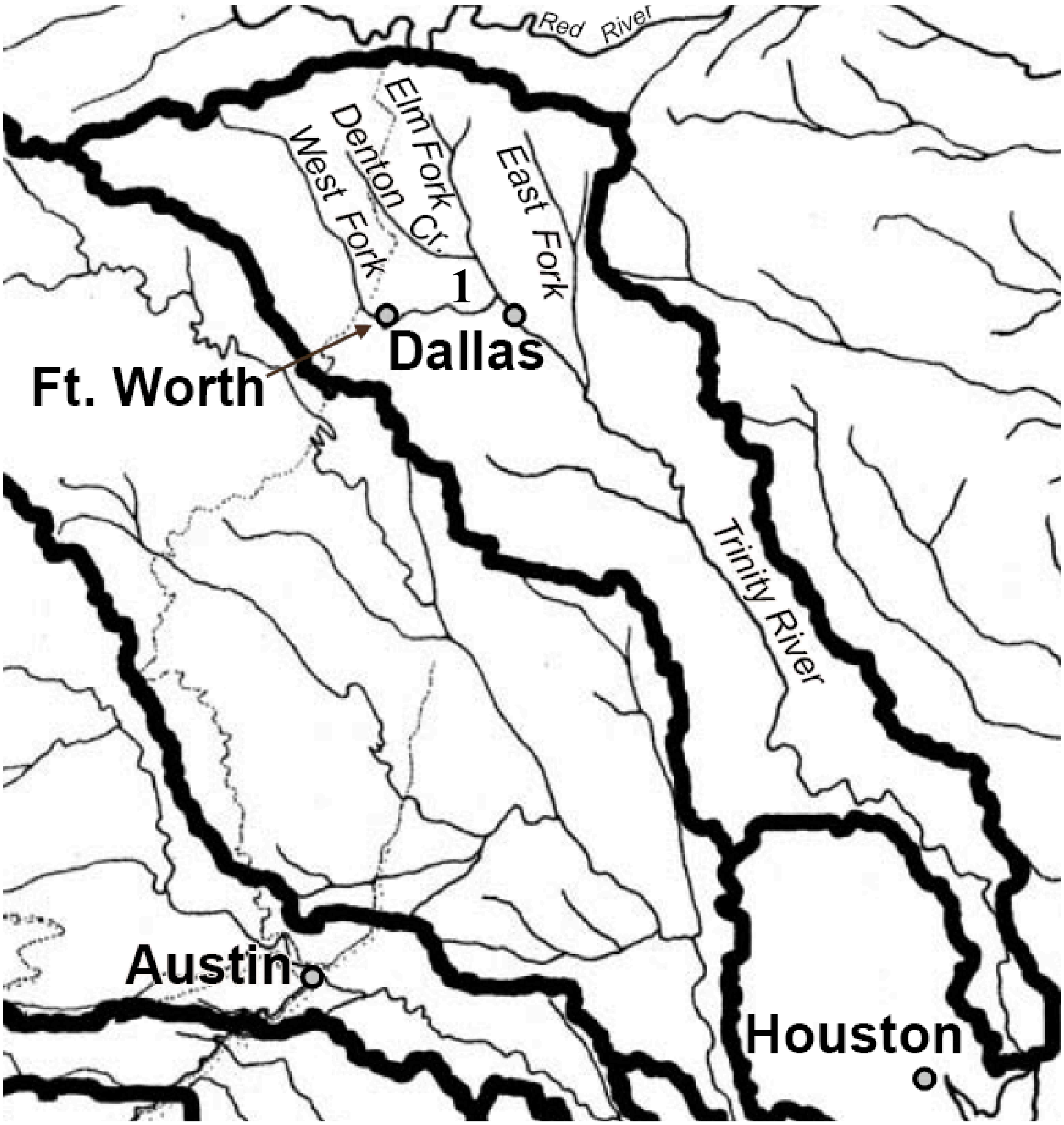


Figure 7.1 Overview of Trinity River Basin: 1) Ray Roberts-Upper Trinity River study area.

which runs through Montague, Cooke, and Denton Counties. The westernmost tributary drainage is the 180 mile (290 km) long West Fork River that runs through Archer, Jack, Tarrant, and Dallas counties. The Trinity River within the Lower extent of the basin runs generally southeast through Kaufman, Ellis, Henderson, Navarro, Freestone, Anderson, Leon, Houston, Madison, Walker, Trinity, San Jacinto, Polk, Liberty and Chambers Counties where it empties into Trinity Bay near Anahuac, Texas.

Previous Investigations

The Trinity River and its deposits have been of interest to geologists and archaeologists for over a hundred years (Ferring 2000). Arguably, the first geoarchaeological investigation to have been conducted in Texas occurred in 1920 in the Trinity River basin (Table 7.1). Specifically, Robert Hill and Ellis Shuler examined a human skeleton discovered at the Lagow Sand Pit along the Trinity River in Dallas County to determine its association with Pleistocene fauna (e.g., mammoth, camel, and horse) also discovered there (Ferring 2000:47). Hill and Shuler interpreted the human remains to be contemporaneous with the Pleistocene fauna, although subsequent analyses in the late 1960s determined that the remains were actually much younger.

Despite the fact that these early researchers (e.g., Robert Hill, Cyrus Ray, or Ellis Shuler) did not benefit from radiocarbon dating, their research attempted to determine the age of the Trinity River terraces and its deposits having some success. The first researchers to characterize the terraces of the Trinity River in combination with reconstructing the paleoenvironment were Stovall and McAnulty (1950) in Henderson

Table 7.1 Previous Geoarchaeological Investigations in the Trinity River Basin

Drainage Extent	Drainage	Resource	Project-Site(s)	Geoarchaeologist or Researcher	Chronometric Data
Upper	Trinity River	Shuler 1935; article		E. Shuler	Relative
Upper	Trinity River	Stovall and McAnulty 1950; article	Henderson, Navarro, and Freestone Counties	J. Stovall and W. McAnulty	Relative
Lower	Trinity River-Coast	Aten 1983	Synthesis Gulf Coast	L. Aten	14c; relative
Upper	Trinity River	Prikryl and Yates (editors) 1987	41CO141 Ray Roberts Reservoir	C.R. Ferring	14c; relative
Upper	Elm Fork	Ferring 1994	Upper Trinity River basin; Dissertation	C.R. Ferring	14c; relative
Upper	Elm Fork	Ferring 1995a; 2001	Aubrey Clovis Site	C.R. Ferring	14c; relative
Upper	Elm Fork	Ferring and Yates 1997	Ray Roberts Reservoir	C.R. Ferring	14c; relative
Upper	Mill Creek	Byers 2007	Dickie Carr Site (41PR26) Dissertation	J. Byers	Relative
Lower	Trinity River	Garvin 2008	Trinity River incised valley; thesis	M. Garvin	OSL; relative
	indicates study selected for recalibration				

County. Similarly, the lower extent of the basin and gulf coast has been extensively considered by numerous researchers (e.g., Bernard et al. 1962, 1970).   Concerted geoarchaeological investigations appear to have begun in the late 1960s in the lower extent of the Trinity River basin and in the 1980s for the upper extent. In the Lower Trinity River basin, Aten (1983) conducted a series of archaeological investigations along the coast with a research focus on geomorphic processes.

For the Upper Trinity River basin, the research that occurred for Lake Ray Roberts involved an extensive geoarchaeological component (Prikryl and Yates 1987). Since then several significant geoarchaeological investigations have been carried out in the Trinity River Basin. Interestingly, the research in the Trinity River basin has largely been conducted either in the upper extent or in the extreme lower extent along the Gulf Coast. Unfortunately, geoarchaeological research along the middle region of the Trinity River has been sparse. Despite the limited amount of geoarchaeological investigations within the basin, the research that has been conducted is thorough and far-reaching.

Some of the first archaeological investigations within the Trinity River basin with a focus on geomorphic processes was conducted by Aten (1983). The initial research was associated with the Wallisville Reservoir project in Chambers County, which later developed into a much larger synthesis. Aten (1983:104–162) supplemented previous archaeological investigations with geologic investigations along the Trinity River and produced a synthesis of Late Quaternary stratigraphy for the drainage and the coast. Within the basin, Aten (1983:105) characterized the Trinity River as having a series of fluvial terraces encompassing the Pleistocene to modern times. From oldest to youngest these include terraces T_4–T_0 with terraces T_4 and T_3 associated with the Pleistocene while T_2–T_0 encompassing the Late Pleistocene to modern (Aten 1983:Table 8.3).

The most extensive geoarchaeological investigations within the Trinity River basin are associated with the Ray Roberts-Lewisville Reservoir project in Cooke, Denton, and Grayson Counties (Prikryl and Yates 1987; Ferring and Yates 1997). The creation of these reservoirs from the impoundment of segments of the Elm Fork River generated archaeological investigations extending over two decades by a variety of interdisciplinary researchers (e.g., SMU, Environmental Consultants Inc., USACE-FW, and University of North Texas). Among the many notable accomplishments from this research was the discovery and investigation of the Aubrey Clovis site (41DN479). The Aubrey Clovis site situated on the Elm Fork River was identified to have an intact stratigraphy extending back into the Pleistocene (Ferring 1990a, 1990b, 1991, 1992, 1994, 1995a, 1995b, 2000, 2001; Humphrey and Ferring 1994). Most significant, the site has a Paleoindian occupation with a well-dated stratigraphy that suggests it is the oldest Clovis site currently known (Ferring 2001). In addition, the extensive investigations at Aubrey Clovis have provided a robust radiocarbon dataset and information from past environments.

Finally, a geoarchaeological examination was conducted at the Dickie Carr site (41PR26) also in the upper extent of the Trinity River basin (Byers 2007). The Dickie Carr site is located in eastern Parker County situated on a terrace of Mill Creek, a tributary of West Fork River. Byers (2007:57–72) identified three stratigraphic units (Units I–III) that contained a complex stratigraphy extending to the Late Pleistocene with the remains of a *Mammuthus columbi* (Unit Ib), a Late Paleoindian component (Unit IIa), and a Late Archaic component (Unit IIb). The researcher compared the site deposits and setting with other archaeological sites in the region. Unfortunately, no chronometric analyses were conducted for this research.

Geomorphic/Alluvial History

The following review of the depositional history of the Trinity River basin is composed of an intensive review of the interpretations associated with the Ray Roberts-Lewisville Reservoir project and particularly the Aubrey Clovis site (41DN479). As mentioned previously, there is a paucity of geoarchaeological research in the interior or middle portions of the Trinity River basin followed by the coastal region. Although this depositional history is in the upper limits of the basin, the data is applicable to the rest of the basin.

Upper Extent Trinity River Basin

In summarizing the alluvial history of the Upper Extent of the Trinity River basin, Ferring (1994) recognizes four morphostratigraphic units (i.e., landforms) composed of deposits from six alloformations (Figure 7.2). The morphostratigraphic units identified from oldest to youngest include the Stewart Creek Terrace, Hickory Street Terrace, Denton Creek Terrace, and the Floodplain that are interpreted to encompass the Middle Pleistocene up to the present.

The Stewart Creek Terrace composed of Irving alloformation deposits and the Hickory Street Terrace, which is composed of the Coppell alloformation deposits are indicated to date to the Pleistocene sometime around 30,000 years ago (Ferring 1994; Ferring and Yates 1997). The more recent Denton Creek Terrace is composed of deposits from the Carrollton alloformation that contain Pleistocene faunal remains (e.g.,

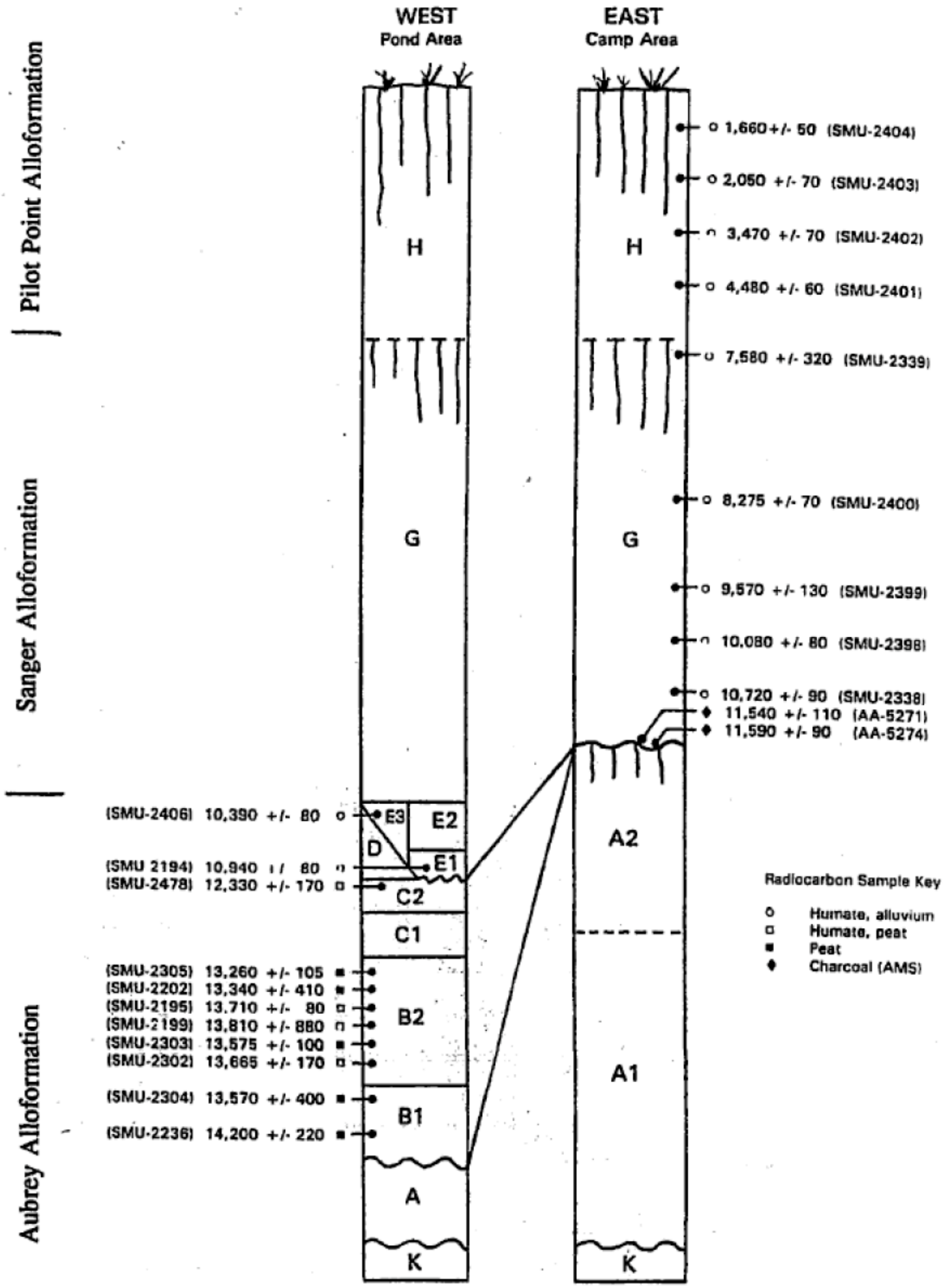


Figure 7.2 Stratigraphic Columns from Aubrey Clovis site (adapted from Ferring 1994: Figure 3.9).

Bison antiquus) and is interpreted to date to roughly 30,000–20,000 years ago (Ferring 1994:47–48). Most relevant to the archaeology of the region is the landform identified as the Floodplain. The Floodplain contains deposits from three alloformations that from oldest to youngest include the Aubrey, Sanger, and Pilot Point alloformations.

Ferring (1994) indicates that the Aubrey alloformation dates to the Late Pleistocene-Holocene transition. The *terminus ante quem* for this alloformation is from the Aubrey Clovis site (41DN479), which initially calibrated to 17,030 cal yr BP (SMU-2236) and terminates sometime after 14,410 cal yr BP (Ferring 1994; Ferring and Yates 1997). The initial calibration of the overlying Sanger alloformation begins in the Late Pleistocene sometime prior to 13,460 cal yr BP (AA-5274) and extends to sometime after 7,550 cal yr BP (SMU-2339) (Ferring 2001: Table 3.2). Ferring (1994:58–59) notes that the Sanger alloformation is capped by a moderately developed buried soil that in several locations has been eroded by the Pilot Point alloformation. The Pilot Point deposits began prior to 4,470 cal yr BP (SMU-2401) and terminated sometime after 1,676 cal yr BP (Beta-14963). A well-developed cumulic soil identified as the West Fork soil frequently caps the Pilot Point alloformation interpreted to encompass the last 4,000 years.

Beginning in the Late Pleistocene, the alluvial history of the Upper Trinity River basin as defined by Ferring (1994:147–149) has a period of stasis with no discernable geomorphic activity occurring between 14,000–11,000 years ago (17,000–13,000 calibrated). Specifically, Ferring (1994:147) notes that no alluvial or colluvial deposition or evidence of a disconformity is associated with this period. Subsequent to 11,000 years (13,000 calibrated) ago, a period of rapid alluviation occurs in the basin initiating a phase of valley filling (Figure 7.3). Interestingly, this period of rapid alluviation occurred shortly after the Clovis occupation at the Aubrey Clovis site and continued until 7,500 years ago (7,550 calibrated) (Ferring 1994:148). This event is inferred to be associated with a shift to a moister (i.e., mesic) climate. By the middle of the Holocene, a shift to a drier (xeric) climate occurred as evidenced by soil development in the Sanger alloformation and eolian deposits in some of the uplands of the upper basin of the Trinity River (Ferring 1994:148). These xeric conditions seemingly continued until roughly 4,500 years ago when a period of rapid alluviation occurred and the deposition of the Pilot Point alloformation began (Ferring 1994:148–149). The rapid alluviation is particularly apparent between 3,000–2,000 years ago (Ferring 1994:149).

In contrast to other researchers, Ferring (1994) notes that alluviation in the Upper Trinity River basin does not correlate with arid conditions. Instead, Ferring (1994:150–153) noted in this basin that the fluvial response to moist conditions was rapid alluviation and/or erosion while drier conditions led to stability and soil development and that the primary internal influence on a landscape's evolution is the underlying bedrock, which affects the vegetation. Specifically, the calcareous loams and clay loams derived from weathered limestone support a prairie environment that is more resistant to erosion. Conversely, the non-calcareous soils derived from sandstone and shale supports a mixed forest environment that has a lower threshold for erosion. Two primary external influences identified are the climate and changes in sea level. Although no examples are provided, eustatic influence is proposed as a possible influence to the upper extent of the basin.

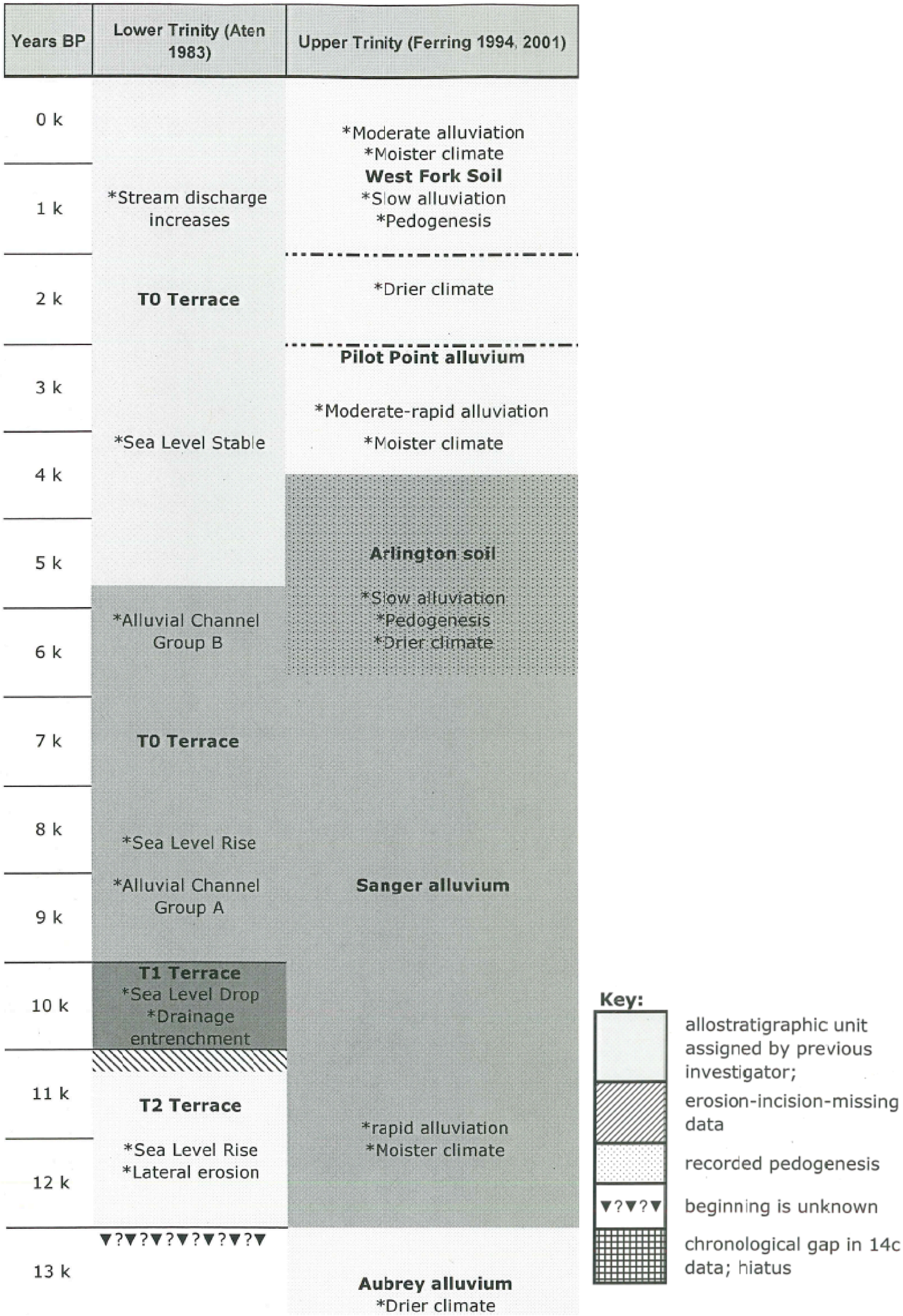


Figure 7.3 Initial Depositional History Trinity River Basin.

Regarding overall archaeological potential within the upper basin, Ferring and Yates (1997) indicate that archaeological sites occur in two principal contexts (i.e., terraces and upon or below floodplains). For the terraces, Ferring and Yates (1997) propose that the Trinity River terraces between Dallas and Valley View are Late Pleistocene in age. As such, any archaeological sites less than 11,000 years old (~13,000 calibrated) could occur on the terrace surfaces, which are supported by numerous surveys in the area particularly in Denton, Dallas, and Tarrant Counties (Ferring and Yates 1997:279).

For the floodplains in the Upper Trinity River basin, the age of the sites on the floodplains can be predicted by their stratigraphic location (Ferring and Yates 1997: Table 18.2). Unfortunately, Ferring and Yates (1997) note that cutbank exposures along Elm Fork River are "poor" and alluvial units thicken as they progress downstream. Consequently, older sites will become increasingly difficult to discern downstream. This will be particularly evident for Paleoindian–Middle Archaic sites, which will likely require mechanical excavation for their discovery. In contrast, the Pilot Point alloformation is exposed within the cutbanks of the entire upper extent of the basin and is characterized as thick, dark and clayey with a buried soil (West Fork soil) located beneath recently deposited sand (Ferring and Yates 1997:280).

Calibration Results

The radiocarbon datasets for the previously reviewed investigations associated with the Ray Roberts-Lewisville Reservoir project in the upper Trinity River basin were recalibrated (Table 7.2). The chronometric data consists of 57 samples derived from a

Table 7.2 Radiocarbon Data Trinity River Basin

Locality	Lab#	13c Adjusted 14c yr BP	Dev +/-	Depth (m)	δ 13 C	Material sampled	Initial 68.2%	Initial 95.4%	IntCal09 68.2%	IntCal09 95.4%
Aubrey alloformation (n=9)										
Aubrey Clovis site										
Strat B1b Trench 2A and 13	SMU-2236	14200	220	85.5	-28	Peat	17030		17340-16910	17630-16790
Strat B2d Trench 1	SMU-2199	13810	880	87.95	-27.6	Humates	16560		17030-15390	17590-14660
Strat B2d Trench 1	SMU-2195	13710	80	87.95	-27.9	Humates	16440		16930-16740	17030-16620
Strat B2a Trench 1	SMU-2302	13665	170	87.2	-28.3	Humates	16380		16930-16560	17110-16060
Strat B1 Trench 1	SMU-2304	13570	400	87.35	-28	Peat	16260		16900-15680	17310-15180
Strat B2b Trench 1	SMU-2303	13575	100	87.95	-28.3	Peat	16260		16840-16570	16940-16320
Strat B2d Trench 1	SMU-2202	13340	410	87.95	-23.4	Peat	15940		16710-15440	17090-14950
Strat B2d Trench 2A and 13	SMU-2305	13260	105	86.75	-29	Peat	15830		16540-15750	16730-15350
Strat C2 Trench 2A and 13	SMU-2478	12330	170	87.2	-24.2	Humates	14410		15100-14490	16010-14140
Sanger alloformation (n=16)										
Strat G/A Trench 2A and 13	AA-5271	11540	110			Charcoal	13460		13510-13280	13650-13180
Strat G/A Trench 2A and 13	AA-5274	11590	90			Charcoal	13520		13550-13330	13670-13260
Aubrey Clovis; Strat E1 Trench 2A and 13	SMU-2194	10940	80	87.8	-18.3	Humates	12860		12940-12710	13070-12640
Aubrey Clovis; Strat G Trench 25	SMU-2338	10720	90	89.05	-17	Humates	12650		12720-12570	12860-12450
Aubrey Clovis; Strat E3 Trench 2A and 13	SMU-2406	10390	80	88.45	-16.9	Humates			12410-12110	12540-11990
Aubrey Clovis	Beta-32002	10360	150			Sediment Humate			12420-11890	12570-11540

Table 7.2 Radiocarbon Data Trinity River Basin

Aubrey Clovis; Strat G Trench 25	SMU-2398	10080	80	89.65	-18.6	Humates	11475		11850-11440	11990-11310
Aubrey Clovis; Strat G Trench 25	SMU-2399	9570	130	90.3	-18.9	Humates	10750		11100-10710	11210-10530
Fullingham Locality 1	GX-18281	9455	255			Charcoal			11120-10410	11580-10110
Gateway Park, Fort Worth	Beta-14905	8940	185			Charcoal			10260-9750	10530-9570
Denton Creek Profile 1	Beta-46150	8510	120			Sediment Humate			9640-9360	9870-9180
Aubrey Clovis; Strat G Trench 25	SMU-2400	7460 (8275 in Ferring 1994)	70	91.55	-18.5	Humates	8210		8350-8200	8390-8090
Aubrey Clovis; Strat G Trench 25	SMU-2339	6740 (7580 in Ferring 1994)	320	92.3	-18.1	Humates	7550		7930-7320	8270-6960
Village Creek	Beta-34049	6445	110			Sediment Humate			7460-7260	7560-7100
Denton Creek Profile 1	Beta-46151	6410	100			Sediment Humate			7420-7230	7510-7070
Village Creek	Beta-34051	5680	80			Soil Humate			6610-6400	6680-6320
Pilot Point alloformation (n=32)										
Village Creek	Beta-26738	4150	100			Soil Humate			4710-4460	4820-4340
Aubrey Clovis; Strat H Trench 25	SMU-2401	4030	60	93.05	-16.3	Humates	4470		4580-4430	4770-4310
Aubrey Clovis; Strat H Trench 25	SMU-2402	3260	70	93.55	-16.4	Humates	3470		3580-3410	3670-3360
41CO150	Beta-16526	2910	250			Charcoal			3380-2800	3700-2450
41CO141-1	Beta-16418	2800	90			Charcoal			3060-2820	3200-2760
41CO150	Beta-32514	2750	60			Charcoal			2930-2790	3020-2760
41CO150	Beta-32515	2600	50			Charcoal			2760-2580	2830-2500
41CO150	Beta-32516	2320	70			Charcoal			2470-2210	2680-2150
Aubrey Clovis; Strat H Trench 25	SMU-2403	2080	70	94.35	-16.8	Humates	2008		2150-1960	2300-1890
41CO150	Beta-32513	1985	70			Charcoal			2040-1860	2130-1760

Table 7.2 Radiocarbon Data Trinity River Basin

Village Creek	Beta-26737	1825	70			Soil Humate			1840-1650	1920-1570
41CO141-1	Beta-16417	1740	90			Charcoal			1780-1550	1870-1430
Aubrey Clovis; Strat H Trench 25	SMU-2404	1730	50	95.05	-16.6	Humates	1676		1710-1570	1800-1530
41CO150	Beta-32982	1680	70			Charcoal			1680-1490	1780-1410
41DN99	Beta-32524	1410	80			Charcoal			1400-1260	1510-1160
Gateway Park, Fort Worth	Beta-14904	1410	100			Soil Humate			1430-1220	1530-1090
Denton Creek Profile 1	GX-18282	1350	120			Soil Humate			1380-1120	1510-1000
Locality RRG-1	Beta-14908	1300	60			Soil Humate			1280-1150	1320-1070
41CO141-2	Beta-32530	1280	90			Charcoal			1280-1090	1350-990
41CO144	Beta-32986	1280	90			Charcoal			1280-1090	1350-990
41DN99	Beta-32523	1270	70			Charcoal			1270-1100	1300-1010
41DL149	Beta-13962	1100	110			Charcoal			1160-910	1260-780
41TR68	Beta-22028	980	70			Charcoal			960-800	1050-740
41CO141-1	Beta-16416	965	60			Soil Humate			930-800	1000-740
41CO141-2	Beta-32529	760	70			Charcoal			770-660	890-560
41CO144	Beta-32521	760	70			Charcoal			770-660	890-560
41DL12	Beta-14907	730	80			Charcoal			750-590	880-550
41TR68	Beta-22487	680	50			Charcoal			670-570	710-550
41DL149	TX-4001	680	200			Charcoal			870-550	1060-430
41TR68	Beta-22488	590	100			Charcoal			660-530	730-480
41DN99	Beta-32522	530	70			Charcoal			630-520	660-480
41DL149	Beta-14963	510	80			Charcoal			630-500	660-420

*standard value of -25.0 assumed by previous investigators

**radiocarbon date not listed on original table

***duplicate sample number in original text

dozen locations (Ferring 1994: Table 3.1; Ferring 2001: Table 3.2). Of note, the radiocarbon assays associated with the Coppell and Carrollton alloformations were not recalibrated for this study due to their early temporal setting (i.e., Pleistocene). Rather, only the assays associated with the Aubrey, Sanger, and Pilot Point alloformations were recalibrated (Table 7.2). These alloformations were selected due to their associations with cultural materials and the implications regarding paleoenvironmental interpretation across the upper extent of the Trinity River basin. The materials composing the radiocarbon assays include charcoal, soil humate, peat organic residue, and sediment humate (Ferring 1994: Table 3.1). Unfortunately, none of the assays for the Aubrey alloformation were derived from charcoal, but the *terminus ante quem* of the overlying Sanger alloformation are from charcoal. The Pilot Point alloformation contained the most radiocarbon assays (n=32) of the three and also had the most samples derived from charcoal (n=22). Thus, the Pilot Point alloformation is the most securely dated of the three.

The results of the recalibration of all the assays revealed an adjustment in the Aubrey alloformation, but admittedly not that dramatic considering the initial calibration (Ferring 2001: Table 3.2). Specifically, the Aubrey alloformation is indicated to have begun sometime prior to 17,340 cal yr BP and terminated sometime after 14,490 cal yr BP (Figure 7.4). The stratigraphic spread of the Aubrey alloformation assays suggests a good, continuous coverage (Figure 7.5). The overlying Sanger alloformation seems to have begun deposition prior to 13,510 cal yr BP and terminated sometime after 6,400 cal yr BP. The *terminus ante quem* for this alloformation are from the two charcoal samples (AA-5271 and AA-5274) recovered from the Aubrey Clovis site.

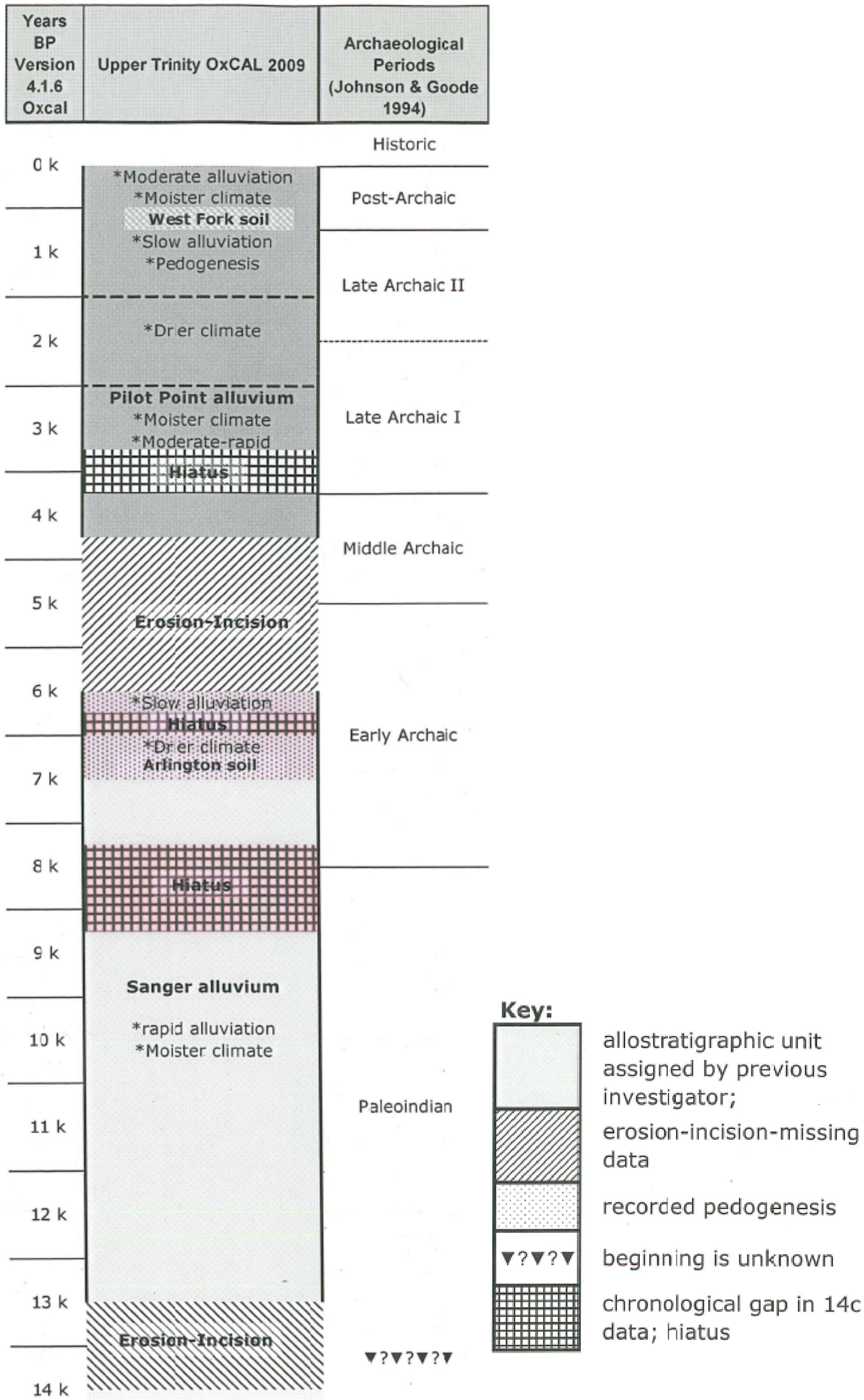


Figure 7.4 Calibrated Depositional History Trinity River Basin.

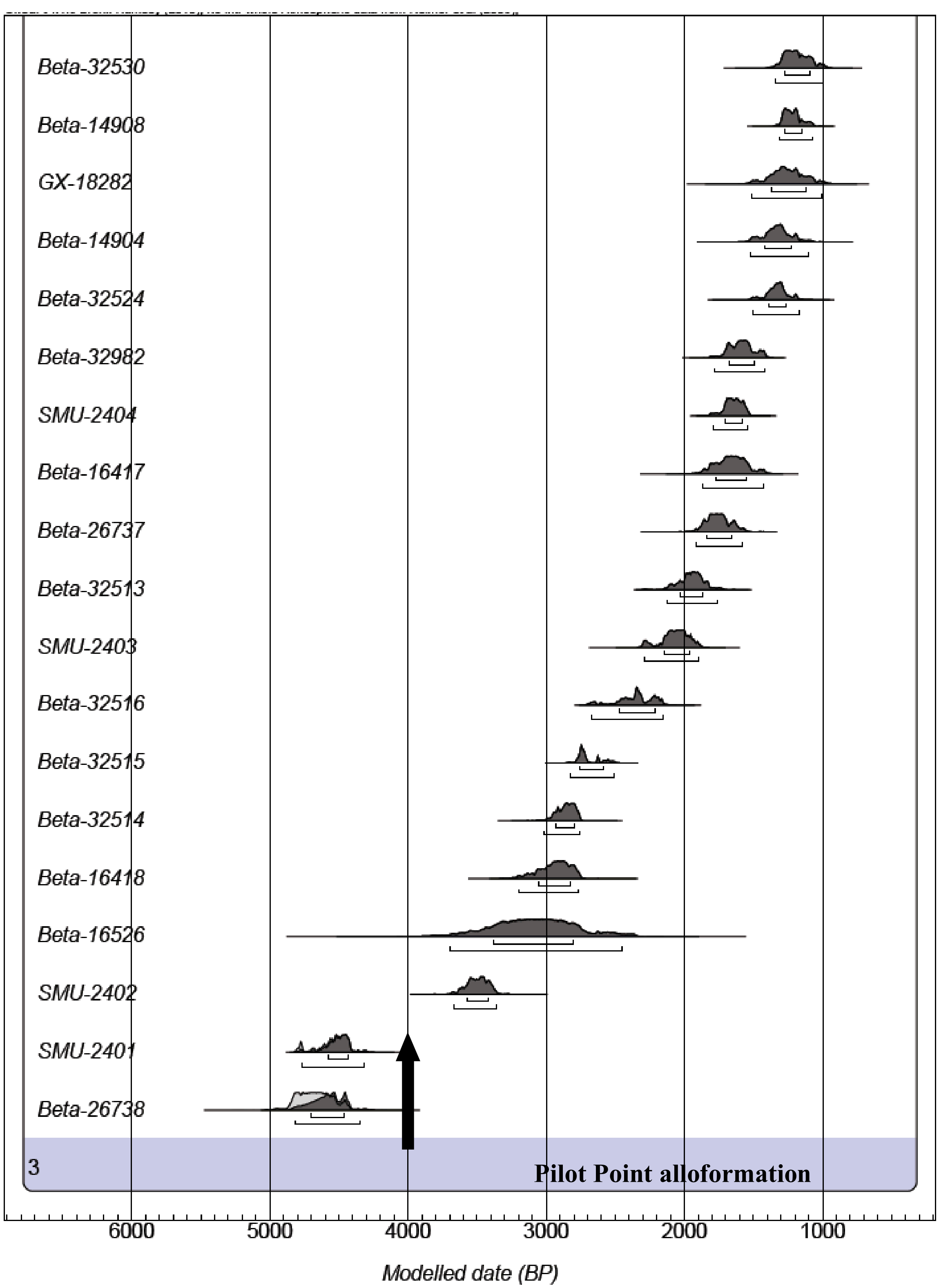


Figure 7.5 Select Calibration Plot of Upper Trinity River Basin assays; arrow indicates hiatus period.

These dates (13,550–13,280 cal yr BP) are significant in that they are at the boundary between the Aubrey and Sanger alloformations and date the Clovis occupation at the site (Ferring 2001:50). Further, the assay (SMU-2194) that caps the Clovis occupation for the site recalibrated to an age of 12,940–12,710 cal yr BP (Table 7.2). The Clovis occupation at Aubrey Clovis seems to have securely occurred between 13,280–12,940 cal yr BP, which makes them the oldest North American Clovis site (Ferring 2001:50–51). Remarkably, these dates do not change from the initial calibration conducted by Ferring (2001: Table 3.2). Consequently, Ferring's (1994, 2001) initial interpretation appears to be unchanged in light of the most recent calibration curve. However, for the remainder of the Sanger alloformation, there appears to be two significant gaps that occurred between 9,360–8,350 cal yr BP and 7,230–6,610 cal yr BP. The overlying Pilot Point alloformation began sometime prior to 4,710 cal yr BP and continued until sometime after 500 cal yr BP. In general, the Pilot Point alloformation has an excellent stratigraphic spread suggesting continuous accumulation, but there is one temporal gap between 4,400–3,580 cal yr BP (Figure 7.6).

Comparing these recalibrated results to the initial investigations, the most prominent changes are in the older dates. As mentioned previously, the adjustments from the current Incal09 curve is negligible. The statistical analyses using MCMC did refine the temporal spread of some of the assays, particularly in the Aubrey alloformation. Possibly as an indicator of the good, continuous coverage of the assays, the adjustments from the MCMC iterations were not drastic. Of note, another reason is likely to be that due to the incorporation of assays from a dozen locations, the stratigraphical arrangement of the assays within the alloformations was commonly unknown and sorted solely by age.

Regardless, the overall temporal extent encompassed within the alloformations is informative.

The results of the recalibrated chronometric data within the Trinity River basin are examined further and compared with other recalibrated data in the following Chapter 8.

CHAPTER 8

Patterns and Correlations across Texas River Basins and Region

This chapter consolidates the results from the previous basin recalibration studies. One of the primary objectives is to determine any depositional patterns within and between drainage basins and, by extension, attempt to correlate them with extrinsic factors (e.g., climate and eustasy). As with any search for patterns, the researcher will inevitably find them in abundance. At issue is the relevance and validity of identified relationships. Simply put, when is a pattern an *a priori* construct made in the researchers' mind and when does it truly reflect the effect of an external agent? This is a particularly apt question in regards to comparing multiple drainage basins over an expansive region using data from disparate researchers each with distinct research foci. The radiocarbon recalibrations for this study have provided a chronological baseline for all of the selected study areas. This recalibrated chronological framework is a factor that previous investigations did not have.

This chapter begins by reviewing *intra*-basinal relationships of each of the drainage basins followed by *inter*-basinal connections, and finally regional patterns. The chapter ends with a review of extrinsic factors that may be attributed to these proposed patterns. For the basin comparisons, there are three basic categories that are used indicate general activity within the drainages: periods of aggradation, periods of stability, and periods of instability. Aggradation is interpreted to be periods when deposition was occurring within the basin represented by recorded allostratigraphic units (e.g., Ford alluvium and Columbus Bend 2). Stability is interpreted to be a period when neither significant erosion nor aggradation is recorded and is associated with pedogenesis (e.g., Royalty and Asa paleosols) (Holliday 1990). Most importantly, instability in a basin is interpreted to be when periods of erosion/incision, a hiatus, or data gap occurs. Examples of erosion/incision are the erosional events noted by Blum (1987, 1992) on the Pedernales and Colorado Rivers. The hiatus periods refers to chronological gaps observed in the recalibration of the radiocarbon assays in allostratigraphic units (Figure 8.1). Some examples of hiatus events are in the Columbus River allostratigraphic units Columbus Bend 1 and Columbus Bend 2 (Figures 5.5 and 5.6). Finally, the data gaps refer to separations between allostratigraphic units where no erosion or aggradation is recorded. An example of this is in the Brazos River between Units II and III (Figures 6.2 and 6.6). The data gaps are likely attributable to erosion.

Intra-Basinal Patterns

Some of the drainage basins in this study are more appropriate for internal comparisons than others. The basins most useful for internal comparison are the Brazos River Basin and to some degree the Nueces and the Guadalupe River Basins. Despite the extensive investigations along the Trinity and Colorado River Basins, only one dataset in each of the drainage basins could be recalibrated.

Nueces River Basin

The alluvial history of the Upper Dry Frio River is seemingly more comparable to the Frio River valley downstream than to the adjacent Sabinal River valley (Figure 8.2). Two of the gaps (i.e., 6,450–5,750 yr BP and 4,050–3,650 yr BP) in the radiocarbon analysis during Phase II investigations at Choke Canyon Reservoir roughly

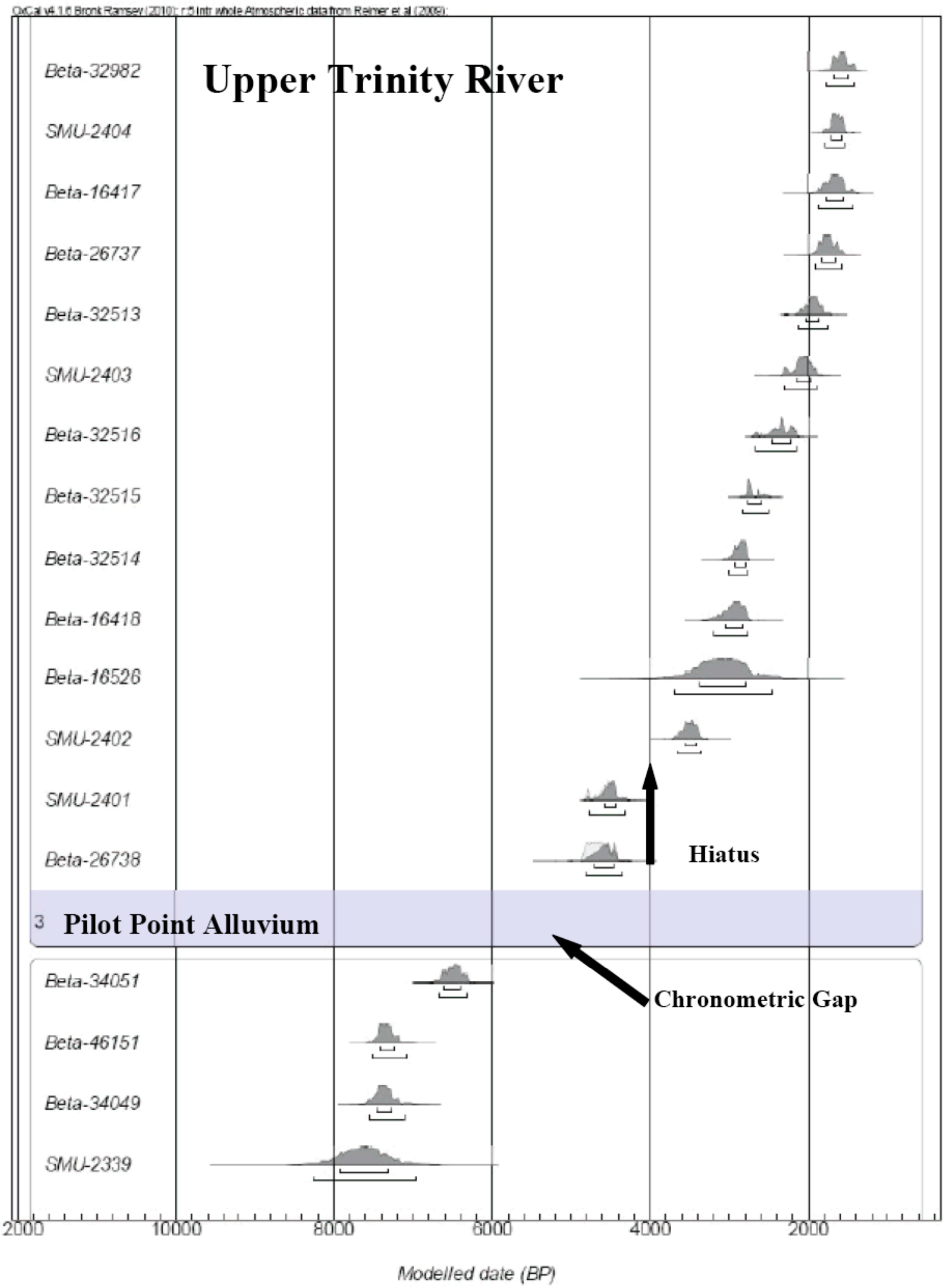


Figure 8.1 Examples of a Hiatus and Chronometric Gap.

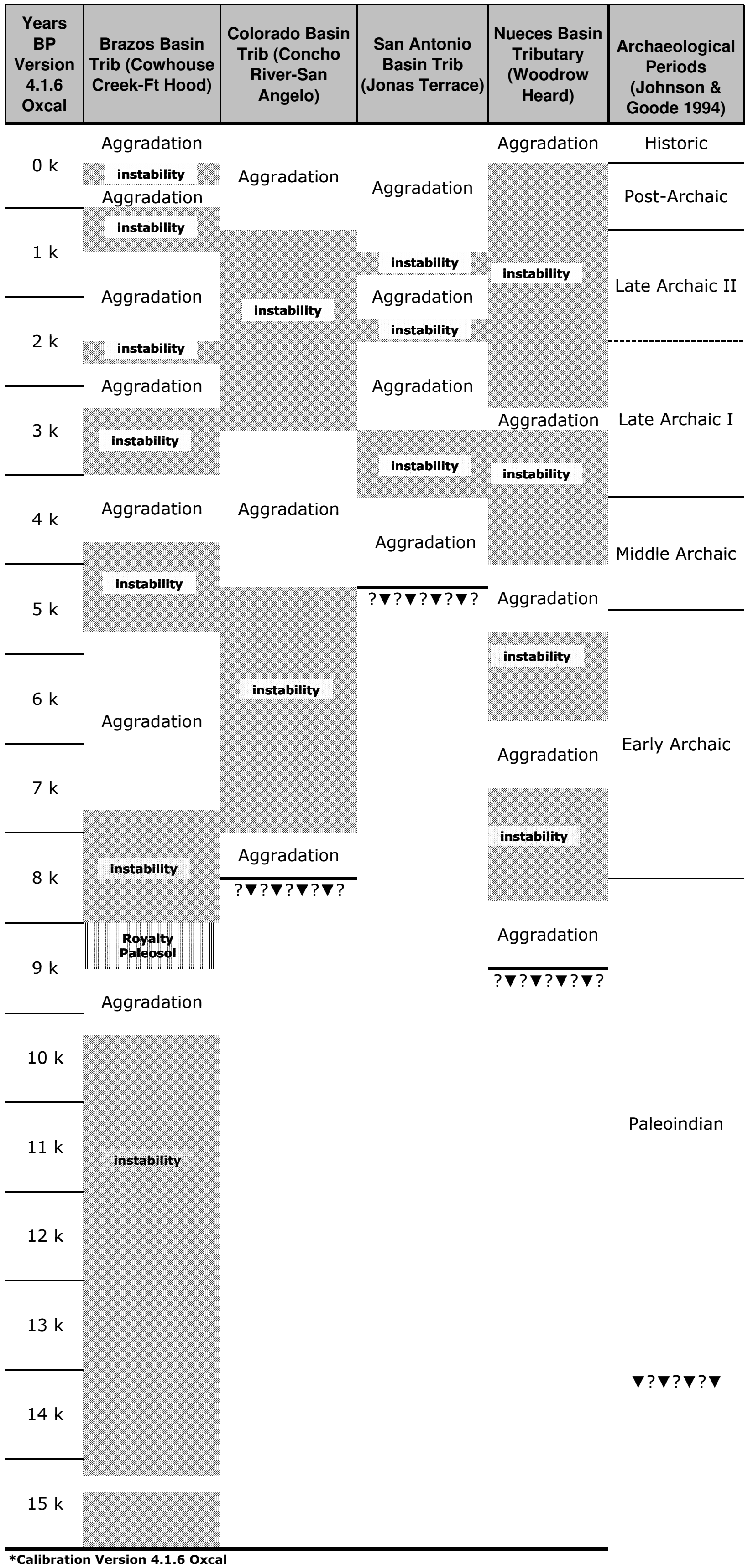


Figure 8.2 Patterns along Tributary Drainages in Study.

correlate with some of the gaps in the Units IIa–IIc (Hall et al. 1986:586–588). While the Choke Canyon Reservoir chronology is crude the comparison may suggest synchronous mechanisms affecting the Dry Frio and Frio Rivers. Unfortunately, the Choke Canyon Reservoir radiocarbon analyses were not corrected for isotopic fractionation and were not recalibrated here.

Similarly, the occupation hiatuses (i.e., 6,800–5,900 and 4,200–3,000 yr BP) identified by Ricklis and Blum (1997) and recalibrated here also seem to correlate with the erosional disconformities-lateral migration of the Dry Frio River at Woodrow Heard (Figure 8.2). If the previously mentioned humate sample (Beta-112981) is omitted from the Woodrow Heard assays, then the disconformity between Unit IIa and Unit IIb dates to 6,880–5,580 cal yr BP (Figure 8.2). This disconformity overlaps the first occupation hiatus identified as a period of rapid sea level rise by Ricklis and Blum (1997). Similarly, the disconformity between Unit IIb and Unit IIc occurred between 5,080–3,570 cal yr BP, which roughly coincides with the second occupation hiatus. Again, the only chronometric data available for Unit IIc is a humate sample (Beta-112980) and may likely date more recent than indicated.

Guadalupe-San Antonio River Basin

For the Guadalupe-San Antonio River Basin, the dissimilarities may be more informative than the similarities. Although the internal comparisons suggest more similarities between the upper and lower extent, than the middle extent these are generally rare. The Jonas Terrace site exhibited similar periods of erosion-incision as those reported at Copano Bay during 4,250–3,000 and 2,500–2,250 cal yr BP (Figure 8.2). Surprisingly, none of the periods of instability or stability seemingly overlap between the Richard Beene site and either the Jonas Terrace site or the Copano Bay study area. The depositional history at the Richard Beene site appears to be unique.

Brazos River Basin

The recalibration results in the Brazos River basin seemingly demonstrated the most intra-basinal patterns of this study. This may be attributed to the abundance of data over a broad geographical range within the basin. Regardless, several phenomena became apparent when the upper, middle, and lower extents were compared.

Beginning with the Late Pleistocene, the proposed period of erosion-incision is present in two of the Brazos River basin study areas. The exception is the A&M study area in the lower extent. This dataset had a suspicious assay dating to roughly 21,000 cal yr BP with no observed disconformities until after 9,300 cal yr BP. Regarding the upper and middle extents, the ending of this Early Holocene erosive event has a different time in each of the study areas, these differences may be due to sampling. However, it is interesting to note that this erosive cycle ended at 13,080 cal yr BP at Lubbock Lake, while Fort Hood has a more recent terminus of 10,100 cal yr BP.

Comparing the three study areas, the most prominent phenomena are periods of incision, hiatus, or data gaps in the radiocarbon record. The middle and lower extents exhibit the most similarity with two periods of overlap at 8,750–7,750 cal yr BP and at 5,750–5,250 cal yr BP. Notable, are overlaps in all three basin areas at 5,250–5,000, 4,000–3,250, and 2,750–2,500 cal yr BP. While these phenomena may in part be attributable to sampling the pervasiveness of the similarities suggests there may be a common synchronous mechanism.

Regarding periods of pedogenesis across the basin, the similarities are surprisingly few (Figure 8.2). At Fort Hood, the Royalty Paleosol roughly correlates with the A&M paleosol at the A&M study area. At Lubbock Lake, the Lubbock Lake soil of Stratum 4B and the Apache soil of Stratum 5A roughly overlap with the Asa and Katie soils, respectively at the A&M study area. However, these are the only similarities suggesting a regional period of stability.

Inter-Basinal and Regional Patterns

Widening the examination, the comparison of the different drainage basins within Texas and region demonstrates some interesting patterns. The inter-basinal comparisons were examined by three different categories (i.e., tributaries, trunk systems, and regional). First, the tributary systems of each of the basins were contrasted for any apparent patterns (Figure 8.2). All of these tributaries were on the Edwards Plateau, affording a comparison with the next comparison category, trunk systems. Trunk systems are the main channels of each of the basins (Figure 8.3). The study areas of each trunk system were on the Coastal plain and off the Edwards Plateau. The third category is a cumulative overview of all the depositional histories of all the Texas drainage basins in this study.

An examination of the tributary drainages in this study suggests some patterns in depositional history in the Edwards Plateau (Figure 8.2). Only three study areas were compared for this tributary comparison, the Cowhouse Creek (Brazos River basin), the Concho River (Colorado River basin), and the South Fork San Geronimo Creek (Guadalupe-San Antonio River basin). Unfortunately, the chronology at the Jonas Terrace site on the South Fork San Geronimo Creek begins at 4,250 cal yr BP and does not extend as far back as the other tributary study areas. Two earlier periods of instability are apparent at the other tributaries. At the Concho River and the Cowhouse Creek study

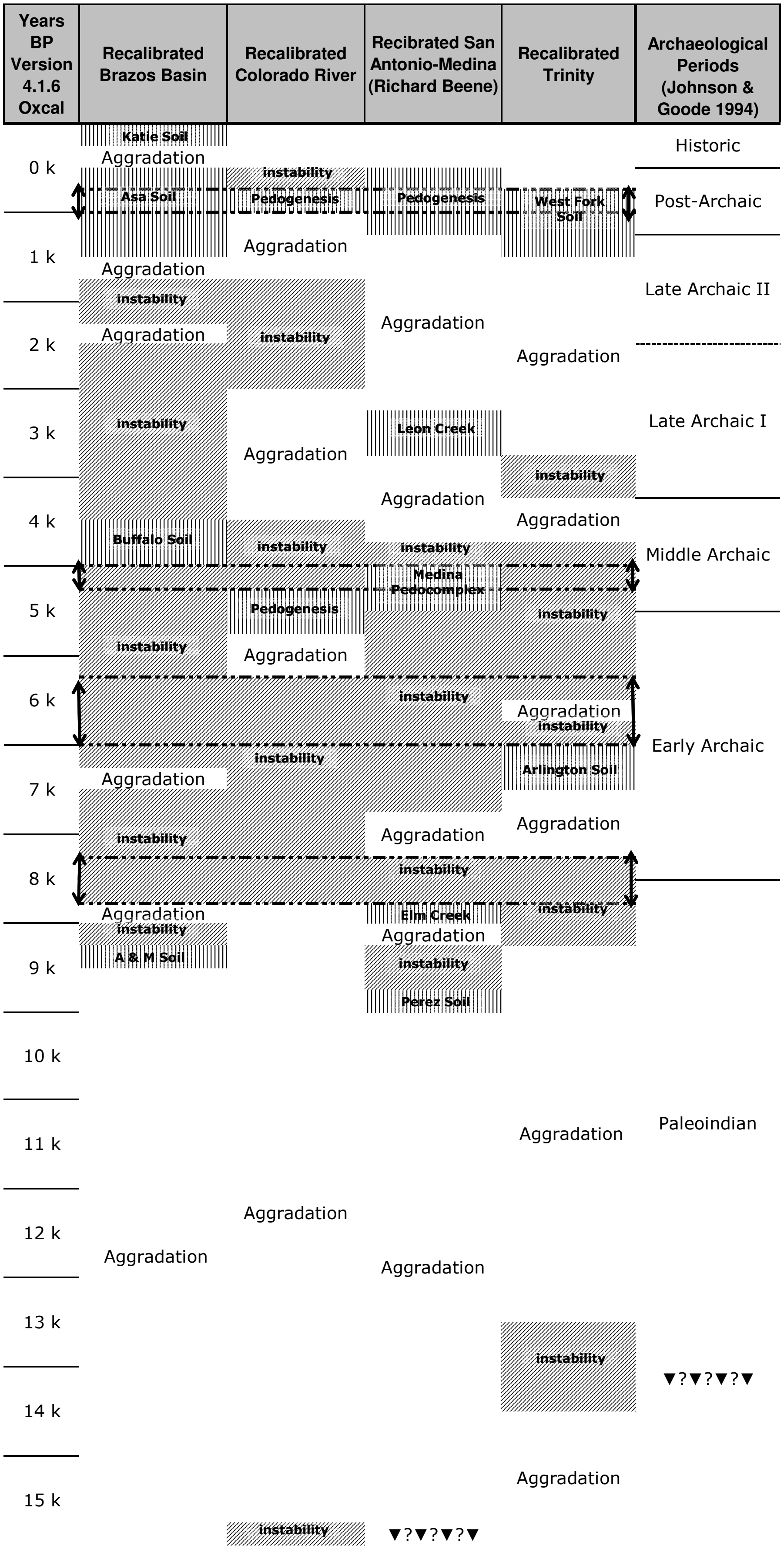


Figure 8.3 Patterns along Trunk Portions of Texas Drainages in Study.

areas, periods of instability occurs at 8,000–7,750 and 5,750–5,250 cal yr BP (Figure 8.2). At all three drainages two periods of instability are inferred at 3,750–3,250 and 2,750–2,250 cal yr BP. Notably, no periods of synchronous stability seem to have occurred at anytime among these tributaries on the Edwards Plateau.

Four study areas were selected for the comparison of Texas drainage basin trunk systems, the Brazos River, Colorado River, Medina River (Guadalupe-San Antonio basin), and the Trinity River. Beginning with the Late Pleistocene, the Colorado and Trinity Rivers exhibit a period of erosion-incision between 19,000–15,940 and 14,500–13,500 cal yr BP, respectively. Interestingly, neither the Brazos nor Medina Rivers exhibit this period of incision prior to the Holocene. The Medina River system may have an incision event prior to 15,900 cal yr BP, which is the *terminus ante quem* for Unit A3 (Perez Horizon). However, no definitive indication is apparent. The Brazos River exhibits continuous deposits up to 21,000 cal yr BP. However, this is based on a single radiocarbon assay from the margins of the floodplain (Waters and Nordt 1995). The applicability of the assay as representative of the Late Pleistocene is dubious. Regardless, deposition is occurring in all four basins by 13,500 cal yr BP and continues until 9,750 cal yr BP.

The first period of synchronous instability (Synchronous Event I) represented in all four basins occurred around 8,750–8,250 cal yr BP. This instability likely encompassed a more extensive period, but the Medina and Trinity River basins suggest normal deposition after 8,250 cal yr BP. The next period of synchronous instability (Synchronous Event II) in all four basins begins at roughly 7,000 cal yr BP and extends until 6,250 cal yr BP. As previously mentioned, several periods of transgression are noted to have occurred in the Early-Middle Holocene. These occurred at roughly 6,800–5,900 cal yr BP (Ricklis and Blum 1997; Paine 1991). Although the period of instability overlaps the period of sea level rise, the concurrence of the two phenomena may imply a correlation.

The next period of synchronous instability (Synchronous Event III) is not as evenly distributed as the other trends and the timing of it is approximate. Specifically, between roughly 5,250–5,000 cal yr BP, there is a period of instability occurring in these four basins. The one tenuous exception may be the Medina River basin, which has a period of stability ending about that time followed by a period of instability. While there does appear to be instability centered around 5,100 cal yr BP, but the duration of it in each basin varies considerably. At this time, the Trinity and the Brazos River basins seem to exhibit the most instability with the Medina and Colorado River basins the least. Previous researchers have noted a paucity of alluvial deposits at roughly this time in Texas and the Southern Plains (Baker et al. 2000; Hall 1990a:343). The scarcity of deposits dating to this time may imply a similar period of instability in those areas. Also, northward in the Great Plains, Schmieder (2008) examining lake sediments in the Sand Hills of Nebraska and observed an extensive period of drought beginning at this time. More locally, Nordt (2004) and other researchers in their examination of C_3 and C_4 isotopes at the Richard Beene site interpreted a decrease in C_4 and a brief cool period at this time. While Cooke (2003) and other researchers propose that the mantle in the uplands of the Edwards Plateau had an intense period of erosion. Not coincidently, this phenomenon also is squarely in the midst of the enigmatic Middle Archaic, which has long been recognized to have a comparatively lower frequency of sites than the other

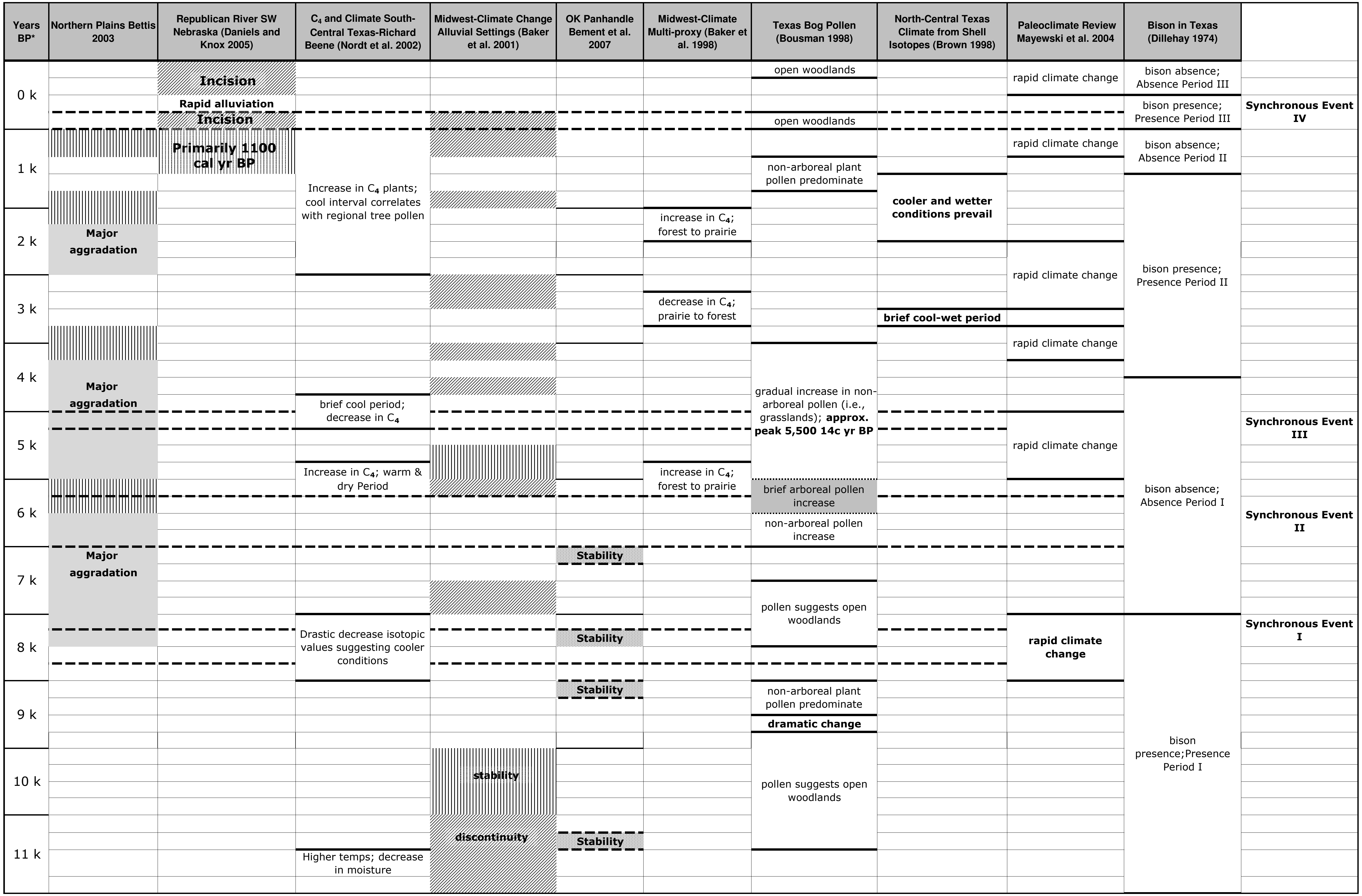


Figure 8.4 Climatic Patterns

cultural periods (Collins 2004). Cumulatively, this all suggests a pervasive synchronous event of instability across the region.

The last synchronous event (Synchronous Event IV) exhibited in all four basins is a period of stability (i.e., pedogenesis). Although periods of soil development are recognized to have occurred sporadically in all of the basins, none of these align except at 1,000–750 cal yr BP (Figure 8.3). Longer periods of stability seemingly occurred in the Brazos and Trinity River basins beginning as early as 1,500 cal yr BP while the Colorado River basin exhibits the weakest correlation. A period of stability at roughly 1,000 cal yr BP is very widespread and has been noted by previous researchers in alluvial settings in Iowa and Missouri (Bettis 2003; Bettis and Mandel 2002:145), in the Kansas River system (Arbogast and Johnson 1994), and possibly in alluvial settings across Oklahoma and Texas (Hall 1990a). Unfortunately, the dataset for Hall's (1990a: Table A) investigations were not corrected for isotopic fractionation and was not calibrated for this study. However, all other descriptions of these depositional histories are in accord with the period of stability observed in the four basins. Furthermore, Collin's compared archaeological sites with stratified cultural and geological horizons (i.e., gisements) compared in nine locations (Collins 1995:374, 2004:111). This comparison revealed a pervasive episode of stability around this time (Collins 1995: Table 2, 2004: Figures 3.9a and 3.9b). While Collin's (1995, 2004) data are reported in radiocarbon years BP, most of these nine study areas are part of the current recalibration study (e.g., Fort Hood and Richard Beene) suggesting an equivalency can be made for the areas not recalibrated (e.g., South Bend Reservoir on Clear Fork of the Brazos River). Thus, there appears to be a widespread synchronous episode of stability at 1,000–750 cal yr BP across these four basins and into alluvial settings on the Great Plains.

Causal Factors

For over a century researchers have examined the relationship between reactions in fluvial systems in response to external effects (e.g., Bull 1991, 2000; Knighton 1998; Knox 2000; Schumm 1993, 2003). See Blum and Törnqvist (2000) for a detailed examination of climate and sea level effects on drainages. However, a brief review follows to provide a general framework for the processes of these interrelated causal relationships.

Four factors are generally recognized to be the primary external influences on fluvial systems: tectonic activity, glaciation, climate change, and eustasy (Blum 1993: Table 1; Blum and Straffin 2001:195; Bull 1991, 2000; Knighton 1998; Schumm 2003). These factors can operate individually or in convergence and the sensitivity of the basins to these factors are filtered through a variety of controls including localized geology. At its simplest level, these factors influence the fluvial response stratigraphically (i.e., the storage or removal of sediment), morphologically (e.g., channel width, sinuousity), and deposition (i.e., bedload) (Blum 2007; Blum and Straffin 2001). An often-overlooked factor influencing drainages is anthropic mechanisms such as cultivation or vegetation removal (Frederick 1995). However, in Texas only the historic era to the present would appear to be affected by this factor.

Considering tectonic activity and glaciation have had little effect to the Texas drainage networks of the Late Quaternary, this leaves climate and eustatic influences as likely causes of the observed patterns. To be sure, tectonism is a factor of influence in Texas basins, but it almost exclusively takes form as a slow subsidence (i.e., 0.05 mm a year) of the continental margin (Paine 1993). Similarly, glaciation has not been proposed to affect the Texas waterways other than as melt water pulses, which ultimately defaults to sea levels and/or the climate. Consequently, researchers almost exclusively focus on climate and eustasy and the responses of drainages in Texas and the region. The influence of these two factors will be considered by reviewing the interpreted paleoenvironmental record and sea levels proposed by previous researchers.

Climate

The review of the climate was accomplished by compiling proxy data (e.g., bog pollen, speleothems, and various isotopic analyses) from several regional and global studies used to reconstruct the paleoenvironment for the late Pleistocene and Holocene in Texas (Bousman 1992, 1994, 1998a; Cooke et al. 2003; Nordt et al. 2002; Toomey et al. 1993). Admittedly, not all data are unanimously accepted and there are gaps in the record, but a preponderance of researchers generally accept the review provided here.

Subsequent to the last glacial maximum approximately 23,500 cal yr BP, the climate has been interpreted to have had cooler temperatures and more mesic conditions for the Central Texas region, South Texas Plains, and Texas coastal plain (Bousman 1998; Bryant and Holloway 1985; Bryant and Shafer 1977; Hudler 2000; Musgrove et al. 2001; Nordt et al. 2002, 2007; Sylvia and Galloway 2006; Toomey et al. 1993). These cool and mesic conditions prevailed until 15,000 cal yr BP and again around 12,000 cal yr BP, when pollen and isotopic analyses data suggest that glacial melt waters entered the Gulf of Mexico and triggered arid and presumably cooler conditions in southern and Central Texas (Bousman 1998:214; Nordt et al. 2002:182). This assessment is further supported by low growth rates on speleothems from dated stalagmites in several central

Texas caves, implying more xeric conditions (Musgrove 2000; Musgrove et al. 2001). This also correlates with investigations in the Southern Plains where Holliday (2000) argues that climatic oscillations occurred around the Late Pleistocene-Holocene transition with cooler and moister conditions for the Clovis period and particularly arid and warmer conditions during the Folsom period. Based upon the recalibration of the Lubbock Lake data for this study (see Chapter 6), this suggests that the climate was cooler and mesic at roughly 13,250–12,750 cal yr BP and conditions were most arid between 12,500–11,500 cal yr BP. The more recent xeric period was followed by a shift back to cooler temperatures and moist conditions in central and southern Texas, which continued into the Early Holocene (Bousman 1998:214).

From the Early to Middle Holocene (~ 11,500–5,000 cal yr BP), the proxy data suggest that the climate became gradually warmer and more xeric (Bryant and Shafer 1977; Toomey et al. 1993). These data include pollen evidence suggesting a decrease in arboreal canopy and open grassland for central and south central Texas (Bousman 1998), various fauna indicator species from cave deposits (Hudler 2000; Toomey et al. 1993), the presence or extinction of various Molluscan fauna (Neck 1983, 1987), and shifts in C_3–C_4 plant production (Nordt et al. 1994, 2002). At this time, Greenland ice core data suggests abrupt climatic changes in the climate at 8,900–8,300 and 8,200 cal yr BP (Hu et al. 1999; Yu and Wright 2001). In conjunction, Barber and others (1999) argue that the Laurentide ice sheet had an abrupt reduction in size and flushed massive amounts of freshwater into the Labrador Sea around 8,400 cal yr BP, which they argue triggered the climatic changes between 8,400–8,000 cal yr BP.

Further, Mayewski and others (2004) examined over 50 paleoclimate records in the Northern and Southern hemispheres from around the world. These researchers observe a period of rapid climate change between 9,000–8,000 cal yr BP, which in North American is exhibited by rapid glacial advances in the northwest and the previously mentioned surge of melt water (Mayewski et al. 2004:248–249). In an alluvial setting (South Fork of the Big Nemaha River) in southeastern Nebraska on the Great Plains, Baker and others (2000) propose that a disappearance of upland forests and an extended period of dry conditions occurred between 9,200–6,500 cal yr BP. More locally, Dillehay (1974) in researching the presence or absence of bison in the Southern Plains inferred an extended period of absence beginning around ~7,900 yr BP (6000 BC) that coincides with this warming period. These warming and xeric conditions existed throughout this time with some minor deviations and probably localized variations (Hudler 2000:88–89).

One anomaly of note is a very brief episode of moister conditions in southern and central Texas occurring ~6,000 yr BP as evidence d by an increase in arboreal pollen and data from isotopic composition of organic and inorganic carbon (Bousman 1998; Nordt et al. 2002:186). This brief cool and moist episode was immediately followed by an extremely arid and warm climate (Bousman 1998; Nordt et al. 2002). This xeric period lasting roughly 1,000 years, was exhibited by a drastic reduction in arboreal pollen and an increase in grassland pollen (Bousman 1998). Further evidence of these xeric conditions, is the reappearance of bison on the Southern Plains beginning around ~4,500 cal yr BP or 2500 BC (Dillehay 1974). Also in the Great Plains, Baker and others (1998) in their examination of pollen and plant macrofossils in northeastern Iowa, note a rapid change in vegetation from a forest to prairie setting at 6,000 cal yr BP and they observed the percentage of C_4 values reached a peak around 5,000 cal yr BP. More broadly, Mayewski and others (2004:250) observe rapid climate change globally between 6,000–5,000 cal yr BP where central North America experiences a strengthening of westerly winds among other widespread climatic events.

After this arid and warm period extreme, the Late Holocene climate is described as gradually increasing in moisture and cooling in temperature (Bousman 1998; Nordt et al. 2002, 2007: Butzer et al. 2008). Johnson and Goode (1994) in their examination of the Jonas Terrace site also propose that conditions were becoming more mesic and cooler, but they have it occurring around 3,850 cal yr BP (1900 BC) and roughly extending until 1,950 cal yr BP (0 BC). The mesic indicators of this time were exhibited through a gradual increase in woodland canopy and data from stable isotope analyses in buried soils (Bousman 1998; Nordt et al. 2002, 2007). Nordt and others (2007:159) characterize this period as a 'cool interlude' before conditions again transition into a more xeric and warm climate. This arid interval extends from roughly 2,600–1,000 cal yr BP before again becoming slightly more mesic and continuing as such up to the present (Nordt et al. 2007). Coinciding with these swift transitions from mesic to xeric conditions includes the absence of bison in the Southern Plains between roughly (~1,500–950 cal yr BP (AD 500–1200) and subsequent reappearance between ~950–400 cal yr BP or AD 1200–1550 (Dillehay 1974).

More broadly, at 4,200–3,800 cal yr BP glaciers advanced in western North America and central North America had intense westerly winds, which weakened at 3,500–2,500 cal yr BP (Mayewski et al. 2004:250). Rapid climate changes are also indicated globally at 1,200–1,000 cal yr BP manifesting as cooler temperatures in the Sierra Nevada mountains based on tree ring data while between 600–150 cal yr BP a period of polar cooling and increased moisture in the tropics occurred (Mayewski et al. 2004). In an alluvial setting in southeastern Nebraska, an abrupt, but brief disappearance of riparian trees indicates arid conditions at 3,360–2,910 cal yr BP (Baker et al. 2000). Further, Huckleberry and Duff (2008) note in western New Mexico that increased moisture caused widespread valley entrenchment around ~1050–900 yr BP (AD900–1050) and 650–550 cal yr BP (AD 1300–1400) with the latter followed by an extended period of arid conditions. Locally, the last 1,000 years are indicated to have some brief fluctuations of arid conditions occurring around before trending toward modern climates of the present (Bousman 1998:216).

Eustasy

The effects of changes in worldwide sea levels (eustasy) are more limited on drainage systems than that of climatic changes. Researchers have investigated various aspects of rising and falling sea levels at global and local levels and the distance upstream of those influences have on drainage basins. There is considerable debate regarding the influence eustasy has on a drainage system and to what degree (Schumm 1993). At its simplest form, the influence is generally interpreted to result in as drainage incision (down cutting) for lowering sea levels (regression) and avulsion and aggradation for a rise in sea levels (transgression) (Anderson et al. 2004; Banfield and Anderson 2004; Blum 1993; Blum and Aslan 2006; Blum et al. 2001; Blum and Price 1998; Blum and Törnqvist 2000; Durbin 1999; González 2008; González and Törnqvist 2009; Leeder and Stewart 1996; Schumm 2003; Thomas and Anderson 1994; Törnqvist et al. 2004; Van de Plassche et al. 1998; Zaitlin et al. 1994). Regarding the distance upstream the influence of sea level has on a drainage basin, one of the primary factors is the slope of the coastal plain. In periods of regression when the coastal plain is roughly equal to that of the coastal shelf, there should be a slight extension of the channel onto the coastal shelf. If the coastal plain is noticeably steeper than the coastal shelf the channel will extend and aggradation of deposits will occur, and if the coastal plain is shallower than the coastal shelf, then the channel will extend in conjunction with dramatic incision (Blum and Törnqvist 2000; Schumm 1993:281–282). For Texas, the coastal plain is generally steeper than the coastal shelf.

Furthermore, the effects of sea level changes may be severely limited in coverage to the drainage basins. Specifically, previous researchers indicate that eustatic effects on drainages are generally limited to within 100 km (62 miles) of the coast, which falls within the lower extent of all the examined basins of this study (Blum 1993; Durbin 1999; Etheridge et al. 1998). Most confounding is discerning the difference between influences of eustatic effects versus climate within a basin, particularly within the lower extent. Researchers Blum and Aslan (2006) have proposed criteria for determining the influences of climate versus sea level change on drainage valleys. They indicate that climatic influences should be exhibited by stratigraphic units that extend from mixed-bedrock valleys (upstream) across the coastal plain to the distal reaches (downstream) of a basin. There is a recognized continuity of facies architecture throughout the drainage basin particularly if the climatic influence is major. In contrast, the signature of sea level influences on a drainage basin is more complex. During a drop in sea levels, there is incision within the drainage, which may result in a valley separation on the coastal plain concurrent with lateral migration and meander belt construction. The mixed-bedrock valleys will incise with periodic lateral migration and creation of terraces while a rise in sea levels trigger a shortening of the channel and expansion of the deltas. Notably, Blum and Aslan do not identify characteristics for the mixed-bedrock valleys upstream during the periods of sea level rise.

Previous investigations within the Gulf of Mexico have characterized the Late Quaternary stratigraphy, but unfortunately, most of these focus on periods much older than the latest Pleistocene. As with the paleoclimate interpretations, not all data for sea levels are widely accepted and are frequently contradictory. The following review includes some of the more recent investigations in the region, which largely concur in their interpretations.

Since the Last Glacial Maximum (~23,500 cal yr BP) in the Gulf of Mexico, researchers have identified at least two pulses of glacial melt water that entered the gulf prior to the Holocene (Figure 8.5). Fairbanks and others (1989) examined coral reefs in the Caribbean and argue that these pulses occurred at 13,500–13,000 cal yr BP and 11,000–10,500 cal yr BP. Off the Texas coast, Snow (1998) examined near shore core samples of the Colorado River delta and radiocarbon data from previous investigations and observed the first melt water pulse (MWP 1A) occurred at roughly 14,500–13,750 yr BP. This first pulse produced a rise in sea level of roughly 36 mm a year. The second melt water pulse (MWP 1B) occurred at roughly 12,000–11,500 yr BP and produced a sea level rise of approximately 16 mm a year. Snow (1998:129–131) characterized these pulses as producing high sediment yields that were primarily controlled by climate. Following the second melt water pulse, the sea level continued to gradually rise at a roughly constant rate of 10 mm a year between 11,500–5,000 cal yr BP. Snow (1998) observed a transition from fluvial dominated deposits of the Colorado River to wave

Years BP*	Nueces Bay data (Ricklis and Blum 1997)	IntCal 09 Curve Copano Bay Area (Paine 1991)	Colorado Delta data (Snow 1998)**	Mississippi Delta (Gonzalez 2008; Gonzalez & Tornqvist 2009)	Mississippi Delta (Tornqvist et al. 2004)	Colorado River Delta-Copano Bay (Blum et al. 2001)	Ice Core Data (Alley et al. 1997)	Paleoclimate Review Mayewski et al. 2004	Carribean Coral reefs (Fairbanks et al. 1989)	
0 k				sea level drop; sea rise peak				rapid climate change		Synchronous Event IV
1 k				Slow sea level rise begins 1350 yr BP				rapid climate change		
2 k		Incision; Incision								
3 k	rapid sea level rise; coincides with coastal occupation hiatus	Incision						rapid climate change		
4 k		Drop in Sea Level; Regression			Gradual sea level rise about 1.5 mm/yr			rapid climate change		
5 k	rapid sea level rise; coincides with coastal occupation hiatus	Third transgressive pulse of sea level rise				Younger 14c data suggests sea level rise about 3-4 mm yr; rose above modern sea level by 2 m		rapid climate change		Synchronous Event III
6 k										Synchronous Event II
7 k			Eustatically influenced Phase 2: Wave deposits dominate; sea level rise 10mm/yr; climate continues to be warm-dry		Generally gradual rise about 3.5 mm/yr; interpreted to be end of glacial melt water pulse	Older 14c data suggest sea level rise interpreted to be 9-11 mm/yr				
8 k							extensive dramatic cold-dry cycle			Synchronous Event I
9 k										
10 k			Climatic influenced Phase 1: Fluvial deposits dominate;sea level rise 10mm/yr; transitions from cool-moist to warm-dry climate						large glacial melt water pulse	
11 k			Meltwater Pulse 1B; sea rise 16mm/yr							

Figure 8.5 Eustatic Patterns

dominated deposits (i.e., eustatic) around 9,500 cal yr BP. Considering the rates of sea level between 11,500–5,000 cal yr BP were rising at an equivalent level (i.e., 10mm/yr) this transition is interpreted as evidence of a shift from climate influence to eustatic influence.

More controversially, Blum and others (2001) in their examination of the Colorado River delta and nearby Copano Bay interpreted a dramatic rise in sea level exceeding modern mean sea levels (msl) by over 2 m. The researchers interpreted this transgression to have occurred between either 7,800–6,800 cal yr BP or 7,800–4,800 cal yr BP depending on the dataset used (Blum et al. 2001). Specifically, a few samples are indeterminate if they are affected by younger calcite thus providing two datasets (Blum et al. 2001:586). In contrast, Törnqvist and others (2004) analyzed deposits of basal peat in the Mississippi delta, which are typically deposited in coastal settings between the msl and high water mark. These researchers encountered deposits between 8,000–3,000 cal yr BP that exhibited a gradual rise of sea level with no drastic jumps in sea level. A slight bump in sea level rise (3.5 mm/yr) did occur between 8,000–7,000 cal yr BP followed by a decrease with a sea level rise of 1.5 mm a yr up to 3,000 cal yr BP. Further, no indications of sea levels exceeding modern msl were observed, but they did not exclude the possibility of it occurring between 3,000 cal yr BP and the present.

In the Middle Holocene, the previously mentioned research by Ricklis and Blum (1997) interpret a rise in sea levels that coincides with a hiatus in coastal occupations by native groups. The recalibration of these data (see Chapter 3) did not adjust the initial conclusions of sea level rise occurring at 6,800–5,900 and 4,200–3,000 cal yr BP (Ricklis and Blum 1997). In the Copano Bay area of the Guadalupe-San Antonio River basin, the previously mentioned research of Paine (1991) examined a variety of datasets (e.g., sea cores, trench profiles, archaeological investigations) to characterize the Late Quaternary deposits of the bay. Unfortunately, only a portion of these data could be recalibrated for this study. Therefore, Paine's (1991) interpretations prior to 6000 cal yr BP are not calibrated. Regardless, three transgressive pulses are recognized to have occurred during the Holocene. With only the last transgressive pulse could be recalibrated (see Chapter 4). Briefly, the first pulse is described as a transition from fluvial (i.e., stream) to marine (i.e., sea) influenced deposition implying a rapid rise in sea level followed by a return to fluvial deposition interpreted to be a period of stillstand or possible drop in sea level (Paine 1991:61–64). The second pulse is again suggested by a transition from stream deposition to marine deposition inferring another sea level rise shortly followed by a transition back to a dominant stream deposition suggesting another stillstand.

The third pulse was recalibrated for this study and dates to 5,750–4,750 cal yr BP. Interestingly, this roughly correlates with the sea level rise interpreted by Ricklis and Blum (1997). Paine (1991:64) characterized this last transgressive pulse as a transition from stream to marine deposition suggesting a slow sea level rise. Of note, this rise in sea levels rose approximately 0.9 m above modern sea levels (Paine 1991:170–171). However, this interpretation is in the minority, as most researchers do not interpret a sea level rise of that magnitude at this time. Subsequent to the last transgressive pulse a sea level stillstand begins that continues to the present (Paine 1991:57). Simply put, these three pulses are argued to be evidence for eustatic effects. If correct, only the lower portions of the basins would be affected.

For the Late Holocene, extensive investigations have recently been conducted in the Mississippi River delta (e.g., González 2008; González and Törnqvist 2009). These investigations analyzed basal deposits of peat, which, as previously mentioned, are interpreted to be deposited between the mean sea level and high water mark (González and Törnqvist 2009:1739). Additionally, the peat provided the source for the radiocarbon assays that enabled high-resolution chronological control. These researchers observed a gradual rise in sea levels beginning around 1,350 cal yr BP (AD 600) that peaked around 850 yr BP (AD 1100) and declined until roughly 450 cal yr BP or AD 1500 (González 2008; González and Törnqvist 2009: Figure 11).

Correlations

A comparison of the recalibrated data from this study will now be conducted with the available information of climate and eustatic factors. Understandably, the recognition of contemporaneous events does not confirm a correlation. However, the intent of this component of the study is to identify areas and temporal periods where more research may be warranted.

The first correlation study is of the four synchronous events observed within the four basins identified during the Inter-basinal comparisons. These synchronous events consist of three apparent periods of instability at 8,750–8,250, 7,000–6,250, and 5,250–5,000 cal yr BP and one period of stability between 1,000–750 cal yr BP.

Synchronous Event I

For the first period of instability (8,750–8,250 cal yr BP), several studies indicate pervasive events occurring immediately preceding or contemporaneous with this phenomenon. In particular, an abrupt change in the global climate occurred between

9,000–8,000 cal yr BP likely triggered by a large pulse of glacial melt water (Alley et al. 1997; Barber et al. 1999; Hu et al. 1999; Mayewski et al. 2004). In the paleoenvironmental research of the Oklahoma Panhandle along an alluvial setting (Bull Creek), Bement and others (2007) note a period of pedogenesis suggesting stability at roughly 8,460 cal yr BP. Similarly, in an alluvial setting (South Fork of the Big Nemaha River) in southeastern Nebraska on the Great Plains, Baker and others (2000) propose that a disappearance of upland forests occurred between 9,200–6,500 cal yr BP. Also, bog pollen in Texas exhibits a transition from more diverse forests to open woodlands while C_4 isotopic values at the Richard Beene site decreased, all inferring a cool, moist climate at this time (Bousman 1998; Bousman and Oksanen in press; Nordt et al. 2002). Interestingly, this is also roughly the end of Dillehay's (1974) Presence Period I for bison in the Southern Plains. Regarding eustatic effects, an abrupt increase of sea level occurs at roughly this time, but this interpretation is not widely accepted (Blum et al. 2001;Törnqvist et al. 2004).

Considering the archaeological record in Texas at this time, this synchronous event falls at the transition from Late Paleoindian to Early Archaic archaeological period or at the beginning of the Early Archaic archaeological period (Figure 8.6). A pervasive geomorphic period of instability seemingly occurs roughly simultaneous to a period of transition within the archaeological record. McKinney (1981:114) does interpret changes in Central Texas Archaic lithic technology as adaptation to environmental changes. Contemporaneity of events does not indicate causality and reaction, but these concurrent phenomena do warrant some attention.

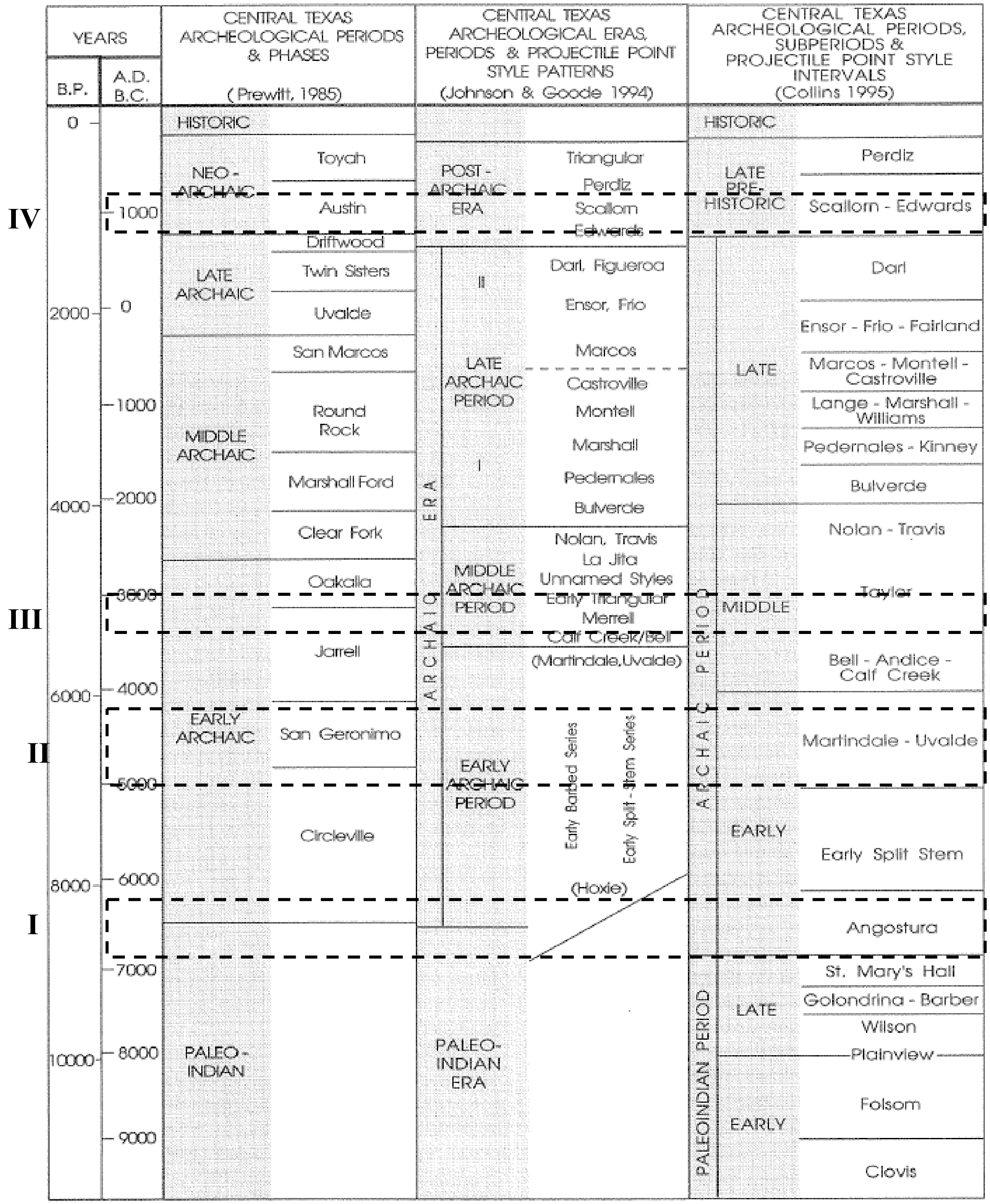


Figure 8.6 Calibrated cultural chronology contrasted with Synchronous Events I–IV (adapted from Mehalchick et al. 2000).

Synchronous Event II

The second period of synchronous instability (7,000–6,250 cal yr BP) is the longest of those identified. This period immediately precedes an abrupt climate change in the global record (Mayewski et al. 2004). In Nebraska of the Central Plains, an extended period of drought occurred at this time while in the Midwest, various data (e.g., speleothems and alluvium) suggest a major climatic transition near the end of this second period of instability (Baker et al. 1998; Baker et al. 2001). Similarly, in alluvial settings in Iowa and Illinois an extended period of drainage aggradation is indicated for this time (Bettis 2003). Within Texas, the bog pollen data suggests a transition to non-arboreal plants inferring grassland prairies and by extension xeric conditions (Bousman 1998).

Notably, the previously mentioned ‘cool interlude’ associated with a short-lived increase in arboreal pollen and data from isotopic composition of organic and inorganic carbon occurred at ~6,000 cal yr BP (Bousman 1998:210; Nordt et al. 2002:186). However, this interlude was preceded by a period increased of $\delta^{13}C$ values denoting xeric conditions, which concurs with the second period of instability (Nordt et al. 2002). Interestingly, this period is noted as a time of alleged bison absence (Absence Period I) (Dillehay 1974). However, occurrences of bison have been encountered on archaeological sites (41HY160 and 41HY165) in Central Texas clustering around 5,900–5,700 cal yr BP (Lohse 2010). The presence of bison at that time implies xeric conditions, which concurs with the pollen and isotopic data. Concerning eustatic effects, no prominent rise or drop in sea levels are recorded for this time.

Synchronous Event II occurs roughly in the middle of the Early Archaic (Figure 8.6). This period of instability does not appear to coincide with any obvious widespread cultural change.

Synchronous Event III

The third identified period of synchronous instability (5,250–5,000 cal yr BP) has long been recognized as a time of geomorphic change likely accounting for the paucity of Middle Archaic data (Collins 2004:115;McKinney 1981). Mayewski and others (2004) have identified widespread evidence of abrupt climate change occurring at this time. Some indications of these include large-scale glacial advances in the northern and southern hemispheres and an increase in aridity in the Maya lowlands of Central America among others (Hodell et al. 2001; Mayewski et al. 2004). Further, considering that no glacial melt water pulses are interpreted to occur at this time, researchers propose that these climatic fluctuations are possibly attributed to solar variability (Hodell et al. 2001; Mayewski et al. 2004:251). In northeastern US, dramatic shifts in pollen are noted, which are attributed to repeated droughts (Shuman et al. 2009). More locally in the Great Plains, lake sediments suggest a dramatic shift from a wet cycle to drought conditions while assessments of the stable isotopic compositions of buried soils indicate warmer temperatures at roughly this period (Nordt et al. 2007; Schmeider 2009).

Within Texas, the bog pollen data indicates the lowest percentage of arboreal pollen occurred at roughly 5,500 yr BP suggesting grassland prairies and xeric conditions (Bousman 1998:210). Further, the soil mantle in the uplands of the Edwards Plateau is recorded to be ending an extended period of erosion at roughly this time (Cooke 2006; Cooke et al. 2003). Using data from Hall's Cave in Kerr County, the researchers propose that the Central Texas uplands were generally emptied of its soil mantle beginning in the Late Pleistocene and ending roughly concurrent with this third period of synchronous instability (Cooke 2006; Cooke et al. 2003). One corroboration of this may be present as Nordt (1996:16–17) recorded a depositional history at Leon Creek (Guadalupe-San Antonio River basin) situated at the base of the Edwards Plateau, which prior to this time was composed of both alluvial and colluvial deposits and switched to become more gravelly with no evidence of colluvium afterwards.

Large fluctuations in sea level are also interpreted to have occurred at this time. Ricklis and Blum (1997) recognize a short-lived rise in sea level that overlaps with the third period of synchronous instability (Figure 8.5). Further, this sea level rise coincides with a hiatus in cultural occupations along the coast (Ricklis and Blum 1997). Similarly, the recalibrated data of Paine's (1991) Copano Bay research also indicates a period of sea level rise at this time. As previously mentioned in the Nueces River basin (Chapter 3), similar gaps in chronometric data were recognized during the Choke Canyon Reservoir investigations. These gaps are roughly contemporaneous with this period of sea level rise. However, as previously indicated eustatic effects on drainages are generally limited to within 100 km (62 miles) of the coast, which puts the Choke Canyon Reservoir right at the limits of eustatic effects (Blum 1993; Durbin 1999; Etheridge et al. 1998).

Concerning the Texas archaeological record, this synchronous event falls roughly at the beginning of the Middle Archaic (Figure 8.6). Thus, another pervasive geomorphic period of instability coincides with a period of transition within the archaeological record. Further, examining Black and Creel's (1997) radiocarbon chronology of burned rock middens, this event is situated near the beginning of an extended period of increased burned rock midden use (Figure 8.7). However, the assays of the burned rock midden study have not been calibrated for this study and this comparison is approximate. It is probable, that Synchronous Event III will fall within the radiocarbon gap preceding the increase in burned rock midden exploitation after the assays have been calibrated with IntCal09.

Synchronous Event IV

The final period of synchronous geomorphic activity is a period of pervasive stability between 1,000–750 cal yr BP. Oddly, this period has the most contradictory climatic data possibly because of the plethora of investigations (Figure 8.4). In the western US, a period of cooler temperatures and drought are indicated by tree ring data in the Sierra Nevada Mountains occurring at AD 892–1112 (1,058–838 cal yr BP) and AD 1209–1350 (741–600 cal yr BP), which are argued to coincide with the Mediaeval Warm Period (Mayewski et al. 2004; Stine 1994). In western New Mexico widespread valley entrenchment from an increase in moisture is indicated between roughly 1,050–900 cal yr BP (Hall 1990b; Huckleberry and Duff 2008). Similarly, on the Republican River in Nebraska, after a period of pedogenesis ending at roughly 1,100 cal yr BP, a period of drainage incision occurred between 1,100–750 cal yr BP (Daniels and Knox 2005). However, a period of prolonged pedogenesis is recognized at this time in alluvial settings in the east-central Plains (Johnson and Martin 1987), in the Kansas River basin in the central Plains (Arbogast and Johnson 1994; Johnson and Logan 1990: Figure 9), and in the previously mentioned 15 alluvial settings studied by Hall (1990a).

Locally in Texas, the bog pollen data suggests a period of open woodlands while bison are indicated to have been present during Presence Period III (Bousman 1998;

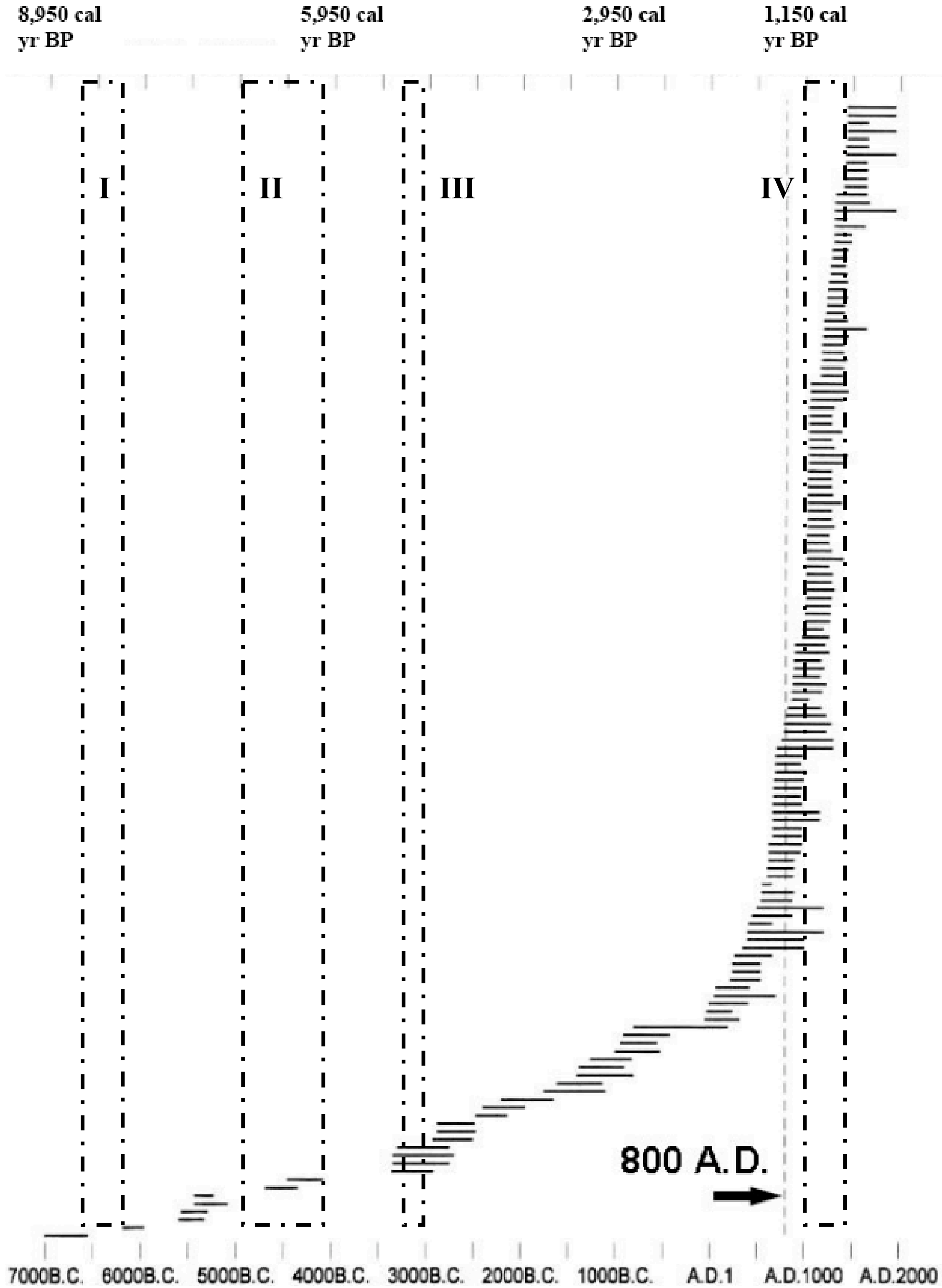


Figure 8.7 Radiocarbon dates from burned rock middens on Edwards Plateau suggesting frequency of use (adapted from Black and Creel 1997).

Dillehay 1974). Regarding eustatic effects, only recent investigations in the Mississippi River delta provide any information from this time (González 2008; González and Törnqvist 2009). These data from radiocarbon dating basal peat deposits enabling high-resolution chronological control suggested a gradual sea level rise beginning around 1,350 cal yr BP and peaked between 1,000–750 cal yr BP (González 2008; González and Törnqvist 2009).

Similar to the diverse paleoenvironmental results, the archaeological record in Texas at this time is extremely varied (Pertulla 2004: Table 1.1). Regardless of archaeological region, the synchronous period of stability seemingly occurs at a time of transition across Texas. Furthermore, comparing Synchronous Event IV again with Black and Creel's (1997) burned rock midden frequency, the peak of midden use appears to coincide with this period of stability (Figure 8.7). This high frequency of burned rock midden use may be reflective of improved integrity of this period of geomorphic stability. Again, these phenomena warrant further investigation.

Summary

The results of the recalibrated datasets from the drainage basins were consolidated and examined for patterns both within and between the Texas basins and, to a lesser degree, the region. A review of extrinsic factors that possibly influenced the depositional history of these basins was conducted. Finally, the recognized patterns (i.e., Synchronous Events I–IV) of the drainage basins were compared with the extrinsic factors (i.e., climate and eustatic effects) identified within Texas and the region. The contemporaneous occurrence of events does not verify a correlation or causation between the incidents, but the synchronous occurrences may imply valid relationships or minimally a shared causal mechanism. Therefore, these interpretations are malleable and may be adjusted when new data is encountered.

In sum, based on the recognized patterns within the drainage basins and the reviewed paleoenvironmental and sea levels through the Late Pleistocene-Holocene, it appears that climate was the primary forcing mechanism on the Texas drainage systems. This is particularly evident for Synchronous Events I–III that have the most robust evidence for climatic data within Texas and the region. However, all four of the recognized patterns appear to have been triggered by climatic influences. The clearest evidence of this exists in the depositional histories of alluvial settings in the Great Plains and Midwest far removed from the influence of eustatic effects, but are similar to those exhibited in Texas during these periods.

CHAPTER 9

Conclusions and Future Research

The primary goal of this study was to provide a chronological baseline for the comparison of archaeological sites in Texas drainage basins. To accomplish this objective, an extensive archival review of predominantly geoarchaeological research was undertaken to gather as much data as possible that met several criteria. There were three main criteria used for selecting the radiocarbon assays for this recalibration study. First, assays of charcoal were given priority over other dated materials; second, samples that have been previously 'corrected' for isotopic fractionation; and finally, datasets composed of samples in good stratigraphic context. With these criteria, the archival research was scrutinized for investigations that had been conducted in alluvial settings and, most importantly, had at least minimally considered chronometrically dating depositional stratigraphy, which was actually more difficult than initially envisioned. Furthermore, samples from humate materials were used more than initially intended, but these were reluctantly accepted. As discussed in Chapter 2, all calibrations of samples derived from humate materials tend to date inconsistently, sometimes drastically older (approximately 1,000–1,500 years) than comparable charcoal samples. Thus, it was only out of necessity that these samples were utilized and the results of these data should be used with caution.

Subsequent to the recalibration of the various datasets within the select Texas drainage basins, the data were consolidated and examined for any intra-basinal or inter-basinal patterns in depositional history. These comparisons recognized four contemporaneous events that occurred within most, if not all, of the Texas drainage basins. These events include three periods of apparent instability (i.e., Synchronous Events I–III) and one of stability (i.e., Synchronous Event IV). These events were then compared to possible external mechanisms (e.g., climate and eustatic effects) that may have contributed to these occurrences. Based on similar depositional histories in the Great Plains and Midwest, the most probable trigger for the four synchronous events is climate. Furthermore, when the four events were compared to the archaeological record in Texas, three of them (i.e., Synchronous Events I, II, and IV) aligned during periods of cultural transition while the remaining one (i.e., Synchronous Event III) not surprisingly occurred during the enigmatic Middle Archaic, long recognized for poor integrity. This begs the question, were these adjustments in cultural lifeways a result of the changing environment or something else (e.g., social)? Although not definitive, these data do appear to corroborate the argument that the changing environment is the significant contributing factor to these transitions.

Interpretations

Several general interpretations developed from the review of the archival data and the results of the analyses. One general interpretation is that depositional landforms will exhibit more integrity as the distance downstream from the Edwards Plateau increases. This is almost assuredly due to the more confining channels that have incised into limestone bedrock in the uplands. The fluvial history of these areas demonstrates that they are periodically flushed out removing much of the deposition while in the prairies where the channels become more sinuous, the fluvial deposits are more complete and intact providing a better depositional history. Some examples of this include the Jonas Terrace site (upper Guadalupe-San Antonio River Basin) and the Woodrow Heard site (upper Nueces River Basin), which have truncated depositional histories. Comparatively, the Richard Beene site (Guadalupe-San Antonio River Basin) has exceptional stratigraphy and integrity. To be sure, outside bends in higher sinuousity channels are eroded, but the interior bends preserve their deposits. Also, smaller tributary channels are more noticeably affected by changes in deposition than larger waterways. Thus, if the research focus is attempting to characterize changes in past climates then smaller channels should be analyzed (e.g., Dry Frio River, South Fork San Geronimo, Cowhouse, Salado, and Medio Creeks), but if the research is investigating continuous alluvial stratigraphy with possibly robust archaeological deposits then more substantial drainages should be explored (e.g., Brazos, Colorado, Medina and San Antonio Rivers).

Another interpretation from this study includes the issue of integrity of particular time periods and drainages. First, the pervasive period of instability that occurred during the Middle Archaic in Central Texas (i.e., Synchronous Event III) where archaeological sites and cultural activities associated with this temporal setting are expected to be sparse. Thus, any modeling attempting to attribute the paucity of Middle Archaic groups to cultural influences (e.g., low population density or settlement) should first consider the site's location and geomorphic causes. Conversely, any Middle Archaic deposits encountered should be regarded as significant and warranting extensive investigation. Similarly, the low frequency or paucity of radiocarbon data should rarely be used to infer the absence or limited occurrence of cultural activities–to do so is almost assuredly an incorrect interpretation. An example of this (and there are many) include research at Fort Hood where the low frequency of radiocarbon data had been used to imply limited cultural activities during the beginning and end of the Early Archaic, and the Middle

Archaic, while the Late Prehistoric period is indicated to be an era of high cultural activity (Thoms and Olive 1993: Figure 12). Not coincidentally, these periods all align with the four synchronous events identified in the study. Specifically, three periods identified as having low cultural activity coincide with the three periods of instability (i.e., Synchronous Events I–III) identified in this study. Conversely, the era identified as having high cultural activity occurred during the time of pervasive stability (i.e., Synchronous Event I) (Figure 9.1). The initial interpretation of the researchers may be correct in attributing the low frequency of radiocarbon dates at Fort Hood to cultural reasons and not geomorphic integrity (i.e., instability or stability). However, the geomorphic factor of integrity should be seriously considered first.

Another observation derived from the study regards the magnitude of adjustment of radiocarbon assays after calibration. A predominance of recalibrated assays younger than 7,000 cal yr BP exhibited no significant adjustments from the initial calibration. Specifically, the changes usually fell within the standard deviation. This was particularly evident the more recent the initial calibration occurred. Those assays older than 7,000 cal yr BP always demonstrated some significant change, which was more pronounced the older the assay. This phenomenon is attributed to the continued refinement of the calibration curve where more data are added. Presently, Intcal09 has abundant data points that extend to 18,000 cal yr BP. Thus, subsequent calibrations of radiocarbon assays calibrated with the Intcal09 curve should likely not demonstrate any significant adjustments in the future. There will certainly be refinements, but just as the pre-7,000 cal yr BP recalibrations do not noticeably adjust, the assays encompassing the last 12,000 years should not alter significantly.

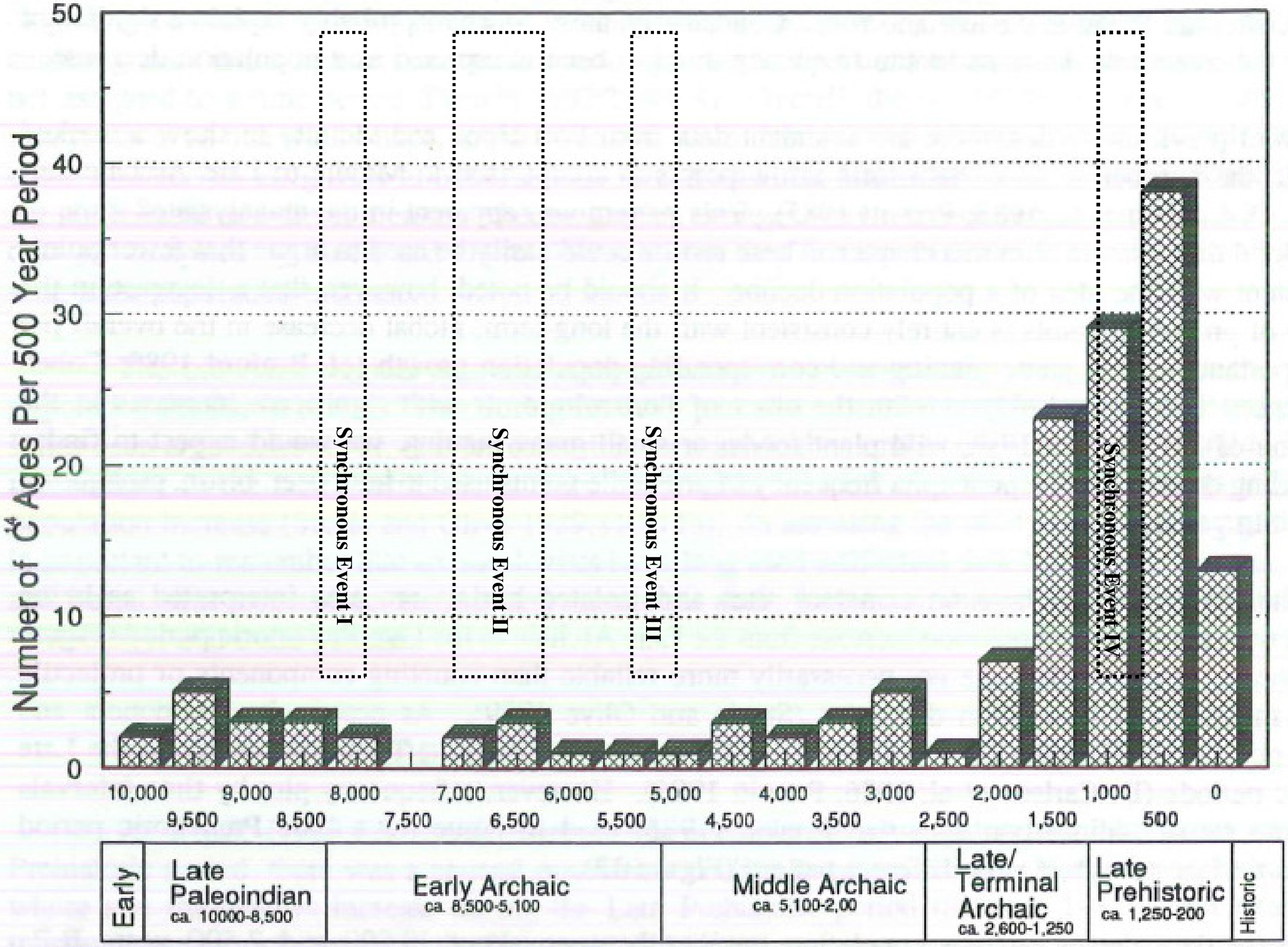


Figure 9.1 Radiocarbon Frequency at Fort Hood Equated with Cultural Activity (adapted from Thoms and Olive 1993: Figure 12).

Conversely, the use of the statistical calibration models within the OxCal programs (i.e., Bayesian statistics) proved very informative and useful. As previously noted in Chapter 2, each set of assays would be analyzed by a minimum of 30,000 iterations, but frequently went over 3 million iterations to get the most probable outcome with the available data (i.e., radiocarbon age and stratigraphic position). The most informative implementation of these statistical procedures occurred when samples were within a well-defined stratigraphy and were temporally close. The Fort Hood dataset are a good example of this situation. In contrast, the statistical models typically did not assist assays collected from multiple profiles with a vague stratigraphy and/or broad temporal range. Simply put, those investigations that had a research focus aimed at characterizing the chronology of geomorphic stratigraphy are perfectly suited for this application. Whereas, those investigations that have little or no focus on geomorphic stratigraphy are minimally enhanced if at all.

One constructive aspect garnered from this study may be the use of a chronostratigraphic marker in future research. At several locations in the review of the Guadalupe-San Antonio River basin (e.g., Unit II on Leon Creek and Unit 2 San Antonio River) periods of stability that preceded a dynamic erosion-incision event were identified (Nordt 2001a). The combination of a marked phase of stability followed by a period of very dynamic flow may be indicative of the 5,000–4,000 cal yr BP (calibrated IntCal 09 curve) time period. Coupled with this, the paucity of colluvial deposits (e.g., Unit IV at Culebra Creek) previously attributed to an exhausted supply of upland plateau sediments (Nordt 2001a:42). Therefore, geoarchaeological investigations could possibly use this suite of attributes for chronostratigraphic purposes while investigating the drainages (e.g., Leon Creek, Salado Creek, Culebra Creek, Medina River, and San Antonio River) along the margins of the Edwards Plateau in the Guadalupe-San Antonio River basin. Numerous researchers have previously proposed using chronostratigraphic markers within and around Texas (e.g., Abbott 2001, Blum 1992, and Bousman and Skinner 2007), but the implementations of these are used by a select few. This is a resource that should be fostered and utilized more in the future by archaeologists aware of these possibilities.

Future Research

Similar to a variety of interpretations that developed over the course of these investigations are several avenues of future research that have also been identified. The first and obvious area of future investigations is testing the validity of the four recognized synchronous events. The most tenuous component of the previous interpretations concerns the data gaps and 'hiatuses' within each of the investigated basins. Have these phenomena been affected or made more substantial through sampling or interpretive bias (e.g., poor chronological controls)? This research avenue can be achieved by attempting a more robust chronometric study in each of these basins. Also, the comparison of the drainage basin depositional histories was conducted at 250-year intervals. Future research should focus on tightening the intervals to determine if the synchronous events become more pronounced or vanish.

Furthermore, a portion of the assays from the current study were not corrected for isotopic fractionation. As with this study's use of select radiocarbon samples derived from humate, the assays that were not 'normalized' were used out of necessity. Consequently, future research should adjust for these discrepancies and combine all of the radiocarbon samples thus providing for a more robust dataset. The result of this effort can also be used for testing the interpretation of the four recognized synchronous events.

A corollary of this concerns filling the gaps of investigation across Texas. Specifically, there are several large regions in Texas that have little or no geomorphically slanted investigations. One of these regions is East Texas, where targeted research evaluating the drainages has not been done to any significant degree. This includes the middle extent of the Trinity River, the Neches River, Angelina River, the Sabine River, and their tributaries. Granted, geoarchaeological investigations have been conducted in this region (e.g., Phillips and Marion 2001), but these are in upland settings, are very focused, and/or do not truly regard depositional histories. The limited geoarchaeological research that has been conducted in the region suggests some significant deposits. Specifically, at the northern end of this region in the Sulphur River basin several researchers have devoted considerable attention to the area (Bousman et al. 1988; Bousman and Skinner 2007; Darwin et al. 2007; Rainey 1974). These researchers have encountered some promising evidence of Pre-Clovis deposits, which warrant further investigations (Bousman and Skinner 2007).

Similarly, select sections of drainage basins included within this study should be investigated. In particular, the upper extent of the Colorado River basin and the lower extents of the San Antonio, Guadalupe River, and Nueces River basins. The closing of these gaps in select areas could add significant data and immeasurably refine the interpretations (e.g., geochronological) held today. The enhancement of these drainage depositional histories could more effectively examine the response of a drainage to external factors. A limitation of this study was utilizing the stratigraphy of archaeological site investigations and equating that with drainage depositional history. Again, this was done largely out of necessity, but future research can fill the gaps in coverage and refine or replace the interpretations provided here.

Additionally, some consideration should be put into the construction of a radiocarbon database for the use of Texas researchers. A system such as this has been in operation for years in Europe with some very intriguing developments (e.g., Chiverrell et al. 2009;Howard et al. 2009; Johnstone et al. 2006; Lewin et al. 2005; Macklin et al. 2002, 2005, 2006, 2010; Macklin and Lewin 2008). Admittedly, there are some significant obstacles that would likely arise, but the compilation and ready access of chronometric data from archaeological sites and depositional settings for the use of archaeological research is an attainable goal.

Finally, on a related note, some efforts should be put into developing an accepted form of reporting ^{14}C results. The archival research for this study has encountered a multitude of disparate ways of reporting what should be a straightforward dataset. Granted, there is prevalent confusion on the use and interpretation of chronometric data, but this would be made simpler if the presentation of data had some standardization.

Glossary

Aggradation: refers to the addition of sediment to drainage floodplain elevating the height of terraces.

Allostratigraphic unit: a mappable body of sedimentary rock bounded by a discontinuity (NACSN 2005:1578). The use of allostratigraphic unit in this study is considered a recognizable system for characterizing fluvial deposits of previous investigations.

Avulsion: refers to the rapid abandonment of a river channel and the formation of a new river channel.

Calibration: when a radiocarbon date is converted to a calendrical format (McCormac and Baillie 1993; Mook and Waterbolk 1985:20; Lowe and Walker 1997:243; Ramsey 2009:337; Stuiver and Suess 1966; Taylor 1997:68).

cal yr BP: in this study indicates the dates have been calibrated with IntCal 2009 calibration curve using A. D. 1950 as date before present.

Corrected: assays that have been adjusted for isotopic fractionation (i.e., $\delta\,^{13}C$ value of -25.0$^{0}/_{00}$) (Hua 2009). Sometimes identified as conventional or normalized.

Data Gap: in the depositional history tables, this refers to a separation between allostratigraphic units where no erosion or aggradation is recorded. The data gaps are likely attributable to erosion, but more data is needed.

Hiatus: in the depositional history tables, this refers to chronological gaps within allostratigraphic units between radiocarbon assays.

Likelihood: in Bayesian analysis, the likelihood is the measured data (absolute dates) that is compared with the prior probability (Ramsey 2009).

MCMC: Markov chain Monte Carlo method that randomly examines each event across a defined distribution gradually increasing the confidence of the result. Also, allows for the inclusion of the uncertainty of multiple factors that can allow for the comparison of points as well as their deviations on a curve (Breyer 2009; Buck and Blackwell 2004:1101; Everitt 2002; Heaton et al. 2009; Ramsey 2009;Upton and Cook 2006).

Prior: in Bayesian analysis, the prior probability is inferred from relative dates, which for this study is stratigraphy and compared with the likelihood probability culminating in the determination of the posterior probability (Ramsey 2009).

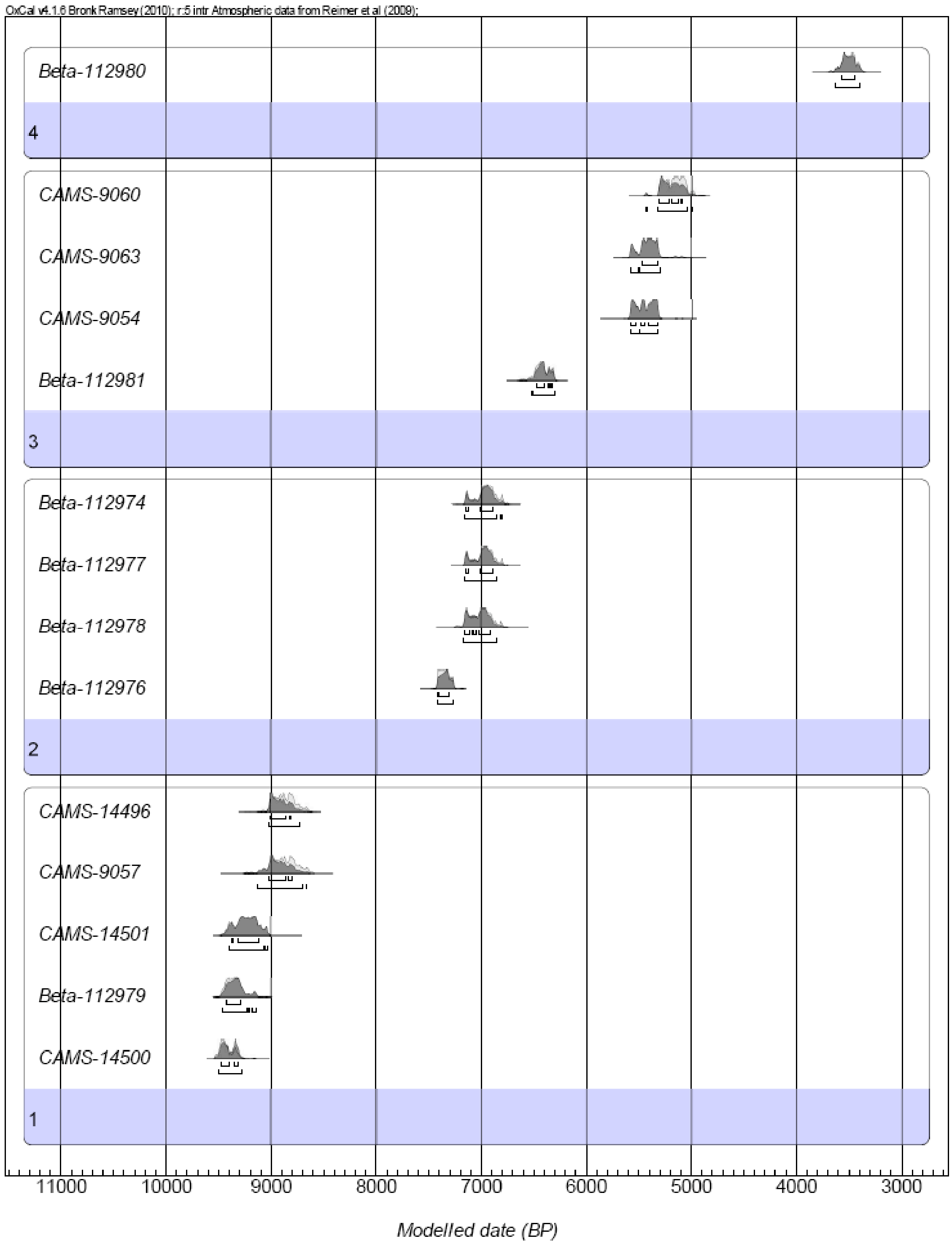
^{14}C yr BP: refers to the uncalibrated radiocarbon age and is in radiocarbon years.

APPENDICES

APPENDIX I-Nueces River Basin OxCal Results

Woodrow Heard assays (Decker et al. 2000)

Name Show all Show structure	Unmodelled (BP)						Modelled (BP)						Indices A_{model}=98.7 $A_{overall}$=98					Select All Visible	Page break
	from	to	%	from	to	%	from	to	%	from	to	%	A_{comb}	A	L	P	C		
End 4							3570	3140	68.2	3650	2260	95.4					95.8		
Beta-112980	3570	3440	100.0	3640	3380	100.0	3570	3440	68.2	3630	3390	95.4		99			99.7	✓ 19	
▲ 4																		✓ 18	
Start 4							4100	3450	68.2	4800	3410	95.4					98.5		
End 3							5260	4700	68.2	5310	4050	95.4					98.7		
CAMS-9060	5310	5040	100.0	5320	4970	100.0	5310	5080	68.1	5440	4990	95.4		100			99.4	✓ 17	
CAMS-9063	5580	5310	100.0	5590	5290	100.0	5470	5310	68.2	5590	5300	95.4		100.3			99.5	✓ 16	
CAMS-9054	5580	5320	100.0	5590	5310	100.0	5580	5320	68.3	5590	5310	95.4		99.8			99.3	✓ 15	
Beta-112981	6490	6390	100.0	6550	6300	100.0	6480	6320	68.1	6530	6300	95.4		99.2			99.7	✓ 14	
▲ 3																		✓ 13	
Start 3							6690	6410	68.2	6850	6340	95.4					99.6		
End 2							6950	6730	68.2	7030	6530	95.4					99.4		
Beta-112974	7010	6880	100.0	7160	6790	100.0	7150	6880	68.2	7160	6800	95.4		99.5			99.5	✓ 12	
Beta-112977	7010	6890	100.0	7160	6790	100.0	7150	6890	68.2	7160	6850	95.4		100.4			99.6	✓ 11	
Beta-112978	7160	6890	100.0	7170	6790	100.0	7160	6910	68.2	7170	6850	95.4		102.8			99.6	✓ 10	
Beta-112976	7430	7310	100.0	7430	7260	100.0	7420	7310	68.2	7430	7270	95.4		95.1			99.6	✓ 9	
▲ 2																		✓ 8	
Start 2							7610	7300	68.2	8120	7270	95.4					97.9		
End 1							8950	8590	68.2	9010	8120	95.4					97.9		
CAMS-14496	9010	8770	100.0	9030	8640	100.0	9010	8810	68.2	9030	8720	95.4		104.1			99.1	✓ 7	
CAMS-9057	9020	8770	100.0	9130	8640	100.0	9030	8790	68.2	9130	8660	95.4		103.3			99.3	✓ 6	
CAMS-14501	9400	9120	100.0	9440	9020	100.0	9380	9120	68.2	9410	9030	95.4		100.9			99.5	✓ 5	
Beta-112979	9440	9280	100.0	9480	9140	100.1	9430	9280	68.2	9470	9140	95.4		99.7			99.6	✓ 4	
CAMS-14500	9490	9400	100.0	9530	9290	100.0	9480	9310	68.2	9510	9280	95.4		89.3			99.5	✓ 3	
▲ 1																		✓ 2	
Start 1							9610	9360	68.2	9930	9300	95.4					96.1		
▲																			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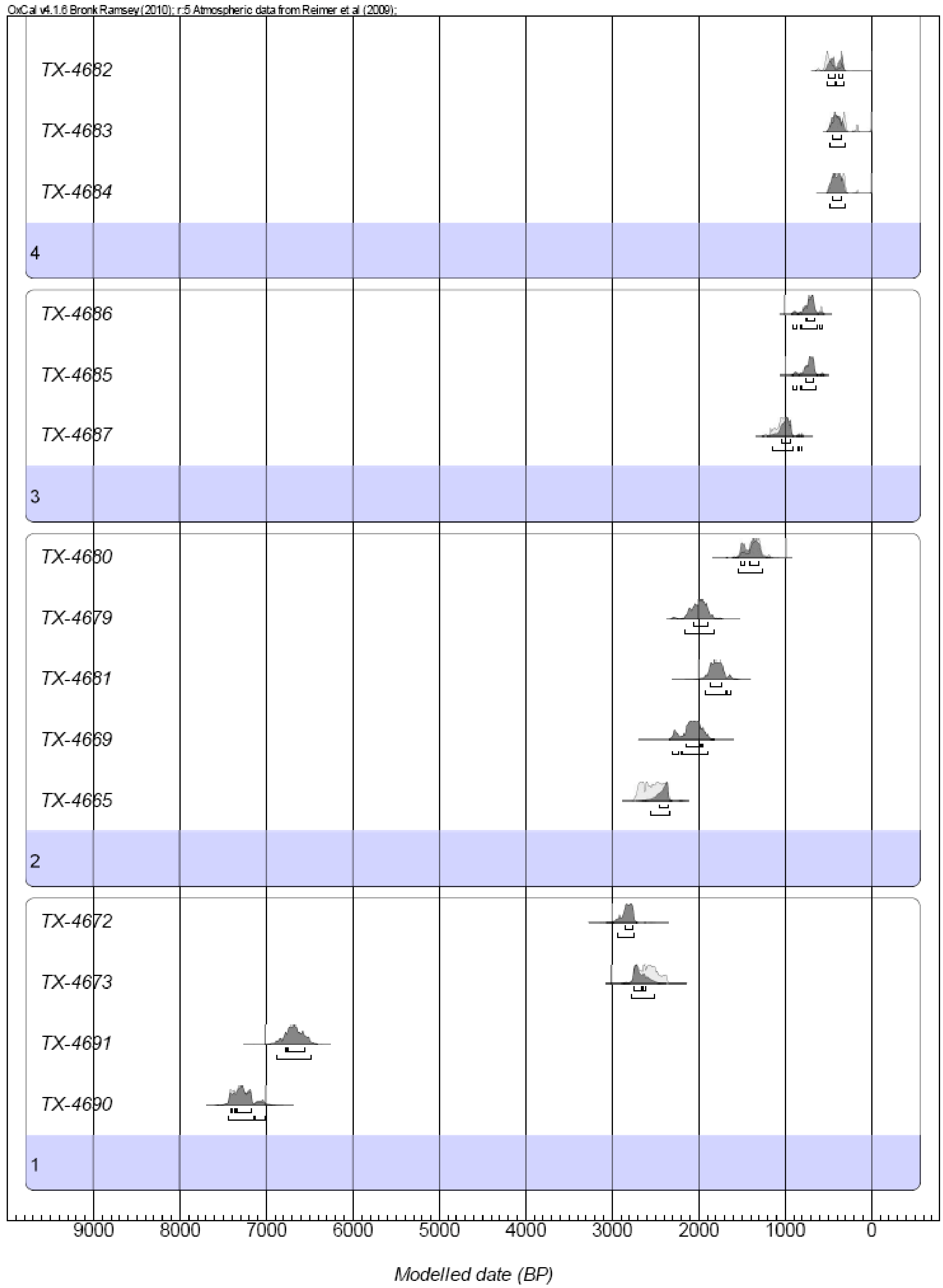
CAMS-9060
CAMS-9063
CAMS-9054
Beta-112981
3
Beta-112974
Beta-112977
Beta-112978
Beta-112976
2
CAMS-14496
CAMS-9057
CAMS-14501
Beta-112979
CAMS-14500
1
11000
10000
9000
8000
7000
6000
5000
4000
3000
Modelled date (BP)

Choke Canyon assays

Name	Unmodelled (BP)						Modelled (BP)						Indices A_{model}=90 $A_{overall}$=90.5					Select	Page break
Show all / Show structure	from	to	%	from	to	%	from	to	%	from	to	%	A_{comb}	A	L	P	C	All / Visible	
End 4							430	290	68.2	470	250	95.4					99.4		
TX4668	460	300	68.2	510	150	95.4	460	340	68.2	490	310	95.4		107.8			99.9	✓ 24	
TX-4667	490	320	68.2	510	310	95.4	470	330	68.2	500	310	95.4		103.4			99.9	✓ 23	
TX-4678	460	310	68.2	510	280	95.4	470	330	68.2	490	310	95.4		107.4			99.9	✓ 22	
TX-4677	540	320	68.3	630	300	95.4	480	330	68.2	510	310	95.4		96.1			99.9	✓ 21	
TX-4682	550	330	68.2	630	310	95.4	490	330	68.2	520	310	95.4		62.5			99.9	✓ 20	
TX-4683	440	290	68.2	500	-10	95.3	460	350	68.2	480	300	95.4		101.2			99.9	✓ 19	
TX-4684	460	300	68.2	500	290	95.4	460	340	68.2	490	310	95.4		104.3			99.9	✓ 18	
4																		✓ 17	
Start 4							530	370	68.2	570	330	95.4					99.8		
End 3							700	540	68.2	760	430	95.4					99.9		
TX-4686	750	570	68.2	900	550	95.4	770	650	68.2	910	560	95.4		99.9			99.9	✓ 16	
TX-4685	760	660	68.2	900	560	95.4	770	670	68.2	910	650	95.5		97.8			99.9	✓ 15	
TX-4687	1070	930	68.2	1180	920	95.4	1040	930	68.2	1150	790	95.4		102			99.8	✓ 14	
3																		✓ 13	
Start 3							1170	970	68.2	1350	840	95.4					99.9		
End 2							1410	1160	68.2	1510	1050	95.4					99.9		
TX-4680	1410	1280	68.2	1530	1180	95.4	1520	1300	68.2	1550	1260	95.4		87.1			99.7	✓ 12	
TX-4679	2060	1880	68.2	2290	1820	95.4	2060	1880	68.2	2160	1820	95.4		99.9			99.8	✓ 11	
TX-4681	1870	1720	68.2	1930	1620	95.4	1870	1720	68.2	1930	1620	95.4		99.9			99.8	✓ 10	
TX-4669	2150	1950	68.2	2310	1890	95.4	2150	1950	68.2	2310	1890	95.5		100			99.9	✓ 9	
TX-4665	2700	2360	68.2	2720	2350	95.4	2450	2350	68.2	2560	2330	95.4		99.9			99.9	✓ 8	
2																		✓ 7	
Start 2							2550	2380	68.2	2650	2360	95.4					99.9		
End 1							2690	2500	68.2	2740	2420	95.4					99.9		
TX-4672	2860	2750	68.2	2950	2740	95.4	2860	2750	68.2	2950	2740	95.4		100			99.8	✓ 6	
TX-4673	2750	2490	68.2	2750	2360	95.4	2760	2610	68.2	2780	2500	95.4		104.2			99.9	✓ 5	
TX-4691	6780	6560	68.1	6890	6480	95.4	6780	6560	68.2	6890	6480	95.4		100			99.8	✓ 4	
TX-4690	7420	7170	68.3	7440	7020	95.4	7420	7160	68.2	7440	7000	95.4		94.2			99.6	✓ 3	
1																		✓ 2	
Start 1							8120	7170	68.2	9560	6980	95.4					96.6		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TX-4687
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TX-4680
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TX-4665
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TX-4672
TX-4673
TX-4691
TX-4690
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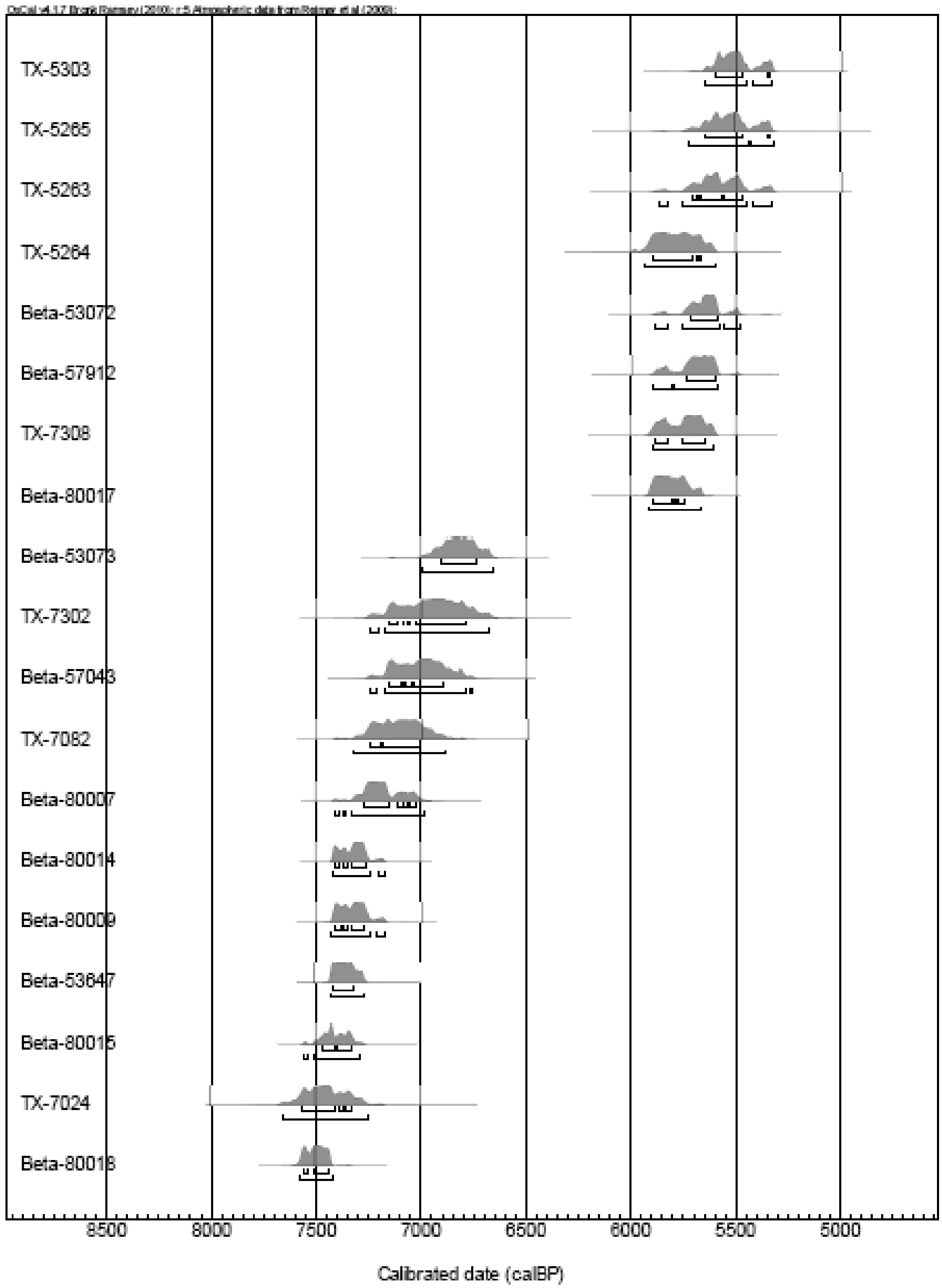
Modelled date (BP)

Ricklis and Blum 1997 data

Name Show all Show structure	Unmodelled (BP) from	to	%	from	to	%	Select All Visible	Page break
	Warning! Duplicate names - Beta-80009							
TX-6125	780	660	68.2	910	560	95.4	☑ 69	☐
TX-6127	900	560	68.2	930	530	95.4	☑ 68	☐
TX-7306	920	760	68.2	940	690	95.4	☑ 67	☐
TX-7305	920	770	68.2	940	690	95.4	☑ 66	☐
TX-6925	960	790	68.2	1060	730	95.4	☑ 65	☐
TX-6919	1060	790	68.2	1080	740	95.4	☑ 64	☐
TX-6926	1060	800	68.2	1170	770	95.4	☑ 63	☐
TX-6924	1170	960	68.1	1240	960	95.4	☑ 62	☐
TX-522	1060	970	68.2	1170	930	95.5	☑ 61	☐
TX-521	1240	1070	68.2	1280	1010	95.4	☑ 60	☐
TX-523	1240	1070	68.2	1280	1010	95.4	☑ 59	☐
TX-7312	1180	980	68.2	1270	960	95.4	☑ 58	☐
TX-7313	1350	1180	68.2	1390	1170	95.4	☑ 57	☐
TX-7304	1400	1290	68.2	1520	1190	95.4	☑ 56	☐
Beta-77683	1610	1410	68.3	1700	1400	95.4	☑ 55	☐
TX-5892	1540	1390	68.2	1690	1320	95.4	☑ 54	☐
Beta-80016	1690	1520	68.2	1710	1410	95.4	☑ 53	☐
TX-6062	1690	1420	68.2	1710	1410	95.4	☑ 52	☐
TX-5893	1700	1420	68.2	1730	1390	95.4	☑ 51	☐
TX-5891	1880	1710	68.2	1950	1600	95.4	☑ 50	☐
Beta-57911	1700	1550	68.2	1820	1510	95.4	☑ 49	☐
TX-7084	1780	1560	68.2	1870	1520	95.4	☑ 48	☐
Beta-77684	1830	1630	68.2	1880	1570	95.4	☑ 47	☐
UGA-6151***	1810	1560	68.2	1890	1410	95.4	☑ 46	☐
Beta-80008	1930	1740	68.2	1990	1710	95.4	☑ 45	☐
UGA-6151	2110	1870	68.2	2300	1730	95.4	☑ 44	☐
Beta-77685	2310	2060	68.3	2330	2000	95.4	☑ 43	☐
TX-7303	2330	2150	68.2	2350	2060	95.4	☑ 42	☐
Beta-77686	2700	2360	68.2	2720	2350	95.4	☑ 41	☐
Beta-57915	2720	2460	68.2	2730	2360	95.4	☑ 40	☐
Beta-80012	2770	2540	68.1	2790	2480	95.4	☑ 39	☐
Beta-77687	2840	2540	68.2	2860	2490	95.4	☑ 38	☐
TX-5664	2840	2540	68.2	2860	2490	95.4	☑ 37	☐
UGA-6152	2850	2510	68.2	2920	2360	95.4	☑ 36	☐
Beta-80005	3320	3070	68.2	3350	2990	95.4	☑ 35	☐
Beta-47105	3070	2860	68.1	3160	2790	95.4	☑ 34	☐
TX-7311	4530	4290	68.2	4810	4150	95.4	☑ 33	☐
TX-7310	4850	4580	68.3	4960	4440	95.4	☑ 32	☐
TX-6881	4850	4620	68.2	4950	4520	95.4	☑ 31	☐
Beta-80009	4960	4640	68.1	5040	4570	95.4	☑ 30	☐
TX-7309	4960	4150	68.2	5440	3860	95.4	☑ 29	☐
Beta-80013	5030	4860	68.2	5270	4830	95.5	☑ 28	☐
Beta-80006	5040	4860	68.2	5280	4840	95.4	☑ 27	☐
TX-7307	4960	4150	68.2	5440	3860	95.4	☑ 26	☐
Beta-53198	5280	4870	68.2	5290	4860	95.4	☑ 25	☐
TX-6963	5280	4870	68.2	5290	4860	95.4	☑ 24	☐
TX-7083	5300	5040	68.2	5440	4880	95.4	☑ 23	☐
Beta-80019	5590	5330	68.2	5590	5320	95.4	☑ 22	☐
TX-7081	5590	5320	68.2	5660	5300	95.4	☑ 21	☐
TX-5303	5600	5330	68.2	5650	5320	95.4	☑ 20	☐
TX-5265	5650	5330	68.2	5730	5320	95.4	☑ 19	☐
TX-5263	5710	5470	68.2	5860	5320	95.4	☑ 18	☐
TX-5264	5900	5660	68.2	5940	5590	95.4	☑ 17	☐
Beta-53072	5720	5580	68.2	5890	5470	95.4	☑ 16	☐
Beta-57912	5740	5600	68.2	5900	5580	95.4	☑ 15	☐
TX-7308	5890	5640	68.2	5900	5600	95.4	☑ 14	☐
Beta-80017	5900	5740	68.2	5910	5660	95.4	☑ 13	☐
Beta-53073	6910	6730	68.2	7000	6660	95.4	☑ 12	☐
TX-7302	7160	6780	68.2	7250	6670	95.4	☑ 11	☐
Beta-57043	7160	6890	68.2	7250	6750	95.4	☑ 10	☐
TX-7082	7250	7000	68.2	7320	6880	95.4	☑ 9	☐
Beta-80007	7280	7020	68.1	7420	6980	95.4	☑ 8	☐
Beta-80014	7420	7260	68.2	7430	7170	95.4	☑ 7	☐
Beta-80009	7420	7260	68.2	7430	7170	95.4	☑ 6	☐
Beta-53647	7420	7320	68.2	7430	7260	95.4	☑ 5	☐
Beta-80015	7470	7320	68.2	7560	7280	95.4	☑ 4	☐
TX-7024	7570	7320	68.2	7660	7250	95.4	☑ 3	☐
Beta-80018	7560	7430	68.2	7580	7420	95.4	☑ 2	☐



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TX-5263
TX-5264
Beta-53072
Beta-57912
TX-7308
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Beta-53073
TX-7302
Beta-57043
TX-7082
Beta-80007
Beta-80014
Beta-80009
Beta-53647
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Beta-80018
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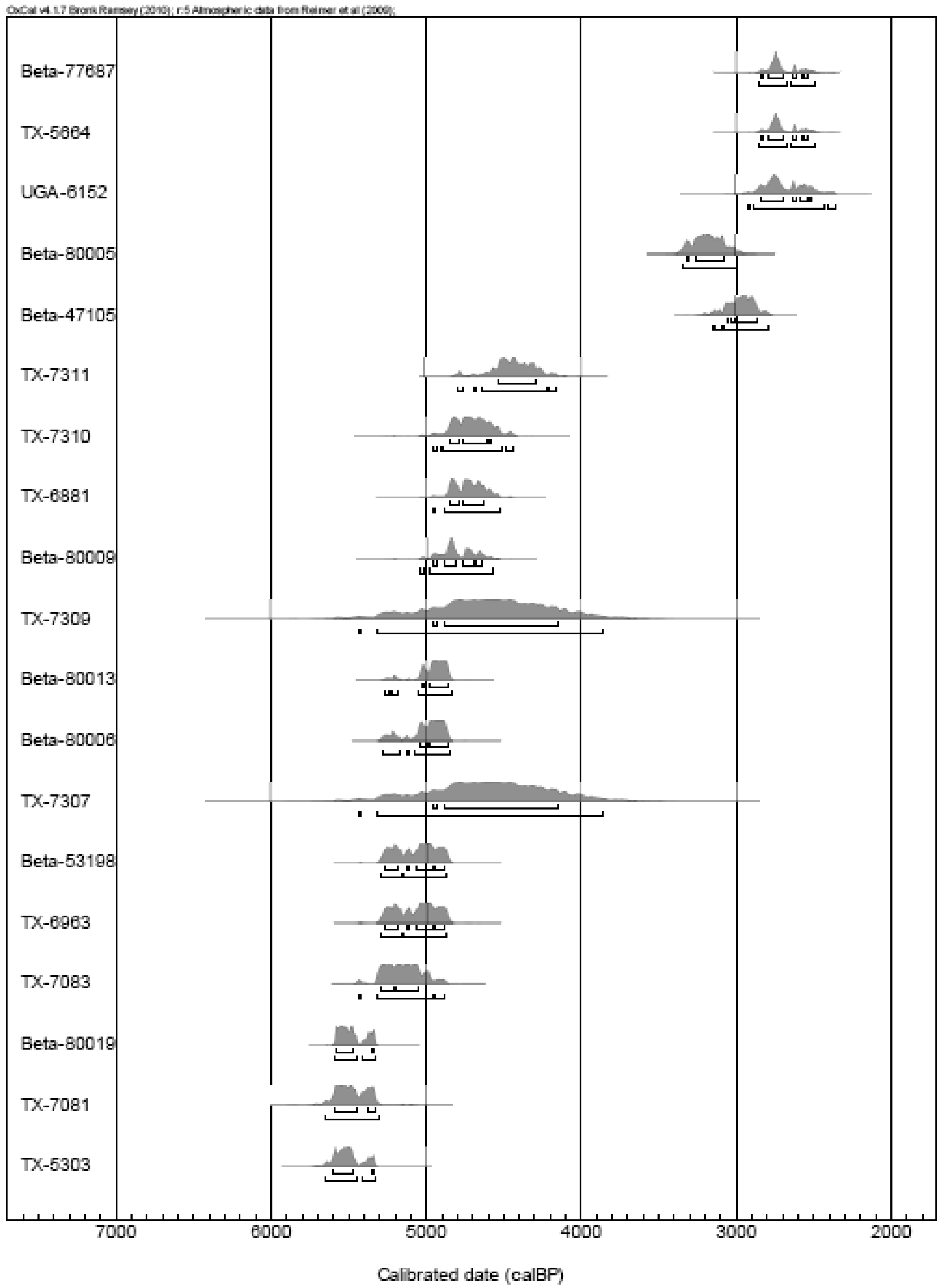
Calibrated date (calBP)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UGA-6152
Beta-80005
Beta-47105
TX-7311
TX-7310
TX-6881
Beta-80009
TX-7309
Beta-80013
Beta-80006
TX-7307
Beta-53198
TX-6963
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Beta-80019
TX-7081
TX-5303
7000
6000
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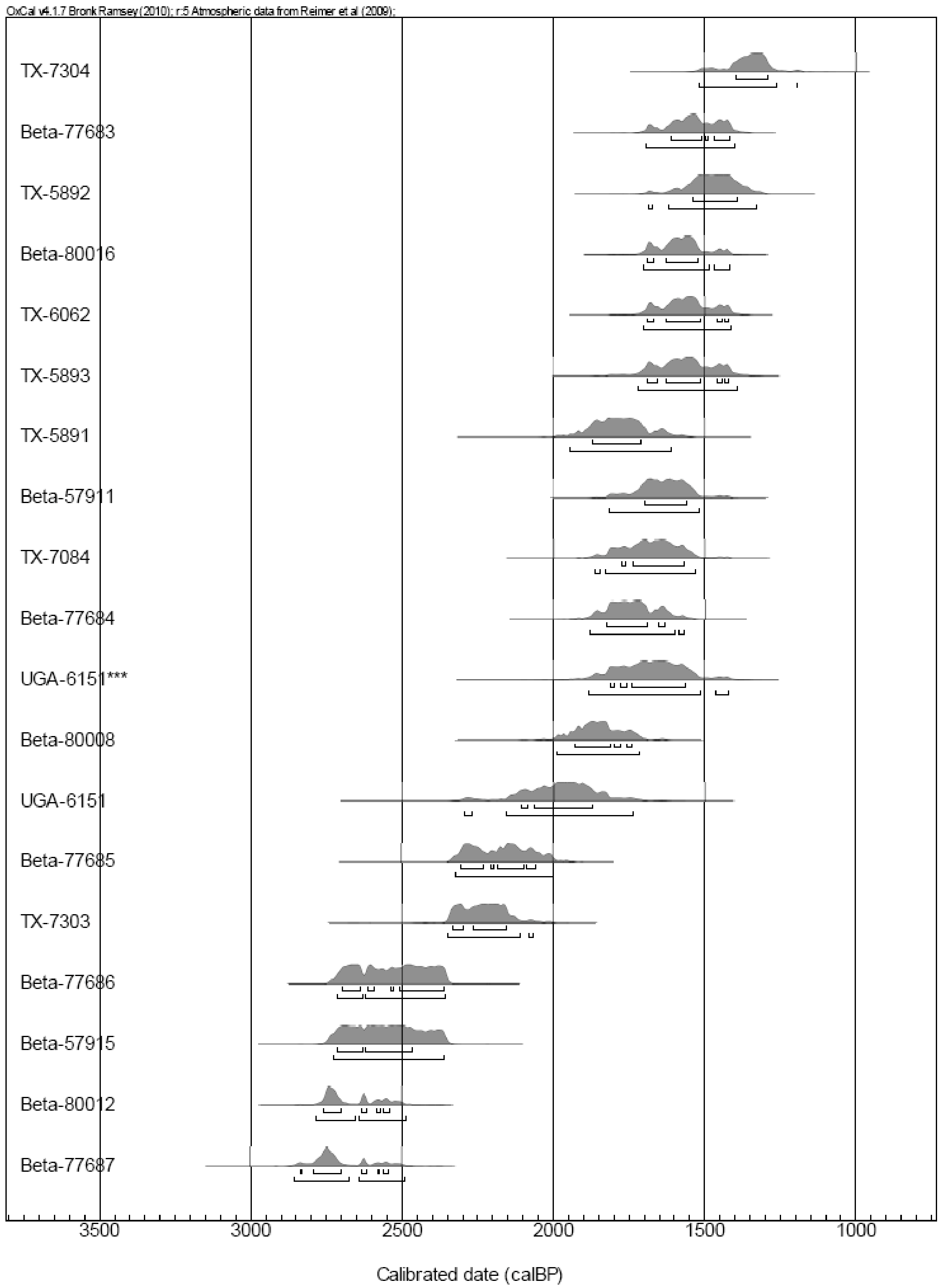
2000
Calibrated date (calBP)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TX-7304
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TX-5892
Beta-80016
TX-6062
TX-5893
TX-5891
Beta-57911
TX-7084
Beta-77684
UGA-6151***
Beta-80008
UGA-6151
Beta-77685
TX-7303
Beta-77686
Beta-57915
Beta-80012
Beta-77687
3500
3000
2500
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1500
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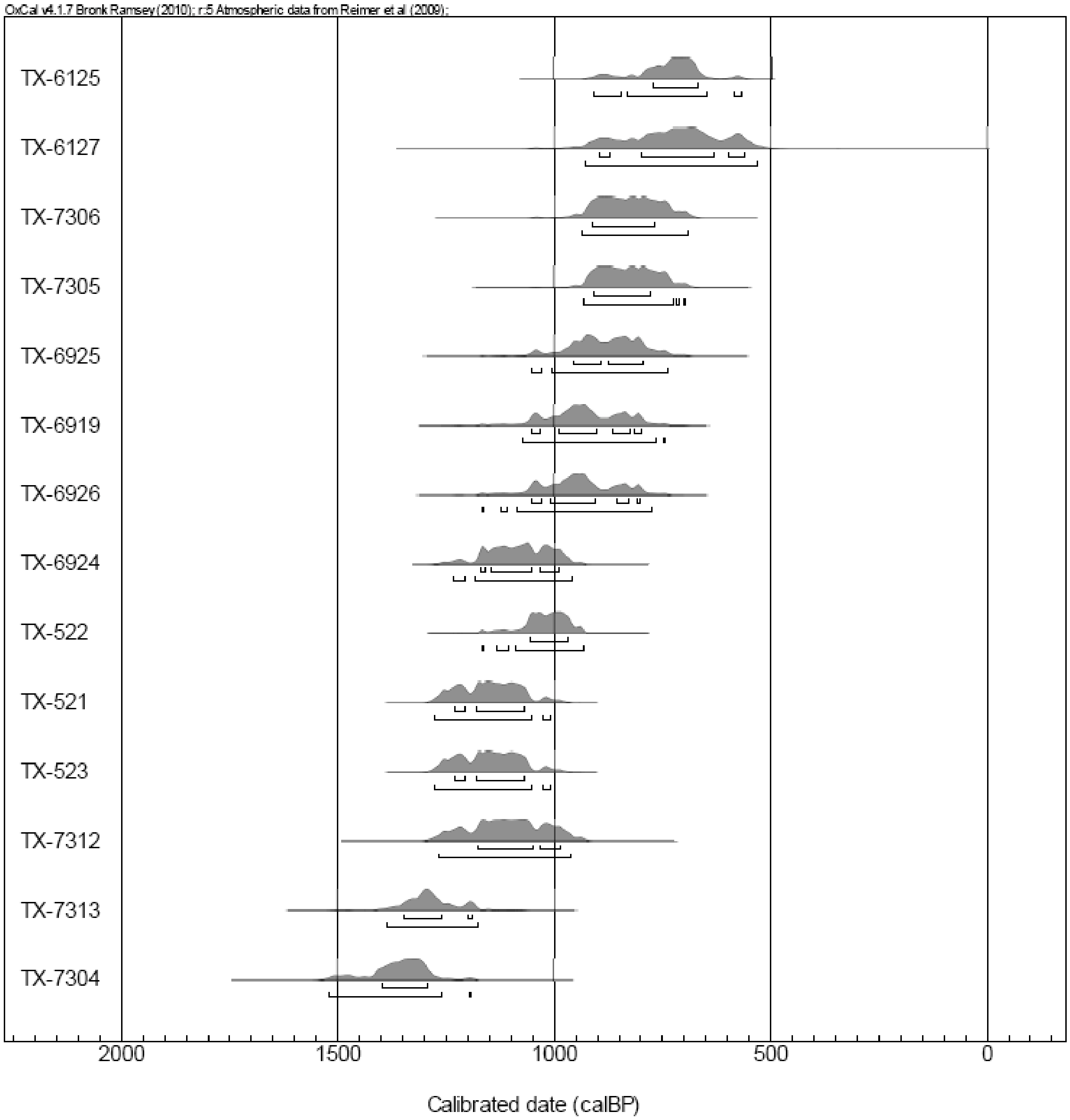
Calibrated date (calBP)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TX-6127
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TX-7305
TX-6925
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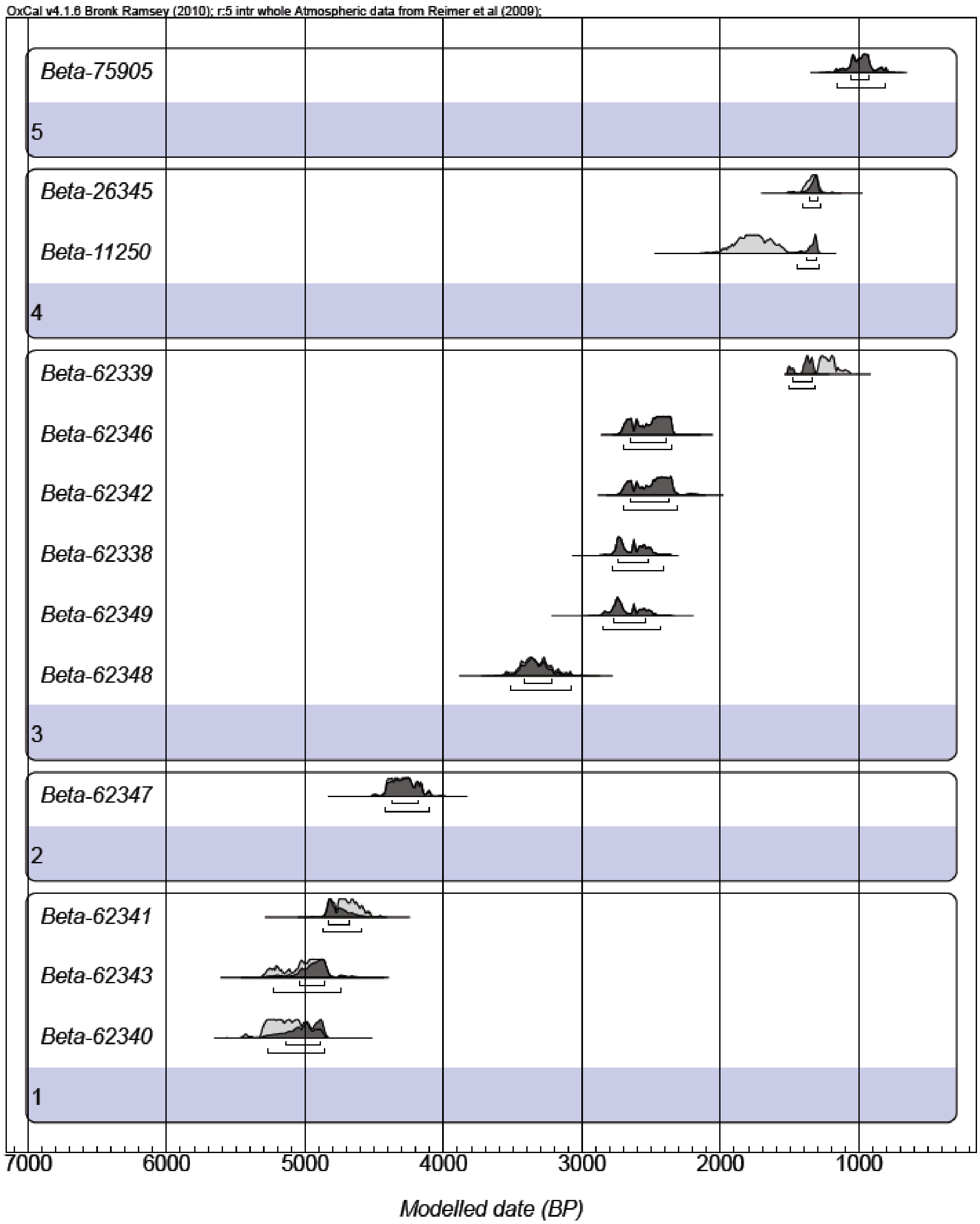
TX-6926
TX-6924
TX-522
TX-521
TX-523
TX-7312
TX-7313
TX-7304
2000
1500
1000
500
0
Calibrated date (calBP)

APPENDIX II-San Antonio River Basin OxCal Results

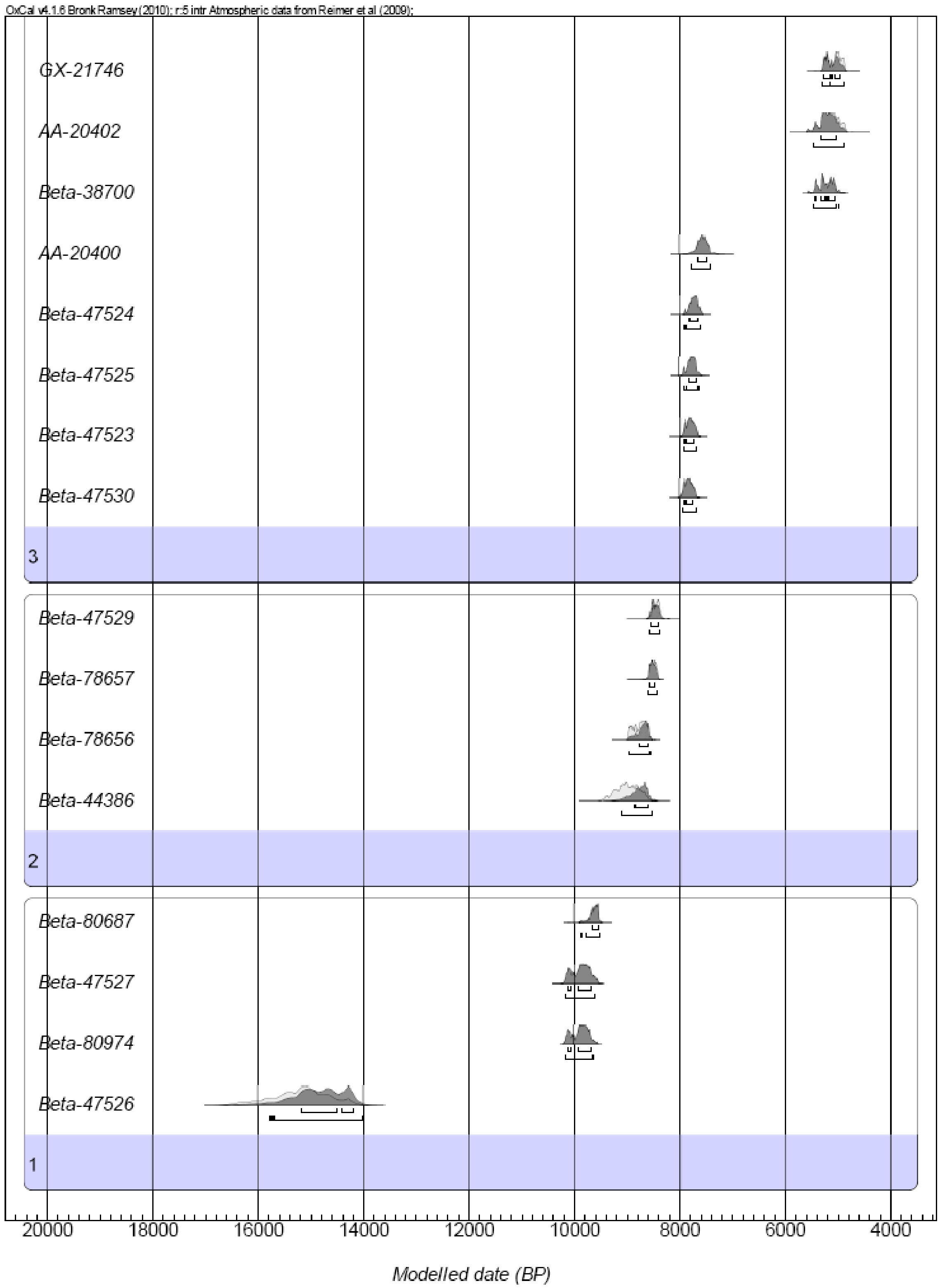
Jonas Terrace assays (Johnson 1995: Table 1)

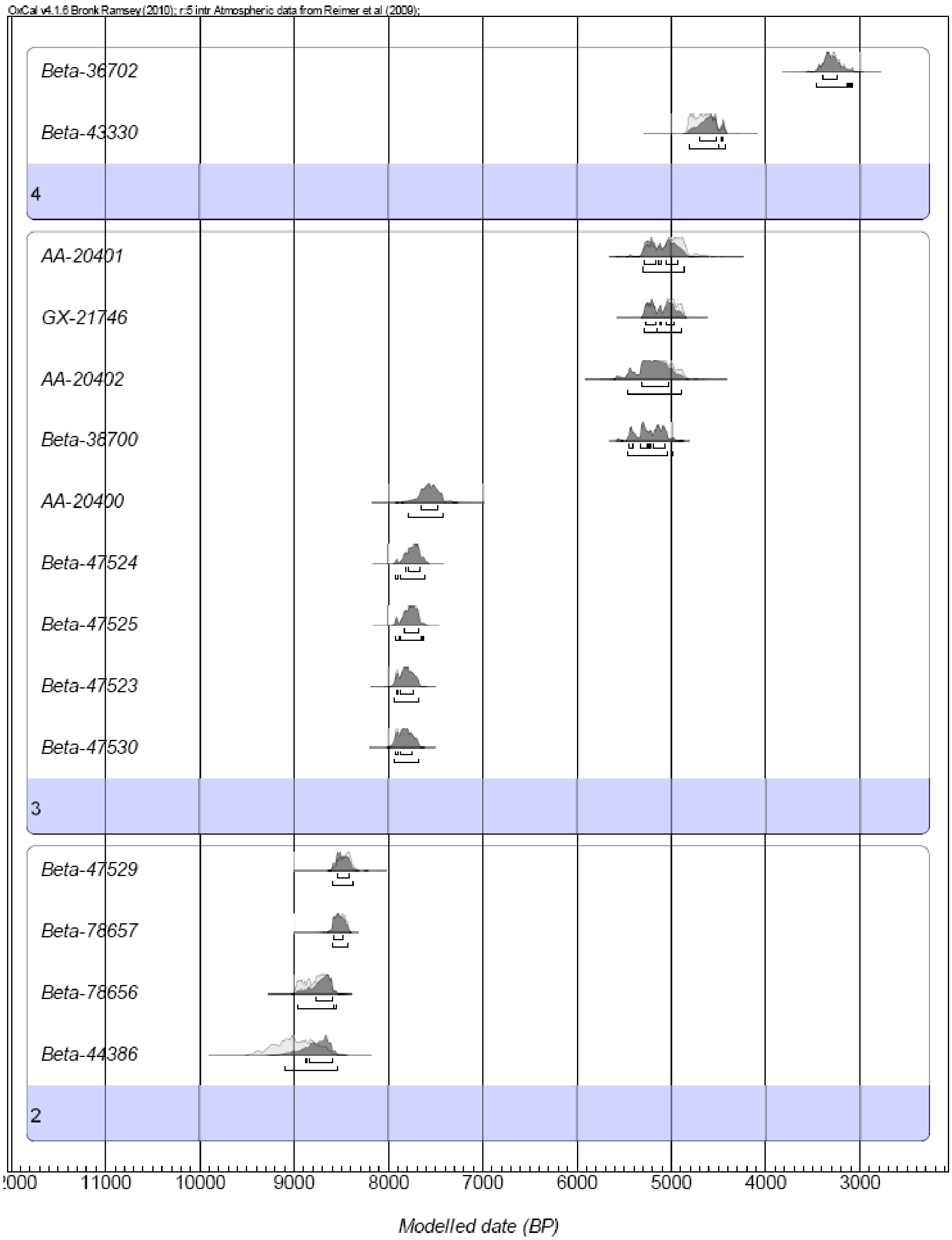
Name	Unmodelled (BP)						Modelled (BP)						Indices A_{model}=5 $A_{overall}$=10			Select	Page break
Show all / Show structure	from	to	%	from	to	%	from	to	%	from	to	%	A_{comb}	A	L P C	All / Visible	
							Warning! Poor agreement - A= 10.0%(A'c= 60.0%) Warning! Poor agreement - A= 5.0%(A'c= 60.0%)										
End 5							1010	640	68.2	1120	130	95.4			98.3	[ ]	[ ]
Beta-75905	1060	920	100.0	1170	790	100.0	1060	920	68.2	1170	810	95.4		100.6	99.8	[x] 23	[ ]
▲ 5																[x] 22	[ ]
Start 5							1230	980	68.2	1310	870	95.4			99.6	[x] 21	[ ]
End 4							1340	1250	68.2	1390	1120	95.4			99.5	[x] 20	[ ]
Beta-26345	1380	1290	100.0	1420	1270	100.0	1360	1300	68.2	1410	1270	95.4		118.3	99.7	[x] 19	[ ]
Beta-11250	1890	1610	100.0	2000	1520	100.0	1380	1300	68.2	1450	1290	95.4		1.3	99.6	[x] 18	[ ]
							Warning! Poor agreement - A= 1.3%(A'c= 60.0%)										
▲ 4																[x] 17	[ ]
Start 4							1400	1310	68.2	1470	1290	95.4			99.5	[ ]	[ ]
End 3							1450	1320	68.2	1500	1300	95.4			99.4	[ ]	[ ]
Beta-62339	1290	1170	100.0	1310	1070	100.0	1480	1330	68.2	1520	1320	95.4		1.8	99	[x] 16	[ ]
							Warning! Poor agreement - A= 1.8%(A'c= 60.0%)										
Beta-62346	2700	2350	100.0	2730	2330	100.0	2660	2380	68.2	2710	2350	95.4		99.8	99.6	[x] 15	[ ]
Beta-62342	2690	2340	100.0	2730	2320	100.0	2650	2370	68.2	2710	2310	95.4		99.8	99.5	[x] 14	[ ]
Beta-62338	2760	2610	100.0	2780	2470	100.0	2740	2520	68.2	2780	2410	95.4		99.4	99.6	[x] 13	[ ]
Beta-62349	2770	2710	100.0	2850	2490	100.0	2780	2540	68.2	2850	2430	95.4		99.7	99.6	[x] 12	[ ]
Beta-62348	3450	3260	100.0	3560	3160	100.0	3420	3210	68.2	3520	3080	95.4		93.8	99.4	[x] 11	[ ]
▲ 3																[x] 10	[ ]
Start 3							3800	3340	68.2	4100	3180	95.4			99.4	[ ]	[ ]
End 2							4280	3790	68.2	4380	3480	95.4			99.4	[ ]	[ ]
Beta-62347	4420	4150	100.0	4500	4090	100.0	4380	4180	68.2	4430	4100	95.4		99.6	99.8	[x] 9	[ ]
▲ 2																[x] 8	[ ]
Start 2							4580	4280	68.2	4730	4170	95.4			99.7	[x] 7	[ ]
End 1							4790	4520	68.2	4850	4360	95.4			99.6	[x] 6	[ ]
Beta-62341	4840	4580	100.0	4860	4520	100.0	4840	4680	68.2	4870	4590	95.4		100.2	99.7	[x] 5	[ ]
Beta-62343	5220	4840	100.0	5300	4820	100.0	5040	4860	68.2	5240	4740	95.4		113.5	99.7	[x] 4	[ ]
Beta-62340	5310	4970	100.0	5440	4850	100.0	5140	4890	68.2	5280	4850	95.4		82.7	99.6	[x] 3	[ ]
▲ 1																[x] 2	[ ]
Start 1							5350	4960	68.2	5770	4890	95.4			95.9	[ ]	[ ]
▲																[ ]	[ ]


OxCal v4.1.6 Bronk Ramsey (2010); r:5 intr whole Atmospheric data from Reimer et al (2009);
Beta-75905
5
Beta-26345
Beta-11250
4
Beta-62339
Beta-62346
Beta-62342
Beta-62338
Beta-62349
Beta-62348
3
Beta-62347
2
Beta-62341
Beta-62343
Beta-62340
1
7000
6000
5000
4000
3000
2000
1000
Modelled date (BP)

Richard Beene assays (Mandel and Thoms 2007)

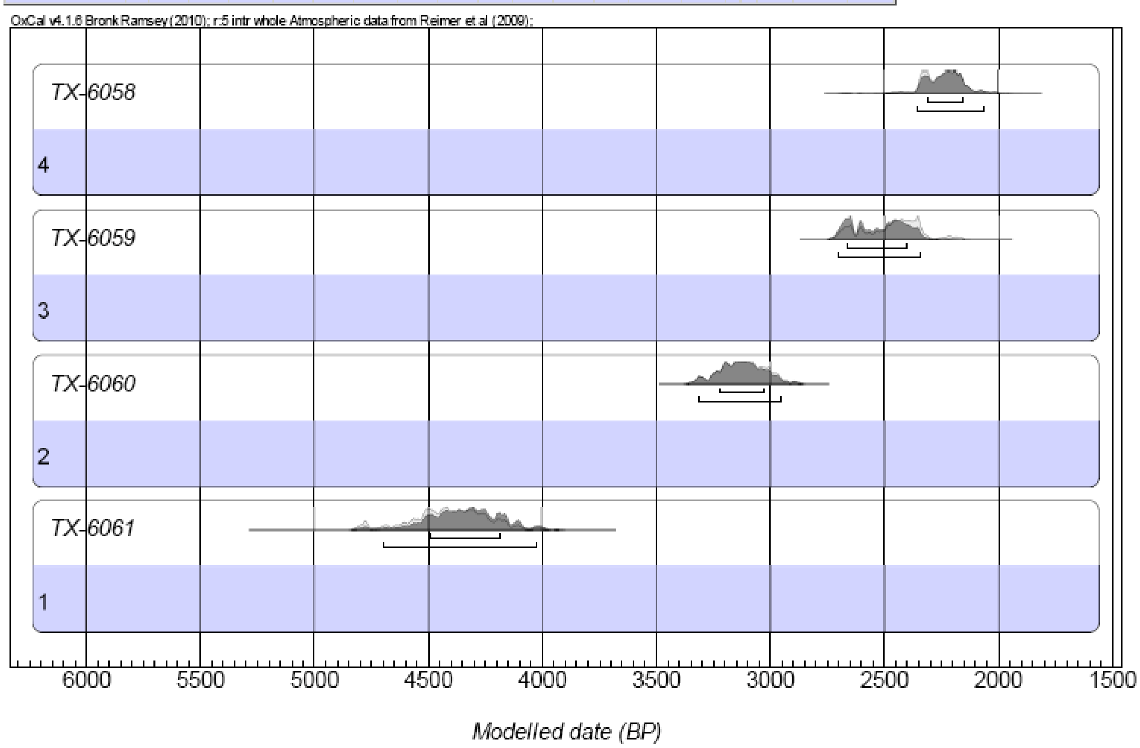
Name Show all Show structure	Unmodelled (BP)						Modelled (BP)						Indices Amodel=91.1 Aoverall=90.8					Select All Visible	Page break
	from	to	%	from	to	%	from	to	%	from	to	%	Acomb	A	L	P	C		
End 4							3370	2590	68.2	3450	1170	95.4					99.2	☐	☐
Beta-36702	3390	3210	100.0	3450	3080	99.9	3400	3230	68.2	3470	3080	95.4		101.1			99.9	☑ 24	☐
Beta-43330	4830	4520	100.0	4850	4430	100.0	4700	4440	68.2	4810	4430	95.4		92.1			99.9	☑ 23	☐
▲ 4																		☑ 22	☐
Start 4							4870	4600	68.2	5000	4480	95.4					100	☐	☐
End 3							5030	4780	68.2	5160	4650	95.4					99.9	☐	☐
AA-20401	5260	4840	99.9	5310	4720	100.0	5290	4930	68.1	5310	4850	95.4		95.3			99.8	☑ 21	☐
GX-21746	5270	4880	99.9	5300	4850	100.0	5280	4960	68.2	5290	4880	95.4		98			99.9	☑ 20	☐
AA-20402	5320	4970	100.0	5580	4850	100.0	5320	5030	68.2	5470	4880	95.4		102.9			99.9	☑ 19	☐
Beta-38700	5440	5070	100.0	5470	4970	100.0	5450	5060	68.2	5470	4980	95.4		100.5			99.9	☑ 18	☐
AA-20400	7670	7470	100.0	7750	7420	100.0	7660	7480	68.2	7790	7420	95.4		100.1			99.9	☑ 17	☐
Beta-47524	7820	7660	100.0	7930	7600	100.0	7830	7660	68.2	7930	7600	95.4		101			99.9	☑ 16	☐
Beta-47525	7840	7680	100.0	7940	7650	100.0	7830	7680	68.2	7930	7620	95.4		101.2			99.9	☑ 15	☐
Beta-47523	7930	7730	100.0	7960	7670	100.0	7920	7730	68.2	7940	7680	95.4		100.5			99.9	☑ 14	☐
Beta-47530	7940	7740	100.0	7970	7670	100.0	7930	7740	68.2	7950	7680	95.4		100.1			99.9	☑ 13	☐
▲ 3																		☑ 12	☐
Start 3							8160	7850	68.2	8370	7800	95.4					99.9	☐	☐
End 2							8520	8290	68.2	8570	8090	95.4					99.9	☐	☐
Beta-47529	8520	8380	100.0	8590	8340	100.0	8550	8410	68.2	8600	8370	95.4		93			99.9	☑ 11	☐
Beta-78657	8590	8440	100.0	8610	8410	100.0	8590	8470	68.2	8600	8420	95.4		100.5			100	☑ 10	☐
Beta-78656	8980	8600	100.0	9000	8580	100.0	8770	8590	68.2	8960	8550	95.4		103.9			99.9	☑ 9	☐
Beta-44386	9140	8770	100.0	9410	8590	100.0	8880	8590	68.2	9100	8530	95.4		82.5			99.9	☑ 8	☐
▲ 2																		☑ 7	☐
Start 2							9030	8660	68.2	9310	8600	95.4					99.8	☐	☐
End 1							9600	9130	68.2	9680	8820	95.4					99.9	☐	☐
Beta-80687	9660	9530	100.0	9740	9520	100.0	9670	9540	68.2	9890	9510	95.4		96.3			99.9	☑ 6	☐
Beta-47527	10120	9680	100.0	10180	9550	100.0	10120	9680	68.2	10160	9600	95.4		100.3			99.9	☑ 5	☐
Beta-80974	10120	9690	100.0	10170	9600	100.0	10120	9700	68.2	10160	9630	95.4		100.2			99.9	☑ 4	☐
Beta-47526	15460	14900	100.0	16190	14180	100.0	15190	14190	68.2	15780	14030	95.4		91.5			99.5	☑ 3	☐
▲ 1																		☑ 2	☐
Start 1							15950	14340	68.2	18030	14110	95.4					95.7	☐	☐
▲																		☐	☐


OxCal v4.1.6 Bronk Ramsey (2010); r:5 intr Atmospheric data from Reimer et al (2009);
GX-21746
AA-20402
Beta-38700
AA-20400
Beta-47524
Beta-47525
Beta-47523
Beta-47530
3
Beta-47529
Beta-78657
Beta-78656
Beta-44386
2
Beta-80687
Beta-47527
Beta-80974
Beta-47526
1
20000
18000
16000
14000
12000
10000
8000
6000
4000
Modelled date (BP)


OxCal v4.1.6 Bronk Ramsey (2010); r:5 intr Atmospheric data from Reimer et al (2009);
Beta-36702
Beta-43330
4
AA-20401
GX-21746
AA-20402
Beta-38700
AA-20400
Beta-47524
Beta-47525
Beta-47523
Beta-47530
3
Beta-47529
Beta-78657
Beta-78656
Beta-44386
2
11000
10000
9000
8000
7000
6000
5000
4000
3000
Modelled date (BP)

Copano Bay-Egery Island assays (Paine 1991:Table 5)

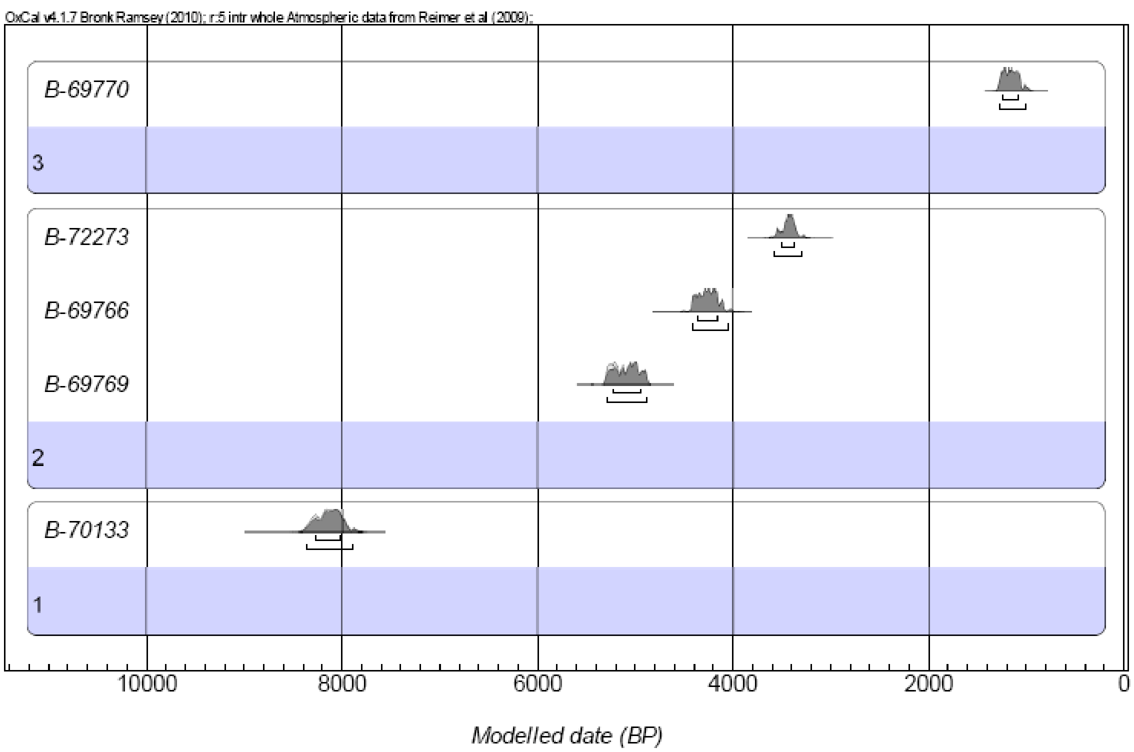
Name Show all Show structure	Unmodelled (BP)						Modelled (BP)						Indices Amodel=96.5 Aoverall=96.5					Select All Visible	Page break
	from	to	%	from	to	%	from	to	%	from	to	%	Acomb	A	L	P	C		
End 4							2260	1920	68.2	2340	1410	95.4					97.8	☐	☐
TX-6058	2350	2150	100.0	2360	2060	100.0	2320	2150	68.2	2360	2060	95.4		101.1			99.8	☑ 17	☐
▲ 4																		☑ 16	☐
Start 4							2410	2200	68.2	2550	2120	95.4					99.7	☐	☐
End 3							2590	2320	68.2	2670	2220	95.4					99.7	☐	☐
TX-6059	2660	2340	100.0	2720	2210	100.0	2670	2400	68.2	2710	2340	95.4		94.3			99.8	☑ 13	☐
▲ 3																		☑ 12	☐
Start 3							2830	2470	68.2	3040	2370	95.4					99.5	☐	☐
End 2							3130	2770	68.2	3250	2550	95.4					99.6	☐	☐
TX-6060	3220	3000	100.0	3340	2940	100.0	3230	3020	68.2	3320	2950	95.4		100.4			99.8	☑ 9	☐
▲ 2																		☑ 8	☐
Start 2							3750	3150	68.2	4170	3020	95.4					99.3	☐	☐
End 1							4350	3720	68.2	4550	3320	95.4					99.1	☐	☐
TX-6061	4530	4240	100.0	4810	4090	100.0	4500	4180	68.2	4700	4020	95.4		97.2			99.6	☑ 5	☐
▲ 1																		☑ 4	☐
Start 1							4800	4280	68.2	5540	4110	95.4					95.5	☐	☐
▲																		☐	☐



APPENDIX III-Colorado River Basin OxCal Results

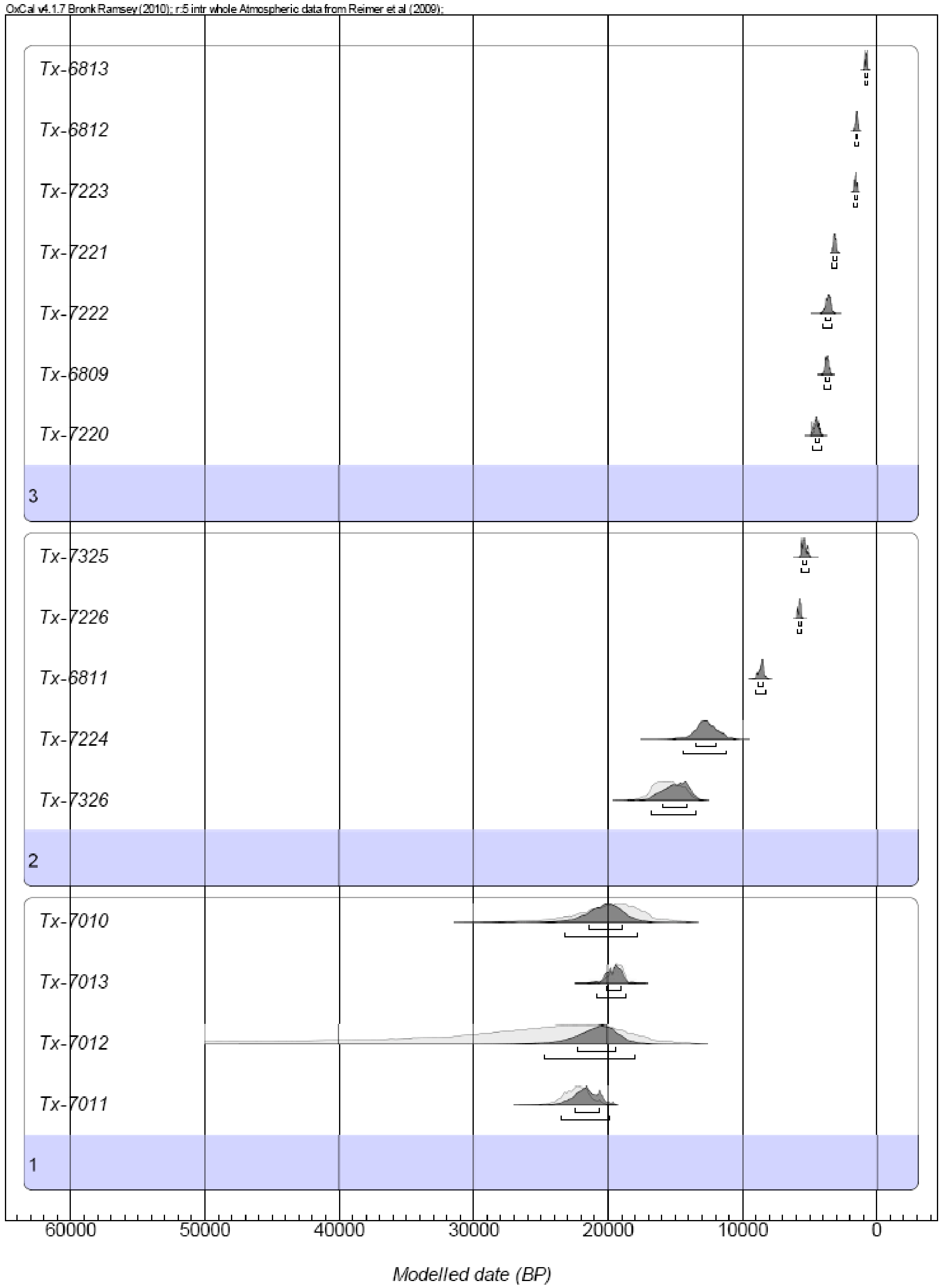
Concho River Results (Quigg et al. 1996: Table 12.2)

Name Show all Show structure		Unmodelled (BP)						Modelled (BP)						Indices Amodel=98.9 Aoverall=98.9					Select All Visible	Page break
		from	to	%	from	to	%	from	to	%	from	to	%	Acomb	A	L	P	C		
End 3								1130	150	68.2	1230	-1450	95.4					98.2	☐	☐
B-69770		1270	1060	100.0	1290	980	100.0	1250	1080	68.2	1280	1000	95.4		100.4			99.9	☑ 15	☐
▲ 3																			☑ 14	☐
Start 3								2300	1230	68.2	3020	1100	95.4					99.4	☐	☐
End 2								3320	2260	68.2	3470	1560	95.4					99.5	☐	☐
B-72273		3470	3360	100.0	3570	3270	100.0	3510	3370	68.2	3580	3290	95.4		98.8			99.8	☑ 11	☐
B-69766		4410	4150	100.0	4430	4080	100.0	4370	4160	68.2	4420	4050	95.4		99.9			99.8	☑ 10	☐
B-69769		5290	4960	100.0	5310	4860	100.0	5230	4940	68.2	5290	4870	95.4		98.7			99.8	☑ 9	☐
▲ 2																			☑ 8	☐
Start 2								6510	5200	68.2	7520	4990	95.4					99.2	☐	☐
End 1								8040	6580	68.2	8250	5610	95.4					99.1	☐	☐
B-70133		8310	8000	100.0	8390	7930	100.0	8270	8010	68.2	8360	7890	95.4		99.8			99.8	☑ 5	☐
▲ 1																			☑ 4	☐
Start 1								9280	8150	68.2	11770	8000	95.4					96.9	☐	☐
▲																			☐	☐

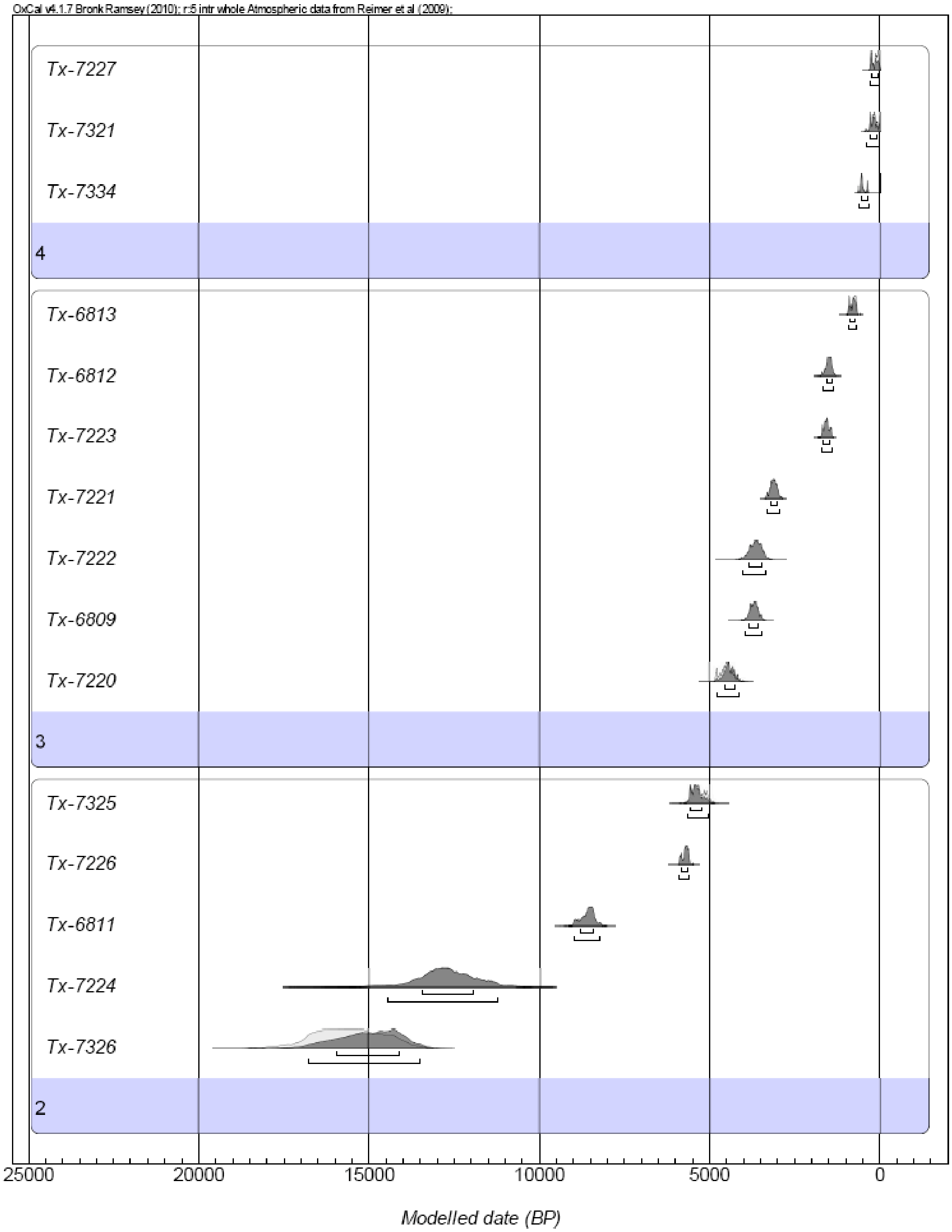


Lower Extent Colorado River (Blum 1992: Tables 6.1-6.4)

Name	Unmodelled (BP)						Modelled (BP)						Indices Amodel=95.2 Aoverall=95.7					Select	Page break
Show all Show structure	from	to	%	from	to	%	from	to	%	from	to	%	Acomb	A	L	P	C	All Visible	
End 4							130	-360	68.2	230	-930	95.4					99.9	☐	☐
Tx-7227	260	20	100.0	290	0	100.0	250	50	68.2	280	-10	95.4		95			100	☑ 32	☐
	Warning! Date may extend out of range - 70+/-60BP																		
Tx-7321	300	-10	100.0	430	-10	100.0	290	90	68.2	410	0	95.4		99.5			100	☑ 31	☐
Tx-7334	550	500	100.0	640	460	100.0	540	340	68.2	620	320	95.4		82.7			100	☑ 30	☐
▲ 4																		☑ 29	☐
Start 4							660	440	68.2	770	350	95.4					100	☐	☐
End 3							800	580	68.2	880	460	95.4					100	☐	☐
Tx-6813	790	670	100.0	920	660	100.0	890	710	68.2	920	670	95.4		86.4			100	☑ 26	☐
Tx-6812	1550	1390	100.0	1690	1330	100.0	1560	1400	68.2	1680	1340	95.4		99.9			100	☑ 25	☐
Tx-7223	1690	1520	100.0	1710	1400	100.0	1660	1460	68.2	1710	1410	95.4		99.8			100	☑ 24	☐
Tx-7221	3220	3000	100.0	3340	2940	100.0	3220	3010	68.2	3320	2930	95.4		100			100	☑ 23	☐
Tx-7222	3840	3450	100.0	3990	3350	100.0	3820	3480	68.2	4020	3340	95.4		100			99.9	☑ 22	☐
Tx-6809	3840	3570	100.0	3960	3460	100.0	3830	3580	68.2	3950	3480	95.4		99.9			100	☑ 21	☐
Tx-7220	4790	4410	100.0	4830	4150	100.0	4570	4260	68.2	4770	4120	95.4		94.5			99.9	☑ 20	☐
▲ 3																		☑ 19	☐
Start 3							4920	4420	68.2	5210	4240	95.4					100	☐	☐
End 2							5330	4760	68.2	5510	4490	95.4					100	☐	☐
Tx-7325	5580	5080	100.0	5610	4970	100.0	5550	5210	68.2	5630	5040	95.4		105.1			100	☑ 16	☐
Tx-7226	5840	5600	100.0	5910	5580	100.0	5840	5630	68.2	5890	5590	95.4		99.9			100	☑ 15	☐
Tx-6811	8640	8380	100.0	9000	8210	100.0	8790	8410	68.2	8980	8230	95.4		100			99.9	☑ 14	☐
Tx-7224	13380	12100	100.0	14050	11210	100.0	13430	11940	68.2	14450	11220	95.4		100.6			99.8	☑ 13	☐
Tx-7326	16820	14190	100.0	17540	13640	100.0	15940	14090	68.2	16790	13510	95.4		93.9			99.8	☑ 12	☐
▲ 2																		☑ 11	☐
Start 2							17570	14930	68.2	18870	14080	95.4					99.8	☐	☐
End 1							19460	17330	68.2	20270	15840	95.4					99.8	☐	☐
Tx-7010	21400	17580	100.0	24380	15920	100.0	21470	19000	68.2	23190	17790	95.4		117.7			99.8	☑ 8	☐
Tx-7013	19760	18800	100.0	20290	18540	100.0	20060	19000	68.2	20840	18660	95.4		90.2			99.8	☑ 7	☐
Tx-7012	28480	18540	100.0	49730	15230	100.0	22300	19380	68.2	24770	18050	95.4		143.3			99.8	☑ 6	☐
	Warning! Date may extend out of range - 18380+/-3890BP																		
Tx-7011	23270	21410	100.0	24010	20440	100.0	22500	20630	68.2	23470	19940	95.4		86.2			99.8	☑ 5	☐
▲ 1																		☑ 4	☐
Start 1							24500	21270	68.2	28130	20270	95.4					95.6	☐	☐
▲																		☐	☐



OxCal v4.1.7 Bronk Ramsey (2010); r:5 intr whole Atmospheric data from Reimer et al (2009);
Tx-6813
Tx-6812
Tx-7223
Tx-7221
Tx-7222
Tx-6809
Tx-7220
3
Tx-7325
Tx-7226
Tx-6811
Tx-7224
Tx-7326
2
Tx-7010
Tx-7013
Tx-7012
Tx-7011
1
60000
50000
40000
30000
20000
10000
0
Modelled date (BP)

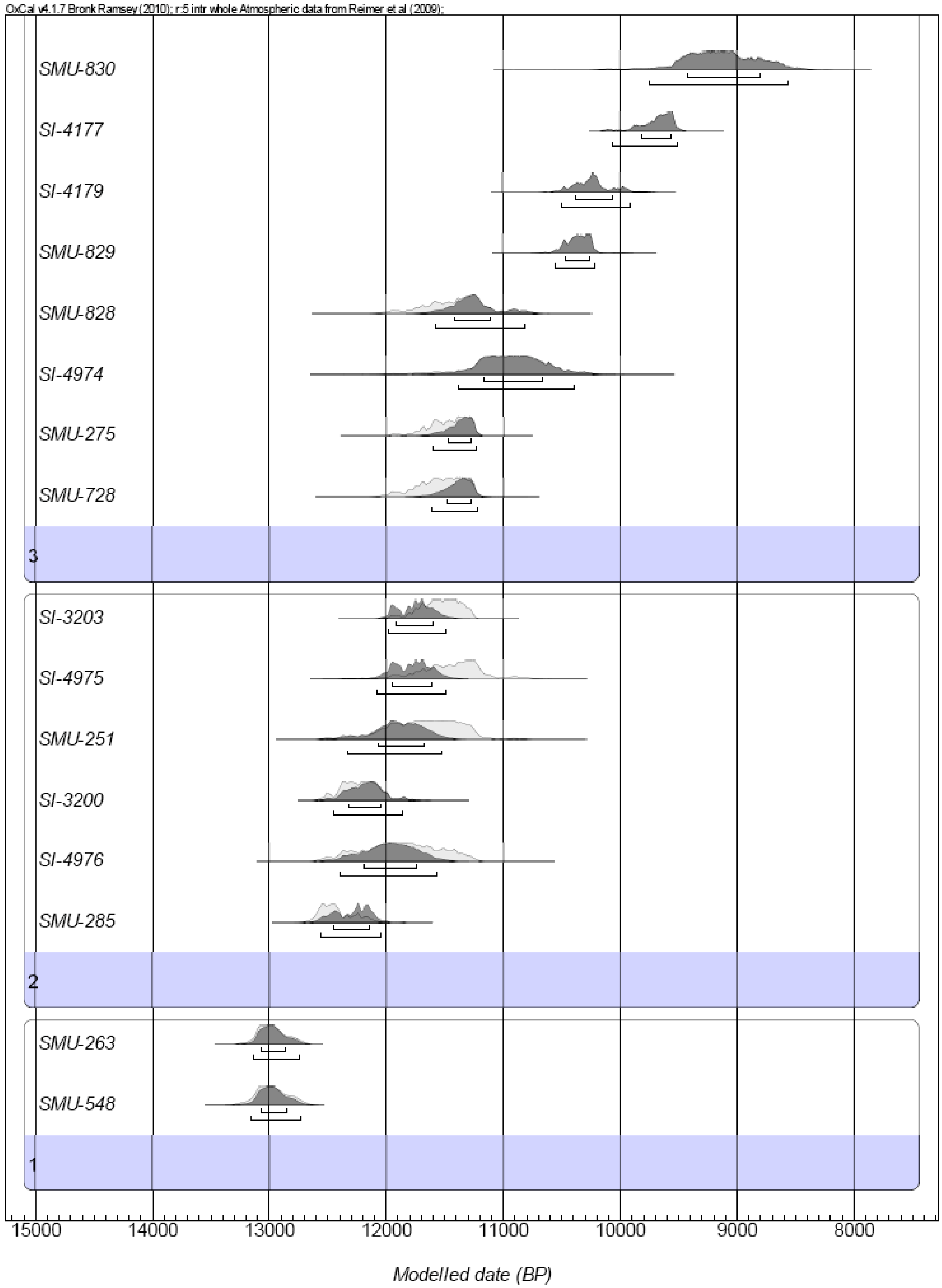

OxCal v4.1.7 Bronk Ramsey (2010); r:5 intr whole Atmospheric data from Reimer et al (2009);
Tx-7227
Tx-7321
Tx-7334
4
Tx-6813
Tx-6812
Tx-7223
Tx-7221
Tx-7222
Tx-6809
Tx-7220
3
Tx-7325
Tx-7226
Tx-6811
Tx-7224
Tx-7326
2
25000
20000
15000
10000
5000
0
Modelled date (BP)

APPENDIX IV-Brazos River Basin OxCal Results

Lubbock Lake site (Haas et al. 1986:Table 1;Holliday et al. 1983, 1985)

Name	Unmodelled (BP)						Modelled (BP)						Indices Amodel=50.1 Aoverall=48.3					Select	Page break
Show all Show structure	from	to	%	from	to	%	from	to	%	from	to	%	Acomb	A	L	P	C	All Visible	
							Warning! Poor agreement - A= 48.3%(A'c= 60.0%) Warning! Poor agreement - A= 50.1%(A'c= 60.0%)												
End 8							170	-200	68.2	260	-490	95.4					98.3	☑ 74	☐
SMU-343	290	-10	100.0	310	-10	100.0	230	30	68.2	290	0	95.4		101			99.6	☑ 73	☐
	Warning! Date may extend out of range - 160+/-60BP																		
▲ 8																		☑ 72	☐
Start 8							300	110	68.2	360	30	95.4					99.8	☑ 71	☐
End 7							390	270	68.2	420	200	95.4					99.5	☑ 70	☐
SMU-555	310	0	100.0	430	-10	100.0	430	300	68.2	470	270	95.4		48.2			99.7	☑ 69	☐
							Warning! Poor agreement - A= 48.2%(A'c= 60.0%)												
SI-2703	440	280	100.0	500	-10	100.0	460	350	68.2	500	290	95.4		107.4			99.8	☑ 68	☐
SMU-345	470	290	100.0	510	-10	100.0	460	350	68.2	500	300	95.4		106.2			99.8	☑ 67	☐
SI-2704	470	300	100.0	510	150	100.0	460	350	68.2	500	300	95.4		101.7			99.8	☑ 66	☐
SMU-546	490	300	100.0	510	150	100.0	470	350	68.2	500	300	95.4		103.8			99.8	☑ 65	☐
SMU-970	510	320	100.0	520	300	100.0	490	360	68.2	520	320	95.4		101.5			99.8	☑ 64	☐
SI-2700	510	330	100.0	520	310	100.0	490	360	68.2	510	320	95.4		102			99.9	☑ 63	☐
SMU-968	520	490	100.0	540	340	100.0	520	460	68.2	540	340	95.4		102.9			99.9	☑ 62	☐
SMU-893	530	490	100.0	550	330	100.0	530	450	68.2	550	340	95.4		104.9			99.8	☑ 61	☐
SI-2701	550	500	100.0	640	490	100.0	560	500	68.2	630	450	95.4		109.2			99.8	☑ 60	☐
SI-3208	680	540	100.0	700	510	100.0	610	540	68.2	660	510	95.4		101.1			99.8	☑ 59	☐
SMU-314	690	660	100.0	730	560	100.0	650	560	68.2	680	550	95.4		47.1			99.9	☑ 58	☐
							Warning! Poor agreement - A= 47.1%(A'c= 60.0%)												
▲ 7																		☑ 57	☐
Start 7							680	580	68.2	720	560	95.4					99.8	☑ 56	☐
End 6							760	630	68.2	820	590	95.4					99.9	☑ 55	☐
SMU-534	900	730	100.0	920	690	100.0	890	740	68.2	910	700	95.4		98.3			99.8	☑ 54	☐
SI-4169	920	720	100.0	940	670	100.0	900	750	68.2	930	700	95.4		101.7			99.8	☑ 53	☐
SMU-651	920	730	100.0	940	670	100.0	900	750	68.2	940	700	95.4		102.3			99.6	☑ 52	☐
SI-3201	1260	1050	100.0	1290	970	100.0	1230	1060	68.2	1280	980	95.4		99.9			99.6	☑ 51	☐
SMU-1090	1280	1170	100.0	1290	1070	100.0	1260	1150	68.2	1290	1080	95.4		99.9			99.7	☑ 50	☐
SMU-1177	1530	1380	100.0	1550	1330	100.0	1510	1380	68.2	1550	1340	95.4		100			99.7	☑ 49	☐
SI-4174	2000	1820	100.0	2120	1710	100.0	2000	1820	68.2	2110	1720	95.4		100			99.2	☑ 48	☐
SMU-1191	2300	1880	100.0	2350	1720	100.0	2240	1900	68.2	2340	1740	95.4		99.9			98.9	☑ 47	☐
SI-4171	5580	5320	100.0	5590	5300	100.0	5550	5340	68.2	5580	5310	95.4		99.9			99.6	☑ 46	☐
SMU-492	5740	5610	100.0	5890	5590	100.0	5690	5610	68.2	5730	5590	95.4		102.5			99.6	☑ 45	☐
▲ 6																		☑ 44	☐
Start 6							5750	5640	68.2	5790	5610	95.4					99.9	☑ 43	☐
End 5							5790	5690	68.2	5830	5640	95.4					99.8	☑ 42	☐
SMU-1200	6280	5900	100.0	6400	5660	100.0	5810	5720	68.2	5850	5660	95.4		46.2			99.9	☑ 41	☐
							Warning! Poor agreement - A= 46.2%(A'c= 60.0%)												
▲ 5																		☑ 40	☐
Start 5							5830	5740	68.2	5870	5670	95.4					99.8	☑ 39	☐
End 4							5860	5780	68.2	5890	5710	95.4					99.9	☑ 38	☐
SMU-531	5660	5580	100.0	5750	5480	100.0	5890	5830	68.2	5900	5730	95.4		9.6			99.8	☑ 37	☐
							Warning! Poor agreement - A= 9.6%(A'c= 60.0%)												
SMU-1093	6000	5920	100.0	6180	5900	100.0	6100	5930	68.2	6180	5910	95.4		100.3			99.7	☑ 36	☐
SMU-545	6670	6470	100.0	6750	6400	100.0	6630	6440	68.2	6720	6340	95.4		96.8			99.5	☑ 35	☐

▲ 4															☑ 34	☐
Start 4							6950	6550	68.2	7190	6430	95.4		99.6	☑ 33	☐
End 3							7320	6940	68.2	7410	6690	95.4		99.5	☑ 32	☐
SMU-544	7430	7250	100.0	7460	7160	100.0	7420	7270	68.2	7480	7180	95.4	102.2	99.7	☑ 31	☐
SI-4178	7660	7490	100.0	7700	7420	100.0	7650	7490	68.2	7750	7430	95.4	100	99.5	☑ 30	☐
SI-3204	8180	7980	100.0	8200	7940	100.0	8160	8000	68.2	8270	7950	95.4	99.9	99.5	☑ 29	☐
SMU-262	9000	8640	100.0	9030	8590	100.0	8960	8680	68.2	9030	8600	95.4	100	99.5	☑ 28	☐
SMU-302	8980	8580	100.0	9020	8450	100.0	8920	8600	68.2	9000	8470	95.4	99.9	99.1	☑ 27	☐
SMU-830	9490	8780	100.0	9670	8540	100.0	9420	8800	68.2	9750	8560	95.4	100.1	98	☑ 26	☐
SI-4177	9700	9530	100.0	9910	9490	100.0	9820	9560	68.2	10070	9500	95.4	99.9	99.1	☑ 25	☐
SI-4179	10280	10180	100.0	10500	9920	100.0	10390	10070	68.2	10510	9910	95.4	99.9	99.3	☑ 24	☐
SMU-829	10490	10230	100.0	10570	10190	100.0	10470	10260	68.2	10560	10210	95.4	99.9	99.3	☑ 23	☐
SMU-828	11600	11190	100.0	11830	10870	100.0	11420	11110	68.2	11590	10810	95.4	113.7	99.1	☑ 22	☐
SI-4974	11230	10600	100.0	11410	10400	100.0	11170	10660	68.2	11390	10390	95.4	103.5	99	☑ 21	☐
SMU-275	11610	11250	100.0	11770	11210	100.0	11470	11270	68.2	11600	11230	95.4	114.1	99.7	☑ 20	☐
SMU-728	11710	11250	100.0	11980	11210	100.0	11490	11270	68.2	11620	11220	95.4	110.6	99.3	☑ 19	☐
▲ 3															☑ 18	☐
Start 3							11640	11390	68.2	11790	11310	95.4		99.7	☑ 17	☐
End 2							11770	11490	68.2	11910	11390	95.4		99.5	☑ 16	☐
SI-3203	11710	11310	100.0	11960	11240	100.0	11920	11600	68.2	11990	11480	95.4	64.5	99.3	☑ 15	☐
SI-4975	11620	11200	100.0	11970	11090	100.0	11950	11610	68.2	12080	11490	95.4	53.6	99	☑ 14	☐
							Warning! Poor agreement - A= 53.6%(A'c= 60.0%)									
SMU-251	11990	11250	100.0	12390	11180	100.0	12070	11680	68.2	12340	11520	95.4	92.8	99.5	☑ 13	☐
SI-3200	12410	12050	100.0	12540	11830	100.0	12330	12040	68.2	12450	11860	95.4	100.9	99.3	☑ 12	☐
SI-4976	12140	11410	100.0	12550	11240	100.0	12190	11740	68.2	12400	11560	95.4	112.3	99.6	☑ 11	☐
SMU-285	12590	12390	100.0	12650	12110	100.0	12460	12140	68.2	12570	12050	95.4	66.8	99	☑ 10	☐
▲ 2															☑ 9	☐
Start 2							12620	12240	68.2	12820	12120	95.4		99.2	☑ 8	☐
End 1							12980	12630	68.2	13070	12390	95.4		99.2	☑ 7	☐
SMU-263	13120	12870	100.0	13180	12700	100.0	13070	12860	68.2	13150	12740	95.4	105.3	99.6	☑ 6	☐
SMU-548	13120	12860	100.0	13230	12680	100.0	13080	12850	68.2	13170	12730	95.4	108.4	99.7	☑ 5	☐
▲ 1															☑ 4	☐
Start 1							13340	12960	68.2	14060	12810	95.4		96.8	☑ 3	☐
▲															☑ 2	☐



OxCal v4.1.7 Bronk Ramsey (2010); r:5 intr whole Atmospheric data from Reimer et al (2009);
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SI-4179
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SMU-828
SI-4974
SMU-275
SMU-728
3
SI-3203
SI-4975
SMU-251
SI-3200
SI-4976
SMU-285
2
SMU-263
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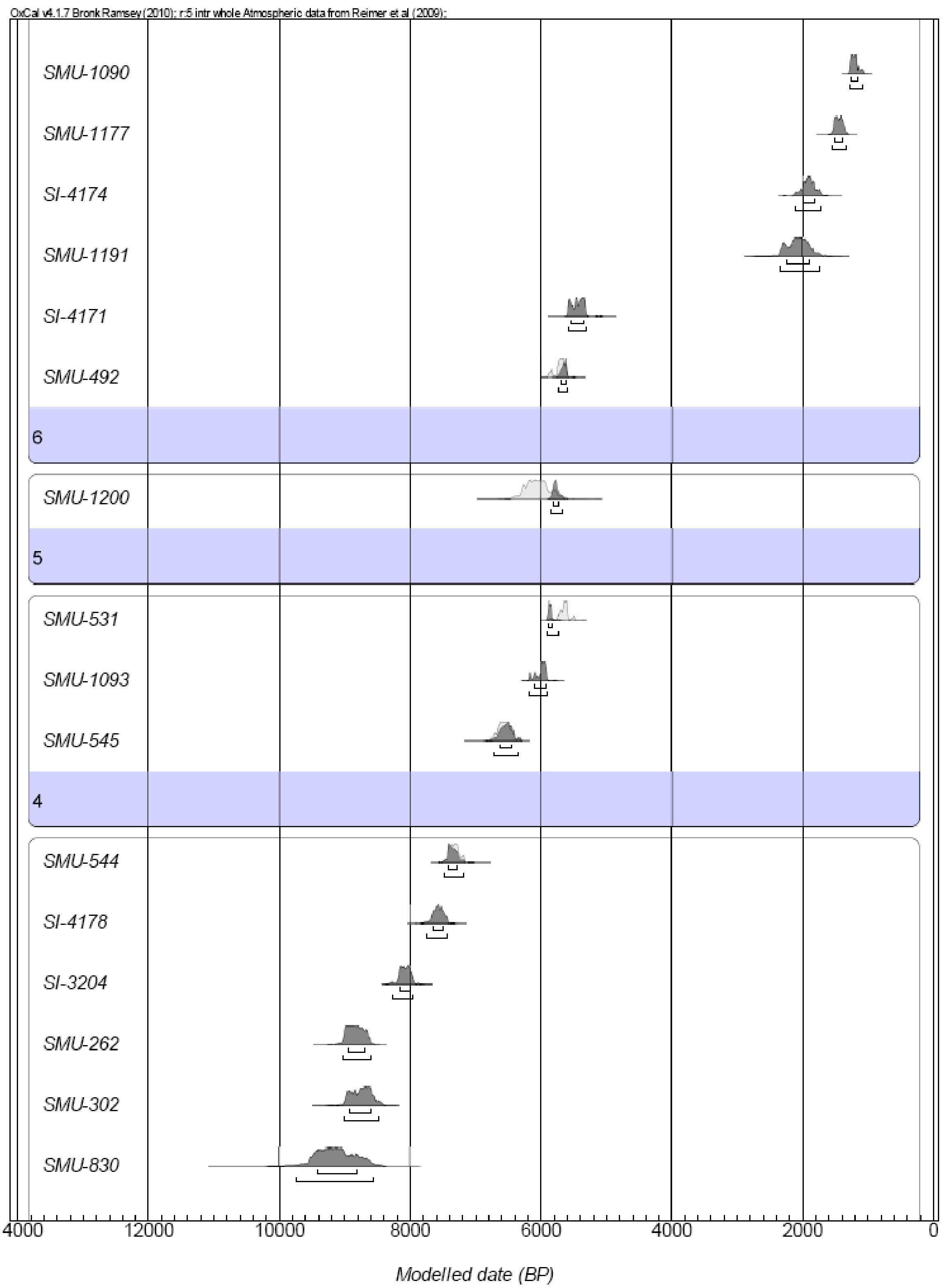
9000
8000
Modelled date (BP)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SI-4174
SMU-1191
SI-4171
SMU-492
6
SMU-1200
5
SMU-531
SMU-1093
SMU-545
4
SMU-544
SI-4178
SI-3204
SMU-262
SMU-302
SMU-830
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10000
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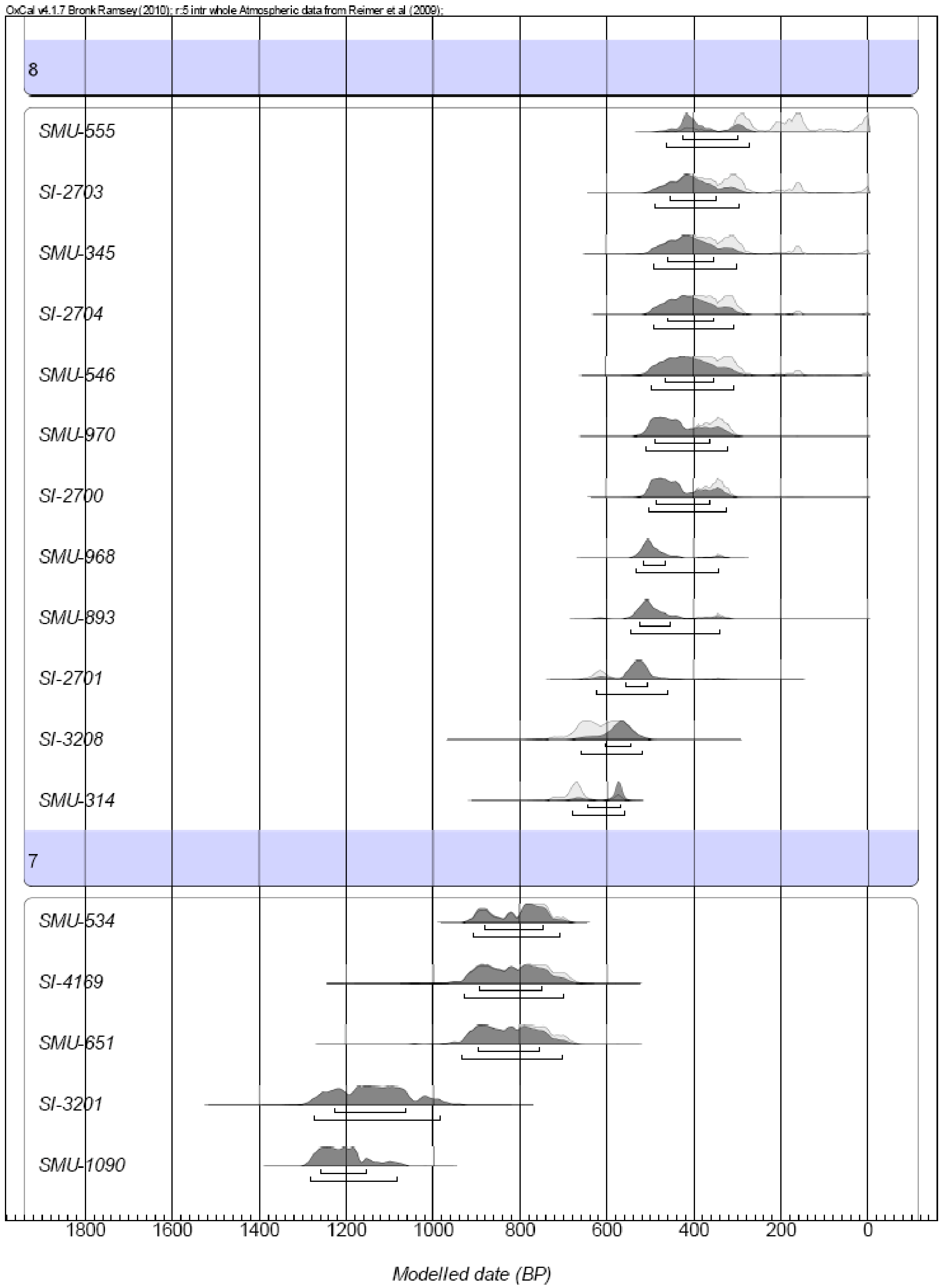
6000
4000
2000
0
Modelled date (BP)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SMU-555
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SMU-345
SI-2704
SMU-546
SMU-970
SI-2700
SMU-968
SMU-893
SI-2701
SI-3208
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7
SMU-534
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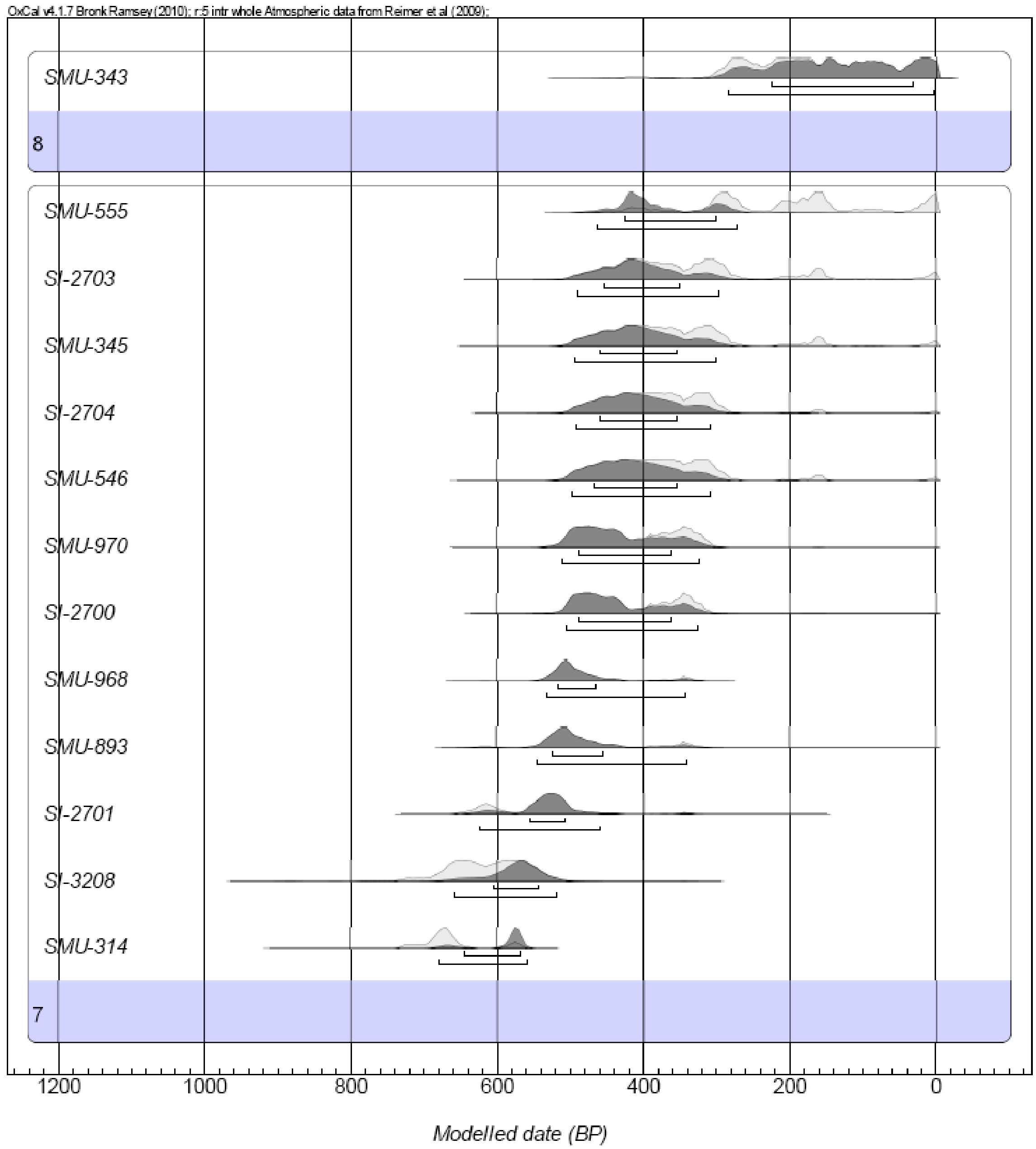
Modelled date (BP)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SMU-555
SI-2703
SMU-345
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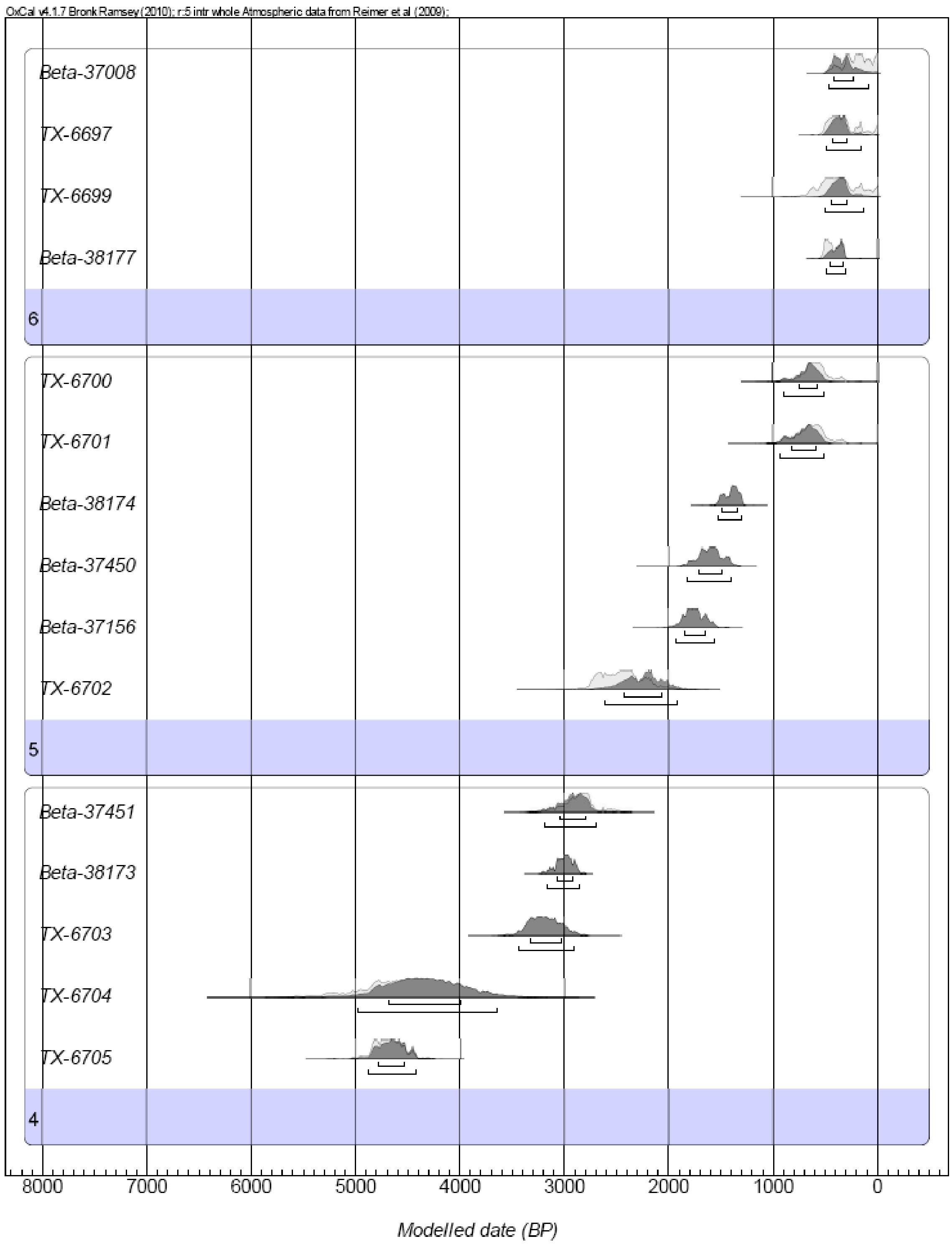
SMU-970
SI-2700
SMU-968
SMU-893
SI-2701
SI-3208
SMU-314
7
1200
1000
800
600
400
200
0
Modelled date (BP)

Fort Hood- Cowhouse Creek (Nordt 2004: Table 1)

Name Show all Show structure	Unmodelled (BP)						Modelled (BP)						Indices A_{model}=91.9 $A_{overall}$=92.7					Select All Visible	Page break
	from	to	%	from	to	%	from	to	%	from	to	%	A_{comb}	A	L	P	C		
End 6							370	90	68.2	440	-210	95.4					99	41	
Beta-37008	310	-10	100.0	480	-10	100.0	420	220	68.2	470	70	95.4		71.8			99.8	40	
	Warning! Date may extend out of range - 190+/-90BP																		
TX-6697	500	150	100.0	530	-10	100.0	440	290	68.2	490	150	95.4		117.8			99.9	39	
	Warning! Date may extend out of range - 300+/-100BP																		
TX-6699	550	0	100.0	680	-10	100.0	440	290	68.2	500	120	95.4		123.3			99.9	38	
	Warning! Date may extend out of range - 370+/-180BP																		
Beta-38177	510	320	100.0	530	300	100.0	450	320	68.2	500	300	95.4		92.9			99.9	37	
▲ 6																		36	
Start 6							510	360	68.2	590	320	95.4					99.9	35	
End 5							630	460	68.2	740	380	95.4					100	34	
TX-6700	680	510	100.0	790	310	100.0	750	570	68.2	900	500	95.4		99.3			99.9	33	
TX-6701	730	520	100.0	930	330	100.0	830	580	68.2	940	510	95.4		100.9			99.8	32	
Beta-38174	1420	1320	100.0	1530	1290	100.0	1490	1330	68.2	1530	1300	95.4		99.9			99.9	31	
Beta-37450	1710	1520	100.0	1830	1380	100.0	1710	1480	68.2	1820	1390	95.4		99.9			99.9	30	
Beta-37156	1870	1620	100.0	1930	1540	100.0	1850	1640	68.2	1930	1560	95.4		100			99.9	29	
TX-6702	2720	2200	100.0	2780	2040	100.0	2430	2060	68.2	2620	1910	95.4		75.7			99.8	28	
▲ 5																		27	
Start 5							2620	2190	68.2	2800	2010	95.4					99.9	26	
End 4							2870	2510	68.2	2990	2270	95.4					99.9	25	
Beta-37451	2950	2740	100.0	3140	2540	100.0	3040	2790	68.2	3200	2700	95.4		96.3			99.9	24	
Beta-38173	3070	2880	100.0	3160	2850	100.0	3070	2910	68.2	3170	2860	95.4		100			99.9	23	
TX-6703	3370	3000	100.0	3450	2870	100.0	3330	3030	68.2	3440	2900	95.4		100.6			99.8	22	
TX-6704	4840	3980	100.0	5300	3630	100.0	4680	3980	68.2	4980	3650	95.4		106.2			99.6	21	
TX-6705	4850	4520	100.0	4960	4420	100.0	4790	4520	68.2	4890	4420	95.4		97.5			99.8	20	
▲ 4																		19	
Start 4							5340	4710	68.2	5800	4530	95.4					99.8	18	
End 3							6100	5330	68.2	6370	4910	95.4					99.7	17	
Beta-37452	6280	5710	100.0	6470	5480	100.0	6350	5860	68.2	6620	5640	95.4		95.1			99.6	16	
GX-15892	6900	6270	100.0	7280	5910	100.0	6960	6290	68.2	7280	5990	95.4		102			99.7	15	
Beta-46192	6750	6490	100.0	6900	6390	100.0	6770	6500	68.2	6910	6390	95.4		100.1			99.8	14	
Beta-37618	7790	7600	100.0	7930	7560	100.0	7780	7600	68.2	7890	7520	95.4		101.6			99.9	13	
▲ 3																		12	
Start 3							8580	7760	68.2	9310	7630	95.4					99.7	11	
End 2							9790	8550	68.2	10050	7980	95.4					99.7	10	
Beta-63007	10160	9700	100.0	10190	9600	100.0	10100	9750	68.2	10170	9630	95.4		100.2			99.9	9	
▲ 2																		8	
Start 2							13970	10130	68.2	16920	9810	95.4					98.8	7	
End 1							18160	14170	68.2	18640	11310	95.4					98.5	6	
Beta-38694	18720	18090	100.0	18920	17930	100.0	18680	18080	68.2	18960	17790	95.4		97.6			99.6	5	
▲ 1																		4	
Start 1							20610	18370	68.2	24020	18010	95.4					95.9	3	
▲																		2	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TX-6699
Beta-38177
6
TX-6700
TX-6701
Beta-38174
Beta-37450
Beta-37156
TX-6702
5
Beta-37451
Beta-38173
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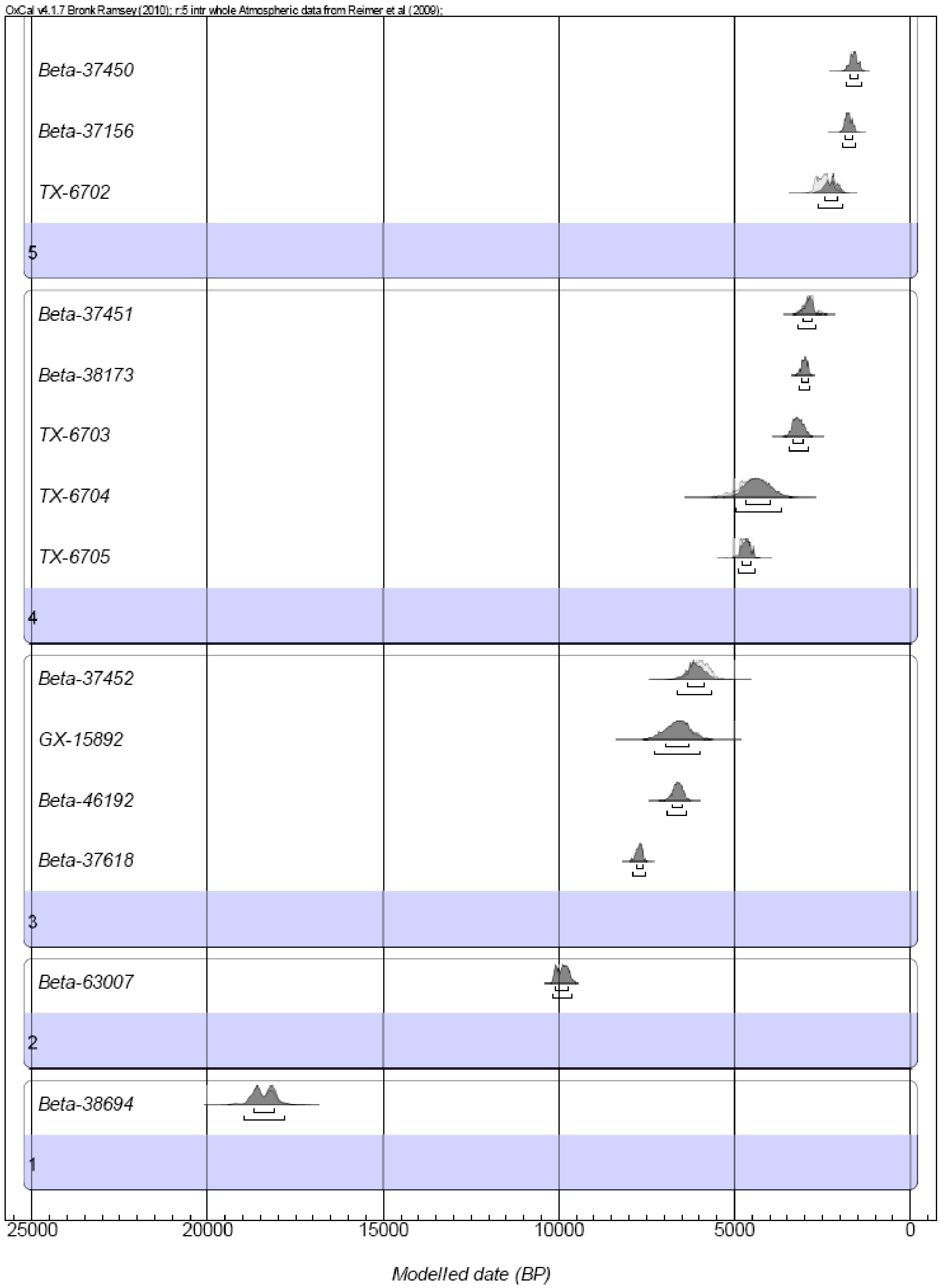
Modelled date (BP)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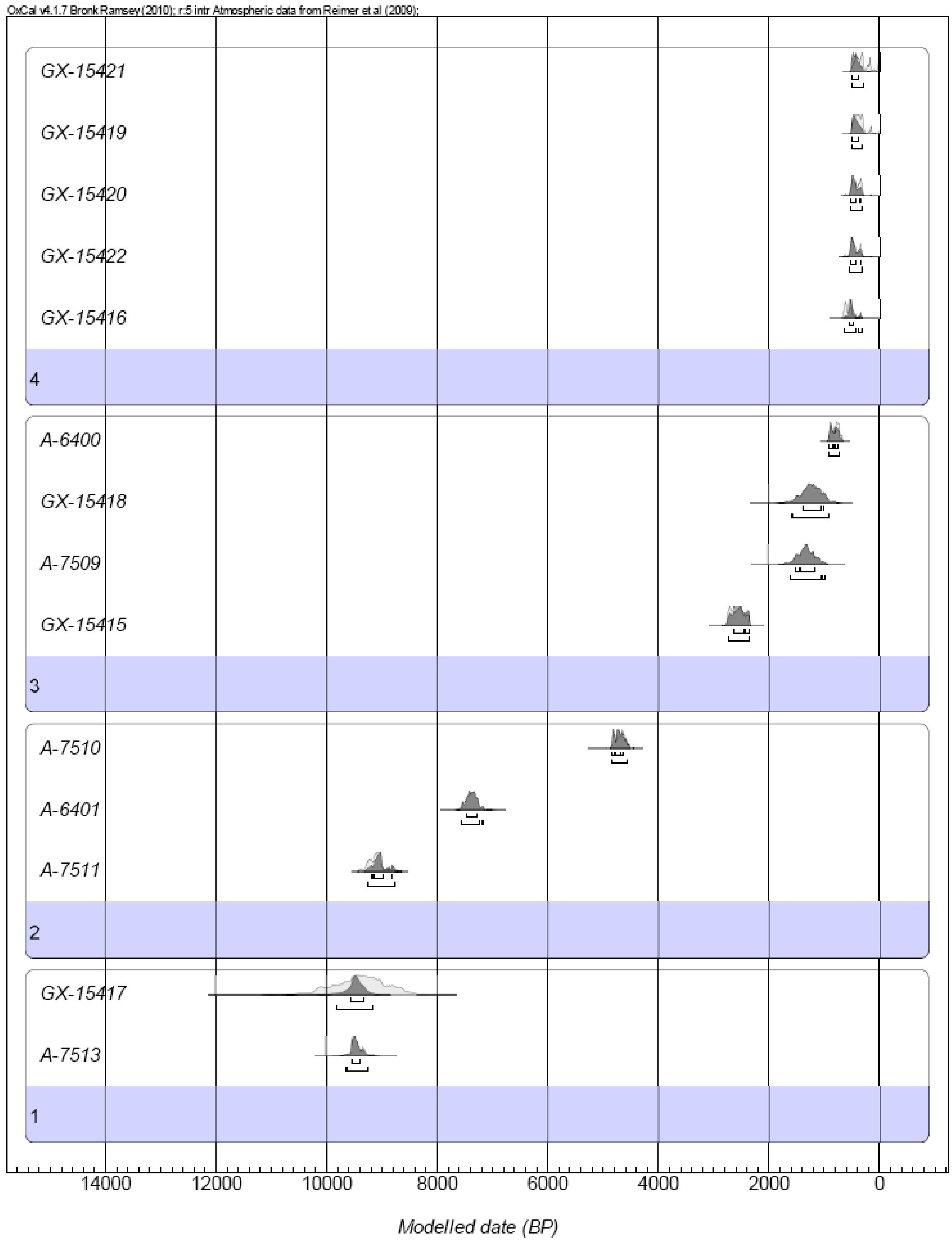
Beta-37156
TX-6702
5
Beta-37451
Beta-38173
TX-6703
TX-6704
TX-6705
4
Beta-37452
GX-15892
Beta-46192
Beta-37618
3
Beta-63007
2
Beta-38694
1
25000
20000
15000
10000
5000
0
Modelled date (BP)

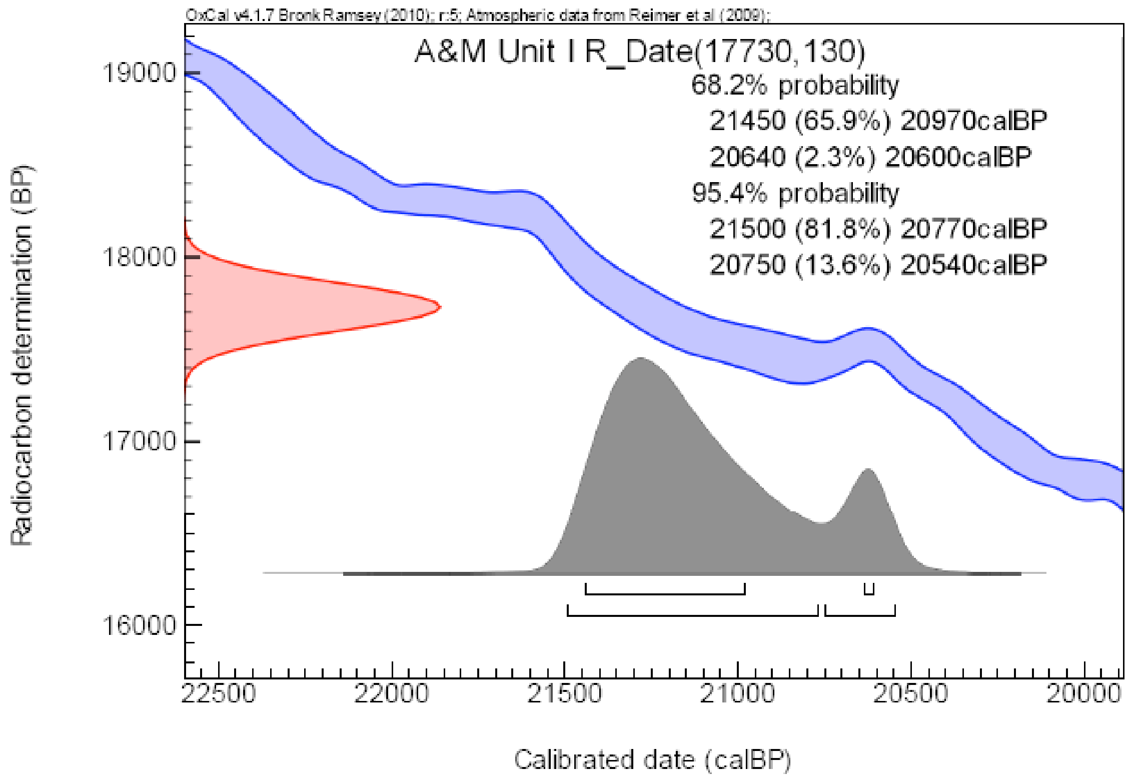
A & M Study Area (Waters & Nordt 1995: Table 1)

Name Show all Show structure	Unmodelled (BP)						Modelled (BP)						Indices A_{model}=104.7 $A_{overall}$=104.3					Select All Visible	Page break
	from	to	%	from	to	%	from	to	%	from	to	%	A_{comb}	A	L	P	C		
End 4							460	290	68.2	500	140	95.4					98.1	☑ 28	☐
GX-15421	440	150	100.1	500	-10	100.0	500	380	68.2	510	290	95.4		96.4			99.8	☑ 27	☐
GX-15419	490	290	100.0	510	-10	99.9	500	390	68.2	510	310	95.4		102.3			99.8	☑ 26	☐
GX-15420	520	320	100.0	540	300	100.0	520	330	68.2	530	320	95.4		108.1			99.9	☑ 25	☐
GX-15422	530	340	100.0	560	300	100.0	530	340	68.2	540	320	95.4		109.3			99.9	☑ 24	☐
GX-15416	630	510	100.0	660	480	100.0	560	460	68.2	630	320	95.4		75.1			99.8	☑ 23	☐
▲ 4																		☑ 22	☐
Start 4							610	470	68.2	700	340	95.4					99.7	☑ 21	☐
End 3							810	590	68.2	890	510	95.4					99.9	☑ 20	☐
A-6400	910	730	100.0	930	680	100.0	910	740	68.2	930	720	95.4		98.4			99.8	☑ 19	☐
GX-15418	1380	1060	100.0	1560	920	100.0	1390	1010	68.2	1610	910	95.4		100.2			99.5	☑ 18	☐
A-7509	1420	1180	100.0	1610	1000	100.0	1520	1170	68.1	1620	980	95.4		99.9			99.7	☑ 17	☐
GX-15415	2750	2460	100.0	2760	2350	100.0	2650	2360	68.2	2740	2350	95.4		97.3			99.8	☑ 16	☐
▲ 3																		☑ 15	☐
Start 3							3150	2470	68.2	3900	2370	95.4					99.4	☑ 14	☐
End 2							4720	3700	68.2	4810	2940	95.4					99.5	☑ 13	☐
A-7510	4840	4620	100.0	4860	4520	100.0	4840	4640	68.2	4860	4570	95.4		100.8			99.8	☑ 12	☐
A-6401	7480	7300	100.0	7580	7170	100.0	7480	7290	68.2	7580	7170	95.4		99.8			99.7	☑ 11	☐
A-7511	9250	9000	100.0	9300	8810	100.0	9200	8810	68.2	9270	8770	95.4		97.7			99.7	☑ 10	☐
▲ 2																		☑ 9	☐
Start 2							9340	9060	68.2	9480	8880	95.4					99.9	☑ 8	☐
End 1							9500	9270	68.2	9570	9070	95.4					99.8	☑ 7	☐
GX-15417	9690	9000	100.0	10240	8540	100.0	9570	9320	68.2	9830	9160	95.4		133.1			99.8	☑ 6	☐
A-7513	9540	9420	100.0	9560	9270	100.0	9550	9400	68.2	9660	9260	95.4		106.6			99.8	☑ 5	☐
▲ 1																		☑ 4	☐
Start 1							9730	9370	68.2	10330	9210	95.4					96.7	☑ 3	☐
▲																		☑ 2	☐


OxCal v4.1.7 Bronk Ramsey (2010); r:5 intr Atmospheric data from Reimer et al (2009);
GX-15421
GX-15419
GX-15420
GX-15422
GX-15416
4
A-6400
GX-15418
A-7509
GX-15415
3
A-7510
A-6401
A-7511
2
GX-15417
A-7513
1
14000
12000
10000
8000
6000
4000
2000
0
Modelled date (BP)

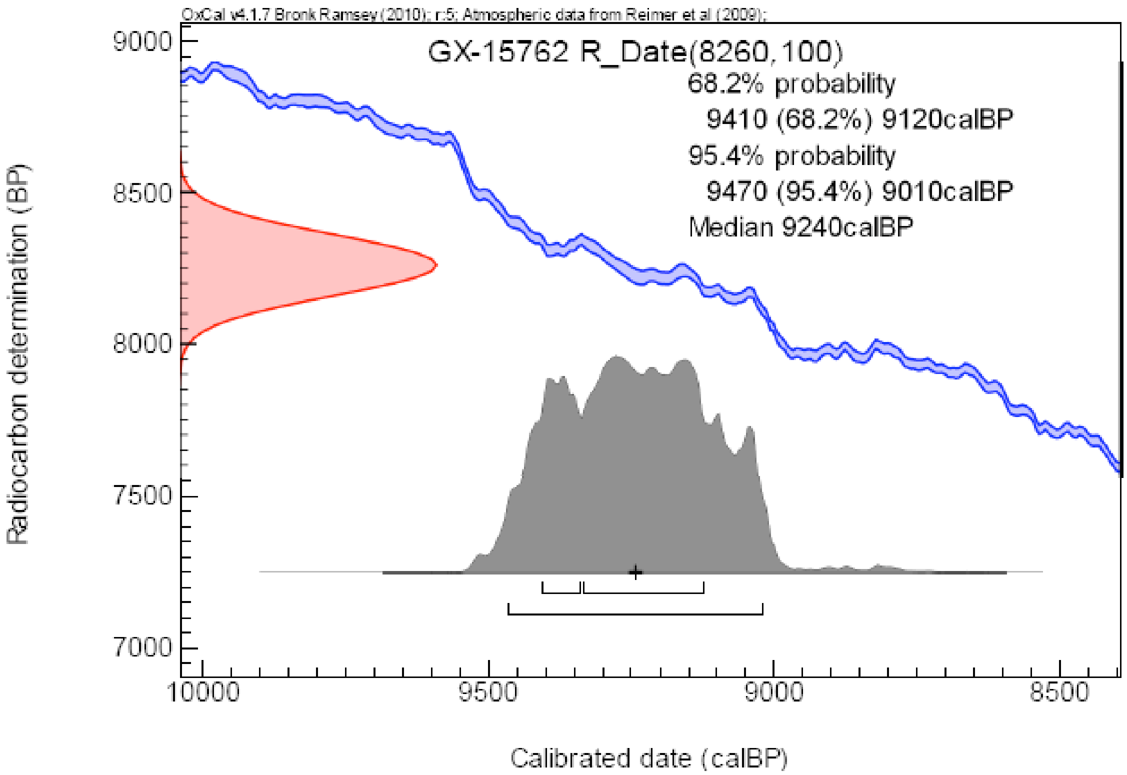
A&M Unit I

Name Show all Show structure		Unmodelled (BP)						Select All Visible	Page break
		from	to	%	from	to	%		
R_Date A&M Unit I		21450	20600	68.2	21500	20540	95.4	☑ 2	☐



Royalty Paleosol

Name Show all Show structure		Unmodelled (BP)							Select All Visible	Page break
		from	to	%	from	to	%	m		
R_Date GX-15762		9410	9120	68.2	9470	9010	95.4	9240	☑ 2	☐

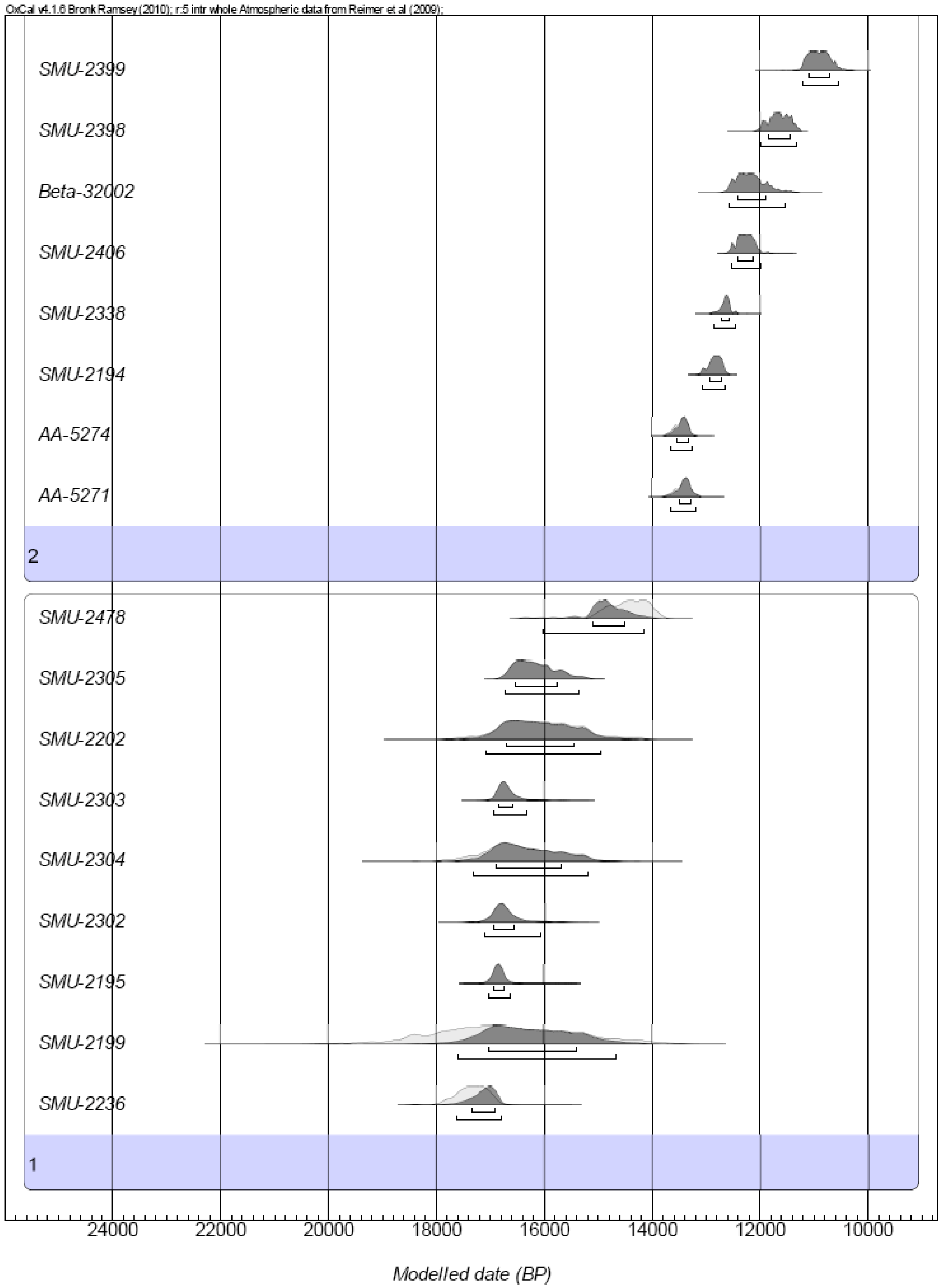


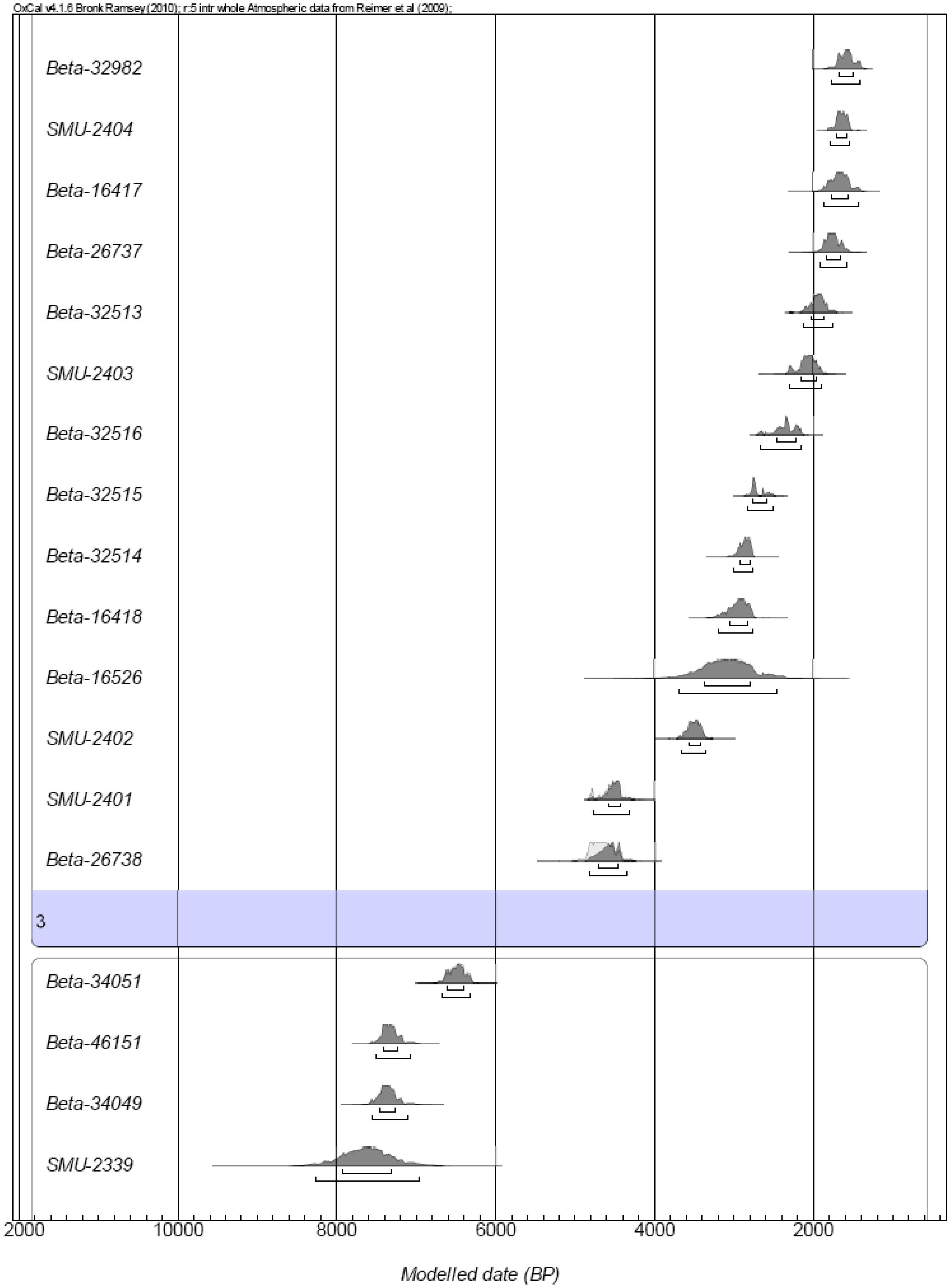
APPENDIX V: Trinity River Basin OxCal Results

Upper Extent Trinity River assays (Ferring 1995a)

Name Show all Show structure	Unmodelled (BP)						Modelled (BP)						Indices A_{model}=99 $A_{overall}$=100					Select All Visible	Page break
	from	to	%	from	to	%	from	to	%	from	to	%	A_{comb}	A	L	P	C		
End 3							520	280	68.2	570	30	95.4					99	✓ 68	
Beta-14963	630	500	100.0	660	330	100.0	630	500	68.2	660	420	95.4		105.9			99.9	✓ 67	
Beta-32522	630	510	100.0	660	480	100.0	630	520	68.2	660	480	95.4		101.7			99.9	✓ 66	
Beta-22488	670	510	100.0	700	480	100.0	660	530	68.2	730	480	95.4		103.3			99.8	✓ 65	
TX-4001	790	510	100.0	980	300	100.0	870	550	68.2	1060	430	95.4		106.8			99.8	✓ 64	
Beta-22487	680	560	100.0	690	550	100.0	670	570	68.2	710	550	95.4		99.5			99.9	✓ 63	
Beta-14907	730	570	100.0	800	540	100.0	750	590	68.2	880	550	95.4		100.1			99.9	✓ 62	
Beta-32521	740	660	100.0	800	560	100.0	770	660	68.2	890	560	95.4		99.9			99.9	✓ 61	
Beta-32529	740	660	100.0	800	560	100.0	770	660	68.2	890	560	95.4		100			99.9	✓ 60	
Beta-16416	940	790	100.0	980	730	100.0	930	800	68.2	1000	740	95.4		99.9			99.9	✓ 59	
Beta-22028	960	790	100.0	1060	730	100.0	960	800	68.2	1050	740	95.4		99.9			99.9	✓ 58	
Beta-13962	1180	920	100.0	1290	780	100.0	1160	910	68.2	1260	780	95.4		99.9			99.7	✓ 57	
Beta-32523	1290	1090	100.0	1310	1010	100.0	1270	1100	68.2	1300	1010	95.4		99.9			99.9	✓ 56	
Beta-32986	1300	1070	100.0	1350	980	100.0	1280	1090	68.2	1350	990	95.4		100			99.8	✓ 55	
Beta-32530	1300	1070	100.0	1350	980	100.0	1280	1090	68.2	1350	990	95.4		99.9			99.8	✓ 54	
Beta-14908	1300	1170	100.0	1310	1060	100.0	1280	1150	68.2	1320	1070	95.4		99.8			99.9	✓ 53	
GX-18282	1360	1170	100.0	1520	980	100.0	1380	1120	68.2	1510	1000	95.4		100			99.8	✓ 52	
Beta-14904	1400	1270	100.0	1530	1140	100.0	1430	1220	68.2	1530	1090	95.4		100			99.8	✓ 51	
Beta-32524	1380	1280	100.0	1520	1170	100.0	1400	1260	68.2	1510	1160	95.4		100			99.8	✓ 50	
Beta-32982	1700	1520	100.0	1740	1400	100.0	1680	1490	68.2	1780	1410	95.4		99.9			99.9	✓ 49	
SMU-2404	1710	1560	100.0	1820	1520	100.0	1710	1570	68.2	1800	1530	95.4		100			99.9	✓ 48	
Beta-16417	1780	1540	100.0	1880	1410	100.0	1780	1550	68.2	1870	1430	95.4		100.1			99.9	✓ 47	
Beta-26737	1870	1630	100.0	1930	1560	100.0	1840	1650	68.2	1920	1570	95.4		100			99.9	✓ 46	
Beta-32513	2000	1870	100.0	2130	1810	100.0	2040	1860	68.2	2130	1760	95.4		100			99.8	✓ 45	
SMU-2403	2150	1940	100.0	2310	1880	100.0	2150	1960	68.2	2300	1890	95.4		100			99.8	✓ 44	
Beta-32516	2360	2310	100.0	2680	2150	100.0	2470	2210	68.2	2680	2150	95.4		99.7			99.8	✓ 43	
Beta-32515	2760	2720	100.0	2790	2540	100.0	2760	2580	68.2	2830	2500	95.4		99.5			99.9	✓ 42	
Beta-32514	2930	2770	100.0	3000	2750	100.0	2930	2790	68.2	3020	2760	95.4		99.9			99.9	✓ 41	
Beta-16418	3010	2780	100.0	3210	2740	100.0	3060	2820	68.2	3200	2760	95.4		99.9			99.8	✓ 40	
Beta-16526	3390	2760	100.0	3690	2360	100.0	3380	2800	68.2	3700	2450	95.4		100			99.5	✓ 39	
SMU-2402	3570	3390	100.0	3680	3350	100.0	3580	3410	68.2	3670	3360	95.4		100			99.9	✓ 38	
SMU-2401	4580	4420	100.0	4810	4400	100.0	4580	4430	68.2	4770	4310	95.4		107.3			99.9	✓ 37	
Beta-26738	4840	4520	100.0	4880	4410	100.0	4710	4460	68.2	4820	4340	95.4		89.2			99.8	✓ 36	
▲ 3																		✓ 35	
Start 3							4900	4570	68.2	5190	4480	95.4					99.5	✓ 34	
End 2							6430	5640	68.2	6580	5000	95.4					99.6	✓ 33	
Beta-34051	6560	6390	100.0	6670	6300	100.0	6610	6400	68.2	6680	6320	95.4		97.6			99.8	✓ 32	
Beta-46151	7430	7250	100.0	7510	7160	100.0	7420	7230	68.2	7510	7070	95.4		99.9			99.8	✓ 31	
Beta-34049	7440	7260	100.0	7570	7160	100.0	7460	7260	68.2	7560	7100	95.4		100			99.8	✓ 30	
SMU-2339	7940	7320	100.0	8200	6990	100.0	7930	7320	68.2	8270	6960	95.4		100			99.5	✓ 29	
SMU-2400	8380	8180	100.0	8410	8160	100.0	8350	8200	68.2	8390	8090	95.4		100			99.9	✓ 28	
Beta-46150	9550	9430	100.0	9730	9270	100.0	9640	9360	68.2	9870	9180	95.4		100.1			99.8	✓ 27	
Beta-14905	10250	9700	100.0	10550	9530	100.0	10260	9750	68.2	10530	9570	95.4		100			99.6	✓ 26	
GX-18281	11190	10290	100.0	11400	10170	100.0	11120	10410	68.2	11580	10110	95.4		100			99.6	✓ 25	
SMU-2399	11180	10690	100.0	11240	10510	100.0	11100	10710	68.2	11210	10530	95.4		100			99.7	✓ 24	

SMU-2398	11950	11390	100.0	12030	11270	100.0	11850	11440	68.2	11990	11310	95.4		100			99.8	☑ 23	☐
Beta-32002	12530	11970	100.0	12610	11610	100.0	12420	11890	68.2	12570	11540	95.4		99.9			99.7	☑ 22	☐
SMU-2406	12420	12080	100.0	12580	11980	100.0	12410	12110	68.2	12540	11990	95.4		100			99.8	☑ 21	☐
SMU-2338	12690	12570	100.0	12780	12540	100.0	12720	12570	68.2	12860	12450	95.4		99.9			99.8	☑ 20	☐
SMU-2194	12920	12670	100.0	13090	12610	100.0	12940	12710	68.2	13070	12640	95.4		100			99.8	☑ 19	☐
AA-5274	13500	13320	100.0	13690	13260	100.0	13550	13330	68.2	13670	13260	95.4		103.9			99.9	☑ 18	☐
AA-5271	13470	13280	100.0	13670	13180	100.0	13510	13280	68.2	13650	13180	95.4		104.1			99.8	☑ 17	☐
▲ 2																		☑ 16	☐
Start 2							14130	13520	68.2	14610	13390	95.4					99.8	☑ 15	☐
End 1							14950	14150	68.2	15770	13770	95.4					99.6	☑ 14	☐
SMU-2478	14890	14000	100.0	15140	13810	100.0	15100	14490	68.2	16010	14140	95.4		70.4			99.6	☑ 13	☐
SMU-2305	16630	15910	100.0	16810	15280	100.0	16540	15750	68.2	16730	15350	95.4		100.5			99.7	☑ 12	☐
SMU-2202	16880	15220	100.0	17220	14900	100.0	16710	15440	68.2	17090	14950	95.4		104.5			99.6	☑ 11	☐
SMU-2303	16870	16660	100.0	16940	16450	100.0	16840	16570	68.2	16940	16320	95.4		100.1			99.8	☑ 10	☐
SMU-2304	17020	16150	100.0	17600	15120	100.0	16900	15680	68.2	17310	15180	95.4		106			99.6	☑ 9	☐
SMU-2302	16930	16690	100.0	17090	16430	100.0	16930	16560	68.2	17110	16060	95.4		101.9			99.7	☑ 8	☐
SMU-2195	16920	16760	100.0	17020	16670	100.0	16930	16740	68.2	17030	16620	95.4		100.7			99.8	☑ 7	☐
SMU-2199	17950	15270	100.0	18900	14040	100.0	17030	15390	68.2	17590	14660	95.4		112.3			99.6	☑ 6	☐
SMU-2236	17610	16970	100.0	17910	16810	100.0	17340	16910	68.2	17630	16790	95.4		94.4			99.4	☑ 5	☐
▲ 1																		☑ 4	☐
Start 1							17760	17060	68.2	18550	16910	95.4					96.9	☑ 3	☐
▲																		☑ 2	☐


OxCal v4.1.6 Bronk Ramsey (2010); r:5 intr whole Atmospheric data from Reimer et al (2009);
SMU-2399
SMU-2398
Beta-32002
SMU-2406
SMU-2338
SMU-2194
AA-5274
AA-5271
2
SMU-2478
SMU-2305
SMU-2202
SMU-2303
SMU-2304
SMU-2302
SMU-2195
SMU-2199
SMU-2236
1
24000
22000
20000
18000
16000
14000
12000
10000
Modelled date (BP)


OxCal v4.1.6 Bronk Ramsey (2010); r:5 intr whole Atmospheric data from Reimer et al (2009);
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Beta-16417
Beta-26737
Beta-32513
SMU-2403
Beta-32516
Beta-32515
Beta-32514
Beta-16418
Beta-16526
SMU-2402
SMU-2401
Beta-26738
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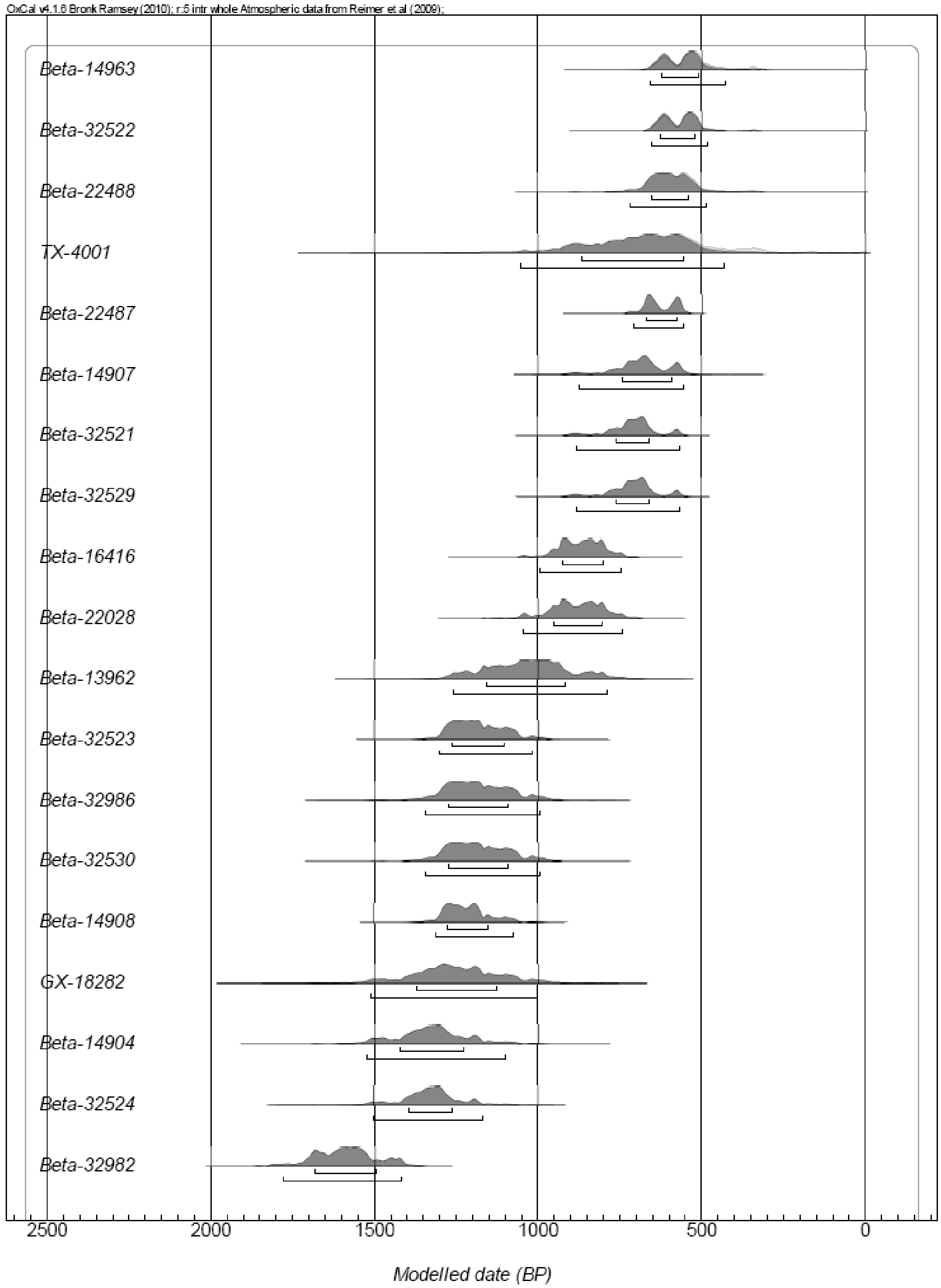
Modelled date (BP)



OxCal v4.1.6 Bronk Ramsey (2010); r:5 intr whole Atmospheric data from Reimer et al (2009);
Beta-14963
Beta-32522
Beta-22488
TX-4001
Beta-22487
Beta-14907
Beta-32521
Beta-32529
Beta-16416
Beta-22028
Beta-13962
Beta-32523
Beta-32986
Beta-32530
Beta-14908
GX-18282
Beta-14904
Beta-32524
Beta-32982
2500
2000
1500
1000
500
0
Modelled date (BP)

APPENDIX VI-Categorized Bibliography

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