GEOLOGY

Evidence of an early projectile point technology in North America at the Gault Site, Texas, USA

Thomas J. Williams[1*†], Michael B. Collins[1*†], Kathleen Rodrigues[2,3*†], William Jack Rink[4*], Nancy Velchoff[1], Amanda Keen-Zebert[2], Anastasia Gilmer[5], Charles D. Frederick[6], Sergio J. Ayala[1], Elton R. Prewitt[7]

American archeology has long been polarized over the issue of a human presence in the Western Hemisphere earlier than Clovis. As evidence of early sites across North and South America continues to emerge, stone tool assemblages appear more geographically and temporally diverse than traditionally assumed. Within this new framework, the prevailing models of Clovis origins and the peopling of the Americas are being reevaluated. This paper presents age estimates from a series of alluvial sedimentary samples from the earliest cultural assemblage at the Gault Site, Central Texas. The optically stimulated luminescence age estimates (~16 to 20 thousand years ago) indicate an early human occupation in North America before at least ~16 thousand years ago. Significantly, this assemblage exhibits a previously unknown, early projectile point technology unrelated to Clovis. Within a wider context, this evidence suggests that Clovis technology spread across an already regionalized, indigenous population.

INTRODUCTION

Current research on the early human occupation of the Americas no longer recognizes Clovis as the expression of a founding population (*1*, *2*). Increasing diversity, range, and time depths within the expanding database of sites predating Clovis attest to greater complexity in the early record (*3*) than previously thought. Archeological opinion on the nature, timing, arrival, and peopling scenarios remains divided (*4*–*6*). Despite this, there is increasing evidence to support a number of contemporaneous (*7*) and older (*2*, *8*) cultural manifestations at least 2 thousand years (ka) before the appearance of Clovis (*9*). This includes the Western Stemmed Tradition (*10*), Beringian assemblages (*11*), and Eastern Seaboard sites (*12*–*14*) in North America alongside the El Jobo/Monte Verde and fishtail bifacial technologies and edge-trimmed traditions in South America (*15*–*17*). These technological patterns require careful and systematic evaluation to address the nature and timing of both the early occupation of the Americas and, subsequently, the origins of Clovis (Supplementary Materials).

Background

Initially identified in 2002, excavation at Area 15 of the Gault Site (Fig. 1) was undertaken to explore evidence of early cultures in Central Texas. Research focused on the manufacturing technologies, their relationship to Clovis, and the associated age of this assemblage. This report focuses on the optically stimulated luminescence (OSL) ages obtained from the lowest deposits in Area 15 that contain a material that predates Clovis, referred to as the Gault Assemblage.

[1]Prehistory Research Project, Department of Anthropology, Texas State University, 601 University Drive, San Marcos, TX 78666, USA. [2]Division of Earth and Ecosystem Sciences, Desert Research Institute, 2215 Raggio Parkway, Reno, NV 89503, USA. [3]Department of Geological Sciences and Engineering, University of Nevada, Reno, 1664 North Virginia Street, Reno, NV 89557, USA. [4]School of Geography and Earth Sciences, McMaster University, 1280 Main Street West, Hamilton, Ontario L8S 4K1, Canada. [5]SWCA Environmental Consultants Inc., 200 West 22nd Street #220, Lombard, IL 60148, USA. [6]Independent Scholar, 2901 FM 1496, Dublin, TX 76446, USA. [7]Texas Archaeological Research Laboratory, The University of Texas at Austin, 1 University Station, R7500, Austin, TX 78712, USA.
*These authors contributed equally to this work.
†Corresponding author. Email: tjw69@txstate.edu (T.J.W.); mc82@txstate.edu (M.B.C.); kathleen.rodrigues@dri.edu (K.R.)

The site occupies an upstream first- to second-order floodplain of the Buttermilk Creek valley, which has reliable springs and high-quality chert outcrops. The setting is an ecotone with mesic, riparian flora in the valley floor and xeric-adapted plants on the adjacent uplands. Regionally, the setting is in the Balcones Canyonlands, itself an ecotone, where resources of the limestone uplands (the Edwards Plateau) interface with the Blackland Prairie on the adjacent coastal plains.

The Area 15 excavation block, located within the valley floor, is a 56-m^2 grid, which was stepped down in meter increments. Excavation was conducted in 1 m × 1 m squares within this grid in arbitrary levels of 5 cm deep from 93.00 m and below (based on an arbitrary site datum of 100.00 m). The upper ~1.8-m deposit is a midden, common to Central Texas (*18*). Below this is a ~1.2-m-thick silty clay deposit atop a ~0.20- to 0.50-m-thick fluvial gravel. The gravel rests on Cretaceous-age limestone bedrock of the Comanche Peak Formation (Supplementary Materials).

The sediments in Area 15 are well stratified with diagnostic projectile points and associated artifact complexes in chronological order (Fig. 2) and, in many cases, are separated from one another by a decrease in debitage counts. The midden deposit contains Archaic projectile points in good stratigraphic order. Within the midden, there is a vertically constrained distribution of small (<1 cm) diagnostic Andice notching flakes recovered between 94.90 and 94.00 m (fig. S5). Field observations of the orientation of artifacts suggest that shrink-swell movement of the soil has reoriented some materials and favored the downward migration of some of the smallest artifacts, but the absence of diagnostic artifacts like Bell-Andice notching flakes (Supplementary Materials) below the appropriate age deposit suggests that this movement has been limited. The silty clay beneath the Bell-Andice occupation contains an ~50-cm-thick sequence of Late Paleoindian components in a stratified order overlying an ~25-cm-thick Clovis component. Below this is an ~65- to 80-cm-thick deposit overlying undulating bedrock that consists of silty clay and fluvial gravel deposits, containing the Gault Assemblage. A further indicator of the stratigraphic integrity of the site is the separation between cultural components. Furthermore, bioturbation, such as animal or root disturbances, was identified and excavated separately

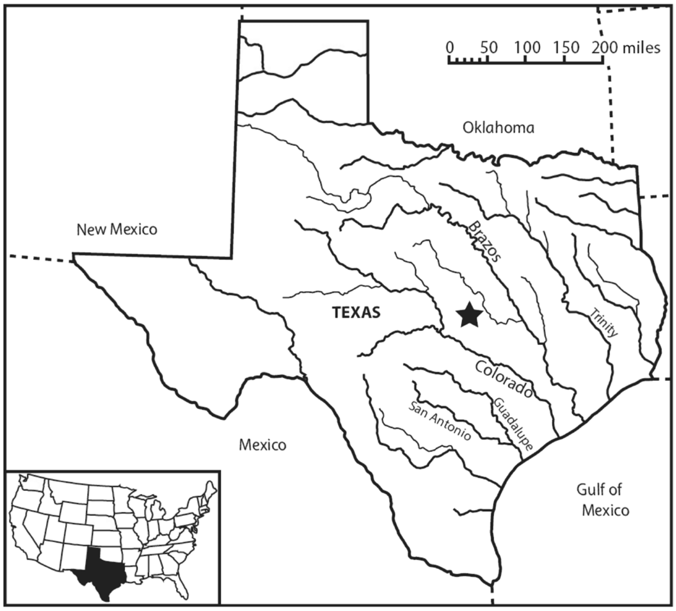

Fig. 1. Location of the Gault Site, Texas, USA.

in the field. Debitage counts indicate that decreased cultural material frequencies occur between the Gault, Clovis, and Paleoindian components. There is an ~10-cm-thick zone of decreased cultural material between the Clovis and Gault components. This suggests a reduction in site activity or possible occupational breaks between the three cultural depositions.

Stone tool assemblage

The stone tool assemblage recovered from the lowest, earliest deposits exhibits a small projectile point technology as well as both a biface and a blade-and-core tradition. The projectile points from the Gault Assemblage exhibit two stem morphologies: stemmed and lanceolate (Supplementary Materials). One stemmed projectile point (Fig. 3I) exhibits a slightly concave base, with concave lateral margins and short shoulders with beveled edges. In profile, this point is slightly curved, suggesting that it was manufactured on a flake. Two bifurcate stemmed points were also recovered (Fig. 3, H and J); both have a deep concave base, an expanding stem, and exhibit beveling. A small proximal tip with beveled edges was also recovered (Fig. 3K). These points were likely produced on flakes and predominantly manufactured using pressure flaking to shape and finish the points. These stemmed points are technologically and morphologically distinct from any later regional cultural manifestations. Superficially, they resemble point types within the regional Early Archaic yet differ in base treatment and blade bevel (Supplementary Materials). The two lanceolate projectile points (Fig. 3, X and Y) are similar in

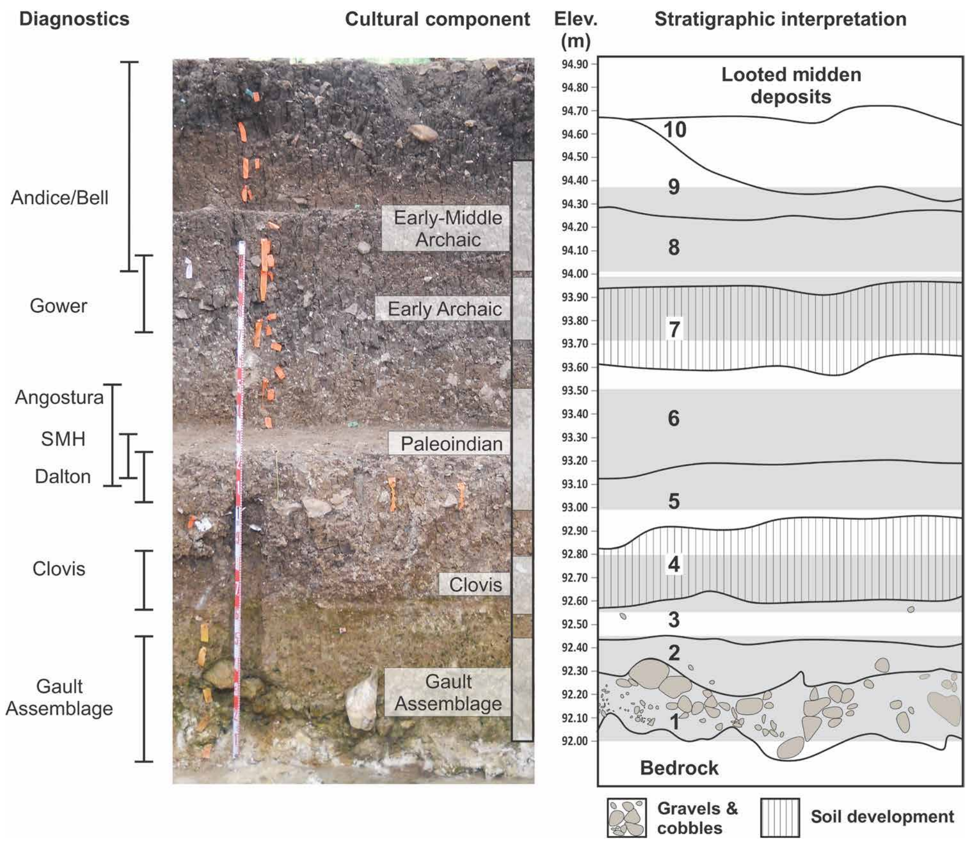

Fig. 2. Stratigraphic profile of the Area 15 excavation block showing the diagnostic cultural materials and components alongside the stratigraphic sequence. Diagnostic projectile points listed on the left were all found within the associated deposits (SMH, St. Mary's Hall). Stratigraphic unit numbers are shown on the right, and the cultural horizons are highlighted in gray.

Fig. 3. Gault Assemblage artifacts (A to D, F, and L) Bifaces. (**E**) Blade core. (**G**) Quartz projectile point. (**H** and **I**) Projectile points. (**K**) Projectile point tip. (**M**, **V**, and **W**) Blade. (**N**) Unifacial tool. (**O** and **T**) Gravers. (**P**) Discoidal biface. (**Q**) End scraper. (**R** to **U**) Modified flake tools. (**X** and **Y**) Lanceolate projectile points. Descriptions are given in the Supplementary Materials.

size, exhibit a concave base, and share similarities in the basal flaking and finishing. Only one point (Fig. 3X) is ground along the edges. Both points are snapped at the stem, but existing flaking pattern suggests comedial (midline) flaking. The lanceolate points superficially resemble Late Paleoindian types but do not fit any single point type from this period. A sixth point exhibits weak shoulders and a contracting stem (Fig. 3G). This point is made from smoky quartz and exhibits a central ridge produced from comedial flaking. Unlike the three points discussed above, the morphology of this point resembles Western Stemmed points, but its age places it outside of the known chronology for this type (*7*). All projectile points were recovered from undisturbed sediments within Area 15 with no evidence for the downward movement within their excavation units. This projectile point assemblage is unlike anything in the early archeological record of the Americas and indicates complex behavioral activities associated with a group or groups who colonized the New World.

Alongside these points, approximately 150,000 artifacts, consisting mainly of debitage, have been recovered from these lowest two units (see strata 1 and 2 in the Supplementary Materials). To date, 184 flaked stone artifacts have been analyzed (Supplementary Materials). These include the distinct stemmed projectile points, blades and blade cores, bifaces, and flake tools. The Gault Assemblage shares this generalized biface and blade-and-core lithic tradition with the overlying Clovis materials but differs significantly in the following ways.

The Gault biface assemblage exhibits the prevalent use of comedial (midline) flaking indicative of proportionally thinning a biface, which closely parallels the reductive technology used to create the Gault Assemblage projectiles. Clovis, however, demonstrates the use of full-face and overshot flaking to produce thinned bifaces. In addition, the flake striking platforms produced during manufacture are larger and less prepared than the Clovis flake platforms (*19*).

In contrast, the blade-and-core assemblage shares more commonalities with Clovis technology. Both technologies exhibit flat-backed blade cores that use a single blade face with an acute platform and unidirectional blade removals as well as conical cores that have blade removals around the circumference of the core. Evidence from the blade platforms indicates that the Gault Assemblage generally exhibits less preparation than Clovis platforms.

The similarities and differences suggest that there is no single linear trajectory toward Clovis technology within the Gault Assemblage. Instead, parts of the technological repertoire, like the blade-and-core tradition, appear to have continued in the Clovis levels at the Gault site, while the projectile points and the biface traditions underwent significant changes. In a broader context, the technologies present in the Gault Assemblage appear to represent a unique pattern within the early human occupations of the Americas that indicates a regional adaptation after the initial colonization of the New World.

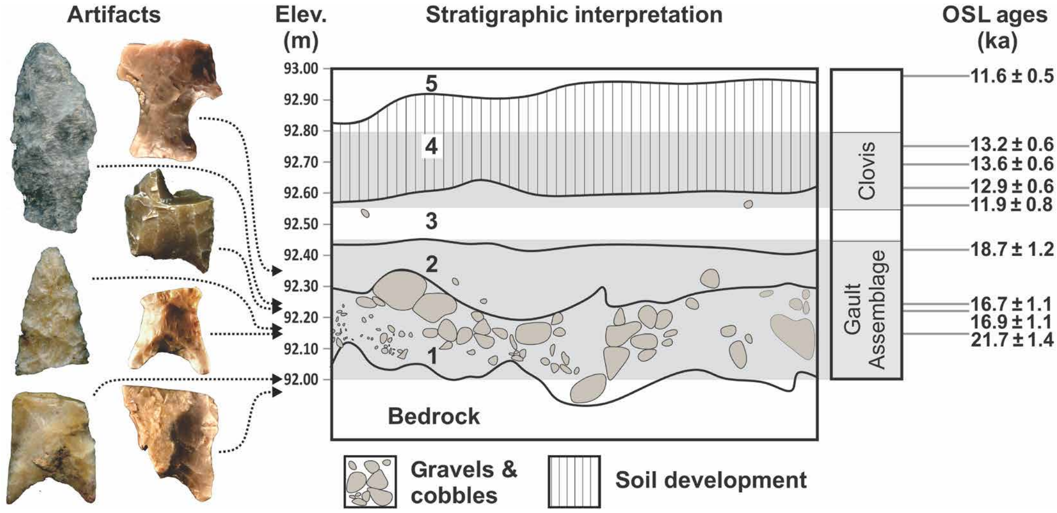

Fig. 4. OSL ages in association with the stratigraphic units and the projectile points recovered from the Gault Assemblage (not to scale). Stratigraphic unit numbers are shown on the left, and the cultural horizons are highlighted in gray. Clovis ages have been reported elsewhere (see text).

MATERIALS AND METHODS

Four OSL samples were collected from the lowest cultural bearing deposits (see strata 1 and 2 in the Supplementary Materials) in Area 15 of the Gault Site (Fig. 4 and table S1). Samples were collected by horizontally hammering 4.5-cm-diameter steel tubes into clean open sections. After collection, the sample holes were slightly enlarged to obtain in situ gamma spectrometric measurements at all locations.

Samples were prepared at the Department of Geosciences at Murray State University, Murray, KY under low red fluorescent lighting fitted with Lee 106 filters. Pure quartz grains were obtained using standard OSL preparation methods, including treatment with 10% HCl and 30% H_2O_2, to remove carbonates and organic material, respectively. The samples were wet-sieved to obtain a 32- to 63-μm grain size fraction, and a heavy liquid separation using lithium polytungstate was performed to isolate quartz. No HF etching was applied.

Luminescence measurements were conducted at McMaster University, Hamilton, ON using a Risø OSL/TL-DA-15 reader fitted with a 7-mm-thick Hoya U-340 filter. Measurements were carried out using blue diodes (470 nm) operating at 90% power (~30 mW/cm^2). Laboratory irradiations were performed using a calibrated $^{90}Sr/^{90}Y$ radioactive source attached to the Risø luminescence reader. Blue LED's (light-emitting diode) multigrain aliquots were prepared on 9.8-mm-diameter stainless steel discs using a silicon spray and a 0.5-mm mask (~72 grains).

An initial equivalent dose (D_e) estimate was made by comparing the natural OSL signal of four aliquots to their OSL signal after a given dose. A second identical regenerative dose was applied to the same four aliquots, and the Infrared Stimulated Luminescence (IRSL) signal was measured as a check for feldspar contamination. All aliquots had an IRSL-to-OSL ratio of <1%, suggesting no significant feldspar contamination in the prepared samples. A dose recovery test was used to determine the preheat temperature (160°, 200°, 240°, and 260°C) at which a given dose could be best recovered. A preheat temperature of 200°C and a cut-heat temperature of 160°C produced a dose closest to the given dose and was used in all subsequent D_e measurements. Thermal transfer tests that were carried out to assess the possibility of charge transfer from light-insensitive shallow traps to light-sensitive OSL traps showed no significant thermal transfer (*20*). During this experiment, the OSL signal of several aliquots was first bleached by a 400-s exposure to blue LED's. Apparent D_e's were then calculated using the SAR protocol (*21*), but applying different preheat temperatures to different aliquots. Significant thermal transfer [>1 gray (Gy)] was only observed with the application of preheat temperatures more than 260°C.

Final D_e measurements were made on 48 aliquots for each measured sample. All measurements followed the SAR protocol (*21*, *22*) on 0.5-mm multigrain aliquots of 32- to 63-μm quartz with a total stimulation time of 100 s. This fraction was targeted to isolate quartz-rich silt identified through petrography (*23*) that was presumed to be incorporated in the floodplain sediments through aeolian processes. The OSL signal was integrated from the first 0.4 s of the decay curve, and the subtracted background was integrated from the last 4 s. Aliquots were required to pass the following criteria for further analysis: <10% test dose error, <10% recycling ratio error, <10% recuperation, <10% palaeodose error, and a signal greater than 3σ above background. All D_e values incorporated an instrumental error of 1.5%.

Final D_e values used for age calculation were statistically modeled using the central age model [CAM; (*24*)] owing to low overdispersion (that is, <10%) and the normal distribution of D_e's in each sample. A σ_b value of 0.045, calculated from dose recovery results, was added in quadrature to all D_e estimates to account for variability arising from the intrinsic luminescent properties (*25*).

External α and β dose rates were determined from the U, Th, and K concentrations of a small amount of sediment (~2 g) collected from each OSL sample and measured with neutron activation analysis and delayed neutron counting (conducted at the McMaster University Nuclear Reactor). Conversion of radioisotope concentrations was done using the data of Guérin *et al.* (*26*). Dose rates were calculated, assuming secular equilibrium in the U and Th decay chains. Dose rates were corrected for water content using laboratory-based measurements and for attenuation using factors from Brennan *et al.* (*27*) and Guérin *et al.* (*28*). External gamma dose rates were obtained in situ at all sample locations using a NaI(Tl) Harwell four-channel gamma spectrometer. Cosmic dose rates were calculated on the basis of the methods by Prescott and Hutton (*29*, *30*) and calculated using a 2.0 g/cm^3 of overburden density, assuming a linear sediment accumulation.

Ages were calculated by dividing the D_e modeled with the CAM by the corresponding total dose rate. In addition to the errors on the modeled D_e's, the following systematic errors were incorporated into each age calculation: ±25% for moisture content and ±10% for cosmic dose rate. OSL age results are reported with 1σ errors in table S1. An average of the laboratory-measured moisture content from each sample of 20% was used for age calculation.

Disequilibrium measurements were not conducted on the samples at Gault (*31*). To investigate its potential impact on age estimations, Rn loss calculations were carried out using data tables provided by Guérin *et al.* (*26*). Ratios of ^{238}U pre-Rn loss to ^{238}U total U energy release were used to calculate multiplication factors to modify U concentration in the age calculations. Factors were calculated separately for alpha, beta, and gamma energy releases and then applied to find the effective U concentration for 100, 50, and 25% Rn loss. A U-only dose rate was obtained for each calculation and added back in to the total dose rate from Th, K, and cosmic rays (table S2).

RESULTS AND DISCUSSION

The OSL samples displayed favorable luminescence characteristics including low overdispersion (<10%) and normally distributed D_e distributions. Moreover, the fast component contributed more than 90% of the signal measured in the first 0.4 s of stimulation, suggesting that the OSL signals from these samples are fast component–dominant. A representative decay curve and growth curve are shown in fig. S1. All measured D_e's were significantly lower than their corresponding D_0 values (~65 Gy). Equivalent dose distributions are displayed as histograms and radial plots in fig. S2.

The OSL ages presented here establish the presence of a cultural component, stratified below Clovis, and associated with ages older than ~16 ka (Fig. 4 and table S1). These OSL ages range from 21.7 ± 1.4 ka to 16.7 ± 1.1 ka and, within error, are in the expected stratigraphic order (Fig. 4 and table S1). On the basis of the results of OSL dating presented here, we find a mean age for the Gault Assemblage (n = 4) of 18.5 ± 1.5 ka.

Ages associated with the temporal diagnostic artifacts above the Gault component are in excellent stratigraphic agreement (*32*). This includes four OSL ages of 11.9 ± 0.8 ka, 12.9 ± 0.6 ka, 13.2 ± 0.6 ka, and 13.6 ± 0.6 ka from the Clovis component (Fig. 4) (*32*). These dates agree with the known Clovis range of ~13.5 to 12.9 ka (*33*–*35*) and agree with the ages from other Clovis sites in Texas (*36*–*38*). These data emphasize the stratigraphic integrity of Area 15 and the agreement between the temporal diagnostic artifacts and OSL ages (Supplementary Materials).

The OSL ages for these early levels at the Gault Site are in good stratigraphic agreement with the known, younger, temporal diagnostic artifacts and age estimates indicating the reliability of this dating sequence (*32*). The significant reduction in artifact frequencies between the Clovis and Gault Assemblage confirms the presence of an older, isolated, assemblage below Clovis. Given the SDs for these OSL ages (Fig. 4 and table S1), the Gault Assemblage is dated to at least 16 ka, which is the youngest possible age for this occupation; however, the time span suggests that the inhabitation of the Gault site began ~1 to 2 ka before.

The Gault Site differs from other OSL-dated sites relevant to the early occupation of North America for two reasons. First, there is a well-dated (*32*) long stratigraphic sequence above the Gault Assemblage with distinct and well-separated occupational horizons. In addition, the OSL D_e distributions are normal and exhibit low (<10%) overdispersion, which provide more confidence for the modeled final D_e values used in age calculation (Supplementary Materials).

Disequilibrium in the U-series is commonly present in carbonate-rich environments and can potentially change the dose rate over time, leading to inaccurate age estimations (*39*). Although disequilibrium measurements were not carried out for the Gault samples, several inferences can be made about the potential impact that this would have on the ages we report. The samples collected at Gault have U contents that make up a relatively small (~20%) contribution to the total dose rate, so any influence of disequilibria on the resulting ages may not be very significant. For samples studied with a similar U content, and assuming a >50% disequilibrium in the U-series chain, OSL ages have been in 8% error from the true age (*39*). This generally falls close to or within the 1σ age errors that we report. Moreover, our Rn loss calculations suggest that for the Rn loss to have a statistically significant effect on age calculations relative to 0% Rn loss, for nearly all samples, >50% Rn loss would have had to have occurred (table S2).

In general, U concentrations in carbonate rocks are quite uniform at approximately 2 parts per million (ppm) (*40*). Phreatic cements have been less well studied; however, a U concentration of 1.80 ± 0.75 ppm was found for a series of freshwater phreatic cements by Chung and Swart (*41*). The total U concentration in our Gault dating samples ranges from 2.13 ± 0.1 ppm to 2.48 ± 0.1 ppm, indicating the possibility that much of the dose rate comes from carbonate elements. This is expected when examining the lithology of the units. The Gault Assemblage layers are the major host of phreatic carbonates at Gault.

Phreatic carbonates routinely form in situ as postburial phases and occur as surface coatings on grains and larger elements. If these had formed during the burial history and had reduced pore volume by their presence, then they may have added U to the source of dose rate to the quartz grains, changing the bulk dose rate over time. On the basis of earlier work of U concentrations in carbonate rocks and phreatic carbonates cited above, it would probably have added U to the pore space volume at a similar concentration as the surrounding host material. As this occurred over time, incremental increases in bulk dose rate would have occurred, and thus, the bulk dose rate over the burial history would have been lower than observed at the time of sampling. Thus, any effect from the crystallization of U-containing phreatic carbonate would make the ages older, in the same direction as any effects of Rn loss >50%.

The evidence from Area 15 at the Gault Site demonstrates the presence of a previously unknown projectile point technology in North America before ~16 ka. The physical and cultural stratigraphic evidence recovered from Area 15, as well as the associated OSL ages reported here and elsewhere (*32*), are consistent in showing a coherent sequence of the Gault Assemblage, Clovis, Late Paleoindian, Early Archaic, and Middle/Late Archaic occupations over an apparent span of more than 16,000 calendar years (Fig. 4). This sequence corresponds well with previous studies in Central Texas (*42*). The distinct technological differences between Clovis and Gault Assemblage, together with the stratigraphic separation between the cultural depositions, indicate a lack of continuity between the two complexes.

The Gault Assemblage at the Gault Site, specifically the projectile points, represents a regional manifestation within a number of possible contemporary patterns (Supplementary Materials). As evidence for the complexity in the early occupation of the Americas increases (*1*, *2*), a more elaborate framework (*9*) for these early human occupations is required.

SUPPLEMENTARY MATERIALS

Supplementary material for this article is available at http://advances.sciencemag.org/cgi/content/full/4/7/eaar5954/DC1
Table S1. Sample OSL ages and dose rate data.
Table S2. Radon loss effects on each Gault OSL sample.
Table S3. Summary of the Gault Assemblage.
Table S4. Summary counts of the Gault biface assemblage.
Fig. S1. A representative decay curve (upper), growth curve (middle), and plot showing sensitivity changes through the SAR cycle (lower) for Gault 11-18.
Fig. S2. Equivalent dose (D_e) distributions for all samples displayed in a histogram (left) and radial plot (right).
Fig. S3. Location of the Area 15 excavation block and the excavation grid and profile.
Fig. S4. Relationship between the stratigraphy and cultural components in Area 15.
Fig. S5. Results of the geoarcheological analysis of the sediments in Area 15.
Fig. S6. Andice projectile point (left) with representative diagnostic notching flakes (right).
Fig. S7. Backplots of northing (blue) and easting (red) profiles showing the elevation of diagnostic Andice notching flakes and the cultural components discussed in the text.
Fig. S8. Limestone bedrock of Area 15, with three sets of flutes scoured into the limestone (discussed in the text).
Fig. S9. Pollen data from Boriack Bog and the NGRIP and GRIP ice core record as compared to stratigraphic units at Area 15.
Fig. S10. Gault Assemblage stone tool types and frequency (see table S2).
Fig. S11. Gault Assemblage projectile points.
Fig. S12. Principal components analysis of the Gault Assemblage stemmed projectile points and the Gower and Uvalde types.
Section S1. Area 15 stratigraphy
Section S2. Context of early dates in North America
Section S3. Gault Assemblage in Area 15
References (*43*–*85*)

REFERENCES AND NOTES

1. M. B. Collins, D. J. Stanford, D. L. Lowery, B. A. Bradley, in *Paleoamerican Odyssey*, K. E. Graf, C. V. Ketron, M. R. Waters, Eds. (Center for the Study of the First Americans, 2013), pp. 521–539.
2. M. R. Waters, T. W. Stafford Jr., in *Paleoamerican Odyssey*, K. E. Graf, C. V. Ketron, M. R. Waters, Eds. (Center for the Study of the First Americans, 2013), pp. 541–560.
3. M. B. Collins, in *The Cambridge World Prehistory Volume 2: East Asia and the Americas*, C. Renfrew, P. Bahn, Eds. (Cambridge Univ. Press, 2014), pp. 903–922.
4. B. A. Potter, A. B. Beaudoin, C. V. Haynes, V. T. Holliday, C. E. Holmes, J. W. Ives, R. Kelly, B. Llamas, R. Malhi, S. Miller, D. Reich, J. D. Reuther, S. Schiffels, T. Surovell, Arrival routes of first Americans uncertain. *Science* **359**, 1224–1225 (2018).
5. T. J. Braje, T. C. Rick, T. D. Dillehay, J. M. Erlandson, R. G. Klein, Arrival routes of first Americans uncertain—Response. *Science* **359**, 1225 (2018).
6. A. D. Wheat, Survey of professional opinions regarding the peopling of the Americas. *The SAA Archaeological Record* **12**, 10–14 (2012).
7. L. G. Davis, A. J. Nyers, S. C. Willis, Context, provenance and technology of a western stemmed tradition artifact cache from the Cooper's Ferry Site, Idaho. *Am. Antiq.* **79**, 596–615 (2014).
8. T. D. Dillehay, Probing deeper into first American studies. *Proc. Natl. Acad. Sci. U.S.A.* **106**, 971–978 (2009).
9. D. B. Madsen, A framework for the initial occupation of the Americas. *PaleoAmerica* **1**, 217–250 (2015).
10. C. Beck, G. T. Jones, Clovis and western stemmed: Population migration and the meeting of two technologies in the Intermountain West. *Am. Antiq.* **75**, 81–116 (2010).
11. T. Goebel, I. Buvit, in *From the Yenisei to the Yukon: Interpreting Lithic Assemblage Variability in Late Pleistocene/Early Holocene Beringia*, T. Goebel, I. Buvit, Eds. (Center for the Study of the First Americans, 2011).
12. J. M. Adovasio, J. Page, *The First Americans: In Pursuit of Archaeology's Greatest Mystery* (Random House, 2002).
13. J. C. Lothrop, D. L. Lowery, A. E. Spiess, C. J. Ellis, Early human settlement of northeastern north America. *PaleoAmerica* **2**, 192–251 (2016).
14. J. M. McAvoy, L. D. McAvoy, *Archaeological Investigations of Site 44SX202, Cactus Hill, Sussex County, Virginia* (Department of Historic Resources, 1997).
15. A. L. Bryan, R. Gruhn, Some difficulties in modeling the original peopling of the Americas. *Quat. Int.* **109–110**, 175–179 (2003).
16. T. D. Dillehay, in *Paleoamerican Odyssey*, K. E. Graf, C. V. Ketron, M. R. Waters, Eds. (Texas A&M Univ. Press, 2013).
17. A. G. M. Araujo, On vastness and variability: Cultural transmission, historicity, and the Paleoindian record in eastern south America. *An. Acad. Bras. Cienc.* **87**, 1239–1258 (2015).
18. A. V. Thoms, Rocks of ages: Propagation of hot-rock cookery in western North America. *J. Archaeol. Sci.* **36**, 573–591 (2009).
19. N. V. Littlefield, thesis, University of Exeter (2015).
20. E. J. Rhodes, Observations of thermal transfer OSL signals in glacigenic quartz. *Radiat. Meas.* **32**, 595–602 (2000).
21. A. S. Murray, A. G. Wintle, Luminescence dating of quartz using an improved single-aliquot regenerative-dose protocol. *Radiat. Meas.* **32**, 57–73 (2000).
22. A. S. Murray, A. G. Wintle, The single aliquot regenerative dose protocol: Potential for improvements in reliability. *Radiat. Meas.* **37**, 377–381.
23. H. M. Luchsinger, thesis, Texas A&M University, College Station (2002).
24. R. F. Galbraith, R. G. Roberts, G. M. Laslett, H. Yoshida, J. M. Olley, Optical dating of single and multiple grains of quartz from Jinmium rock shelter, Northern Australia: Part I, Experimetal design and statistical models. *Archaeometry* **41**, 339–364 (1999).
25. Z. Jacobs, G. A. T. Duller, A. G. Wintle, Interpretation of single grain D_e distributions and calculation of D_e. *Radiat. Meas.* **41**, 264–277 (2006).
26. G. Guérin, N. Mercier, G. Adamiec, Dose-rate conversion factors: Update. *Ancient TL* **29**, 5–8 (2011).
27. B. J. Brennan, R. G. Lyons, S. W. Phillips, Attenuation of alpha particle track dose for spherical grains. *Int. J. Rad. Appl. Instrum. D* **18**, 249–253 (1991).
28. G. Guérin, N. Mercier, R. Nathan, G. Adamiec, Y. Lefrais, On the use of the infinite matrix assumption and associated concepts: A critical review. *Radiat. Meas.* **47**, 778–785 (2012).
29. J. R. Prescott, J. T. Hutton, Cosmic ray contributions to dose rates for luminescence and ESR dating: Large depths and long-term time variations. *Radiat. Meas.* **23**, 497–500 (1994).
30. J. R. Prescott, J. T. Hutton, Cosmic ray and gamma ray dosimetry for TL and ESR. *Int. J. Rad. Appl. Instrum. D* **14**, 223–227 (1988).
31. Following the acceptance of this manuscript, we obtained the results from two samples collected from Area 15 (~2.24- and 2.78-m depth) and studied with high-resolution gamma spectrometry (Ge detector) at the United States Geological Survey Laboratory in Denver, USA. Gamma counts in each sample from ^{226}Ra, ^{214}Pb, and ^{214}Bi demonstrated equilibrium in the ^{238}U decay chain within counting error, indicating that there was no need to account for any Rn loss in the age calculations for samples from the same levels.
32. K. Rodrigues, W. J. Rink, M. B. Collins, T. J. Williams, A. Keen-Zebert, G. I. López, OSL ages of the Clovis, Late Paleoindian, and Archaic components at Area 15 of the Gault Site, Central Texas, U.S.A. *J. Archaeol. Sci. Rep.* **7**, 94–103 (2016).
33. V. T. Holliday, The evolution of Paleoindian geochronology and typology on the Great Plains. *Geoarchaeology* **15**, 227–290 (2000).
34. M. R. Waters, T. W. Stafford Jr., Redefining the age of Clovis: Implications for the peopling of the Americas. *Science* **315**, 1122–1126 (2007).
35. D. J. Meltzer, *First Peoples in a New World* (University of California Press, 2009).
36. M. B. Collins, in *Wilson-Leonard: An 11,000-year Archeological Record of Hunter-Gatherers in Central Texas*, M. B. Collins, Ed. (Studies in Archeology 31, Texas Archeological Research Laboratory, The University of Texas and Archeology Studies Program, Report 10, Texas Department of Transportation, Environmental Affairs Division, 1998), pp. 123–159.
37. C. R. Ferring, *The Archaeology and Paleoecology of the Aubrey Clovis Site (41DN479) Denton County, Texas* (Centre for Environmental Archaeology, Department of Geography, University of North Texas, 2001).
38. M. B. Collins, D. B. Hudler, S. L. Black, "Pavo Real (41BX52): A Paleoindian and Archaic Camp and Workshop on the Balcones Escarpment, South-Central Texas" (Texas Department of Transportation: Archeological Studies Program, Report No. 50, 2003).
39. J. M. Olley, A. Murray, R. G. Roberts, The effects of disequilibria in the uranium and thorium decay chains on burial dose rates in fluvial sediments. *Quat. Sci. Rev.* **15**, 751–760 (1996).
40. K. H. Wedepohl, *Handbook of Geochemistry* (Springer-Verlag, 1969), 442 pp.
41. G. S. Chung, P. K. Swart, The concentration of uranium in freshwater vadose and phreatic cements in a Holocene ooid cay: A method of identifying ancient water tables. *J. Sediment. Res.* **60**, 735–746 (1990).
42. M. R. Waters, S. L. Forman, T. A. Jennings, L. C. Nordt, S. G. Driese, J. M. Feinberg, J. L. Keene, J. Halligan, A. Lindquist, J. Pierson, C. T. Hallmark, M. B. Collins, J. E. Wiederhold, The buttermilk creek complex and the origins of Clovis at the Debra L. Friedkin Site, Texas. *Science* **331**, 1599–1603 (2011).
43. W. J. Rink, A. L. Odom, Natural alpha recoil particle radiation and ionizing radiation sensitivities in quartz detected with EPR: Implications for geochronometry. *Int. J. Rad. Appl. Instrum. D* **18**, 163–173 (1991).

44. B. D. Gibson, thesis, Texas A&M University (1997).
45. Soil Survey Staff, *Web Soil Survey* (Natural Resources Conservation Service, United States Department of Agriculture); https://websoilsurvey.sc.egov.usda.gov/ [accessed 19 December 2016].
46. Soil Survey Staff, *Official Soil Series Descriptions* (Natural Resources Conservation Service, United States Department of Agriculture); www.nrcs.usda.gov/wps/portal/nrcs/detail/soils/survey/geo/?cid=nrcs142p2_053587 [accessed 19 December 2016].
47. R. C. Graham, in *Encylopedia of Soil Science*, L. Rattan, Ed. (Taylor & Francis Press, 2006).
48. R. Schaetzl, S. Anderson, *Soils: Genesis and Geomorphology* (Cambridge Univ. Press, 2005).
49. J. A. Hildebrand, S. M. Wiggins, J. L. Driver, M. R. Waters, Rapid seismic reflection imaging at the Clovis period Gault Site in Central Texas. *Archaeol. Prospect.* **14**, 245–260 (2007).
50. A. Gilmer, thesis, Texas State University (2013).
51. M. R. Waters, C. D. Pevny, D. L. Carlson, *Clovis Lithic Technology: Investigation of a Stratified Workshop at the Gault Site, Texas* (Texas A&M University Press, 2011).
52. D. G. Weston, Soil and susceptibility: Aspects of thermally induced magnetism within the dynamic pedological system. *Archaeol. Prospect.* **9**, 207–215 (2002).
53. V. T. Holliday, *Soils in Archaeological Research* (Cambridge Univ. Press, 2004).
54. I. Bartington, *Magnetic Susceptibility Measurement in Archaeology* (2013).
55. M. B. Collins, The Gault Site, Texas, and Clovis research. *Athena Rev.* **3**, 31–42 (2002).
56. W. H. J. Toonen, M. G. Kleinhans, K. M. Cohen, Sedimentary architecture of abandoned channel fills. *Earth Surf. Process. Landforms* **37**, 459–472 (2012).
57. L. C. Nordt, T. W. Boutton, C. T. Hallmark, M. R. Waters, Late quaternary vegetation and climate changes in central Texas based on the isotopic composition of organic carbon. *Quat. Res.* **41**, 109–120 (1994).
58. R. S. Toomey III, M. D. Blum, S. Valastro Jr., Late quaternary climates and environments of the Edwards plateau, Texas. *Glob. Planet. Change* **7**, 299–320 (1993).
59. C. B. Bousman, E. Oksanen, in *From the Pleistocene to the Holocene: Human Organization and Cultural Transformations in Prehistoric North America*, C. B. Bousman, B. J. Vierra, Eds. (Texas A&M University Press, 2012).
60. D. L. Nickels, R. P. Mauldin, "An Archaeological Survey of Twin Buttes Reservoir, Tom Green County, Texas, Volume 1" (Archaeological Survey Report, No. 300, Center for Archaeological Research, The University of Texas at San Antonio, 2001).
61. C. B. Bousman, Paleoenvironmental change in central Texas: The palynological evidence. *Plains Anthropol.* **43**, 201–219 (1998).
62. H. A. Meier, S. G. Driese, L. C. Nordt, S. L. Forman, S. I. Dworkin, Interpretation of late quaternary climate and landscape variability based upon buried soil macro- and micromorphology, geochemistry, and stable isotopes of soil organic matter, Owl Creek, central Texas, USA. *Catena* **114**, 157–168 (2014).
63. L. C. Nordt, T. W. Boutton, J. S. Jacob, R. D. Mandel, C_4 plant productivity and climate-CO_2 variations in South-Central Texas during the late quaternary. *Quat. Res.* **58**, 182–188 (2002).
64. D. J. Stanford, A. T. Stenger, *Pre-Clovis in the Americas: International Science Conference Proceedings* (CreateSpace Independent Publishing Platform; Smithsonian Institution edition, 2014).
65. N. Toth, in *The First Americans: Search and Research*, T. Dillehay, D. J. Meltzer, Eds. (CRC Press, 1991).
66. D. J. Stanford, B. A. Bradley, *Across Atlantic Ice: The Origin of America's Clovis Culture* (University of California Press, 2012).
67. M. J. O'Brien, M. T. Boulanger, M. Collard, B. Buchanan, L. Tarle, L. G. Straus, M. I. Eren, On thin ice: Problems with Stanford and Bradley's proposed Solutrean colonisation of North America. *Antiquity* **88**, 606–613 (2014).
68. D. Stanford, B. Bradley, Reply to O'Brien *et al*. *Antiquity* **88**, 614–621 (2014).
69. D. J. Stanford, D. Lowery, M. Jodry, B. A. Bradley, M. Kay, T. W. Stafford Jr., R. J. Speakman, in *Prehistoric Archaeology on the Continental Shelf*, A. M. Evans, J. C. Flatman, N. C. Flemming, Eds. (Springer, 2014), 73–93.
70. M. J. O'Brien, M. T. Boulanger, M. Collard, B. Buchanan, L. Tarle, L. G. Straus, M. I. Eren, Solutreanism. *Antiquity* **88**, 622–624 (2014).
71. J. S. Dunbar, in *First Floridians and Last Mastodons: The Page-Ladson Site in the Aucilla River*, S. D. Webb, Ed. (Springer, 2006), pp. 403–435.
72. J. J. Halligan, M. R. Waters, A. Perrotti, I. J. Owens, J. M. Feinberg, M. D. Bourne, B. Fenerty, B. Winsborough, D. Carlson, D. C. Fisher, T. W. Stafford Jr., J. S. Dunbar, Pre-Clovis occupation 14,550 years ago at the Page-Ladson site, Florida, and the peopling of the Americas. *Sci. Adv.* **2**, e1600375 (2016).
73. S. R. Holen, K. A. Holen, in *Paleoamerican Odyssey*, K. E. Graf, C. V. Ketron, M. R. Waters, Eds. (Center for the Study of the First Americans, 2013), pp. 429–444.
74. D. K. Grayson, D. J. Meltzer, Revisiting Paleoindian exploitation of extinct North American mammals. *J. Archaeol. Sci.* **56**, 177–193 (2015).
75. M. R. Waters, T. W. Stafford Jr., H. G. McDonald, C. Gustafson, M. Rasmussen, E. Cappellini, J. V. Olsen, D. Szklarczyk, L. J. Jensen, M. T. P. Gilbert, E. Willerslev, Pre-Clovis mastodon hunting 13,800 years ago at the Manis Site, Washington. *Science* **334**, 351–353 (2011).
76. B. G. Redmond, H. G. Mcdonald, H. J. Greenfield, M. L. Burr, New evidence for Late Pleistocene human exploitation of Jefferson's Ground Sloth (*Megalonyx jeffersonii*) from northern Ohio, USA. *World Archaeol.* **44**, 75–101 (2012).
77. D. C. Fisher, Mastodon butchery by North American Paleo-Indians. *Nature* **308**, 271–272 (1984).
78. M. B. Collins, in *Foragers of the Terminal Pleistocene in North America*, R. B. Walker, B. N. Driskell, Eds. (University of Nebraska Press, 2007), pp. 59–87.
79. J. M. Erlandson, T. C. Rick, T. J. Braje, M. Casperson, B. Culleton, B. Fulfrost, T. Garcia, D. A. Guthrie, N. Jew, D. J. Kennett, M. L. Moss, L. Reeder, C. Skinner, J. Watts, L. Willis, Paleoindian seafaring, maritime technologies, and coastal foraging on California's Channel Islands. *Science* **331**, 1181–1185 (2011).
80. M. Brenet, J. P. Chadelle, É. Claud, D. Colonge, A. Delagnes, M. Deschamps, M. Folgado, B. Gravina, E. Ihuel, The function and role of bifaces in the Late Middle Paleolithic of southwestern France: Examples from the Charente and Dordogne to the Basque Country. *Quat. Int.* **428**, 151–169 (2017).
81. J. Gandy, thesis, Texas State University (2013).
82. J. J. Shea, Lithic microwear analysis in archeology. *Evol. Anthropol. Issues News Rev.* **1**, 143–150 (1992).
83. M. Shoberg, in *Clovis Technology*, B. A. Bradley, M. B. Collins, C. A. Hemmings, Eds. (International Monographs in Prehistory, Archaeological Series 17, 2010), pp. 138–156.
84. G. H. Odell, *Lithic Analysis* (Springer, 2003).
85. M. J. Shott, On tool-class use lives and the formation of archaeological assemblages. *Am. Antiq.* **54**, 9–30 (1989).

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