Pre-Clovis projectile points at the Debra L. Friedkin site, Texas—Implications for the Late Pleistocene peopling of the Americas

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Lanceolate projectile points of the Clovis complex and stemmed projectile points of the Western Stemmed Tradition first appeared in North America by ~13 thousand years (ka) ago. The origin, age, and chronological superposition of these stemmed and lanceolate traditions are unclear. At the Debra L. Friedkin site, Texas, below Folsom and Clovis horizons, we find stemmed projectile points dating from ~13.5 to ~15.5 ka ago, with a triangular lanceolate point form appearing ~14 ka ago. The sequential relationship of stemmed projectile points followed by lanceolate forms suggests that lanceolate points are derived from stemmed forms or that they originated from two separate migrations into the Americas.

INTRODUCTION
Our understanding of the process of the peopling of the Americas is undergoing rapid change with new archaeological and genetic discoveries. For decades, it was believed that the first people entered the Americas ~13.5 thousand years (ka) ago via an ice-free corridor, developed the distinctive Clovis tool kit with its iconic, fluted, lanceolate projectile point, and then rapidly spread across North America, with their descendants eventually reaching South America ~12.9 ka ago. However, over the past decade, genetic studies of modern Native Americans and prehistoric skeletons have shown that the initial movement of people south of the continental ice sheets occurred as early as ~15 to ~16 ka ago and that there is genetic continuity between the first immigrants to enter the Americas and modern Native Americans (1, 2). Archaeological studies over the last 25 years show that people successfully occupied the Americas ~14 to ~15 ka ago, in agreement with the genetic estimates. In South America, humans occupied Monte Verde, Chile, by ~14.2 ka ago (3), indicating that people must have been in North America ≥14.2 ka ago. In North America, humans were present during the period ~14 to ~15 ka ago, as documented by archaeological evidence radiocarbon dated to ~14.6 ka ago at Page-Ladson, Florida (4); ~14.2 ka ago at Paisley Caves, Oregon (5); ~14.2 and ~14.8 ka ago at Schaefer and Hebior, Wisconsin (6, 7); and ~13.8 ka ago at Manis, Washington (8). However, the artifact assemblages from these ~14- to ~15-thousand-year-old North American sites are small and nondiagnostic, and lithic projectile points are absent. It was not until ~13 ka ago that the first recognizable and widespread North American archaeological traditions appeared, with people making lanceolate fluted points in central and eastern North America (Clovis Tradition) and others using stemmed projectile points in unglaciated western North America (Western Stemmed Tradition) (9, 10). The connection between the artifact assemblages of the ~14- to ~15-thousand-year-old North American sites and later Clovis and Western Stemmed Traditions remains unclear. Here, we report a robust lithic projectile point assemblage from the layers dated between ~13.5 and 15.5 ka ago at the Debra L. Friedkin site, Texas (11), which has implications for the origin of both the ~13-thousand-year-old lanceolate and stemmed point traditions of North America.

RESULTS
Geology and geochronology
At the Debra L. Friedkin site, we excavated 104 m² of an area known as Block A, which is located on the second terrace flanking Buttermilk Creek (Fig. 1) (11). The Late Quaternary stratigraphy exposed by our excavations consists of colluvium resting on limestone bedrock, which in turn is buried by 1.2 to 1.4 m of unstratified clay that was deposited incrementally during overbank floods from Buttermilk Creek (Figs. 1 to 3). The archaeological record at the Friedkin site is buried in the upper portion of the floodplain clays, with up to 30 cm of archaeologically sterile sediments below the cultural horizons (Figs. 2 and 3).

The radiocarbon dating method was not used to date the archaeological components at the Friedkin site because there were no carbon samples that would yield reliable and accurate ages. In situ charcoal is not preserved, and all bones are leached of collagen. Dating of bulk sediment organics was not undertaken because these ages are usually inaccurate. For example, two bulk sediment ages from the Clovis horizon (unit 3a) at Excavation Area 8 of the Gault site, located ~400 m upstream of the Friedkin site, produced ages of 7130 ± 40 radiocarbon years before the present (¹⁴C yr B.P.) (CAMS-65535; ~7.9 to ~8.0 ka ago) and 9300 ± 40¹⁴C yr B.P. (CAMS-65986; ~10.4 to 10.6 ka ago) (12). These ages are 2 to 5 ka younger than the known age of Clovis.

Instead, the OSL dating method was used to determine the age of the artifacts at the Friedkin site by dating the floodplain sediments that bury them. This method is well suited for the site because according to the geological principle of inclusions, any items, such as artifacts, in an undisturbed sedimentary deposit, such as the floodplain clays at the Friedkin site, are at least as old as the sediments that contain them. The OSL method has been used for decades to date Late Quaternary deposits and has been shown to yield accurate ages.
Fig. 1. Block A at the Debra L. Friedkin site. (A) Map showing the location of the Debra L. Friedkin site along Buttermilk Creek. The geomorphic setting of the site is shown along with the location of the excavated areas. The red-colored area is Block A. The location of the four optically stimulated luminescence (OSL)–dated columns is indicated. Solid squares and rectangles indicate the location of trenches and excavation units. T-1, Terrace 1; T-2, Terrace 2. The inset map shows the location of the Friedkin site in Texas. (B) Map of Block A excavation area and the year each area was excavated. OSL sample locations are shown. Geological sections A-A', B-B', and C-C' are indicated with dashed lines and correlate with Figs. 2 and 3. Modern topographic contours are shown with elevations in meters above datum (m AD). (C) Photograph of the flood-plain sediments (north wall of excavation unit N1312 E1362). Late Archaic hearth feature occurs near the top of the section, and the complete lanceolate stemmed point (AM9875-2) dating ~15 ka ago is seen in the excavation unit at the base of the wall profile. Photo Credit: Michael Waters, Texas A&M University.
many tests have shown that OSL ages are in agreement with radiocarbon ages (13). Luminescence dating has also been used to successfully date archaeological sites in North America such as the Clovis horizon at Pavo Real, Texas, and the Archaic, Paleoindian, and pre-Clovis horizons at the Gault site, Texas (12, 14, 15).

The sediments at the Friedkin site are ideal for OSL dating because of the low-energy fluvial depositional environment. The slow incremental deposition on the floodplain and associated weak pedogenic alteration ensured solar resetting of sediment grains before burial. After burial, the sediments on the floodplain were minimally disturbed (11, 13, 16, 17).

Seventy OSL ages were obtained from the Late Pleistocene and Early Holocene sediments of Block A (Figs. 1 to 3 and figs. S1 to S3). Thirty-eight OSL ages were previously published (11). Here, we present 32 new OSL ages obtained in 2015 and 2016 (table S1). Bayesian analyses of all OSL ages from four sediment columns yielded modeled ages with reduced SDs (fig. S1 and table S2). The Bayesian-modeled OSL ages are used to resolve a sediment deposition chronology and associated artifact ages (Figs. 2 and 3 and table S2). Correlation of Bayesian-modeled OSL ages and time-diagnostic artifacts shows that, in most areas of the site, floodplain sediments were horizontally deposited, but slope slightly upward at the northwest end of the 2007 excavation area and downward at the southeast end of the 2016 excavation area of Block A (Figs. 1 to 3).

Late Prehistoric to Clovis archaeological horizons
In this section, we discuss the post–13-thousand-year-old time-diagnostic artifacts and associated OSL ages from the floodplain sediments that overlie the deposits containing the pre-Clovis Buttermilk Creek Complex. This discussion provides an archaeological and chronological context for the pre-Clovis horizon and demonstrates the archaeological integrity of the deposits at the Debra L. Friedkin site and the accuracy of the OSL ages.

In the upper 0.8 to 1.1 m of the floodplain sequence at Block A, we recovered over 639,000 artifacts, including over 4600 tools, of which 130 are time diagnostic (mostly projectile points). The position of the time-diagnostic artifacts is collapsed onto three transects across different portions of Block A (Figs. 2 and 3). These artifacts group into four mutually exclusive zones that correspond to the prehistoric cultural periods of central Texas (18, 19). These zones occur in chronological order, with Late Prehistoric and Late Archaic artifacts occurring near the surface, followed by a zone with only Middle Archaic and Early Archaic artifacts, then by a deeper zone with Late Paleoindian point types, and below this a zone containing only Folsom and Clovis artifacts (Figs. 2 and 3). In situ diagnostics of one zone are not found in overlying or underlying zones. Within a zone, most projectile points are in correct chronological order. This shows that there were sequential occupations on the Buttermilk Creek floodplain that were incrementally buried over time by sediment during repeated overbank
The C-C′ profile includes all OSL ages and artifacts from the areas excavated in 2007, 2008, 2009, and 2011. The B-B′ profile includes all OSL ages and artifacts from the areas excavated in 2015 beginning with the designation AM allows identification of specific artifacts. The B-C′ line along this transect (see Fig. 1B for the location of these cross sections). The location of each pre-Clovis projectile point is identified, and the artifact number (BCC). Some Late Prehistoric and Late Archaic artifacts appear above the C-C′ profile because there are places where the ground surface is higher than the contour.

Archaeological time periods are used as the basis for identifying a Late Prehistoric/Late Archaic zone in the uppermost portion of the site (Figs. 2 to 4). The Late Prehistoric period is recognized by 10 time-diagnostic projectile points: 7 Perdiz, 1 Scallorn, 1 Bonham, and 1 Chadbourne. The Late Archaic is represented by 35 time-diagnostic projectile points: 2 Darl, 7 Edgewood, 2 Ellis, 14 Ensor, 1 Fairland, 1 Gary, 4 Castroville, 1 Lange, 1 Pedernales, and 2 Hare bifaces. The age range of only a few sites overlaps between the Late Prehistoric and Late Archaic periods, 10.45 to 10.99 ka ago (18, 19). Diagnostic artifacts associated with these two cultural periods are used as the basis for identifying a Late Prehistoric/Late Archaic zone in the uppermost portion of the site (Figs. 2 to 4). The Late Prehistoric period is recognized by 10 time-diagnostic projectile points: 7 Perdiz, 1 Scallorn, 1 Bonham, and 1 Chadbourne. The Late Archaic is represented by 35 time-diagnostic projectile points: 2 Darl, 7 Edgewood, 2 Ellis, 14 Ensor, 1 Fairland, 1 Gary, 4 Castroville, 1 Lange, 1 Pedernales, and 2 Hare bifaces. The age range of only a few sites overlaps between the Late Prehistoric and Late Archaic periods, 10.45 to 10.99 ka ago (18, 19). Diagnostic artifacts associated with these two cultural periods are used as the basis for identifying a Late Prehistoric/Late Archaic zone in the uppermost portion of the site (Figs. 2 to 4). The Late Prehistoric period is recognized by 10 time-diagnostic projectile points: 7 Perdiz, 1 Scallorn, 1 Bonham, and 1 Chadbourne. The Late Archaic is represented by 35 time-diagnostic projectile points: 2 Darl, 7 Edgewood, 2 Ellis, 14 Ensor, 1 Fairland, 1 Gary, 4 Castroville, 1 Lange, 1 Pedernales, and 2 Hare bifaces. The age range of only a few sites overlaps between the Late Prehistoric and Late Archaic periods, 10.45 to 10.99 ka ago (18, 19). Diagnostic artifacts associated with these two cultural periods are used as the basis for identifying a Late Prehistoric/Late Archaic zone in the uppermost portion of the site (Figs. 2 to 4). The Late Prehistoric period is recognized by 10 time-diagnostic projectile points: 7 Perdiz, 1 Scallorn, 1 Bonham, and 1 Chadbourne. The Late Archaic is represented by 35 time-diagnostic projectile points: 2 Darl, 7 Edgewood, 2 Ellis, 14 Ensor, 1 Fairland, 1 Gary, 4 Castroville, 1 Lange, 1 Pedernales, and 2 Hare bifaces. The age range of only a
Fig. 4. Lithic artifact counts by depth and maps of diagnostic artifacts for Block A. (A) Total artifacts from 52 units with comparable data for all horizons excavated between 2009 and 2016, including all tools and debitage >0.625 cm in size, by 5-cm levels for the Late Archaic (LA), Middle/Early Archaic (MA/EA), Late Paleoindian (LP), Folsom/Clovis (F/C), and Buttermilk Creek Complex (BCC) horizons. (B) Total formal and informal tools from 52 units with comparable data for all horizons excavated from 2009 to 2016 (>0.625 cm in size) by 5-cm levels. (C) Counts of formal and informal tools from all 104 units from 2006 to 2016 (>0.625 cm in size for only the LP, F/C, and BCC layers) at 2.5-cm levels. Occurrence of artifacts below 90.15 m AD is accounted for by the slope of the BCC artifact-bearing deposits. (D) Counts of formal and informal tools from 2015 to 2016 excavations >0.625 cm in size for the LP, F/C, and BCC layers west of E1363. (E) Counts of formal and informal tools from 2015 to 2016 excavations >0.625 cm in size for the LP, F/C, and BCC layers east of E1363. (F) Horizontal distribution of diagnostic artifacts by archaeological component for Block A.
few of these types is known: Darl, ~0.65 to ~1.3 ka ago; Ensor and Edgewood, ~1.3 to ~2.1 ka ago; Castroville, ~2.1 to ~3.1 ka ago; and Pendenaules, ~3.1 to ~4.2 ka ago (19). A single OSL age of 1000 ± 70 yr B.P. (UIC2352; Figs. 2 and 3 and table S2) was obtained from the Late Prehistoric and Late Archaic horizon associated with the Ensor and Ellis points at the Friedkin site. This age is in general agreement with the known age for these types. Forty-four Late Prehistoric and Late Archaic points are in chronological order (Figs. 2 and 3). Four points (one Pendenaules, one Bonham, one Darl, and one Castroville) are out of chronological order within the Late Prehistoric and Late Archaic zone. This type of mixing of Late Prehistoric and Late Archaic point types in central Texas sites is common because of repeated use of cooking features during the Late Holocene [e.g., (18, 20)]. In the Late Prehistoric and Late Archaic zone at the Friedkin site, there are a number of burned rock features with fire-cracked rock (as seen in Fig. 1C). The reuse of these features likely accounts for mixing of the few points within this zone.

In central Texas, the Middle Archaic dates between ~4.2 and ~5.7 ka ago, and the Early Archaic dates from ~5.7 to ~8.6 ka ago (18–20). In the Middle Archaic and Early Archaic zone at the Friedkin site, 15 time-diagnostic Early Archaic projectile points were recovered (Figs. 2 to 4). This horizon includes two Andice, two Wells, one Hoxie, two Baird (Early Triangular), and eight Angostura points. Most Early Archaic point types are poorly dated in Texas, but Andice is well dated to ~5.7 to ~6.0 ka ago (19). Baird (Early Triangular) points are tentatively dated to the beginning of the Middle Archaic ~5.5 to ~5.6 ka ago (19), but this type was recently dated at Hall’s Cave, Texas, to ~8.6 ka ago (21), showing that it spans both the Middle Archaic and Early Archaic. Angostura is poorly dated but is generally thought to be a long-used type spanning the Early Archaic to the Late Paleoindian periods from ~8.6 to ~10.4 ka ago (18, 22, 23). At the Friedkin site, these point styles are generally in chronostratigraphic order, with two Andice points occurring with two Wells points near the top of this zone, two Baird points below these, and eight Angostura points in the lowest portion of the Middle Archaic and Early Archaic zone.

Six OSL ages from the Middle Archaic and Early Archaic horizon at the Friedkin site range from 7295 ± 315 yr B.P. (UIC2360) to 9000 ± 375 yr B.P. (UIC2061; Figs. 2 and 3 and table S2). An age of 7760 ± 370 yr B.P. (BG4066) occurs in close proximity to the Baird points, and this date falls within the age range for this type (Figs. 2 and 3). Angostura points are associated with all six OSL ages; four ages overlap with the known minimum age for Angostura (~8.6 ka ago), but two OSL ages appear too young for Angostura. This suggests that either this type extends later in time or some of the Angostura points at the Friedkin site may be intrusive into the youngest Early Archaic sediments. It is not uncommon for older projectile point types to be found in a younger cultural context because prehistoric people would sometimes pick up older points from the surface and bring them to their camps. This also holds true for the Golondrina point found at the base of this layer in close proximity to the Late Paleoindian boundary.

Below the Middle Archaic and Early Archaic zone is a 25-cm-thick zone with Late Paleoindian diagnostic artifacts, known to date ~9 to 12 ka ago in central Texas (18, 20, 22, 23). The Late Paleoindian zone at the Friedkin site contains five Angostura, five St. Mary Hall, nine Golondrina, and five Dalton/Dalton series points (Figs. 2 and 4). Angostura, St. Mary Hall, and Golondrina points co-occur in the upper and middle portions of the Late Paleoindian zone. These types are poorly dated, but estimates place Golondrina at ~9.6 to ~11.2 ka ago, St. Mary Hall at ~9.8 to ~11.5 ka ago, and Angostura at ~8.6 to 10.4 ka ago (18, 22, 23). These types commonly co-occur at sites such as the Wilson-Leonard site, located 40 km from the Friedkin site, where Golondrina, St. Mary Hall, and Angostura types overlap in deposits radiocarbon dated between ~9.7 and ~11.1 ka ago (20). Near and at the base of the Late Paleoindian zone at the Friedkin site are Dalton/Dalton series points that are radiocarbon dated elsewhere to between ~11.2 and ~12 ka ago (18, 22, 23). Fourteen OSL ages, ranging from 9590 ± 370 yr B.P. (UIC2363) to 11,980 ± 555 yr B.P. (UIC2048; Figs. 2 and 3 and table S2), are from the Late Paleoindian horizon at the Friedkin site. These OSL dates encompass the known ages for the various Late Paleoindian projectile point types. More specifically, 10 OSL ages ranging from 9590 ± 370 yr B.P. (UIC2363) to 10,965 ± 380 yr B.P. (BG4207; Figs. 2 and 3 and table S2) are associated with the Angostura, St. Mary Hall, and Golondrina types and overlap well with the radiocarbon ages from Wilson-Leonard and other sites where these types co-occur. The OSL ages ranging from 11,210 ± 405 yr B.P. (BG4206) to 11,980 ± 555 yr B.P. (UIC2048) occur in the zone with the Dalton/Dalton series points (Figs. 2 and 3) and again agree well with the known age for Dalton at other sites. One Dalton point was found in the middle of this zone and appears out of context. Again, it is not uncommon to find old time-diagnostic projectile points in younger contexts at sites in central Texas [e.g., (20)].

A 10-cm-thick zone with Folsom and Clovis artifacts occurs below the Late Paleoindian horizon (Figs. 2 and 3). Near the top of this zone are a Folsom point fragment and two late-stage Folsom preform flute failures (fig. S4). These Folsom artifacts are separated up to 9 m horizontally (Fig. 4F) but only 1.7 cm vertically. Underlying these Folsom lithics are time-diagnostic Clovis artifacts that include the following: (i) 1 end thinned, concave base, projectile point base (AM12018-1); (ii) 1 point midsection with channel flake scar terminations on each face (AM4447-1); (iii) 5 point fragments; (iv) 17 preforms and secondary bifaces with overshort and overface flaking, with some showing squared and beveled bases, and end thinning scars; and (v) 10 blades and blade segments (figs. S4 and S5). In addition, nine channel flakes were recovered. Seven were found within the Folsom and Clovis zone, one was found <2.5 cm below the lower boundary, and one was found <5 cm above the upper contact of this zone (Figs. 2 and 3). The Clovis point base (AM12018-1) is within 20 cm of the 2016 column of OSL ages and is bracketed by ages of 12,500 ± 480 yr B.P. (BG4209) and 12,950 ± 480 yr B.P. (BG4218). Seven ages from the Folsom-Clovis zone range from 11,980 ± 490 yr B.P. (BG4208) to 13,590 ± 720 yr B.P. (UIC2059; Figs. 2 and 3 and table S2). These ages fall within the known age range for Folsom (~12.2 to 12.7 ka ago) and Clovis (~12.7 to ~13 ka ago) (7). Overall, these results show that within the Late Prehistoric to Clovis horizons at the Friedkin site, the relative order of time-diagnostic artifacts matches the known cultural chronology for central Texas, and the known ages for time-diagnostic artifacts overlap with OSL ages.

**Buttermilk Creek Complex horizon**

About 100,000 artifacts, including 328 tools and 12 complete and fragmentary projectile points of the Buttermilk Creek Complex, were excavated from the floodplain clays, 15 to 20 cm below the Folsom-Clovis zone (Figs. 2 to 5). These artifacts are dated to ~13.5 and ~15.5 ka ago by 19 OSL ages (table S2). The deepest floodplain clays are OSL dated to >16 ka ago (n = 13) and have no in situ artifacts (Figs. 2 and 3 and table S2) (17). The artifacts comprising the Buttermilk
Creek Complex assemblage are described elsewhere (11, 24). Here, we describe the Buttermilk Creek Complex projectile point assemblage that includes lanceolate stemmed and triangular lanceolate forms (Fig. 5 and fig. S6). We also discuss the associated Buttermilk Creek Complex bifaces (fig. S7).

Lanceolate stemmed points include one complete specimen, one base fragment, four medial fragments, and five tips (Fig. 5, fig. S6, and table S3). The complete point (AM9875-2) was resharpened but appears to reflect its original size and morphology. The blade of the point is alternately beveled with convex lateral edges. The hafting element is stemmed with ground concave lateral edges and a ground concave base that was thinned by removing multiple short flakes from each face. The base fragment (AM8286-16) has a contracting stem with a subtle concave base. The edges and base of the stem are ground. A subtle shoulder is present where the blade expands outward from the base. The four medial fragments (AM12017-1, AM6233-1, AM12271-1, and AM4819-7) repeat the characteristics of the complete specimen with a beveled blade and a ground and contracting stem. These fragments show that as resharpening occurred, the blades became beveled and indented relative to the base. Four point tips (AM12029-2, AM8380-3, AM4668-6, and AM12170-1) are alternately beveled and are consistent with the morphology of the blades displayed by the complete point and three medial fragments. Distal fragment AM12274-13 is not beveled. All specimens show microscopic

Fig. 5. Pre-Clovis projectile points from the Debra L. Friedkin site and other sites in North America. (A) Triangular lanceolate point (AM9811-1), (B) lanceolate stemmed point (AM9875-2), (C) lanceolate stemmed point midsection with base and blade sections (AM12017-1), (D) lanceolate stemmed point midsection with base and blade sections (AM6233-1), (E) lanceolate stemmed point midsection with base and blade sections (AM12271-1), (F) point tip (AM4668-6), (G) lanceolate stemmed point base (AM8286-16), (H) point midsection (AM4819-7), (I) beveled point tip (AM12170-1), (J) beveled point tip (AM8380-3), (K) beveled point tip midsection (AM12029-2), and (L) point tip (AM12274-13). (M) Point from Iztapan Mammoth II, Mexico [from (29)], (N) point from Iztapan Mammoth II, Mexico [from (29)], (O) point from Iztapan Mammoth I, Mexico [from (29)], and (P) Miller point from Meadowcroft Rockshelter, Pennsylvania.
use-wear consistent with hafting and use as projectile points (fig. S8). It is important to note that lanceolate stemmed points are confined exclusively to the Buttermilk Creek Complex horizon; none are found in the post–13-thousand-year-old sediments. The lanceolate stemmed points of the Buttermilk Creek Complex closely resemble an undated Texas projectile point type defined as “Early Stemmed Lanceolate” (25).

Lanceolate stemmed points at the Friedkin site are confined to the clays dating between ~13.5 and ~15.5 ka ago (Figs. 2 and 3 and table S2). Seven of the 11 projectile points and point fragments occur in close proximity to specific OSL ages. Three OSL ages temporally bracket the complete point (AM9875-2) that rested horizontally on older floodplain clays; the two ages below the point are 18,480 ± 880 yr B.P. (BG3994) and 19,410 ± 650 yr B.P. (BG4076), and, at 3 cm above this point, the age is 15,190 ± 465 yr B.P. (BG3995). Likewise, a beveled point tip midsection (AM12029-2) was bracketed by these same three ages. One medial point fragment (AM12271-1) lies 50 cm horizontally from the age of 15,035 ± 530 yr B.P. (BG4263), one point tip (AM12274-13) lies 50 cm away from the age of 15,470 ± 590 yr B.P. (BG4238), and one medial fragment (AM12017-1) lies between ages 13,280 ± 500 yr B.P. (BG4219) and 13,920 ± 540 yr B.P. (BG4220). Another point tip (AM4668-6) lies 65 cm west of the 2008 column of OSL ages and between sediments dated to 13,565 ± 465 yr B.P. (UIC2354) and 14,235 ± 375 yr B.P. (UIC2367) and at the same elevation as sediments dated to 13,356 ± 465 yr B.P. (UIC2354). A point midsection (AM4819-7) lies 1 m north of the 2008 column of OSL ages, is bracketed between ages 14,315 ± 360 yr B.P. (UIC2369) and 14,980 ± 445 yr B.P. (UIC2359), and is at the same elevation and in the same sediments that yielded an age of 14,475 ± 365 yr B.P. (UIC2350). The other point fragments (AM12170-1, AM6233-1, AM8380-3, and AM8286-16) occur 2.4 to 5.3 m from the nearest OSL column. These points lie in the horizon dated between ~13.5 and ~15.5 ka ago.

A broken triangular lanceolate projectile point (AM9811-1) occurs in the uppermost portion of the clays ranging in age from ~13.5 to ~14 ka ago, below the Clovis horizon (Fig. 5A, fig. S6, and table S3). This point lacks the distal tip due to a diagonal snap fracture that probably resulted from impact. The remaining lateral blade edges are gently concave with a pronounced alternate bevel. The haft element has straight lateral edges that expand outward with a concave base. The haft edges and base are ground. The base is thinned on both sides by irregular, fluted-like flakes that extend upward. This point was heavily used and resharpened; use-wear analysis shows that it was hafted and used as a projectile (fig. S8). This point was found at the same elevation and 1 m south of the OSL age 14,270 ± 365 yr B.P. (BG4017). A second age 13,625 ± 455 yr B.P. (BG4019) was obtained 4.5 cm above the point.

Forty late-stage biface fragments were found in the ~13.5- to ~15.5-thousand-year-old sediments. Of these, 13 are large enough to provide insights into the production of stemmed lanceolate points (fig. S7 and table S3). Most flake scars on these bifaces terminate at the midline, but five bifaces show flakes crossing over the midline of the biface (overface flaking) and two display a rolled edge from an overshot flake removal. Two overshot flakes were found in the same deposits. The bifaces show no evidence of end thinning or preparation of a beveled base for later fluting. All bifaces are plano-convex in cross section, indicating that lanceolate stemmed points were made from flake blanks that were bifacially reduced by lateral thinning. similarities and differences exist between the pre–13-thousand-year-old and Clovis bifaces at the Friedkin site. Both exhibit overface and overshot flaking, reflecting similar biface thinning strategies; however, these flaking techniques were used with greater frequency to produce Clovis preforms. End thinning and base beveling in preparation for end thinning found on Clovis preforms are absent in the pre–13-thousand-year-old biface assemblage. The pre–13-thousand-year-old bifaces are predominately made on large flake blanks, whereas the Clovis bifaces were made from both nodules and flake blanks.

In addition to the points and other bifaces, the ~13.5- to ~15.5-thousand-year-old assemblage at the Friedkin site also includes blade segments, bladelets, scrapers, bifacial discoidal cores, and snap fracture tools (radial and bend break) most commonly made on flakes but also bifaces, retouched flakes, expedient tools, and ground hematite. This assemblage, combined with the newly described projectile points, makes up the Buttermilk Creek Complex (11, 24). This assemblage compares well with the pre-Clovis assemblage from the Gault site (15).

Integrity of the Late Prehistoric to Buttermilk Creek Complex horizons

Previous studies of the geology, pedology, micromorphology, and magnetic properties of the site’s sediments show that the deposits at the Friedkin site are minimally disturbed by postdepositional processes (11, 16, 17). Despite this evidence, the stratigraphic integrity of the deposits has been questioned, and it has been suggested that artifacts moved downward through the profile, resulting in the mixing of the artifacts at the site and creating the layer that is identified as the Buttermilk Creek Complex horizon (26). The superposition of cultural time horizons described for the Late Prehistoric through Clovis horizons at the site based on the distribution of 130 time-diagnostic artifacts shows that downward movement of large artifacts, such as projectile points, did not occur. If downward movement had taken place over time, then we should expect to see multiple time-diagnostic artifacts from the overlying horizon within the cultural zone immediately beneath it and associated with older ages, but this is not the case. Furthermore, a previous study of artifact size classes with depth at the Friedkin site (11, 16) showed no change in relative size class from the surface down to 90.225 m AD for artifacts larger than 0.625 cm in diameter. In short, 130 time-diagnostic artifacts within the Late Prehistoric to Clovis horizons, coupled with all other previous studies (11, 16, 17), show that downward movement of artifacts did not take place at the site. In addition, the OSL ages associated with each cultural zone agree with the known age of the time-diagnostic artifacts found in each zone, demonstrating the accuracy of these ages.

Variation in the number of formal tools with depth also demonstrates the presence of intact cultural horizons at the Friedkin site. A site with intact occupation surfaces usually has fluctuating quantities of tools with depth representing either successive periods of occupation and abandonment or shifting site usage over time. A site with substantial mixing of younger artifacts from a single occupation into older contexts, such as Clovis artifacts moving downward to create the Buttermilk Creek Complex horizon, should show a single mode with a decline in artifact numbers and a general decrease in the size of artifacts with depth (27).

At the Friedkin site, there is a general increase through time in total lithic tools anddebitage that appears to reflect a continuous increase in lithic reduction activity from the Late Pleistocene through the Holocene because of either increasing human populations or increasing site occupation span and decreasing mobility over time (Fig. 4A). This pattern is often seen at other North American sites with multiple occupation episodes (e.g., 20)]. Intense use of the Friedkin site over time combined with slow deposition has resulted in no clear
indication of multimodal distribution of artifacts when all tools and debitage are considered (Fig. 4A). When only the quantities of formal and informal tools with depth are plotted (Fig. 4, B and C), multiple modes of artifact concentrations appear, which suggest changes in local lithic reduction activities through time. A large increase in tools at 90.50 to 90.45 m AD correlates with the top of the Folsom and Clovis horizon—with two smaller peaks below this, at 90.375 to 90.35 m AD and 90.30 to 90.275 m AD, that seem to reflect separate occupation episodes in the Buttermilk Creek Complex horizon. In the 2015–2016 excavation area where the sediments slope, we divided this assemblage into two samples along the E1363 line. When the number of formal and informal tools is plotted with depth, the same peaks in the number of tools are still present but offset ~10 cm due to slope (Fig. 4, D and E). These distributions again show that artifacts have remained in their original context, albeit on a sloping surface in the 2015–2016 block excavation. These lines of evidence demonstrate that there has been minimal to no movement of artifacts between cultural zones at the site, that the OSL ages from the site are accurate, and that there is an in situ cultural horizon pre-dating Clovis at the site.

**DISCUSSION**

In 1949, excavations at Blackwater Draw showed that Clovis projectile points occurred in a layer stratigraphically below one containing Folsom points. It was not until many years later that Clovis was dated to ~12.7 to ~13 ka ago and Folsom ~12.2 to ~12.7 ka ago (7). Here, we reported an assemblage of stemmed projectile points associated with other artifacts, below a Folsom and Clovis artifact–bearing layer at the Debra L. Friedkin site along Buttermilk Creek, Texas, dated to ~13.5 to ~15.5 ka ago. Also, along Buttermilk Creek, in similar deposits just 250 m upstream of Block A at the Friedkin site, stemmed projectile points dated to ~16 ka ago are reported below a Clovis horizon at Area 15 of the Gault site, Texas (15). The earliest stemmed points elsewhere in North America occur in the Intermountain West at Paisley Caves, Oregon (Fig. 6A). These Western Stemmed
Tradition projectile points are at least contemporaneous with Clovis, dated to ~12.7 to ~13 ka ago (9). The oldest occupation at Paisley Caves includes artifacts and human coprolites that date to ~14.2 ka ago. No projectile points were found in the earliest layers of the site, but the only diagnostic lithic technology present at Paisley Caves is related to the Western Stemmed Tradition. This, combined with the lack of diagnostic Clovis technology in the site assemblage, suggests that stemmed points may date to the earliest occupation at Paisley Caves (9). At Cooper’s Ferry, Idaho, stemmed points are reported to date to ~13.2 ka ago (Fig. 6) (28), but additional chronological information is needed to confirm this proposed age. At Meadowcroft Rockshelter, Pennsylvania (Fig. 6A), the Miller point (Fig. 5P) with its subtle shoulder and short stem may be dated to ~14 ka ago (7), but this age remains to be confirmed. In Mexico, a stemmed projectile point (Fig. 5O), along with other artifacts, was associated with the bones of a single mammoth buried in undisturbed lacustrine sediments at Santa Isabel Iztapan I (Fig. 6A) (29, 30). Four hundred meters away, at Santa Isabel Iztapan II, two stemmed points (Fig. 5, M and N) were associated with butchered mammoth bones in the same lacustrine sediments (29). The Iztapan sites are not directly dated, but dated tephra layers bracketing the mammoth remains and associated artifacts suggest that they fall between ~14.5 and ~10.8 ka ago (30). In South America, there is a long history of the use of stemmed points by the earliest inhabitants of the continent and their descendants. At Monte Verde, Chile (Fig. 6A), people used stemmed El Jobo projectile points by ~14.2 ka ago (7), with El Jobo and later stemmed Fishtail points becoming widespread across South America ~13 ka ago (31).

The evidence from Friedkin, Gault, and other sites suggests that the earliest known people to enter the Americas were using stemmed points. These people likely arrived by traversing the Pacific coast using watercraft (Fig. 6A) (10, 32). This corridor would have been open for migration by ~16 ka ago as the Cordilleran Ice Sheet retreated and exposed tracks of land along the coast (32). The interior corridor between the Cordilleran and Laurentide ice sheets did not open until ~14 ka ago, and bison and other animals were passing through the corridor by ~13 ka ago (32). The ice-free corridor did not open soon enough to explain the presence of people south of the ice before ~14 ka ago.

As people occupied the coast, some began to move inland (Fig. 6A). By ~13.8 ka ago, they were on the Olympic Peninsula of Washington as witnessed by the Manis site. Traveling close to the ice margin, people are present in Wisconsin by ~14.8 and ~14.2 ka ago and in Pennsylvania by ~14 ka ago. By ~14.2 ka ago, people trekked into the northern Great Basin, as witnessed by Paisley Caves. Farther south, people made their way to the Valley of Mexico, as witnessed by the Iztapan Mammoth sites. Some people appear to have entered the Gulf of Mexico and made their way to Page-Ladson by ~14.6 ka ago. Others moved inland and discovered the Friedkin and Gault sites by ~15.5 ka ago. Some groups, carrying stemmed El Jobo points, continued south and reached the southern portion of South America by ~14.2 ka ago.

A new point form, a triangular lanceolate point, appears at the Friedkin site by ~14 ka ago. This form could have developed in situ from the earlier lanceolate stemmed point and could be the precursor to the lanceolate, fluted Clovis point. Similarities exist between the bifaces and tool assemblages of the Buttermilk Creek Complex and Clovis and may suggest that Clovis emerged in situ from the Buttermilk Creek Complex (11, 24). Once developed, lanceolate fluted concave base point technology could have rapidly spread over the eastern two-thirds of North America and into northern Mexico, while people using stemmed points remained in the western third of the continent where that technology developed into the distinct Western Stemmed Tradition by ~14 ka ago (Fig. 6B). During this time, people continued to use stemmed points in South America.

Alternatively, the stemmed and lanceolate point traditions of North America may represent two separate human migrations that took different routes south of the continental ice sheets and accessed and settled different parts of the unglaciated continent at the end of the Pleistocene (Fig. 6C) (33). Stemmed points could have arrived with the first people to settle the Pacific and Gulf coasts, while other groups carrying some form of lanceolate point could have entered later through the inland, ice-free corridor (33). The progenitor of the ~13-thousand-year-old Clovis concave base, fluted, lanceolate point may have been a triangular lanceolate point such as the one found at the Friedkin site. The age associated with this point form at the Friedkin site may indicate the arrival of lanceolate points ~14 ka ago, with later in situ development of Clovis from this point form by ~13 ka ago.

Both models are compatible with the current human genetic evidence and what is known about the opening of the coastal and inland corridors (1, 2, 32). More excavations of buried and datable Late Pleistocene sites are needed to find the archaeological data and materials for genetic testing that will test our hypotheses and continue to decipher the complex story of the first Americans.

**MATERIALS AND METHODS**

**Excavation and curation**

Excavations at the area known as Block A took place in 2006, 2007, 2008, 2009, 2015, and 2016. During this time, 104 m² of this area was excavated (Fig. 1B). Standard archaeological excavation methods were used at the Debra L. Friedkin site, Texas (41BL1239). Excavation units were 1 m by 1 m and were designated by their southwestern corner coordinates that were determined from an arbitrary datum originally established at the Gault site. Generally, the upper portions of the units were excavated in 5- and 2.5-cm levels in the Paleoindian levels. Artifacts larger than ~1.5 cm were generally mapped in place in the Paleoindian levels, and the elevation was determined relative to the site datum. In the Late Prehistoric and Archaic levels, diagnostic artifacts and features were mapped. The sediment excavated from each level was screened through one-quarter inch (6.35 mm) mesh, and a sample from the southwest corner was additionally screened through one-eighth inch (3.175 mm) mesh. All artifacts were assigned a unique catalog number (the letters “AM,” followed by a number) that ties the artifact to a specific unit and level. All artifacts were washed, processed, and cataloged in the Center for the Study of the First Americans laboratories. All artifacts were curated in the Center for the Study of the First Americans at Texas A&M University.

**OSL dating**

Sediments targeted for OSL dating are clay-rich distal overbank sediments in close association with artifact-bearing levels. Because these sediments did not contain a sand (2000 to 63 μm) fraction or appreciable coarse silt (63 to 44 μm), we focused on OSL dating the 4- to 11-μm quartz fraction, which had yielded previously accurate ages (11). Samples for optical dating were taken by hammering 10- to 12-cm-long, 2.6-cm copper tubing into profile walls at close vertical intervals (Figs. 1 to 3). Under safe-light conditions (Na-vapor indirect illumination) in the Geoluminescence Dating
Research Laboratory at Baylor University, the outermost 1.0-cm length of sediment inside the tube was removed, leaving an interior segment with zero ambient light exposure and which was acceptable for OSL dating. Organic matter and carbonate content were removed from the sample by soaking in H₂O₂ for 24 hours and reaction with HCl (12%), respectively. Fine-grained (4 to 11 μm) quartz was extracted by suspension settling, following Stokes’ law. Subsequently, quartz grains for this fine fraction (4 to 11 μm) were isolated by digestion in hydrofluorosilicic acid (with prior silica saturation) for 6 days (34). The mineralogical purity of this fine-grained fraction was checked by an assay with a Raman spectrometer, with a 1-μm beam width. The optical purity of quartz separates was tested by exposing aliquots to infrared excitation (1.08 W from a laser diode at 845 ± 4 nm), which preferentially excites feldspar minerals. If these tests indicated feldspar contamination, then the hydrofluorosilicic acid soaking was repeated. All resultant samples showed weak emissions (<400 counts/s) with infrared excitation at or close to background counts, and the ratio of emissions from blue to infrared excitation of >20, indicating a spectrally pure quartz extract (35).

Single aliquot regeneration (SAR) protocols (36, 37) were used in this study to estimate the equivalent dose (Dₑ). This analysis was completed on the quartz fraction (4 to 11 μm) for 32 sediment samples and for 30 to 50 separate aliquots for each sample (tables S1 and S2). In the laboratory, the sediment was adhered to a 1-cm-diameter circular aluminum disc as a thin coating (<20 μm). This thin layer of sediment was achieved by suspending the fine quartz in methanol (1 cm³) within a 2-cm³ flat-bottom tube, with an aluminum disc at the tube bottom. The evaporation of the methanol over 2 to 3 days in total darkness results in the fine-grained fraction adhering to the disc.

An Automated Riso TL/OSL-DA-15 system (38) was used for SAR analyses. Blue light excitation (470 ± 20 nm) was from an array of 30 light-emitting diodes that deliver ~15 mW/cm² to the sample position at 90% power. Optical stimulation for all samples was completed at an elevated temperature (125°C) using a heating rate of 5°C/s. All SAR emissions were integrated for the first 0.8 s of stimulation out of 40 s of measurement, with background emissions integrated for the last 10 s of data collection, for the 30- to 40-s interval. The luminescence emission for all quartz fractions showed a dominance of a fast component [see (36)] with >90% diminution of luminescence within 4 s of excitation (fig. S2), with blue light and with corresponding “fast ratio” of >20 (39).

A series of experiments was performed to evaluate the effect of preheating at 160°C, 170°C, 180°C, 190°C, 200°C, 210°C, 220°C, 240°C, and 260°C on isolating the most robust time-sensitive emissions and thermal transfer of the regenerative signal before the application of SAR dating protocols [fig. S3; see 36, 37]. These experiments entailed giving a known dose (2 to 10 Gy and 31 Gy) and evaluating which preheat temperature resulted in recovery of this dose. There was discordance (±10%) with the known dose for preheat temperatures between 160°C and 200°C with a used initial preheat temperature of 180°C for 10 s in the SAR protocols (fig. S3). A second preheat at 180°C for 10 s was applied prior to the measurement of the test dose. A final heating (hot wash) at 260°C for 40 s was applied to minimize carryover of luminescence to the succession of regenerative doses for the equivalent dose analyses (table S1 and fig. S3). A test for dose reproducibility was also performed following procedures of (36) with the initial and final regenerative dose of 4.2 Gy (fig. S2), with the resultant recycling ratio of 1.00 ± 0.05.

The SAR protocols were used to resolve equivalent dose for 32 samples (table S1). The statistical significance of an equivalent dose population was determined for 27 to 45 quartz aliquot per sample (table S1). Aliquots were removed from the analysis if the recycling ratio was not between 0.90 and 1.10, the zero dose was >5% of the natural emissions, or the error in equivalent dose determination was >10%. Dₑ distributions were log normal and exhibited over-dispersion values ≤20%, except for sample DF16-05 (table S1 and figs. S1 and S2). An overdispersion percentage of a Dₑ distribution is an estimate of the relative SD from a central Dₑ value in the context of a statistical estimate of errors (40, 41). A zero overdispersion percentage indicates high internal consistency in the Dₑ values with 95% of the Dₑ values within 2σ errors. Overdispersion values <20% are routinely assessed for small aliquots of quartz grains that are well isolated, such as far-traveledolian and fluviatile sands [e.g., (42, 43)], and this value is considered a threshold metric for calculation of a Dₑ value using the central age model in (41).

The determination of the environmental dose rate is a needed component to calculate an optical age. The dose rate is an estimate of exposure to ionizing radiation for the dated quartz grains. This value is computed from the content of U and Th, ⁴⁰K, Rb, and cosmic radiation during the burial period (table S1). The U and Th content of the sediments, assuming secular equilibrium in the decay series, ⁴⁰K, and Rb, was determined by inductively coupled plasma mass spectrometry by ALS Laboratories (Reno, NV). A significant cosmic ray component between 0.24 and 0.29 mGy/year was included in the estimated dose rate, taking into account the current depth of burial (44). Moisture content (weight percent) during the burial period was derived from instrumented, nearby pedons whose floodplain soils were similar to those that formed along a higher-order tributary, such as Buttermilk Creek (11). Moisture content for these clay-rich sediments (>50% clay) varied between 30 and 38% with an error of 3%. The datum year for all OSL ages is AD 2000.

Statistical analysis: Bayesian analysis of OSL ages
Most of the OSL ages from the Friedkin site were collected in four vertical sediment columns in 2007, 2008, 2015, and 2016. The 2008 and 2015 columns span the south-north extent of Block A. The 2007 column is in the west part of the block, and column 2016 is in the northeast part of the excavation area (Fig. 1B). In addition, OSL samples were taken from areas of interest that were adjacent to the columns. Figure S1 shows the age estimates with 1 SD error bars for the 2007, 2008, 2015, and 2016 columns. OSL ages from specific depths obtained over multiple years mostly overlap at the 68% confidence intervals. The 2008 and 2015 OSL column of dates are consistently very similar to one another (i.e., similar ages are generated at the same depths). The 2007 column ages are similar to the 2008 and 2015 ages with depth, but there are some discrepancies near the top and base of the 2007 column. The 2016 column of ages yielded ages that are consistently younger than those of the other three columns. This is explained by the upward slope of the deposits reflected in the 2007 column of ages and the downward slope of the deposits in the 2016 OSL record.

Bayesian models were created in OxCal to identify outliers and compute posterior age estimates using a Poisson deposition model (45, 46). An age model was created for the 2007 sequence of ages (fig. S1A and table S2), the combined 2008–2015 ages (fig. S1B and table S2), and the 2016 column of ages (fig. S1C and table S2). All four columns are internally consistent with very good agreement levels. The 2007 column of OSL ages shows agreement indices of 115.4/116.7 (model and overall agreement) with a single outlier (UC2050). Rerunning...
the model with the outlier removed increased the agreement indices to 135.9/136.8. The 2008 and 2015 columns were combined into a single Bayesian age model that resulted in model agreement values of 182.3/185.7 with two outliers (UIC2361 and UIC2349). Removing those outliers produced a model with agreement indices of 239/235.2. This combined model was used to produce interpolated ages at approximately 15-mm intervals. Analysis of the 2016 column produced agreement indices of 187.1/179.8 with no outliers.

SUPPLEMENTARY MATERIALS
Supplementary material for this article is available at http://advances.sciencemag.org/cgi/content/full/4/10/eaat4505/DC1

Supplementary Text
Fig. S1. Bayesian ages of Block A OSL columns.
Fig. S2. Regenerative growth curves and plots of \( D \) values for six OSL samples.
Fig. S3. Preheat dose recovery test for sample BG4066 that was completed for two initial doses of 8 and 31 Gy.
Fig. S4. Diagnostic Folsom and Clovis artifacts.
Fig. S5. Clovis biface.
Fig. S6. Pre-Clovis projectile points.
Fig. S7. Pre-Clovis biface.
Fig. S8. Use-wear on pre-Clovis artifacts.
Table S1. OSL ages on 4- to 11-mm quartz grains for sediments from the Debra L. Friedkin site, Texas.
Table S2. Correlation of OSL ages with archaeological horizons.
Table S3. Clovis, Folsom, and Buttermilk Creek Complex biface.

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Acknowledgments: We thank Debra and Dan Friedkin for permission to excavate at the site and for field logistical support, R. Lopez and M. Yalch for assistance during the excavation, and T. Stafford and J. Halligan for reviewing the drafts of this manuscript. Funding: Funds generated by the North Star Archaeological Research Program Endowment established by J. Cramer and R. Cramer funded most of the fieldwork and analyses conducted at the Friedkin site. Funding from the Elfrieda Frank Foundation supported the 2016 excavations. Laboratory analysis was funded in part by the Chair in First Americans Studies. The open access publishing fees for this article have been covered by the Texas A&M University Open Access to Knowledge Fund (OAKFund), supported by the University Libraries and the Office of the Vice President for Research. Author contributions: M.R.W. and J.L.K. conducted the excavations and artifact analysis and wrote the paper. S.L.F. conducted the OSL dating and wrote the corresponding supplemental section. E.R.P. identified and described all the projectile points from the Friedkin site. D.L.C. conducted the Bayesian analysis and wrote the corresponding supplemental section. J.E.W. conducted the artifact use-wear analysis and wrote the corresponding supplemental section. All authors reviewed the final draft. Competing interests: All authors declare that they have no competing interests. Data and materials availability: All data needed to evaluate the conclusions in the paper are present in the paper and/or the Supplementary Materials. Additional data related to this paper may be requested from the authors.

Submitted 27 February 2018
Accepted 19 September 2018
Published 24 October 2018
10.1126/sciadv.aat4505

Citation: M. R. Waters, J. L. Keene, S. L. Forman, E. R. Prewitt, D. L. Carlson, J. E. Wiederhold, Pre-Clovis projectile points at the Debra L. Friedkin site, Texas—Implications for the Late Pleistocene peopling of the Americas. Sci. Adv. 4, eaat4505 (2018).