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Supporting Online Material
www.sciencemag.org/cgi/content/full/331/6024/1596/DC1
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8 November 2010; accepted 2 February 2011
10.1126/science.1200183

The Buttermilk Creek Complex and the Origins of Clovis at the Debra L. Friedkin Site, Texas

Michael R. Waters,[1]* Steven L. Forman,[2] Thomas A. Jennings,[3] Lee C. Nordt,[4] Steven G. Driese,[4] Joshua M. Feinberg,[5] Joshua L. Keene,[3] Jessi Halligan,[3] Anna Lindquist,[5] James Pierson,[2] Charles T. Hallmark,[6] Michael B. Collins,[7] James E. Wiederhold[3]

Compelling archaeological evidence of an occupation older than Clovis (~12.8 to 13.1 thousand years ago) in North America is present at only a few sites, and the stone tool assemblages from these sites are small and varied. The Debra L. Friedkin site, Texas, contains an assemblage of 15,528 artifacts that define the Buttermilk Creek Complex, which stratigraphically underlies a Clovis assemblage and dates between ~13.2 and 15.5 thousand years ago. The Buttermilk Creek Complex confirms the emerging view that people occupied the Americas before Clovis and provides a large artifact assemblage to explore Clovis origins.

Nearly 80 years ago, Clovis was identified as the oldest archaeological horizon in North America [~12.8 to 13.1 thousand years ago (ka)]. Decades of subsequent research have advanced our understanding of Clovis chronology, adaptations, and technological organization (*1*–*3*). Whereas genetic studies indicate that the first Americans hailed from northeast Asia (*1*), no fluted Clovis points or other diagnostic characteristics of Clovis have been identified there (*4*). Additionally, fluted points in Alaska are rare, are technologically different, and postdate Clovis (*5*, *6*). These lines of evidence suggest that, although the ultimate ancestors of Clovis originated from northeast Asia (*1*), important technological developments, including the invention

[1]Center for the Study of the First Americans, Departments of Anthropology and Geography, Texas A&M University, 4352 TAMU, College Station, TX 77843–4352, USA. [2]Luminescence Dating Research Laboratory, Department of Earth and Environmental Sciences, 845 West Taylor Street (m/c 186), University of Illinois, Chicago, IL 60607–7059, USA. [3]Center for the Study of the First Americans, Department of Anthropology, Texas A&M University, 4352 TAMU, College Station, TX 77843–4352, USA. [4]Department of Geology, Baylor University, One Bear Place no. 97354, Waco, TX 76798–7354, USA. [5]Department of Geology and Geophysics, Institute for Rock Magnetism, University of Minnesota, Minneapolis, MN 55455–0219, USA. [6]Department of Soil and Crop Science, 2474 TAMU, Texas A&M University, College Station, TX 77843–2474, USA. [7]Department of Anthropology, Texas State University, 232 Evans Liberal Arts, San Marcos, TX 78666, USA.

*To whom correspondence should be addressed. E-mail: mwaters@tamu.edu

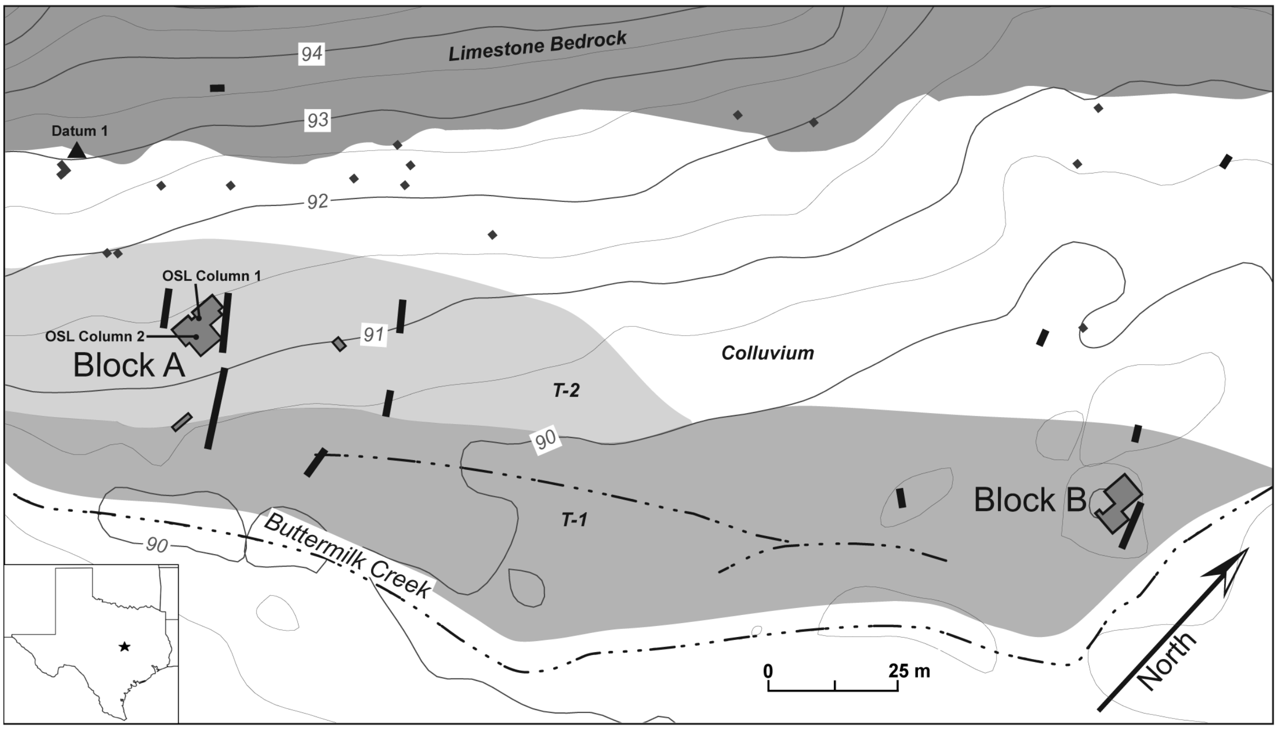

Fig. 1. Geomorphic surfaces and excavation areas and trenches (black rectangles and squares) at the Friedkin site.

of the Clovis fluted point, took place south of the North American continental ice sheets before 13.1 ka from an ancestral pre-Clovis tool assemblage. Over the past few decades, some credible evidence for pre-Clovis occupation of the Americas has emerged, but this evidence is not robust (*1*).

Here, we describe a large assemblage of pre-Clovis artifacts from the Debra L. Friedkin site (41BL1239) in central Texas and address both the pre-Clovis colonization of North America and Clovis origins. The site is located along Buttermilk Creek (Fig. 1) in a small valley incised into chert-bearing Edwards Limestone about 250 m downstream of the Gault Clovis site (*1*, *2*). We excavated two areas at the Friedkin site: block A on terrace 2 (T-2) and block B [supporting online material (SOM) text] on terrace 1 (T-1). The evidence for pre-Clovis lies in block A.

At the base of block A, limestone bedrock is overlain by colluvium (Fig. 2 and fig. S3, 2Bk horizon). Overlying the colluvium is 1.4 m of clay that was deposited incrementally in a floodplain environment by overbank flooding from Buttermilk Creek with some sediment derived from the adjacent slope. Stratification that may have existed within the floodplain deposit has been obscured by pedogenesis (A-Bss horizons).

To date the floodplain clays, we obtained 49 optically stimulated luminescence (OSL) ages from two columns (Fig. 2, A and B, and table S2) (*7*). OSL ages were determined on the quartz-dominated signal of the 4- to 11-μm fraction extracted from these deposits by using multiple-aliquot (*8*) and single-aliquot protocols (*9*). Ages are concordant by these different analytical

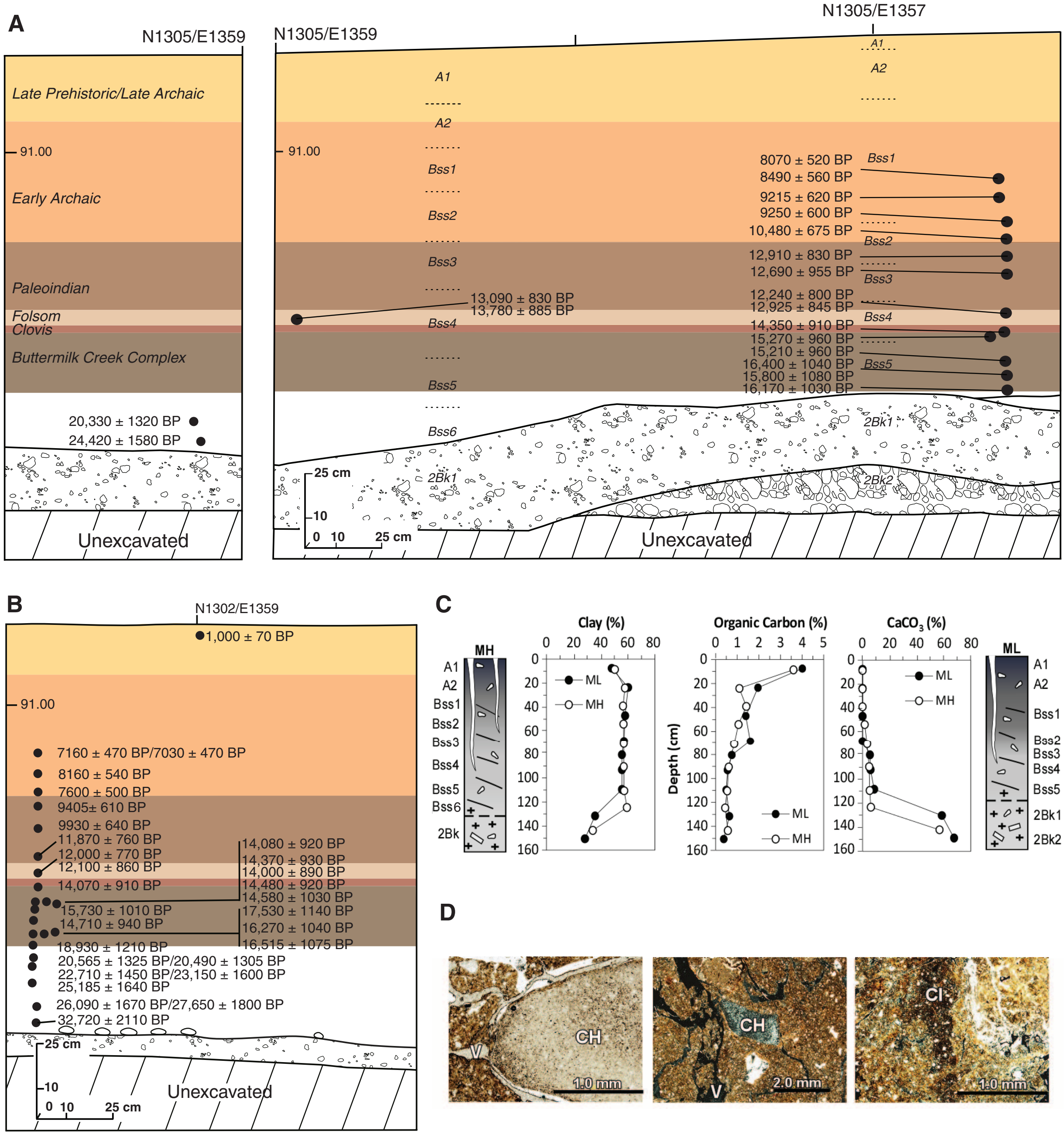

Fig. 2. Block A stratigraphy, archaeological complexes, and OSL ages (one-sigma) from column 1 (**A**) and column 2 (**B**). BP indicates years before the present. (**C**) Schematic diagram of the microlow (ML) and microhigh (MH) profiles of the alluvial Vertisol (A-Bss) overlying colluvium (2Bk). (**D**) Photomicrographs illustrating in situ chert microdebitage (CH) larger than the adjacent voids (V) and vertical crack infill (CI) in the Buttermilk Creek Complex layer of the Bss5 horizon.

approaches (*7*). The multiple-aliquot analyses, which evaluate equivalent doses for fast, medium, and slow luminescence components (*10*), yielded a uniform response indicating full solar resetting. Single-aliquot analyses show a normal unimodal distribution also indicative of full solar resetting. All ages are in chronological order, and the two columns of dates correlate in time and depth (Fig. 3).

Late Prehistoric, Late Archaic, Early Archaic, Paleoindian (Golondrina and Dalton), Folsom, and Clovis horizons occur in the floodplain clays (figs. S8 and S9). Time-diagnostic artifacts recovered from these horizons are in correct stratigraphic order and correlate with corresponding OSL ages (Fig. 3). The Folsom horizon is identified within a 2.5-cm-thick layer with three Folsom points. The Clovis horizon is defined within a 2.5-cm-thick layer in which Clovis diagnostics were found, including three bifaces with overshot flake removal scars, three channel flakes, and five blade segments. Below the Clovis horizon is a 20-cm-thick layer containing artifacts that represent repeated visits to the site and together define the Buttermilk Creek Complex. Eighteen OSL ages, ranging from ~14 to 17.5 ka, were obtained from this layer, and all but three overlap at one standard deviation (Fig. 2, A and B, and table S2). The most conservative estimate of the age of the Buttermilk Creek Complex is ~13.2 to 15.5 ka, on the basis of the minimum age represented by each of the 18 OSL ages.

The high clay content and pedogenic characteristics—including slickensides, surface cracking, and evidence of subsurface microlow and microhigh topography—indicate that the floodplain deposit containing the Buttermilk Creek Complex artifacts is a Vertisol (*11*) (SOM text). Although Vertisols were once thought to be well mixed by argilliturbation processes (*12*), more recent pedologic studies show this is not true and that Vertisols are minimally mixed (*13*). At the Friedkin site, the vertic features of the soil are weakly expressed. Horizonation is preserved within the soil with the amount of clay, organic carbon, and calcium carbonate, as well as color, soil structure, and pH varying systematically with depth (Fig. 2C). Crack infills constitute a minor portion of the soil volume with diameters rapidly decreasing from 2 cm near the surface to <1 cm at a depth of 1 m. Soil material between the crack infills is intact with few rodent burrows and limited root penetration (<2 mm diameter). Only a few cracks reach the Clovis and Buttermilk Creek Complex levels, and crack apertures are <1 mm diameter, smaller than the microdebitage (sizes 6 to 7, table S15) from these levels (Fig. 2D).

There is no sorting of artifacts by size from the surface through the Buttermilk Creek Complex layers (fig. S11). Refitted artifacts occur in the Paleoindian and Buttermilk Creek Complex levels (table S16). The number of artifacts with pedogenic calcium carbonate adhering to them (sizes 1 to 5, table S15) increases with depth. No calcium carbonate accumulated on artifacts in the Late Prehistoric and Archaic levels, about 40 to 60% of the artifacts from the Paleoindian levels are coated with $CaCO_3$, and about 90% of the artifacts in the Buttermilk Creek Complex levels have $CaCO_3$ coatings. The percentage of calcium carbonate coatings on artifacts parallels pedogenic $CaCO_3$ occurrence and concentration within the soil horizons.

Measurements of mass-normalized magnetic susceptibility show a smooth decrease through the floodplain clays with depth, typical of uninterrupted soil development (*14*, *15*) (fig. S7). Further, the magnetic mineralogy gradually changes from an assemblage dominated by magnetite in the upper 40 cm to an assemblage dominated by hematite and/or goethite at depths >40 cm. This trend of increasing oxidation with depth is indicative of undisturbed, nonsaturated, modern soils. Measurements of natural remnant magnetization are all of normal polarity, and magnetic inclinations are consistent with the latitude of the field site. Thus, on the basis of multiple lines of evidence—pedologic, magnetic, chronologic ordering of dates and diagnostic artifacts, artifact size distribution, and distribution of artifacts with and without calcium carbonate accumulations—we conclude that the artifacts from block A lie in undisturbed contexts and have not worked downward or displaced upward by soil-forming processes.

The Buttermilk Creek Complex assemblage consists of 15,528 lithic artifacts—tools (n = 56), macrodebitage (n = 2268), and microdebitage (n = 13,204). The 56 tools include 12 bifaces, 1 discoidal core, 23 edge-modified flake tools, 5 blade fragments, 14 bladelets, and 1 piece of polished hematite (Fig. 4) (SOM text). All flaked stone tools and debitage are Edwards chert.

Buttermilk Creek Complex biface technology (Fig. 4) includes three trajectories—preform, chopper/adze, and discoidal core production. Ten of the 12 bifaces are late-stage fragments, and one with a lanceolate-like shape may be a point preform fragment. Another biface is large and thick and may be a chopper or adze. The discoidal flake core has removals from both faces and from all directions. A core rejuvenation flake from a similarly sized discoidal core was also recovered. The assemblage also includes blade technology. Five blade and 14 bladelet fragments were recovered; all have two or three prior blade removal scars. Microscopic analyses indicate that some of the blades and bladelets were used (figs. S12 and S13). No blade or bladelet cores were found, but two possible bladelet core fragments were recovered.

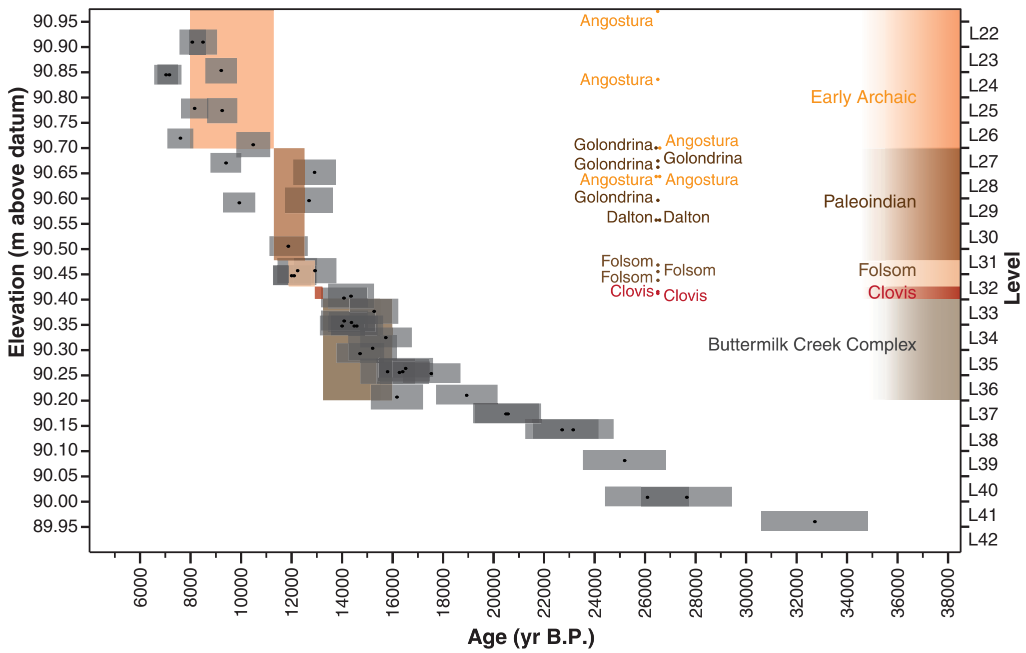

Fig. 3. OSL ages (1σ) from columns 1 and 2 in block A with the positions of diagnostic artifacts and archaeological complexes indicated.

Twenty-three edge-modified tools were made on flake fragments and include 17 straight-to-convex edged tools, 4 notches, 1 graver, and 1 bifacially worked tool. These tools are generally small, with most (n = 21) falling into debitage size classes 2 through 4 (table S15). The assemblage also includes bend and radially broken artifacts. One biface has radial breaks on three of the four sides, appears to have been intentionally broken, and has evidence of use wear on the radial edges (fig. S13). The graver and one of the retouched flakes were resharpened along a fractured edge, demonstrating that bend and radially broken flakes also served as unifacial tool blanks. Of the macrodebitage with platforms (n = 843), 47% are normal and 51% are biface thinning flakes, including 1 distal overshot fragment, 3 partial overshots, and 10 end-thinning flakes (SOM text). In addition, we found a polished piece of hematite that is multifaceted with three primary worked surfaces.

In general, the Buttermilk Creek Complex tools and cores are small in size and lightweight, a tool kit designed for high residential mobility. Although no organic artifacts were preserved, the Buttermilk Creek Complex stone tools have wear that is indicative of use on both soft and hard materials (SOM text), suggesting that organic materials were also part of this assemblage.

The Debra L. Friedkin site provides empirical evidence that people were in North America by 15.5 ka, as suggested by genetic models (*1*, *16*). The Buttermilk Creek Complex tool kit—bifaces made through core reduction including end thinning, a lanceolate-like preform, a discoidal core, blades, bladelets, radially broken tools, a variety of edge-modified tools (notches, gravers, and scrapers), and ground hematite—also provides an ancestral assemblage from which the biface- and blade-dominated Clovis tool kit (*1*) could have evolved (SOM text).

Artifacts in a similar dated geological context have been reported at the Gault site, Texas (*17*). Bifaces, flake tools, and debitage dating to 14.2 and 14.8 ka occur at the Schaefer and Hebior sites, Wisconsin, and are associated with the remains of two mammoths (*18*). At Meadowcroft Rockshelter, Pennsylvania, an assemblage of bladelets, flakes, and one bifacial projectile point date between 13.4 and 15.2 ka (*19*). At Paisley Caves, Oregon, artifacts and human coprolites occur at 14.1 ka (*20*). A small number of flakes appear in stratigraphic contexts at Page-Ladson, Florida, that date to 14.4 ka (*21*). These data are evidence that by 15.5 ka, human populations occupied the continental United States and that they had biface, blade, and bladelet assemblages. The sites of Cactus Hill, Virginia, and Miles Point, Maryland, hint that these technologies may have been present a few millennia earlier (*22*, *23*). This early occupation of North America provides ample time for people to settle into the environments of North America, colonize South America by at least ~14.1 to 14.6 ka (Monte Verde, Chile) (*24*, *25*), develop the Clovis tool kit, and create a base population through which Clovis technology could spread.

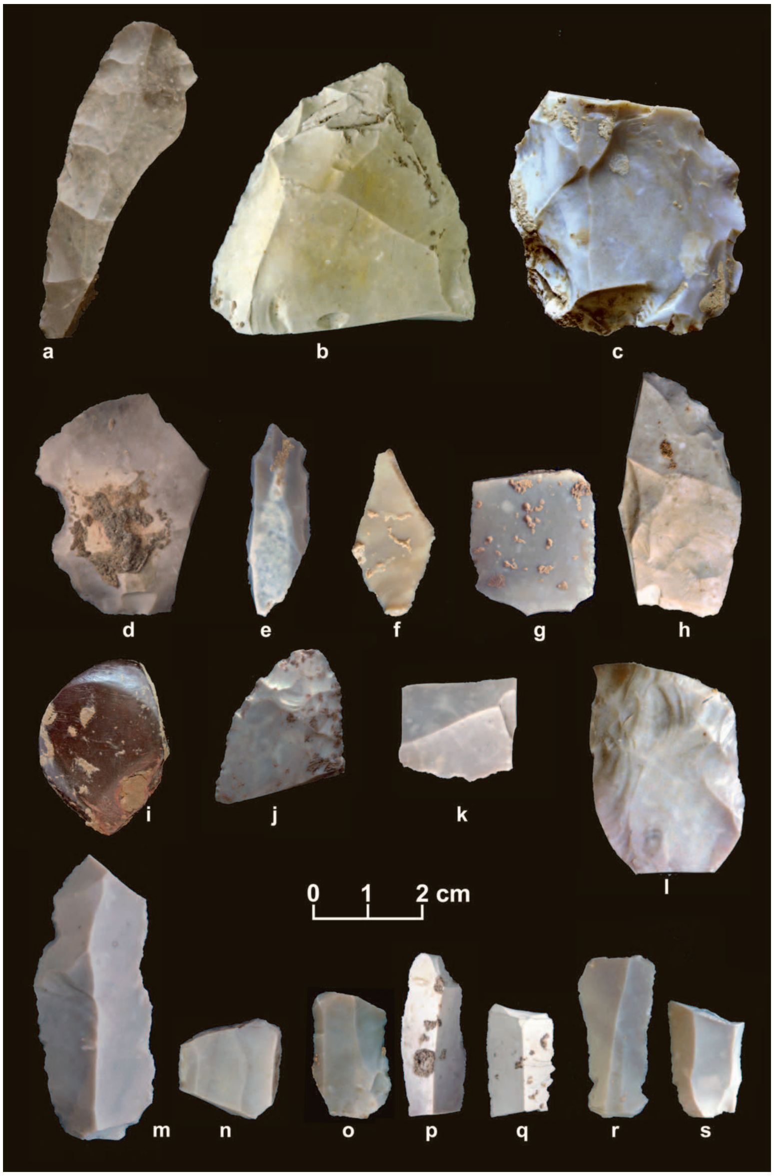

Fig. 4. Buttermilk Creek Complex artifacts: (a) lanceolate point preform, (b) chopper/adze, (c) discoidal flake core, (d) radially broken flake with notch, (e) graver, (f) flake tool with retouch on a radially broken edge, (g and h) flake tools with marginal edge retouch, (i) polished hematite, (j) bifacially retouched flake, (k) radially/bend broken flake, (l) radially broken biface, (m and n) blade midsections, (o to s) bladelets.

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Supporting Online Material
www.sciencemag.org/cgi/content/full/331/6024/1599/DC1
Materials and Methods
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References

17 December 2010; accepted 7 February 2011
10.1126/science.1201855

Dental Occlusion in a 260-Million-Year-Old Therapsid with Saber Canines from the Permian of Brazil

Juan Carlos Cisneros,[1,2] Fernando Abdala,[3] Bruce S. Rubidge,[3] Paula Camboim Dentzien-Dias,[4] Ana de Oliveira Bueno[2]

Anomodonts, a group of herbivorous therapsid "mammal-like reptiles," were the most abundant tetrapods of the Permian. We present a basal anomodont from South America, a new taxon that has transversally expanded palatal teeth and long saber canines. The function of the saber teeth is unknown, but probable uses include deterring attack from predators and intraspecific display or combat. The complex palatal teeth were used to process high-fiber food and represent early evidence of dental occlusion in a therapsid. This discovery provides new insight into the evolution of heterogeneous dentition in therapsids and broadens our understanding of ecological interactions at the end of the Paleozoic.

Critical modifications in terrestrial communities occurred during the Permian period as an increasing variety of herbivorous tetrapods and their predators evolved. This process resulted in the establishment of a modern trophic pyramid by the end of the period (*1*). A key faunal element in this ecological transformation was the appearance of therapsid "mammal-like reptiles" during the Middle Permian (*2*–*4*) and the development of heterodont dentition and diverse feeding adaptations within this group, which facilitated their exploitation of different ecological niches (*1*, *2*).

By far the most successful Permo-Triassic therapsid lineage in terms of individual abundance was the herbivorous Anomodontia [~130 species (*5*)], which includes the paraphyletic basal anomodonts and the more derived monophyletic dicynodonts (*5*). Basal anomodonts comprise only 11 species and are known from Middle-Late Permian rocks of China, Russia, and South Africa (*6*). Dicynodonts, the most speciose clade within Anomodontia, are known from every continent (*6*) and have a distinctive keratinous beak that replaced marginal dentition and, together with modification of the occlusal musculature, facilitated propalinal jaw masticatory movements (*7*). This adaptation was probably the key to their successful exploitation of herbivory. Here we report an early basal anomodont from the Permian of South America, *Tiarajudens eccentricus* gen. et spec. nov. (*8*) (Fig. 1), a taxon with dentition that is markedly different from all other anomodont and therapsid dental patterns.

The skull of *Tiarajudens* (~225 mm long) is large for a basal anomodont, with a preorbital length only slightly shorter than the postorbital length (~45% of cranial length). Most anomodonts have shorter snouts, but these proportions are comparable to those of the South African *Anomocephalus* (*9*) and the Chinese *Biseridens* (*6*). *Tiarajudens* has five prominent leaf-shaped upper incisiform teeth (Fig. 1F) with coarse serrations on their crowns. The last tooth in the maxillary row, below the anterior margin of the orbit, is a large canine measuring ~120 mm in length despite post-fossilization damage to the tip. This laterally compressed fang is reniform in basal cross section (Fig. 1E) and features enamel.

Thirteen large, transversally expanded palatal teeth (Fig. 1G) are present on the pterygoid and ectopterygoid, medial to the canine. The crown blades are oblique, arranged in echelon, and the palatal tooth row is straight, oriented 20° in relation to the lateral margin of the jugal. Unworn teeth are tall and chisel-like (Fig. 2A) and old, worn teeth display wide occlusal surfaces (Fig. 2, B and C), subdivided into two uneven wear platforms; a labial wear facet separated by a step from a larger, ventrally convex lingual facet. Palatal teeth have long roots, partially exposed in lateral view (Fig. 1H), and distinct alveoli, indicating thecodont implantation.

The presence of a shortened snout and elevated zygoma (Fig. 1) identify *Tiarajudens* as an anomodont (*6*), but it is the only one yet described to possess large canines. The flattened cross section of these teeth contrasts with the much shorter and thicker tusks of dicynodonts, which are circular in basal cross section and lack enamel (*10*–*12*). The leaf-shaped and serrated upper incisiform teeth resemble those of the plant-eating Russian basal anomodonts *Ulemica* and *Suminia* (*13*, *14*), and are also characteristic of other herbivorous groups such as pareiasaurs, ornithischian and prosauropod dinosaurs, and extant iguanid lizards (*1*, *13*).

Tiarajudens is also unusual in having large, transversally expanded palatal teeth. Palatal teeth are absent in all basal anomodonts except *Biseridens*, in which they are small, rounded, and bulbous (*6*). The presence of teeth in the ectopterygoid is a feature unknown in any other therapsid but is characteristic of pelycosaur-grade synapsids such as *Edaphosaurus* (*15*). In occlusal aspect, the palatal teeth of *Tiarajudens* resemble the maxillary molariforms of the Early Permian *Diadectes* (*16*), except that they have the codont implantation, evinced by long roots and distinct alveoli. The dentary is not preserved, but wear facets on the palatal teeth suggest that they occluded against mandibular teeth, resembling a mechanism present in *Edaphosaurus* (*15*), where a cluster of homodont palatal teeth are opposed to a matching set of lower teeth on the coronoid, anterior coronoid, and prearticular bones (*15*, *16*). The presence of replacement teeth (Figs. 1H and 2A) and their positioning and

[1]Universidade Federal do Piauí, Centro de Ciências da Natureza, 64049-550, Ininga, Teresina, Piauí, Brazil. [2]Universidade Federal do Rio Grande do Sul, Departamento de Paleontologia e Estratigrafia, Avenida Bento Gonçalves 9500, Porto Alegre, Rio Grande do Sul, Brazil. [3]Bernard Price Institute for Palaeontological Research, University of the Witwatersrand, Private Bag 3, WITS 2050, Johannesburg, South Africa. [4]Universidade Federal do Piauí, Picos, Piauí, Brazil.

The Buttermilk Creek Complex and the Origins of Clovis at the Debra L. Friedkin Site, Texas

Michael R. Waters, Steven L. Forman, Thomas A. Jennings, Lee C. Nordt, Steven G. Driese, Joshua M. Feinberg, Joshua L. Keene, Jessi Halligan, Anna Lindquist, James Pierson, Charles T. Hallmark, Michael B. Collins and James E. Wiederhold (March 24, 2011)

Science **331** (6024), 1599-1603. [doi: 10.1126/science.1201855]

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