MAMMOTH TRUMPET

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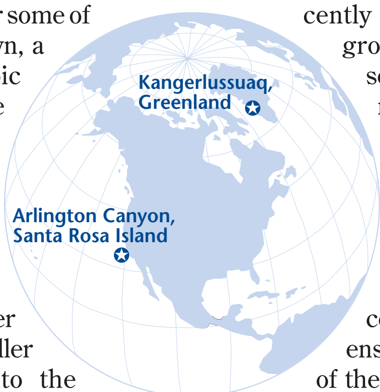
The Nanodiamond Controversy, Part I

THE CLOVIS COMET REVISITED

IF DIAMONDS REALLY ARE FOREVER, as the saying goes, then natural specimens should provide excellent records of geological history—assuming we can decipher the clues hidden in their structures. That's precisely what one group of scientists claims to have done for some of the tiniest diamonds known, a collection of microscopic particles dating from the end of the Pleistocene epoch called *nanodiamonds*. If they're correct, the very existence of these minuscule gemstones chronicles one of the most dramatic catastrophes ever to befall our species: a killer comet that slammed into the Earth, altering the climate and destroying an entire human culture.



Fire from the sky?

It was a day like any other, except that it was, perhaps, warmer than most; over the previous few years the world had been shaking off its latest Ice Age. In North America, the surviving large animal populations were poised to recover, and an upstart species called humanity—which until recently had been thin on the ground—had established a solid foothold on the continent at last. Things looked promising . . . until something smashed into the world like the fist of God. Entire populations were flash-fried as the fireball exploded high over the continent; others died in the ensuing firestorms, and many of the rest perished in the deep winter that followed. The Clovis culture vanished with the blast, and with it most of the surviving species of North American megafauna.

At least, that's the theory advocated by the Extraterrestrial Impact Hypothesis (EIH) camp, which cites more than a dozen lines of evidence suggesting that an enormous extraterrestrial

INSIDE

(ET) body struck North America at the end of the Pleistocene. Along with trillions of nanodiamonds, they've documented peaks of aciniform soot, charcoal, magnetic microspherules, iridium, and a number of other purported impact markers at the Younger Dryas Boundary (YDB), a continent-wide stratigraphic layer that dates to about 12,900 CALYBP. Unsurprising, not everyone agrees with the EIH interpretation; while something dramatic certainly triggered the 1,000-year climatic reversal known as the Younger Dryas, they consider mechanisms other than an ET impact more likely culprits.

JAMES KENNETT

Kennett (*above*) in the field at Taroko Gorge, Taiwan, 2006; Kurbatov (*below*) in Greenland, 2008.

SOLANA PYNE

We examined the EIH closely in a four-part series a while back (**MT 23-1, -2, -3, -4,** "The Clovis Comet"), even as interested observers were scrambling to test it. In the three years since, dozens of research teams have published their findings. Many, including geoarchaeologists Todd Surovell and Vance Holliday (**MT 25-2,** "The Clovis Comet Revisited"), have been unable to reproduce the EIH camp's results, even when working at the same sites. One by one, critics have dismissed most of the evidence supporting the EIH. Some fault the original Impact Team's conclusions, charging that they deliberately stretched the evidence to fit a preexisting hypothesis; others condemn their collecting and analysis techniques, or alleged that they've simply misinterpreted their findings.

Nanodiamonds have largely resisted criticism, since there's only one known way that they can form naturally: in a high-temperature, high-pressure environment such as that of an ET impact. But even nanodiamonds have recently come under increased scrutiny, with critics becoming progressively more vocal in their claims that at least some of the particles cited by the EIH supporters as nanodiamonds are not, in fact, diamonds at all.

In this two-part story, we'll take a look

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Department of Anthropology, Texas A&M University
4352 TAMU
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–Michael R. Waters, Director

MAMMOTH TRUMPET

at the argument from both sides. Part I outlines recent research supporting the presence of nanodiamonds in YDB deposits, both in California and on the Greenland ice sheet. In Part II we'll tell you why other researchers believe that this evidence is either inconclusive, or dead wrong.

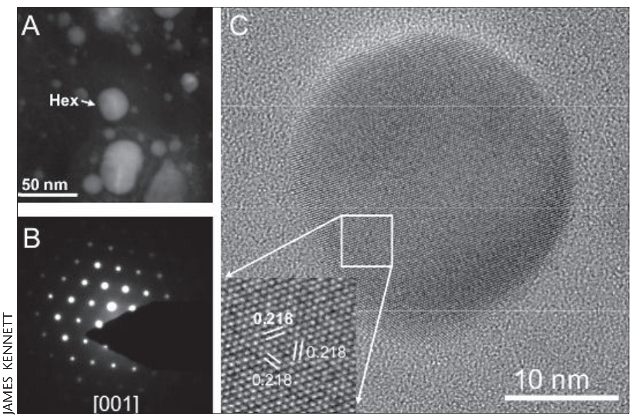
◀ An overview of the Kangerlussuaq sampling site.

▼ Greenland team member Jøergen-Peder Steffensen identifying the YD sampling site near Kangerlussuaq.

The nanodiamond record

Nanodiamonds are so incredibly tiny that millions can get lost in a liter of soil; it takes exquisitely high-powered microscopes simply to find them, much less analyze their content and structure. They can take a number of forms, including cubic, tabular, and near-spherical. Recent interest, however, has focused on shocked hexagonal nanodiamonds known as *lonsdaleite*.

As far as we know, natural lonsdaleite occurs only in association with meteorites and other cosmic impacts. Lacking undeniable impact markers such as a crater, tektites, and shocked quartz, many EIH supporters cite the lonsdaleite found in YDB deposits as convincing evidence that an impact may have triggered the Younger Dryas. Geologist James Kennett of the University of California, Santa Barbara summarizes the argument when he states, "Lonsdaleite has never been found associated with diamonds that formed through regular terrestrial processes, so its presence in the YDB suggests a cosmic connection."



Three images of a hexagonal nanodiamond (lonsdaleite) from the YDB layer, Greenland Ice Sheet. **A,** scanning transmission electron microscope (STEM) image; **B,** X-ray diffraction image; **C,** crystallographic high-resolution transmission electron microscope (HRTEM) image.

Q.E.D.? Maybe, assuming we can decisively rule out a terrestrial formation process for lonsdaleite—which hasn't been an issue so far. A bigger problem seems to be proving to the critics that what the EIH proponents are calling lonsdaleite really *is* lonsdaleite, a topic we'll take up in detail in Part II.

The Arlington Canyon evidence

In a recent paper in the *Proceedings of the National Academy of Science*, Dr. Kennett and 16 colleagues reported on lonsdaleite and other nanodiamonds detected in YDB sediments at Arlington Canyon on Santa Rosa Island, just off the California coast. While the team is confident that an impact event deposited the diamonds, they're uncertain whether they were carried to Earth inside an impactor or created in place. They lean toward the latter. "We've performed geochemical analyses on nanodiamond residues," says Kennett, "and the results indicate that the nanodiamonds are *not* cosmic material, but instead formed from terrestrial material." Experiments have proven that lonsdaleite can be created from oxygen-deficient, very hot carbon vapor quenched in a warm substrate (such as soil) by a process known as carbon vapor deposition (CVD). A CVD origin for the nanodiamonds seems to rule out the possibility that they might have been deposited by means of some ET-related process other than an impactor, such as a "cosmic rain."

The Arlington Canyon team has also isolated a number of proxies suggesting extensive biomass burning at the YDB contact, including charcoal, carbon spherules, and aciniform soot, which resembles tiny clusters of grapes. (This form of soot is extremely rare in the geological record, known only to be associated with ET impacts.) In addition, electron microscopy studies revealed cubic nanodiamonds and metastable "n-diamonds" embedded in the carbon spherules. Both cubic diamonds and n-diamonds are also impact markers; and like lonsdaleite, n-diamonds are never associated with terrestrial formation processes. What's more, the team has identified a phenomenon they attribute to mass wasting, the sudden down-slope movement of massive amounts of sediment. All AMS dates from the lower 4 m of the Arlington Canyon stratigraphic profile cluster around 12,950 ± 50 CALYBP, suggesting that the entire sequence was deposited quickly, possibly after fires denuded the region of vegetation.

While other researchers have since challenged their conclusions, the evidence from Arlington Canyon is intriguing. Not only are nanodiamonds and proxies for biomass burning abundant in the YDB sediments there, they're roughly contemporaneous with known wildfire events elsewhere on the Channel Islands, as well as with the extinction of the Santa Rosa Island pygmy mammoths, *Mammuthus exilis.* This pattern of nanodiamonds, fire evidence, and megafaunal extinction crops up at terminal-Pleistocene sites all across North America. It's not clincher evidence for an impact, perhaps, but it's certainly thought-provoking—especially since the only other known co-occurrence of all three factors is at the famous Cretaceous-Tertiary boundary, the worldwide stratigraphic layer that demarks the impact of the city-sized asteroid that finished off the dinosaurs.

The Greenland evidence

In addition to the Arlington Canyon study, Kennett and 24 coauthors recently reported in the *Journal of Glaciology* on the discovery of a discrete, nanodiamond-rich layer in the Greenland ice sheet. In a 2008 expedition, spearheaded by Paul Mayewski and Andrei Kurbatov of the University of Maine Climate Change Institute and accompanied by a NOVA television team, the team pinpointed a layer of dusty ice near Kangerlussuaq that they determined is coeval with YD sediments elsewhere in the Northern Hemisphere. They couldn't use conventional chronometric methods to determine the age of the ice, given the dearth of datable material; instead, the researchers used as markers stratigraphic context and oxygen-isotope variations, focusing particularly on Oxygen-18 (^{18}O). As Kennett notes, "^{18}O is a proxy for temperature. The ^{18}O values suggest the diamond layer occurred at or near the onset of a major cold period, and the only known postglacial cold period is the Younger Dryas."

The team collected samples along a trench 17 m long, representing about 6,000 years of ice accumulation. Later analysis revealed a significant nanodiamond spike immediately below the dusty ice: at 5–50 parts per billion, concentrations were as much as 5,000,000 times higher than background levels observed in the surrounding ice. One third of the Greenland nanodiamonds were n-diamonds; another third were lonsdaleite. Says Dr. Kurbatov, "We were very excited when we determined that the number of lonsdaleite particles increased sharply and was associated with one layer."

ANDREI KURBATOV

The Nova team in Greenland, led by Doug Hamilton.

Of course, it's possible that something other than the hypothesized YDB impactor enriched the ice with nanodiamonds. For example, other researchers have found nanodiamonds in "cryoconite" holes, where meteors have melted depressions in the ice, so it's conceivable the spike resulted from a series of meteor strikes combined with some factor that concentrated the diamonds in one thin layer, as wind can do with lag gravels. Kennett dismisses this as unlikely; cryoconite holes are rare and isolated, and they found none in the study area. Kurbatov is more cautious, pointing out tersely, "We mentioned in our paper interpretations made by other scientists. We did not study cryoconite holes in our work."

Actually, it's hard to explain away the Greenland nanodiamonds as the result of some event unrelated to the YDB nanodiamond deposits observed elsewhere. It would require an astonishing coincidence, since this find represents the only nanodiamond concentration in that interval of ice, and it apparently dates to exactly the right time. Furthermore, the Greenland nanodiamonds are comparable in abundance, morphologies, and size range to other known YDB nanodiamonds.

Some critics speculate that the team misidentified the particles, suggesting that instead of being nanodiamonds they were actually quartz, rutile, copper, graphite, and carbonized spherules known as graphenes that can all display similar results. However, the Kurbatov group considers this highly unlikely, since they identified the Greenland particles as nanodiamonds based on six different techniques of X-ray and electron microscopy studies of their atomic structures. In particular, the shapes appear to be wrong for most of those other possibilities; and in any case, according to several different analyses, the particles are made primarily of carbon. Furthermore, the fact that the Greenland particles identified as lonsdaleite display a crystalline lattice spacing of 1.93 angstroms and a robust, multilayered atomic structure seems to rule out graphenes, which are single-layered and have a significantly larger crystalline lattice spacing.

One way to test their findings, Kurbatov suggests, is to drill new deep ice cores elsewhere in Greenland and in the Canadian Arctic, and determine if nanodiamonds peak in layers of the right age. The problem, as always, is expense. "Because of the serious price tag associated with this activity, one of the compromises was to look on the edge of the Greenland ice sheet," Kurbatov says. "Ice sublimation during the summer leaves a residue of dust particles embedded in the ice. Such a natural enrichment mechanism helped us to locate the nanodiamond layer, which is probably harder to find in ice cores."

Intriguing possibilities

The EIH is a relatively simple concept, but as Kurbatov points out, "It is changing existing concepts in several disciplines." That being the case, it continues to undergo rigorous testing—as any hypothesis that offers a new paradigm must do, before it's either added to the edifice of scientific knowledge or relegated to the dustbin of history. The current nanodiamond controversy is just one aspect of that testing. It's hard to say

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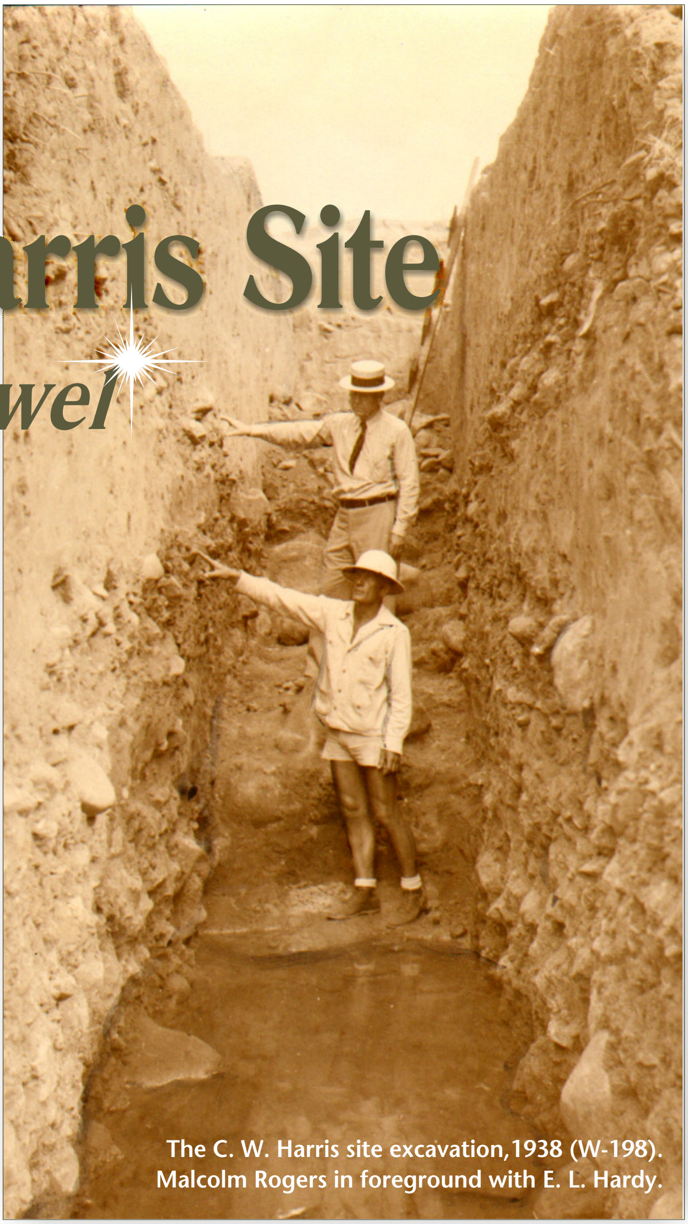
The C.W. Harris Site

An Enigmatic Jewel



The C. W. Harris site excavation,1938 (W-198). Malcolm Rogers in foreground with E. L. Hardy.

ON THE BORDERS of an exclusive private community of million-dollar homes just north of San Diego, California, sits what researchers at the San Diego Archaeological Center call "one of the most important archaeological sites in the United States."

Studied repeatedly over the last seven decades, the C. W. Harris site posts radiocarbon dates showing people lived here more than 10,000 years ago. Although its earliest occupation is as old as the Folsom culture, the site has been eclipsed by other sites, some earlier, occupied by people who left distinctly different artifacts. But C. W. Harris remains an enigma: Not only is it a Folsom-age site with no Folsom-type artifacts, there are no conclusive data that tell us who its oldest occupants were, what they were doing at the site, or how they got there in the first place.

Sparse findings at its discovery

First discovered in 1927, the C. W. Harris Site (CA-SDI-149) is the type site for the San Dieguito complex of Early American sites. In fact, it contains artifacts from three prehistoric cultural periods, San Dieguito the oldest. Later components move upward in age through the La Jolla period (7000–3000 years ago), and into the late-Prehistoric period (3000 years ago to contact). Other sites in the overall complex include those of Pleistocene Lake Mojave, to which it's most closely linked, and several other sites that have yielded artifacts characteristic of early-Holocene inhabitants of Southern California and surrounding areas of the Southwest and northern Mexico.

The earliest occupation of the San Dieguito complex is characterized by:

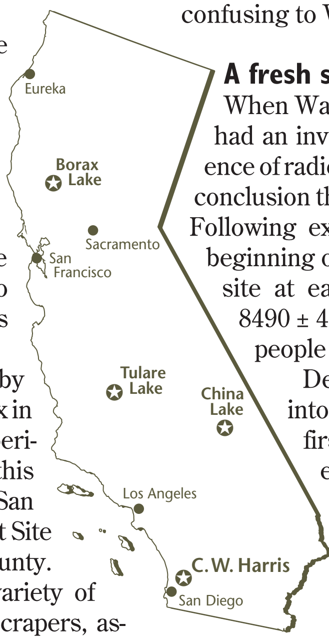
- large percussion-flaked biface knives and projectile points (but no fluted points similar to those of Clovis and Folsom-age artifact assemblages);
- numerous scrapers and one crescent-shaped stone considered by some researchers as an amulet; by others as spear-shaft scrapers or food processors; by still others as hunting amulets, specialized projectile points used to stun water fowl, or even ritual scarification knives (**MT 25-3,** "Studying Crescentics: Form or Function?");
- a perplexing near-absence of grinding implements such as *manos* and *metates,* artifacts considered identifiers at so-called "Desert Culture" inland sites.

Claude Warren and D. L. True, taking stock of the artifacts in the C. W. Harris assemblage, judged them "quite different from those found on Great Plains sites." Nevertheless they determined that the assemblage argued for a hunting economy. The oldest part of the site, they concluded, was occupied by "an early hunting culture" with its closest affinity to "the early cultural levels of sites from the California desert area." The conclusions these researchers reached during the 1960s were a brave attempt to illuminate a site dogged by a confusing history.

The first unsure steps

Claude N. Warren was a young man when he plunged into the murky history of the site in the late 1950s. Now a professor emeritus at the University of Nevada, Las Vegas, Dr. Warren has spent half a century investigating the site and writing articles about it.

In 1958, Warren was a graduate student at the University of California Los Angeles (UCLA) and a new hire to the university's fledgling Archaeology Survey program. "After a few months my professors told me to go to San Diego and find out what San Dieguito was," he says. "I went down there but I didn't really know what I was looking for." He found the available literature riddled with a baffling jumble of terms and no consistent definition of the site or theory of its origin.



Part of the problem was the terminology used by Malcolm J. Rogers, who first identified the complex in 1919. Rogers, a geologist by training and an experienced archaeologist, first explored a facet of this complex, which was ultimately named after the San Dieguito Valley and the river flowing through it, at Site SDI-W-240 in Escondido, also in San Diego County. Rogers, finding at the Escondido site a wide variety of unifacially flaked stone tools he believed were scrapers, assigned the designation "Scraper Makers" to the occupants. He later suggested that these toolmaker inhabitants (whom we now know as the San Dieguito culture) were the *second* occupation in the region. Rogers believed the site was earlier occupied by people from a shell-midden culture near the Pacific Coast, where Rogers also explored. Rogers placed these coastal-oriented people in the context of what became known as the La Jolla complex.

It wasn't long, Warren tells us, before Rogers changed his theories about human presence in North America (at the time his theories were considered pretty eccentric). Warren reminds us that Rogers worked in the 1920s, when American archaeology was in its infancy and few people believed there were sites more than 2,000 years old. Rogers's geologic training convinced him that the remnants of cultures he was finding were far older than that, although he lacked the means to prove it conclusively.

EDWARD J. KNELL

Retouched flakes and scraping tools.

A lucky break came for Rogers in 1927, when flooding exposed artifacts in the San Dieguito River valley on a farm owned by C. W. Harris. After examining the C. W. Harris site, as it was later known, he struggled for 10 years—Great Depression years, remember—to get money to excavate it. When he dug there in 1938 the well-preserved stratigraphy he found led him to revise his earlier conclusions. It was now clear to him that the San Dieguito component lay beneath the La Jolla component, thus making San Dieguito the older people. Unfortunately for North American archaeology, Rogers published few of his findings and what eventually made it into print was confusing to Warren and other investigators.

A fresh start with new tools

When Warren began digging at the site in the late 1950s he had an invaluable tool that Rogers had lacked, the new science of radiocarbon dating. Warren was able to verify Rogers's conclusion that San Dieguito was indeed the older component. Following excavations in 1965 and 1967, Warren dated the beginning of the San Dieguito component at the C. W. Harris site at earlier than 9030 ± 350 RCYBP and ending after 8490 ± 400 RCYBP. Calibrated dates demonstrate that people lived there around 10,365 calendar years ago.

Despite the march of decades since sinking a shovel into the C. W. Harris site, Warren still recalls that his first encounter with it was a "really amazing" experience. The site, he says, was largely exposed in a cutbank that the river had sliced right through. "We could see San Dieguito artifacts in deposits," he says, that were really "very deep," some 14 ft below the ground surface.

Warren's long career at the site had been born. Today, half a century after he first set foot on the C. W. Harris site, he believes that although the cultural history of the site has been well delineated, questions remain to be answered.

For a start, archaeologists can't agree on what constituted the daily activity of the earliest inhabitants. In true scientific form, interpretations abound, and they have varied through the years as investigators test theories with new excavations or reexamine artifacts pulled from earlier digs. Some researchers have seen the very early San Dieguito as big-game hunters, possibly following Clovis and Folsom hunters; others have viewed them as more generalized foragers; a few have declared the artifacts collected there examples of specialized tool production, possibly morphing into the later La Jolla complex and its artifacts.

A plan of attack for the future

Edward Knell, an assistant professor of anthropology at California State University, Fullerton, seeks to determine if the site was a specialized tool-production locus by taking an extremely close look at the lithic artifacts collected from the C. W. Harris site during the 1950s. Besides a detailed study of how the lithic technology was organized, his plans call for high-power microscopic use-wear analysis of the artifacts. Ultimately, he hopes to make a contribution to the site literature by showing what the tools found there were used for—reading from the record of the lithic technology and use wear on the stone tools to determine what people *did* there.

Dr. Knell's special field of interest is the Paleoindian period.

Although his primary work has concentrated on Great Plains components of the Alberta and Cody complexes, the C. W. Harris site has long been at the forefront of theories concerning early-Holocene origins and the cultural historical relationship of the Great Plains sites and to the La Jolla and San Dieguito complex. “People know about the C. W. Harris site,” Knell says, “but they don’t quite know what to make of it.” What strikes him in the discussions about the site is that “nobody—nobody—has thus far published a detailed analysis where they actually tried to assess what the San Dieguito people actually were doing at the C. W. Harris site. . . . I’m just hoping to contribute to that debate.” In fact, he has already done so with a paper he presented at the 2010 Society for American Archaeology meeting in St. Louis on an assemblage-level analysis of Claude Warren’s 1958 and 1959 excavations at the Harris site. His purpose was to assess how the occupants from the oldest site component organized their stone tool technology. Among his conclusions:

EDWARD J. KNELL

Later-stage bifaces.

- biface production and the use of scraping tools were major on-site activities, and the bulk of the toolstone found on the site originated locally;
- the flaking patterns and morphology of the few (four) biface cores suggest that “flake blank production was minor in the scheme of on-site production activity”;
- substantial quantities of thinning flakes from 49 biface blanks indicate biface manufacturing was a major activity there; most of the bifaces, however, are “manufacturing failures,” tools broken during manufacture and discarded.

EDWARD J. KNELL

Knell at the Hell Gap site, Wyoming.

Knell pays particular attention to tools he believes were used on site: 35 retouched flakes, 11 scrapers, 11 utilized flakes, 4 retouched flakes probably used as multipurpose tools, 2 bifacial tools, a crescent, and a chopper.

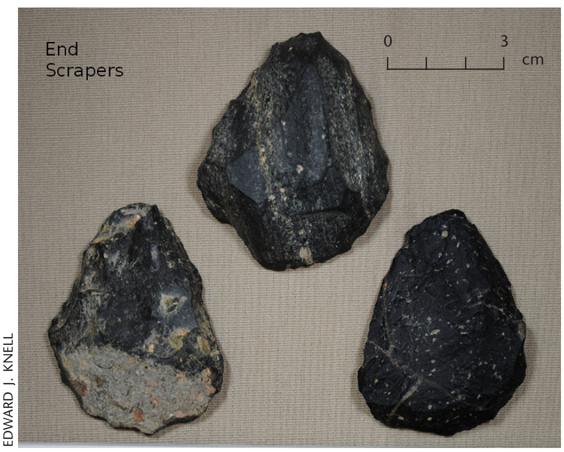
Preliminary use-wear analysis of biface tools under low magnification suggests they were used on softer materials. Preliminary use-wear analysis of scrapers—the collection contains more than 100 of various types collected from different levels—indicates they were primarily used to process harder materials, but the exact nature can’t be identified under low-power magnification.

Which leads to another mystery: No faunal remains have been recovered from the site. In his paper Knell poses the question: “So what else were they using all those scrapers for?”

A theory to test

His working hypothesis, which he hopes to test with detailed use-wear analysis of the tools, is that the scraping tools were used to manufacture hafts from hard materials. Many of the scrapers show evidence of continual resharpening and reshaping, a pattern that Knell argues could result from “processing hard materials that rapidly deplete tool edges.” Shaping hard wooden shafts for stone tools would certainly wear scraper edges. “I want to stress my work is very, very preliminary,” Knell, a careful scientist, cautiously adds. He emphasizes that further testing is necessary.

If this hypothesis holds true, Knell says, it will strongly suggest that the C. W. Harris site was “a campsite as is generally perceived, and a whole lot more—a specialized shaft-shaping factory and activity center producing tools used to shape shafts for projectile points, as well as the points themselves.” He is excited by the possibilities. In his paper he conjectures that “the remaining tools could be by-products of other production-related activities, food consumption/campsite activities by the workers, or both.”



EDWARD J. KNELL

Scraping tools.

More surprises may be in store at the site as new technology is employed on the older artifacts or on other parts of the site. Some surprises, in fact, have already emerged as the result of CRM studies mandated in anticipation of development of the San Dieguito Valley during the 1990s. The San Diego Archaeological Center reports that a new wave of archaeological

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In situ biface and flake cluster at Unit #1 of the C. W. Harris site complex (Sdi-4935B), 1990.

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testing with new technology has disclosed some tantalizing findings. Pollen analysis, for example, reveals that as a result of increasing aridity during the period of early occupations, grasses gradually replaced amaranth and pigweed. Traces of deer and rabbit blood detected in blood-residue analysis of tools are the first solid evidence that occupants exploited faunal resources. Microspectroscopy of a tool revealed that one end is coated with asphaltum, thereby confirming that natural tar was locally available. And excavation revealed intact rock hearth features and grinding tools dating to the late–La Jolla period.

Satisfaction after a long journey

Warren is delighted with the renewed interest in the site, now that new technology and new ideas can be brought to bear on solving its mysteries. "There is no question that the site is old," he says. Today he stands by conclusions he reached more than 40 years ago, that the San Dieguito complex of sites is unique and shouldn't be lumped in with Great Plains sites or Desert Culture sites as some researchers have tried to do. "The assemblages of the San Dieguito complex include large, leaf-shaped knives and rather crudely made points and a series of scrapers that are typologically and technologically distinct from the material of the Great Plains," he wrote in 1967. Put simply, Warren remains convinced that the earliest occupation is as old as Folsom; but because the artifacts don't resemble Folsom at all, he believes San Dieguito and Folsom are culturally distinct.

Our blurred vision of the C. W Harris site is sure to come into focus with future investigations. In the meantime Warren has no doubt its earliest people "were living there seasonally, using local toolstone and making lots of tools." His long-held conviction that people came to the Americas at different times and along different routes is being confirmed as sites older than benchmark Clovis and Folsom cultures emerge.

Today we don't know where the San Dieguito people came from. Warren is confident we'll know tomorrow.

–George Wisner

How to contact the principals of this article:
Edward J. Knell
Assistant Professor
Department of Anthropology
California State University, Fullerton
P.O. Box 6846
Fullerton, CA 92834-6846
e-mail: eknell@fullerton.edu

Claude N. Warren
e-mail: claudius@xenei.net

Suggested Readings

Beck, C., and G. T. Jones 2010 Clovis and Western Stemmed: Population Migration and the Meeting of Two technologies in the Intermountain West. *American Antiquity* 75(1) pp. 81–116.

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San Diego Archaeological Center Website: www.sandiegoarchaeology.org/PDF/Harris%20Exhibit.pdf

The Clovis Comet Revisited

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what consensus will ultimately be reached, given the difficulty of testing such a brief event, which produced only trace amounts of materials that are, as Kennett observes, very difficult to isolate. "This is very demanding work," he explains.

So how is the EIH faring as a scientific theory these days? "That's a question for others to answer," Kennett avers. "For us, the evidence has only become stronger—and so far, we see no new evidence that refutes it."

Join us next issue for Part II, when we'll examine arguments from the other side of the theoretical fence.

–Floyd Largent

How to contact the principals of this article:
James P. Kennett
Professor of Oceanography
Department of Earth Science
University of California
Santa Barbara, CA 93106 -9630
e-mail: kennett@geol.ucsb.edu

Andrei V. Kurbatov
Climate Change Institute
University of Maine
303 Bryand Global Sciences Center
Orono, Maine 04469-5790
e-mail: akurbatov@maine.edu

What It Means to Be Clovis

GAULT SCHOOL OF ARCHAEOLOGICAL RESEARCH

Collins examining an artifact recovered during excavation at the Gault site, Texas.

Part III: Producing Clovis Blades

BLADE TECHNOLOGY has woven its way in and out of the archaeological record for tens of millennia, appearing on different continents and at different latitudes, and perhaps even "invented" by a different species of *Homo*. Though the ability to produce blades and reliance on blade technology are often associated with anatomically modern humans, new sites and dating techniques have demonstrated that our nearest hominid neighbor, *Homo neanderthalensis*, was clearly capable of producing blades in the Old World more than 250,000 years ago, before the advent of modern *Homo sapiens sapiens*. By and large, though, they made the same stone tools using the same technique for more than 100,000 years. French prehistorian François Bordes says of the Neanderthal lithic industry, "They made beautiful tools stupidly," meaning repeatedly or by rote. Neanderthals, however, may have been more innovative than we previously believed.

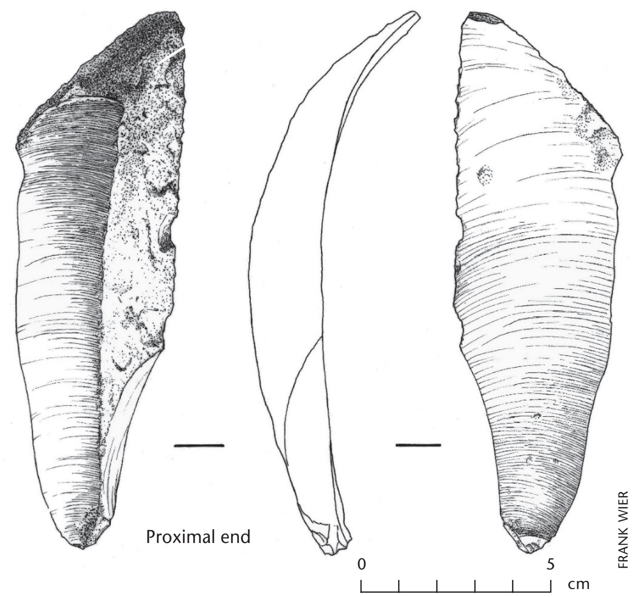
But it wasn't until about 45,000 years ago, during the Upper Paleolithic in Eurasia (a.k.a. the Late Stone Age in Africa) that blade technology really took off. Until recently, many archaeologists have argued that this occurred solely because we put the *sapiens* in *sapiens*; that is, our evolved intellectual capacity spawned new technologies. As mentioned above, however, it seems that's not quite true. Some archaeologists believe that such factors as increased mobility or perhaps access to high-quality raw material spurred on the UP/LSA blade revolution; others, like Ofer Bar-Yosef of Harvard and Steve Kuhn of the University of Arizona, suggest that blades became popular and stayed in fashion because toolmakers increasingly relied on hafted tools and composite or multicomponent tools, which require interchangeable parts. Blades are really good for this . . . but, as usual, I'm getting ahead of the story.

Back home in the New World, there are essentially nine instances—at various places and times—when blade technology comes into play in North America. These nine instances are strictly associated with modern humans. In the mid '90s, Bill Parry (CUNY) provided a fine summary of these blade ***industries***, as they are sometimes referred to, which stretch from Alaska into California, across to various places along the Mississippi Valley, and down into Mesoamerica. They're associated with long-ago mobile hunter-gatherers like Clovis folks, as well as more sedentary, complex societies found in Mexico, Central America, and the larger valleys of the Ohio, Illinois, and lower Missouri rivers. Not only is there a broad "space-time continuum" associated with these industries, technological diversity (e.g., variation in blade size and manner of production) exists as well. The upshot is that there is no historical continuity. Clovis blade technology didn't evolve down the line into the blade technology seen, let's say, thousands of years later during the Poverty Point period in parts of Louisiana and Mississippi. There are, however, a few things in common among these assorted and sundry industries: the products and by-products . . . and, of course, the particular kind of debitage that archaeologists and lithics analysts define as ***blades***.

Not all rectangles are squares, and not all flakes are blades

Back in grammar school, we learned that a square is a special type of rectangle with four 90° angles and four sides equal in length. (The equal length is what makes it a square, right?) Well, a similar rule exists for debitage: All blades are flakes. In Part II of this series, we discussed a number of different types of flakes: biface thinning flakes, overshot flakes, normal flakes, etc. This list goes on to include blades; after all, just like a flake, a blade is struck from a "parent" core.

In its simplest form, a blade is defined as a flake that is twice as long as it is wide. Early on, the definition of blades followed this deceptively straightforward rule. The trouble is that it's not really that easy. (You're starting to anticipate this about lithics, aren't you?) A suite of other characteristics besides the 2L-W guideline are essential for defining what's referred to as a "true" blade technology—a ***prismatic*** blade technology. This is critical because long, narrow flakes can be incidentally produced during other types of lithic reduction. Jay Johnson of the University of Mississippi provided some pretty useful criteria in addition to length for defining prismatic blades: They should have prepared platforms, parallel lateral edges, and exterior



A regular cortical blade showing the exterior and interior blade surfaces and a lateral view that shows how radically curved Clovis blades can be. Note the parallel lateral margins and the previous blade removal on the exterior surface that creates a triangular cross section. This blade has a cortical margin that creates a naturally backed blade, which makes it easy to grip.

flake scars that are parallel to the long axis of the blade itself. Add to these a trapezoidal cross section and two ridges on the

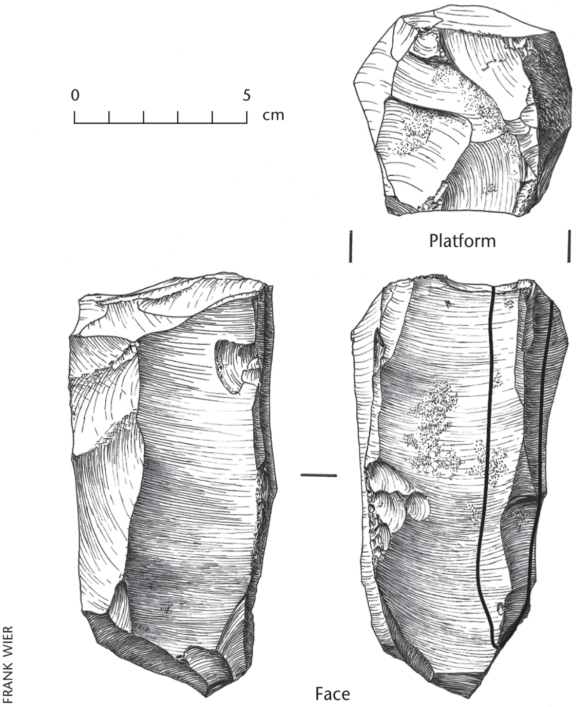
LITHICS SPEAK
Knockin' on Rock

THREE TECHNIQUES used to create blades, or any type of flake for that matter, are direct percussion (using either a hard or soft hammer), indirect percussion, and pressure flaking. Direct percussion is perhaps the easiest of the three, and if you've ever watched a skilled knapper, it looks so darned simple. Ha! Try it sometime, though. Making stone tools is a most amazing experience. Replicating, experimental archaeology if you will, is truly the best way to understand the whole process of reducing lithics, whether producing bifaces or blades. But watch out for sharp edges!

Dr. Bill Dickens explains the importance of preparing and maintaining the correct platform angle on an experimental blade core.

Hard-hammer direct percussion produces flakes by striking a stone (one suitable for producing flakes) with another stone (one suitable for use as a hammerstone). A ***hammerstone*** should be of a material that's denser and less brittle than the material being worked (you want to drive off a flake, not shatter your hammer). The platform on the core should have an angle of less than 90°, and the striking angle (the angle of the blow) must be less than 90°. Aim at a spot about 3–6 mm from the core edge, as far back as the thickness of the flake you want to make. Use an easy, natural swing and follow through; a great deal of force usually isn't necessary, but developing a good aim is (just as in golf—trying to hit exactly the right spot on a platform can be as frustrating as trying to hit a little white ball).

Soft-hammer percussion uses a material as a hammerstone that's softer than the material being flaked, such as antler, bone, or a "soft" rock like dolomite or limestone. Because the hammer is softer, more force may be required to remove a flake. Soft-hammer percussion is useful in thinning, flattening, and shaping bifaces; the platform (the edge of the biface) generally forms an angle well under 90°. A soft hammer slightly compresses when striking a core, thereby diffusing the force of the blow over a larger area. When using a soft hammer, swing it in an arc. Aim most of the force onto the edge to detach a long flake, and direct a little of the force downward to begin



Moreover, to constitute a "true" prismatic blade technology, a lithic assemblage must contain blade cores (the parent rock from which a blade is removed) and specific types of debitage that are exclusive to producing blades. For instance, if a potential core doesn't have a suitable starting point for removing blades, the toolmaker must prepare and shape it to detach blades. Core preparation is a key element in defining a blade technology. Either bifacial or unifacial flaking can be used to create a ridge—or crest—to guide the first blade removal. Detaching this ***crested blade*** establishes ridges for subsequent blade removals. As blades are successively removed, the platform from which they are struck may need to be "rejuvenated" to reestablish the proper angle before another blade can be detached. This platform-rejuvenation flake is often referred to as a ***core-tablet flake***. Expended or exhausted ***wedge-shaped*** and ***conical***

Conical blade core, showing the platform surface and blade removal faces. Blades are removed in a single direction from the proximal, or platform, end downward toward the tapering distal end. The platform surface is scarred from multiple deep flake removals as a result of maintaining the platform. Several scars that terminate in a hinge or step fracture will need to be cleared by detaching a core-tablet flake before more blades can be removed. The dark outline *(bottom right)* shows the next potential blade that could be removed.

exterior blade surface that define this cross section, and you've got yourself a bona fide blade.

detaching the flake. It's EXTREMELY IMPORTANT to prepare the platform beforehand by abrading. To avoid breaking the piece you're working, it's equally important to support it (your thigh protected with a sturdy piece of leather or a folded towel makes a good work surface).

You use soft- and hard-hammer percussion to remove a flake by striking the stone. With ***pressure flaking,*** on the other hand, you remove a flake from a stone by pressing a smaller, pointed pressure flaker (an antler tine probably served Paleoindians wonderfully) against a prepared platform. Pressure flaking gives you optimum control and is therefore usually used to finish the fine edges of tools. Pressure flaking removes flakes similar in shape to those made by soft-hammer percussion, but smaller. Place the pressure flaker on the edge of the stone tool, then apply firm pressure downward and in the direction you want the flake to follow. The edge must be dull enough not to crush under the flaker, but sharp enough to prevent its slipping off. Again, abrading is a good technique to use to prepare the edge. Not an easy technique to master. And beware of driving the detached flake into your finger or hand!

Dickens has removed a large endthinning flake from the biface.

Indirect percussion is a valuable technique for use when making blades, especially small blades or blades of consistent size, that require directing a blow at a precise spot on the core platform. With this method you don't directly strike the core platform. Instead, you hit a punch, which can be antler or wood or today even metal, with a hammer, thereby directing force at exactly the spot needed to detach uniform flakes. The question that has plagued archaeologists and lithics analysts is, Who or what held the core while the Paleoindian knapper's one hand was holding the punch and the other hand was striking the hammer? Theories have varied widely; most rely on the idea of some sort of vise—perhaps holding the core between one's toes or feet, as adept Oriental artisans do today.

Indirect percussion explains how Clovis and Folsom knappers probably removed fluting flakes. After all, a fluting or end-thinning flake is a flake usually twice as long as it is wide and very bladelike in that respect. Removing a fluting flake from the base of a projectile point requires extremely accurate aim. This is especially true if the base of the point is concave and the "ears" of the point obstruct the platform of the fluting flake. Not only does a punch improve the likelihood you'll detach the flake, it also lessens the risk you'll break the point.

LITHICS SPEAK

Blades vs. Bifaces in the World Series of Clovis Technology

IN THE PAST, blade technology generally has been considered a way to "get more bang for your buck," an efficient means of producing a fairly standardized product (e.g., long, sharp blades) that yields the maximum amount of usable cutting edge from a piece of toolstone. And, as we learned last time in part II of this series, the biface is a resourceful, long-life tool, which at the end of its use life can be used as a core to produce flakes (which can then be made into other tools). Thus the biface itself can be made into a knife, projectile, or other bifacial tool. So which technology, blade or biface, is *really* more efficient?

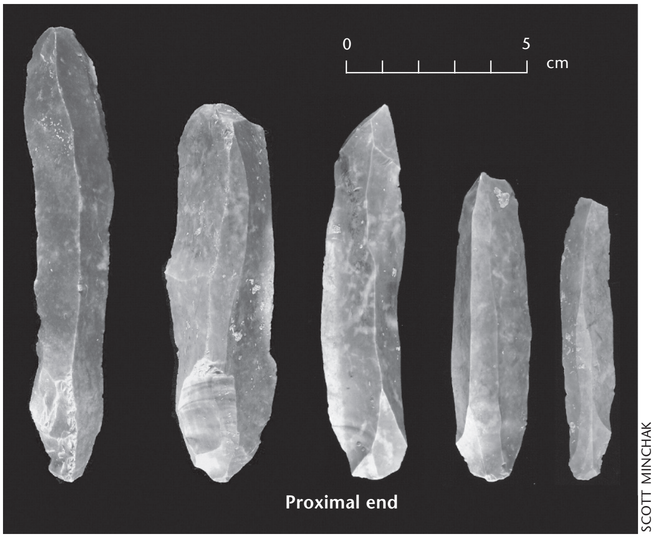
This question hasn't been an easy one for archaeologists to answer, and attempts to answer it have produced mixed results from researchers. For example, in recent experiments Mary Prasciunas of Westland Resources, Inc. found no significant difference in the yield of usable flake edge from reducing bifacial cores compared with ***informal cores.*** (So far, we've only talked about bifacial and blade cores, but there are other types lurking out there. With an informal, or ***amorphous,*** core, flakes are removed in many directions and from many platforms around the circumference of the core. Informal cores are usually considered less efficient because flakes aren't removed consistently in any one direction from a single platform.) Mary's research suggests that informal cores are actually *more* efficient producers of flakes than bifacial cores.

Metin Eren of Southern Methodist University and his cohorts recently tackled the issue of core efficiency to better understand the Middle to Upper Paleolithic technological transition in Europe. Their experiment compared the efficiency of prismatic blade cores with ***discoidal cores.*** (Yes, another core type. We archaeologists just love to "type" things. The discoidal or ***Levallois core,*** a type of bifacial core shaped like a disc, is almost exclusively associated with Neanderthal lithic technology.) Metin and company found that reducing discoidal cores yields more usable flakes per gram of raw material than reducing prismatic blades.

Hmmmm. . . . Informal beats out bifaces. Discoidal trumps blades. The top two long-standing contenders, biface and blade technologies, knocked out of the efficiency race. So what's *really* more efficient? More importantly, and to return to our subject matter at hand, "What Does It Mean to Be Clovis?" what does this mean for Clovis, which incorporates both biface and blade ***cores*** also can be considered by-products of producing blades.

A brief history of Clovis blade technology

First reported in the '60s, blades were identified in two separate Clovis caches at Blackwater Draw Locality 1 in New Mexico. But they were rarely noted elsewhere in the U.S., and most archaeologists considered the Blackwater Draw and Green blade caches (as they are referred to) mere isolated occurrences. Paleoindian archaeologists just didn't believe blades were a common component of the Clovis toolkit. Of course, the evidence at the time was sparse, and over the years that misperception has been set right, along with several other misconceptions concerning Clovis blade technology. Things really started getting interesting in the late '90s for two reasons: 1) Texas State archaeologist Mike Collins published his seminal book on Clovis blades, and 2) new Clovis sites, with an abundance of blades and blade by-products in good stratigraphic context, were thoroughly excavated.



Regular noncortical blades showing the exterior surface. Because these were removed by direct percussion, the margins are generally parallel. Note the previous blade removals on the exterior surface that create trapezoidal and triangular cross sections.

Collins was the first to try to understand and define Clovis blade technology by comparing blades from known Clovis contexts (like those found in the Blackwater Draw and Green caches and at Clovis sites like Murray Springs) with blades from other sites that may or may not be Clovis (like the Keven Davis cache in Texas) or sites with surface context (like the Adams site in Kentucky). His research prepared him to define "a distinctive constellation of attributes" for known Clovis blades (in addition to the basic characteristics that define blades). These include small abraded platforms, longitudinal curvature, smooth interior surfaces, and length. Clovis blades are loooooong, frequently longer than 100 mm—that's over 4 inches on a regular basis! Contrast that with the average length of Alaskan microblades of around 20 mm, less than an inch.

Since Collins's initial research we've dispelled several other misunderstandings about Clovis blade technology. For example, we used to believe Clovis blades were produced using indirect percussion; we also believed that conical cores were typical of Clovis blade technology and that wedge-shaped cores were the anomaly. Both false perceptions were the fault of a simple lack of data. Identifying new Clovis sites

MAMMOTH TRUMPET

technologies? Well, my good friend and colleague, doctoral candidate Tom Jennings of Texas A&M—with the help of knapper extraordinaire Bill Dickens—set out to do some experimenting to address this question.

À la Clovis, we directly compared the flake-production efficiency of bifaces with the blade-production efficiency of wedge-shaped cores. Our data appear to show that the package size of raw material, which considers *weight,* not the count of usable flakes, determines which core-reducing strategy to use. Minimizing stone transport weight was a primary concern for mobile Early Paleoindian hunter-gatherers. Makes sense, right? Who wants to lug around a bunch of heavy rocks? Though it may seem counterintuitive, reducing informal or amorphous cores is the most transport-efficient technology; small informal cores (<1000 g) are more efficient than biface or blade cores.

CHARLOTTE PEVNY

Cortical and noncortical blades litter the ground after a knapping session by Dickens.

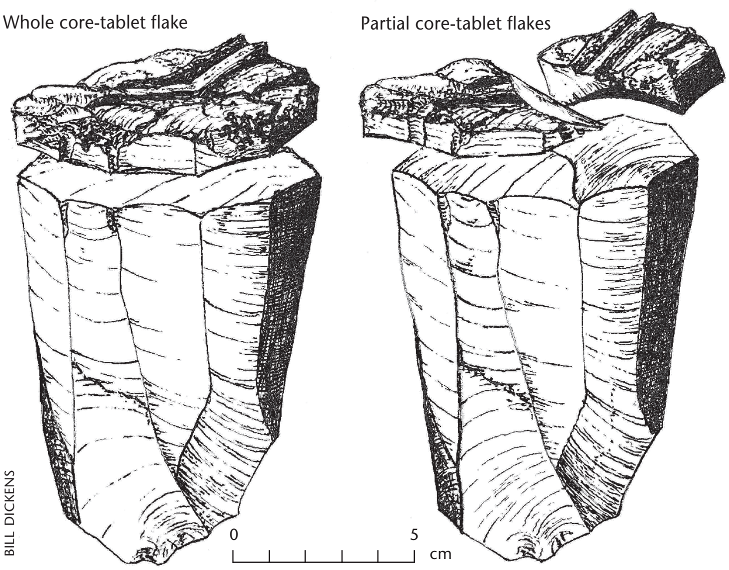
Folsom hunter-gatherers—the most mobile of the mobile—transported stone very efficiently. On the Southern Plains, where high-quality, large nodules of Edwards or Alibates chert were readily accessible, Folsom knappers used bifaces as cores. In areas where raw-material size and abundance varied, say farther to the north, then informal cores were the core of choice.

Clovis knappers, however, didn't rely heavily on informal cores, though they occasionally appear at a few sites and in a few caches. Reducing biface and blade cores is the staple of Clovis lithic technology, attested to by their abundance in caches (they're part of the mobile toolkit) and at archaeological sites of all types—kills, camps, and quarries. Perhaps Clovis groups weren't always *über* highly mobile foragers, like their Folsom successors. If so, then their core technology wouldn't value transport above other considerations, such as the distribution of raw material and package size.

like Gault in Texas and Topper in South Carolina, and reanalyzing existing collections, especially those recovered from caches on the Southern Plains, have demonstrated that wedge-shaped cores are definitely the "norm" and that direct percussion was the technique most often used to remove Clovis blades from the parent core.

Clovis blade technology is a strong presence on the Southern Plains and its periphery. In Texas it's well represented at the Gault and Pavo Real sites and the Keven Davis cache. Small blades and a core-tablet flake were found at the Aubrey site, also in Texas. The Anadarko blade cache, another find rich in specimens, is located just north in adjacent Oklahoma. Blades and tools made on blades were recovered from the kill-associated camp at Murray Springs, Arizona, west of Blackwater Draw. Blade cores (and broken bifaces with endthinning) have even been recovered from the El Bajio site in Sonora, Mexico (**MT 24-3,** "Beyond the Border: Paleoamericans in Sonora, Mexico"). The location of these sites and caches isn't an accident: They're all within walking distance of high-quality Edwards chert (that is, if you happen to be a member of a group of mobile hunter-gatherers and are used to walking).

Clovis blade caches vary widely in location (they've been identified as far away as northern Minnesota in the Pelland cache) and in raw-material type. David Kilby has done legwork similar to Mike Collins's (and then some) and come to the conclusion that the blades in these caches and others match the defining characteristics of Clovis blades. Farther east, blade technology is robustly represented at the Topper site in South Carolina. A few other sites in the East, such as the Carson-Conn-Short and Johnson sites in Tennessee, hold promise for additional comparative information on Clovis blade technology.



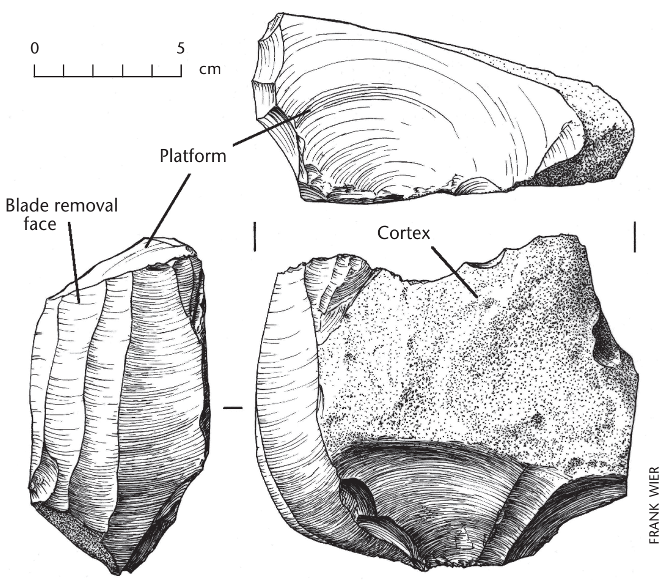
BILL DICKENS

Core-tablet flakes rejuvenate the platform by removing scars and other flaws, making a fresh surface for striking off blades.

Producing Clovis blades

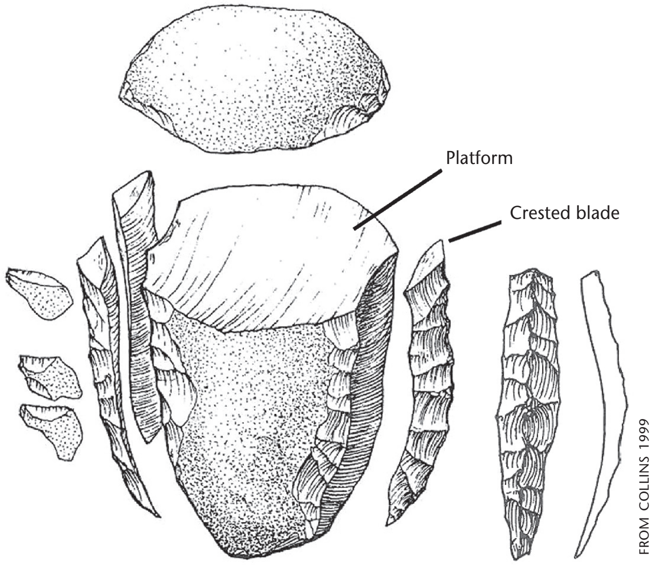
Based on our discussion above, we know that Clovis blades are removed in a definite sequence from a prepared core. A specific set of skills is employed to create a desired product—

a Clovis blade isn't just a random flake with a length twice its width. As we mentioned in Part II of this series, the by-products related to initial core preparation (e.g., normal flakes) aren't always easy to assign to either reducing bifaces or producing blades, mainly because of the limitations imposed by certain raw materials. But some of these by-products, termed ***cortical bladelike flakes*** and ***cortical irregular blades***, are definitely more bladelike than others. Even though they may not be related to blade production, they can be twice as long as they are wide, with triangular or trapezoidal cross sections. Where do these imposters come from? Well, take an angular piece of Edwards chert, for instance; the intersecting faces frequently provide naturally occurring ridges for detaching the initial blade. If there's no ridge, then small flakes are removed to create the edge or crest, which directs the removal of the first blade, referred to as a ***crested blade***. Detaching a crested blade leaves two ridges on the face of the core, which guide other blade removals. Flakes and blades like to follow ridges on core faces, be they bifacial or blade cores; in Lithics Speak, these ridges are known as ***arrises***.



Wedge-shaped core from the Gault site, Texas, showing the platform, blade removal face, and lateral or side view. The platform is free of hinge and step fractures, which implies that the platform either had been freshly rejuvenated or required little maintenance.

After the blade face and platform are established—ideally 90° for conical cores, an acute angle greater than 45° for wedge-shaped cores—blades can be detached. Depending on the exact shape of the initial piece of raw material and the pattern of blade removal, two types of blade cores may be formed, ***conical*** and ***wedge-shaped cores***. Clovis blades are removed around the circumference of a conical core parallel to its long axis; blade scars commonly meet at the distal or bottom end of the core, creating a cone or pyramid shape. In the case of a wedge-shaped core, blades are removed from along the intermediate axis and are typically curved in profile. On a conical core, blades are typically removed from only one or two platforms (if blades are removed from the top and bottom it's considered a bidirectional core). Blades from wedge-shaped cores, on the other hand, often are removed from several faces, resulting in multidirectional cores.



Conical blade core prepared by removing one end and bifacially flaking two faces to create a ridge to guide the removal of the initial crested blade.

As blades are detached, the platform angle changes and the platform is crushed, which makes it necessary to reestablish a viable platform. To further complicate the toolmaker's task, a failed blade removal may terminate in a step or hinge fracture on the face of the core; this flaw must be removed from the face before more blades can be detached. In making Clovis blades, the platform is rejuvenated by removing core-tablet flakes. Sometimes removing a core-tablet flake from a conical core detaches the entire platform surface with a single blow—a phenomenon observed at the Gault site. Core-tablet flakes are fairly easy to recognize because they bear the scars of previous blade removals around their perimeter. The platform of a wedge-shaped core is rejuvenated by removing one or two flakes, or occasionally a core-tablet flake, from the platform surface. Once the proper angle and an acceptable platform are reestablished on the core, blades are removed until the core is exhausted. The complex 3-D puzzle of refits from the Pavo Real site clearly demonstrates this repetitive process of removing blades and rejuvenating the core.

Noncortical regular blades are the desired product from conical cores. Noncortical regular blades are also the intended product from wedge-shaped cores; in practice, however, blades removed from wedge-shaped cores are often ***cortical regular blades*** that retain cortex on one side of their exterior face. The cortical edge retained on some blades is a natural "backing" that makes it easier to grip an unhafted blade without cutting yourself on sharp edges. These "regular" blades (regular, because they unequivocally fit the definition of classic Clovis blades) were then used by Clovis folks for a variety of activities. Mike Collins refers to Clovis blades as "Swiss Army knives," and he's got solid data to justify the playful nickname—extensive analyses over the last 10-plus years by a variety of microwear analysts like Marvin Kay of the University of Arkansas, Scott Minchak of Texas A&M University, and Marilyn Shoberg of the Gault School of Archaeological Research.

Clovis blades were used to cut and scrape a wide variety of materials like meat, hide, bone, and plant resources. Usually they were used "as is" with little additional modification. Sometimes they were shaped into a form appropriate for a specific task, like boring or drilling. We haven't found evidence, at least not yet, that Clovis blades were ever segmented or broken for making composite tools similar to those found in Alaska (e.g., harpoons) and parts of the Old World (e.g., sickles).

How to contact the author of this article:
Charlotte Donald Pevny, PhD, RPA
R. Christopher Goodwin & Associates, Inc.
309 Jefferson Highway, Suite A
New Orleans, LA 70121
e-mail: cpevny@rcgoodwin.com

Suggested Readings

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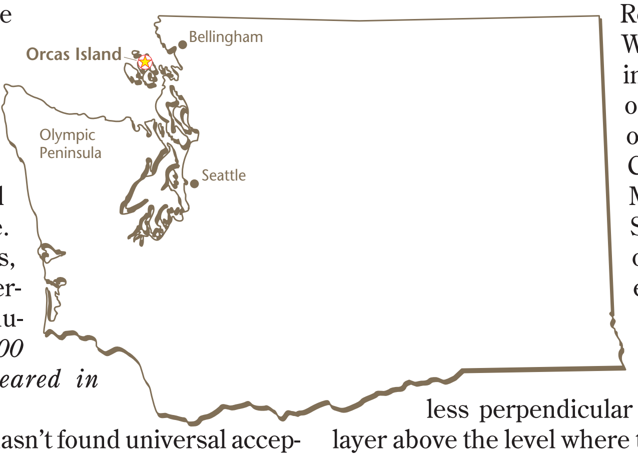
The well-preserved skull of the Ayer Pond male *Bison antiquus,* radiocarbon dated to 11,990 ± 25 RCYBP (UCIAMS-53549). Note the healed injury to the left nasal. Wilson notes that *B. Antiquus* specimens found in the San Juan Islands had a body comparable in size to any of this species, "but the horn cores were reduced in size, in comparison with animals of comparable antiquity from the Great Plains. This is likely an insular effect—island animals often undergo size reduction or other changes, due to dietary or other factors. So there is much more still to be said (and learned) about these particular bison."

EXCEPT AS NOTED, ALL PHOTOS: STEPHEN KENADY

Pre-Clovis Butchers of *Bison antiquus*

WORKMEN digging out a peaty wetland to create a pond on the south end of Orcas Island in Washington State made a discovery that is contributing to our understanding of when and how the first Americans discovered and peopled this New World. In 2003, when a trackhoe operator noticed a bone sticking out of the side of his excavation, he and his coworkers became curious. Digging into ancient peat with their bare hands, they recovered the well-preserved skull and 97 other bones and bone fragments of *Bison antiquus,* an extinct form of bison that lived in this region during the Ice Age. Despite the absence of stone tools, a team of scientists has found powerfully convincing evidence that humans butchered this animal *400–800 years before Clovis hunters appeared in America.*



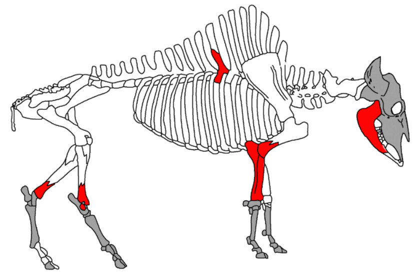
Although this astonishing find hasn't found universal acceptance throughout the scientific community, it has caught the attention of so many scientists and members of the general public that *Discover* magazine included it in the 10 top science stories for 2008.

Perhaps the most complete *B. antiquus* specimen ever found

The Ayer Pond bison was found in 2003, but the bones remained in a cardboard box stored in the garden shed of one of the workers until 2005, when the remarkable discovery came to the attention of archaeologist Stephen Kenady with Cultural Resource Management in Sedro-Woolley, Washington. To him the importance of the bones was obvious, so in 2007 Kenady, with archaeologists Dr. Randall Schalk, from Cascadia Archaeology, and Robert Mierendorf, from the National Park Service, conducted a geoarchaeological investigation of the discovery site assisted by volunteers Norm Exton and Marshall Sanborn. Using a trackhoe, they excavated four trenches more or less perpendicular to the edge of the pond. An ash layer above the level where the bones were found proved to be tephra from the 6730 RCYBP eruption of Mount Mazama. The bones therefore had to be considerably older than this.

The Ayer Pond bison skeleton, though missing many members, nonetheless is remarkably intact. Kenady notes that

◀ **Loose relative refit of major skeletal elements of Ayers Pond bison.**



▼ **The Ayers Pond *Bison antiquus* skeleton. Shaded areas identify unmodified bones; bones in red bear green-bone fractures, points of impact, cutmarks, or polish. Unshaded bones are missing.**

more-complete bison skeletons have been assembled (at La Brea, for example) as composites of bones from many different individuals. In the Ayer Pond specimen, Dr. Michael Wilson of Douglas College in New Westminster, British Columbia, notes that "we have the luxury of an associated individual, and one with a cranium, at that—and all of it beautifully preserved."

Kenady's team found sediment layers that closely matched what the workmen had described. The bones lay well below the ash layer and the peat in a layer of gray clay and mucky silts that rested on a layer of blue sand, which contained marine shellfish remains. As relative sea level dropped, this region changed from a marine to a nonmarine environment and the depression became a freshwater pond. A radiocarbon date on the bones places the death of the bison at around 11,990 RCYBP, which agrees with the geological age of the deep layer where the bones were found.

A setting on the pathway to the Americas

Orcas Island, lying between the southern end of Vancouver Island in Canada and the coast of Washington, is one of scores of large and small islands in the San Juan archipelago, which skirts the northwest coast of North America. These islands are the remains of a much more extensive land mass that existed prior to the melting of the Pleistocene glaciers. It's understandable that the western coast of the Americas is widely considered to have been one of the avenues traveled by the original colonizers of this hemisphere.

The Orcas Island bison isn't the first discovery of late-Pleistocene megafauna made in this region. Nearby Vancouver Island has yielded three *Bison antiquus* finds. In the San Juan Islands at least 11 others have been found as well as the remains of ground sloth and giant short-faced bear. The dated bison from three locations date from 11,990 to 10,800 RCYBP; the supporting ecosystem therefore survived at least that long. The profusion of ancient bones found in this region attests to the abundant megafauna that once thrived here; their exceptional state of preservation can be attributed to numerous wetlands with low acidity.

▲ **Angular green-bone fractures, right distal humerus.**

◀ **Tibia with V-section chop/cut mark aligned with astragalus split.**

Paleoamerican presence has also been documented in the northern Pacific coast region. Clovis points and early stemmed lanceolate points have been stray finds in the Puget Sound area, and points similar in form to Western Stemmed and Windust types were found at the DeStaffany site in the San Juan Islands. Documented evidence for a pre-Clovis human occupation includes coprolites and other traces of human activity at the Paisley Caves in Oregon (**MT**

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25-4, 26-1, “Paisley Caves”) and the Manis mastodon, found on the Olympic Peninsula in Washington State with a putative antler spear point embedded in a rib.

Who (or what) killed the Ayer Pond bison?

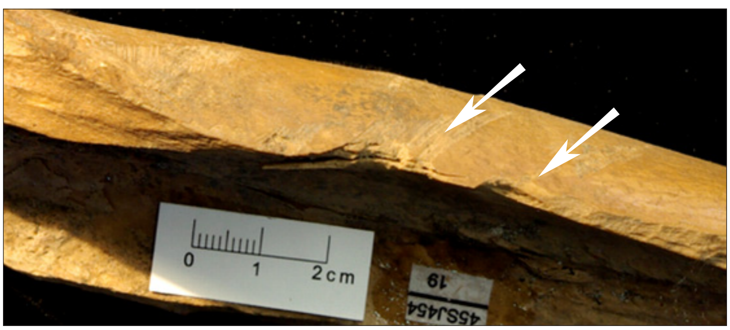
Bison antiquus was an extinct ancestor of modern bison, a monster 25% larger than its modern descendants. Fluted spear points found with *Bison antiquus* bones at Folsom, New Mexico, in 1926 provided the first clear evidence for the presence of people in America during the Ice Age.

Examples of possible cutmarks *(right)* and polish *(below).* Kenady and his team don’t credit such indicators of possible butchering because they can be the result of natural agents.

No projectile points or stone tools of any kind were found with the Ayer Pond bison, so what makes the investigators think early Paleoamericans had anything to do with its demise? Various features of the site and the bison skeleton eliminate the possibility that natural agents were involved and lead to the conclusion that the animal was killed or at least scavenged by human hands. The evidence falls into three categories: site taphonomy, patterns of bone breakage, and traces on the bones that meet the criteria for stone-tool impact marks and cutmarks.

Evidence from taphonomy

The collection of beautifully preserved Ayer Pond bison bones includes both large and small bones. Features of the skull and teeth indicate the animal was a mature male 7–8 years old. That both large and small bones of the skeleton were found together argues against the possibility that they were washed into the pond by rushing water, which would have transported smaller bones farther than larger bones, especially the skull. Moreover, there are no scratches on the bones that would indicate they had been tumbled roughly along a stream bed before coming to rest at the bottom of the pond.



Impact fractures.

The Ayer Pond bison skeleton includes the skull, one thoracic vertebra (the spinal member that anchors a rib), the right lower front leg, left lower front foot, and both lower hind legs. Kenady and his co-researchers observe that the bones that are present consist largely of “non-meaty, low-utility elements,” which suggests the highest-value parts of the carcass have been removed. This “gourmet butchering” pattern, they note, is typical of Paleoamerican bison kill sites.

In examining the breaks and markings on the bone, it became clear to the investigators that “nearly all fractured, cut, or polished bone surfaces had the same color as adjacent unmodified bone.” This means that all bone modifications share “a common history of exposure to processes which have effected color change.” And because the workmen that discovered the bones excavated them without using metal tools, apparent cutmarks on the bones couldn’t have been made by shovels or trowels.

Evidence from bone-breakage patterns

The larger limb bones “show spirally-fractured ‘green bone’ breaks.” Green-bone fractures, characterized by sharply defined edges and smooth fracture surfaces, identify bone that is from a living or very recently dead animal. Dried, older bone shatters in a very different way. Green-bone fractures, especially when associated with points of localized impact, suggest that humans may have intentionally broken the bones to obtain the rich marrow or to quarry stock for making bone tools (**MT 23-1,** “Early Mammoth Bone Flaking on the Great Plains”). Natural processes, however, can also account for green-bone fractures. That’s why the taphonomy of the site as well as other evidence for bone modification must be taken into consideration.

Evidence from markings on the bones

Kenady and his co-investigators interpret a variety of markings on the bones as evidence of human modifications, including “points of impact” and cutmarks.

A point of impact—damage caused by a localized sharp blow or crushing force—is identified by a ring-shaped fracture radiating from a single point. Kenady and his team observed 13 points of impact, of which 5 were associated with concentric ring fractures. Four bones exhibit polish, defined as a bone having “a rounded visibly shiny edge or point.” Four bones had parallel, straight, shallow V-shaped scratches less than 1 mm deep. Finally, V-shaped cuts more than 2 mm deep were found on a distal right tibia and fragments of the right astragalus; in fact, it was one cut that severed the astragalus into two pieces.

The right radio-ulna—the lower front limb (forearm) bones of the Ayer Pond bison—exhibits two impact fracture points that

Kenady and his coauthors attribute to "blows by a heavy object with a gritty surface, likely a cobble chopper." Large grooves with V-shaped cross sections they interpret as "cleaver-like chop marks." They acknowledge that whereas some researchers regard such gouges as "definitive of butchering," others caution against drawing conclusions from isolated occurrences.

The relatively small number of cutmarks might be dismissed by some authorities as evidence of butchering, but Kenady and his coauthors observe that "experimental butchering studies using large ungulate bones have shown no relationship between carcass processing intensity and creation of cutmarks." Moreover, they note that cutmarks are rarely found on bones from Paleoamerican butchering sites compared with sites of later time periods.

The kinds of bones, and even the particular places on the bones, on which marks are found are almost as revealing as the marks themselves. On a butchered bison at the Casper site in Wyoming, for example, the bones exhibiting the greatest incidence of impact marks were the upper and lower limb bones. Kenady and his coauthors note that the Ayer Pond specimen "fits this pattern closely."

Moreover, on the Casper bison impact marks occur in the same places on the bones as on the Ayer Pond bison bones. The same patterning holds true on bison bones at the Hell Gap site in Wyoming and the Stewart's Cattle Guard site in Colorado. In both these instances the damage was attributed to Paleoamericans breaking the bones to get at the rich marrow.

Further arguing the case that humans and not natural agents modified the Ayer Pond bison bones, Kenady and colleagues point out that two impact-fracture points on the right radio-ulna lie on the front-facing surface of the bone. These blows could only have been struck "with the limb segment rotated and supported so that the [front] surface was uppermost." They note that "similar fracture patterns have been interpreted as evidence for butchering on other bison" and that "almost identical fractures are known from Plains bison kills spanning the Holocene." Wilson argues their case most strongly: "If we reject the Ayer Pond butchering evidence we also call into question a lot of the butchering evidence from Plains Paleoindian bison kills."

Mierendorf in an exploratory trench adjacent to Ayer Pond, 2007. The arrow marks where the bison was found.

Alternative explanations

In the absence of stone tools, the case for human involvement depends upon interpreting the Ayer Pond bison bones themselves—the presence and absence of certain bones, their spatial orientation, breakage patterns, and various marks found on the bones. Can these data prove categorically that humans butchered the carcass, or could the damage be the result of other processes, such as predation by carnivores?

Kenady and his colleagues studied examples of bone modification by wolves, dogs, wolverines, African lions, hyenas, bears, and the extinct giant short-faced bear, *Arctodus simus,* to determine whether any of these predators and scavengers could have caused the damage to the Ayer Pond bison bone assemblage. Of all these candidates, only wolverines and short-faced bears regularly fractured bones as large as those from bison, but they inevitably left large bones heavily tooth-marked. Considering that no large teeth marks were observed on the Ayer Pond bison bones, these animals don't appear to have been involved with this carcass.

It's noteworthy that Kenady and his team have dismissed as indicators of a human presence such bone modifications as polish and parallel scratch marks. "Polish can result from many other processes such as abrasion from wind or waterborne abrasives, licking by carnivores, and persistent

Bison aren't what they used to be

The American buffalo, *Bison bison,* is an impressive beast. A bull may stand 6 ft high at the shoulder and weigh upwards of a ton.

It pales beside its giant ancestors, though. Paleoamerican hunters had to contend with *Bison antiquus.* Extrapolating from skeletal remains, Larry Todd at Colorado State University estimates that a large bull stood 7½ ft tall and weighed 2,400 pounds! Its horns were equally daunting, 4½ ft from tip to tip. (The long-horned bison, a rarer species, had a span of 6 ft.)

B. antiquus is a hypermorph, the term paleontologists use to identify megafauna that flourished in the Pleistocene—giant beaver, Irish elk with 11-ft antlers, ox-size ground sloths. Why they grew so huge is still debated. Perhaps it was a result of the super-fertile periglacial environment, or a response to the increasing size of predators—saber-tooth cats, dire wolves, and the giant carnivorous bear *Arctodus.*

Paleoamerican peoples surely deserve respect: they killed and butchered *B. antiquus* using only flintknapped tools.

–*Ed.*

***Bison antiquus,* formidable prey for Paleoamerican hunters**

DRAWING COURTESY OF HISTORIC RESOURCES BRANCH, MANITOBA CULTURE HERITAGE AND TOURISM.

rubbing," Kenady explains. "Likewise parallel scratch marks can be the result of movement across a coarse surface caused by many natural agencies, and therefore they do not necessarily indicate human activity." This is a team of careful scientists who are confident they have excluded all natural agents as the possible cause of the extensive systematic damage found on the Ayer Pond bison skeleton.

MEREDITH GRIFFITH/ISLANDS' SOUNDER NEWSPAPER

Conclusions

Drawing on all the various lines of evidence, Kenady and his colleagues suggest that the *Bison antiquus* was killed, or at least butchered, by precursors of Clovis people on the frozen surface of Ayer Pond. Any carcass parts left over would have frozen rapidly and so might have escaped the notice of scavengers, which would account for the absence of tooth marks on the bones. When the ice melted in early spring, the remains of the carcass would simply have settled gently to the bottom of the pond, which would account for the tightly clustered large and small bones in the pond deposits.

Kenady x-raying the bison skull to search for possible lithic fragments embedded in a healed nasal injury, June 2010. ▲

Wilson on Orcas Island presenting the first public lecture on the Ayer Pond bison, 2006. ▶

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An alternative hypothesis is that human hunters killed and butchered the bison elsewhere, then transported the remainder of the carcass to the pond, where they deliberately submerged it to serve as a meat cache. This borrows from the idea proposed by University of Michigan paleontologist Dan Fisher to account for clusters of mastodon and mammoth bones found at the Heisler site in Michigan (**MT 6-4,** "Clues to Paleoindian Survival: Underwater Caches May Have Supplied Meat in Winter"). Kenady and colleagues, however, regard the caching interpretation as unlikely because most of the bones in the Ayer Pond assemblage yielded relatively little meat. They admit the possibility, however, that high-yield bones may later have been removed from the cache and only the least useful parts were never retrieved.

Kenady and his coauthors conclude their analysis by stating that "butchering by humans is the explanation that is most consistent with all of the physical evidence that is currently available." If they are correct in their interpretation, then the date of 11,990 ± 25 RCYBP for the Ayer Pond *Bison antiquus* assumes enormous significance, for it becomes irrefutable evidence for the presence of pre-Clovis humans along the Pacific Coast, which in turn lends credence to the increasingly popular theory that immigrants from Northeast Asia entered this hemisphere following a coastal route instead of waiting for the Ice-free Corridor to open. Further investigations in this region may someday turn up evidence of similar-age kill sites with stone or bone tools. This would provide the "smoking spear point" needed to convince doubting scientists that pre-Clovis Paleoamericans were present in the Pacific Northwest and that they killed and butchered the Ayer Pond bison.

–Bradley Lepper

How to contact the principals of this article:
Stephen M. Kenady
Cultural Resources Management
5319 Cedar Ridge Place
Sedro-Woolley, WA 98284
e-mail: smkenady@gmail.com

Michael C. Wilson, Chair
Department of Earth and Environmental Sciences
Douglas College
P.O. Box 2503
New Westminster, BC V3L 5B2, Canada
e-mail: wilsonmi@douglas.bc.ca

Suggested Readings

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