MAMMOTH TRUMPET

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Center for the Study of the First Americans
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Tracking hardy Paleoamericans

Equally hardy members of Kurt Rademaker's team venture from this base camp at 4480 masl in the Peruvian Andes to investigate the Cuncaicha Rockshelter (*arrow*), where they found occupations dating from the terminal Pleistocene. See our story on **page 15.** Photo by Kurt Rademaker

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Genetics Studies Reveal Rich History of Ancient America

Part 2
Peopling of Central and South America

IN PART 1 OF THIS 2-PART SERIES reviewing the latest genetic evidence for the peopling of the New World, we looked at the work of Eske Willerslev and his team, which encompassed the entire Western Hemisphere. In part 2 we focus narrowly on research in Central and South America. This research shows why this region is so important for our understanding of the peopling of the Americas. For example, it reveals that some ancient Central and South American populations share especially close ties with the Anzick child (**MT 29-2,** "Clovis child answers fundamental questions about the First Americans"), but that the majority of later groups don't. This shows us that the idea that a single, small, homogenous population entered the Americas at one time, spread rapidly through the hemisphere, and became the ancestors of all indigenous Americans is wrong.

David Reich of Harvard Medical School, Johannes Krause with the Max Planck Institute for the Science of Human History, and Lars Fehren-Schmitz of the University of California, along with a team of 70 coauthors from 13 countries, conducted genome-wide analyses of 49 individuals from Central and South America. Their goal is to reconstruct the population history of Central and South America over the last 11,000 years. They present their results in the November 2018 issue of the journal *Cell*. The first shared authors are Cosimo Posth and Nathan Nakatsuka, who also are with the Max Planck Institute for the Science of Human History and Harvard Medical School, respectively.

Genetic history revealed by 49 genomes

Reich, Krause, Fehren-Schmitz, and their team obtained genomes of 49 indigenous individuals from across Central and South America, including 15 from Peru, 15 from Brazil, 11 from Argentina, 5 from Chile, and 3 from Belize. Of these individuals, 41 were more than 1,000 years old. They include an 11,900-year-old individual from the Los Rieles site in Chile, 7 individuals 10,000–9,200

INSIDE

years old from Lapa do Santo in Brazil, and individuals from Arroyo Seco 2 and Laguna Chica in Argentina that date to 8570–7160 CALYBP. They then combined "ancient and present-day data to study genetic changes over the last 11,000 years."

The team's analyses reveal that the Anzick child is more closely related to Central and South American groups than to any North American population. They all are part of the Southern Native American family, which diverged from the Northern Native American group shortly after the First Americans moved south of the ice sheets. There are some exceptions, however. For example, the Anzick child is also closely related

Nakatsuka.

to individuals nearly 5,000 years old from the Channel Islands of California. This North American population may represent an early migration of relatives of the Anzick child that settled on the islands and became largely isolated from genetic exchanges with other North American populations. The team also found that some regional populations in South and Central America, such as the Los Rieles individual from Chile, the individuals from Lapa do Santo in Brazil, and those from southern Peru, are more closely related to the Anzick child than are other South Americans. The team observed that this finding supports the idea that the North American Clovis culture "also affected Central and South America." Clovis points are absent in South America, but it long has been supposed that the South American Fishtail Point Complex was directly related to Clovis. Reich, Krause, Fehren-Schmitz, and their coauthors note that testing this hypothesis would "require ancient DNA from a Fishtail context."

The team found that the most ancient individuals in their sample didn't have strong genetic ties to the people currently living in the same areas. As an example, they note that the Los Rieles individual, who lived in Chile 11,900 years ago, was only slightly more closely related to later peoples in the region than to groups from across Central and South America. And the Brazilian individuals, from Lapa do Santo dating

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–Michael R. Waters, Director

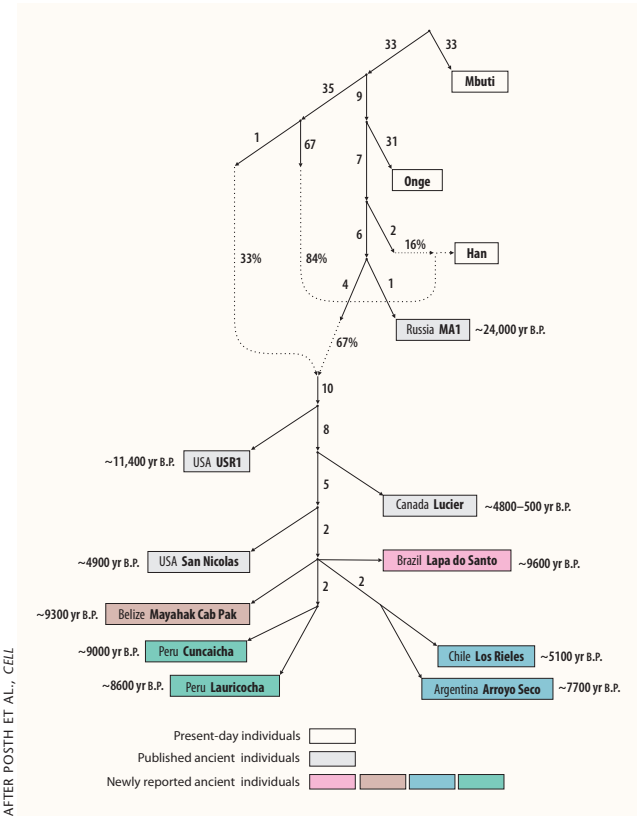
to 9200–10,000 CALYBP and those from the 6,700 CALYBP site of Laranjal, "show no distinctive shared ancestry with present-day Brazilians." In contrast, the team detected "continuity between ancient and present-day Native Americans in each of the regions of South America" beginning by at least 5800 CALYBP and in some regions, such as the Central Andes, as early as 9000 CALYBP.

Modeling genetic exchanges between regions

Reich, Krause, Fehren-Schmitz, and their team created a series of models to determine the "relationships among diverse ancient Americans," and produced two admixture graphs that confirm "a minimum of four genetic exchanges between South America and regions outside South America." These sources of South American genetic variability include a "primary source" of Southern Native American ancestry; a separate branch of Southern Native American ancestry concentrated in Chile, Brazil, and Argentina, with a distinct connection to the Anzick child; yet another branch of the South Native American lineage with connections to the ancient individuals from the California Channel Islands; and finally, a distinctive but poorly understood source that contributed genetically to present-day Amazonian groups. This fourth source may have some connection to a group identified as "Population Y" that has some sort of Australasian connection (**MT 32-1,** "Genetic clues answer fundamental questions about the peopling of the Americas").

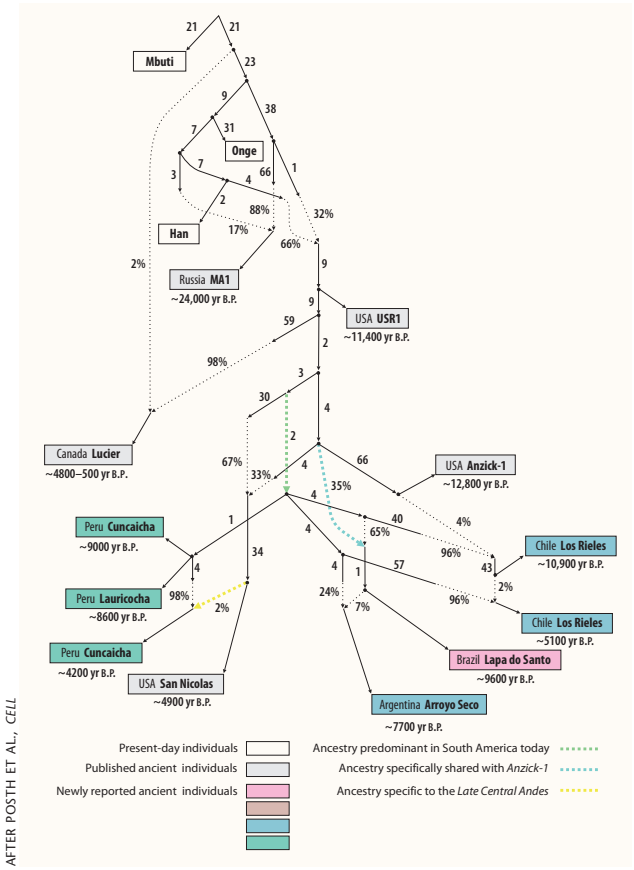
Perhaps not surprisingly, the two admixture graphs also indicate there was only a minimal contribution of Northern Native American ancestry to South American groups. In addition, the data suggest a rapid spread into and through the continent of the population that provided the bulk of the ancestry to later South Americans.

The evidence for a connection between the Anzick child's lineage and the most ancient South American individuals, including the Lapa do Santo individuals from Brazil and the Los Rieles individuals from Chile, suggests that descendants of this lineage spread far beyond the southernmost evidence of the Clovis culture. Neither admixture graph, however, supports the hypothesis that descendants of members of the Clovis culture provided the "primary source of the ancestry of later Central and South Americans." Instead, both models show that the "overwhelming majority" of the ancestry of most indigenous Central and South Americans comes from one or more lineages not directly linked to the Anzick



AFTER POSTH ET AL., *CELL*

This model shows the most likely genetic relationships between nine ancient American populations without the necessity of admixture events. The American populations obviously are most distantly related to the Mbuti of Africa and the Onge of the Andaman Islands. They are more closely related to the Chinese Han and most closely related to the Ancient North Eurasian MA-1. Branch lengths are in units of $F_{ST} \times 1000$. (F_{ST} is a measure of the genetic difference between populations.)



AFTER POSTH ET AL., *CELL*

A more complicated and realistic model of the relationships between these groups, which now includes the Anzick child and the Los Rieles individuals from Chile. This model takes into account the possibility of admixture as indicated by the color-coded lines connecting various groups. Note the significant presence of ancestry present ~4200 yr B.P. at Cuncaicha in Peru, which is absent in the other model. The authors created this model by "manually exploring models guided by common sense principles (geography, time, and archaeology) as well as the genetic data."

child's lineage. Therefore, a separate branch of the Southern Native Americans made the biggest genetic contribution to ancient South Americans, and a later population moved into the region and replaced the descendants of the Lapo do Santo and Los Rieles individuals.

Reich, Krause, Fehren-Schmitz, and their team raise the possibility that this separate branch of the Southern Native Americans is related to pre-Clovis peoples whose archaeological footprints, including literal impressions of feet, have been found at Monte Verde. On the other hand, since the earliest studied Central and South American individuals are related to the Anzick child, the team notes that these data also are consistent with a scenario in which "nearly all the ancestry of the South American genomes" is a result of population movements into South America from North America that took place during or shortly after the Clovis period.

BIZU TESFAYE. COURTESY OF HOWARD HUGHES MEDICAL INSTITUTE

Reich.

Who were the Paleoamericans?

Many ancient American human remains, such as Kennewick Man (**MT 30-1,** "Ambassador from our ancient past") and Spirit Cave Man, have distinctive physical characteristics, including a long, narrow skull with a small, projecting face, that some researchers have attributed to a population that wasn't directly related to Native Americans. We refer to these individuals as *Paleoamericans*. Reich, Krause, Fehren-Schmitz and their colleagues found no evidence that any "non-Native American" population contributed to the genomes of any of the ancient Central or South American human remains they studied. They therefore conclude that so-called Paleoamericans, including the Lapo do Santo individuals, derived "all their ancestry" from the same population that gave rise to all other Native American populations. This observation is corroborated by the findings of Eske Willerslev and his team discussed in part 1 of this series. Willerslev and his coauthors observed that all so-called Paleoamericans whose genomes have been sequenced "are genetically closer to contemporary Native Americans, than to any other ancient or contemporary group sequenced to date."

Posth working on the Lapa do Santo specimens in the ancient DNA facilities of the Department of Archaeogenetics at the Max Planck Institute for the Science of Human History in Jena, Germany.

These results make it increasingly clear that there is no evidence for any ancient Europeans, Africans, or Australians in the Americas prior to the historic era. The Paleoamericans therefore are simply Paleoindians.

What about Population Y?

Reich, Krause, Fehren-Schmitz, and their team failed to detect any "significant evidence of Australasian or Paleolithic East Asian" ancestry in any of the ancient human remains from Central and South America. This, of course, raises the question of what ancient population provided the traces of Population Y ancestry that are found in the modern Surui as well as other contemporary Amazonian groups. Although the team recommend that the search for the Population Y genetic signal in other ancient humans should be accorded research priority, they admit that the absence of this signal in their data increases the likelihood that this signal was a "false positive" and that in fact there was no Population Y.

We still have much to learn

The work of Reich, Krause, Fehren-Schmitz, and their team represents a giant leap forward in the study of the First Americans. Prior to the their research, there was only one individual with genome-wide ancient DNA data from Central and South America older than 1,000 years, whereas now the database includes 41 such individuals. Nevertheless, the team frankly admits that its research hasn't answered all our questions about the peopling of the Americas and that much more research is needed. They point out that their conclusions are limited by the fact that none of the ancient individuals they studied is older than about 11,000 CALYBP. They were therefore unable to "directly probe the initial movements of people into Central and South America." Moreover, their sample didn't include any ancient individuals from wide swaths of Central

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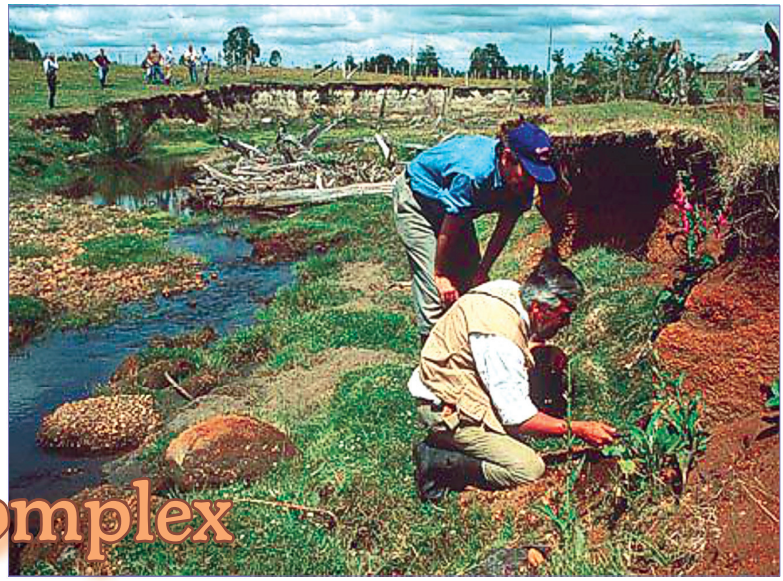


A "Blue Ribbon panel" of North American and Latin American colleagues visited the Monte Verde site in 1998. Visible in the background are visitors; in the foreground Chilean geologist Mario Pino (*kneeling*) and Dillehay are examining stratigraphy.

40 YEARS
Excavating the Monte Verde Complex

The National Council of Monuments in Santiago, Chile, in 2013 asked Vanderbilt University archaeologist Tom Dillehay to survey and test the full scale of Monte Verde. The organization wanted a better idea of the horizontal and vertical extent of the site, which had been nominated for world heritage status by UNESCO. Dillehay, however, was skeptical to return.

"I didn't want to go back, because I'm kind of tired of Monte Verde and I'm heavily involved in other things," says Dillehay. But when it was proposed that others with less expertise go in to do some of the testing and digging, Dillehay volunteered to return. "I went back again in 2017, and we excavated at Monte Verde (MV) I and also at Chinchihuapi (CH) I and II, and then last year [2018] we reexcavated exclusively at CH I, and an article just came out about that in *Quaternary Research*."

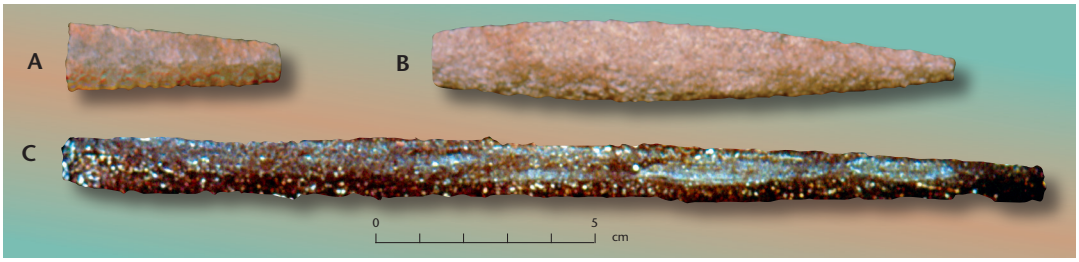
Recently, Dillehay spent 2 weeks at Monte Verde with an American crew doing a magnetometer and ground-penetrating-radar survey of the entire Monte Verde site complex, 5000-m^2 worth. "We're just now working on those data," he says, "so that's where we are."

The Monte Verde complex, a handful of sites

Dillehay's four decades of work at the Monte Verde complex revealed these sites and localities:

- MV II, dated to 14,500 yr B.P., a campsite buried in the north terrace of Chinchihuapi Creek. It has yielded the remains of a tent-like dwelling and the foundation of another structure, hearths, human footprints, remains of edible plants, and wood, reed, bone, and stone artifacts;
- MV I, dated to 33,000 yr B.P., an older, possible cultural horizon associated with a cold, non-glacial environment. It was initially defined by scattered occurrences of 3 clay-lined culturally produced burnt areas and 26 stones, of which at least 6 suggest modification by humans. MV I is buried in a sandur plain (a plain formed of sediment deposited by glacial meltwater), the Salto Chico Formation, which developed as part of the Llanquihue drift during the LGM by meltwater from moraines located 7½ km to the southeast;
- The Chinchihuapi site, dated to at least 14,500 and possibly 18,000 years ago. Its localities CH I and CH II, both on the southern end of Chinchihuapi Creek 500 m upstream from MV II, yielded a few burnt areas, chestnut seeds and other edible plants, and fragments of scorched animal bone associated with a fragment of a rhomboidal shaped projectile point made of an exotic white quartz similar to the projectile fragments excavated at MV II. This site also yielded a later-terminal-Pleistocene cultural layer with several Paiján-like projectile points, a wide variety of lithic debris, and hearths.

In terms of cultural material in strata spanning the multi-millennia period separating MV I and MV II, Dillehay's team has radiocarbon dates of 20,000–26,000 ago from burnt areas associated with a few flakes and spheroids, but the data, he admits, "are very sparse and at present inconclusive."



Lithic artifacts from the 14,500 yr B.P. Monte Verde II site. A, drill-like instrument made of an exotic slate from the coast; B–C, fragments of bipointed rhomboidal projectile points.

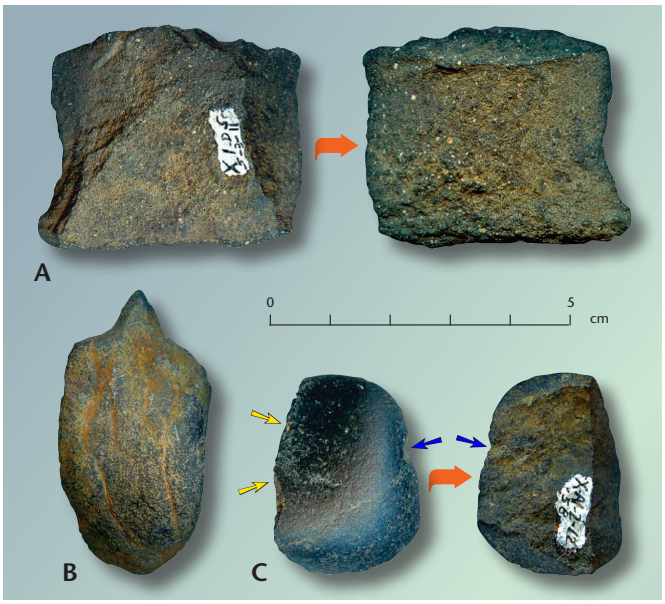
Four decades of excavation—and frustration

Over his career Dillehay has led excavations at the Monte Verde complex, and his discoveries play a crucial role in interdisciplinary research on the dating and nature of the initial peopling of South America. Recent excavations at the MV sites and the nearby CH I and II sites have discovered new cultural evidence that lends credence to the possibility of an earlier human presence on the continent.

"In regard to CH I and MV I as part of the larger MV complex," Dillehay says, "we archaeologists and geologists—usually about 10 total in collective decision making—have excavated many, many odd-looking stains and anomalies, but unless they had structure, meaning a shallow basin-like format, or a burnt area with a clay-lined pit, or contained exotic plants or mixtures of bone, lithics, and plants also associated on the same buried use surface, we didn't classify them as cultural."

Basalt flake from the 17,000 yr B.P. level, associated with other lithic artifacts and a hearth, at the Chinchihuapi I site near Monte Verde.

Based on these classification standards, Dillehay is quite confident that human activity dates back to 15,500–16,000 yr B.P. and possibly as far back as 18,000 yr B.P., at which point possible evidence is difficult to evaluate. "And then there are a few features and exotics and other materials in deeper levels, but we're not confident enough to reject or accept them, which has been the case with various deeper things at MV since the late '70s and early '80s."



Unifacial flake tools made from pebbles: A, C, from Monte Verde I, dating to ca. 16,000 yr B.P.; B, unifacial tool made into a punch from Monte Verde II, dating to ca. 14,500 yr B.P. Tools A and B were associated with small hearths in a stone-free sand layer. On tool C the yellow arrows indicate areas of use wear; the blue arrows point to a bulb of percussion and striking platform.

Concerning skeptics who doubt that the earlier cultural materials recovered at the MV complex are human made, Dillehay, exasperation showing, admits that he sometimes wishes they were right: "I'm tired of this damn stuff," he confesses, "I want it to go away. I hope I don't find anything that's cultural because I don't want to deal with it. I have other things going on and don't want to give more time to this. But anomalies that appear to be cultural, the way they're patterned, indicate something that's not natural and thus requires more attention."

Burnt features: natural or human agency?

Similar to Dillehay's certainty of cultural activity due to human presence is his confidence that the recovered burnt features are anthropogenic in origin. "We now have almost 43 years of experience in taphonomic questioning of that specific environment by people who know the terrain really well—sedimentologists, morphologists, geologists. The burnt spots are clearly several millimeters to centimeters thick and different from anything else we've excavated. Okay, maybe beyond 16,000 yr B.P. we could say it's a forest fire, but fires should produce several of these, if not clusters of them, and they appear very spottily and with artifacts. But what we have around the MV complex after the LGM is a sandur plain, which would have been cool to cold, rainy, with maybe a few trees here and there. The environment around 14,500 to 15,500 years ago indicates an open grassy terrain with patchy forest stands," Dillehay says. There's evidence of forest fires due to human presence after about 10,000 years ago, but back at 18,000 there weren't forest fires. He emphasizes that Linda Scott Cummings at University of Colorado, Boulder, along with glaciologists and geologists on the project, analyzed the seeds and pollen and confirmed the sandur-like, pre-moraine environment.

The new evidence all points to multiple, spatially discontinuous occurrences of stratigraphically secure artifacts in situ, faunal remains, and burnt zones that indicate discrete horizons of ephemeral human activity radiocarbon dated to between 14,500 and 18,000 CALYBP. This must mean that people were in South America before 15,000 years ago. Furthermore, they were highly mobile and adapted to a wide variety of environments, including cold non-glacial environments.

Initial return to Monte Verde in 2013

When Dillehay's team returned in 2013, the objective wasn't to undertake a full-scale excavation to resolve previous research questions. Instead, the goals were three-fold: to explore previously unknown geoarchaeological deposits in sites MV I and MV II, CH I and CH II; to investigate the time span between sites MV I and MV II; and to specify the geological setting of the sites by sedimentological, microstratigraphic, magnetic, optically stimulated luminescence dating (OSL), and macro and microbotanical analyses.

Previous discoveries at MV I revealed possible cultural evidence laterally spread out in deeper, sandy levels of the sandur plain, but Dillehay's work in 2013 focused on spatially intermittent excavations and core drillings across a 500-m expanse between the MV I and CH sites, searching for additional scattered remains above and below these levels.

Over two field seasons in 2013 Dillehay's team dug 50 test trenches across a 10,000-m^2 area of late-Pleistocene deposits, which turned up 161 stone artifacts including flakes, a chopper, and cores embedded near plants or animal bones that had been burned in small fires in 12 areas. To Dillehay, this suggests a spotty, ephemeral human presence.

Dillehay dated the plants and animal bones to 14,500–18,500 yr B.P. The last ice age was just starting to wind down at that time, creating a cool-to-temperate rain forest at Monte Verde, about 60 km from the Pacific coast. Early humans probably moved along deglaciated corridors between the coast and the Andes, hunting paleo llamas and elephant-like gomphotheres. Although this scheme of migration fits in with the coastal-migration hypothesis, Dillehay believes multiple migration routes were in play. "If they came down the Pacific side, why not the Atlantic side, or right down the middle? Multiple routes, multiple times, by multiple people: I published that and stick to it. Maybe during later times the Pacific coastal route became one of the more popular ones."

Dillehay doing survey work near Monte Verde, 1981.

Bubblepacked Dillehay caught in a downpour in a test pit at the El Gato site near Monte Verde, 1979.

Environmental records at the MV complex

A key part of the 2013 excavations involved correlating the local geology with established regional paleoenvironmental records from nearby Andean glaciers and volcanoes, and from studies of pollen, starch grains, and phytoliths. This strategy helped develop models to predict future sites in the region and initiated studies of how people exploited Monte Verde and similar landscapes.

Paleovegetation records indicate that the climate warmed 26,000–18,400 yr B.P., with short cooling events 25,000–18,000 yr B.P. Post-LGM warming was already taking place 17,600 yr B.P. Further warming periods, 18,500–15,000 yr B.P., coincide with most of the archaeological horizons recorded in sites MV I, CH I, and CH II. A more prolonged human presence at MV II was established around 14,500 yr B.P. During these warming periods, human migrations may have been impeded by volcanic eruptions, suggested by tephra lenses and ash coating on artifacts at MV II, and by ecological barriers.

Horizons formed during the warming periods are low-density, interrupted cultural deposits that contain little material evidence, which suggests they were sites of short-term human activities such as hunting and gathering, cooking food in small hearths, and making stone tools. More than a third of the tools are made of exotic toolstone. Since it's unlikely that occupants at these sites had first-hand knowledge of resources spread over the vast area from the western Argentina steppes to the Pacific coast, the influx of toolstone from distant sources implies either busy traffic of migrants passing through the Monte Verde area, or the existence of a flourishing exchange network among hunter-gatherer groups.

Most likely, the pattern of settlement may have involved small groups of people seasonally adapted to cold, boreal environments, likely during the warmer months. After 17,000 yr B.P., when the environment grew warmer, and after 15,000 yr B.P., when the Chinchuhuapi Creek formed, occupations were of longer duration, testified by more varied resources and artifact types as well as more extensive cultural deposits at MV II.

Dillehay draws an analogy with the Nunamiut of northern Alaska, who made

sporadic hunting trips into cold, post-glacial environments and left a material record of scattered hearths and bone remains.

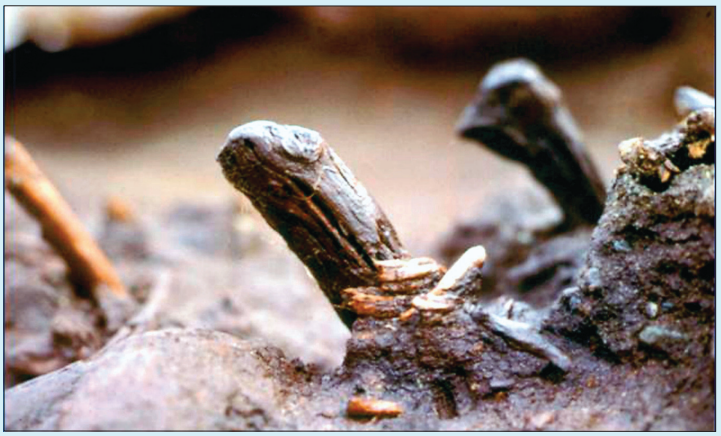
Recent work at Chinchihuapi I

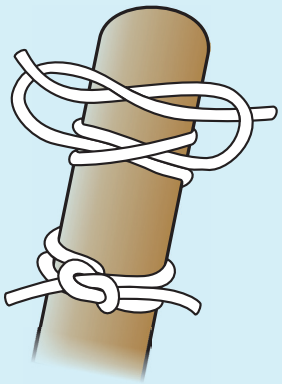
In 2017 and 2018 Dillehay moved on from MV I and II and returned to CH I, a locality within the Monte Verde complex located along the Chinchihuapi Creek in the Valdivian rain forest of south-central Chile. He recalls that "what we observed at CH I the first time in 1983 was 3 flakes and a partially burnt gomphothere rib bone that radiocarbon dated to 14,500 years ago, and I didn't go back to the site right away because I didn't want to deal with it." Interestingly, one of those burnt bones later recovered at CH I was a fragment of an American horse tibia, "the first time we found American horse."

Based on the new ages, lithics, and burnt features discovered in the three use surfaces and reinforced with information from previous investigations, Dillehay confidently places human presence during the Pleistocene–Holocene transition.

The two types of stone-tool technologies found here were present in the region from about 14,500 yr B.P., when the geological record notes increased fires and charcoal deposits in, suggestive of greater human presence. The oldest tools, edge-trimmed pebble-tool flakes, date to at least 16,000 yr B.P. Recently Dillehay's team found a rhomboidal-shaped projectile-point fragment at CH I embedded in a burnt area, a setting similar to what they found at MV II; the fragment radiocarbon dated to 14,500 CALYBP. Dillehay remarks drolly, "We continued to find exotics."

He tells us, "As you go back in time to 15,000 to 18,000 years ago, there's less content scattered more spatially, and it's more ephemeral." Morphologically, it's obvious that the lithic objects are human made. As an example he points to abladed pebbles that clearly come from ocean beaches. "They're not from the creek. Back then the Chinchihuapi Creek didn't even exist, not till 15,000 years ago. And these exotics coming in, they're minor, but they're there." Most of the exotics recovered at the MV complex were made from exotics like limestone and white quartz.





Well-preserved hammered wooden stakes brace the log foundation of a long tent-like structure recovered in MV-II. Note the cordage used to secure the stake against the log. The knot is a double-S slip knot (courtesy of Jim Adovasio).

Also found at CH I were Paiján-like points appearing at 10,500 yr B.P. That they are a few hundred years younger than their counterparts in Peru suggests continued migration of people southward along the Pacific coast at the end of the Pleistocene. Dillehay's use-surface reports on CH I depict continuous ephemeral cultural events along Chinchihuapi Creek and similar ecological zones over 5,000–6,000 years. The events characterize a complex hunter-gatherer society in which small groups performed seasonal tasks in particular locations for short bursts of time.

A sticking point: seasonal, ephemeral sites

The ephemeral use of the localities within the Monte Verde area, which Dillehay proposes, signifies seasonal movements between the Pacific coast to the west and the Andean mountain range and lakes to the east. Dillehay suspects that the scientific community doesn't object to the age he claims for the MV complex as much as to the ephemeral nature he attributes to the sites. Witness a colleague of Dillehay's who recently said, "It can't be." In defense of his conclusions, Dillehay points to the archaeological record of modern-day hunter-gatherers and the work done by ethnoarchaeologists and Lewis Binford on logistical and residential patterns: They all include, Dillehay points out, "not only a base camp, but also outlying small activities, and these produce ephemeral archaeological sites, lithic scatters, bone scatters, maybe a small hearth. We are to expect that in the record."

The sites that make up the MV complex seem to have reached a transition point about 14,500 years ago, when a more extensive and permanent occupation was established at the MV II site. "Around late-Pleistocene times there's still a certain degree of ephemerality, nothing like what we found at MV II, which was heavily preserved on account of the overlying peat bog," Dillehay explains. "CH I is situated at a higher elevation, and as a result you just don't get the peat covering it up and preserving it well, so the archaeological record is different."

At MV II, the more permanent nature of human occupation is demonstrated by a slightly thicker use surface, more hearths, dwelling remains, and a wider variety of domestic items, including species of local and exotic plants and animals. Before this, in the period 15,000–18,000 yr B.P., the record at MV I, CH I, and CH II is discontinuous and ephemeral, associated with small burnt features, unifacial lithics of local toolstone and only a few of exotic varieties, and sparse bone and plant remains.

Dillehay's excavations at these localities reveal a continuity of stratigraphy and cultural deposits in the MV I, CH I and CH II sites. Bifacial projectile points and their lithic technology

are forerunners of the type that became universal across the continent, but not until 12,000–13,000 yr B.P.

Assemblages of simple or crudely made core and flake pebble tools produced by direct percussion, which may date to as early as 15,000–16,000 yr B.P., are distributed across several regions of the continent. Not only are such simple artifacts found at sites in the Monte Verde area, they also appear in various point industries after 13,000 yr B.P. They beg for new studies into the behavior of early humans across South America.

On the need to look again, and closer

When Dillehay's team first excavated the MV II site in the late '70s, they opened spatially limited areas, several 2-by-3-m test pits and a few outlying 1-by-2-m. These areas revealed a bifacial tool, a few unifacial flakes, and the bone remains of mastodonts.

Says Dillehay, "We produced edge-trimmed unifacial flakes on basalt pebbles and experimentally tested the effectiveness of the sharp edges on horse meat, wood, plants, etc. This shot shows a person cutting horse meat and bone."

In the '80s the team excavated 3 6-by-15-m excavation blocks and more test pits, which revealed the dense, more extensive evidence of the MV II occupation. After the 2013 excavation of a more extensive area and of other types of depositional environments in the site, they discovered a more complex ecological and ephemeral archaeological setting. If more sites like those at MV complex were reexamined and more extensively excavated, perhaps they would also reveal new types of evidence.

Dillehay is convinced there's more material at Monte Verde. The problem is finding it. "What's stimulated me to go back and do this ground-penetrating-radar study," he confides, "is the fact that we keep finding scattered things. I want to see what comes out of this study. We're sending out the analysis to the GPR people. We're looking at every 5- to 10-cm increment of depth once we get down to the late-Pleistocene levels, and we'll see what happens after that. If there are interesting anomalies there, we may go back and test them."

What he's attempting to avoid is what he deems spotty archaeological practices. He finds it interesting that "if you go into some of the cave sites excavated over the last 20 to 30 years in South America, there's a deeper level, and they've got a single radiocarbon date, say, 12,000 uncalibrated, or 12,500 on a burnt spot in a 1-by-1-m test pit. And people say, 'The evidence is too minimal.' It's like what I said about the deeper stuff at MV." But, as he points out, in a deep cavern or cave, a 1-by-1-m aperture or even smaller doesn't tell you what's down there. We shouldn't expect an early floor to be horizontally and vertically dense with artifacts. "We should rethink our expectations," he cautions, and budget for more extensive excavations and interdisciplinary work.

Archaeology in the future

Dillehay calls for more geochemistry and genetics studies. By completely filtering possible use floors, he hopes it will someday be possible to recover human, plant, or animal protein. He's optimistic about the work of geneticists like Eske Willerslev in Denmark, who's trying to detect human proteins outside the human organism itself. Above all, he's concerned "about an absence of people looking at internal structures of a site because not enough of the site is excavated. What's reported is chronology and archaeological content, and not enough about internal structure."

Dillehay encourages others to take over the excavations. "There are qualified Chileans who can do it," he insists. "Let them do it."

Does he consider Monte Verde his greatest achievement? Dillehay answers with a resounding *no.* The Vanderbilt University Professor of Anthropology, Religion and Culture places more value on the archaeological and ethnoarchaeological work he's done with the Mapuche (his project since 1975, when he was a student), on his investigation into plant domestication and early civilization on the northwest coast of Peru, and on teaching and developing students and academic programs in numerous universities in Latin America." MT

–Katy Dycus

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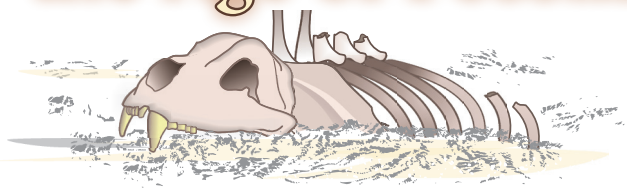
Suggested Readings

Dillehay, T. D. 2019 New excavations at the Late Pleistocene site of Chinchihuapi I, Chile. *Quaternary Research*.

Dillehay, T. D., et al. 2015 New archaeological evidence for an early human presence at Monte Verde, Chile. *PLOS ONE*.

Master of Validating the Age of Fossils



Tom Stafford

WHEN ARCHAEOLOGISTS make discoveries they must verify their ages to ascertain the significance of the finds and determine where they fit into the archaeological record. This is when many turn to geochemist Thomas Stafford, Jr. for validation of evidence.

With a Ph.D. in Geosciences from the University of Arizona, Stafford's list of scientific specialties embraces a vast range of subjects: AMS C-14 dating and Quaternary geochronology, stable-isotope applications in paleoecology, late-Cenozoic sedimentology and stratigraphy, geoarchaeology, organic geochemistry of vertebrate fossils and sediments, cave stratigraphy and paleontology, vertebrate paleobiology and anatomy, vacuum instrumentation design, database design and image storage, paleoepidemiology, and evolutionary medicine. That's quite a bill of fare for a single scientist.

"Tom Stafford is the quintessential scientist and teacher," says colleague Dennis Jenkins of the University of Oregon. "His love in life is documenting the processes that have formed and are forming the world around us, particularly those processes involved in the formation of pre-Clovis sites. He is a brilliant chemist, deeply devoted to removing environmental contaminants from extremely sensitive radiocarbon samples. In doing this, he is brutally honest in questioning our elementary level of understanding of site chemistry in general, and the reliability of samples proposed for dating. He has little patience with simplistic explanations based on speculation. If I care deeply about the reliability of a particular radiocarbon date because I think it is absolutely vital to my comprehensive understanding of the site or a particular context within a site, I send it to Tom Stafford and no one else."

Formative years

By age 8, Stafford was intensely interested in geology, archaeology, paleontology, and earth history from 4.6 Ga (Geologic Time) to the present. Beginning in middle school and continuing until he started college, he participated in numerous archaeological excavations and lab work with the Archaeological Society of Delaware and the State Archaeologist's Office in Dover. This experience encompassed excavating a 115-individual Adena-period burial ground, numerous 16th- to 19th- century historical and industrial sites in Delaware, Pennsylvania, and Virginia, and an early-Paleoindian lithic quarry.

"Throughout this experience," Stafford tells us, "my real interest was how the physical sciences could help archaeologists and paleontologists better understand and quantify their research questions. How old were the skeletons and their sediments; how were cherts and flints formed and what was their geographic origin; what happens when bodies, wood, and skeletons decay; how has sea-level rise since the end of glaciation buried sites?"

LEVON YEPISKOPOSYAN

Stafford exploring Upper Paleolithic cave sites, Nagorno-Karabakh Republic, Southern Caucasus, 2014.

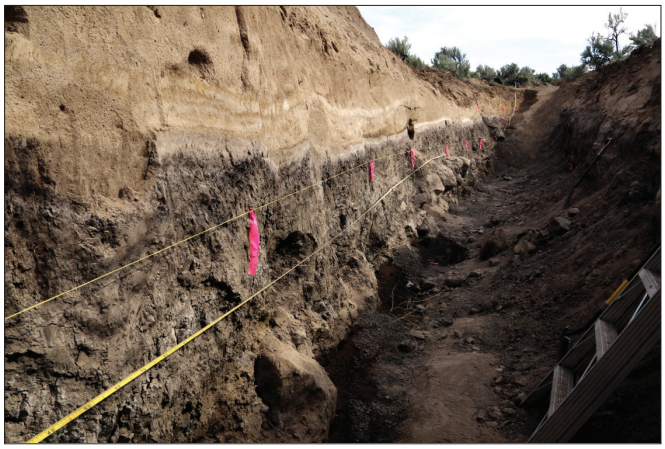
When he completed his studies, Stafford joined the University of Colorado–Boulder, where he established a dedicated research AMS C-14 lab studying early American archaeological and late-Pleistocene megafauna-extinction sites across the US, Chile, and Argentina, and Pacific Islands from Tonga to Hawaii.

"I've had my research lab, Stafford Research, since 1997," he tells us. "In addition to providing C-14 dates on all ages of sites, my field and laboratory research has focused on the late Pleistocene and older paleontological and archaeological sites around the world, including excavations throughout the US, and in Chile, Argentina, Uruguay, and the southern Caucasus of Nagorno-Karabakh Republic.

Pinpointing the age of Kennewick Man

The discovery of about 300 human bones and fragments, together with a skull, of uncertain ancestry along the banks of the Columbia River sparked a 20-year effort to identify the individual's lineage and learn more about the lives of Paleoamericans and

the conditions they lived in during the early Holocene. The bones, which were taken under the care of the U. S. Army Corps of Engineers because they were found on federal land, ignited a fiery debate among anthropologists and Native American tribes for rights to the ancient skeleton. Scientists wanted to study it, and Native Americans wanted to rebury it as an honored ancestor. In 2002 a U.S. magistrate ruled that scientists could study the bones, since it was impossible to establish a certain linkage to Native American tribes.



T. STAFFORD, JR.

Trackhoe trench at Rimrock Draw Rockshelter in Burns, Oregon, reveals basal stream gravels containing Clovis and pre-Clovis lithics. 2018.

Tasked with determining an accurate age for the Kennewick Man skeleton, Stafford applied his considerable skills. Previous attempts by various laboratories to radiocarbon date the skeleton yielded random-appearing dates that varied by 2660 RC years. Using small fragments of bone from 15 different samples previously tested by other laboratories, Stafford performed stable-isotope, amino-acid, and AMS C-14 analyses.

Bone samples were broken into 4- to 5-mm fragments and decalcified. The decalcified collagen was extracted with 0.1% KOH at 4°C for 24–30 hours to determine the percent yield of collagen relative to modern bone. A total of 17 radiocarbon measurements were made on carbonates and collagen fractions from 5 different samples.

To establish an absolute age, Stafford used the C-14 age as an initial benchmark, incorporated reservoir effects related to diet (marine or terrestrial), and used this reservoir-corrected value to calculate a calendar age in absolute years B.P. Isotopic data showed that Kennewick Man's diet was approximately 90% marine foods, which helped to pinpoint his age at 8358 ± 21 RCYBP, corresponding to 8690–8400 CALYBP.

With a more accurate calendar age in hand, Stafford was able to interpret the stratigraphy of the site, the taphonomic history of the bones, and their diagenesis—the physical and chemical changes that occur during the conversion of sediment to sedimentary rock. Data drawn from wet chemistry, visual inspection, and quantitative amino-acid analyses indicated that the bones had the internal structures of modern human bones.

After three visits to the Burke Museum, the Washington State Museum of Natural History, which housed the bones, scientists successfully sequenced the genome. In comparing DNA from a bone of the hand with worldwide genetic data, they found Kennewick Man more closely related to modern Native Americans than to any other living population. As a result of this discovery, the bones were ceded to Native American tribes, who claim him as their ancestor, "the Ancient One." The bones were reburied in 2017 in a private ceremony at an unknown location.

Stafford (*right*) exploring the remote stretches of Karin Tak Cave with University of Armenia archaeologist Levon Yepiskoposyan, Nagorno-Karabakh Project director, 2014.

Stafford recalls that he started working on the geology, stratigraphy, dating, and legal issues associated with Kennewick Man in November 1997, shortly after the skeleton was discovered that summer. "I did the field work with anthropologist Jim Chatters, the Corps of Engineers, and Tribes a few days before Christmas 1997, and spent at least one month a year for the next 15 years helping with either the science or legal issues."

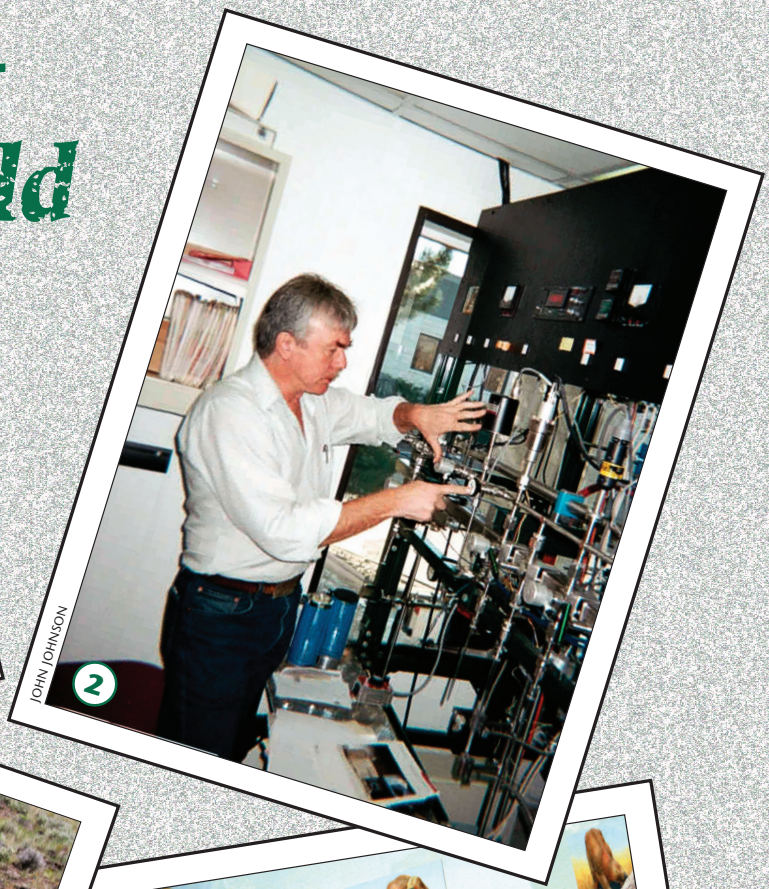
A changing take on First Americans

In the early 2000s accumulating evidence convinced Stafford and CSFA Director Mike Waters (former classmates in graduate school) that Clovis-First, the long-lived model of American archaeology, was no longer tenable. It wasn't possible to assert that the Clovis people were the First Americans in the face of mounting evidence that the New World was inhabited long before Clovis. Stafford and Waters believed that the heyday of the Clovis culture occurred much later than previously thought and lasted for a shorter period of time.

Research Team, Arlington Springs Channel Islands in California (*l–r*) John Johnson, Stafford, Jim West, 2013.

Radiocarbon dates for Clovis sites had been accumulating for 40 years, dates often obtained using outdated technology and

DATING
all over the world



1 Unknown mammal bones (e.g., astragli) are identified through Digital-Linnaeus™, a library of digital images accessible by novices and the most advanced researchers.

2 Stafford with hand-made research-grade vacuum line for AMS C-14 dating at Stafford Research Labs, Boulder, Colorado, 2000.

3 Pat O'Grady delicately removing basalt boulders, Rimrock Draw Rockshelter, Oregon, 2018.

4 C-14 dating extinct South American megafauna, Museo de la Plata, Argentina, 2013.

5 Auger testing in Karin Tak Cave revealed at least 4 m of undisturbed sediment. Samples at 1-m depth date earlier than 50,000 yr B.P. ; basal strata at 4 m may contain Neanderthal-age occupations dating earlier than 150,000 yr B.P.

6 Coring 16-plus m of alluvial stratigraphy at the Arlington Springs Early Man Site , Santa Rosa Island, Channel Islands, CA, 2006.

7 Typical reuse of 50-mm shell casings from the 1990–1994 Nagorno-Karabakh and Azerbaijan war. Near Karin Tak Cave excavations, 2014.

8 Showing how to really explore alluvial stratigraphy, Scott Thomas (*left*) and Pat O'Grady, Rimrock Draw Rockshelter, Oregon, 2018.

unreliable samples. Standard deviations sometimes spanned 250 years (today's geochemists can tighten that to 25–30 years). With 43 samples acquired from documented Clovis sites, Stafford and Waters obtained new dates from bone, charcoal, and seeds using highly accurate accelerator mass spectrometer (AMS) dating methods. Since Stafford and Waters were directly involved in fieldwork at most of the sites, they were confident about the integrity of the new data. Thus they were able to assess differences in opinions among archaeologists, geologists, and paleontologists, and focus their investigations on new materials and horizons that would yield reliable data.

T. STAFFORD, JR.

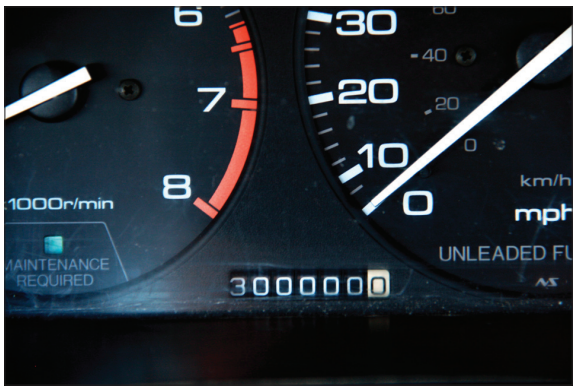
Stafford calls this treat served at Rimrock Draw Rockshelter "edible stratigraphy."

The new dates defining the Clovis culture ranged between a minimum of 13,125–12,925 CALYBP and a maximum of 13,250–12,800 CALYBP, a duration of 200 to 450 years—the blink of an eye in the archaeological record! Firmly dated sites in both North and South America existed at the same time as the Clovis culture or earlier, and reason denied the possibility that these cultures could have spread across the New World in less than 500 years.

"We need 20 times more Clovis sites to adequately test our data," Stafford admits, "and scores if not hundreds more radiocarbon and other radiometric dates." At the moment, however, there aren't any other Clovis sites to date. If any turn up, Stafford and Waters would love to date them. They hope someday to witness a new model that explains the rapid spread of Clovis technology across North America.

Geochemistry of Arctic lake systems

Arctic lakes are a valuable source of proxy data for scientists studying late-Quaternary global climate because they are exquisitely sensitive to changes in the environment. A core from an Arctic lake is a precise timeline of successive events that affected the paleoclimate. To precisely date an event, however, has been traditionally difficult because terrestrial organic matter decomposes very slowly in the Arctic and is therefore already quite old when it enters the lake system. This influx of C-14-depleted organic matter, washed in from the watershed, skews the apparent age of the lake contents in the ancient direction. As an example, Stafford cites samples taken from a sediment-water interface that register a radiocarbon age of about 1000 RCYBP—brand-new matter that appears to be 1,000 radiocarbon-years old!



T. STAFFORD, JR.

The odometer of Stafford's car on a road near Ft. Collins, Colorado, 2014. Says Stafford, "Hondas are highly recommended for peripatetic geologists."

A study by Stafford and Mark Abbott, an M.S. student in geology at University of Colorado–Boulder, found that small, shallow Arctic lakes with watersheds have soil and peat stratigraphic sections whose $^{14}C/^{12}C$ ratio ranges from 98% to 51% of the modern value of 1.02.

Three lake systems on southern Baffin Island in Canada were sampled and cored during May and June of 1990. Soil and sediment samples were fractionated chemically for radiocarbon measurements into fluvic acid I, fluvic acid II, humic acid, and humin fractions.

For the greatest accuracy in dating matter associated with Arctic lake systems, Stafford and Abbott recommend that whenever possible, researchers avail themselves of the following sample types:

- discrete terrestrial plant macrofossils;
- discrete aquatic plant macrofossils from relatively shallow, well-mixed lakes;
- chemically specific organic-matter fractions when plant macrofossils are absent.

Accelerator radiocarbon dating at the molecular level

Isolating specific classes of molecules for AMS C-14 dating yields molecular-level C-14 dates. This procedure becomes necessary when dating fossil bones, which are extremely difficult to date accurately unless individual amino acids are first isolated and contaminants (humates) are removed; the resulting crystalline amino acids can then be accurately dated.

Bones are dated most accurately when structural collagen is present, Stafford tells us. Humic acids are the main source of error in the C-14 and stable-isotope analysis of organic matter in fossil bones. Contaminants can be removed with XAD-2, a hydrophobic resin that has a high affinity for humic acids but passes amino acids through unaffected; treating with XAD-2 gives the highest yields of protein from bones with varying levels of preservation.

Bones with ≤0.1% N and noncollagenous compositions yield dates hundreds to thousands of years too young. Radiocarbon dates on collagenous and noncollagenous bones therefore aren't comparable, owing to intrinsic dating inaccuracies.

"Simultaneous analysis of C-14 age, $\delta^{13}C$, and $\delta^{15}N$ is recommended because each isotope value can be independently affected by the diagenetic history of the bone," Stafford explains. Radiocarbon analysis is the most sensitive, $\delta^{15}N$

continued on page 20

Living the High Life

The Early Humans of Cuncaicha Rockshelter

Team member Judith Beier holding the face of the Lady of Cuncaicha.

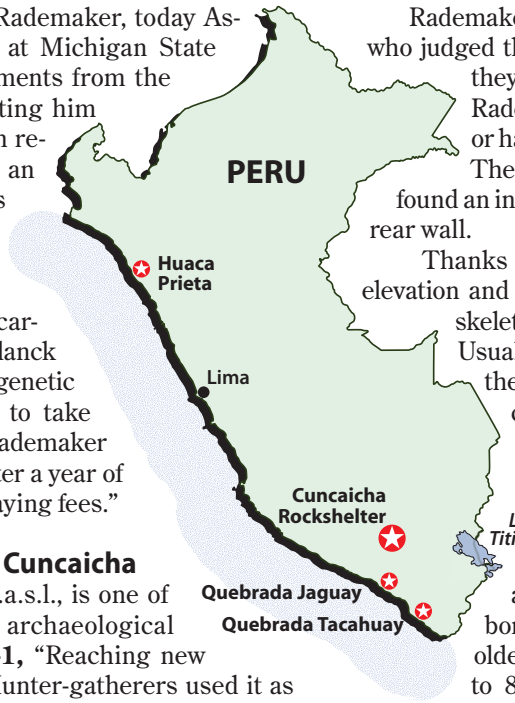
GREG HODGINS

Part 1

ON HALLOWEEN 2015, an American checked in at the airport in Lima, Peru, for his flight. His final destination: Tübingen, Germany. The police showed up moments after the man declared that he wished to check in five crates containing human skeletons.

On questioning by police, Kurt Rademaker, today Assistant Professor of Anthropology at Michigan State University, presented official documents from the Peruvian Ministry of Culture granting him special permission to export human remains from Cuncaicha Rockshelter, an archaeological site high in the Andes mountains.

Once landed in Germany, Rademaker transported the skeletons to the University of Tübingen, then carried specific samples to the Max Planck Institute in Jena, Germany, for paleogenetic analysis. "It was surprisingly easy to take five skeletons out of Peru," says Rademaker tongue-in-cheek, before adding, "After a year of arranging all the permissions and paying fees."



Discovering human remains at Cuncaicha

Cuncaicha Rockshelter, at 4,500 m.a.s.l., is one of the highest-elevation Pleistocene archaeological sites in the world (**MT 30-4, 31-1,** "Reaching new heights in the Peruvian Andes"). Hunter-gatherers used it as a residential camp beginning in the late Pleistocene, some 12,000–12,500 years ago. In the early Holocene it became a symbolically significant place where people buried their dead.

"The first time I dug was in 2010, when I was just trying to determine the antiquity of the site," Rademaker remembers, "and in 2012 I returned with a team to gather larger samples of materials from the site to see how people lived there. It wasn't until the field season ended, when we were going through the faunal remains, that we found a couple of carbonized skull fragments that we recognized were human."

Rademaker showed them to a forensic anthropologist, who judged they were from a single adult female. Because they were carbonized, it was uncertain whether Rademaker's team had stumbled upon a cremation or had accidentally intruded into a burial at the site. The answer came when they returned in 2014 and found an intact burial of a nearly complete female near the rear wall.

Thanks to the year-round cold temperature at this elevation and dry conditions in the rockshelter sediments, skeletons from Cuncaicha are excellently preserved. Usually you're lucky to get bone-collagen levels in the single digits, Rademaker explains, but in the case of Cuncaicha, there are "bucket loads of collagen," which can make for surprises: "You prepare these bone samples, and the bone doesn't appear to be very old, but then you get a date that's 9,000 years ago."

Once the team determined they had a burial, they could date the remains. Radiocarbon dating placed the age of this burial at slightly older than Kennewick Man, whose skeleton dates to 8900–9000 CALYBP (**MT 31-3,** "Kennewick Man's DNA reveals his ancestry"). "Realizing we had a human buried at the site and that it was that old, and also at high elevation, set up all these answerable questions," Rademaker says.

At the time Rademaker was a postdoc at Tübingen University. Johannes Krause, current director of The Max Planck Institute for the Science of Human History, and University of Tübingen colleagues Katerina Harvati and Hervé Bocherens became interested in working with him to analyze the paleogenetics. They decided to do a field season in 2015 specifically aimed at recovering human remains at the site. "The first time I went to Cuncaicha," Rademaker admits, "I never could have envisioned what I'd be doing the fourth time around!"

Based on where the skull fragments were earlier excavated, Rademaker tells us, "I knew exactly where we should target in 2014 to figure out if we had a cremation or a burial. Then once we revealed it, the stratigraphic position of that single burial indicated an age older than 5700 yr B.P. (the age of the overlying stratum), so I expected that first burial to be 9000 years old or older. Based on other cave sites with early burials in South America, I had a strong suspicion that other burials would be located along the rear wall of Cuncaicha, so that inspired the research design for the 2015 field expedition.

KURT RADEMAKER

Cuncaicha Rockshelter.

They ended up discovering a total of five burials. "We were thrilled," Rademaker vividly recalls, "because we had multiple individuals to study, and we understood the site must have been really important symbolically."

Flakes popped off the rear wall of the cave revealed paint made of red ocher, which emphasizes Cuncaicha's significance in the imagination of early humans. Rademaker also found artifacts associated with the human remains and is working on preparing that information for publication. All in all, the collective evidence reveals that, alternating throughout prehistory, Cuncaicha was a space to live in, to decorate, to make tools, to bury loved ones.

KURT RADEMAKER

Cuncaicha excavations in progress, 2015.

Rademaker recounts the changing picture of Cuncaicha: "The site is first used as a base camp in the terminal Pleistocene. Then people leave for a couple of thousand years. In the early Holocene people come back and use the site as a base camp. Then 100 to 400 years pass, and the first burials are put into the site." All five individuals recovered date to different periods in time. It's evident that early dwellers at Cuncaicha, like modern humans, didn't bury their dead in their living space.

Respecting indigenous voices

Ancient burials enjoyed cultural significance in the minds of early humans. Cosimo Posth, group leader in Archaeogenetics at the Max Planck Institute for the Science of Human History, is reconstructing the maternal line—half the family tree—of Cuncaicha individuals through mitochondrial DNA analysis. He sees his contributions as a way to connect ancient humans with their modern counterparts.

Posth recognizes the great responsibility of working with human material, even though the individuals are dead. In South America, he explains, "we have used a case-by-case approach, talking to curators and institutions in different countries. We need to listen to concerns and requests and know what indigenous groups want to discover from their past. It's important to see that as an added value of our research, which makes it more personal, more tangible."

In North America, if you find an ancient skeleton, you consult Native American tribes who claim ancestry and honor their wishes. A noteworthy example is the

2014 reburial of the Anzick children in Montana (**MT 30-2,** "We are all one: Anzick Children reburied"). In Peru, the Peruvian Ministry of Culture directly represents indigenous people. "You deal with the government agency directly," Rademaker says. (Cuncaicha is located in the state of Arequipa.) "We follow its regulations to the tee when we request to export and sample and eventually return skeletons."

The research team is given a year to test exported materials. Anything taken out of the country for non-destructive analysis must be returned. The Cuncaicha skeletons have already been returned to Peru, where they were placed in the general curation facility of the Ministry of Culture. "Departments are like states," Rademaker explains, "each with its own repository for archaeological materials, and that's where they'll stay." Rademaker's team received permission to perform destructive sampling on some of the exported skeletal remains, which are still in Germany undergoing tests.

The story of the colonizing of South America is getting curiouser and curiouser

The Cuncaicha individuals have added to our growing body of knowledge about the earliest arrivals from Asia, who by the late Pleistocene were already dividing into distinct groups. Some of these populations thrived, becoming the ancestors of indigenous peoples throughout the hemisphere. Others left no trace except for what can be discerned in ancient DNA.

WALTER BECKWITH

Kurt Rademaker and Sonia Zarrillo verifying the presence of an intact burial along the rear wall, 2014 excavation. Note the red ocher on the wall above the burial.

Around 16,000 years ago the ancestors of living indigenous Americans split into two main branches, ANC-A (Southern Native American, or Ancestral A) and ANC-B (Northern Native American, or Ancestral B) (**MT 35-2,** "Genetics studies reveal rich history of ancient America"). An individual dating to 12,750–12,850 yr B.P. from the Anzick site in Montana and associated with the Clovis culture expressed the ANC-A lineage, which is richly represented in present-day Central and South Americans and ancient Californians. ANC-B ancestry is represented in eastern North Americans and in ancient people from southwest Ontario.

Sometime after, the southern branch, ANC-A, split into new branches that rapidly spread into South America. According to Posth's study in Cell, ancestry is shared between the Anzick-1 lineage, associated with the Clovis culture, and the earliest residents in South America from Lapa do Santo in Brazil and Los Rieles in Chile. "These guys, despite their broad geographic distribution, have extra affinity with Anzick/Clovis. It's quite surprising that all the individuals we find afterwards, from different regions, do not have this affinity," Posth says.

It's all bewilderingly dynamic. "There are more groups of people than we're used to thinking about," Rademaker confesses. "We have Anzick-related people on both sides of the continent—the one in Chile and the one in Brazil—and as far as we know, there's no mobility or cultural connection between the groups. It's not like the people in Chile came from Brazil or the other way around." It's more likely these groups came from the same parent group, which means that when colonizers came to South America, the parent group divided and went in two directions, resulting in two populations of the same lineage on opposite sides of the continent. Soon after that, at Cuncaicha, high in the Andes mountains, appears a completely different group, which was later supplanted.

It's tempting to say, says Posth, "'Look, there's population expansion of a group as part of the ANC-A lineage, closely related to Anzick/Clovis, and then this group was replaced by a later migration.' But we cannot rule out the possibility that these two waves were there at the same time. It could simply be we haven't yet found the lineage of Cuncaicha in South America. It could be it was there before 9000 B.P."

The humans of Cuncaicha

The genetic data from the Cuncaicha individuals adhere to this timeline. Three of the five genomes have been sequenced so far. Two of those genomes confirm that two distinct groups of people were using Cuncaicha at different times. The oldest human at the site, the Lady of Cuncaicha, which comprises a nearly complete skeleton, dates to about 9000 yr B.P. and is from a group distinct from the Anzick group. A second skeleton, of a 4,200-year-old human buried in a seated position with crossed arms, Rademaker's team calls The Thinker because the burial position resembles the famous bronze statue by Rodin. The Thinker is from a genetic lineage different from the Lady. "So we know," Rademaker summarizes, "just looking at two different burials in a set of five, that we have at least two different groups at two different times. There is turnover. We know sometime between 9,000 and 4,000 years ago there was some kind of genetic switch."

A gap of 5,000 years separates the individuals, and the current genetic database from South America lacks the continuity to explain how one lineage is related to another. When was the 9,000-year-old group replaced by the 4,000-year-old group? Was there only one turnover or many? How many groups were present at a given time? Questions like these entice Rademaker to col-

laborate with ancient DNA researchers: "If you can put the skills of archaeologists, physical anthropologists, and geneticists together, come on! The world gets way more interesting. You have this ability to build all these different lines of evidence." And Posth agrees: If you find a genetic signal but can't contextualize it, then what's the point?

"The Lady of Cuncaicha is the earliest individual in our dataset that shows genetic continuity with modern-day people," Posth tells us. "That's something we don't see in Europe, where there's multiple population replacement down to the Neolithic and Bronze Age. Instead, at Cuncaicha we have this data point that tells us that at least from 9,000 yr B.P. there's genetic continuity through time. We don't need to imagine it as a full continuity; of course, it's dynamic history. You could have multiple additional waves that mix with the local people."

KURT RADEMAKER

The team: (*back row, l–r*) Michael Francken, Sarah Meinekat, Judith Beier, Brett Furlotte, Sophia Haller, Dobereiner Chala-Aldana, Tatiana Feuerborn, Katherine Moore, David Reid, Gabriela de la Puente Leon; (*front row, l–r*) Kurt Rademaker, Katherine Morucci, OB the Dog.

The researchers dated the second individual, The Thinker, to 4200 yr B.P. A portion of its genetic lineage is local, but it also carries the DNA of an ancestry from somewhere else. "Right now we have no idea where it comes from, because we have so many gaps," says Posth. "We don't have any samples from Ecuador, Venezuela, Colombia, from Amazonia. But this individual at 4200 yr B.P. has distinct affinity with individuals from the California Channel Islands." Although we can't identify a migration from North America into South America bringing this ancestry, he argues, "we can spot a migration or gene flow from somewhere north of Peru bringing this different ancestry to Cuncaicha and creating the gene pool that survives until today."

Posth.

Although The Thinker is related to a population found much earlier in the Channel Islands of California, we can't take a leap and say that people migrated from the Channel Islands and directly populated the high Andes. "All we can say is that those two groups are related in some genetic way," Rademaker explains. "When you have two dots, it's tempting to connect them to make a story, but these are just two dots in a whole web of migrations—back migrations and forward migrations."

Hard work for geneticists

One of the greatest hindrances today in ancient DNA studies in the Americas, according to Posth, is the regrettably poor resolution: "We are looking at these 1.2 million SNPs [single nucleotide polymorphisms, instances of a variation in a single nucleotide at a specific position in the genome, which distinguishes members of a population] in DNA, but we aren't able to distinguish populations so clearly. People going through Beringia and then through Panama to reach South America went through two massive population bottlenecks, where the population lost a lot of diversity. A lot of these SNPs are fixed."

Suggested Readings

Posth, C., et al. 2018 Reconstructing the deep population history of Central and South America. *Cell* 175:1185–97.

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Lindo, J., et al. 2018 The genetic prehistory of the Andean highlands: 7000 years BP though European contact. *Science Advances* 4:1-11.

Francken, M., et al. 2018 The human skeletal remains from the Cuncaicha rockshelter. *New Perspectives on the Peopling of the Americas,* ed. by K. Harvati, G. Jäger, H. Reyes-Centeno. Words, Bones, Genes, Tools: DFG Center for Advanced Studies Series, Tübingen.

Rademaker, K., and G. Hodgins 2018 Exploring the chronology of occupations and burials at Cuncaicha rockshelter, Peru. *New Perspectives on the Peopling of the Americas,* ed. by K. Harvati, G. Jäger, H. Reyes-Centeno. Words, Bones, Genes, Tools: DFG Center for Advanced Studies Series, Tübingen.

In addition to the difficulty in resolving SNPs, scientists are also burdened with the high cost of doing business. To sequence an entire genome is expensive, especially considering only 1%–2% of extracted DNA is human; the rest comes from bacteria that invade the skeleton after death. Posth suggests that partial relief could be achieved by selecting other SNPs specific for the Americas so we can better distinguish within the American population, but to do that, "we need to have a clearer idea of the diversity within the Americas." He also advocates further research into modern genomics from the Americas to enhance our understanding of the genetic markers that distinguish, for example, Brazilians from Peruvians from Chileans.

WALTER BECKWITH

Rademaker.

Attacking the task from a different direction

Sometimes scientists must turn to other lines of evidence to achieve the degree of resolution that DNA can't provide. Whereas paleogenetics offers at best an incomplete narrative, morphological analysis constructs a more complete history of how people were living in the high Andes by the early Holocene.

When the skeletons from Cuncaicha arrived at the lab in Tübingen, the first thing scientists did was to CT scan all the bones—nearly a thousand. From these bone scans, says Rademaker, "We can look at muscle attachments that leave tell-tale signatures on bones of the kinds of activities people did during their life." Long bones of the lower limbs tell us if someone has been traversing long distances, or climbing steep slopes, or running a lot, or carrying heavy loads. Long bones of the arms reveal evidence of repetitive activities like scraping hides or paddling a kayak. "You can look at muscle attachments in the hand to see if someone is doing heavy lifting—indicated by a power grip—or is doing precision work like a tailor."

The long bones of the lower limbs can provide information related to mobility: what distances early humans were covering, topographic relief, and overall range. In addition, Rademaker's team has both male and female skeletons, so they can inspect sex-related differences in activity. "And by comparing the variation in cranial morphology throughout South America, we can get a feel for the relative roles of diet, climate, and ancestry in shaping the crania," Rademaker explains. "That's because the crania are very responsive to those variables."

–Katy Dycus

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Genetics Studies Reveal Rich History

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and South America, including the Caribbean, northern South America, and Amazonia. As a result, they can't say anything about how individuals from these regions might relate to the people they were able to study. Future research aimed at filling in these gaps in both time and geography is needed, and the results are sure to provide us with an even clearer understanding of the peopling of the Americas.

It's best to collaborate with indigenous communities

Michael Waters, Director of the Center for the Study of the First Americans, wrote in the July 12 issue of the journal *Science* that "we must always remember that we are investigating the ancestors of contemporary Indigenous peoples and as such, we should strive to include Indigenous Americans in our studies

Suggested Readings

Posth, C., N. Nakatsuka, I. Lazaridis, P. Skoglund, S. Mallick, T. C. Lamnidis, N. Rohland, K. Nagele, N. Adamski, E. Bertolini, N. Broomandkhoshbacht, A. Cooper, B. J. Culleton, T. Ferraz, M. Ferry, A. Furtwangler, W. Haak,K. Harkins, T. K. Harper, T. Hunemeier, A. M. Lawson, B. Llamas, M. Michel, E. Nelson, J. Oppenheimer, N. Patterson, S. Schiffels, J. Sedig, K. Stewardson, S. Talamo, C-C. Wang, J-J. Hublin, M. Hubbe, K. Harvati, A. N. Delaunay, J. Beier, M. Francken, P. Kaulicke, H. Reyes-Centeno, K. Rademaker, W. R. Trask, M. Robinson, S. M. Gutierrez, K. M. Prufer, D. C. Salazar-García, E. N. Chim, L. M. P. Gomes, M. L. Alves, A. Liryo, M. Inglez, R. E. Oliveira, D. V. Bernardo, A. Barioni, V. Wesolowski, N. A. Scheifler, M. A. Rivera, C. R. Plens, P. G. Messineo, L. Figuti, D. Corach, C. Scabuzzo, S. Eggers, P. DeBlasis, M. Reindel, C. Méndez, G. Politis, E. Tomasto-Cagigao, D. J. Kennett, A. Strauss, L. Fehren-Schmitz, J. Krause, and D. Reich 2018 Reconstructing the deep population history of Central and South America. *Cell* 175:1–13.

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Waters, M. 2019 Late Pleistocene exploration and settlement of the Americas by modern humans. Science 365(6449).

as partners in our quest to uncover their past. Collaboration between scientists and Indigenous peoples will enrich our understanding of the story of the first Americans."

Reich, Krause, Fehren-Schmitz, and their coauthors fully agree that it is vitally important to be attentive to the "perspectives of indigenous communities." Given the vast size of their research area, they pursued this collaboration on "a case-by-case approach in each region." In the case of human remains from the site of Laguna Chica in Argentina, for example, the team consulted with the local community, which approved the study and even participated in the excavations. In such countries as Peru, where "government officials are recognized as representatives of indigenous perspectives," they worked closely with the relevant government agencies. The acknowledgments section of the paper includes expressions of thanks to all the various indigenous groups they worked with.

–Brad Lepper

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Tom Stafford

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analysis the least sensitive for detecting exogenous organic matter. The uncertainty of $\delta^{13}C$ and $\delta^{15}N$ analyses on the best pretreated protein is ±0.5% for both, which is larger than previously estimated. Stafford emphasizes that the accuracy of all isotope analyses is optimized by analyzing individual amino acids instead of total collagenous residues.

"Tom Stafford is one of the most open-minded scientists I know," says colleague E. L. Lundelius of the University of Texas. "He will listen to any argument, but if he differs, lets you know in a very positive, civil way and with evidence."

First AMS dates of nonanalog species in late-Pleistocene mammal communities

Species that don't live together today, but which appear associated in stratigraphy, characterize late-Pleistocene terrestrial mammals. Two American and two Russian sites document for the first time that currently allopatric mammals dwelt together in the period 12,000–22,000 yr B.P.. The existence of these mammal communities without modern analogs demonstrates that Northern Hemisphere biological communities lasted only a short time. In the absence of current counterparts, these fossil communities can be described as nonanalog or disharmonious. They imply the existence of ecological conditions different from today and raise interesting questions about the response of biotas to climate change.

"Absolute C-14 dating of individual fossil specimens," Stafford insists, "is the best method to test whether nonanalog species associations are taphonomic artifacts without biological implications or are evidence of communities dramatically different from those of today."

Current and future projects

The scope of an article like this can only scratch the surface of the research Stafford is currently pursuing. A list of his projects and selected publications can be found on his website, stafford-research.com/index.htm

Stafford believes that his most important contributions in coming years will be "determining whether humans were in the New World 20,000 to 50,000 years and more, increasing the use of molecular biology in paleontology and archaeology, and improving excavating, recording, and analyzing of archaeological and paleontological sites, all of which are non-renewable, invaluable records of the geological past—veritable time capsules of earth history."

Stafford suggests two books that, for him, define, exemplify, and serve as models for a career in the sciences (see "Suggested Readings"). Wilson states that "all sciences are interconnected, that no one field is more important than another, and that discoveries demand the broadest understanding of our world." Braben's book "summarizes the pursuit of science and confirms that personal discouragement, unfounded self-doubt, and, above all, unrelenting, invalid criticism are part of life as a scientist and that we must ignore the Luddites and mental troglodytes whose single goal is preventing the advancement of science."

"I doubt that anyone now living has been so innovative as Tom Stafford in mastering the nuanced chemistry of radiocarbon dating, and in advancing precision dating of the truly important Quaternary sites and specimens," says Timothy Rowe, a University of Texas colleague. "He is great fun to work with, always interesting, and I owe him a considerable intellectual debt for leading me through the intricate maze of the Pleistocene world."

–Martha Deeringer

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Suggested Readings

Braben, D. W. 2014 *Promoting the Planck Club: How Defiant Youth, Irreverent Researchers and Liberated Universities Can Foster Prosperity Indefinitely.* Wiley & Sons, NJ. 239 pp.

Wilson, E. O. 1998 *Consilience: The Unity of Knowledge.* Alfred A. Knopf, NY. 384 pp.

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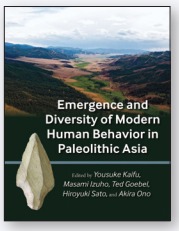

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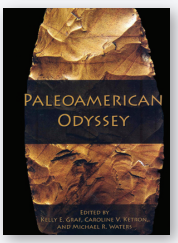

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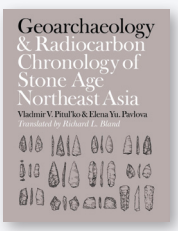

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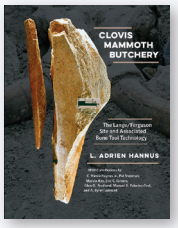

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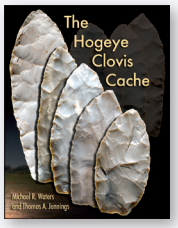

The Hogeye Clovis Cache, Michael R. Waters and Thomas A. Jennings. 2015. 159 pages. Hardback or e-book (ISBN 978-1-62349-214-4).
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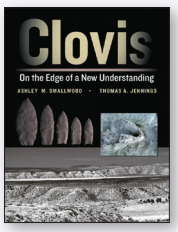

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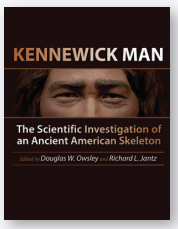

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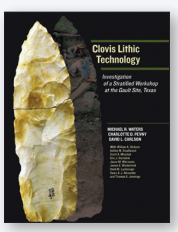

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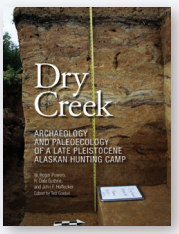

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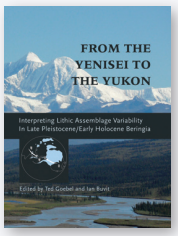

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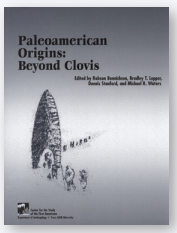

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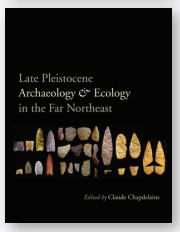

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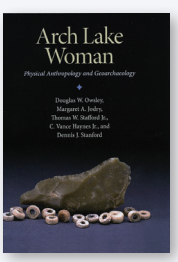

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