time. He presented data showing that most mutations arise in humans and other species when their DNA is being copied to produce sperm in males, and to a lesser degree, egg cells in females (Li *et al.*, *Nature* **362**, 745–747, 1993). Because rodents and monkeys go through more generations per unit time than humans do, they accumulate mutations at a faster rate. Britten, whose genetic studies also point to a primate slowdown (*Science* **231**, 1393–1398, 1986), has suggested that longer lived animals may have a greater ability to repair their DNA than do short-lived species, and this would also serve to reduce mutation rates. Says Li: "On the whole, this means molecular evolution may have slowed down for longer generation organisms."

One consequence of this work, say Li and Goodman, is that scientists are going to have to be a lot more careful when they use evolutionary rates to date the separation of different species of animals from each other. An interspecies "molecular clock" hypothesis was put forth in 1965 by the late Linus Pauling of Stanford University and his collaborator, Emile Zuckerkandl. They proposed that for any protein, rates of change were roughly the same over time in all lineages of mammals. The implication was that differences among proteins or DNA sequences could be used to date the separation of mammalian lineages. One such study, using a mutation rate derived from primates, joined rats and mice through a common ancestor that lived 40 million years ago. Most researchers today, however, put that split at 15 million years ago. "If you look at all of the mammalia and use the same mutation rate, you could come up with wildly wrong dates," says Goodman.

That doesn't mean every scientist is now ready to reset the molecular clock using data for individual species. Sarich, for one, argues that the new studies represent sequence data from only a small portion of primate genomes and says he is unconvinced that there are rate differences between primates. "I hardly find it surprising that there can be slowdowns in individual molecules," says Sarich. He cites a 1985 DNA hybridization study by Raoul Benveniste of the National Cancer Institute that showed no slowdown between humans and baboons.

Li thinks his sequence data are stronger. And he gets the same results from very different parts of the genome: "In every kind of noncoding sequence of DNA we look at we see a slowdown," including introns, pseudogenes, and flanking regions. Goodman agrees, citing his own DNA sequence studies and DNA hybridization data. "This gives me confidence that the results from noncoding DNA tell the whole story," says Goodman. And for him, it's a story with a very satisfying ending.

–Ann Gibbons

ARCHAEOLOGY

The Earliest Art Becomes Older—and More Common

Rare and recent. When archaeologists discuss the earliest cave paintings and other symbols made by modern humans, those two terms are usually applied. In the consensus view, the spectacular red or black mammoths, horses, and geometric figures occasionally found on cave walls, which are among the first signs of fully modern human behavior—the ability to manipulate symbols—are at most 40,000 years old.

But these twin notions were severely undermined 2 weeks ago at a conference called "Upper Paleolithic Image and Symbol" at the California Academy of Sciences in San Francisco. Much of the undermining data came from the land down under: Australia. Researchers presented new results that may push the first signs of human artistic behavior—and Australia's first colonization—back an extra 20,000 years. Other scientists demonstrated that art may have been all around, both in Australia and Europe, and apparently was a part of everyday life for our ancestors rather than just a mysterious underground event.

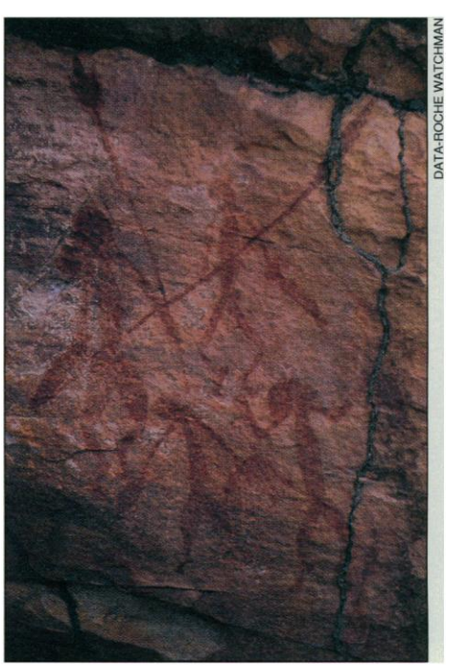
Toss another paint brush on the barbie. Australians have long been viewed by archaeologists as Johnny-come-latelies to the human settlement scene. Based on genetics and the fossil record, many scientists believe modern humans evolved in Africa 100,000 to 140,000 years ago, arrived in Europe around 50,000 years ago, and found their way to Australia 10,000 years later. And it wasn't until 30,000 years ago, according to this consensus view, that early Australians began decorating rock shelters and cliff faces with elaborate paintings of animals and geometric shapes.

But Rhys Jones, an archaeologist from the Australian National University in Canberra, told the San Francisco gathering that he has concluded that human beings arrived in Australia at least 60,000 years ago. And, he suggested, they were already painting when they landed.

Jones drew on recently published data from two northern Australian sites, rock shelters known as Nauwalabila I and Malakunanja II. Both sites were excavated in the 1970s and early 1980s, but because their lowest occupation levels—3 meters down—lacked charcoal for radiocarbon dating, their age remained unknown. But in the last 15 years, geochronologists have developed and refined two dating techniques that don't require carbon samples and are not subject to the 40,000-year limit that applies to radiocarbon dating.

The methods, thermoluminescence (TL) and optical dating, rely on a type of quartz timing unused by even the finest Swiss watchmakers. In essence, the methods date sediments containing grains of quartz by counting electrons trapped by quantum mechanical or physical defects in the mineral. The electrons are bumped into these traps at a regular rate, providing the basis for a clock. They can be released by energy absorbed from sunlight, which sets the quartz timing to zero; if the grains are then buried safely in sediments, the clock starts ticking. Millennia later, by heating the quartz in a lab or flashing it with light, geochronologists can release the electrons. Before returning to their natural places within the material, the freed particles release energy in the form of photons, producing a brief glow whose intensity is in direct proportion to the number of released electrons. Measuring this light thus reveals the ticks of the clock, and the techniques can date deposits exposed to sunlight from 1000 to several hundred thousand years ago.

TL frees the electrons by heating them, and Jones's team first used the method in 1990, on deposits at Malakunanja II. He obtained an age of 55,000 to 60,000 years for the lowest level. That level contained flaked



DATA-ROCHE WATCHMAN

Early arrivals. Australians who painted figures like these may have been on the continent 20,000 years earlier than previously thought.

stone tools that resemble artifacts that have been dated to about the same period in Africa. But the fact that the Australian site was "20,000 years earlier than any modern human site in Europe ... really caused people to raise their eyebrows," says Jones. Because the date was also more than 20,000 years older than any human site in Australia, many researchers just didn't believe Jones's dates.

In an effort to support his 60,000-year-old date, Jones's team decided to try optical dating. Unlike TL, optical dating uses light to eject the electrons from their traps. When Jones and his colleagues used optical dating on the lowest stratum at Nauwalabila I, the resulting dates of 53,000 to 60,000 years old seemed to confirm his earlier findings. Moreover, Jones found worn and faceted chunks of hematite—a mineral containing iron that many early human people ground into fine, red powder and used for painting—in the lowest artifact levels at both sites. He contends that the early Australians were probably painting rock walls even at that early date.

It's a striking idea, although claims of early artistry may be a bit premature, says Richard Klein, a Stanford University anthropologist. "Similar hematite fragments have been found in many Neanderthal sites and sites of comparable age in Africa without evidence for art," he says. But the issue of art aside, Klein notes that "if people were in Australia 60,000 years ago, then they must have been capable of fully modern behaviors," as they would have had to sail 80 to 100 kilometers across the open ocean to reach the continent—a complex task in any age.

But that notion creates a lot of theoretical headaches for anthropologists. Beyond changing the Australians' arrival time, Klein says, it upsets the "Out of Africa" paradigm for the emergence of fully modern humans. Sailors and painters on the Pacific Rim tens of thousands of years before they appeared in Europe give credence to the idea that modern people developed independently in different regions. And this unsettling development comes just when genetic tracking of population movements appears to firmly support the African origins of moderns (*Science*, 3 March, p. 1272).

For that reason, Klein, along with several geochronologists, wants additional sites dated. "I can't find any good reason to dispute these dates," says James Bischoff, a geochronologist with the U.S. Geological Survey in Menlo Park, California. "But because of the importance of the issue I would like to see additional samples dated." If the dates hold up, says Klein, "it will force an enormous amount of rethinking."

Seeing the invisible. The time when humans became artists isn't the only thing that will have to be rethought if other presentations at the meeting hold up. Alan Watchman, a geologist who heads Data-Roche Watchman, an independent consulting company on rock art in Quebec, Canada, thinks that rock art was also far more abundant than most other scholars have believed. Carefully prying small flakes off the surface of apparently bare walls of rock shelters in Australia, Watchman thinks he has found signs of paintings that may be 20,000 to 30,000 years old—but the paintings are invisible to the naked eye. "Most of the paintings on the surface are only a few thousand years old," says Watchman, but older signs of symbolic behavior lie hidden beneath hard crusty layers of gypsum and salts.

DATA-ROCHE WATCHMAN

Seeing red. A new technique reveals hidden red bands of hematite—possibly used to make a prehistoric painting—in rock walls.

Watchman discovered the first clues to these older paintings when he pried flakes off a large, apparently blank boulder at one painted rock shelter site, Walkunder Arch. "Everyone has to pass by this boulder to reach the rock shelter," he says, "and I always thought it was curious that it was not painted, since it has a perfect surface and is in the right spot." And, in fact, Watchman discovered telltale yellow and reddish-brown layers in flakes from the rock, layers that have the hue and consistency of powdered ocher: "I can't prove it yet, but I suspect that there is a painting on that boulder that we just can't see." Layers of gypsum and salts have grown over it in the intervening years, he says.

Since that initial discovery, Watchman has sampled apparently blank walls at other rockshelters. He pries off 4-mm-thick flakes of crust and seals them with epoxy. After slicing the crust into thin vertical sections with a diamond saw, he polishes the surface, revealing stratified layers of rocks and minerals. Often sandwiched between two of these layers is a band of hematite or charcoal—the same materials Australian aborigines used for their painting. Watchman reports that preliminary radiocarbon dating on some of these samples has resulted in dates of "20,000 to 30,000, and older."

While Watchman's research intrigued the gathering, several scientists cautioned that traces of paint do not by themselves mean there are paintings beneath the crusty surfaces. "It may only mean that someone wiped his or her hand on a wall after rubbing their body with ocher," said David Lewis-Williams, an anthropologist from the University of Witwatersrand. "And there's a great difference between that and making a symbol." Watchman hopes to resolve this issue by examining a wider area of a wall, searching for patterns—figures, perhaps—via a geophysical, x-ray-like scan that might reveal the hidden shapes beneath the masking crust.

Such prospecting for invisible art may help archaeologists find symbolic works on other continents, where scientists have long suspected that there was more art than met archaeologists' eyes. "I've always thought that people were producing more art than what we saw in the caves," says Paul Bahn, a free-lance archaeologist in England and an expert on Ice Age art. Bahn and others suspect paintings or engravings on rocks in open air sites, rather than in caves, were common in Europe during the Upper Paleolithic (which lasted from 40,000 to 11,000 years ago), but have been obscured by erosion and sediment deposition. Randall White, an archaeologist at New York University, is co-excavating a rock shelter in France, Abri Castenet, that has "tantalizing fragments of black lines or smudges." Watchman's technique might bring them to light again.

At the meeting, Bahn provided more support for the notion of abundant open-air art when he described an extensive outdoor site of more than 150 rock engravings in Portugal. The site, discovered last October along the Coa River in northern Portugal, bears images of aurochs, horses, ibexes, and deer chiseled into rock walls beside the river up to 20,000 years ago. It is only the sixth such site known, and the largest, with animal images extending some 13 kilometers along the river.

Inside caves, paintings have a "mysterious air," says Bahn, so that they've been interpreted as being highly symbolic or religious and tied in to secret initiation rites. "But these outdoor sites are inherently less mysterious," he says, and imply that art was far more common and far better integrated into daily life than the cave painting alone would suggest. "It suggests that the 'sacred' was far less separate from their lives than the caves would have led us to believe," says Bahn.

–Virginia Morell