HUMAN ORIGINS

Homo erectus in Java: A 250,000-Year Anachronism

The story of human evolution has lately become as complicated as a Tolstoy novel. It used to be a simple and lonely tale of one species living at one time and evolving gradually into another species. Even the renowned geneticist Theodosius Dobzhansky wrote in 1944 in the *American Journal of Physical Anthropology* that "as far as is known, no more than one hominid species existed at any one time level."

But lately, this tale has become thick with new subplots and characters. The recent recognition of several different species of early *Homo* living in Africa about 2 million years ago, and various forms of *Australopithecus* before that, has made it clear that there were far more lineages in the early history of the human family than previously believed. Now, it seems that later chapters may also have to be rewritten to include at least one more character: a relative who makes a surprise reappearance long after it was presumed dead.

In a report on page 1870, an interdisciplinary team of scientists suggests that one relative, *H. erectus*, was still alive in Java, Indonesia, as recently as 27,000 to 53,000 years ago—at least 250,000 years after it was thought to have gone extinct in Asia. If so, this remnant population of *H. erectus*, a species that first appeared in the fossil record about 2 million years ago, would have been alive when modern humans and Neandertals roamed the earth. The team, led by geochronologist Carl C. Swisher of the Berkeley Geochronology Center, came to this stunning conclusion after redating two important fossil sites in Java. "If the dates are right, we have three different species coexisting at the same time," says Chris Stringer, a paleoanthropologist at The Natural History Museum, London. It also means, says American Museum of Natural History paleoanthropologist Ian Tattersall, that "being alone on Earth is unusual."

The new dates also cast doubt on a theory, held by some paleoanthropologists, that the Java people were the ancestors of the first Asians, including the first Australians, who appeared in the fossil record about 40,000 years ago. It is therefore no surprise that these findings are proving controversial. "There is a real problem with the dates," claims Australian National University paleoanthropologist Alan Thorne, who notes that the site is notoriously difficult to date. And even if the dates hold up, he and others argue, they wouldn't necessarily rule out the Java-Australian lineage.

Swisher, however, is confident of the findings, which come mainly from a fossil site on a terrace above the Solo River in Java, in the village of Ngandong. This is where Dutch archaeologists discovered the faceless skulls of 12 prehistoric humans between 1931 and 1933. Their identity mystified anthropologists from the start: Over the years, individual skulls were variously identified as that of a tiger, an ape, a Neandertal, and a modern human. But in recent years, most anthropologists who have seen them agree that the Solo skulls belong to *H. erectus*—making them the largest assemblage of this early human ever found, says University of Florida paleoanthropologist Susan Antón, a co-author of the paper.

It has been even more difficult to pin down their age. No teeth—the best material for dating—were found with the skulls, and the keeper of the fossils, Teuku Jacob of Gadjah Mada University in Java, has not allowed chips to be removed from the skulls for direct dating. A French team did date one of the skulls years ago using an experimental method that doesn't damage the specimen. They came up with an age of at least 300,000 years, says geologist Christophe Falguères of the National Museum of Natural History in Paris, where the skull was dated. The group has had problems with the dating, however, and has yet to publish results.

KENNETH GARRETT/NATIONAL GEOGRAPHIC SOCIETY

Heady stuff. Susan Antón and Teuku Jacob with Ngandong hominid skulls.

For the most part, geologists have had to use indirect methods to date the fossils—by dating volcanic rock at the site or the teeth and bone of animals found in the same fossil-bearing layer as the skulls. The results have varied widely. A Japanese team in 1985 dated volcanic rock near the site to about 250,000 years. But in 1988 came tantalizing hints that the skulls might be much younger when a Dutch team published ages of about 100,000 years for nearby animal bone chips.

Swisher, who is systematically using state-of-the-art argon/argon methods to redate volcanic rock at early human fossil sites in Indonesia, had hoped to settle this question. First, he and other geologists ruled out the Japanese team's date because it was on rock that, he says, "had nothing to do with the skulls." After searching in vain for a layer of volcanic minerals closer to the fossils, he turned to other material for dating. He dug a test trench at the site to confirm that the half-meter layer of sandstone and clay cobbles that had yielded the skulls was the only fossil-bearing layer, and collected water buffalo teeth from the same level where the skulls were found. He also collected bovid teeth from a nearby site, Sambungmacan, where remains thought by many to be *H. erectus* have been found.

He sent those teeth, as well as bovid teeth that had been collected with the human fossils in the early 1930s, to McMaster University in Hamilton, Ontario, for dating by geochemist Henry Schwarcz and geologist Jack Rink. Their lab is one of a half-dozen that uses the relatively new method of electron spin resonance (ESR), which measures the electric charges induced in tooth enamel over time by radioactive materials, such as uranium, in the surrounding soil. When the team came up with its surprising results—a minimum age of about 27,000 years and a maximum age of 53,000 years—they tried a different technique: uranium series dating, which measures the clocklike radioactive decay of uranium to thorium in the teeth to date the enamel. The results checked out.

Despite those precautions, some other geologists remain skeptical. The animal teeth themselves contain high levels of uranium, which can throw off ESR dating, according to studies by Falguères's group at a site in Italy. Another concern raised by Thorne and others is that the animal teeth may not be the same age as the skulls, because flooding or erosion at the site may have washed older skulls out of their original resting place and into the young fossil bed.

Schwarcz and Rink respond that there are geologic problems at the site in Italy, where the volcanic minerals used to check the ESR dates might have been swept into the site by water—and have been much older than the teeth. As a result, there is no body of evidence to make them doubt the reliability of using ESR to date teeth with high uranium at other sites. Also, they say they got the same dates on all the teeth from the same layer at two sites—with two dating methods. "We're very confident about these dates," says Schwarcz. As for the flooding theory, Swisher's team points out that it's hard to imagine how 12 crania and other human remains could have moved to the same level and at two sites. Moreover, the uniformity of

the dates and earlier fluorine analysis of the hominid bone and bovid teeth show that they had undergone the same amount of decay and, hence, were of similar age.

Nonetheless, say Swisher's collaborators, he kept trying to find alternative explanations for the young age for *H. erectus*. "Every time the dates came back, Carl [Swisher] would say, 'Are you sure these aren't *H. sapiens*?' " says Antón. "And I'd go back to Indonesia to have another look." What Antón saw convinced her that the Solo skulls had not been misidentified. "They are unequivocally *H. erectus*," agrees Philip Rightmire of the State University of New York, Binghamton, who examined them in March.

These findings may spell trouble for the regional continuity model of human origins, which proposes that *H. erectus* in Asia was among the ancestors of modern humans in Asia. A competing—and more widely held—theory is that modern humans evolved in Africa and displaced *H. erectus* as they migrated around the globe. A key prediction of the regional continuity theory is that the Java people were among the ancestors of modern Australians. But, as Swisher points out, his new dates imply that the Solo people may be younger than the first Australians, arguing against a direct ancestor-descendant link.

Thorne and University of Michigan paleoanthropologist Milford Wolpoff—a leading proponent of the regional continuity theory—disagree. "There is a great, long list of characters that are the same in the Solo skulls and the earliest known human people from Australia," says Thorne, including the unusually large size of the Solo brain cases. Thorne also argues that even if the Java fossils are relatively young, they look so much like the Australian fossils that they may have shared a recent ancestor.

To try to nail down the dates of the Solo people more firmly, Swisher is planning to return to the Java site next year to look for organic material to date with radiocarbon methods and soil carbonate for uranium series dating. But until he finds such material, or until Jacob allows direct dating of the human fossils with proven methods, Swisher says, "we have two options: Sit on our data, or say that we've done the best we can with the technology available to us and throw them out there for people to evaluate." Given the startling nature of the data, there will be no shortage of evaluators.

–Ann Gibbons

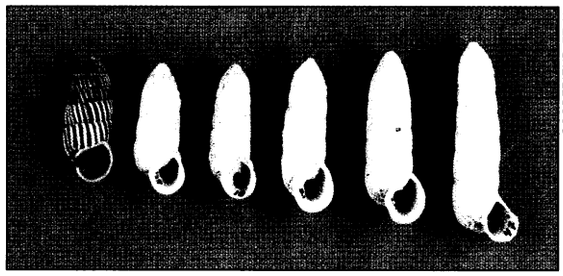
PALEONTOLOGY

Unscrambling Time in the Fossil Record

Time is the great bugaboo of paleontologists. All too often, a thin sliver of the fossil record spans a vast sweep of geologic history that is too broad to show exactly how, and how quickly, evolution works: how one species gives rise to another, why one species dies out and another survives, or how an invading species does battle with the defending locals. Now, two researchers have stretched a fossil record that would normally look like an instant of geologic time into a portrait of a prolonged evolutionary transition.

On page 1894 of this issue of *Science*, geochronologist Glenn Goodfriend of the Carnegie Institution of Washington's Geophysical Laboratory and paleontologist Stephen Jay Gould of Harvard University report how they used a combination of two dating techniques to extract a 15,000-year-long record of one campaign in a land snail's long and ultimately successful battle to win the Bahamian island of Great Inagua from a native species. They reconstructed this evolutionary shift, which ended within the past few thousand years, from a single, jumbled bed of snail shells. "The significant thing is that Goodfriend was able to put things in order," says paleontologist Stephen Stanley of The Johns Hopkins University. "It's a neat way to sort out [fossil] ages." In this case, it revealed a surprisingly prolonged intermingling of an invading species and its eventual victim.

Gould picked up the fossilized shells from a sand flat on the south shore of 80-kilometer-long Great Inagua. If they had come from the usual sort of stratified fossil deposit, Gould says, they would probably have told a far less interesting story: The deepest and therefore oldest snail fossil would be *Cerion excelsior*, above that would be a thin layer in which both *C. excelsior* and the invader *C. rubicundum* are mixed together, and then there would be *C. rubicundum*—now a widespread form—by itself. "It would be a classic punctuation" in the evolutionary record, Gould notes, a transition from one species to another that appears to be geologically instantaneous. Gould himself co-originated the term "punctuated equilibrium" more than 20 years ago to describe in particular the abrupt formation of new species. Abruptness, he argued, was the evolutionary norm: Speciations appear suddenly, he said, rather than gradually over hundreds of thousands or millions of years, as had generally been assumed.



GOODFRIEND *ET AL.*

Going, going, gone. A now-extinct snail *(right)* and an invader *(left)* hybridized *(middle)* during thousands of years.

Goodfriend and Gould set out to put the shells of the temporally jumbled *Cerion* fossils in chronological order to try to trace just how abrupt this invasive transition really was. Absolute dating of enough shells by the radiometric carbon-14 method would have been too expensive, so Goodfriend used the more economical technique of amino acid racemization to determine their relative ages. The amino acid molecules that make up proteins come in only the L structural form but, with time, slowly transform, or racemize, into an equal mix of the D and L forms. When amino acids from 19 shells from the sand flat were analyzed, the oldest, which were dated to 16,000 years and older by carbon-14, were pure *C. excelsior*, while younger fossils had shell shapes intermediate in appearance between *C. excelsior* and *C. rubicundum*, and the youngest of these intermediate forms were just 3000 years old.

Apparently, *rubicundum* arrived on the island and interbred with the indigenous *excelsior* to produce hybrids at this site with characteristics of both species, says Gould. Either the two species coexisted on the island to produce hybrids on the south shore during thousands of years before *excelsior* disappeared entirely, or it became extinct earlier, and the hybrids sustained themselves.

"The great thing is that they've projected the [snail] population they see now back in time," says paleontologist David Jablonski of the University of Chicago, "and put a number on how stable these hybrids actually were. It's evolution in action." And that evolution may surprise some paleontologists. "Many people think hybrids are short-lived," says paleontologist Gary Vermeij of the University of California, Davis. "Here, they lasted a long, long time" without merging with or losing out to other species.

Gould is quick to point out, however, that this transition was not gradual, as paleontologists understand the term. Punctuated equilibrium is often misinterpreted "as a catastrophic, one-generation, overnight theory," he says. "It's never been that." Evolutionary change may be slow on the scale of a human lifetime, he says, but 5000 or 10,000 years is still abrupt in geologic time.

–Richard A. Kerr