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**

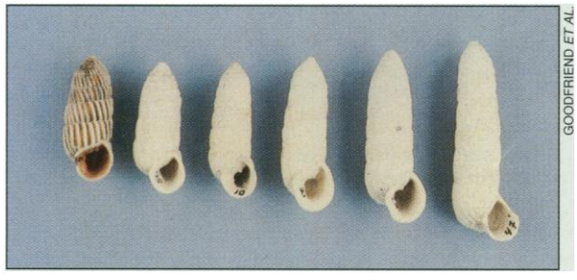
PALEONTOLOGY

# 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**