turns out, the first publication on the find was greatly understated.

Two groups report in the February issue of *Geology* that the rock marked by the putative tracks is a whopping 1.6 billion years old. That predates the earliest generally accepted trace fossil of a complex animal—dated at 575 million years ago—by about a billion years. To some researchers, such a long gap strains credulity. Instead of traces of life, they are now seeing meaningless doodlings in ancient, squishy muds.

The new, solid age for the Indian grooves comes from radiometric dating by two independent groups. They measured the clocklike rate of radioactive decay of uranium to lead in tiny crystals of zircon deposited with volcanic ash just before and just after the grooves formed. Both groups—one led by paleontologist Birger Rasmussen of the University of Western Australia in Crawley, the other by geochemist Jyotiranjan Ray, now at the University of Hawaii, Manoa—got ages of just over 1.600 billion years, give or take less than 0.008 billion years.

"There's no question" that the groovy rock is very ancient, says geochronologist Samuel Bowring of the Massachusetts Institute of Technology, a co-author of the Ray paper. Dating by various other techniques that pointed to an age of 1.1 billion years or younger (*Science*, 16 April 1999, p. 412) must have been affected by alteration of the rock, Bowring says.

With doubts about the appropriate age resolved, the biological origins of the grooves become "even more exciting or more improbable," says paleontologist Adolph Seilacher of Yale University, who with colleagues proposed that the grooves were formed by evolutionarily advanced worms burrowing just beneath the sea floor. "This age makes it unlikely these are animal trace fossils," Seilacher says. "At the same time, I have to go with the evidence. I have not found or heard of any other explanation. Do we have any nonbiological interpretation of these things?"

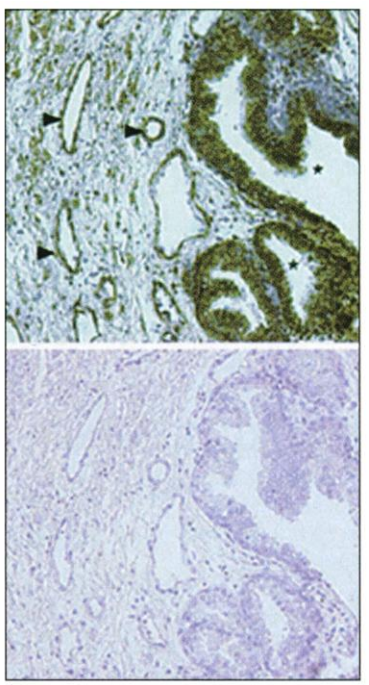
As it happens, the answer is yes. "No one is better in the field than Seilacher," says paleontologist Mary Droser of the University of California, Riverside, but, on closer inspection, she finds that the grooves "look much more like cracks than trace fossils." The details of groove diameter, the V shape of groove floors, and the irregular pattern of grooves all point to cracked mud rather than burrowing, Droser says. In addition, "you wouldn't expect a billion years without [similar traces]."

The debate over the earliest traces of animal life "is a great dress rehearsal for when we get samples from Mars," says Bowring. "How do you decide when something is biogenic? Paleontologists haven't completely come to grips with that." Perhaps squiggly grooves from India can help prepare us for that encounter. **–RICHARD A. KERR**

BIOMEDICAL ETHICS

Study of Brain Dead Sparks Debate

Renata Pasqualini and her husband Wadih Arap, biologists at the M. D. Anderson Cancer Center in Houston, Texas, had for several years been working on a new approach to designing targeted cancer drugs, but they were not sure how to test it on people. At the same time, they were deeply moved by the families of cancer patients they encountered. Watching loved ones decline, their brains silent, their bodies tethered to life support, the families sometimes offered to donate their relative's organs, but advanced cancer made that impossible. From this juxtaposition arose a novel experiment: Pasqualini, Arap, and their colleagues have infused millions of peptides into brain-dead and near-death patients to determine which ones end up in specific tissues.



Picky. Certain peptides latch onto prostate blood vessels (*top*) but not skin (*bottom*) in tissue collected from a brain-dead man.

Despite the initial "yuck factor," as Anne Flamm, a clinical ethicist at M. D. Anderson who helped design the protocol, describes it, she and others believe that with stringent informed consent procedures, such studies are ethically sound. And the first of the experiments, on a 48-year-old brain-dead man, reported in the February issue of *Nature Medicine*, has yielded a wealth of data.

"Being able to get information from a human being, in vivo—not just taking cells out—has wide-ranging implications," says Donald McDonald, a vascular biologist at the University of California, San Francisco (UCSF). "Everyone recognizes that this was a risk that [the researchers] took because of the [study's] obvious sensitivity."

Pasqualini, Arap, and their colleagues believe that tracking which peptides—short strings of amino acids—are drawn to blood vessels in certain tissues could pave the way toward drugs that might target those peptides, and hence the blood vessels feeding particular tumors. In the late 1990s, they helped establish that in mice, different peptides bind to blood vessels in different parts of the body, and that vessels feeding tumors differ from healthy ones. From tissue biopsies taken after infusing the peptides, the team determined which classes of peptides were present in each. But they worried that the same types of peptides would not migrate to the same blood vessels in humans.

Finding out posed ethical challenges: The multiple biopsies needed—of skin, muscle, bone marrow, prostate, fat, and liver—would be too invasive to gather from conscious individuals. So in late 1999, Arap and Pasqualini approached M. D. Anderson ethicists about the idea of experimenting on brain-dead and near-death patients.

Flamm and fellow ethicist Rebecca Pentz scanned medical literature for precedents but unearthed few. In 1981, researchers received permission to test an artificial breathing device on brain-dead children; 6 years later a brain-dead man was infused with monoclonal antibodies.

The pair recommended strict rules. First, the impetus to participate must come from families: Only after a family inquires about organ donation or research can it be told of the study. The procedure must last no more than an hour, and families of near-death patients must be warned that death could occur during the experiment. In early 2000, the hospital's Institutional Review Board (IRB) gave the green light for the team to infuse roughly 200 million different peptides into their subjects.

Still, the studies have prompted ethical questions few have considered before. Elizabeth Hohmann, an infectious-disease specialist and chair of the IRB for Massachusetts General Hospital and Brigham and Women's Hospital, both in Boston, says she has never encountered proposals to experiment on brain-dead people on life support. Nor has John Falletta, a pediatric oncologist and lead chair of Duke University's IRB. If the body is respected, he says, "such research could be very important."

A smattering of hospitals seem to agree. Pasqualini's group has since infused peptides into two more individuals as part of the same study. The University of Pittsburgh in Pennsylvania recently approved two studies on brain-dead subjects on life support; one tests a device to treat heart and lung failure. And M. D. Anderson approved another study last May, in which patients declared dead are connected to a mechanical resuscitation device intended for those in cardiac

CREDIT: W. ARAP *ET AL.*, *NATURE MED.* 8, 126 (2002)

arrest; researchers then determine whether it induces blood flow. "It can't inflict pain," explains Lee Parmley, interim chair of critical care and the leader of the study.

The second and third subjects in the Pasqualini team's study are not brain dead but "nearly dead"—unconscious patients on ventilators with failing organs but continued brain activity. This set prompted additional scrutiny to ensure respect for the patients' wishes.

Although the team has published results on just one subject, scientists such as McDonald are impressed. The group homed in on certain sets of peptides that share similar amino acids, including one that appears specific to prostate blood vessels. But uncertainties remain. Due to their grave condition, these subjects may not be broadly representative, says UCSF ethicist Bernard Lo. In addition, the sheer number of peptides infused could interact with each other to skew results. Arap says that double-checking against other tissue samples to confirm results suggests that thus far, these problems haven't surfaced.

Meanwhile, the biomedical community is notably silent, says Michael DeVita, a University of Pittsburgh physician. DeVita and three colleagues are planning a presentation at a conference this fall, where they will explore how the dead, on and off life support, may appropriately be used in research—and how they may not. **–JENNIFER COUZIN**

NUCLEAR HISTORY

Letters Aver Physicist Supported Nazi Bomb

For more than half a century, historians have speculated about a private conversation that took place in September 1941 between German physicist Werner Heisenberg and Danish physicist Niels Bohr. Long-secret letters released on 6 February by the Niels Bohr Archive in Copenhagen finally provide an answer. They flatly contradict claims made by Heisenberg after the war that he told Bohr he intended to subvert the Nazi bomb program from within.

Eighteen months after German troops occupied Denmark, while the Nazi war machine was still crushing all in its path, Heisenberg traveled to Copenhagen to see his former mentor, Bohr. The two Nobel laureates talked in private, and Heisenberg said something about nuclear fission that so disturbed Bohr that the Dane abruptly ended both the exchange and their long friendship.

Heisenberg later implied he had tried to signal that he knew it was possible to make an atomic bomb, but that he would subtly sabotage the German drive to do so. Bohr misunderstood his intentionally oblique language, Heisenberg said in a letter published in 1957 in Robert Jungk's history of atomic weapons, *Brighter Than a Thousand Suns*. Bohr disagreed with this account and drafted a letter to Heisenberg to set the record straight. He never posted the letter, however, and it surfaced only after Bohr died in 1962, folded into his copy of Jungk's book. The letter was to have remained sealed in the Bohr archive until 2012, but the Bohr family agreed to release it and 10 other secret documents ahead of schedule in response to the intense interest sparked 4 years ago by *Copenhagen*, the award-winning play by writer Michael Frayn that speculates about what the two men said. The archive published the documents on the Internet (www.nba.nbi.dk).

In the letter found in the book, Bohr writes: "You spoke in a manner that could only give me the firm impression that, under your leadership, everything was being done in Germany to develop atomic weapons and that you said that there was no need to talk about details since you were completely familiar with them and had spent the past two years working more or less exclusively on such preparations." In another letter, Bohr explicitly repudiates Heisenberg's contention that he implied he would undermine the Nazi bomb program. "It is therefore quite incomprehensible to me," Bohr writes, "that you should think that you hinted to me that the German physicists would do all they could to prevent such an application of atomic science."

Of course, the letters provide only Bohr's recollection of the conversation, says Gerald Brown, a physicist at the State University of New York, Stony Brook, who knew both men. "I don't think Bohr understood what Heisenberg was trying to say," Brown says. Heisenberg, who died in 1976, had no reason to endanger himself by revealing the Nazi nuclear research program unless he was try-

Fallout. Werner Heisenberg (left) and his mentor Niels Bohr, shown here in 1934, later split over German A-bomb research.

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ScienceScope

Northern Innovation Will the rhetoric match the reality? That's what Canadian scientists are asking after Industry Minister Allan Rock (below) unveiled a 10-year innovation plan this week. The long-overdue white paper affirms a government commitment to double annual R&D spending, to $9.2 billion, by 2010. It also backs greater commercialization of publicly funded academic research and at least 10 Silicon Valley–like "technology clusters." But academia must "more aggressively" contribute to industrial innovation if it wants more cash, the plan says.

The white paper kicks off 7 months of meetings leading up to a national innovation summit in October. Robert Giroux, president of the Association of Universities and Colleges of Canada, says that "the real test will be whether the government will be prepared to properly fund these initiatives."

Never Too Old Japan's rigid retirement rules have allowed Singapore to recruit an entire top-notch research lab, boosting the tiny nation's efforts to become a biomedical power. Molecular biologist Yoshiaki Ito, one of Japan's top cancer researchers, last week announced that his 10-person team at Kyoto University will soon move to the National University of Singapore. Ito will use a joint appointment at the Institute of Molecular and Cell Biology and the medical school to launch an Oncology Research Institute, another piece of Singapore's $1-billion-a-year investment in the life sciences.

Ito hopes his move will help shake up Japan's national universities, which require professors to retire in their early 60s. "I want to show that productivity [can extend] beyond retirement age," he says.

No to Lab Animal-rights protesters have blocked the development of a new primate research laboratory in Cambridge, U.K. Local officials last week rejected the University of Cambridge's request for a permit to plan the new center after police leaders said it might cost too much to protect the facility from protesters. The British Union for the Abolition of Vivisection and other groups had rallied against the lab. The decision sets a "worrying precedent," says the Research Defence Society, an advocacy group. The university may appeal, saying the setback could hamper its neuroscience program.

Contributors: Eliot Marshall, Constance Holden, Wayne Kondro, Dennis Normile, Anna Baynham