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EARTHQUAKES

In Turkey, Havoc From a Falling-Domino Fault

There were plenty of cruel surprises when the magnitude 7.4 earthquake struck northwestern Turkey early last week. Apartment houses and hotels collapsed when shaky soil turned to jelly and shoddy concrete crumbled. The rescue effort was slow and chaotic. By the end of the week, the death toll was rising to the tens of thousands and recriminations were flying. But one aspect of the disaster offered no surprise at all: the behavior of the ultimate culprit, the North Anatolian fault. Although seismologists could not have predicted when the earthquake would strike, they had long expected it.

Last week's cataclysm was just the latest in a series of massive earthquakes that have marched along 1000 kilometers of the fault since 1939. The sequence began that year in eastern Turkey with a magnitude 7.9 earthquake that killed more than 20,000, then moved westward in six other major events. "This is probably the most spectacular example of earthquake progression known," says Ross Stein of the U.S. Geological Survey (USGS) in Menlo Park, California. The most recent quake in the series had been a magnitude 7.0 that struck in 1967. The quiet stretch of fault to the west, passing near the port of Izmit, "was the obvious candidate" for a future earthquake, says Nicholas Ambraseys of Imperial College London.

Such knowledge wasn't much help to the residents of the area when the quake finally came, in the wee hours of 17 August. Even though the dangers of the fault had been well publicized and decent construction standards were on the books, "there was a total absence of enforcement of the regulations," says Ambraseys. As rescuers tried to free people trapped in the wreckage, geologists took to the field to map the rupture, which had started 17 kilometers belowground near Izmit, 100 kilometers east of Istanbul. By late last week, Aykut Barka of Istanbul Technical University and his colleagues had traced the break for more than 100 kilometers and measured up to 4 meters of ground displacement along the fault. The eastern end of the rupture overlaps the site of the 1967 earthquake, says Ambraseys. "It extends the earthquake sequence to 2000."

March of destruction. Seven large earthquakes had ruptured the North Anatolian fault in a westward progression starting in 1939; last week's event makes eight. (Thick lines indicate past ruptures.)

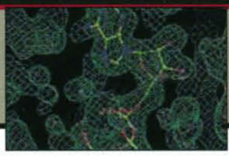
The ultimate impetus for the earthquakes is the collision of two tectonic plates carrying the Arabian Peninsula and Eurasia. Caught in between, Turkey is being squeezed to the west like an orange seed, geophysicists say. The slip takes place along two major faults, the North Anatolian and the Southeast Anatolian, which bracket the country to the north and south. Historical records show that both faults have experienced periodic clusters of large earthquakes, says Ambraseys, with clusters flip-flopping between the faults every century or two. The previous major cluster on the North Anatolian fault struck in the late 1600s and early 1700s, flattening Izmit at least once.

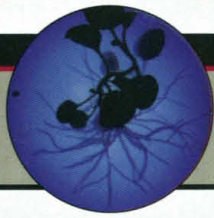
And something about the fault—perhaps the way it is broken into a series of segments—makes it uniquely prone to orderly earthquake sequences. "We shouldn't get too comfortable with the falling-domino character of this fault, because it's not the way most other faults work," says Stein. But 3 years ago he, Barka, and James Dieterich of the USGS tried to explain how the dominoes fall. They calculated how each earthquake, while relieving stress along one segment of the fault, transfers stress to the next, unbroken segment. Because of the 1939–67 earthquakes, "we suggested that there was an increased hazard in the region of Izmit," says Dieterich. The calculated risk, high right after the 1967 earthquake, had dwindled over time, however. He and his colleagues put it at 12% in the next 30 years —"not a huge effect by any means," Dieterich says.

Other researchers viewed the fault segment as dangerous simply because it was a seismic gap, where the stresses of plate motion had not been released by a recent earthquake. In theory, such stresses can be dissipated slowly and harmlessly, by fault "creep." But Massachusetts Institute of Technology seismologist M. Nafi Toksöz and colleagues in Turkey monitored the Izmit section of fault using the satellite-based Global Positioning System (GPS), which is sensitive to the tiny ground movements that might indicate creep. Two years ago, he says, they raised the alarm: "Our GPS result showed the fault was truly locked, and stress was accumulating."

Toksöz and others note that in spite of these warning signs, no one knew exactly when an earthquake might strike, or whether it would be a single large event or a series of smaller, less destructive tremors. "What's unclear to me, and probably never will be clear, is why it waited 30 years" after the 1967 quake, says Stein. Even so, seismologists are already speculating about the North Anatolian fault's next move. As James Dewey of the USGS's National Earthquake Information Center in Golden, Colorado, puts it, "Is this the end of the sequence, or does it go on from here?"

SOURCE: STEIN *ET AL*.; ILLUSTRATION: ALAN STONEBRAKER/*SCIENCE*





The fault continues west from the ruptured area, diving under the Sea of Marmara and skirting 30 kilometers from Istanbul. "If there's any stress transfer mechanism, it's scary," says Toksöz. "We are convinced that the next segment is locked, it's a seismic gap, and it's sitting right next to Istanbul, with 12 million people." Toksöz is planning to extend his network of GPS stations to this next fault segment, to monitor any buildup of stress that might indicate that the seismic activity on the North Anatolian fault is about to take another mighty step to the west. –TIM APPENZELLER

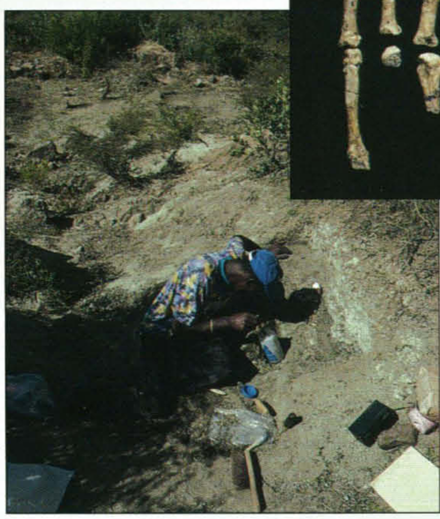
PALEOANTHROPOLOGY

Kenyan Skeleton Shakes Ape Family Tree

In the summer of 1993, fossil hunter Boniface Kimeu walked down a slope in the Tugen Hills of north central Kenya and noticed a single tooth sticking out of a wall of rock. He returned with other researchers from the Baringo Paleontological Research Project, who worked their way deeper into the rock and discovered a jaw with more teeth, plus bones from the spine, rib cage, arms, wrists, and hands. Kimeu had found the most complete ape fossil known from about 11 million to 16 million years ago—a crucial transition time when primitive apes looking something like howler monkeys were evolving into the ancestors of the living great apes, including humans. Now, after 6 years of preparation and study, a research team presents the find on page 1382 of this issue. Paleontologists say it shines light into an extremely murky phase of ape evolution, forcing researchers to reexamine the family tree of our distant ancestors and offering a glimpse of new connections across continents.

Initially the research team, led by paleoanthropologist Steve Ward of the Northeastern Ohio Universities College of Medicine in Rootstown, Ohio, thought the skeleton belonged to a 15-million-year-old primate called *Kenyapithecus*, a controversial genus once considered the ancestor of modern apes. But closer analysis proved this idea only partly correct. The team now argues that the new fossils, as well as some previously collected specimens of *Kenyapithecus*, are actually so different from the original *Kenyapithecus* fossils that they belong in an entirely new genus. The new primate, which the team calls *Equatorius*, is not a close relative of living apes after all, but it does record apes' first steps down from the trees—a crucial evolutionary step that our own ancestors must have taken independently. And the reclassification suggests that *Kenyapithecus* was part of a great migration of apes out of Africa. The new find is "extremely important," says David Begun, a paleoanthropologist at the University of Toronto. Adds paleoanthropologist Peter Andrews of The Natural History Museum in London: "It shows general evolutionary patterns in Africa and a migration between Africa and Europe and Asia. That's a lot from just one new name."

Kenyapithecus was first discovered by pioneering paleontologist Louis Leakey in 1961. At a site called Fort Ternan in western Kenya, he found an upper jaw and a few teeth dating back 14 million years, which he dubbed *Kenyapithecus wickeri*. Then in 1965 he sifted through bits of jaw and teeth from Maboko Island in Lake Victoria, 100 kilometers away, and decided that they represented a second species, *K. africanus*, which paleontologists now date back to about 15.5 million years ago. Impressed by its modern-looking teeth, Leakey declared *Kenyapithecus* to be "a very early ancestor of man himself."



Hand from the past. Boniface Kimeu unearthed a partial ape skeleton in Kenya's Tugen Hills, including the bones of the hand.

CREDITS: S. WARD *ET AL.*

Since then, as paleontologists have gathered more data on the evolution of apes—the lineage of large primates that includes humans, chimps, gorillas, and orangutans—they have argued about where *Kenyapithecus* fits into the picture. The first apes seem to have arisen from monkeylike primates in African forests more than 20 million years ago, and by 10 million years ago they had blossomed into a huge radiation reaching across Europe and much of Asia. But sometime in the next 10 million years, almost all went extinct.

Kenyapithecus, with its scant fossil record but intriguing teeth, has been cast in many different roles in this story. A few researchers stand by Leakey's original idea (*Science*, 18 April 1997, p. 355), but many consider *Kenyapithecus* to be more primitive. They see our own roots in later European apes, which might have evolved from *Kenyapithecus*.

The new fossil suggests that both sides might be right, because it shows that *Kenyapithecus* is not one genus but two. Ward recognized the split thanks to the nearly complete set of teeth of the new find, particularly the canines and incisors, which set it apart from *K. wickeri*. "That was the catalyst that caused us to carefully reassess everything else, and everything else just about fell into place," says Ward. When they looked with fresh eyes at the specimens assigned to *Kenyapithecus*, they realized that the new fossil and other *K. africanus* material lacked many of the distinctive features of *K. wickeri*, including details of the canines. They conclude that *K. africanus* and *K. wickeri* were profoundly different apes, belonging to two separate genera. "Everything we tried kept pointing in the same direction," says Ward.

In their report, the researchers therefore rechristen *Kenyapithecus africanus* as *Equatorius africanus*, so named because all known specimens come from near the equator. This was the earliest known ape to occasionally leave the treetops for the ground, about 15 million years ago when the dense African rainforests began to turn into a more open woodland, says Jay Kelley, a co-author from the University of Illinois, Chicago.

The new fossils, together with previously collected specimens, give a clearer picture of the functional changes made by this pioneer. In Ward's words, it was "an animal about the size of a big adult male baboon, an animal whose arms and legs were about equivalent length, with a long, flexible vertebral column and powerful grasping hands and feet. We're dealing with an animal that spent considerable time on the ground but