California issues first quake prediction

In a drama that could have come from a Hollywood script, the San Andreas fault started showing signs of seismic activity beneath the tiny town of Parkfield, Calif., just in the nick of time. The moderate earthquakes that occurred there last week have raised scientists' hopes that a major jolt will shake this rural region before time runs out on the only long-term quake prediction ever sanctioned by the U.S. seismic community.

Located midway between Los Angeles and San Francisco, the town of Parkfield has suffered strong earthquakes on a remarkably regular schedule almost every 21 years. The small patch of the San Andreas running through this town produced jolts between magnitude 5.5 and 6.0 in 1857, 1881, 1901, 1922, 1934, and 1966. Recognition of this regularity led scientists with the U.S. Geological Survey to predict in 1985 that a magnitude 6.0 earthquake would occur along the 25-kilometer-long Parkfield segment of the San Andreas fault by the end of 1992. The USGS and the State of California funded a multimillion-dollar experiment to monitor the fault in hopes of issuing a short-term prediction hours to days before the actual quake hit.

In recent years, some seismologists have criticized the original prediction and the decision to pour what has amounted to $19 million into the Parkfield experiment while restricting funds for other earthquake research. This year, with time on the prediction running out, the Parkfield segment of the San Andreas has remained particularly quiet, adding to the feeling that the original prediction had overestimated the quake's chances.

In early October, though, the Parkfield region started popping with a series of three small earthquakes, the largest of which reached magnitude 3.1, says John O. Langbein of the USGS in Menlo Park, Calif., who heads the Parkfield experiment. The three tremors emanated from the San Andreas near Middle Mountain — a region where past Parkfield earthquakes have started. That activity triggered a C-level alert on a five-level rating system.

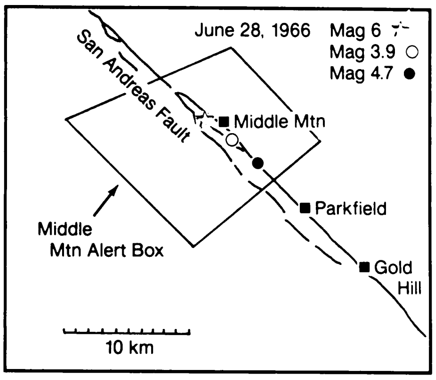
On Oct. 19, the same area of the fault produced a much larger jolt, measuring magnitude 4.7, which set off an A-level alert, the highest possible. This was the first A-level alert in the seven-year-long experiment.

As part of the prearranged Parkfield plan, the California Office of Emergency Services issued a public earthquake prediction — the first of its kind in state history. Officials announced there was a 33 percent chance that a magnitude 6 quake would come within three days, a statement that turned out to be a false alarm.

Scientists with the USGS say they are surprised the program went so long without an A-level alert. "We expected maybe two or three by this time," says William Bakun, one of the people who set up the Parkfield experiment.

The magnitude 4.7 tremor caused a stir because past Parkfield earthquakes have been preceded by similar or slightly larger shocks near Middle Mountain. But researchers last week did not see any of the other activity expected before a major quake. In 1966, the San Andreas fault began to creep several hours before the main shock, breaking an irrigation pipeline and producing cracks in the ground. The USGS has installed sensitive creepmeters along the fault, but they did not detect any abnormal activity last week.

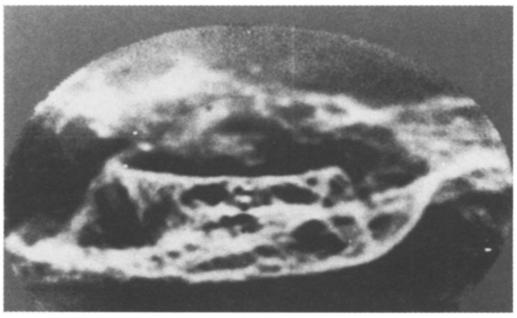
After the A-level alert, the fault quieted down for several days. It reawoke on Oct. 25, producing several earthquakes near Middle Mountain, the strongest of which reached magnitude 3.9. This jolt triggered a B-level alert, signifying a 10 percent chance that the expected earthquake would come in 72 hours.



Last week's jolts occurred within the Middle Mountain alert box.

If the quake does not occur by the end of the year, the original Parkfield prediction will be judged a failure. The experiment will continue, but as the years pass it will be harder to keep equipment operating, says Langbein. "Scientifically, though, if the earthquake doesn't come now, but in three years, we'd be pretty happy with the results." — *R. Monastersky*

New twist in the old search for dark matter



Kormendy

Dust lanes of the galaxy NGC 4753 indicate it harbors a twisted disk.

For two decades, astronomers have inferred the presence of galactic dark matter by measuring the velocities of gas and stars orbiting near the visible edge of galaxies. The farther any orbiting material lies outside a known concentration of mass, the slower its velocity. Yet researchers have repeatedly found that the rotational velocity of material at the visible outskirts of galaxies doesn't slow down. Instead, it levels off, indicating that a halo of unseen matter — perhaps black holes or some other type of exotic, invisible mass — extends beyond the visible edge of galaxies, providing the extra gravitational tug needed to keep material orbiting at a constant, high speed.

But such evidence of dark matter says little about its shape or about the overall distribution of mass in galaxies. Now, a group of astronomers reports that the presence of a twisted disk of material, sticking out of the plane of a galaxy, has revealed the shape of dark matter in that galaxy.

Thomas Y. Steiman-Cameron of NASA's Ames Research Center in Mountain View, Calif., and Richard H. Durisen of Indiana University in Bloomington began their study about 10 years ago, using a computer to simulate the evolution of a tilted disk of matter, formed when a galaxy's gravity grabs a nearby blob of material. Over time, the inclined disk would become twisted or warped, depending on the overall distribution of mass in the galaxy — both visible and dark matter. The flatter, or less spherical, the galaxy, the more rapid the twisting.

Steiman-Cameron adds that a disk lying flat in the plane of a visible galaxy can't become twisted and thus can't help define the full three-dimensional structure of the galaxy in which it lies.

While such a model suggested that a study of galaxies with twisted, inclined disks could reveal the shape of dark matter, the researchers hadn't applied the results of their study to any particular galaxy. That state of affairs changed dramatically when a colleague showed them a picture of the galaxy NGC 4753. The unusual pattern of dust lanes in the galaxy, imaged by John Kormendy of the University of Hawaii in Honolulu, matched the dust pattern the researchers had predicted would be produced by their model of a twisted disk, inclined about 15 degrees toward the plane of the visible galaxy.

Though NGC 4753 — twisted disk and all — appears nearly as flat as a slightly bulging pancake, the galaxy's true shape is very different, asserts Steiman-Cameron. Estimating the disk's age and using Kormendy's image to analyze the amount of twisting, he and his research team conclude that NGC 4753 has a nearly spherical shape.

The dark, or unseen, matter in the galaxy must take the shape of a slightly flattened sphere and accounts for the vast majority of the total mass in NGC 4753, report Steiman-Cameron, Durisen, and Kormendy in the October ASTRONOMICAL JOURNAL.

Theorist Scott D. Tremaine of the University of Toronto says he agrees that twisted disks can reveal the geometry of dark matter in a galaxy. But he adds that the details of the team's calculations need to be repeated using other galaxies. "If they had 12 galaxies like this, everyone would sit up and take notice," Tremaine says. "But with just one case, you have to be cautious."

He adds that the near-spherical shape of dark matter inferred by the researchers may challenge theorists, who have postulated that galactic dark matter has a far flatter shape. But he notes that the finding generally agrees with dark matter estimates inferred from observations of polar-ring galaxies – bodies in which a ring of gas and dust orbits at nearly right angles to the plane of the galaxy. *– R. Cowen*

Cutting magnets down to quantum-effect size

The rules of quantum mechanics allow the safe passage of a truck *through* a mountain instead of over it. But for objects larger than an atom, such extraordinary events have an extremely low probability of happening because of the objects' size.

Nonetheless, theorists have suggested that quantum tunneling may occur not only in submicroscopic systems, but also on a macroscopic scale – in tiny magnets made up of several thousand atoms each. Using naturally produced magnets encased in protein molecules, researchers have now obtained a hint that quantum tunneling within a magnet allows a transition from one magnetic field direction to another to occur in large aggregations of atoms or ions.

"Our interest is in testing whether macroscopic quantum phenomena can be directly observed experimentally," says physicist David D. Awschalom of the University of California, Santa Barbara. The idea that quantum tunneling can occur in sufficiently small magnets also has important technological implications as a fundamental barrier to ongoing efforts to pack increasing amounts of information on magnetic tapes or disks.

To search for macroscopic quantum tunneling, Awschalom and his co-workers turned to a protein known as ferritin, which serves as a storehouse for iron in cells. Each protein molecule has a magnetic core containing about 4,500 iron ions. In this particular case, the spins of neighboring ions line up parallel to each other but in opposite directions to create what is known as an antiferromagnet.

"The whole magnet acts like one big quantum particle – one big spin – which could point up or down," Awschalom says.

To measure the exceedingly weak magnetic fields involved, the researchers used advanced superconducting sensors and performed their experiments at temperatures below 1 kelvin. They describe their technique in the Oct. 16 SCIENCE.

The measurements revealed that ferritin molecules strongly absorb electromagnetic radiation at a frequency near 1 megahertz. Awschalom and his colleagues attribute that absorption to quantum tunneling back and forth between two particular magnetic states.

"It's qualitatively consistent with all of the quantum-mechanical predictions in terms of temperature, field, and density – every parameter that we varied," Awschalom says. "Though some of the numbers are not in exact agreement, there is no other self-consistent explanation that anyone's been able to provide."

Other researchers remain skeptical. "I think their technique is very interesting and promising," says Anupam Garg of Northwestern University in Evanston, Ill., "but I'm very doubtful that they're seeing macroscopic quantum coherence."

One problem involves uncertainties in the geometry of the magnetic protein cores. "If one were actually capable of making such small particles, one would have to be very careful in how one aligns them, and one would have to expend considerable effort characterizing them," Garg notes.

Similar concerns surround earlier work done by B. Barbara and co-workers at the Louis Néel Laboratory of Magnetism in Grenoble, France. Their findings also revealed an unusual magnetic effect that they attributed to quantum tunneling in ferromagnetic particles somewhat larger than those used by Awschalom's group.

"No one has yet done the conclusive experiment," says Philip C. E. Stamp of the University of British Columbia in Vancouver. "There are hopeful signs, but there is no proof."

Awschalom and his group are now looking for quantum tunneling in precisely manufactured magnetic particles about 100 times larger than the 7.5-nanometer, naturally occurring protein magnets they had previously used. "We've spent a year and half making these particles, which is the hard part," Awschalom says. "We're measuring [their magnetic properties] now." *– I. Peterson*

Taking the measure of volcanic eruptions

The size of a volcanic eruption – and its potential to threaten nearby population centers – depends on processes that occur deep underground, hidden from the eyes of curious scientists and anxious disaster planners.

But chemical analysis of lava may allow scientists to forecast the size of ongoing or future eruptions, say geochemist Donald J. DePaolo of the University of California, Berkeley, and his collaborators in the United States and Japan.

In a study presented this week at the Geological Society of America meeting in Cincinnati, the researchers argue that certain isotopic ratios in lava – notably, high neodymium-143 to neodymium-144 – can indicate whether a volcanic system is undergoing a major eruption.

Although using lava composition to infer the behavior of vast underground magma systems is not new, DePaolo's model is the first to link certain combinations of elements in lava directly to eruption volume, he says.

DePaolo's group bases its study on lavas disgorged by Japan's Unzen volcano over the past 300,000 years. Unzen, located on the Simabara peninsula of western Kyushu, began its latest eruption in 1990 after lying dormant nearly 200 years.

Chemical analysis of the material ejected by Unzen both before and since its 1990 outburst indicates that the volcano is probably in the middle of a relatively large eruption, says DePaolo.

Unlike large systems that take millenniums to build up enough energy for a major outburst, some volcanoes' cycles can be measured in decades. Thus, chemical analysis of the precursory burps of a small volcano may yield a rough estimate of when the Big One will erupt. Such a forecast could be valuable to current or future generations living near such a volcano.

DePaolo cautions, however, that chemical messages from magma chambers are no sure thing. Although the chemical composition of lava may indicate that a large eruption is imminent, "it doesn't guarantee you're going to get one," he notes.

Geochemist Alexander N. Halliday of the University of Michigan in Ann Arbor says that DePaolo's model of magma chambers is essentially sound, although it may not work for all volcanoes. "There are some systems that I don't think fit so well," he says. *– D. Pendick*