Early Warning For Earthquakes

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PHOTO: AAMIR QURESHI/AFP/GETTY IMAGES

FAULT: A 7.6-magnitude earthquake in October 2005 opened this crevice in a Kashmiri road.

Spooky lights in the night sky, a low burbling of radio noise, odd bright patches in infrared satellite images.... Harbingers of an alien invasion? Actually, no. Some geologists think they are indications of an impending earthquake and perhaps the only hope of ever predicting a quake in the hours or days before it strikes.

Although evidence that electromagnetic events precede quakes is mounting quickly, the main theory to explain that evidence has had a gash in it the size of the San Andreas Fault. Now, NASA scientist Friedemann Freund, a faculty member at San Jose State University, in California, may have filled the gap by demonstrating in the laboratory how the earth's crust can act as a gigantic battery to drive a geological radio circuit that extends more than 30 kilometers below the ground.

What makes this crucial is that Freund's experiments go a long way toward explaining not only why radio frequency phenomena precede some quakes but also why they do not precede others.

Years ago Freund showed that igneous rocks can become semiconductors when oxygen bonds in their silicate molecules are stressed, liberating electrons as well as electron deficiencies known as holes. As it happens, only the holes pass freely through unstressed rocks. Freund experimented by crushing rocks, and he also replicated a host of electronic earthquake precursors, including infrared emissions, electrical discharges, and radio noise. But he couldn't really explain why circuits sometimes—but not always—get established in geological formations and generate radio signals.

A key new insight came last year, when Freund conducted experiments that treated rocks more gently. He found that when rocks were subjected to moderate pressure or heat, a long and sustained hole current can result. The relevance to earthquake prediction is this: quakes commonly occur as two adjoining landmasses slide past each other at a fault. From time to time, this imperceptible creep is jammed by relatively small, resistant rock masses. Long before the rock snaps, causing the two landmasses to lurch past each other, stress builds rapidly deep below. According to the battery phenomenon Freund found, hundreds of cubic kilometers of rock might feel enough stress to send hole currents toward the Earth's surface in the hours and days before a quake, generating infrared signals near the surface and interactions with electrons in the ionosphere.

Still, to explain the fickleness of precursor radio emissions, something more was needed. Down to 20 km, holes flow freely but electrons remain trapped within the stressed rock. But at 30 km and below, the rules change. Although it's too hot for holes deep down there, electrons are free to roam. (With increasing heat, electrons are kicked up into the valence band and n-type electron conductivity occurs.) So Freund speculates that if the stressed rock volume extends deep enough—or if there is some other connecting path—electron currents could flow out of the stressed rock at this lower level, paralleled by a hole current above. These parallel currents could reach 50 000 amperes per cubic kilometer of stressed rock. Whether or not a quake is preceded by a low-frequency radio warning will depend on whether and how these parallel currents form and how long they persist.

Freund reported on his most recent experiments at the December meeting of the American Geophysical Union, in San Francisco, drawing warm praise from several physicists. Nevin Bryant, a prominent satellite analyst at the Jet Propulsion Laboratory, says no one else in the scientific community has come close to presenting a rational explanation for the rapid onset and disappearance of infrared anomalies. Bodo Reinisch, inventor of the radio plasma imager, dismisses alternative theories for quake-related ionospheric perturbations as fanciful thinking, summing up Freund's presentation with: "At last, real physics!"

One skeptic about electromagnetic precursors is geophysicist Stephen Park, of the University of California, Riverside, a critic of infrared anomaly claims because they fail to account adequately for weather and ocean effects. Park reports that he has had no success finding changes in the resistance of rock at the San Andreas Fault.

A little over a year ago, Freund and Thomas Bleier, CEO of QuakeFinder, a Palo Alto–based quake-sensing network, summarized the theory and observation of electronic earthquake precursors as it stood then in *IEEE Spectrum* [see "Earthquake Alarm," December 2005]. That summary drew criticism from seismologists, who have tended to see quakes as inherently unpredictable. Electronic precursor studies, according to the mainstream view, chase a will-o'-the-wisp of inconsistent, retrospectively identified phenomena.

It's too soon to say whether Freund's theories will be upheld or refuted, but the balance of expert opinion and evidence clearly is beginning to shift in his favor. Bryant and others, in work not yet published, have compiled hundreds of anomalous infrared events that are sharply aligned with faults and preceded quakes.