Predicting earthquakes

Granite batteries

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Earthquakes may cause electrical surges—which might help predict them

THE inhabitants of San Francisco would dearly like to know when the San Andreas fault that runs by their city is going to snap again. But even after almost 12,000 geophysicists met there last week for the autumn conclave of the American Geophysical Union (AGU), they were little the wiser. Most geophysicists agree that earthquakes cannot be predicted, although every large one brings tales of animals sensing trouble hours beforehand and of people seeing strange lights.

No one knows what might cause such phenomena. Indeed, so many different mechanisms have been proposed as being behind the apparent warnings of impending disaster, that seismologists tend to look upon any claim with suspicion. There is, however, one set of observations that may yet receive a scientific imprimatur. This is the suggestion—yet to be confirmed by an unambiguous statistical analysis—that space-borne instruments such as France's *Demeter* satellite have seen changes in the radio waves of the ionosphere that coincide with, and sometimes precede, earthquakes in the ground below.

In the light of this suggestion, Friedemann Freund, a physicist at San Jose State University in California, has stuck his neck out. As he told the AGU meeting, he thinks he knows what is going on, and it is this: if you squeeze a block of granite hard enough, it becomes a battery.

If he is right, an earthquake will generate enormous electrical currents in the ground—precisely the sort of thing that would upset the ionosphere and generate strange lights in the form of lightning-related phenomena. More to the point, it is possible that some of this power might be released before a fault moves catastrophically, and thus provide some warning of an earthquake.

The idea that squeezing crystals has electrical consequences is not new. A phenomenon called piezoelectricity, which is exploited in pressure sensors and quartz watches, involves creating a voltage between the ends of a piece of crystal by applying pressure. In this case, the voltage arises because the crystal deforms and a symmetry between positively and negatively charged atoms is disturbed.

Piezoelectricity, however, cannot sustain a sizeable current. So Dr Freund is proposing a different mechanism—similar to the one that goes on in the semiconductors from which computer chips are made. This mechanism relies on another phenomenon, called charge separation.

In many kinds of rock, most notably granite, the application of pressure and the resulting deformation of the rock's constituent crystals turn some of the oxygen atoms in those crystals into charge carriers. These atoms are missing an electron and are thus positively charged.

When the rock is further deformed, it becomes possible for these atoms, called “holes”, to steal an electron from a neighbouring atom, in effect shifting the hole. In this way, the holes can move through the rock. Indeed, they do this so easily, Dr Freund has calculated, that many of them move out of the section of rock under stress altogether, leaving it with a surplus of electrons. Thus, a granite battery is charged.

The electrons from the stressed rock cannot follow the holes, because granite is not a very good conductor of this more usual form of electricity. But when, if you do this trick in a laboratory, you give the electrons the chance to bypass a section of rock by way of a metal wire, quite large currents will flow. Outside the laboratory, Dr Freund believes, the role of the wire is played by heated rock (at temperatures above 500°C, granite becomes conductive to electrons as well as holes).

Extrapolating from Dr Freund's laboratory experiments, the strain in a real-life geological fault such as the San Andreas could, as it shifted, generate hundreds of thousands of amperes per cubic kilometre in a fluctuating pattern that would cause very low frequency radio waves to be emitted, thus disrupting the ionosphere.

Whether such currents could act as earthquake predictors depends on whether there are changes in the strain on a fault before it slips. To date, no such changes have been detected, but Dr Freund argues that the strain gauges deployed at the moment are too near the surface to pick up shifts that happen at the depths where earthquakes occur. His electrical currents, by contrast, would be detectable by magnetometers at the surface as well as by satellites watching the ionosphere—if they do indeed exist in the ground as well as the lab.