Electric and magnetic sensing in predicting earthquakes

Detecting Oncoming Disaster

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Earthquakes might appear sudden and unpredictable, but are actually not so. They are in fact preceded by numerous signals that are imperceptible to human beings, but can be picked up by sensitive devices and interpreted using complex mathematical methods

In general terms, the problem of predicting earthquakes can be approached in two ways. On the one hand there is a very widespread, well-developed, and reliable prediction method based on statistics. By analyzing the history of seismic shocks in a given region within the context of its tectonic structure, this method allows seismologists to calculate the probability that a shock of a given force will occur within a certain future timeframe. However, this technique does not identify any specific tremor location, nor any precise date of its occurrence. This is why attempts have been underway for years to develop a different approach to the problem, by trying to identify the signals that immediately precede an earthquake (known as precursors).

Searching for earthquakes' immediate precursors is a very extensive field, which employs comprehensive methods based on diverse observations and measurements. One of the main research trends involves monitoring fluctuations in the physical fields present on the Earth's surface, i.e. electrical or magnetic fields. Although the results of such research is very promising, given the extremely complex tectonic conditions that usually must be taken into account and given the limited number of sensing devices that have

A team installing sensing equipment in the field

Waldemar Jóźwiak

been installed, this method frequently does not suffice to identify clear-cut relationships between the variations noted in the lithosphere's physical parameters and the seismic activity subsequently observed.

Electric signals from rocks

Before an earthquake occurs, significant mechanical tensions build up in rocks as a consequence of tectonic movement. Such tensions are accompanied by diverse physical phenomena that we attempt to monitor. For example, there might be large fluctuations in the electrical conductivity of rock complexes, or in the spatial distribution of this conductivity within the Earth's crust in the vicinity of the epicenter. Model theoretical calculations developed for two-dimensional structures have shown that such variations can be observed on the surface only a small distance away from the epicenter. This is why the study of such precursors demands the use of a large number of sensors constantly recording concurrent measurements at many locations. The sensors themselves must be sufficiently sensitive yet suitable for constant, long-term operation in the field.

The mounting tensions that can lead to a release of seismic energy are also accompanied by the emission of electrical impulses, generated in the epicentral region. Structural variations occur in a rock as tensions mount, involving a rising density of linear defects (dislocations) within the crystal lattice of minerals. This causes the bonds between atoms in the crystal lattice to deform, while still preserving the consistency of the rock. Since tensions are present within the entire rock mass, neighboring mineral grains interact with each other, propagating defects in the form of "dislocation arrays," which are in fact the beginnings of a fault. In such places, tensions approach the rock's threshold of endurance. As tensions increase, this ultimately leads to a local snapping of crystal bonds and a cracking of the mineral grain, or of many grains connected via a dislocation array. This is how an earthquake starts.

The appearance of dislocations in a crystal lattice typically results in the generation of a certain electric charge, which is released as an impulse when the crystal cracks.

Deciphering the signals

One of the most important problems in seeking earthquake precursors is finding the proper method for processing the collected measurement data, so as to tease out various sorts of signals. Standard registration of variations in electric conductivity and in the electric and magnetic fields provides overlapping evidence of various phenomena. Identifying the sought-for signals within such data, therefore, requires that signals be effectively filtered out by means of complex numeric algorithms. We have developed our own algorithms for this purpose.

Supersensitive device for measuring electromagnetic fields in bedrock


Janusz Marianiuk

Variations in the electric charge measured on the Earth's surface are linearly proportional to changes in the horizontal components of the magnetic field, due to the phenomenon of electromagnetic induction within the Earth's crust and mantle. Moreover, the propagation of impulses that portend an earthquake is closely related to the geological structure in the immediate vicinity of the measurement-taking site, and so they are of a local character. As a result, even a dense concentration of sensing devices across an area does not guarantee that the sought-after signals will definitely be registered.

Precise filtration chiefly hinges upon the signal-to-noise ratio. The most favorable situation occurs during periods of great seismic activity. The errors in the data registered are then small, and the values obtained are reliable. Nevertheless, algorithm-processed data might reflect not only the tectonically related signals we are seeking, but also other undesired signals, such as industrial interference. To try to minimize the latter, we always strive to install our measuring devices at sites that are at a considerable distance from any potential interference.

Aside from analyzing the inductive and noninductive components of the magnetic field, measuring the geomagnetic field vector also seems to be a promising approach to earthquake prediction. The geomagnetic vector is dependent upon the geological structure more on a regional than a local scale, and so it is less sensitive to small local variations in conductivity.

Our Tests

In the past 15 years, we have taken part in three large research projects striving to identify earthquake precursors in seismic regions using an original methodology. These projects were carried out in various regions of Europe, in close cooperation with local research centers: in the Friuli region of northern Italy in 1987-88, in the L'Abruzzo region of central Italy in 1992-94, and in the Sterea Ellas region of Greece in 1997. The data so gathered was chiefly processed at our Institute, using our own original software.

Unfortunately, during all of these measurement campaigns the actual seismic activity was notably lower than the average. Despite this, we managed to obtain many interesting results. In the Friuli region we observed a considerable increase in residual signal variation in the period prior to a strong earthquake. In one case, we even managed to isolate a common signal of a regional nature, i.e. a signal registered concurrently at two measuring points 50 km from each other. In the L'Abruzzo region's Apennines, numerical analysis showed notable variations in residual components, correlated with the occurrence of strong shocks. The research in Greece ultimately demonstrated that analyzing residual signals offers a better instrument for seeking precursors than direct analysis of the recorded variations in resistance or geomagnetic vector.

In the case of weak tremors, all the variations in the analyzed quantities remained within the bounds of measurement and calculation errors. This indicates that further research needs to be carried out in regions of greater seismic activity, as free of industrial interference as possible. ■

Further reading:

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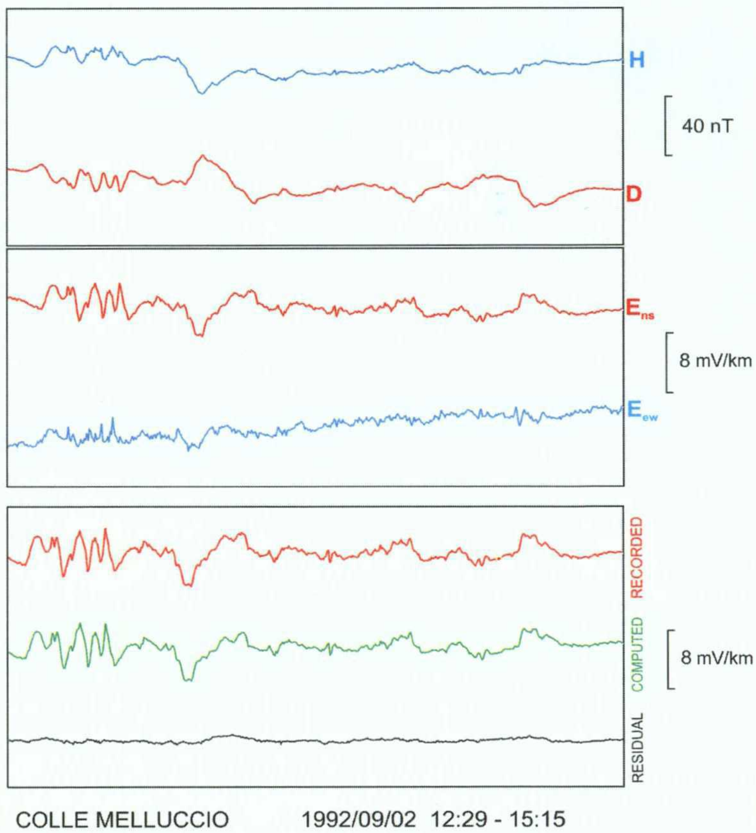

An example showing the horizontal components of the magnetic and electric field registered prior to a seismic shock in central Italy