et al. and others that simple manipulation of F-actin—including treatment with latrunculin A to decrease F-actin or treatment with jasplakinolide to increase F-actin—either increases or decreases mitochondrial membrane potential, respectively.

Alternatively, F-actin may be critical for delivering proapoptotic molecules to mitochondria (*11*). F-actin has a role in delivery of other "cargo" to mitochondria. For example, dynamin-related protein 1 is delivered by F-actin in order for mitochondria to undergo fission (*12*). In yeasts, the F-actin anchoring complex on mitochondria has been defined by genetic studies (*13, 14*). On this basis, a simple model can be conceived in which coronin-1 reduces the efficiency with which proapoptotic complexes are delivered to the mitochondrial outer membrane (see the figure).

A surprise in this study is that coronin-1 has no role in forming the immunological synapse. Knowledge in this area is exploding, with recent demonstrations that the WAVE2 complex and HS-1 protein are essential activators of Arp2/3 for immunological synapse formation (*15*, *16*). The physiological role of coronin-1 appears to end when the T cell receptor is engaged with antigen, although coronin-1 accumulates in actin-rich projections in the periphery of the immunological synapse (*6*). It is possible that the role of coronin-1 is redundant with that of other factors that are recruited to the immunological synapse. These studies predict that distinct negative regulators of Arp2/3 will likely play an important role in T cell homeostasis after engagement of the T cell receptor. Negative regulators of Arp2/3 that control F-actin accumulation in the immunological synapse will likely play an important role in postactivation migration, energetics, and survival. The control of survival after activation is fundamental to immunological tolerance for prevention of autoimmunity and the formation of immunological memory—areas in which F-actin is likely to have a new role.

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GEOPHYSICS

Toward "Supervolcano" Technology

Time-lapse seismic tomography can provide detailed insights into magma movements in an active volcano and may help to predict volcanic hazards in the future.

Gillian R. Foulger

In addition to depicting the ultimate volcano-eruption horror story, the recent Discovery Channel/BBC coproduction "Supervolcano" speculates about what technology will be available to the geophysicist in 2025 to monitor active volcanoes. The result is a fictional Virtual Geophysical Laboratory that, when fed the right data, predicts eruption scenarios, thereby providing information to help guide civil emergency–response decisions. On page 821 of this issue, Patanè *et al.* (*1*) report a key step toward realizing such an advanced volcano-monitoring technology.

The authors have used time-dependent seismic tomography to study Mount Etna during its pre-eruptive and eruptive phases between August 2001 and January 2003 (see the figure). This method is analogous to CAT (computerized axial tomography) scanning in medical technology, except that earthquakes are used as energy sources and that regions of Earth are the target. In the present case, the region of interest is Mount Etna, a basaltic volcano in Sicily that is ~30 km in diameter and rises to ~3000 m above sea level.

The greatest challenge in this type of work is to obtain a sufficiently good earthquake data set. Patanè *et al.* combine data from multiple seismic networks to overcome this difficulty. They observe major changes in the ratio of seismic compressional to shear-wave speed (V_P/V_S) during the buildup to an eruption and during the eruption itself; these changes correlate closely with observed magma movements (*2*). Most notably, the authors map regions where V_P/V_S decreases, and attribute this decrease to the influx of magma that is rich in volatiles (SO_2, CO_2, and water vapor).

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Toward predicting volcanic hazard. Mount Etna emits plumes of ash on 29 October 2002. Patané *et al.* have used time-dependent seismic tomography to gain detailed insights into magma movements within this volcano. Further development of this method should help to predict volcanic hazards at Mount Etna and elsewhere in the future.

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This is the first report of time-dependent seismic tomography applied to an erupting volcano. It builds on earlier work of the same kind done in geothermal areas in California and Iceland and the Long Valley Caldera, California. But the seminal example of major changes in V_P/V_S comes from The Geysers geothermal area in northern California.

During the 1980s and 1990s, some 13,600 tons of steam per hour were extracted from The Geysers to generate electricity. As a result of this overexploitation, the reservoir became progressively depleted as pore water was replaced by steam. Repeat seismic tomography showed the steady growth of a reservoir-wide negative V_P/V_S anomaly that coincided with the steam-production zone. This anomaly was caused by the combined effects of the replacement of pore liquid with steam, the resulting decrease in pressure, and the drying of clay minerals. A remarkable series of snapshots showed the relentless growth of a volume of heavy depletion (*3*, *4*). The work helped to increase awareness of the nonsustainability of such high rates of fluid withdrawal. Production at The Geysers has now been reduced to sustainable levels. Time-dependent tomography is currently used to monitor the Coso Geothermal Area, southern California (*5*).

Time-dependent seismic tomography was first applied to a volcano in a study of Mammoth Mountain, a volcano on the rim of Long Valley Caldera, California. In 1989, an intense swarm of hundreds of earthquakes accompanied an injection of new magma into the roots of this volcano, and triggered the outpouring of some 300 tons of CO_2 per day from the volcano's surface. Several broad swaths of trees died as a result of high levels of CO_2 in the soil, and the CO_2 also presented an asphyxiation hazard to humans. A comparison of V_P/V_S tomographic images calculated for 1989 and 1997 showed changes that correlated well with areas of tree death on the surface above, and were attributed to migration of CO_2 in the volcano (*6*).

By showing that time-dependent seismic tomography can be used to monitor structural changes directly associated with a volcanic eruption cycle, Patanè *et al.* take a critical step toward developing a useful volcano-hazard-reduction tool based on seismic tomography. As with all good experiments, however, it ushers in new challenges. V_P/V_S is affected by several factors, including pore fluid phase, pressure, mineralogy, and fracture density. However, determining how each of these has changed when changes in only two quantities (V_P and V_S) have been measured is not possible and requires the addition of other kinds of data. Both theoretical advances and more data from different volcanoes are needed before the potential of the method can be fully assessed.

At present, monitoring of active volcanoes still rests mostly on relatively unsophisticated seismic networks and the monitoring of simple parameters, such as the numbers of earthquakes and the amplitude of harmonic tremor. Patanè *et al.* show that much more sophisticated methods can now be used. Some of these methods only need to be automated—a critical factor if they are to be useful in situations where information is needed on an hourly basis. It is hoped that this automation work will be pushed forward rapidly in the near future, putting us on track to realizing technological capabilities resembling those of the fictional Virtual Geophysical Laboratory by 2025.

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COMPUTER SCIENCE

Creating a Science of the Web

Tim Berners-Lee, Wendy Hall, James Hendler, Nigel Shadbolt, Daniel J. Weitzner

Understanding and fostering the growth of the World Wide Web, both in engineering and societal terms, will require the development of a new interdisciplinary field.

Since its inception, the World Wide Web has changed the ways scientists communicate, collaborate, and educate. There is, however, a growing realization among many researchers that a clear research agenda aimed at understanding the current, evolving, and potential Web is needed. If we want to model the Web; if we want to understand the architectural principles that have provided for its growth; and if we want to be sure that it supports the basic social values of trustworthiness, privacy, and respect for social boundaries, then we must chart out a research agenda that targets the Web as a primary focus of attention.

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When we discuss an agenda for a science of the Web, we use the term "science" in two ways. Physical and biological science analyzes the natural world, and tries to find microscopic laws that, extrapolated to the macroscopic realm, would generate the behavior observed. Computer science, by contrast, though partly analytic, is principally synthetic: It is concerned with the construction of new languages and algorithms in order to produce novel desired computer behaviors. Web science is a combination of these two features. The Web is an engineered space created through formally specified languages and protocols. However, because humans are the creators of Web pages and links between them, their interactions form emergent patterns in the Web at a macroscopic scale. These human interactions are, in turn, governed by social conventions and laws. Web science, therefore, must be inherently interdisciplinary; its goal is to both understand the growth of the Web and to create approaches that allow new powerful and more beneficial patterns to occur.

Unfortunately, such a research area does not yet exist in a coherent form. Within computer science, Web-related research has largely focused on information-retrieval algorithms and on algorithms for the routing of information through the underlying Internet. Outside of computing, researchers grow

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