Perils of Prediction

Are scientists prepared to warn the public about geologic hazards?

By RICHARD MONASTERSKY

The town of Mammoth Lakes doesn't look kindly on federal geologists. In this quiet ski-center community nestled at the foot of California's Sierra Nevada range, residents have even coined their own name for the U.S. Geological Survey.

They call it the U.S. Guessing Society.

The town's antipathy toward the USGS has stewed for almost a decade, ignited in 1982 by a series of federal announcements and media reports about a potential volcanic eruption, which residents blame for a subsequent nose dive in the local economy. Only recently has the local real estate market climbed back up to its pre-1982 level, they say.

The USGS suffered painful reverberations of its own. The Mammoth Lakes communications fiasco, along with similar incidents elsewhere, exposed major weaknesses in the Survey's approach to issuing public warnings, forcing it to face the fact that hazard prediction requires expertise in the social sciences as well as in the earth sciences.

Quite simply, Mammoth Lakes and its nearby ski resort sit atop a living volcano. Experts don't know when the next eruption might occur or whether it would seriously threaten the scattered towns in the region. But in the early 1980s, a series of strong earthquakes and other signs of volcanic activity convinced USGS scientists they needed to say something to the public.

No one anticipated the fallout from that decision. Bad planning, poor lines of communication and misleading news reports combined with vivid memories of the 1980 blast at Mount St. Helens to spark a public relations eruption perhaps more fierce than the feared natural disaster itself.

The Mammoth Lakes misadventure followed a surge of technological advances for detecting hints of impending earthquakes and volcanic eruptions. With the undeniably worthy aim of saving lives and property, the USGS had recently begun using these new instruments, developed in the late 1970s and early '80s, to monitor various faults and volcanoes. But the scientific progress had outstripped the Survey's ability to disseminate its predictions in a useful way.

In another small town in California, USGS and state officials are currently testing a more sophisticated strategy for alerting the public to geologic hazards. But the new system has yet to face its first real test — a major quake or volcanic eruption — and even its developers acknowledge that problems still plague the public-alert process.

Until May 1982, most residents of Mammoth Lakes had no idea they lived above a volcano, with molten rock stirring just a few kilometers beneath Main Street. True, the region shook with numerous earthquakes, but that seemed normal by California standards.

Geologists themselves remained unaware of the town's full potential for a volcanic crisis until the mid-1960s, when field research revealed the unmistakable shape of a caldera, a basin-like depression created by a colossal volcanic eruption. The caldera's outline resembles a 32-kilometer-long potato, with the town of Mammoth Lakes sitting in the southwest section. Geologists named the volcanic depression the Long Valley caldera.

That discovery explained the huge deposit of volcanic rock dominating the landscape from Mammoth Lakes to the town of Bishop. Judging from this rock formation, geologists believe the Long Valley blast — which occurred some 700,000 years ago — spewed out about 1,000 times more material than the 1980 eruption of Mount St. Helens.

While 700,000 years seems an eternity by human standards, it's a mere tick on the geologic clock. The region between Long Valley and Mono Lake has since spawned many smaller blasts, the most recent of which occurred around 550 years ago. These eruptions, though minuscule compared with the caldera-forming blowout, may have equaled Mount St. Helens in the amount of rock ejected, says David P. Hill, a USGS geophysicist based in Menlo Park, Calif.

Hill and his colleagues suspect these smaller eruptions will resume sometime in the future. And if one blows during winter, he says, it will release a torrent of melted snow and mud that could devastate some of the towns lying at lower elevations, including Mammoth Lakes.

Geologically, the 1982 incident had begun brewing in May 1980, when a series of four strong earthquakes, measuring around magnitude 6, shook the Long Valley area within a harrowing 48-hour period. Then came swarms of smaller shocks, which rattled the region for months. Residents of Mammoth Lakes weren't the only ones to notice the flurry of seismic shocks. The quakes also shook up USGS scientists, forcing them to consider whether the volcano might be awakening from its centuries of slumber.

Over the next two years, geophysicists detected other signs of volcanic activity. New steam vents developed, and surveying measurements showed the caldera surface bulging by about 25 centimeters. Taken together, the signs suggested the movement of molten rock, or magma, toward the surface.

Having only recently placed monitoring instruments around the caldera, USGS researchers couldn't tell whether such stirrings were normal for this volcano. The activity might represent geologic preparations for an imminent eruption, or it might just be something that happens every 50 or 100 years within Long Valley caldera.

Despite the uncertainty, USGS scientists decided they had to make some public announcement regarding the no-

Hill

This photo, taken from Mammoth Mountain on the caldera's western edge, looks across Long Valley to the caldera's eastern edge, bounded by Glass Mountain on the left horizon. Mammoth Lakes appears in the foreground.

ticeable quakes and the less obvious changes in the region. In late May of 1982, the Survey prepared to issue a "notice of potential volcanic hazard," the lowest-level volcano alert then in use. The notice stated that the area faced a long-term chance of an eruption and that scientists didn't know enough to predict when it might occur or how large it might be.

USGS officials informed state emergency coordinators about their plans to release the notice, but somehow the word never reached local officials at Mammoth Lakes. "At the time, we really hadn't developed much rapport with emergency management officials in the area," recalls John Filson, who formerly headed USGS' earthquake and volcanic hazard office.

The Los Angeles Times compounded the communication problem when it learned of the planned notice and broke the story, forcing the USGS to release the notice just before Memorial Day weekend, a time when legions of vacationers from southern California traditionally head to Mammoth Lakes. Local officials, who learned of the alert by opening their morning paper, were left completely unprepared for the public relations nightmare that ensued.

The notice blossomed into a media melee. "It was really chaos," Hill says. "Some wild things were coming out. Evidently, one newspaper in Nevada reported that magma was flowing down the streets of Mammoth."

Even the more responsible newspapers and television stations ran into problems covering the story. With reporters questioning many different scientists, media accounts differed markedly in their assessments of the Long Valley area's risk.

"The chamber of commerce in Mammoth Lakes was getting concerned that the USGS was not giving a consistent or accurate story about what might happen and what the possibilities were there," Filson says.

"There was a great deal of anger and frustration at the scientists, who really were not able to demonstrate a strong base of understanding for what was going on here," says Mammoth Lakes town manager Glenn Thompson.

Adds Wally Hofmann, editor and publisher of the Mammoth Times, "It was irresponsible of them to raise the fear factors of residents and traveling guests in the region on the basis of data which were incomplete and inconclusive."

Relations between the USGS and Mammoth Lakes have improved since then, but resentment still smolders. The community blames the USGS for subsequent economic hardships, which struck mainly in the local tourist and real estate markets, sending property values plummeting by 40 percent. While USGS scientists acknowledge some responsibility, they contend the Survey has served as a scapegoat for unrelated problems experienced by the town. According to Hill, many ski centers across the Sierra Nevada suffered downturns in the early 1980s after a boom period in the '70s.

Thompson, on the other hand, says, "Mammoth Lakes is the only place that experienced a deep decline."

Whether or not the caldera confusion caused the town's economic woes, it clearly pointed to a communications problem among the various officials and scientists charged with handling public warnings — a problem the USGS would have to solve if it expected people to take future warnings seriously.

"The event in 1982 was the catalyst for all parties involved to realize that we didn't want to do this again," says Richard Andrews, chief deputy director of the State Office of Emergency Services in Ontario, Calif. "It was not productive for communicating risk, for developing public support for preparedness actions, or in generating public confidence in the scientific community."

Taking to heart the lessons learned at Mammoth Lakes, USGS and state officials set about designing a major earthquake-prediction experiment in central California. For years, Congress had urged such a program; in 1985, the USGS finally ventured out onto prediction's shaky limb.

For the site of the experiment, scientists chose a particularly active stretch of the San Andreas fault. Records showed that this area, near the tiny town of Parkfield, had apparently generated strong jolts on a regular schedule — about every 22 years during the past century. The most recent shock came in 1966, so the next seemed due within a few years of 1988.

In the spring of 1985, the USGS issued a formal prediction that a magnitude 6 quake would shake the Parkfield segment of the fault before 1993. It remains the only prediction ever sanctioned by the National Earthquake Prediction Evaluation Council, a committee of federal and university scientists who review the validity of earthquake predictions.

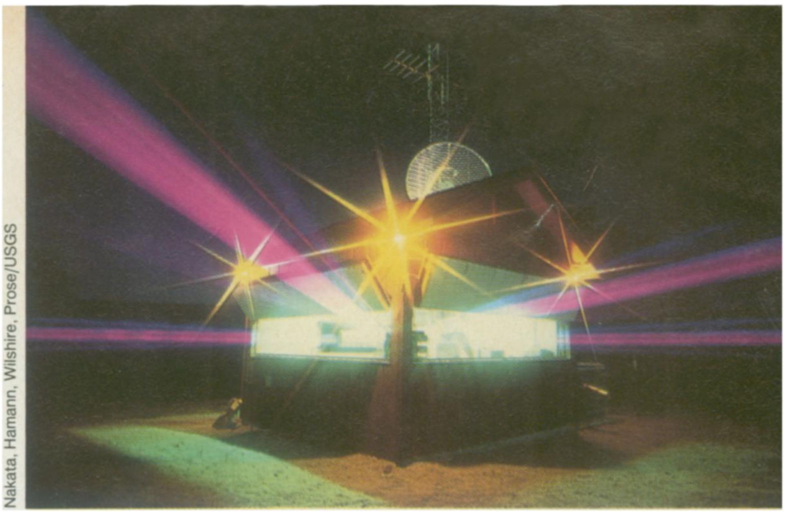
Hoping to catch any subtle signs that might precede the tremblor — which has yet to occur — the USGS and the State of California positioned millions of dollars' worth of equipment along the Parkfield section. One of the chief goals of the experiment is to issue a short-term warning, hours to minutes before the quake starts.

Previous quakes in this sparsely populated region suggest that a magnitude 6 temblor would cause little damage. However, the USGS calculates a 10 percent chance the next quake could reach magnitude 7 — about 30 times stronger than magnitude 6. Damage from an earthquake of that size could extend to larger communities nearby, Andrews says.

The road running east to Parkfield takes a twisted course, weaving around the hills that border California's central valley. On the outskirts of town, right about where the San Andreas fault passes by, a sign advertises the hamlet's statistics: "Population 34, elevation 1,530 feet."

While such numbers don't earn Parkfield a place on many maps, the town's diminutive size belies its impact on earthquake preparedness in California.

The USGS has approached the Parkfield experiment in a manner completely opposite to its handling of the Mammoth



By bouncing lasers off distant hills, geophysicists monitor subsurface warping caused by the San Andreas fault.

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A deep division: The leaning posts and the jog in the fenceline indicate the location of the San Andreas. Land in the foreground is moving to the left in relation to land in the background.

Monastersky

USGS

Lakes incident. Where the Survey once appeared arbitrary and uncertain, it now strives for a approach based on a codified set of actions. In the event of any strange stirrings along the fault, USGS scientists must follow a carefully preset plan.

The centerpiece of the experiment is a five-level alert system that ranges from E (situation normal) through A (the predicted quake appears imminent). Researchers have wired the fault region with a battery of instruments designed to detect unobtrusive geologic changes such as surface warping or slight movement along the fault. If the San Andreas begins acting abnormally, scientists will use a strict set of criteria to determine the appropriate alert level. For instance, a minor shock of magnitude 3.5 near Parkfield would set off a C-level alert — unless it occurred in a special section believed to be the nucleation zone for the predicted earthquake. In that case it would trigger a B-level alert.

At level C or higher, Parkfield's chief scientist will notify the State Office of Emergency Services, which will pass the information to local officials in the areas involved. When the situation reaches an A-level alert, the counties around Parkfield will issue a public warning, released through emergency radio networks and the media, announcing a greater than one-in-three chance that the earthquake will occur in the next 72 hours. Emergency response personnel, such as sheriff's offices and fire departments, and the community at large have already been instructed in how to prepare for the quake and what to do at an A-level alert.

The groundwork appears to have paid off, says sociologist Dennis Mileti of Colorado State University in Fort Collins, who has assessed Parkfield-area residents' reactions to the 1985 prediction. The USGS ran into trouble at Mammoth Lakes, he notes, because it failed to prepare the public for the notice and then provided scant follow-up information. In contrast, people in Parkfield have found themselves inundated by information from the USGS and from newspapers, television and public officials.

Because of their repeated exposure to the idea of a quake striking their town, Parkfield residents have come to take the prediction seriously. "Our single most significant finding is that many people are better prepared to deal with the earthquake than if the prediction had not occurred," Mileti says.

Another strength in the Parkfield system, he says, is a safeguard against a natural human tendency to distort information as it passes from one person to the next. A children's game called "telephone" illustrates the phenomenon: As a whispered message travels along a line of players, its content changes with each step until the final message bears no resemblance to the original.

That same phenomenon infects communications regarding a natural disaster. But while children at play often exaggerate or embellish the "telephone" message, adults who must pass critical information to their bosses tend to downplay any disturbing implications.

"When people transfer information to different organizations and to superiors, there is a significant component of human nature that shows up. Human beings don't want to mess up. The tendency is always to underestimate the risk," Mileti says.

He recalls one instance when the National Weather Service forecast a severe flood for Rapid City, S.D. "By the time it got sent across organizational boundaries, the message the people heard was that it was raining heavily," he says.

Parkfield's multilevel alert system reduces the potential for distortion within its network of communication. Mileti, who helped develop the program, says scientists and officials cannot easily downplay a situation because each alert level has a strict definition that remains constant as the message shuttles from one person to another.

Like military personnel conducting battle exercises, the various players in the Parkfield project run through periodic test drills to stay familiar with the preset crisis procedures. Emergency planners in the San Francisco Bay area credit such drills with saving lives during the Loma Prieta earthquake, which shook the Bay area in October 1989.

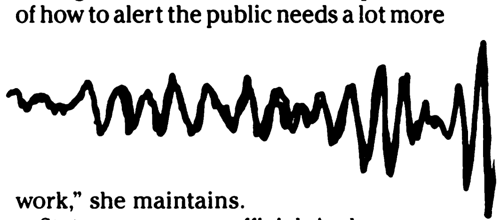
For scientists and officials caught in the imbroglio at Mammoth Lakes, the new system represents a giant step forward. But even those involved in the Parkfield project wonder whether that step reaches far enough.

Parkfield's emergency response system has yet to face an A-level alert. But if recent history repeats itself, unforeseen problems are bound to arise at that critical time.

Last fall, for instance, when the USGS announced two fairly routine C-level alerts, the town turned into a "media circus," says Evelyn A. Roeloffs, who served as Parkfield's chief scientist from January 1990 through March 1991. Communication glitches among USGS, state and local officials led a number of reporters, emergency personnel and townspeople to misinterpret the alerts as important warnings.

The mix-ups spurred a surge of unwarranted concern, Roeloffs says. When a radio station in the Monterey Bay area, 150 kilometers away, reported that a quake was expected, the news frightened listeners in nearby Santa Cruz, who were still jittery from the Loma Prieta disaster. And in Parkfield, a man calling himself the "Parkfield Paul Revere" ran into the town cafe to announce that the quake was coming.

Roeloffs, rattled by such snafus, worries about how the system will work during a real crisis. "The whole question of how to alert the public needs a lot more



work," she maintains.

State emergency official Andrews acknowledges some problems but calls them relatively minor. In general, he says, "we haven't seen a major downside to that effort. We haven't seen public panic. We haven't seen a lot of people getting tired [of hearing lower-level alerts] and saying we're crying wolf too often."

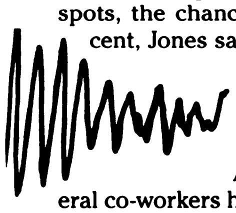
Indeed, the Parkfield plan has generated enough confidence among state and USGS officials that they have decided to export the system to other hazard-prone regions. "The experiment has served as a kind of prototype for how we can approach a number of volcanic or seismic risk areas," Andrews says.

The Survey and the state are now instituting a similar system for the southernmost reaches of the San Andreas, a region of particular concern to seismologists. An independent scientific advisory panel has estimated a 40 percent chance that the San Andreas fault south of Palm Springs will produce a magnitude 7.5 earthquake within 30 years. If that quake extends farther north, it may reach closer to magnitude 8 and pass through the heavily populated San Bernardino area, says Lucile Jones, a USGS seismologist in Pasadena.

The southern end of the San Andreas is far more enigmatic and complex than the stretch running through Parkfield. Major earthquakes occur less frequently in the south, and scientists cannot discern any regular pattern in seismic behavior there over the last few centuries. Moreover, monitoring along this long section relies on a relatively patchy instrument network, in contrast to the dense array watching Parkfield's shorter segment.

While seismologists can't make any medium-range prediction about the chances of a southern California earthquake striking in the next few years, they may be able to provide some warning just before the region's next major quake – if the Earth cooperates. Many big quakes involve foreshocks that precede the most serious shaking by days or minutes.

Of course, scientists cannot definitively label tremors as foreshocks until a larger quake follows, and by then it's too late to issue a warning. However, Jones and Duncan Agnew, a geophysicist at the University of California, San Diego, have devised a method for calculating the odds that any one earthquake represents a foreshock. The answer can vary widely depending on where the quake occurs. On some parts of the San Andreas, Jones and Agnew estimate a greater than 20 percent chance that a stronger quake will follow a magnitude 6 shock. In other spots, the chances are less than 1 percent, Jones says.



Officials are now beginning to apply a Parkfield-like alert system to the southern San Andreas. Jones and several co-workers have established criteria for essentially three "hazard levels" – a term they hope will prove less inflammatory than "alert levels." Unlike the Parkfield system, this rating scheme has no A level, because at present, scientists lack sufficient information to say when the region faces a high probability of a large earthquake striking within days.

Nonetheless, says Andrews, the new system should help emergency planners. When a shock occurs, seismologists will determine the appropriate hazard level based on the potential for a larger quake, and the state can then decide what public announcement to make, if any.

At Mammoth Lakes, Hill is attempting to exorcise the ghosts of 1982 and prevent a repeat of that fiasco by devising yet another Parkfield-like system. In this case, the alert levels denote the near-term potential for a volcanic eruption in the Long Valley area.

Like the San Andreas warning systems, Hill's scheme relies on detecting geophysical changes that might precede dangerous activity. Computers at the USGS complex in Menlo Park continually monitor instruments in the caldera region via satellite, signalling when abnormal events occur. The strength of those changes will determine what alert they trigger.

The lower alert levels serve mostly internal purposes within the USGS. But in the event of a B-level alert, Hill and his colleagues will install more instruments in the region to keep closer watch on the volcano's insides. The A level, he says, "is reserved for the case when there's pretty clear evidence that there is danger of an eruption breaking out in a short time."

The Long Valley system remains in development and has yet to pass through the federal approval process. However, most people involved see it as a major improvement – albeit a belated one.

"In contrast to what appeared to be extremely arbitrary, maybe overresponsive, behavior in the early '80s, this system has a series of steps that are taken based on geophysical events that have occurred and that we can all understand," says town manager Thompson.

Still, he bemoans the pace of the USGS, which he says seems to move as if it worked by geologic time. "We're almost a decade past the 1982 problem and they're still working on adopting a more uniform format for dealing with these things. It's essential that they do that," Thompson says.

Even an organized, efficient system can run afoul of the public. In many instances, the priorities of local residents and business owners differ from those of officials. In 1986, for instance, after a magnitude 6 earthquake shook the Mammoth Lakes region, a local radio station refused to air a public service announcement regarding the tremor and its expected aftershocks. With residents still reeling from the 1982 hazard notice, the announcer presumably wanted to minimize mention of the geologic threats to the area, says Boe Turner, the county's emergency services coordinator. The announcer relented when police drove to the radio station, prepared to arrest her.

No one knows how people will react to these new alert systems when a real threat comes. Jones, for one, wonders how the millions living in the San Bernardino area would respond to a B-level alert, warning of a 10 percent chance that a magnitude 8 earthquake will strike within three days.

People must accept that even with the best possible alert system, a crisis cannot be painless, Hill says. "If we are approaching anything like an A-level alert, it is going to be tough no matter how much planning we do."

As Mount St. Helens demonstrated in 1980, an economic crisis can erupt even before the lava flows. Preliminary upheavals such as earthquakes, steam venting and smaller eruptions can last for months before a big volcanic blast, forcing people to abandon their homes and businesses for a calamitously long time.

"We stand a very high chance of calling evacuations and having it drag on for some time," says Hill. And then, after all that commotion, "nature is just perverse enough that it could stop without ever actually erupting." □

Facing the public: Scientists on shaky ground

David P. Hill spent his grad school years preparing for a lifetime of studying earthquakes and volcanoes. But in the last decade, he has noticed a conspicuous hole in his education. No course ever taught him how to communicate scientific information – some of it potentially lifesaving – to the public.

Hill is not alone. Earth scientists train for the world of research, whose laws call for circumspection and carefully chosen words that rest on solid evidence. Denizens of this realm speak a language of hectasyllabic terms and acronyms incomprehensible to outsiders. Statements come wrapped in layers of qualifiers to protect the speaker against making unsupportable claims.

That world doesn't prepare them for being shoved in front of a television camera and asked to describe the likelihood that a disaster will occur.

"In spite of the progress being made, there are still big problems in the way we communicate with the public. People want to hear clear-cut answers, and particularly in the earth sciences, we don't have clear answers," says Hill, a USGS geophysicist.

Organizations like the USGS have public affairs offices to deal with the press and private citizens. "But the Survey prefers to put scientists in direct contact with the press so that at least the scientific aspects of the story come across right," says USGS seismologist John Filson.

USGS scientists, he adds, are generally unprepared to meet the press. "We have no training that I know of in this organization to help deal with this really important aspect of the job."

The problem has also had some subtle effects within the USGS itself. In the last year, the Survey has had difficulty filling several positions – including the chief scientist job at Parkfield – that involve frequent contact with the media. Researchers eschew these roles in part because they have little interest in dealing with the public and the federal bureaucracy, says USGS seismologist Lucile Jones.

Moreover, these positions do not advance a scientist's career. The Survey generally promotes scientists on their ability to do research, says Filson, and not on their communication skills.

– *R. Monastersky*