diving into the lower mantle.

Since then, seismologists have been trying to pin down the difference between heat conduction and a real slab. Stephen Grand of the University of Texas, Austin, for instance, points to his new seismic images, which show lower mantle features that he thinks look more like slabs than anything else. In a regional study of the eastern margin of the Pacific, where as much as 5000 kilometers of ocean plate has sunk into the mantle during the past 50 million years, Grand finds a thick wedge of cold rock that, below a depth of 660 kilometers, extends more than 500 kilometers horizontally under South America and North America. "My personal belief is that that's slab material in the lower mantle," says Grand. "[Anderson] could be right, but I'd like someone to explain to me how you get that without penetration."

To resolve such doubts, all three bands of researchers studying the workings of the mantle are trying to get closer to the real thing. Mineral physicists hope eventually to duplicate deep-mantle conditions so that they no longer have to extrapolate from what happens at milder conditions. Modelers are constantly increasing the realism of their simulations. But perhaps most crucially, seismologists are gaining on their goal of a complete worldwide network of the latest in seismographs, or "full-fidelity earthquake recorders," as David Simpson of the Incorporated Research Institutions for Seismology (IRIS) in Arlington, Virginia, describes them. These machines digitally record seismic waves at frequencies from 10 hertz to thousands of hertz without chopping off the highest-amplitude waves, unlike the 1960s-vintage instruments they are replacing. "It's the difference between a 78 rpm record and a CD," says Simpson.

IRIS has installed about 65 of these broadband digital instruments around the world and hopes to double that number; meanwhile, other countries are contributing stations as well. Once coverage is fairly even across both land and sea, seismologists should be able to paint a detailed picture of inner Earth that will not be open to artistic interpretation.

–Richard A. Kerr

SEISMOLOGY

Quake Heightens Concern, Uncertainty

A panel of seismologists reported this week that the Landers earthquake—a magnitude 7.5 temblor that shook a thinly populated desert area 105 kilometers east of Los Angeles in June—has made it more likely that another big one will soon strike Southern California. But the panel is unable to say just how much the risks have increased. Its best guess is that the chances of a temblor larger than magnitude 7 striking the Landers area in the year starting last September have increased by a factor of between two and five, and the probability of such a quake in Southern California as a whole has risen between 25% and a factor of 3. The panel's worst-case estimate is that Southern Californians have a one-in-eight chance of experiencing a magnitude 7 quake by next September.

High stress area. Landers quake upped the odds.

These wide ranges of probabilities reflect uncertainties among seismologists themselves about how earthquakes should be forecasted. "There are problems both with the statistical techniques and with our understanding of the physics of earthquakes," says seismologist Thomas Heaton of the U.S. Geological Survey in Pasadena, cochair of the panel.* "We're arguing over what actually goes on in an earthquake."

The first thing the working group did was to question the conventional method of estimating when a fault is next going to fail in a large quake. Used in 1988 to estimate the hazards on the San Andreas fault system throughout California (*Science*, 22 July 1988, p. 413), that method assumed that a specific section of the San Andreas would gradually accumulate stress, reach the breaking point, and rupture, releasing the accumulated stress in an earthquake. The cycle would then repeat to give a series of similar quakes at roughly equal intervals. Seismologists simply forecasted the probability of the next quake from the date and size of the last one and the rate of stress accumulation. But when researchers calculated that the Landers quake transferred enough stress to the adjacent segment of the San Andreas to advance the date of its next rupture by a decade or two (see reports in *Science*, 20 November), the calculated probability of the next magnitude 7 on the San Andreas increased by a meaninglessly small amount. This anomalous result only served to point up the limitations of the technique when forecasts are uncertain by decades.

The panel also decided that the focus of the 1988 report was too narrow: "It's deceptive to focus only on the San Andreas, and only certain segments of it, when in fact there are lots of faults in Southern California," says Heaton. So the panel turned to alternative forecasting techniques and applied them more broadly. The new techniques all involved searching catalogs of past earthquakes to find some that might say something about the possibility of future quakes.

In one approach, panel members asked how often large earthquakes come in pairs. The worldwide record suggested about a 3% chance that the Landers quake would be paired with a similar shock in the vicinity within 2 to 14 months. If quakes were random events with no pairing, the odds would be only 1%. But no one is sure whether California quakes follow the global pattern. Similar uncertainties underlie the estimates for Southern California as a whole. According to one calculation, for example, if the increased frequency of moderate earthquakes seen in the region since 1985 continues, the odds of a magnitude 7 temblor striking there by next September would be 12%—three times greater than if the frequency had not changed. But no one knows whether the recent surge in seismicity will persist.

And the uncertainties would get even worse if the views of David Jackson, a working group member, and Yan Kagan of the University of California, Los Angeles, become widely accepted. Jackson and Kagan argue that faults remain stressed near their breaking point even after being ruptured in a large quake, so that they can soon break again. After a cluster of quakes on the same fault, they say, it can somehow be deactivated for long periods. Thus, Kagan and Jackson would regard a long-quiet fault that others assume to be overdue for another large quake as only a slight threat. Applying this reasoning to Southern California gives a probability increase of only one-third for the region as a whole and less than 50% for the Landers neighborhood. "Dave Jackson's objections are ones we have to deal with," acknowledges Heaton. But that, he says, will have to await the working group's next report, due out after Southern Californians have lived with another 9 months of increased uncertainty.

–Richard A. Kerr

*The Working Group on the Probabilities of Future Large Earthquakes in Southern California is composed of individuals from the national and the California earthquake prediction evaluation councils and the Southern California Earthquake Center.