difficult to predict." Instead of a prediction of 1988±5 years, Matthews argues that 1983±20 years would be more justifiable.

No matter which error range you favor, Parkfield is causing problems for would-be earthquake predictors. But Bakun can imagine a happy ending. "If all this is leading to a larger earthquake, it's proceeding differently [from other Parkfield quakes]. Maybe we're looking at a more protracted preparation time, and we're going to see a few more things before the earthquake happens." Then again, he says, their model of how Parkfield behaves could fail this test. "We go through phases" in seismology, he says, "where we see things that confirm our previous paradigms, and we're confident. Then come the surprises, and we're not so bold about predicting the future." The next few months may well offer a foretaste of earthquake prediction's next phase.

–**Richard A. Kerr**

SEISMOLOGY

Good Forecast, But Missed Prediction

If seismologists are uneasy about their soon-to-expire forecast of a moderate earthquake in central California (see previous story), they can at least take some small comfort from the modest success, announced in this issue of *Science* (p. 726), of a forecast of the deadly Nicaraguan quake that struck early last month. A group of seismologists report that their 1981 forecast that a large quake would occur off the coast of Nicaragua within a few decades was bang on as to location and pretty close on its magnitude. But politics and Mother Nature conspired to frustrate any short-term warning.

From a scientific point of view, the outcome is "encouraging," says David Harlow of the U.S. Geological Survey (USGS) in Menlo Park, the lead author of the forecast that appeared in the 7 August 1981 issue of *Science*, but he concedes that they have not come up with a sure-fire route to long-range prediction. "When we wrote that paper, I was much more optimistic about predicting earthquakes," he says. New theories for earthquake prediction were gaining support, including the sort of analysis of seismicity patterns that Harlow and his colleagues employed in their forecast. But these theories have not fulfilled their promise of providing broadly useful forecasts, and even the patterns on which Harlow based his forecast have not shown up reliably. "I've grown more pessimistic over the years," says Harlow.

Combining two forecasting methods to look decades into the future, Harlow and his colleagues drew on two seemingly related features—a small zone of seismic quiescence wrapped in a broader region called a seismic gap. The gap was defined by an absence of large earthquakes, greater than magnitude 7, off the Pacific coasts of northwestern Nicaragua and El Salvador for more than 50 years. Early in this century, major quakes had rocked the region, where an oceanic plate dives under the edge of the plate that carries Central America, but nothing big had hit since. The longer the period since the last large earthquake in a gap, the reasoning went, the more likely one would strike within years or decades.

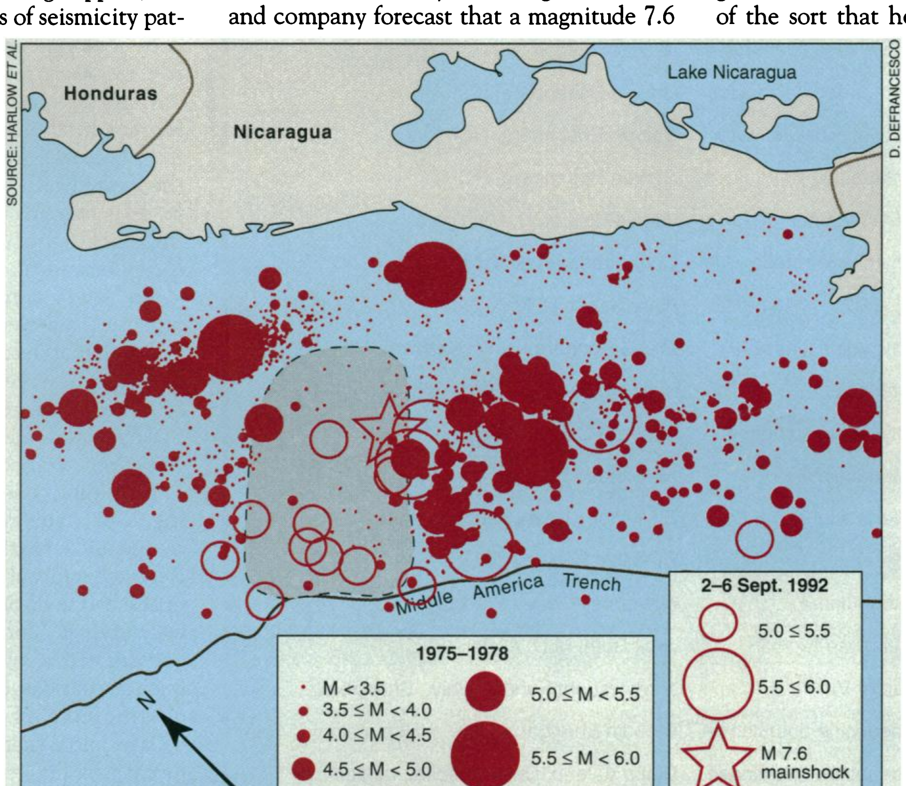
Nestled within this 400-kilometer-long seismic gap, Harlow and his colleagues found a 50-kilometer-wide zone that was even quieter. Virtually no earthquakes larger than magnitude 2 occurred there from 1975 through 1978, when a cooperative U.S.-Nicaraguan seismograph network was operating onshore, while numerous moderate quakes up to magnitude 5.7 struck nearby. Simple empirical analysis of seismic records suggested to some researchers that such quiet zones indicated where stress was building toward the next large quake. Adding in such factors as the seismic history of the region, Harlow and company forecast that a magnitude 7.6 to 7.9 quake would break the silence sometime in the coming decades.

On 2 September, the seismologists got what appeared to be the long-forecasted earthquake when a magnitude 7.6 shock struck at the southeast corner of the quiet zone. "This is an example of what you can do with good, modern data in a subduction zone," says seismologist William Ellsworth of the USGS in Menlo Park. "In general, this is pretty encouraging for long-term forecasting." He notes that the Nicaraguan quake's rupturing of the quiet zone is another example of the way low-level seismicity can outline a section of fault that is preparing to break in a larger earthquake (*Science*, 21 April 1989, p. 286). Seismologists recognized several such cases, including the Loma Prieta quake, in the 1980s, but usually too late to make a forecast.

Encouragement aside, the Nicaraguan quake had its disappointments, too. Following the 1979 Sandinista revolution in Nicaragua, operation of the local seismograph network collapsed and scientific relations were nearly severed. And last August, U.S. seismologists long out of touch with Nicaraguan researchers missed several "preshocks" of the sort that heralded Loma Prieta, because the August report from the worldwide seismic network had not yet arrived.

Even if the preshocks had been recognized as such and a warning had gone out, large loss of life may have been unavoidable. The last major earthquake to strike the vicinity of the quiet zone, a magnitude 7.5 in 1898, heavily damaged towns tens of kilometers inland. In contrast, last month's quake left those towns untouched but swept away coastal villages with a tsunami. Something was different about this quake, and figuring out what it was may have more than the usual urgency about it: The 1898 quake was followed by three more over the next 28 years.

–**Richard A. Kerr**



Filling the seismic hole. The quiet zone (dashed line) bounded by small and moderate quakes of the 1970s (filled circles) became noisy in September (open star and circles).