5.7.4: The Seismic Gap Theory

Overview

Another idea of the 1970s was the seismic gap theory, designed for subduction zones around the Pacific Rim, but applicable also to the San Andreas Fault. According to theories of plate tectonics, there should be about the same amount of slip over thousands of years along all parts of a subduction zone like the Aleutians or Central America (or central Peru, for that matter, leading Brady toward his prediction). Most of the slip-on these subduction zones should be released as great earthquakes. But some segments of each subduction zone have been seismically quiet a lot longer than adjacent segments, indicating that those segments that have gone the longest without an earthquake are the most likely to be struck by a future earthquake. This is a variation of the time-predictable model, of waiting for the bus. The longer you wait, the more likely the bus (or earthquake) will show up.

The San Andreas Fault ruptured in earthquakes in 1812, 1857, and 1906, and smaller earthquakes at Parkfield more frequently than that. But the southeasternmost section of the fault from San Bernardino to the Imperial Valley has not ruptured in the 230 years people have been keeping records. Paleoseismological evidence shows that the last major earthquake struck around A.D. 1680, meaning that this section has gone more than three hundred years without a major earthquake. According to the time-predictable model, this part of the fault is “nine and a half months pregnant,” to quote one paleoseismologist. Is this reach of the fault the most likely location of the next San Andreas earthquake, or have other earthquakes in the region altered the schedule, as at Parkfield?
How good is the seismic gap theory in forecasting? In the early 1990s, Yan Kagan and Dave Jackson, geophysicists at UCLA, compared the statistical prediction in 1979 of where earthquakes should fill seismic gaps in subduction zones with the actual experience in the following ten years. If the seismic gap theory worked, then the earthquakes of the 1980s should neatly fill the earthquake-free gaps in subduction zones identified in the 1970s. But the statistical correlation between seismic gaps and earthquakes of the next decade was found to be poor. Some seismic gaps had been filled, of course, but earthquakes also struck where they had not been expected, and some seismic gaps remain unfilled to this day, including the San Andreas Fault southeast of San Bernardino.

The Japanese had been intrigued by the possibility of predicting earthquakes even before a federal earthquake research program was established in the United States. Like the early stages of the program in the U.S., the Japanese focused on prediction, with their major efforts targeting the Tokai area along the Nankai Subduction Zone southwest of Tokyo. Like the San Andreas Fault at Parkfield, the Nankai Subduction Zone appeared to rupture periodically, with major M 8 earthquakes in 1707, 1854, and a pair of earthquakes in 1944 and 1946. But the Tokai area, at the east end of the Nankai Subduction Zone, did not rupture in the 1944-1946 earthquake cycle, although it had ruptured in the previous two earthquakes. Like Parkfield, the Tokai Seismic Gap was heavily instrumented by the Japanese in search of short-term precursors to an earthquake. Unlike Parkfield, Tokai is a heavily populated area, and the benefits to society of a successful earthquake warning there would be very great.

According to some leading Japanese seismologists, there are enough geologic differences between the Tokai segment of the Nankai Subduction Zone and the rest of the zone that ruptured in 1944 and 1946 to explain the absence of an earthquake at Tokai in the 1940s. One view is that the earlier earthquakes at Tokai in 1707 and 1854 were on local crustal faults, not the east end of the subduction zone, which implies that they would have no bearing on a future subduction-zone earthquake. The biggest criticism was that the Japanese were putting too many of their eggs in one basket: concentrating their research on the Tokai prediction experiment at the expense of a broader-based study throughout the country. The folly of this decision became apparent in January 1995, when the Kobe Earthquake ruptured a relatively minor strike-slip fault far away from Tokai (Figure 7-1). The Kobe fault had been identified by Japanese scientists as one of twelve “precautionary faults” in a late stage of their seismic cycle, but no official action had been taken.

After the Kobe Earthquake, the massive Japanese prediction program was subjected to an intensive critical review. In 1997, the Japanese concluded at a meeting that their prediction experiment was not working—but they elected to continue supporting it anyway, although at a reduced level. Similarly, research dollars are still being invested at Parkfield, but the experiment has gone back to its original goal: an attempt to “capture” an earthquake in this well-studied natural laboratory and to record it with the network of instruments set up in the mid-1980s and upgraded since then. Indeed, Parkfield has already taught us a lot about the earthquake process. In 2004, the Parkfield array did, indeed, “capture” an earthquake of M 6, which,
however, arrived thirty-eight years late.

Cartoonist Morita Tsujimura Figure 7a American and Japanese farming strategies, from Schol (1997).