the low- to mid-latitude Pacific Ocean (*2*). Their conclusion was positive but modest support for the Red Queen. But, as it is virtually impossible to determine whether a steady level of evolutionary activity observed in the fossil record is the result of the highly connected world of the Red Queen or a small, not readily detectable, but real oscillation in physical environmental conditions, the test cannot be unequivocal.

The second test, by Kuo-Yen Wei and James Kennett of the University of Rhode Island, also utilizes the planktonic record, this time collected globally and representing the past 22 million years (*3*). These researchers recognize three distinct periods in this slice of evolutionary history: an initial stage of diversification, between 22 and 16 million years ago; a period of relative equilibrium, lasting from 16 to 5 million years ago; and a declining stage from 5 million years on.

Important in the current context is the observation that the boundaries between the stages are marked by drastic environmental changes, such as major cooling events. Such changes inevitably increased evolutionary lag load, which therefore triggered evolutionary activity. Overall species diversity increased when the current diversity level was below the equilibrium level, decreased when it was above, and remained stable when they were roughly equal. Some climatic changes apparently reset equilibrium diversity levels.

Wei and Kennett judge these observations to be consistent with the predictions of the Stationary model. They can see no way of finding with any great confidence periods of environmental constancy during the oceanic fossil record of the past 22 million years, and therefore concede that, as currently formulated, "The Red Queen hypothesis can be neither corroborated nor rejected." Wei and Kennett, like Hoffman and Kitchell, would prefer to compare specific predictions for periods of environmental change.

When Van Valen's Red Queen hypothesis was first proffered it was greeted as a "major step toward . . . interpreting the evolutionary record in terms of general rules and processes." Its further development and marriage with some high-quality paleontological and paleoenvironmental data promise further valuable insights.—**Roger Lewin**

References

1. N. C. Stenseth and J. Maynard Smith, *Evolution* **38**, 870 (1984).
2. A. Hoffman and J. A. Kitchell, *Paleobiology* **10**, 9 (1984).
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Eastern Quakes Pinned Down?

Two groups of researchers have found convincing evidence in a drainage ditch near Charleston, South Carolina, that the large, damaging earthquake that occurred there in 1886 had at least two prehistoric predecessors. The discovery is the first step in testing the increasingly popular idea that, in contrast to the West, large earthquakes can strike almost anywhere along the eastern seaboard. If only a few, presumably identifiable geological structures along the East Coast can produce large earthquakes, engineers designing nuclear power plants and other critical facilities could be far more certain of the level of safety needed in their design.

Dead horses usually do not figure in a field geologist's or seismologist's work, but one certainly helped researchers pick up the trail of prehistoric Charleston earthquakes. During the search for geological evidence, a farmer informed inquirers that his granddad had told how a jet of wet sand shot out of the ground in 1886. Many reports of such sand blows survive, but lingering evidence of them on the surface had not been found. The farmer knew the spot, however, because a pesky horse had been shot and dumped on the sand-blow crater, the skeleton remaining as a marker. After cutting trenches through the spot, John Cox and Pradeep Talwani of the University of South Carolina had a good idea of what traces remain after the shaking of a large earthquake liquefies shallow, water-saturated sand so that it shoots to the surface through a crater or fissure.

It was Stephen Obermeier and his colleagues at the U.S. Geological Survey (USGS) in Reston, Virginia, who first hit the sand-blow bonanza at the ditch near Hollywood, South Carolina, on which they report in this issue of *Science* (p. 408). Cut to drain the wet, low-lying land, the 2- to 3-meter-deep ditch revealed dozens of filled sand-blow craters along its walls. Some look fresh enough to have been created in 1886, but many others have enough slow-growing organic soils developed in them to show that they predate 1886. Carbon-14 dating of the soils from one crater constrains its age to lie between 1400 and 4700 years. And at least one prehistoric crater cuts through all parts of another, demonstrating that one large (greater than magnitude 5.5) prehistoric earthquake followed another.

Cox and Talwani later independently studied sand-blow craters in the Hollywood ditch and have confirmed the existence of at least two prehistoric Charleston earthquakes. They also have about a dozen carbon-14 dates from soil and roots that limit the two prehistoric events to the period between 1200 and 3000 years ago.

Evidence of recurring Charleston earthquakes is important because no one has ever been able to find the deeply buried fault that slipped and caused the 1886 damage and loss of life. Some researchers have argued that there is not simply the one fault in the Southeast capable of generating large earthquakes. Charleston may not be a special case; instead, there could be many sites—unrecognized and perhaps unrecognizable—where large earthquakes could strike. According to one model, much of the eastern seaboard is underlain by a horizontal fault or detachment that could, for instance, slip beneath North Carolina as readily as it did in 1886 near Charleston. Another model has numerous threatening faults along the coast.

Such uncertainty led the USGS to advise the Nuclear Regulatory Commission in late 1982 that a historical record of only one large earthquake was not sufficient reason to presume—as had been done—that such earthquakes could not strike elsewhere east of the Appalachians. The siting of a nuclear power plant a great distance from Charleston, the USGS suggested, might not provide it with sufficient protection.

The new fieldwork in the Charleston area supports the view that there is something geologically special about Charleston—some structure in the crust leads to repeated large earthquakes there. The next step will be to search for paleoseismological evidence of large earthquakes on the eastern seaboard where there is no historical record of them, such as near the central Virginia zone of low-level seismicity or near the Ramapo fault outside New York City. Only then can anyone say how widespread large earthquakes can be on the East Coast.—**Richard A. Kerr**