20,000 Foreshocks Under the Sea: Capturing the End of a Seismic Cycle on the Gofar Transform Fault, East Pacific Rise

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Large earthquakes on East Pacific Rise transform faults occur according to quasi-periodic seismic cycles with about 10-20% variability in recurrence interval. Despite this apparently simple behavior, the largest transform earthquakes rupture only a small fraction of the available fault area and more than half of plate-motion appears to be accommodated aseismically. Notwithstanding this overall inefficiency in earthquake generation, RTFs produce an order of magnitude more foreshocks than continental faults. These defining features of transform faults may both result from along-strike variations in fault-zone material properties: rupture barrier regions that prevent large earthquakes from covering an entire fault are also the regions that generate spectacular foreshock sequences. With an ocean bottom seismic experiment specifically designed to use the intermediate-term predictability of RTFs, we captured a magnitude 6.0 earthquake and the preceding swarm of over 20,000 foreshocks on the Gofar fault. The week-long foreshock sequence was confined to a 10-km long rupture barrier and coincided with a ~3% decrease in the average shear-wave velocity in the foreshock zone. Both the velocity change and the foreshock swarm suggest the occurrence of a larger, aseismic, slow-earthquake in the barrier region. The foreshock sequence occurred in a portion of the fault with a very pronounced, high-porosity, damage zone all the way through the crust indicating that the rupture barrier may be a zone of high fluid-pressure. Our observations suggest that material properties of fault segments capable of rupturing in large earthquakes and those of rupture-barrier regions differ, possibly as a result of enhanced fluid circulation within the latter. Such heterogeneity may explain why, on a global scale, purely temperature dependent rheologies can explain the maximum depth extent of seismicity but not the paucity of large earthquakes on oceanic transform faults.