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TWO CRITICAL TESTS FOR THE CRITICAL POINT EARTHQUAKE

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It has been credibly argued that the earthquake generation process is a critical phenomenon culminating with a large event that corresponds to some critical point. In this view, a great earthquake represents the end of a cycle on its associated fault network and the beginning of a new one. The dynamic organization of the fault network evolves as the cycle progresses and a great earthquake becomes more probable, thereby rendering possible the prediction of the cycleŠs end by monitoring the approach of the fault network toward a critical state. This process may be described by a power-law time-to-failure scaling of the cumulative seismic release rate. Observational evidence has confirmed the power-law scaling in many cases and has empirically determined that the critical exponent in the power law is typically of the order n=0.3. There are also two theoretical predictions for the value of the critical exponent. Ben-Zion and Lyakhovsky (Pure appl. geophys., 159, 2385-2412, 2002) give n=1/3. Rundle et al. (Pure appl. geophys., 157, 2165-2182, 2000) show that the power-law activation associated with a spinodal instability is essentially identical to the power-law acceleration of Benioff strain observed prior to earthquakes; in this case n=0.25. More recently, the CP model has gained support from the development of more dependable models of regional seismicity with realistic fault geometry that show accelerating seismicity before large events. Essentially, these models involve stress transfer to the fault network during the cycle such, that the region of accelerating seismicity will scale with the size of the culminating event, as for instance in Bowman and King (Geophys. Res. Let., 38, 4039-4042, 2001). It is thus possible to understand the observed characteristics of distributed accelerating seismicity in terms

of a simple process of increasing tectonic stress in a region already subjected to stress inhomogeneities at all scale lengths. Then, the region of accelerating seismic release is associated with the region defined by the stress field required to rupture a fault with a specified orientation and rake; it is thus possible to incorporate tectonic information into the analysis.

Recent analysis of Greek seismicity shows definite power-law acceleration in two areas along the Hellenic Arc, with critical exponents in the expected range of 0.2-0.3. The first area is in the west Hellenic Arc, (Ionian Sea). The projected time of failure is in the interval 2003.05-2003.19 and the projected magnitude is of the order M=7. Tectonic modeling of the accelerating sequence shows that this may be interpreted in terms of stress transfer from two fault geometries generating very similar patterns of stress increase and stress shadows. The first scenario calls for a right-lateral oblique-slip fault of NE-SW orientation at the west boundary of the Aegean microplate, just east of the island of Kefallinia (Kefallinia Fault Zone). The second scenario predicts rupture in a slightly left-lateral inverse fault of NW-SE orientation, underlying Kefallinia, with mechanisms consisted with that of McKenzie (Geophys. J. R. astr. Soc., 30, 109-185, 1972) for the destructive M=7.3 earthquake of 12 August 1953. Both scenaria are consistent with the regional tectonics and kinematics and both are consistent with fault zones known to have generated large earthquakes in the past.

The second area is in the SW Hellenic Arc (Mediterranean Sea). The projected time of failure is 2003.6 +/- 0.6 and the projected magnitude is M=7.1 +/- 0.4. Tectonic modelling of this sequence leads to a unique rupture scenario, on a left-lateral oblique-slip fault, probably lying at intermediate depths between Crete and the Peloponnesus, to the SW of the island of Antikythira.

In both cases, the tectonic modeling has revealed the existence of a region of accelerating seismicity at the areas of positive stress transfer and, importantly, a region of power-law decelerating seismicity at the areas of negative stress transfer (stress shadows), i.e. the reverse effect which should be observed if energy was extracted from a fault system. In both cases the critical exponent of the accelerating sequence at the positive-stress-transfer regions is very close 0.25, consistent with the view of the fault network as a Self-Organizing Spinodal moving toward a first order phase transition.

The reported observations are consistent with almost all of the theoretical predictions and expectations made in terms of the critical point / stress transfer model of seismogenesis. However, there are reservations as to whether they comprise bona-fide predictions.

Time-to-failure modelling of accelerated seismicity is a relatively new field of study with few cases-histories whence to draw experience, most of which in fact comprise retrospective analyses of past earthquakes. Still, very little is known as to the development of real-time situations and their probability of success or failure. Also, the power-law scaling is essentially the result of a renormalisation, in which the process of failure at a small spatial scale and temporarily far from a global event can be remapped to the process of failure at a larger scale and closer to the global event. In consequence, when new elements are added, (i.e. large foreschocks), the sequence is renormalized and the predicted parameters may change, sometimes significantly. Yet another difficulty arises from the fact that even if a full-scale self-organising process is active in the critical area, it is not at all necessary that a large earthquake will occur as soon as the system enters the critical state. The critical point model merely predicts that past this time an earthquake is possible but not certain. The time of the large event may depend on several uncertain factors pertaining to the nucleation process, which may have significant time dependence of their own. Moreover, the stored energy may be dissipated with aseismic (low moment release rate) event(s). Again, the absence of a concrete case history complicates anyoneŠs ability to make solid inferences.

In conclusion, our observations can be considered to be critical tests of the critical point / stress transfer earthquake model. If the expected earthquakes occur, then it is possible that we have a powerful tool. If not, we should contemplate the possibility that this approach has limited predictive capacity and is unsafe in evaluating seismic hazard. The answer is pending and the question is open for discussion.