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A FIRST PRINCIPLES APPROACH TO UNDERSTANDING THE PHYSICS OF PRECURSORY ACCELERATING SEISMICITY

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Observational studies indicate that many large earthquakes are preceded by accelerating seismic release rates (Accelerated Seismic Deformation - ASD), characterized by a cumulative Benioff strain following a power law time Űto failure relation of the form S(t) = K + A(tf Ű t)ˆm, (1)

where tf is the failure time of the large event and m of the order of 0.2 - 0.4. More recent theoretical studies relate the behaviour of seismicity prior to a large earthquake to the excitation in proximity of a spinodal instability and show that the power-law activation associated with the spinodal instability is essentially identical to the power-law acceleration of Benioff strain observed prior to earthquakes, with m = 0.25.

In the present work, we discuss a theoretical framework in which we derive the time-to-failure power-law from basic principles. We use energy conservation in a faulted crustal volume undergoing stress loading and we assume that the fault system obeys a fractal / hierarchical distribution law. Furthermore, we assume that the precursory seismic activation extends over a broad area around the impending failure and rapidly converges to the rupture zone as a function of the time-to-failure. By considering the analytic conditions near the time of failure, we derive the time-to-failure power-law and show that the critical exponent m is a function of the fractal dimension and that the cumulative precursory crustal deformation (A) is a function of the energy supplied to the system and the size of the rupture. The fractallity of the fault system is a necessary condition for the appearance of power-law acceleration in the seismic release rates.

We note that this approach is based on first principles and gives a clear interpretation of the empirical parameters involved in equation (1). On the basis of these results, it is possible to explain a set of empirical laws derived by other researchers (e.g. Papazachos et al., Bull. Seism. Soc. Am., 92, 570-580, 2002), in terms of a plausible physical framework. Furthermore, by considering the relationship of the instantaneous Benioff strain rate with respect to the mean Benioff strain rate, it is possible to construct approximate analytical expressions to estimate the magnitude and time of failure of the impending earthquake. Examples and applications of this technique to observations of accelerating seismicity in Greece and abroad, will also be presented and discussed.

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