Dynamic models of the earthquake source allow simulating the evolution of stress and slip at tectonic faults by coupling the equations of motion in a volume surrounding the fault with a constitutive law that represents the surface forces acting on the fault. In the first part of the thesis, we review important properties of shear rupture for brittle, linear slip-weakening, and rate-and-state constitutive laws. In the second part of the thesis, we present two studies utilizing 3-D dynamic modeling at both long (hundreds of years) and short (seconds) time scales. In the first study, we model seismic cycles using the rate-and-state laws of friction and perform a parametric exploration of the effects of sudden intra-cycle shear stress perturbations on the clock advance or delay of the subsequent large event. We find that when the perturbation is applied during specific time intervals, the earthquakes following the perturbation are only small ruptures that do not completely release stress on the whole fault. The time interval between large earthquakes may thus be prolonged up to 80% when compared to the unperturbed cycles. We reproduce this behavior on a numerical heterogeneous model of the Parkfield segment of the San Andreas fault and demonstrate that the mechanism could have been responsible for the observed large delay of the 2004 Mw 6 Parkfield earthquake. In the second study, we use the linear slip-weakening law with a 12-parametric elliptic model to carry out a Bayesian dynamic inversion of the 2017 Mw 6.3 Lesvos Earthquake. We calculate the most probable values and uncertainties of individual parameters, along with their mutual trade-offs. We also propose a method of assessing the degree to which model parameters and other quantities are resolved by different constraints. In particular, we examine the effect of prior assumptions, a minimum rupture expansion condition, the information about the moment magnitude, and seismic waveforms on the final shape of probability density functions for different quantities.