Community-driven 3D models of faults, strata, and seismic velocity for southern California and northwest Turkey

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Faults used in earthquake hazard models are commonly shown as traces in map view, with ramps of blind faults projected as polygons. This representation can be misleading for non-vertical faults, where much of the potential earthquake rupture area is located several or even many kilometers horizontally as well as vertically away from the surface trace. The Southern California Earthquake Center (SCEC) Community Fault Model (CFM) is composed of digital 3D representations of over 140 faults, which are publicly available (http://structure.harvard.edu/cfm/). Deciding which 3D geometry of intersecting faults to include in preferred models is an exercise in consensus building. These faults are defined from a variety of data, including outcrop, seismic reflection data, seismicity, wells, cross sections, and models. In southern California, many faults are blind or partially blind, with all or part of the dip-slip component absorbed by folding. Strike-slip motion can also be absorbed or transferred by folding. Therefore, it is important to include digital representations of deformed strata in the same models with the faults. Indeed, dated stratigraphy is required if one is to understand the evolution of a fault system through time.

Faults interpreted from seismic reflection data can be included in a model in two-way travel time (TWTT) and linked to a velocity model. Precise earthquake locations are dependent on accurate P-wave velocity models. Perhaps the most societally-relevant reasons to construct community fault and velocity models is to produce 3D ground motion models. Fault representations and kinematics from focal mechanisms, GPS data, and structural modeling allow realistic scenario earthquakes to be modeled. The fault and basin geometries can result in surprising amplifications of ground motion and their durations. Fault geometry and kinematics are also needed to realistically model stress transfer.

Once 3D representations are in place, structural modeling can be done to determine fault slip through time. For example, a left-lateral fault that extends offshore from Los Angeles, the Santa Monica-Dume fault, accumulates structural relief through a restraining double bend (Fig. 1). Modeling shows that left-lateral slip on this fault is associated with clockwise vertical axis rotation of the hanging-wall of this moderately-dipping fault. Published modeling of GPS data show continuing clockwise rotation of the hanging-wall, suggesting that post-Miocene slip rates are similar to present rates.

The North Anatolia fault in Marmara Sea is characterized by various branches and bends. Abundant seafloor and subsurface imaging has been done since the devastating 1999 earthquakes. Much work is being done with the deep crustal and higher resolution seismic reflection and refraction data, as well as seismicity. These abundant data offer an opportunity to develop structural and stratigraphic models that represent 3D geometry provided that a framework for consensus building and constructing the models becomes available. Construction of SCEC-like representations requires cooperation of many people and institutions.

Finally, much of earthquake science is funded by the public, and it ultimately seeks to protect the public. Public outreach has been one of the major goals and successes of SCEC. Animations of southern California faults and seismicity have been completed that have proven to be an effective educational and communication tool used in the class room and for television coverage (http://structure.harvard.edu/cfm/modelaccess.html. -- “flythrough”). Similar animations can be done from existing data for northwest Turkey. There is an opportunity here to combine creativity and science to educate the public to the structure and behavior of the earth beneath them.

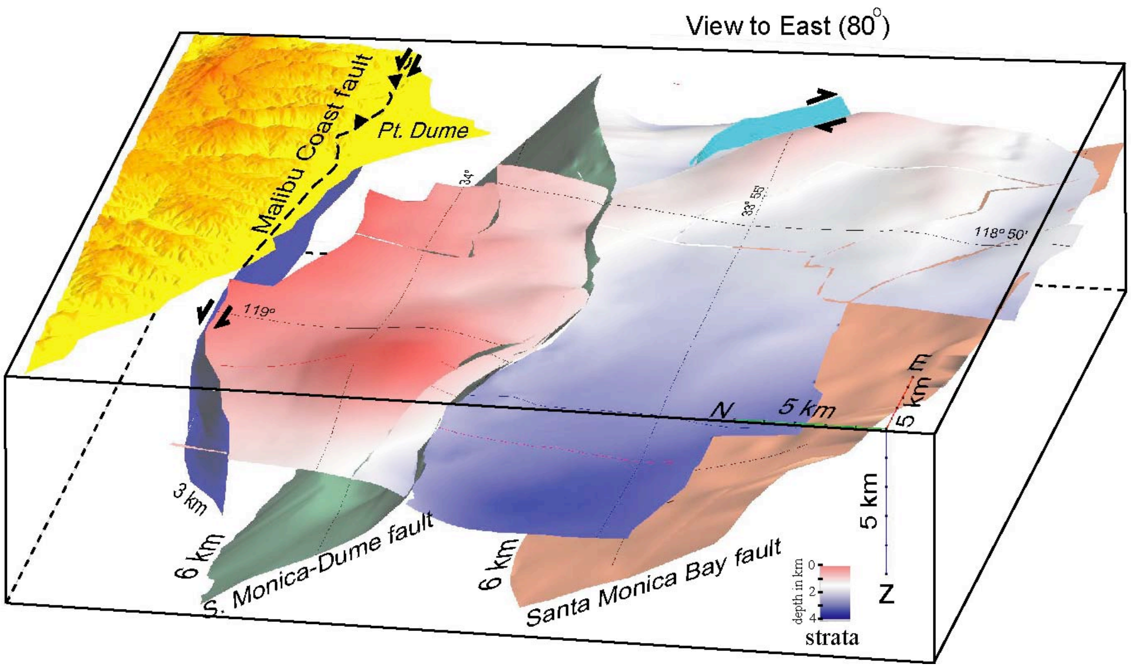

Figure 1: Oblique view eastward (toward 80º azimuth), from 20º above horizontal, of a ~4 Ma horizon, faults (labeled), and the 30 m DEM. Figure modified from Sorlien, Kamerling, Seeber, and Broderick., accepted by Journal of Geophysical Research. Folding is due to oblique-reverse left-lateral displacement in the foreground linked to left-lateral displacement in the background. The farther rocks in the hanging-wall (north) are transported through the restraining segment, the greater the structural relief.