Progress report for 2009 SCEC Proposal

Title of Project

Quantifying Heterogeneity of Active Fault Zones using Fault Trace and Earthquake Focal Mechanism Data

Principal Investigator
Yehuda Ben-Zion
Department of Earth Sciences
University of Southern California

***Proposal Categories*:**
Integration and Theory

Science Objectives:
A2, A4, A10

Summary
Studies under this project attempt to quantify the levels of heterogeneity in California faults using two observational approaches. The two approaches employ different measures of heterogeneities and utilize data with different spatial and temporal sampling. In the first approach, fault trace data describe the surface expression of fault displacement accumulated over tens of thousands of years. In the second, focal mechanism data sample the geometry of seismic faulting throughout the seismogenic crust (~0-15 km) over a ~20 year period. The level of geometrical complexity in a fault zone has important implications for the evolution of faults, the physics of the associated earthquakes. Improved understanding of the variations in the complexity of different fault zones can be useful for future seismic hazard assessments. The studies supported partially two students and led to two submitted papers (one on each research direction). Below we summarize the main results from our last year investigations on these problems.

Evolving Geometrical Heterogeneities of Fault Trace Data

Wechsler, N., Y. Ben-Zion and S. Christofferson
(*Geophys. J. Int.*, in review, 2010)

Abstract
We perform a systematic comparative analysis of geometrical fault zone heterogeneities using derived measures from digitized fault maps that are not very sensitive to mapping resolution. We employ the digital GIS map of California faults (version 2.0) and analyze the surface traces of active strike-slip fault zones with evidence of Quaternary and historic movements. Each fault zone is broken into segments that are defined as a continuous length of fault bounded by changes of angle larger than 1°. Measurements of the orientations and lengths of fault zone segments are used to calculate the mean direction and misalignment of each fault zone from the local plate motion direction, and to define several quantities that represent the fault zone disorder. These include circular standard deviation and circular standard error of segments, orientation of long and short segments with respect to the mean direction, and normal separation distances of fault segments. We examine the correlations between various calculated parameters of fault zone disorder and the following three potential controlling variables: cumulative slip, slip rate, and fault zone misalignment from the plate motion direction. The analysis indicates that the circular standard deviation and circular standard error of segments decrease overall with increasing cumulative slip and increasing slip rate of the fault zones. The results imply that the circular standard deviation and error, quantifying the range or dispersion in the data, provide effective measures of the fault zone disorder, and that the cumulative slip and slip rate (or more generally slip rate normalized by healing rate) represent the fault zone maturity. The fault zone misalignment from plate motion direction does not seem to play a major role in controlling the fault trace heterogeneities. The frequency-size statistics of fault segment lengths can be fitted well by an exponential function over the entire range of observations.

Quantifying focal mechanism heterogeneity for fault zones in Southern and Central California,

Bailey, I. W., Y Ben-Zion, T. W. Becker and M. Holschneider
(*Geophys. J. Int.*, in review, 2010)

Abstract

We present a statistical analysis of focal mechanism orientations for nine California fault zones with the goal of quantifying variations of fault zone heterogeneity at seismogenic depths. The focal mechanism data are generated from first motion polarities for earthquakes in the time period 1983–2004, magnitude range 0–5, and depth range 0–15 km. Only mechanisms with good quality solutions are used. We define fault zones using 20 km wide rectangles and use summations of normalized potency tensors to describe the distribution of double-couple orientations for each fault zone. Focal mechanism heterogeneity is quantified using two measures computed from the tensors that relate to the scatter in orientations and rotational asymmetry or skewness of the distribution. We illustrate the use of these quantities by showing relative differences in the focal mechanism heterogeneity characteristics for different fault zones. These differences are shown to relate to properties of the fault zone surface traces such that increased scatter correlates with fault trace complexity and rotational asymmetry correlates with the dominant fault trace azimuth. These correlations indicate a link between the long term evolution of a fault zone over many earthquake cycles and its seismic behavior over a 20 year time period. Analysis of the partitioning of San Jacinto fault zone focal mechanisms into different faulting styles further indicates that heterogeneity is dominantly controlled by structural properties of the fault zone, rather than time or magnitude related properties of the seismicity.

Publications Supported by this grant

Wechsler, N., Y. Ben-Zion and S. Christofferson, Evolving Geometrical Heterogeneities of Fault Trace Data, *Geophys. J. Int*., in review, 2010.

Bailey, I. W., Y Ben-Zion, T. W. Becker and M. Holschneider, Quantifying focal mechanism heterogeneity for fault zones in Southern and Central California, *Geophys. J. Int*., in review, 2010.