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To my parents, María Lucrecia and Alfredo,

sister, Sara, and wife, María Teresa,

who convinced me I could do it

and supported me all

the way through.

Acknowledgments

"I give this record of my journey
not as a contribution to human knowledge,
because my knowledge is small and of little account,
but as a contribution to human experience."
Henry Miller

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Abstract

This dissertation focuses on processing and migration techniques to enhance the seismic images of two types of faults that are difficult to map in the subsurface: normal and blind thrust. I examine normal faulting in Death Valley, California, with deep crustal reflection data; and blind thrust faulting in the Los Angeles basin, California, with earthquake data. The main findings of my research can be summarized in two parts:

1. Enhanced imaging of a normal fault with seismic reflection data

Motivated by the need to image faults to test Cenozoic extension models for the Death Valley region of the western Basin and Range province, an area of strong lateral velocity variations, I examine the geometry of normal faulting in southern Death Valley by seismic depth imaging. I analyze COCORP (Consortium for Continental Reflection Profiling) Death Valley Line 9 to attain an enhanced image of shallow fault structure to 2.5 km depth. Previous workers used standard seismic processing to infer normal faults from bed truncations, displacement of horizontal reflectors, and diffractions. I use a detailed velocity model obtained by nonlinear optimization of first-arrival times picked from shot gathers, examine the unprocessed data for fault reflections, and use a Kirchhoff prestack depth imaging procedure to properly handle lateral velocity variations and arbitrary dips. Fault-plane reflections reveal the listric true-depth geometry of the normal fault at the Black Mountains range front in southern Death Valley. This is consistent with the concept of low-angle extension in this region and strengthens its association with

crustal-scale magmatic plumbing.

2. Enhanced imaging of crustal faults with earthquake data

An inexpensive means to understand further the geometry of active faults in southern California arises from the use of aftershock recordings to image crustal structures. The advent of regional seismic networks that record digital seismograms from hundreds of stations makes this crustal reflectivity profiling possible even in the absence of conventional active-source seismic data. I show it is feasible to image fault structure using three-dimensional, wide-angle prestack Kirchhoff migration. I achieve this with the use of aftershock traces recorded on the short-period vertical stations of the Southern California Seismic Network. This work complements seismicity and focal mechanism work by imaging reflectivity volumes and cross sections rather than having to associate events with certain faults. Further, it can image below the seismogenic zone to resolve current geologic controversies on how proposed faults extend below focal depths. I demonstrate the validity of these images as showing reflective structures, and the ability to use clipped high-gain seismograms as sign-bit data to yield valid geometric imaging. Work with data from the 1991 Sierra Madre earthquake sequence images the prominent lower crustal reflective zone observed beneath most of the San Gabriel Mountains by the Los Angeles Region Seismic Experiment Line 1. Aftershocks of the 1994 Northridge earthquake allow me to image a north-dipping structure that may represent the fault plane of a crustal-penetrating blind thrust. The images serve as a test for the existence and geometry of thrust ramps and detachments proposed from balanced-section reconstructions of shallow-crustal profiles and borehole data. My results are more consistent with a thick-skinned tectonic regime in the vicinity of the Northridge earthquake, rather than a thin-skinned model.

In addition, my work leads to the following key points that summarize the overall importance of fault zone imaging from seismic reflection studies in the region: it is possible to image active fault zones, but I achieve geometric imaging only, without property descriptions. I constrained tectonic style in two provinces: extensional (Death Valley) and contractional (Los Angeles basin). Each case required three-dimensional treatment of sources and receivers, asymptotic assumptions, and some knowledge of velocities. Normal faulting in Death Valley may be defined as an "intra-plate" feature because it does not provide evidence that faulting cuts the Moho; whereas the Elysian Park Thrust may be an "inter-plate" feature because it appears to cut the Moho.