# Chapter 6

# Conclusions

In this thesis, I investigate the seismic structure along transitions from flat to normal subduction located in central Mexico, southern Peru, and southwest Japan. I explore the nature of the flat-to-normal transitions in central Mexico and southern Peru to determine whether these changes in geometry are accommodated by slab tears or smooth contortions. In southwest Japan, I explore the spatial coincidence of a thin ultra-slow velocity layer (USL) with locations of slow slip events (SSEs) and the possible causal relationship between the two. The results of these studies can be summarized in the following.

In western central Mexico, the results of 1D and 2D waveform modeling techniques and an analysis of P waveform complexities show that the subducted Cocos plate is a complicated, multilayered structure with a thin USL atop the slab. The western lateral extent of this USL is approximately coincident with the western margin of the projected Orozco Fracture Zone (OFZ) region, implying a structural boundary which I interpret as a tear in the Cocos plate. Recent tectonic observations in the region of variable plate motions to either side of the OFZ and a possible small-scale rift-rift-rift triple junction overlying the landward projection of the OFZ have suggested that the Cocos plate is fragmenting along this fracture zone. On the basis of my seismic results and these tectonic observations, I propose a slab tear model, wherein the Cocos slab is currently fragmenting into a North Cocos plate and a South Cocos plate along the projection of the OFZ by a pivoting subduction process similar to that which occurred when the Rivera plate separated from the proto-Cocos plate. This ongoing fragmentation event presents the opportunity to observe and study a young tearing

process in action.

In eastern central Mexico, intraslab seismicity patterns, an analysis of P waveform complexities, and 1D and 2D waveform modeling techniques are used to interrogate the nature of the flat-to-normal transition. The eastern lateral extent of the thin USL atop the slab is marked by a boundary between the USL and no USL zones, followed by a diffuse weakening USL region closer to the coast. A sharp transition in slab dip near the abrupt end of the Trans Mexican Volcanic Belt (TMVB) suggests a possible tear in the South Cocos slab. The coincidence of the boundary between the USL and no USL zones with the margin of a zone of decreased seismicity along this change in dip and the end of the TMVB implies a change in structure which I interpret as evidence of a possible tear. Additional observed intraslab seismicity patterns of clustering, sudden increase in depth, variable focal mechanism orientations and faulting types, and alignment of source mechanisms along the sharp transition in slab dip further support this conclusion. I propose the subduction of parallel ridges of seamounts and/or stress due to the abrupt change in geometry as potential causes of the possible slab tear in the South Cocos plate. Further imaging of the subduction zone structure with denser station coverage over the downdip aseismic portion of the slab may provide a clearer picture of the possible tear at depth.

The morphology of the Nazca slab along the flat-to-normal transition in southern Peru is investigated using intraslab seismicity patterns, focal mechanism orientations, an analysis of P waveform complexities, and 2D waveform modeling techniques. The results show that the subducted Nazca plate is a complicated structure with a possible thin USL atop the horizontal slab. The lateral extent of this USL is coincident with the margin of the projected continuation of the subducting Nazca Ridge, implying a change in structure which I interpret as a causal relationship between these features. A gradual increase in slab dip with no sharp transitions suggests smooth contortion of the Nazca plate. The lack of any gaps or vertical offsets in the intraslab seismicity coupled with the concentration and orientation of focal mechanisms indicative of slab bending further support this conclusion. The absence of a tear in the slab along either the Nazca Ridge or the largest increase in slab dip is also confirmed with 2D waveform modeling. Further modeling of the subduction zone

structure in the flat slab region may provide additional constraints on the presence of the USL.

In southwest Japan, local and teleseismic recordings of complex P waveforms are used to examine the fine-scale seismic structure of the subducted Philippine Sea plate along the transition from flat to normal subduction. Observations of such waveforms both locally and teleseismically for an intraslab earthquake located beneath the Bungo channel yield a possible region for a thin USL along the Philippine Sea slab surface. The spatial coincidence of this region of very low velocity with the locations of SSEs provides further evidence for the proposed causal relationship between the occurrence of SSEs and the presence of an USL atop the slab. I interpret the source of the possible USL in this region as fluids dehydrated from the subducting plate, forming a high pore-fluid pressure layer. Future 2D waveform modeling of the seismic structure of the subduction zone in southwest Japan will be performed in order to provide constraints on the thickness, velocity, and lateral extent of the possible USL here and to explore the nature of its observed lateral heterogeneity. This study can further be strengthened through the analysis of more recent events which have occurred in this region.

## Update to Chapters 2 and 3

The description of simple P waveforms as written in Chapters 2 and 3 has been updated since these chapters were published. The new description (see section 4.3.5) clarifies that the lack of the C phase in these waveforms indicates that there is no high velocity layer present, while uncharacteristically shaped and/or low amplitude A and B phases indicate that there is no USL present. Additionally, the arrival times of the possible A and B phases in the simple waveforms are inconsistent with the presence of the USL.