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Subduction Zone Concepts and the 2010 Chile Earthqake (Arthur Holmes Medal Lecture)

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Knowledge of convergent margin systems evolved from hypothesis testing with marine geophysical technology that improved over decades. Wegener's drift hypothesis, Holmes mantle convection, and marine magnetic anomaly patterns were integrated into an ocean spreading concept that won wide acceptance after ocean drilling confirmed the crustal younging trend toward the Mid-Atlantic ridge. In contrast, the necessary disposal of oceanic and trench sediment at convergent margins remained largely hypothetical. Fresh interpretations of some coastal mountains as exposing ancient convergent margin rock assemblages and the seismologist's "Wadati-Benioff" zone were combined into a widely-accepted hypothesis. A convergent margin upper plate was pictured as an imbricate fan of ocean sediment thrust slices detached from the lower plate.

During the 1980s ocean drilling to test the hypothesis revealed what then were counter-intuitive processes of sediment subduction and subduction erosion. Rather than the proposed seaward growth by accretion, many margins had lost material from erosion. In current concepts, individual margins are shaped by the net consequences of subduction accretion, sediment subduction, and subduction erosion. Similarly, recently acquired age data from ancient subduction complexes reveal periods dominated by accretion separated by periods dominated by tectonic erosion. Globally, the recycling of continental crustal material at subduction zones appears largely balanced by magmatic addition at volcanic arcs. The longevity of the original imbricate fan model in text books confirms its pictorial simplicity, because geophysical images and drill core evidence show that it commonly applies to only a relatively small frontal prism.

A better understanding of convergent margin dynamics is of urgent societal importance as coastal populations increase rapidly and as recent disastrous earthquakes and tsunamis verify. The shift in convergent margin concepts has developed through 50 years of improved acquisition techniques, analysis capabilities, and imaging that greatly improves resolution in observational data. The first observatories in boreholes that place instruments closer to earthquake rupture zones have been deployed. Technological improvement should be strongly pursued to meet future challenges. Advanced seismic imaging and the new riser drilling vessel Chikyu are tools to significantly advance understanding of earthquake mechanics but availability is restricted by current global science budgets. The present scientific knowledge leaves great earthquakes and tsunamis an unpredictable "stealth" natural hazard of great proportions.