Cyclical Behavior in Cordilleran Orogenic Systems

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Cordilleran orogenic systems form along the edges of continental plates above subducting oceanic plates; they are best developed where the rate of convergence between the plates is relatively rapid and the lateral edges of the subducting plate are thousands of kilometers away (Schellart, 2008). Modern Cordilleras occupy the 15,000 km long composite western margin of the American plates, where Pacific-domain plates subduct eastward beneath generally westward moving continental plates. Ancient counterparts abound in the geological record (e.g., Anderson, 1990; Pitcher, 1997; Kapp et al., 2007).

- Outboard arc-trench complexes and inboard retroarc thrust belts constitute the main features of Cordilleran orogenic belts.
- A variety of sedimentary basins, including trench, forearc, intra-arc, hinterland and foreland basins, lie athwart and alongside the orogenic belt.
- Magmatism of calc-alkaline composition is expressed in high elevation stratovolcanoes, ignimbrite platforms, and mid-crustal granitoid batholith belts (Pitcher, 1997). This magmatism exhibits pronounced cyclical behaviour in composition and volume flux (Ghosh, 1995; Haschke et al., 2002; Ducea & Barton, 2007; Gehrels et al., 2009)
- Extensional and strike-slip fault systems cut orogenic hinterland regions, and are commonly associated with mafic magmatism (Marrett et al., 1994; Wells & Hoisch, 2008).
- In the modern South American Cordillera, where crustal shortening is greatest—on the order of several hundred km (McQuarrie, 2002; Oncken et al., 2006)—the crust is approximately double normal thickness (Yuan et al., 2002; Beck & Zandt, 2002), rivaling that of the Tibetan Plateau. Reconstructions of the mainly late Mesozoic North American Cordillera depict an analogous thickening in the central part of the system.
- Peak surface elevations of nearly 7 km and regional average elevation of ~4 km are present in the central Andean Cordillera, and paleoaltimetry studies are beginning to suggest that comparable elevations existed in parts of the central North American Cordillera (Chase et al., 1998; Mulch et al., 2004; Cecil et al., 2006; Cassel et al., 2009).
- Regions of anomalously low elevation also exist in the modern central Andes, and may be linked to dynamic processes in the upper mantle and coupling between upper and lower plates (Beck & Zandt, 2002; Yuan et al., 2002).
- Seismological studies of mantle composition and dynamics in the North and South American Cordilleras demonstrate that large pieces of the mantle lithosphere are presently foundering into the mantle in some regions, and petrological studies of volcanic rocks, xenoliths, and arc batholiths support the idea that delamination or dripping of mantle lithosphere has occurred during the geological past (Kay et al., 1994; Beck & Zandt, 2002; Schurr et al., 2006; Lee et al., 2006).
- Climate in the central Andes is intimately linked to orography, and potential feedback linkages between climate and kinematics are being actively debated (e.g., Vandervoort et al., 1997; Horton, 1999; Montgomery et al., 2001; Lamb & Davis, 2003; Strecker et al., 2009).
- Paleoaltimetry studies of the Neogene central Andes produce seemingly conflicting results, with some datasets indicating abrupt increases to very high elevations, and other datasets suggesting more gradual changes and greater contributions to the isotopic paleoelevation signal by climate (Garzione et al., 2008; Ehlers et al., 2009).

How is one to make sense of all these and many other complexities in Cordilleran systems? Which of these signals are in true conflict, and which are reconcilable within a broader, systems-based synthesis? Which of these signals have unsuspected tele-connections with each other? Clearly an integrated multidisciplinary approach is required to document linkages among these signals.

Significant scientific questions surrounding Cordilleran margins include:

(1) What are the feed-forward and feed-backward relationships among retroarc shortening, hinterland geodynamics, forearc tectonic erosion, arc magmatism, upper mantle dynamics, and climate dynamics in Cordilleran orogenic systems?

(2) Are there temporally predictable, even cyclic, relationships among processes in Cordilleran orogenic belts? For example, cycles in arc magmatism characterize several of the American Cordilleran orogenic belts (Haschke et al., 2002; Ducea and Barton, 2007); are these magmatic cycles expressed in other parts of the Cordilleran system, from the upper mantle to the surface, from the trench to the distal foreland?

(3) How do sedimentary basins that form in Cordilleran systems respond to this array of geodynamic processes? These basins span the entire orogenic system and provide a valuable archive of the tectonic and climatic conditions under which the orogenic belt evolves.

(4) Cordilleran orogenic systems may be considered as the dynamic results of tectonic growth by convergence between oceanic and continental plates, and erosion by processes operating at the lithosphere-asthenosphere boundary and the topographic surface. Thus, the geochemical evolution and dynamics of the upper mantle, oceans, and atmosphere are strongly dependent on the machinery of Cordilleran orogenesis. What are these relationships, and how might they have changed through geological time?

Project focus areas could include virtually anywhere along the western Cordilleras of the Americas (on land and at sea), as well as older Cordilleran systems that expose deeper levels of various parts of the system. Time-space trade-offs would be an obvious way to exploit Cordilleran systems at different stages of evolution, or different stages of exhumation. For example, the North American Laramide province is a natural laboratory for studying highly evolved upper plate response to flat-slab subduction (Saleeby, 2003), whereas modern flat-slab regions in South America provide geodynamic and geophysical views that are no longer available in North America (Wagner et al., 2005). Similarly, the North American and South American Cordilleras provide different vantage points on what was likely a very similar system, with an essentially intact and still developing Cordillera in South America and a deeply exhumed Cordillera (in both the orogenic belt and the flanking basins) in North America (Allmendinger et al., 1997). Approaches to the search for cyclicity in Cordilleran orogenic systems would include structural geology, basin analysis, petrology, geochronology and thermochronology, paleoaltimetry, geodesy, passive and active source seismology, and numerical modeling of geodynamic and climatic processes.

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