The Role of Climate, Surface Processes, and Sedimentation in Continental Rifts and the Transition from Rifting to Seafloor Spreading

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Rift basins preserve long, high-fidelity records of the surficial response to tectonic deformation, climate change, and earth history. Because the generation of accommodation space in rift basins typically is rapid and prolonged, these settings are especially well suited for deciphering such records. We have made significant advances in understanding how sediments in rift settings record deformation and environmental conditions, but fundamental questions remain, especially with regard to contrasting rates of subaerial versus submarine processes and how they are linked across the shoreline. In addition, sediment accumulation appears to exert a direct control on the thermo-mechanical evolution of rifts. We recognize a suite of rate-related problems in which different components of the system operate on different timescales (e.g., erosion, subsidence, and basin filling in response to vertical and horizontal motions). Because of their natural tendency to capture and preserve a sedimentary record, rifts provide an ideal setting with which to advance understanding of these linkages. Below we summarize some leading scientific questions.

1. **How do sediment input and loading affect crustal composition, thermal structure, rheology, rift architecture, magmatism, and structural evolution of rifts?**

Accumulation of sediment has long been recognized as a mechanism of crustal formation in deep continental rifts (e.g., Moore, 1973; Fuis et al., 1984; Nicolas, 1985), but only recently has re-emerged as a primary control on rift evolution. Rapidly buried sediment is transformed in deep rift basins to form metasedimentary rock, possibly explaining: (1) the presence of "transitional crust" at many rifted margins; (2) changes in magmatism and buoyancy forces that favor an early transition to narrow rift mode (Lizarralde et al., 2007; Bialas and Buck, 2009); and (3) diffuse deformation following lithospheric rupture (Persaud et al., 2003). While these studies point to the influence of sediment input on rift processes, many aspects remain controversial and poorly understood. In addition, little is known about tectonic and climatic controls on source dynamics, sediment routing, erosion rates, and timing of regional scale drainage-capture events.

2. **What are the dynamic feedbacks among crustal deformation, erosion, climate, and sedimentation in and adjacent to continental rifts?**

Over the past ~20 years integrated studies of geomorphology, thermochronology, and mechanical modeling have investigated the effects of climate and erosion on the mechanics of thrust belts, crustal exhumation, and related orographic effects in convergent-margin settings (e.g., Willet, 1999; Montgomery et al., 2001; Whipple, 2009). However, these kinds of feedbacks are relatively little studied in rift settings. New studies indicate that even modest topographic elevation on rift flanks can have a substantial impact on atmospheric circulation and erosion of source areas. Recent studies of low-T thermochronology (Spiegel et al., 2007), regional tectonics and climate change (Chapin, 2008), climatic controls on incision rate (Mack et al., 2009), climatic control on rift architecture (Kluesner et al., 2009), and sediment budgets (Dorsey, 2010) point to important but poorly understood feedbacks among rift-related deformation, climate change, erosion, subsidence, and transfer of sediments from eroding highlands to rift basins.

3. **How does evolving rift architecture, including rift segmentation, modify and interact with subaerial and submarine sediment-dispersal pathways through time?**

Prevailing models of erosion and sediment dispersal in rift settings involve transport away from the rift in the footwall of normal faults, and funneling of sediment into rifts via topographic lows in accommodation zones (e.g., Leeder and Jackson, 1993; Jackson and Leeder, 1994; Driscoll and Hogg, 1995; Gupta et al., 1999; Densmore et al., 2004). Some rifts experience sediment transport along the rift axis by fluvial, deltaic and submarine systems, while others are sediment-starved and receive input primarily from small footwall catchments. It is not well understood how 3-D sediment dispersal patterns change in space and through time in response to evolving structural controls such as fault migration and lateral linkages, how fluvial erosion modulates that response, and how these processes vary in marine versus nonmarine environments.

4. **How do sediment type and transport/depositional processes change when continental rifts are flooded by marine water?**

Many uncertainties exist regarding the nature and causes of the transition from nonmarine to marine environments involved in continental rupture and birth of an ocean. We wish to know how sediment-dispersal pathways, transport mechanisms, depositional environments and ecology change during the transition from fluvial/alluvial/lacustrine to marine-dominated. Different stratal architectures can be expected for gradual versus rapid marine flooding, and sea-level change may significantly modulate this transition. Also poorly understood are the subsequent changes in currents, tides, and physical oceanography as a seaway expands during extension and subsidence. How does the production of biogenic and pelagic sediments develop after marine incursion, during expansion and deepening of a new ocean basin? How does the formation of a new ocean basin affect regional biosphere, hydrosphere, and atmospheric systems?

5. **How are break-up unconformities formed, and how is the timing of erosion related to lithospheric processes associated with continental rifting and rupture?**

Break-up unconformities are erosional angular unconformities across which syn-rift deposits and basin bounding faults are overlapped by flat lying “post-rift” deposits. Not all rifted margins display this kind of unconformity, but many do. To date, no model has successfully explained erosion that is required to produce this commonly observed feature. In-plane force (Cloetingh et al., 1985) is insufficient to produce the observed signal (Karner et al., 1993; Christie-Blick and Driscoll, 1995). Break-up unconformities may record an increase in mantle buoyancy or dynamic (i.e. flow-induced) forces associated with continental rupture (Lavier and Manatschal, 2006). Understanding the origin of such unconformities is central to deciphering the mechanisms that control continental extension and rupture at rifted and obliquely rifted margins.

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