ES05: The interaction between climate and tectonics in Late Cenozoic landscape evolution

Conveners: John Gosse[1], and Lindsay M. Schoenbohm[2]

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Session Description

Earth's surface is shaped by both the constructive force of tectonics—which builds mountains, and the destructive force of erosion by rivers, glaciers and landslides—which tear mountains down. Mantle dynamics and lithospheric loading further modifies Earth's topography. Tectonic Geomorphology in its broadest sense, explores these interactions through remotely sensed data (GPS, InSAR, lidar), paleoseismology, geochronology and thermochronology, landscape morphometrics, and numerical and analogue modeling. Two decades of research have shown that rivers, glaciers and landslides are powerful enough as erosive forces to change the mass balance of an uplifting mountain range, and therefore change the pattern and rate of tectonic deformation, all the way at least to the mantle lithosphere. Other research demonstrates the utility of tectonic geomorphology in understanding active tectonic processes in increasingly greater detail, to help establish, for example, strain partitioning and fault kinematics in a tectonically active area, or interrogating the earthquake cycle and constraining seismic hazards. Meanwhile, climate-controlled sediment availability will dictate the rates and styles of sedimentation in various tectonic basins. This session seeks to bring together emerging and established researchers in Canada and abroad to discuss their work around the world on neotectonics, large-scale landscape evolution, and late Cenozoic mountain building.

Primary Affiliation: CGU: Earth Surface Processes and Quaternary Sciences / Geophysics Solid Earth

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NOTE: THIS DOCUMENT CONTAINS INFORMATION FOR ALL SESSION SUB-SECTIONS. PRESENTER ABSTRACTS ARE FOUND AT THE END OF THE DOCUMENT.

SCHEDULE MAY BE SUBJECT TO CHANGE.

ORAL SESSION ES05a

Chairs: L. Schoenbohm and J. Gosse **Room: ESB 2012**

Monday, May 29th

TIME	AUTHORS	TITLE
16:00	Katharine W. Huntington, Karl A. Lang, and Michael D. Turzewski	Interactions of fluvial erosion, climate and tectonics in the Eastern Himalayan syntaxis
16:30	Kristin Morell, Trevor Mearce, and Talat Ahmad	Geomorphology highlights along-strike variations in active strain accumulation in the Northwest Himalaya
16:45	Eric Kirby, Huiping Zhang, and Chen Jie	River profiles and patterns of fluvial incision record deformation in the deep crust along the eastern margin of Tibet
17:15	Gosse, John, Manion, Patrick*, Braschi, Lea, Rybczynski, Natalia, Lakeman, Thomas	Landscape responses to Pliocene-Pleistocene climate changes and lithospheric flexure and the opening of the Northwest Passages, Arctic Canada

POSTER SESSION ES05

Chairs: B. L. Schoenbohm and J. Gosse **Room: ESB Atrium**

Monday, May 29th

Poster No.	AUTHORS	TITLE
P01-ES05	Evelyn Moorhouse*, and Lindsay M. Schoenbohm	Fold segment linkage and uplift rates along the Janauri and Chandigarh anticlines, Northwestern India
P02-ES05	Jeremy Rimando*, Lindsay Schoenbohm, Carlos Costa, Andres Richar	Quaternary deformation at the Andean orogenic front: testing tectonic models of surface faulting at the La Rinconada Fault Zone, West-Central Argentina
P03-ES05	Lindsay M. Schoenbohm, James A. McCarthy, Paul R. Bierman, Dylan Rood, and Alan J. Hidy	Late Quaternary Tectonics, Incision, and Landscape Evolution of the Calchaquí River Catchment, Eastern Cordillera, NW Argentina
P04-ES05	Erin G. Seagren* and Lindsay Schoenbohm	Morphometric and geomorphic evidence of drainage reorganization in intermontane basins of NW Argentina

SUBMITTED ABSTRACTS

ES05-01 Interactions of fluvial erosion, climate and tectonics in the Eastern Himalayan syntaxis

Katharine W. Huntington[1], Karl A. Lang[2], and Michael D. Turzewski[1]

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Abstract

The eastern Himalayan syntaxis of northeastern India and southeastern Tibet is one of the most dynamic regions of Earth's crust, where rapid rock uplift and efficient surface erosion are linked over highly localized spatial scales. Here, the Yarlung-Siang-Brahmaputra River slices a steep knickzone through high Himalayan peaks and a rapidly exhuming crustal-scale antiform—raising questions about the possible role of focused fluvial erosion in initiating and maintaining rapid rock uplift and exhumation. We examine these questions using detrital zircon provenance, detrital zircon and white mica thermochronology, and geomorphological observations and numerical modeling of outburst floods. First, we document the relative timing of two key events: establishment of the river course from Tibet through the syntaxis to the Himalayan foreland, and the onset of rapid exhumation within the syntaxis. Detrital zircon U-Pb, clast provenance and paleocurrent data for Neogene foreland basin (Siwalik Group) deposits indicate that the river course was established by at least ~11 Ma, while thermal modeling of double-dated zircon fission track and white mica $^{40}Ar/^{39}Ar$ cooling ages from the same deposits indicate exhumation rate increased 5-10 fold significantly later at ca. 7-5 Ma. The relative timing suggests tectonics rather than river capture triggered a positive feedback between crustal processes and erosion. Glacial damming and outburst floods may play an important role in halting knickzone migration and focusing erosion in the syntaxis through the Quaternary. We investigate the latter using simulations of a modern dam-break flood through the syntaxis. Simulated peak flow speeds correlate with landslides observed directly after the event, and inundation patterns and flow depths are consistent with the style of deposition observed far downstream, displaying a clear link between flood hydraulics and geomorphic change. These results shed light on the interactions of fluvial erosion and exhumation through the Late Cenozoic tectonic evolution of the syntaxis.

ES05-02 Geomorphology highlights along-strike variations in active strain accumulation in the Northwest Himalaya

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Abstract
The spatial distribution of channel steepness, erosion rate, and physiographic data highlight pronounced along-strike changes in active strain accumulation in the northwest Himalaya. In particular, these data suggest that the mid-crustal ramp of the Main Himalayan Thrust could merge laterally with a recently active portion of the Main Boundary Thrust near longitude ~77º E. This along-strike change in active fault geometry also coincides with the lateral termination of both lesser and greater Himalayan sequences, a significant reduction in total shortening within the wedge, and pronounced variations in the distribution of regional seismicity. Recent activity along extensional structures in the high Himalaya of this same region appears to have led to significant reorganization, modification and capture of the Sutlej River basin, one of the largest Himalayan river systems. Given that the 2015 Gorkha earthquake occurred along a comparable section ~500-km along strike, these new constraints on active fault architecture deduced from geomorphology have implications for how strain is partitioned along seismogenic faults in the northwest Himalaya.

ES05-03 River profiles and patterns of fluvial incision record deformation in the deep crust along the eastern margin of Tibet

Eric Kirby[1], Huiping Zhang[2], and Chen Jie[2]

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Abstract
How the interplay among climate, erosion and tectonics along steep topographic margins of orogenic plateaus is manifest in patterns of rock uplift is strongly modulated by the processes governing crustal thickening. Along the eastern margin of the Tibetan Plateau, a long-standing and vigorous debate persists over whether mountain building occurred largely along upper-crustal faults or was the consequence of distributed thickening in the lower crust. Here, we review this debate and show how surface deformation recorded by geomorphology over millennial timescales (10^4-10^5 yr) can yield insight into the role of flow and thickening in the deep crust along plateau margins. The topographic margin of the Tibetan Plateau north of the Sichuan Basin follows the north-south Min Shan and cuts orthogonally across the structural grain of the Mesozoic West Qinling orogen. The lack of a direct association of topography with upper crustal faults affords an opportunity to evaluate the patterns of differential rock uplift from geomorphology. We employ an empirical calibration of river profile steepness using erosion rate from ^{10}Be concentrations in modern sediment. Application to the channels draining the plateau margin reveals a locus of high (300-500 m/Myr) erosion rate coincident with the Min Shan. New OSL and ^{14}C chronology of fluvial terrace deposits developed across the plateau margin reveals systematic spatial gradients in fluvial incision, with highest incision rates (1000-2000 m/Myr) localized along the axis of the Min Shan. This locus of incision has been sustained through multiple generations of terrace formation for >80ka and is interpreted to reflect sustained differential rock uplift. The wavelength of active rock uplift (~80 km) requires either 1) a deeply buried tip of a blind fault, or 2) thickening in the deep crust. We argue that terrace deformation and associated rock uplift reflects flow and thickening of deep Tibetan crust against the foreland.

ES05-04 Landscape responses to Pliocene-Pleistocene climate changes and lithospheric flexure and the opening of the Northwest Passages, Arctic Canada

Gosse, John[1], Manion, Patrick[1*], Braschi, Lea[1], Rybczynski, Natalia[2], Lakeman, Thomas[3]

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Abstract:

The steepening of the latitudinal thermal gradient during the Pliocene-Pleistocene transition led to significant landscape changes at high latitudes. Here, we report a synthesis of cosmogenic $^{26}Al/^{10}Be$ burial ages, new and previously published bio-, magneto-, and litho-stratigraphy, and numerical modeling of lithospheric flexure associated with loading and incision to reveal the history of the opening of the Northwest Passages. The warm polar Pliocene MAT, e.g. determined to be 19˚C warmer than today's at 78.5˚N, is hypothesized to have thawed permafrost sediment such as the poorly consolidated Eureka Sound Group, and accelerated weathering of exposed bedrock. As climate cooled, sediment fluxes initially increased, particularly during the 3.5 Ma glaciation (recorded as a striated-clast bearing gravel in on Banks Island). The Beaufort Formation (Fm) which once formed a contiguous coastal plain from the Yukon to Axel Heiberg Island, and correlative mature sediments such as the White Channel Gravel and the offshore Iperk Fm, were deposited between approximately 3.8 and 2.7 Ma throughout much of the central and high Arctic. A thick clastic wedge along the western margin formed, and lithospheric flexure associated with loading by the >2 km thick wedge generated a broad low amplitude bulge (elastic thickness 60-90 km) that contributed to the ribbon-like distribution of the remnants of the Beaufort Fm observed on the western islands today. To carve the wide (100s of km), deep (> 400 m), and in places straight-walled straits comprising the Northwest Passages, rivers and then broad ice streams incised through the Beaufort Fm, eroding more than 1.3x more than the modern relief, owing to upward flexure of the passages and erosion of the once widespread Beaufort Fm on land. The incision resulted in upward flexure of the islands that diminishes away from the channels, and together with post-depositional erosion, explains the modern landscape.

ES05-05 Fold segment linkage and uplift rates along the Janauri and Chandigarh anticlines, Northwestern India

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Abstract
The deflection of the Sutlej and Beas rivers in NW India is evidence for fold segment linkage and growth of the Janauri and Chandigarh blind thrust anticlines since the early Quaternary. Constraining fault geometry and slip rates along the anticlines is important for assessing seismic hazards in the densely populated frontal portion of the Himalaya. A digital elevation model (DEM) was used to perform landscape analysis to constrain uplift rates and areas of segment linkage along the anticlines. Basin shape and relief, range-scale factors such as range asymmetry and mountain front sinuosity, and segmentation and steepness of river profiles were assessed. The basin dimensions, range asymmetry and normalized steepness indices of river profiles along the Janauri anticline define six sections with varying uplift rates, with the fastest uplift rate occurring at the northwest end. In contrast, the Chandigarh anticline shows a gradual increase in total uplift from northwest to southeast along its length. The hydrologic and range-scale factors associated with segment linkage and uplift variability identified in this study can be applied to other active blind thrust anticlines to constrain fault geometry, uplift rates, and seismic hazard risk.

ES05-06 Quaternary deformation at the Andean orogenic front: The La Rinconada Fault Zone, West-Central Argentina

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Abstract
The present-day Andean orogenic front is one of the most active thrust zones in the world. It is characterized by heightened crustal seismicity and concentration of almost 90% percent of Quaternary deformation features in Argentina. However, quantitative characterization of many of these Quaternary deformation features is still lacking. The La Rinconada fault is a north-south trending, ~30 kilometer-long, east-dipping reverse fault which can be found southwest of the city proper of San Juan—a city which has been hit by at least 3 large magnitude earthquakes in the past 100 years. It exhibits cumulative scarps (>20 meters) which are counterslope to the eastern flank of the Eastern Precordillera. These scarps displace multiple levels of well-preserved alluvial deposits. Outcrops reveal that the fault is parallel to bedding of east-dipping Neogene sedimentary rocks. The La Rinconada fault also has smaller scarps (~2 meters) which have been linked to the 1952 magnitude (Mw) 6.8 San Juan earthquake on the basis of this fault's proximity to the epicentral location. Paleoseismic trenching at the El Molino site of the La Rinconada fault reveals that the scarp is related to a fault-propagation-fold. Less than a kilometer to the east of the La Rinconada Fault, is a similarly east-dipping subsidiary reverse fault called the Arbol Quemado fault. This fault is only ~2 kilometers long and has a maximum displacement of only 4 meters. Surfaces offset by traces of La Rinconada and Arbol Quemado faults were surveyed with differential GPS and sampled for cosmogenic radionuclide dating to measure long- term slip rates. Assuming that the displacement measured from paleoseismic trenching on most recent scarps of the La Rinconada fault is coseismic (i.e. related to the 1952 San Juan Earthquake), the amount of displacement can be used together with slip rates to determine recurrence intervals of earthquakes of similar magnitude.

ES05-07 Late Quaternary Tectonics, Incision, and Landscape Evolution of the Calchaquí River Catchment, Eastern Cordillera, NW Argentina

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Abstract

In tectonically active regions, channel slopes and erosion rates are controlled by tectonic uplift rate, lithology, and climatically moderated erosion by rivers or glaciers. However, the relative importance of these controls remains elusive. We use soil and desert pavement classification, analysis of longitudinal river profiles, ^{10}Be-derived catchment mean erosion rates, and both paleo-erosion rates and vertical incision rates both inferred from ^{10}Be depth profiles to examine the late Quaternary landscape evolution of the Calchaquí River Catchment (CRC) of the Eastern Cordillera, NW Argentina. The spatial distribution of erosion rates, normalized channel steepness indices, and concavity indices reflect active tectonics and the exposure of resistant lithologies along preexisting structural heterogeneities in the study region. Abundant knickpoints are spatially coincident with tectonic and/or lithologic discontinuities, indicating local base-level control by thrust faulting that is distributed across multiple structures. Catchment mean erosion rates and paleo-erosion rates are similar, suggesting Quaternary climate changes have not influenced erosion rates at ~10 ka time scales. However, field studies document the punctuated abandonment of a sequence of pediment and strath terraces, and disparities between vertical incision rates and catchment mean erosion rates suggest periods of landscape transience, likely reflecting climate cyclicity. Collectively, our data preclude a solely tectonic or climatic driver of landscape evolution in the southern Eastern Cordillera. The long integration time of ^{10}Be catchment mean erosion rates and transitions from detachment-limited to transport-limited channels reduce our capacity to identify landscape transience through the joint analysis of catchment mean erosion rate and river profile morphology, emphasizing the importance of scale and field-based studies in interpretations of tectonic-climate feedback.

ES05-08 Morphometric and geomorphic evidence of drainage reorganization in intermontane basins of NW Argentina

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Abstract

Drainage networks reflect the interaction of climate, surface processes, and tectonics and influence the morphology of orogenic landscapes. Studying the planform evolution of these networks – drainage basin geometry and network topology – can elucidate fundamental information about the topographic evolution of orogens. A variety of morphometric parameters and geomorphic landforms can be used to identify such reorganization. Ranges and intervening basins in NW Argentina are excellent recorders of drainage reorganization due to long-term stable climate, limited glaciation, and low out-of-channel erosion rates. We conducted a systematic analysis of morphometric parameters and geomorphic evidence in two intermontane basins in NW Argentina, Fiambalá and Chaschuil, to identify broad patterns of drainage reorganization. Several morphometric parameters, such as χ and k_{sn}, indicate higher headward erosion rates in the east-draining rivers and a progressive westward migration of the main divide between the two basins. Geomorphic evidence of reorganization includes *in situ* low relief landscapes, capture elbows and associated knickpoints, hairpin turns, and wind gaps. Together, this evidence suggests the intervening range, Sierra de las Planchadas, is being dissected as N-S drainage is diverted east into Fiambalá. These broad reorganization patterns are discussed in the context of local tectonics, lithology, and climate.