The Gulf of Alaska Margin: Potential Focus Site for GeoPRISMS SCD

Lindsay L. Worthington (lindsay@ig.utexas.edu)[1,3], Sean P.S. Gulick (sean@ig.utexas.edu)[1],
John M. Jaeger (jaeger@ufl.edu)[2]
[1]Institute for Geophysics, Jackson School of Geosciences, University of Texas, [2]Department of Geological Sciences, University of Florida, [3]Department of Geology and Geophysics, Texas A&M University

SCD Themes Addressed: 4.1 (Size, location and frequency of subduction zone EQs)
4.2 (Evolution of plate boundary deformation in space and time)
4.7 (Climate/surface/tectonic feedbacks)

Overview - Convergent glaciated continental margins are premier locations on earth where the interaction of tectonics, orogenic and surficial processes, and continental margin sedimentation can be studied in unison. Field studies strongly suggest that subduction zone and orogenic dynamics are influenced by surficial processes and the sediment delivery rates to subduction zones [*Lamb and Davis*, 2003]. Climate, in turn, directly affects precipitation rates and types, thus controlling the rate and timing of sediment production, which has globally increased during the Neogene [*Zhang et al.*, 2001], potential altering subduction zone dynamics. Southeastern Alaska is one such setting where the deformational and depositional products of this interplay between tectonics and climate are recorded at exceptionally high temporal resolution.

The Gulf of Alaska margin is notable for the transition from 'normal' Pacific plate (PP) subduction beneath North America along the Aleutian Trench to flat-slab subduction and oblique collision of the Yakutat (YAK) microplate with North America (NA) beneath southeastern Alaska. The YAK-NA plate interface extends beneath Prince William Sound and the 1964 Mw 9.2 earthquake epicenter was sourced on this plate boundary, jumping to the adjacent Aleutian megathrust coseismically [e.g., *Shennan et al.*, 2009]; this event illuminates the potential for this transitional tectonic system to enhance geohazards. YAK-NA convergence has also resulted in the uplift of the coastal St. Elias Mountains, which are the most extensively glaciated coastal mountain belt on Earth and are home to North America's second and third tallest peaks, Mt. Logan and Mt. St. Elias. Focusing interdisciplinary GeoPRISMS efforts on the complex tectonic relationships, major earthquake potential and strong glacial-climate signal in the Gulf of Alaska margin will improve understanding of plate boundary deformation, feedback between surface and tectonic processes and the role of large earthquakes in the subduction process.

a) Subduction zone earthquakes: Seismic hazard/deformation - Based on modern GPS velocities [*Elliott et al.*, 2010] and plate/microplate reconstructions [*Pavlis et al.*, 2004], the fold-thrust belt of the St. Elias orogen has absorbed between 240 and 300 km of convergence during the last 6 Myr. However, attempts to restore the shortening from surface geology and offshore seismic data yield shortening estimates for the last 6 Myr of as little as 36 km [*Wallace*, 2008] to as much as 82 km [*Meigs et al.*, 2008], with <17% of shortening accommodated in the offshore frontal thrusts [*Worthington et al.*, in press]. As such, significant shortening remains unaccounted for. Movement on the décollement at depth during large earthquakes likely accommodates a significant percentage of YAK-NA convergence that is not expressed in surface faults. Eberhart-Phillips [2006] indicate that the 1964 (M9.2) earthquake in Prince William Sound was caused in part by movement on the YAK-NA plate interface. Paleoseismic studies by Shennan [2009] and Shennan et al. [2009] provide evidence for recurring seismic events (~1500 yrs BP and ~900 yrs BP) with asperities covering the St. Elias margin from Yakutat Bay to Prince William Sound.

These events may have been greater in magnitude than the 1964 event and indicate potential for more great events in the future.

b) Plate boundary deformation and evolution - Geophysical studies focusing on the Yakutat microplate show that it ranges from 15-35 km thick and is underthrusting the North American plate from the St. Elias Mountains to the Alaska Range (~500 km), tapering in the direction of convergence. The thickest YAK crust, ~35 km, enters the St. Elias orogen north of Malaspina Glacier, where the orogen displays its highest relief and highest long-term exhumation rates [*Spotila and Berger*, 2010]. Given proposed limits on subductibility of thickened oceanic lithosphere, it is likely that Yakutat microplate subduction in southern Alaska will eventually cease, causing plate boundary reorganization [*Gulick et al.*, 2007]. This reorganization will likely include accretion of unsubducted Yakutat material and a massive underplating event of the flat-slab segment beneath southern Alaska, similar to the underplating event associated with the Laramide uplift in western North America. As such, flat-slab subduction and collision of the Yakutat (YAK) microplate in southern Alaska may characterize the most recent iteration in the process of terrane accretion that has built the tectonic assemblage of the Canada-Alaska Cordillera since the Mesozoic as well as provide a modern analog of Laramide-style orogeny.

c) Climate/surface/tectonic feedbacks - Glacial advance-retreat cycles provide the primary climate forcing that may affect structural evolution of the Gulf of Alaska margin. Recent thermochronologic studies in the area provide evidence for intensified exhumation and uplift onshore in response to focused erosion by glaciers [*Berger et al.*, 2008; *Enkelmann et al.*, 2009]; offshore drilling shows that terrigenous flux throughout the Gulf doubles (or more) at ~1 Ma [*Lagoe et al.*, 1993; *Rea and Snoeckx*, 1995]. Combined with the offshore sedimentary record, these data make a strong case for climatic influence on the evolving deformation of the orogen [e.g., *Berger et al.*, 2008; *Worthington et al.*, in press]. A five-fold increase in sediment delivery to the Aleutian Trench during the Pleistocene [*Piper et al.*, 1973] may have altered subduction zone dynamics through significant along strike and temporal variations in the incoming sedimentary section as well as sediment loading within forearc basins [e.g., *Simpson*, 2010].

d) Synergistic activities- Geo PRISMS focus in the Gulf of Alaska margin can address questions illuminated by recent results from the NSF-Continental Dynamics St. Elias Erosion and Tectonics Project (STEEP) and the upcoming Shumagin Gap seismic study and build upon these datasets. Using the Gulf of Alaska as a GeoPRISMS focus site can also take advantage of the existing seismic (UAF-AEIC) and geodetic networks (UAF; EarthScope-PBO) and current active monitoring of volcanic hazards by the USGS-AVO. Future potential synergistic efforts include the move of the USArray seismic network to Alaska in 2012. Additionally, GeoPRISM studies in the Gulf of Alaska will be uniquely situated to take advantage of IODP drilling results constraining sedimentary inputs and changes in timing of sediment delivery to the Aleutian subduction zone, as both shallow and deep marine targets in the Gulf are tentatively scheduled for drilling in 2012.

References

Berger, A. L., et al. (2008), Quaternary tectonic response to intensified glacial erosion in an orogenic wedge, *Nature Geosciences*, *1*(10), 793-799.

Eberhart-Phillips, D., et al. (2006), Imaging the transition from Aleutian Subduction to Yakutat collision in central Alaska, with local earthquakes and active source data, *Journal of Geophysical Research*, *111*(B11303), 1-31.

Elliott, J. L., et al. (2010), Tectonic block motion and glacial isostatic adjustment in southeast Alaska and adjacent Canada constrained by GPS measurements, *Journal of Geophysical Research*, *115*.

Enkelmann, E., et al. (2009), Intense localized rock uplift and erosion in the St. Elias orogen of Alaska, *Nature Geosciences*, *2*.

Gulick, S. P. S., et al. (2007), Geophysical insights into the Transition Fault debate; propagating strike slip in response to stalling Yakutat Block subduction in the Gulf of Alaska, in *Geology [Boulder]*, edited, pp. 763-766, Geological Society of America (GSA) : Boulder, CO, United States, United States.

Lagoe, M. B., et al. (1993), Timing of late Cenozoic tidewater glaciation in the far North Pacific, in *Geological Society of America Bulletin*, edited, pp. 1542-1560, Geological Society of America (GSA) : Boulder, CO, United States, United States.

Lamb, S., and P. Davis (2003), Cenozoic climate change as a possible cause for the rise of the Andes, *Nature*, *425*(6960), 792-797.

Meigs, A., et al. (2008), Crustal scale structural architecture, shortening, and exhumation of an active, eroding orogenic wedge (Chugach-St Elias Range, Southern Alaska), in *Tectonics*, edited, American Geophysical Union : Washington, DC, United States, United States.

Pavlis, T. L., et al. (2004), Tectonic processes during oblique collision: Insights from the St. Elias orogen, northern North American Cordillera, *Tectonics*, *23*(TC3001).

Piper, D. J. W., et al. (1973), Late Quaternary sedimentation in the active eastern Aleutian Trench, *Geology*, *1*(1), 19-22.

Rea, D. K., and H. Snoeckx (1995), Sediment fluxes in the Gulf of Alaska; paleoceanographic record from Site 887 on the Patton-Murray Seamount Platform, in *Proceedings of the Ocean Drilling Program, Scientific Results*, edited, pp. 247-256, Texas A & M University, Ocean Drilling Program : College Station, TX, United States, United States.

Shennan, I. (2009), Late Quaternary sea-level changes and palaeoseismology of the Bering Glacier region, Alaska, *Quaternary Science Reviews*, *28*(17-18), 1762-1773.

Shennan, I., et al. (2009), Multi-segment earthquakes and tsunami potential of the Aleutian megathrust, *Quaternary Science Reviews*, *28*(1-2), 7-13.

Simpson, G. D. H. (2010), Formation of accretionary prisms influenced by sediment subduction and supplied by sediments from adjacent continents, *Geology*, *38*(2), 131-134.

Spotila, J. A., and A. L. Berger (2010), Exhumation at orogenic indentor corners under long-term glacial conditions: Example of the St. Elias orogen, southern Alaska, *Tectonophysics*, *490*(3-4), 241-256.

Wallace, W. K. (2008), Yakataga Fold-and-Thrust Belt: Structural Geometry and Tectonic Implications of a Small Continental Collision Zone, in *Active Tectonics and Seismic Potential of Alaska*, edited by J. T. Freymueller, et al., pp. 237-256, American Geophysical Union, Washingtion, DC.

Worthington, L. L., et al. (in press), Coupled Stratigraphic and Structural Evolution of a Glaciated Orogenic Wedge, offshore St. Elias Orogen, Alaska, *Tectonics*.

Zhang, P., et al. (2001), Increased sedimentation rates and grain sizes 2-4 Myr ago due to the influence of climate change on erosion rates, Nature, 410(6831), 891-897.