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Paleoseismology of the Denali fault at the Nenana River

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INTRODUCTION

The Denali fault system is a major, dextral strike-slip fault in south-central Alaska that accommodates deformation resulting from the stresses imposed by subduction of the Pacific Plate beneath the North America plate. This fault is geologically similar to the more widely known San Andreas Fault in California (Fuis and Wald, 2003), but has seen very little detailed study. The lack of seismic hazard analysis on the Denali fault system is due to its rural setting containing a higher population density of moose than people. I documented an area that shows clear evidence of a recent, but prehistoric, large-magnitude seismic event on the Denali fault in the central Alaska Range near the Nenana River. By working out the sequence of geologic events, I will be able to constrain the timing of the most recent earthquake on this section of the Denali fault, which will provide key insights into future earthquake hazards.

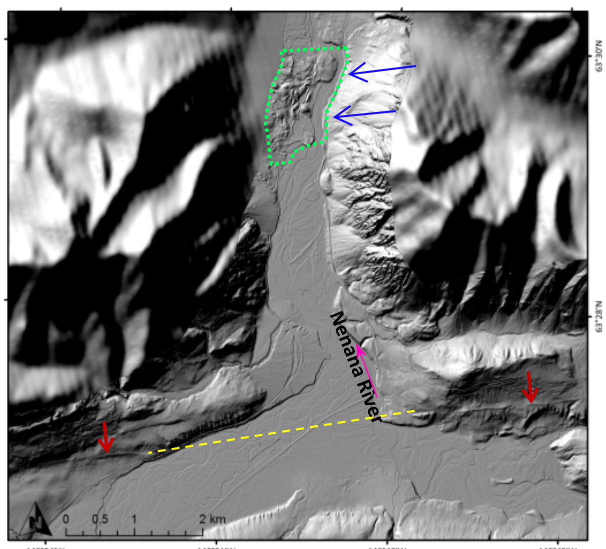

Figure 1: Shaded relief topographic map of the study area: red – visible fault scarp; yellow – projected fault trajectory; green – outline of landslide deposit; blue – landslide source and direction of flow; pink – river flow direction.

Faults that produce large earthquakes typically produce a rupture in the surface of the earth that can be preserved in the landscape as evidence of that earthquake for hundreds to thousands of years, and are generally referred to as fault scarps. On both sides of the George Parks Highway there are fault scarps along the trace of the Denali fault that demonstrate the occurrence of large prehistoric earthquakes (Fig. 1). Between these two exposures there is a 3 km long gap where no fault scarp is visible. It is my hypothesis that the last fault rupture along this section of the Denali fault triggered a massive landslide that dammed the Nenana River causing a lake to form. This lake could have remained long enough to deposit sediment that may have obscured the fault scarp produced by the most recent earthquake.

METHODOLOGY & OBSERVATIONS

I initiated work in my research area on July 7th, and over the next six weeks I spent a total of 21 days working in the area. I began my investigations by exploring for possible paleolake sediment through the use of a soil auger. After discovering a thick section of fluvial deposits located near the fault and on a high bench on the east side of the Nenana River, I chose to focus my studies on exposing these fluvial deposits to see if they contained a record of prehistoric earthquakes on the Denali fault. The site chosen, later dubbed 'Dead Mouse', happened to be located in the vicinity of the Denali fault scarp immediately to the east of the Nenana River. Further augering perpendicular to the projection of the Denali fault revealed 2-3 m of fine-grained sediment above fluvial gravels. These fluvial gravels represent the time when the active river channel was at that elevation whereas the overlying fine-grained sediments represents a lower energy depositional environment, likely occurring only during high water or flood events after the river channel was cut to a deeper depth. These observations made this site a compelling location to employ standard techniques for paleoearthquake investigations. With the help of fellow UK students, I excavated my first trench, DM1, to initial dimensions of 4m x 1m x 2m (L x W x D). This exposed fine grained sediment units composed of alternating layers of thinly laminated fine and medium grained sands below an organic mat. This unit as a whole varies in thickness from 10-20 cm. Below are organic deposits containing silty sands roughly 4-8 cm thick. Each of these layers is capped by layers of woody debris approximately 3-6 cm thick. The center of DM1 uncovered a fissure-like rubble zone with normal displacement that is capped by one of the buried woody layers, providing an ideal target for radiocarbon dating to constrain the timing of this past earthquake event. After finding the offset existed at two of the augering holes suggested, I extended DM1 to the north and the south in an effort to find the youngest event using the organic horizon of the offset as a depth guide. The final dimensions of DM1 were approximately 12m x 1m x 2.5m (L x W x D). When following the organic horizon to the south, no younger events were exposed. However, another deformation zone was exposed and had the same woody horizon which thinned to the south and suggested the same event. To the north the woody horizon also appears to constrain the youngest event. Below the woody horizon and to the north, there are deformational events that were unrelated to the youngest. Digging to the north also revealed a truncation of the woody horizon after steadily thickening to the north. After analyzing the truncation and the thickening trend we interpreted that the thickness of the woody horizon was due to a tree falling during the last deformational event.

The findings in DM1 warranted exploratory augering to the northeast of DM1 and perpendicular to an en echelon fissure that was evident on the surface in LiDAR imagery. These exploratory augering holes also revealed an offset in the fluvial terrace gravels. DM2 is the name of the second trench excavated along strike of the augering holes and perpendicular to the en echelon fissure. DM2 was approximately 3m x 1m x 2m and exposed all fine grained sediment with the same alternating layers of thinly laminated fine and medium grained sands. There were also inter-bedded wavy organic laminations and silt beds that become more prevalent at depth. Furthermore, DM2 exposed a series of north-dipping reverse faults and south-dipping normal faults suggesting multiple deformational events. The southern offset in DM2 is a detachment or fissure-like structure that truncated two sediment layers and was the youngest offset. In the middle of the offset there is evidence of uplift in the form of a large boulder approximately 0.5m in diameter. This boulder also, although displaying significant rounding, had a flat surface with sharp edges on the northern side suggesting an older deformational event unrelated to the fissure. The southern end wall exposed the truncated sediment layers on the southern end of the detachment thus completing the fissure-like structure. Upon further investigation of the structure as a whole and the sediments lying above and below the youngest offset, DM2 now drew a parallel to DM1. The detachment in DM2 offset the same layers in DM1. The fallen tree interpretation in DM1 explains the absence of a thick buried tree layer in DM2 as the distance between the two is assumed to be too great to have deposited the same amount of organic material in both locations. Fault displacements in both DM1 and DM2 trenches are well-constrained by organic-bearing horizons. Preparation of the radiocarbon samples from these horizons is in progress and results are expected by November 2012.

PRELIMINARY RESULTS & ONGOING WORK

When arriving at my site, I had intended log one or more trenches and then move on to cross check my sediment elevations found at Dead Mouse to the elevation of the landslide. I also intended to date the lichen growing on the landslide boulders to draw a parallel with the radiocarbon samples collected at Dead Mouse. In addition, I was planning on exploring the modern river valley to confirm my hypothesized projection across the floodplain. I chose to pass on the opportunity to explore the landslide and the floodplain because once Dead Mouse was excavated and we confirmed the fault was there, the thickness of fine-grained sediment and abundant dateable material illustrated the significant potential for this site to expand the paleoseismic record of the Denali fault by itself. My observations have led me to the conclusion that there were a total of 4 possibly 5 separate prehistoric earthquakes exposed in DM1 and DM2. This preliminary interpretation proves this site to be a significantly active section of the Denali Fault in recent geologic history. And, even though we were unable to establish a link between the earthquakes and the landslide, our radiocarbon results may allow a tentative correlation of these events. At this time I am completing photographic logs illustrating the sedimentary layers, faults, and earthquake deformation in order to better display the multiple deformational events. These photo logs will include projections of the sediment layer contacts and the traces of each of the earthquake offsets in order to visually show the stratigraphy and deformational events.

CONCLUSION

Using the high-resolution topographic data available for my study area, I discovered that the Dead Mouse site lies ~10 m above my estimate of the highest level that could have been flooded by a lake dammed behind landslide a few kilometers downstream. Located high above the modern river as well, with no indication of historic floods occurring as high as this site, it is unclear how these sediments were deposited at this site. One possibility is that my excavation did not cross where the most recent earthquake ruptured, and that the exposed earthquake evidence is for older earthquakes on the Denali fault. Our interpretation of the emplacement of these fine-grained sediments suggests significant flood events during the recent history of the Nenana River. Are these significant flood events related to the landslide or are they simply seasonal flooding events due to snowmelt/glacier runoff? Additional mapping of young geologic features is needed to understand the rate of river down-cutting, if additional, older, landslide deposits are present, or other features that may constrain the relationship between prehistoric earthquakes and the evolution of the Nenana River. Future plans by my mentor's research group includes expanding the excavations at the Dead Mouse site to determine if more earthquake-related deformation exists and to better define the oldest earthquakes.

These efforts are required to better represent earthquake hazards for the Denali fault and south-central Alaska

WORKS CITED

Fuis, G. S., and Wald, L. A., 2003, Rupture in south-central Alaska – the Denali fault earthquake of 2002: USGS Fact Sheet 014-03, http://pubs.usgs.gov/fs/2003/fs014-03.