Final Technical Report for USGS/NEHRP #07HQGR0018 (UO #238810)

Project Title: Paleoseismic and Structural Characterization of Active Thrust Faults in the Northern Foothills Fold-Thrust Belt, Alaska Range, Alaska

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Project Period: December 1, 2006 – November 30, 2008

SUMMARY

This project was designed to establish paleoearthquake chronologies and slip rates for three thrust faults in the northern boundary of the central Alaska Range (Figure 1) and to map and profile structural markers that will help constrain the subsurface geometry of these and related faults. Our work provides the first paleoearthquake constraints in the Northern Foothills Fold-Thrust Belt of north central Alaska Range.

This report presents preliminary interpretations of our paleoearthquake timing, tentative slip rate results, observations of where scarps in mid-late Pleistocene deposits project into latest Pleistocene and Holocene(?) deposits but do not visibly disturb these younger deposits. A subsequent USGS/NEHRP grant was submitted and awarded to fund additional field work in 2008 and 2009 and to provide C14 and in-situ terrestial cosmogenic nuclide ages for critical units and surfaces identified in this project.

This grant provided major support for graduate student Sean Bemis, partial support of graduate student Ben Mackey, and support for several undergraduate field assistants.

While all of the faults we studied are confirmed to be active, the very tentative slip rates and recurrence intervals associated with these faults are quite low suggesting that they are not very significant sources of hazard and that the geomorphic preservation of structures in this area is quite good, so that relatively low activity faults are well preserved on the landscape.

Part 1: Healy and Healy Creek faults

We have excavated three trenches on the Healy fault scarp and one across the Healy Creek fault (Figure 2). The Healy fault was trenched where it offsets ~22-28 ka outwash terraces (Figure 3). A now-drained beaver pond enabled the accumulation of several meters of fine-grained deposits on the footwall of this fault. The most recent earthquake occurred between ~1500 and ~600 yr BP and the inferred slip rate based on reconstruction of the ~22-28 ka outwash terrace surface is ~0.3 mm/yr (Figure 4). Additional dates will yield the ages of earlier earthquakes that contribute to the terrace offset and allow calculation of a recurrence interval.

The Healy Creek fault was trenched where it offsets outwash terraces of unknown age (Figure 5), but likely to be less than 100 ka. While we are still working on fully interpreting the trench, it appears that we will not be able to date individual earthquakes since the scarp is largely formed by folding at the surface and there are few upwardly terminated structures or wedges that can be attributed to individual earthquake events. While the scarp is very fresh appearing, based on hand dug trenches, it does not significantly offset channels through the fault scarp that are inferred to be greater in age than the lower ~22-28 ka outwash terraces. In addition it does not offset the ~22-28 ka terraces that cross its projection to the west side of the Nenana River (Figure 3). Similarly the Healy fault has obvious offsets across the young ~22-28 ka outwash terraces but does not significantly offset much older

moraines immediately to the west. Either both of these faults are very short and simply don't extend to these older and younger units or are only active for short periods of time, with the Healy Creek fault active prior to the ~22-28 ka outwash terraces and the Healy subsequently. Additional dating of samples and analysis of topographic profiles collected for this project will help clarify these possibilities.

Part 2: Northern Foothills fault

We mapped the Northern Foothills thrust and the Quaternary deposits and surfaces it cuts or is projected to cut along a 30 km stretch where the Nenana River crosses the structure (Figure 6). The character changes significantly across the river, probably due to the difference in age in Quaternary surfaces and units exposed at the surface. We mapped all of the terraces and made topographic profiles in key places to locate and characterize the fault. We excavated two small hand dug trenches across the most promising site we found (Figure 7). Based on the preliminary evidence (in the caption of Figure 7; additional age dates are in process) the Northern Foothills thrust appears to have a very low rate of slip and does not appear to have produced an earthquake in at least 26 ka. This would explain its very poor expression in units from ~22-28 ka where the Nenana River leaves the range. Based on these preliminary findings we speculate that this fault either has a very low long term slip rate and or has recently become less active, perhaps as the Healy and Healy Creek and other reverse faults within the range have become more active. In either case, it preservation and expression is quite remarkable given its apparently low rate of activity. Additional dating underway will resolve these issues.

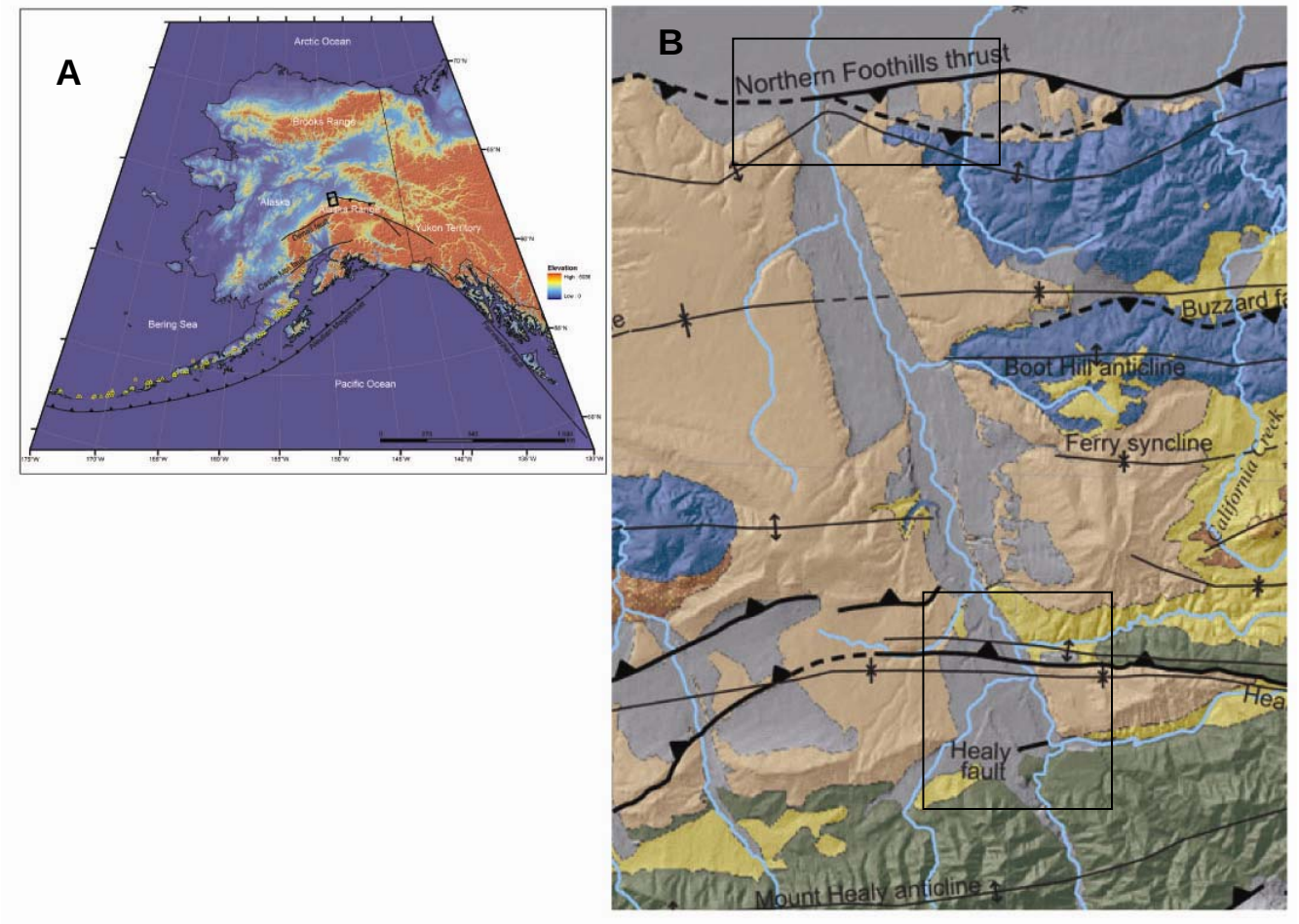

Figure 1. (A) Digital elevation model of Alaska with major geographic features and active structures labeled. The small black box indicates the location of (B). (B) is a portion of the geologic map of the northern foothills of the Alaska Range from Bemis and Wallace (2007) overlain on a shaded relief digital elevation model. The northern 50 kms of the Alaska Range is underlain by east-west striking reverse faults and folds that are inferred to extend down to a detachment surface that daylights at the northern edge of the range as the Northern Foothills thrust. Boxes indicate the locations of figures later in this report that discuss the Healy and the Northern Foothills thrust, respectively.

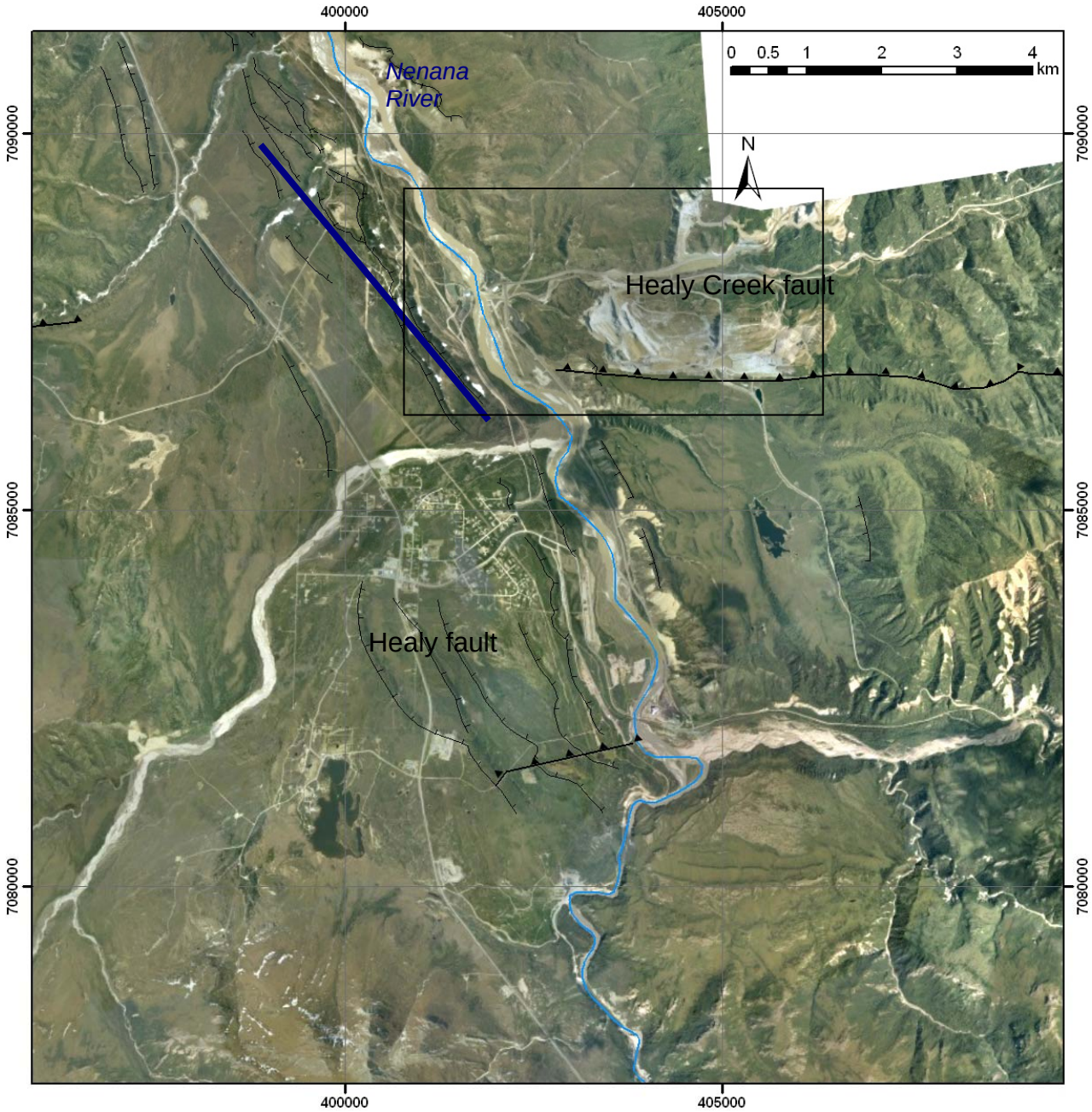

Figure 2. Ortho-imagery of the Healy area, showing the position of the Healy and Healy Creek faults relative to the community and the sequence of fluvial terraces (shown by the NNW-trending hachured lines) preserved above the Nenana River. The terraces (correlated with an ~22-28 ka glacial advance) are offset by the Healy fault. By contrast, immediately west of the Nenana River the projection of the Healy Creek fault shows no indication of a fault scarp although older terraces on the east side of the Nenana River are offset up to tens of meters. Furthermore, a differential GPS survey of a transect (shown by the bold blue line) across the projection of the Healy Creek fault found no indication of folding or tilting of the terraces associated with this fault. Similarly, older moraines west of the Healy fault show little more (if any) offset than the young fluvial terraces. Either the faults are extremely discontinuous spatially or temporally.

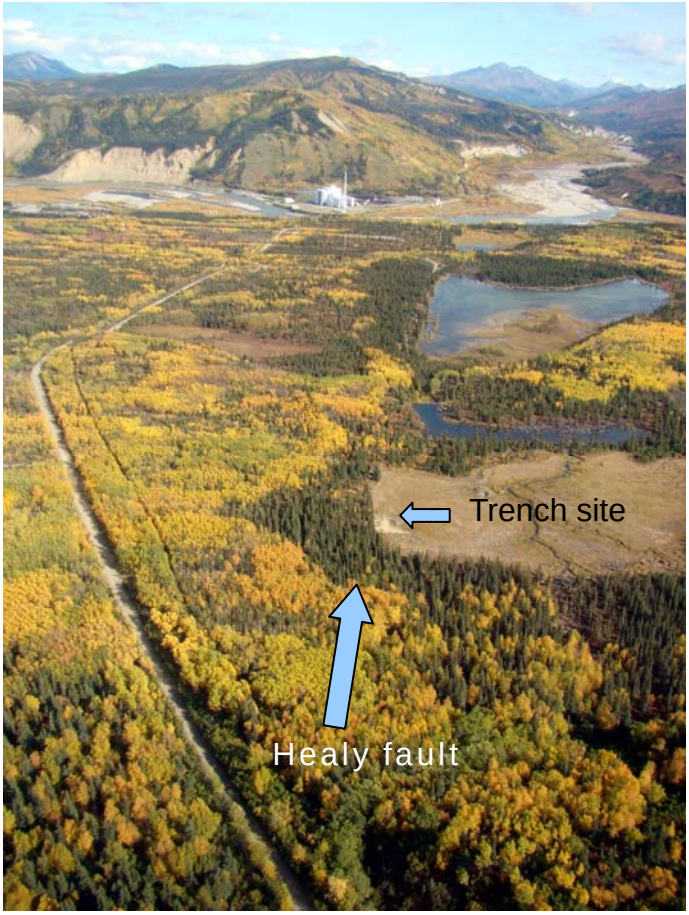

Figure 3. Photograph looking east along the trace of the Healy fault, showing the trench site on the margin of a drained beaver pond, and active beaver ponds on successively lower terraces towards the Nenana River. The fault may extend up the tributary to the east but there are no terraces or other Quaternary surfaces to assess it extent. The large white building on the river in the back of the photo is a coal-fired power plant on the hanging-wall of the Healy fault.

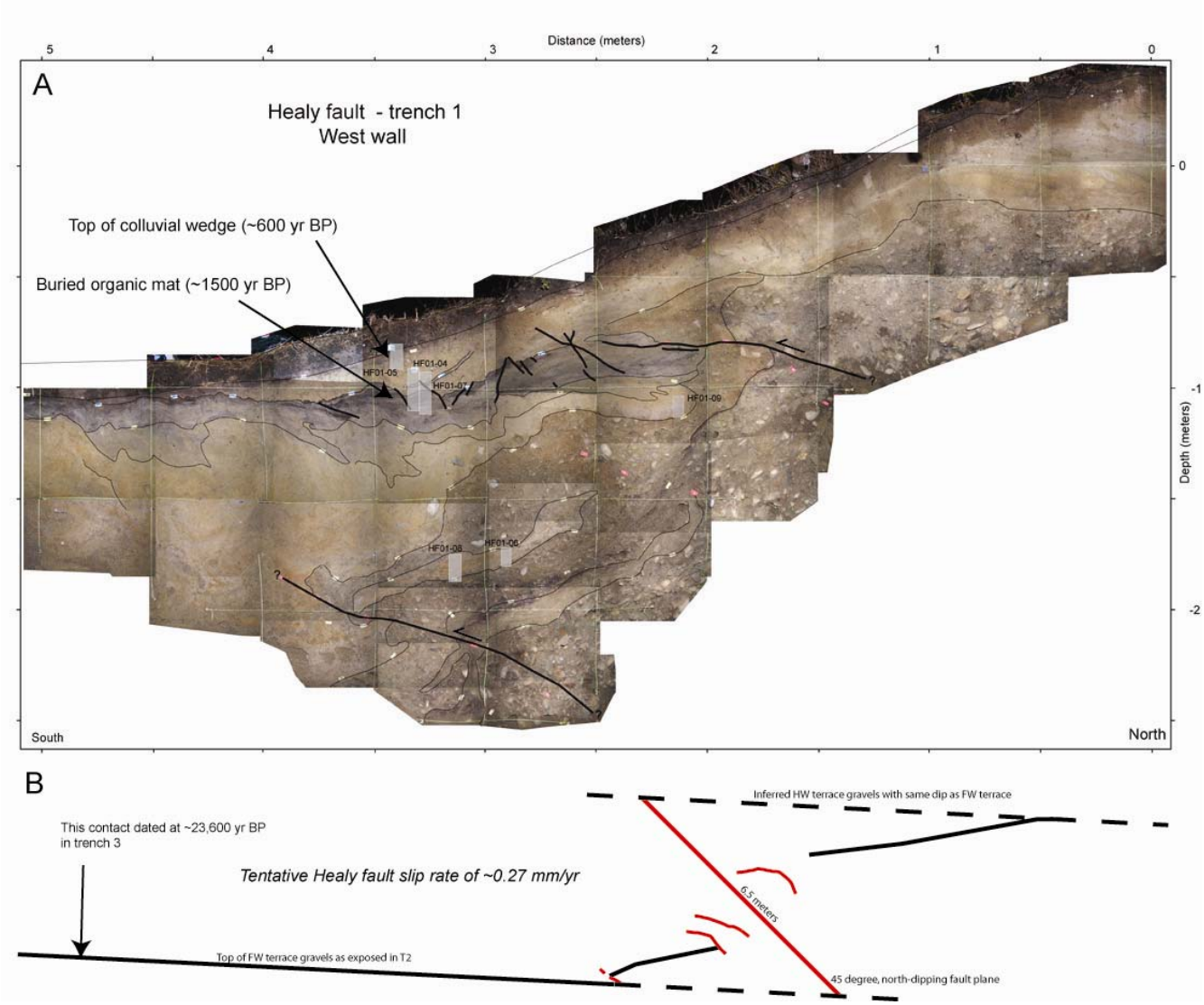

Figure 4. (A) Photomosaic and simplified log of our first Healy fault trench, illustrating the most recent event on the Healy fault. This thrust event offsets colluvial stratigraphy on the pre-existing scarp and buries an organic mat developed on silty pond sediments. Dates from the organic mat and the top of the overlying colluvial wedge constrain this earthquake between ~1500 and ~600 yr BP. We have identified additional samples for C14 that should improve the age constraints on this event. (B) Scaled schematic diagram of the constraints on the Healy fault slip rate determined in our Healy fault trench 2. The solid black lines depict the contact of the top of the terrace gravels with the overlying loess and pond sediments, and the dashed black lines are projections of these contacts for calculating the slip rate. The short red lines are the actual mapped fault traces in trench 2 and the thick red line is the inferred fault plane at depth based on the average dip of the down-dip ends of the mapped faults, and the inferred dip from Bemis and Wallace (2007). Ongoing C14 sample analysis will improve our age control and allow a formal calculation of the slip rate and error.

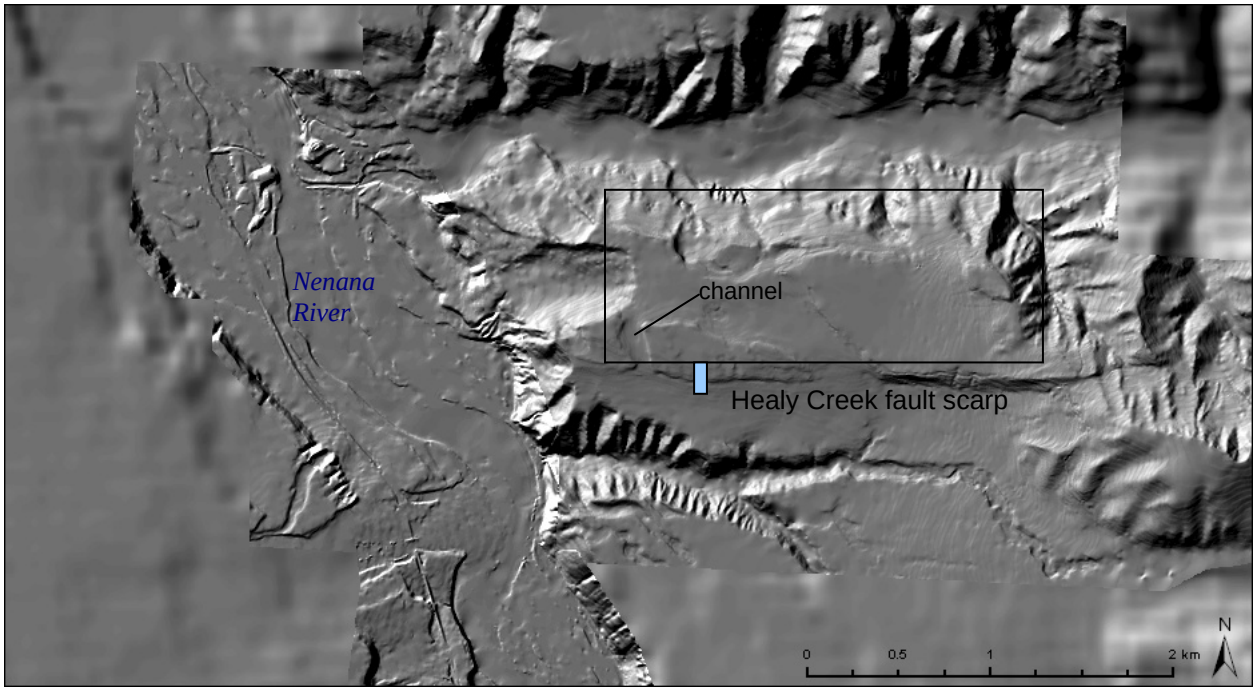

Figure 5. Shaded-relief digital elevation model (DEM) view of the Healy Creek fault scarp. Location of this figure shown on Figure 2. This view is a composite of two high-resolution topographic datasets we acquired from the Usibelli Coal Mine and the best-available, 30 m resolution DEMs from the USGS National Elevation Dataset. Particularly useful is the pre-mining topography because the area within the black outline has been dramatically modified by their strip-mining operations. The blue box shows the location of a 40 m long benched trench we excavated across the Healy Creek fault scarp. The exposed deposits were dominantly loose fluvial gravels which contain numerous shear zones, but these zones could not be tied to any individual paleoearthquake events. The age on the gravel is currently unknown but based on its position above the ~22-28 ka glacial outwash terraces, we infer its age is 10s to 100s of thousands years older. Two small hand-dug trenches were dug across <1 m scarps in the small channel incised across the scarp. These trenches encountered permafrost within 0.5 m of the surface; only one trench was dry enough that we could excavate an additional 0.5 m into the frozen ground. The deposits encountered in this abandoned channel floor were dominantly peat interlayered with thin silt horizons. A plant macrofossil from ~0.75 m depth produced an age of ~4,000 yr BP. This channel formed before that time and most likely significantly before then due to an unknown additional thickness of peat below the sample. Also, in cross-section, the small scarps we excavated across are composed of numerous slope-parallel imbricate shears in the peat, suggesting that the scarps are a result of slope processes as opposed to any fault-related activity. If this channel across the fault formed during a glacial advance prior to the lower ~22-28 ka glacial advance, there has not been significant offset across this fault in that time.

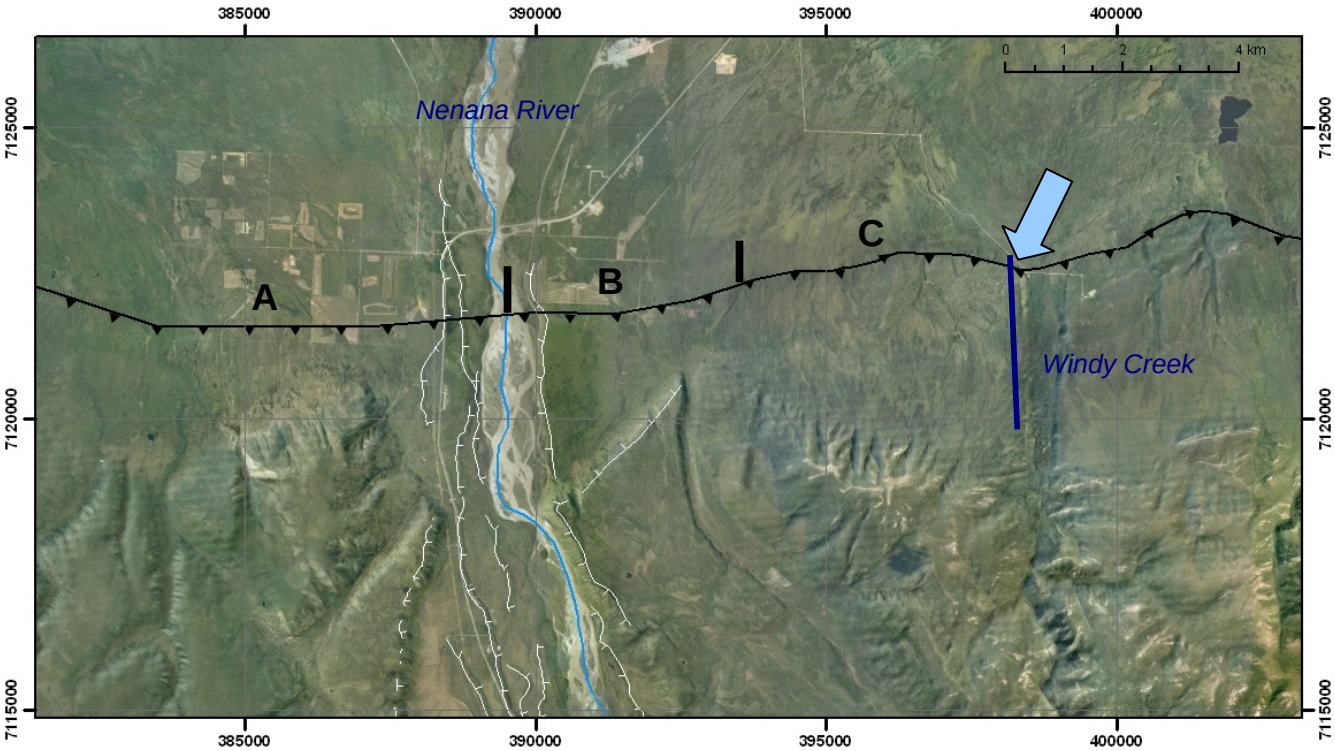

Figure 6. Ortho-imagery (obtained from www.alaskamapped.org) of the mapped and inferred trace of the Northern Foothills thrust. White hachured lines are fluvial terrace risers. Segment A of the fault is inferred and has no obvious surface scarps on the fluvial terraces of the ~22-28 ka and younger glacial advances. Segment B is on an ~60 ka outwash terrace and is cut by a 2-3 meter scarp only visible in the field. Segment C is distinguished by a prominent lineament visible on aerial photos and imagery and very large, complex fault scarp in the field. Segment C offsets and exposes surficial deposits of an uncertain age, but they are clearly much older than the outwash terraces near the Nenana River. These deposits are coalescing alluvial deposits shed from the hills immediately to the south, and form a discrete uplifted surface on the hanging-wall of the Northern Foothills thrust. A differential GPS profile along the thick blue line on this uplifted surface is shown in Figure 7(A). We excavated two small trenches across the base of the scarp at the north end of the GPS profile (location shown by light blue arrow), and an example and interpretation of one of these trenches is shown in Figure 7(B).

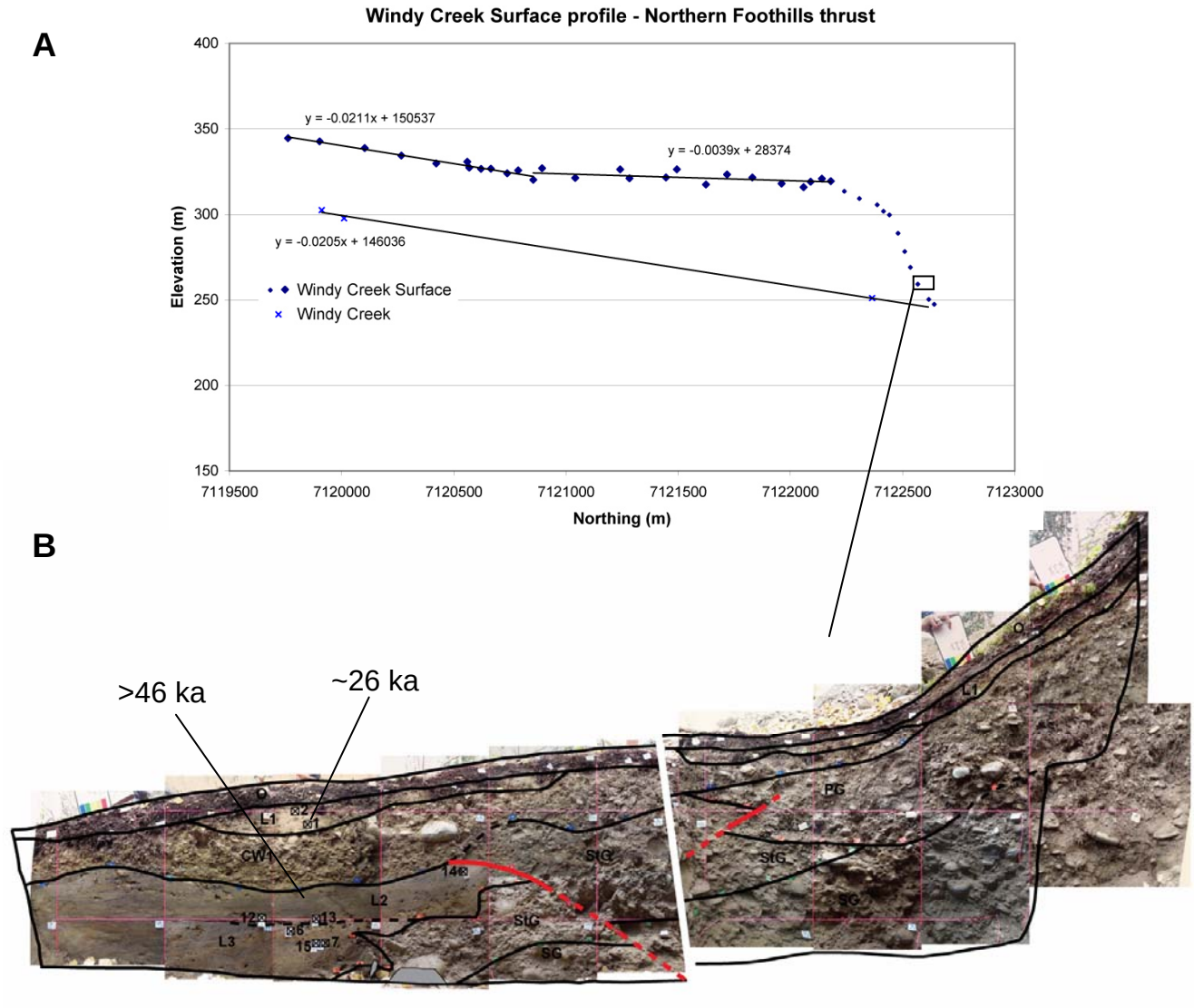

Figure 7. (A) Differential GPS topographic profile along a surface uplifted and deformed in the hanging-wall of the north-vergent Northern Foothills thrust. Two linear segments of this profile show a distinct hinge between the southern, stream-parallel surface and the northern, backtilted surface. We interpret this to represent a planar fault at depth beneath the southern segment, which in the shallow subsurface to the north becomes listric, causing the backtilting of the surface adjacent to the scarp (i.e. Amos et al., 2007). The small box at the north end of the profile indications the location on the profile of the trench shown in (B). The trench is reversed from the orientation of the topographic profile, so that north is to the left on the trench. On the footwall of the scarp, a thick loess deposit is buried by a colluvial wedge, which is in turn buried by a discontinuous thin loess deposit and the modern organic mat. A couple small faults disturb stratigraphy related to the lower loess and adjacent gravel deposits, but there are no major fault offsets present, and the surface expression of the fault appears to largely be a result of folding from distributed deformation in the unconsolidated gravels in the near surface. All C14 samples from the buried loess came out >45 ka, and are likely infinite in age. One sample from the base of the upper loess is ~26 ka, constraining the inferred paleoearthquake that produced the colluvial wedge to be greater than ~26 ka.

References

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