Supplemental File S1

Descriptions of Young or Active Fault Scarps in and Around the Susitna Basin, Alaska

This file shows detailed maps and scarp profiles for newly identified young or active fault scarps described in the main text. All fault locations are shown on Figure 3 of the main manuscript, which is repeated in this file without annotation unrelated to this supplement. Each page of this Supplemental File shows a digital elevation model image of the fault scarp, identifies the fault scarp, and shows some vertical profiles. Brief descriptions of each fault scarp are in the main text, and longer ones are below. Faults are listed in north-to-south order.

1) Bunco Lake Fault Scarp

The northeast trending Bunco Lake fault is located at the northeastern end of the Susitna basin. The fault has a curviplanar fault scarp that offsets (vertical separation of 6-14 m, north-side-down) the postglacial drumlinoid surface and ground moraine. The surface trace is well-defined for ~10 km, and the fault may extend another 10 km to the southwest. The curvilinear surface trace implies a dip-slip fault, and we suggest it is likely a northwest-vergent thrust fault.

2) Larsen Lake Fault Scarp

The north-northwest trending Larsen Lake fault is located ~10 km east-northeast of the town of Talkeetna. The north end of the fault has a well-defined scarp for about 1 km that

cuts across multiple channels of an abandoned braid plain of the Talkeetna River. The fault is weakly defined in bedrock, where it extends almost three kilometers to the south, and then the fault trace intersects Larsen Lake. The vertical separation of the offset braid plain is about 5 meters east-side-up. The offset braid plain surface is pitted with glacial kettles, indicating that the related ancient stream flowed over buried, stagnant glacial ice, and was therefore active soon after deglaciation. The mid-fault vertical separation may be up to 17 meters east-side-up. The vertical separation appears to switch sense at the southernmost end of the fault, with west-side-up separation of 6 meters.

3) Petersville Road Mile 4.6 Fault Scarp

This northwest-trending fault is located just north of the Petersville Road, at about mile 4.6 along the road. The eastern end of the fault has a well-defined scarp that offsets (vertical separation of 7 m, north-side-up) the drumlinoid ground moraine and braided postglacial stream channels for ~1 km. Overall, the eastern 3.25 km length of the fault trace (pictured) is discontinuously well defined. Co-linear swales and scarps to the west-northwest (not pictured) extend the fault length to 6.6 km. Today, the lowland areas between the glacial drumlins are peat bogs, and the once-vigorous stream channels are essentially abandonded. This surface has not been active since soon after deglaciation.

4) Birch Creek Fault Scarp

The west-northwest trending Birch Creek fault is located ~10 km east-southeast of the town of Talkeetna. The western 0.6 km of the fault offsets (vertical separation up to 9 m, north-side-up) ground moraine for the western length of the fault trace. The eastern ~1.6

km of the scarp forms a well-defined lineament without clear surface offset. Total scarp length is about 2.25 km.

5) Parker Lake Scarp

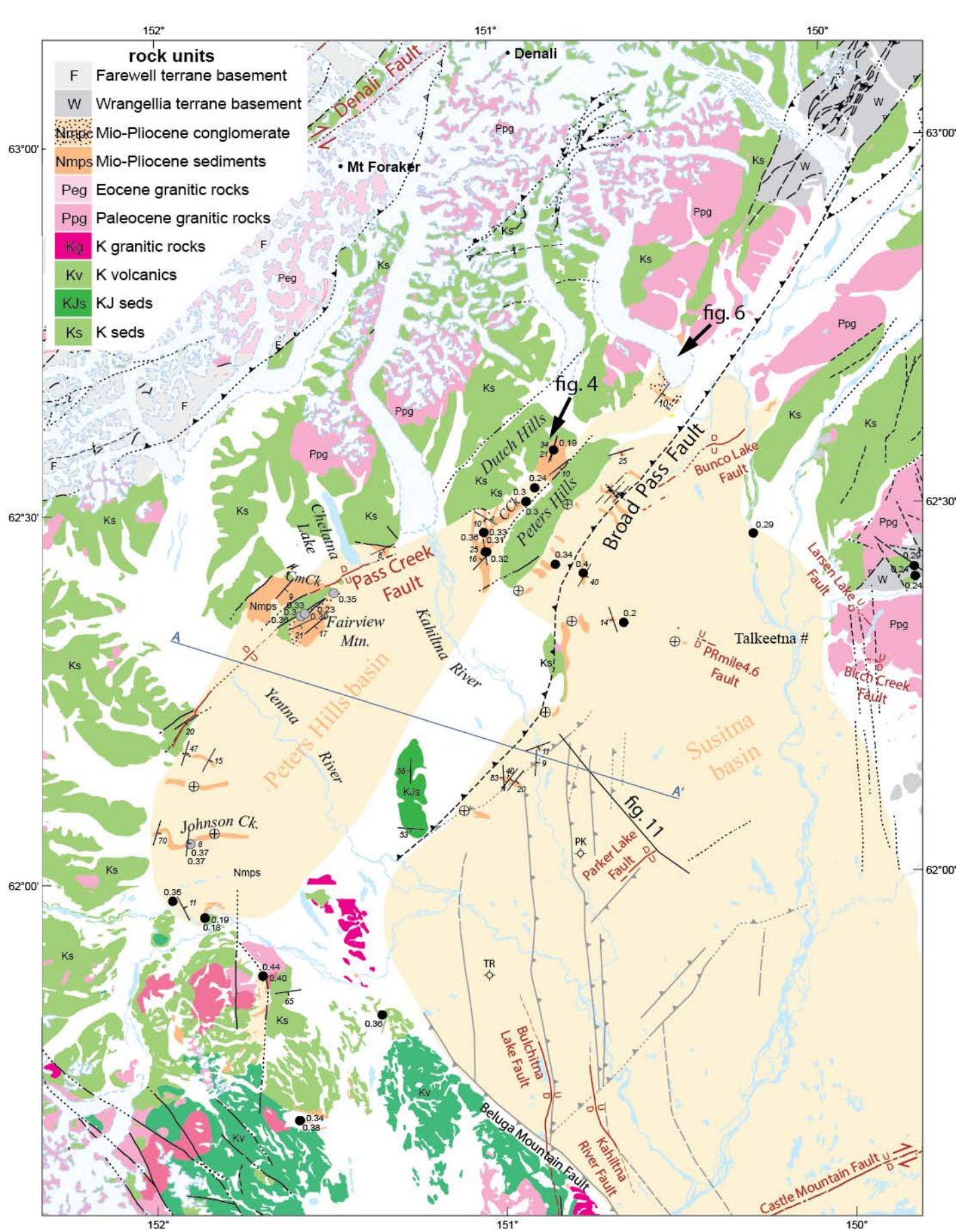
The unique, northwest-trending Parker Lake scarp is 7 km long and up to 160-m tall. No modern streams cut across the escarpment, instead, streams are diverted around the east end of the feature such that it constitutes a small drainage divide. There is no singular linear scarp expressed in the manner of other Holocene faults in the region, such as those described above. No bedrock has previously been mapped here, but it seems likely that some is exposed, given the high relief. The high relief also makes it nearly impossible for it to have formed by tectonic processes in Holocene time. A clue to its origin comes from comparing the scarp location to the faults and folds mapped by Lewis et al. (2015) using oil industry seismic reflection data. Lewis shows a dotted green line on their Figure 3, which shows the location of the crest of a small fault cored fold. This fold is best expressed in the deeper reflectors that Lews et al. (2015) mapped (between ~19,000 and 22,000 meters offset on the profile shown in Figure 5 of Lewis et al. (2015)), but there are indications that a syncline is present in reflectors within the uppermost 0.1 seconds two-way travel time. The shallowness of this syncline is consistent with the idea that this is a very young, or possibly active, fold within the Susitna basin. Therefore, the presence of the Parker Lake scarp lying above the fold imaged on the seismic reflection data is consistent with the idea that folding produced the fault scarp. As the fold is broad, low amplitude, and there is not a major through-going tectonic feature, it seems unlikely that the scarp formed merely by folding after the glaciers retreated. Thus, we infer the scarp

originated by folding in Quaternary (or Neogene?) time. Glaciation did not completely erode the fault scarp, and thus Holocene drainages are diverted around what we infer is a bedrock structure.

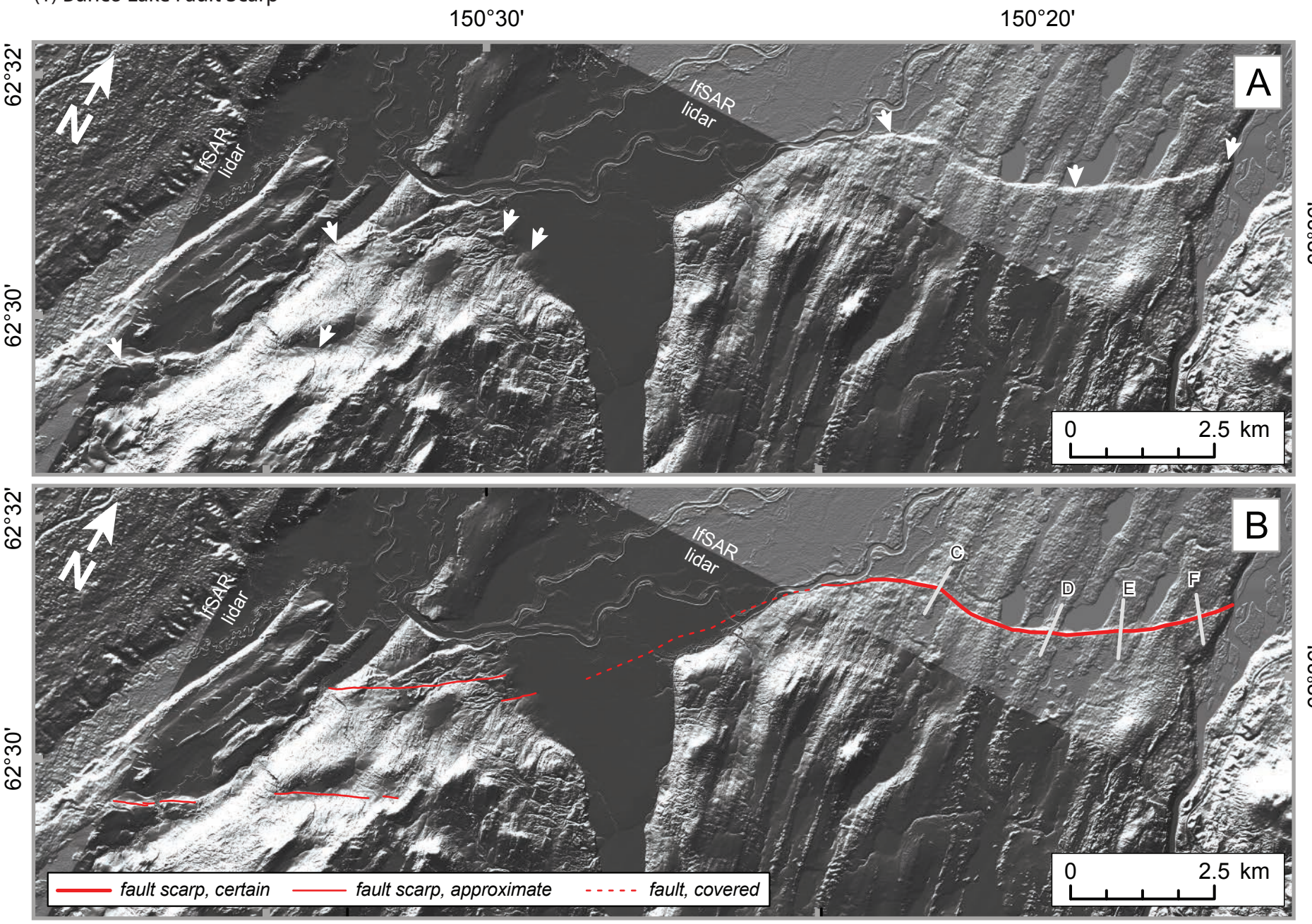
6) Kahiltna River Fault Scarp & 7) Bulchitna Lake Fault Scarp

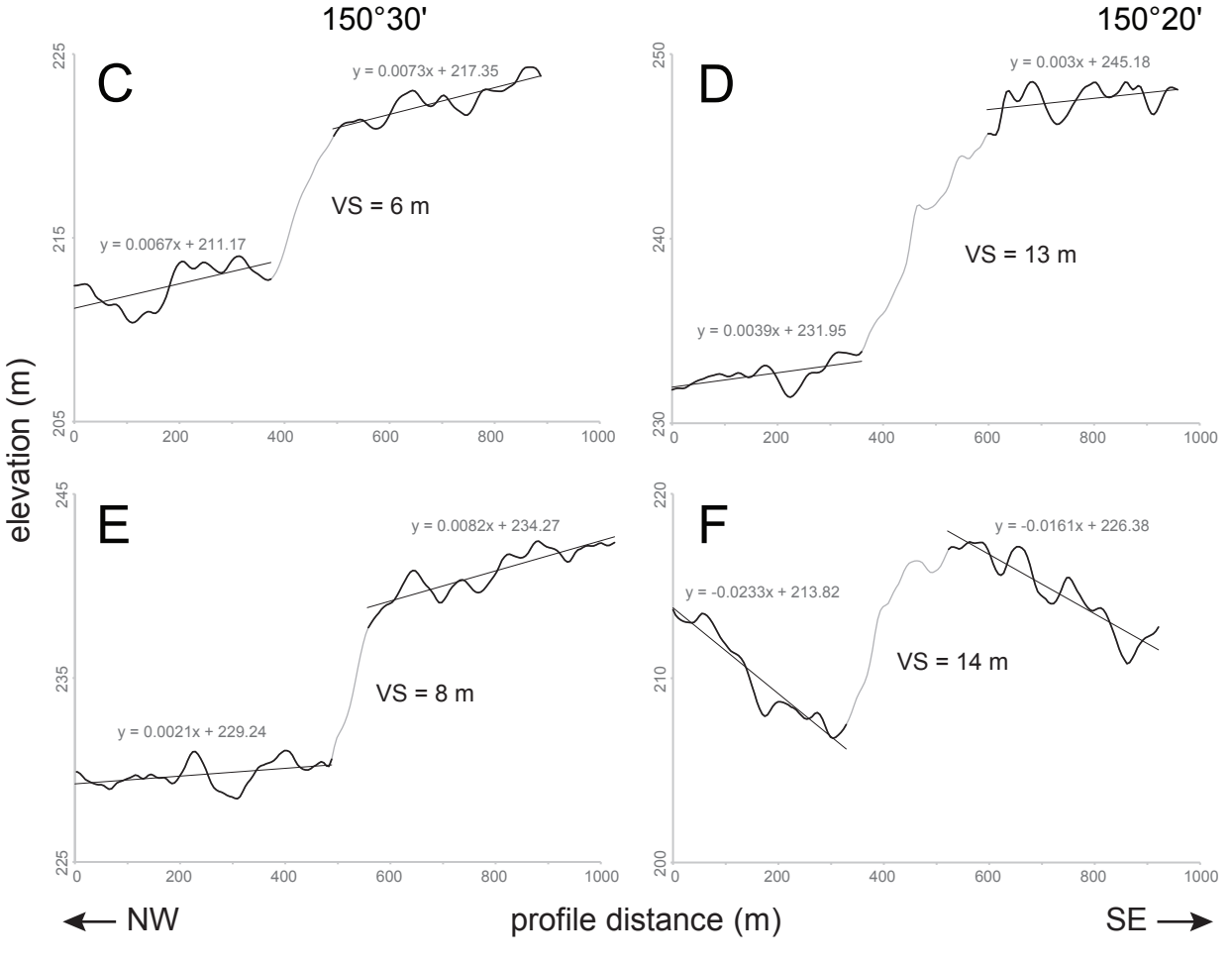
[note: we show both faults together on a series of three diagrams with: 6A and 7A – uninterpreted DEM hillshades, 6B and 7B – interpreted DEM hillshades, and 6C and 7C – scarp profiles showing interpreted vertical separation.] We discuss these two scarps together, because they share similar characteristics. Both scarps are oriented roughly north-south, both offset the post glacial drumlinoid surface, neither are particularly sharp, both are east-side-up, both are fairly long (>20 km), and both appear to be the surface expression of west-vergent reverse faults imaged by seismic reflection data interpreted by Lewis et al. (2015). These faults are some of the more dramatic on the seismic reflection dataset. The seismic reflection interpretation does not tightly constrain the age of folding, other than it is post Miocene. For the western scarp, the Bulchitna Lake fault, the best defined part of the scarp is about 19-km long, and a more liberal interpretation places the length at about 35-km long. The northern part of this interpretation makes sense in that the scarp is subparallel to the faults imaged on the seismic reflection data. The southern part of the scarp appears to cross the trace of the Beluga Mountain fault as mapped by Saltus et al. (2016). The fault trace is not as clear in between Mount Susitna and Little Mount Susitna, but it does seem to be present (see southernmost arrow on figure 6A in this supplement. The Bulchitna Lake scarp heights in well-defined areas are 3-4 meters, and may have been the result of post-glacial faulting. The Kahiltna River scarp is about

24 km long. Granitic bedrock has been mapped along the east side of the scarp on Trail Ridge. One scarp profile across a well defined post-glacial surface had about two meters of vertical separation, but two others gave significantly larger values of 12 and 13 meters. This large scarp height may be entirely post-post glacial, but perhaps more likely the scarp at least partly pre-dates the most recent glaciation. Three earthquakes with north-south reverse faulting nodal planes are shown to lie along this feature in manuscript Figure 10. Another earthquake occurred along this fault on 4 December 2016 at 13:15:44 UTC, with epicenter of 61.948°N, 150.859°W, and at 5.6 km depth, also with a north-south reverse faulting nodal plane. These earthquakes support the idea that this is an active fault.

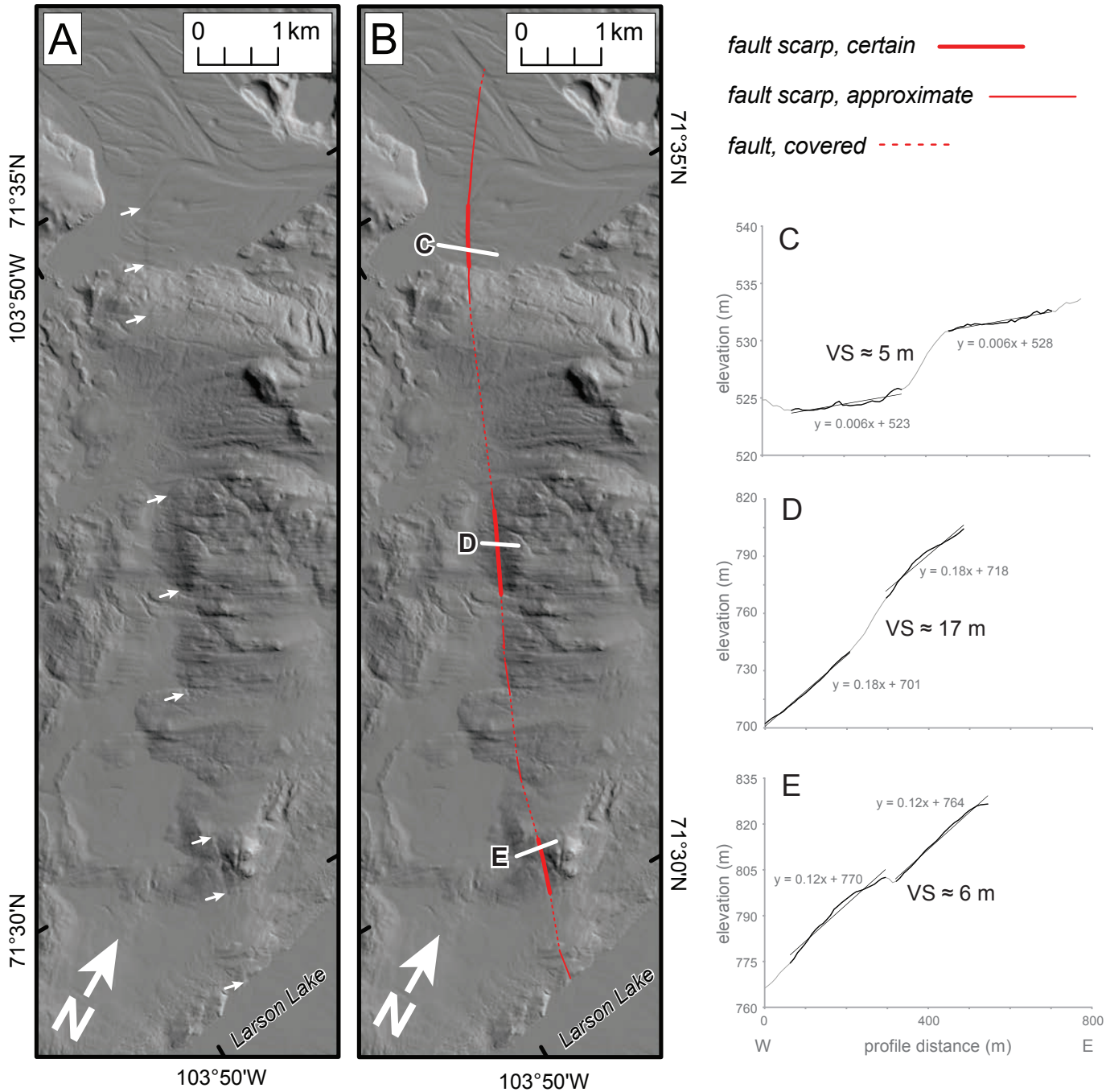

rock units
F Farewell terrane basement
W Wrangellia terrane basement
Nmpc Mio-Pliocene conglomerate
Nmps Mio-Pliocene sediments
Peg Eocene granitic rocks
Ppg Paleocene granitic rocks
Kg K granitic rocks
Kv K volcanics
KJs KJ seds
Ks K seds
152°
151°
150°
63°00'
62°30'
62°00'
Denali Fault
Denali
Mt Foraker
fig. 4
fig. 6
fig. 11
Broad Pass Fault
Dutch Hills
Peters Hills
Bunco Lake Fault
Larsen Lake Fault
Birch Creek Fault
Pass Creek Fault
Chelatna Lake
CmCk
CCk
Fairview Mtn.
Kahiltna River
Talkeetna #
PRmile4.6 Fault
Peters Hills basin
Yentna River
Susitna basin
Johnson Ck.
Parker Lake Fault
PK
TR
Bulchitna Lake Fault
Kahiltna River Fault
Beluga Mountain Fault
Castle Mountain Fault
A
A'

(1) Bunco Lake Fault Scarp

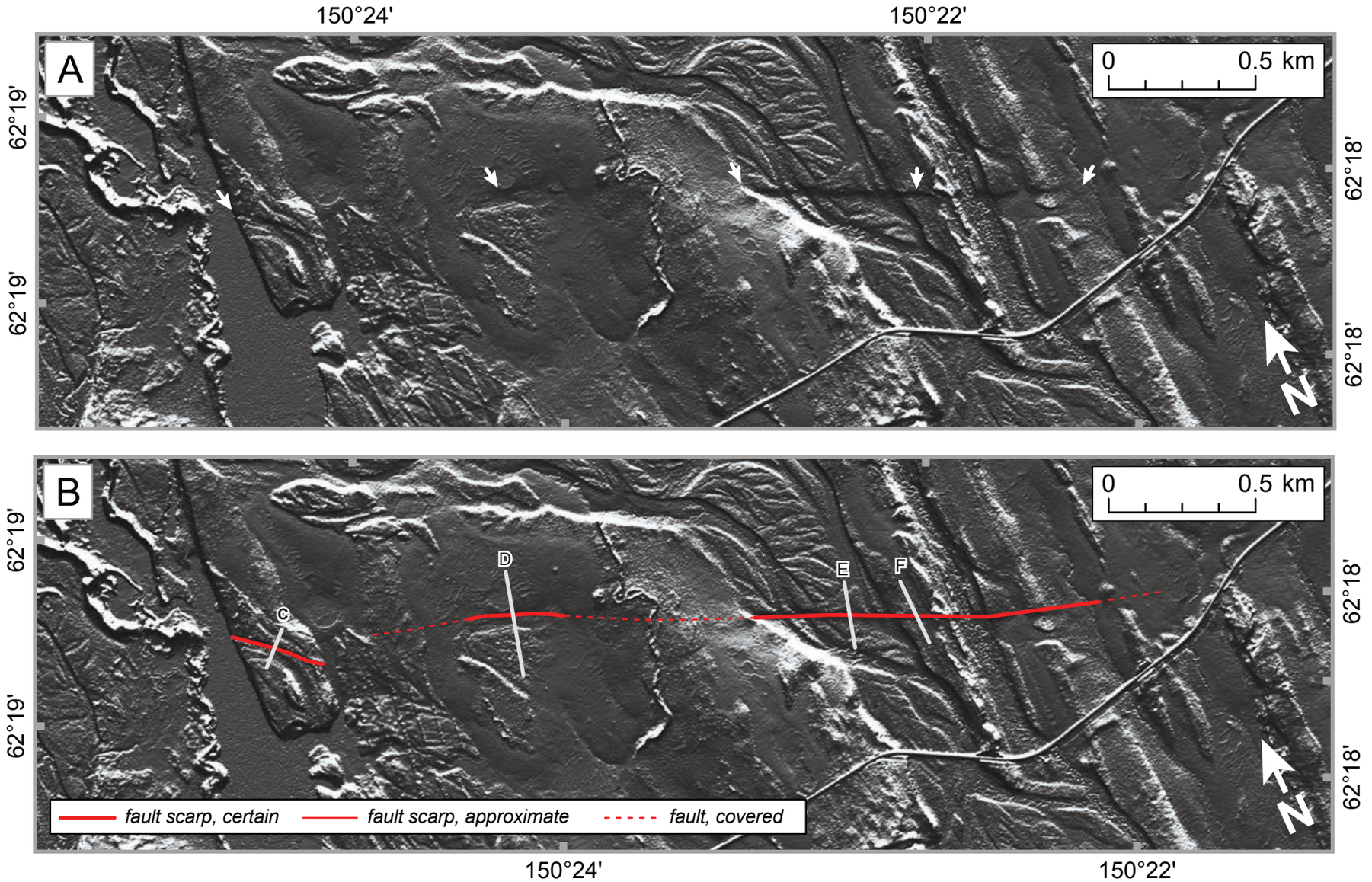


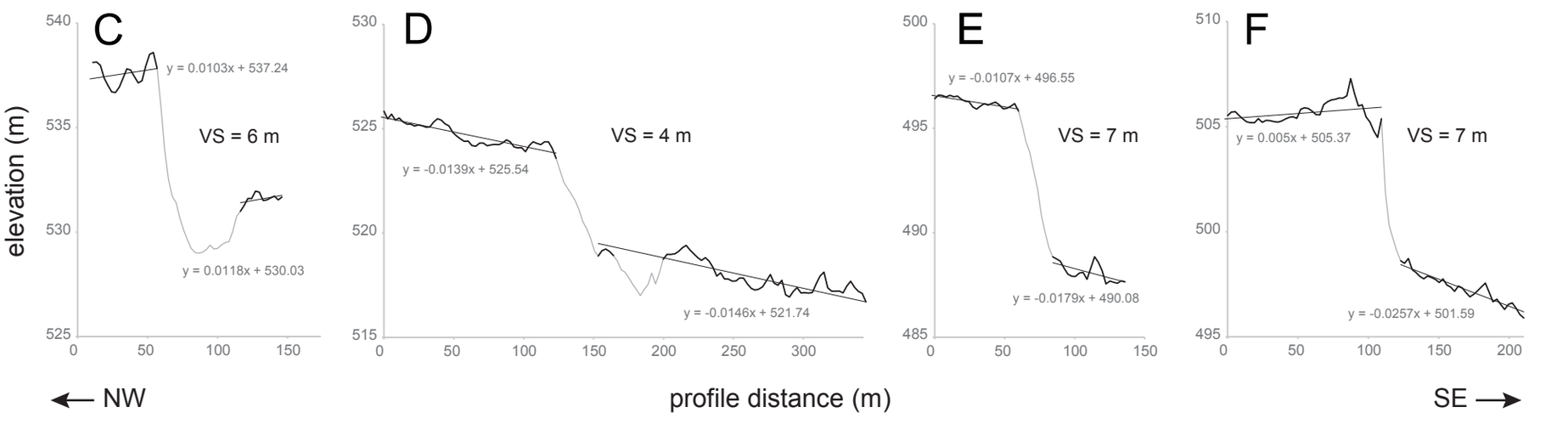


(2) Larsen Lake Fault Scarp

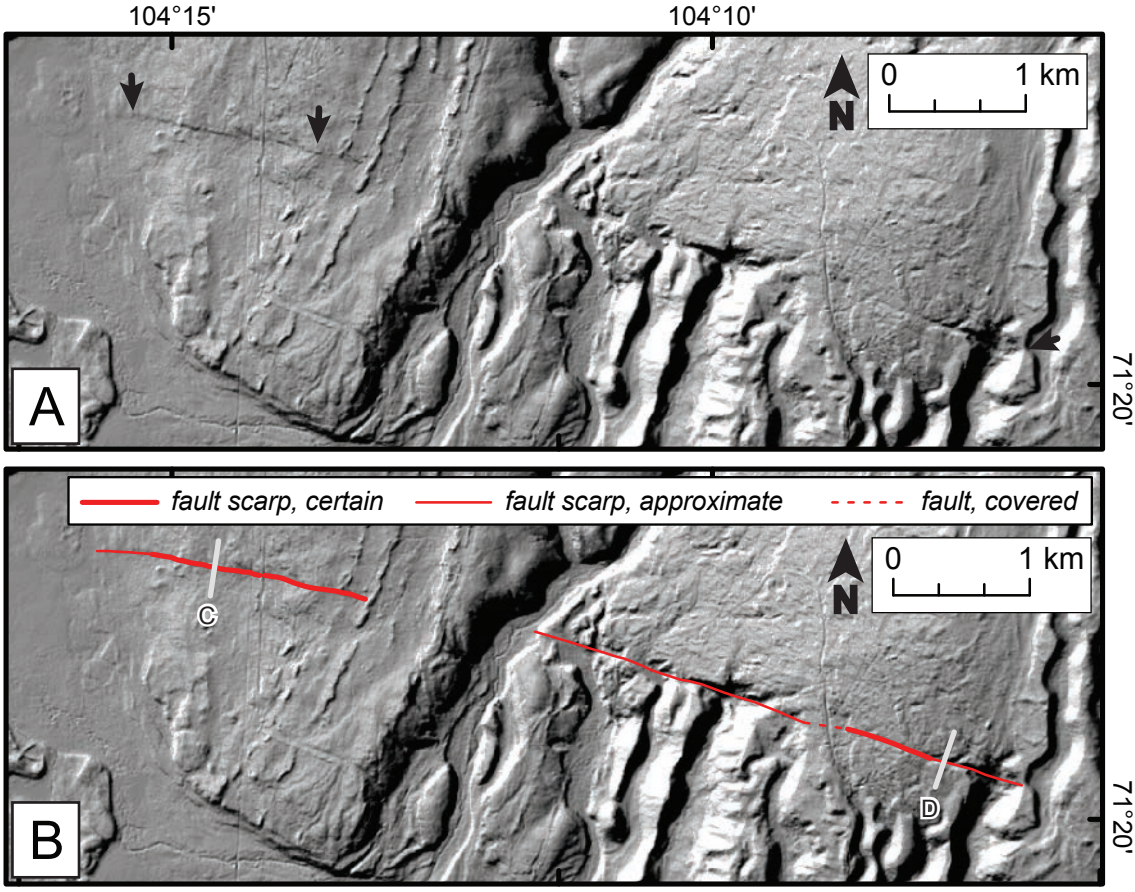


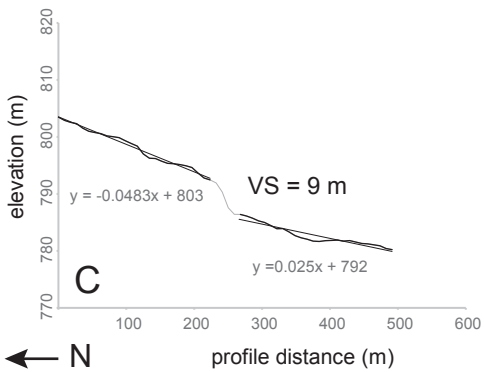
(3) Petersville Road Mile 4.6 Fault Scarp

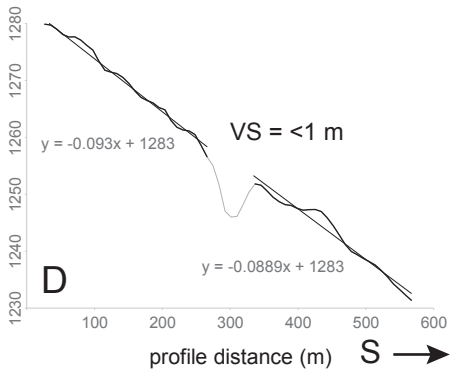




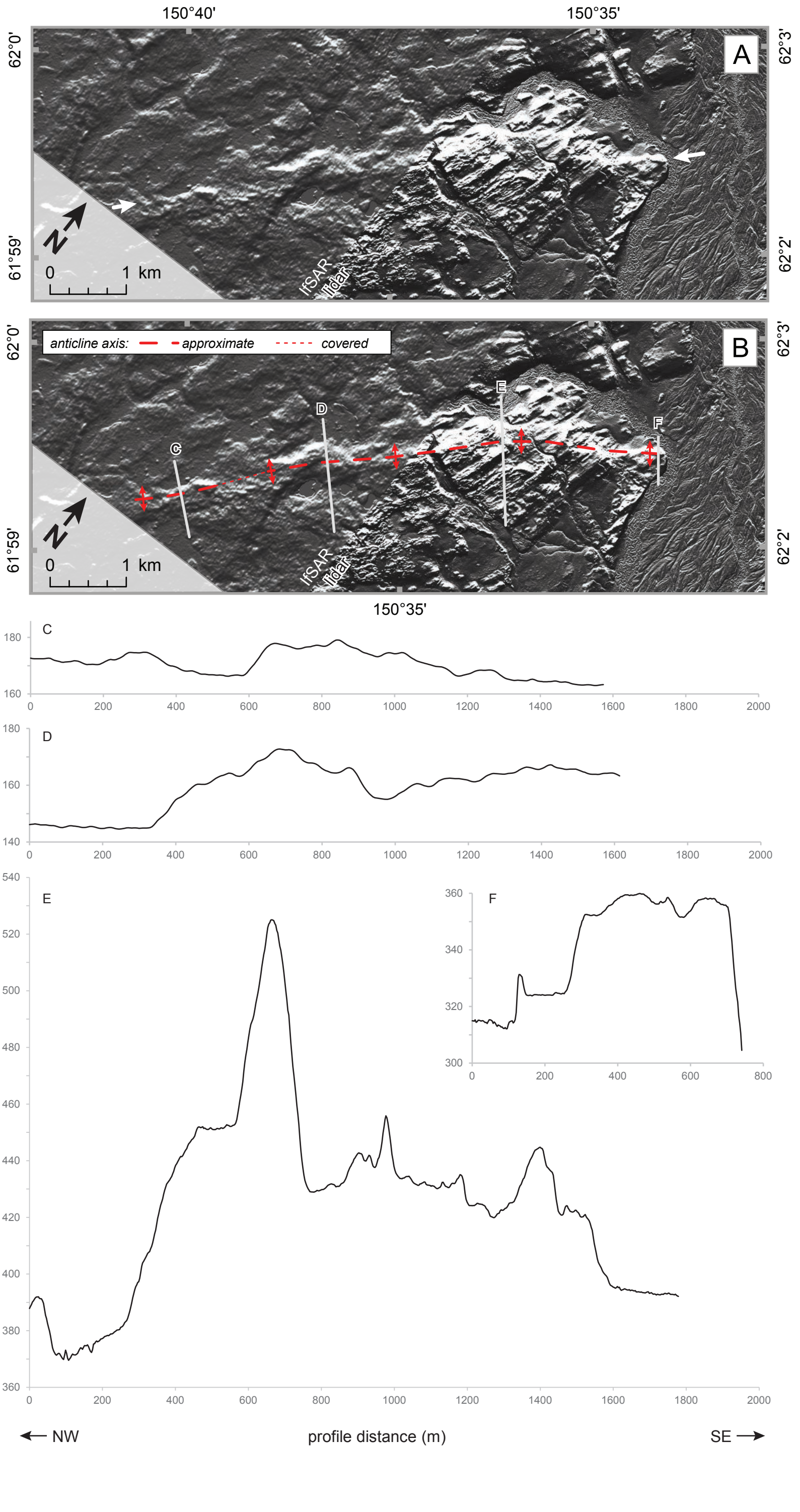
(4) Birch Creek Fault Scarp



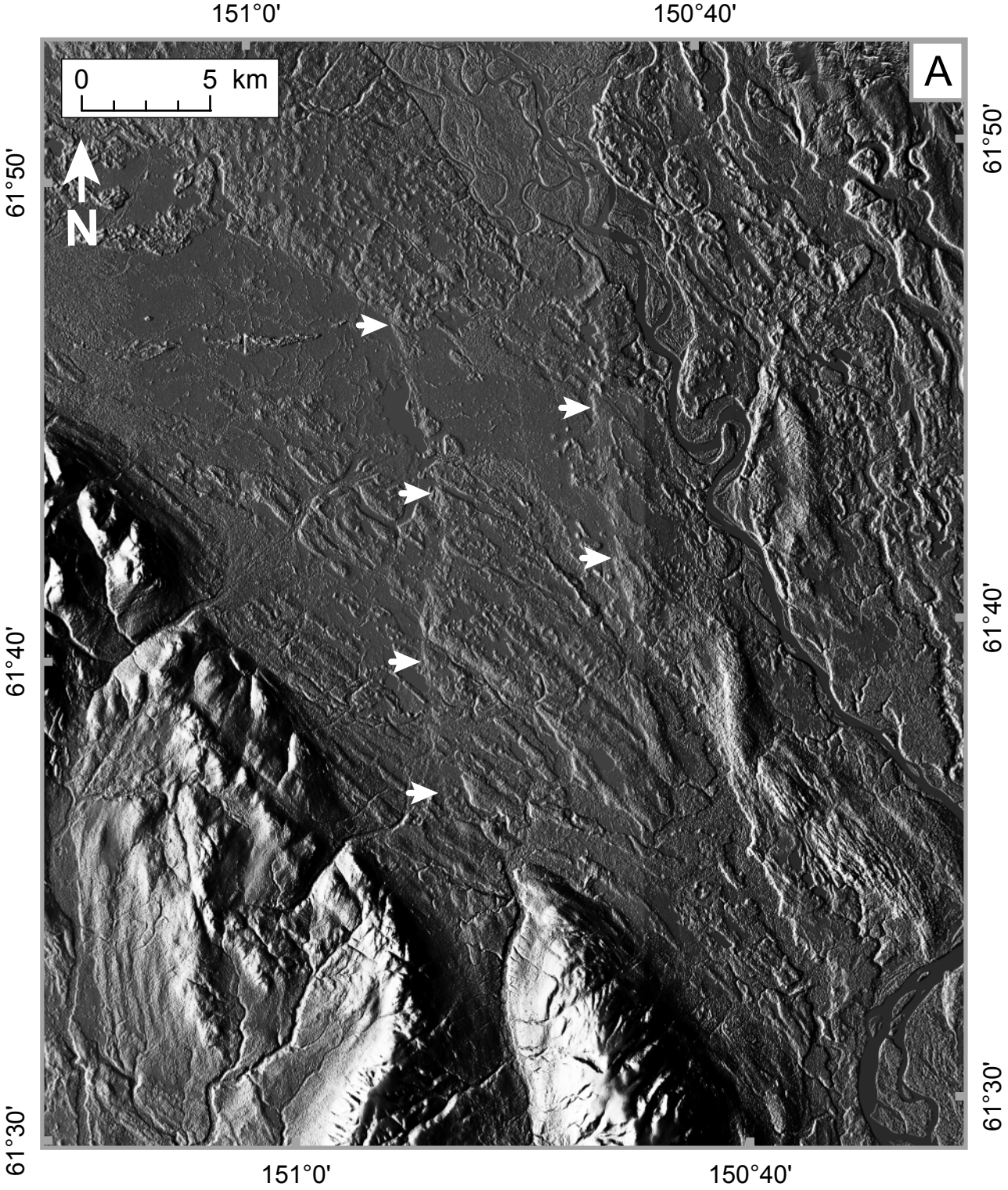




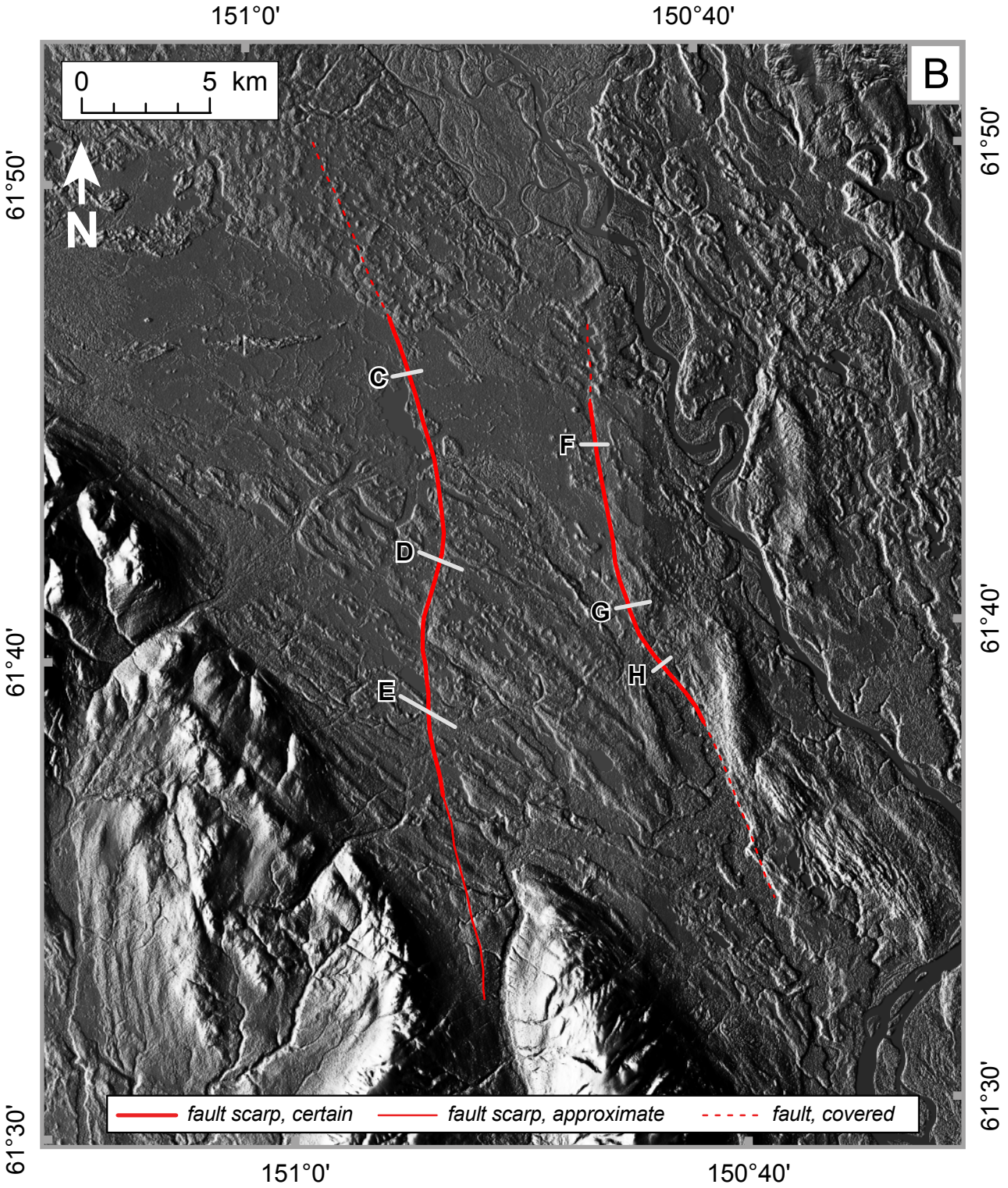
(5) Parker Lake Fault Scarp



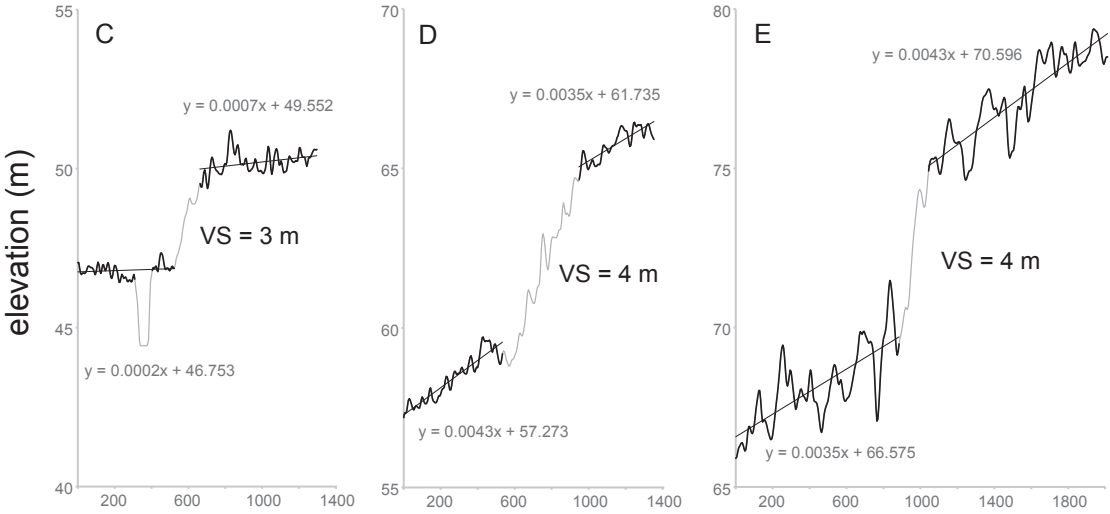
(6A) Kahiltna River Fault Scarp - western scarp
(7A) Bulchitna Lake Fault Scarp - eastern scarp



(6B) Kahiltna River Fault Scarp - interpreted - western scarp
(7B) Bulchitna Lake Fault Scarp - interpreted - eastern scarp



(6C) Bulchitna Lake fault - Scarp Profiles C-E,



(7C) Kahiltna River fault - Scarp Profiles F-H