The Castle Mountain fault, south-central Alaska: New lidar-based observations on the sense of slip

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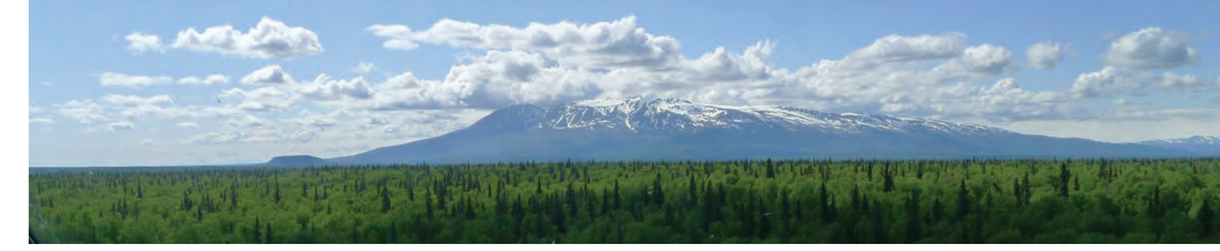

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INTRODUCTION

The Castle Mountain fault extends along the southern Talkeetna Mountains range front and across the Susitna Lowland in south-central Alaska. The fault is an active structural element of the Aleutian forearc and has formed a 4-km-wide anticline associated with at least 0.5 km of north-side-up displacement. Right-lateral bedrock offsets along the eastern part of the fault are poorly constrained to ~14 km. In the Susitna Lowland, the fault is expressed at the surface by a distinct south-facing scarp. Previous paleoseismic studies have described the fault as both a strike-slip fault and a reverse fault, attributed the scarp to the occurrence of one to four paleoearthquakes, and estimated a Holocene right-lateral slip rate of ~3mm/yr.

Motivated by these uncertainties and by inspection of new lidar data along the fault which indicates that Holocene landforms are not laterally offset, we performed surficial-geologic mapping and field surveys with an emphasis on better characterizing the sense of slip. Field work was conducted along approximately 12 km of the scarp between Houston and Susitna River.

This poster presents:

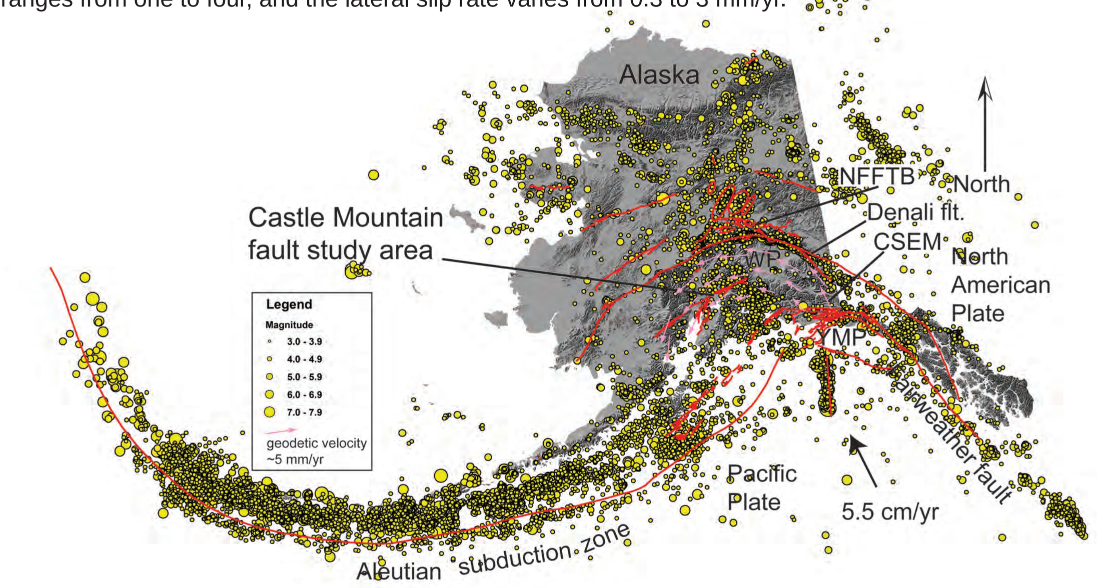
- New lidar- and field-based Quaternary surficial-geologic and tectonic geomorphic mapping.
- Topographic profiles across the Castle Mountain fault and lateral spread/landslide features.
- Lidar derived base maps including hillshade, slope, and 0.25 m topographic maps that illustrate the sense of slip.

TECTONIC SETTING AND PALEOSEISMOLOGY

Compression and shear across southcentral Alaska are driven by north-northwest relative motion (~55 mm/yr) between the Pacific and North American plates along the Fairweather fault, Yakutat microplate, and Aleutian subduction zone. This deformation is accommodated across a >500-km- wide zone by major tectonic structures including the Chugach-St. Elias fold and thrust belt, Denali fault, Northern Foothills Fold and Thrust Belt (NFFTB), and faults in interior Alaska among others. The Wrangell microplate, the region of crust in southcentral Alaska between the Chugach Mountains and the Alaska Range is rotating counter-clockwise relative to North America at a geodetically measured rate of ~5 mm/yr (Fletcher, 2002; Freymueller et al., 2008).

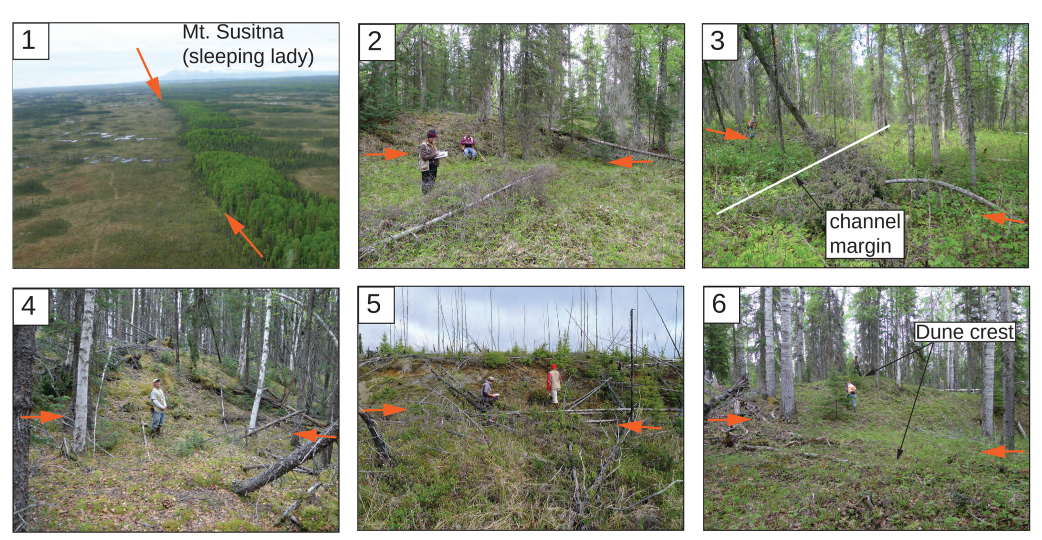
The Castle Mountain fault is a major structural element of the Aleutian forearc basin and extends between the Talkeetna Mountains and the Susitna River within the Wrangell Microplate. In the Susitna lowlands, late Tertiary dip-slip reverse movement has resulted in at least 0.5 km of north-side-up displacement and the fault is associated with a 4-km-wide anticline (Haussler et al., 2000). To the east, post-Palaeocene lateral slip is estimated to be ~14 km (Fuchs, 1980; Kelley, 1963).

The Castle Mountain fault has long been considered an active strike slip fault in Neotectonic and seismic hazards studies, however, previous paleoseismic investigations report conflicting results with regard to the style and rate of Quaternary deformation. For example, Dettermann et al. (1974) dated a buried soil exposed in a trench excavated across a 2.1-m-high scarp east of the Little Susitna River and implied an 1860 +/- 250 yr BP age for the most recent event. At this locality, the fault dips 75˚ north. Detterman et al. (1974) also suggested possible right lateral displacements of 3.6 to 7 meters. More recent trenching studies suggest thrust motion along the fault and the occurrence of four late Holocene earthquakes in the last 2700 yrs (Haeussler et al., 2002). A late Pleistocene-Holocene right lateral slip rate of 2-3 mm/yr was estimated by Willis et al. (2007) based on lateral offset of 36 m meaured on a subtle channel margin. Thus, the fault has been characterized as both a thrust fault and a strike slip fault, the number of late Holocene earthquakes ranges from one to four, and the lateral slip rate varies from 0.3 to 3 mm/yr.



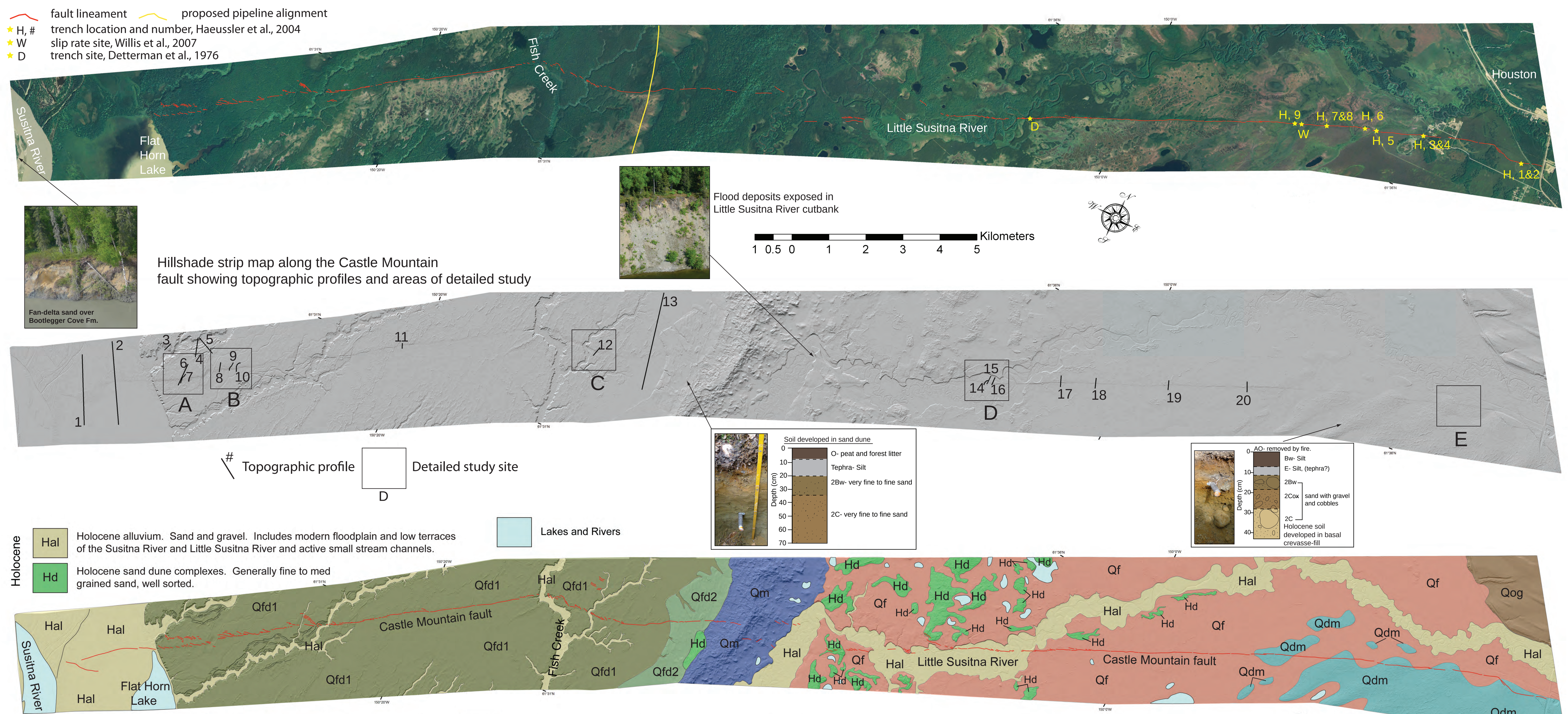
Hillshade of the Alaska Range showing major faults and crustal seismicity. Pink arrows show geodetically measured rotation of the Wrangell microplate relative to North America after Freymueller et al., (2008). WP, Wrangell microplate; YMP, Yakutat microplate; CSEM, Chugach-Saint Elias Mountains; NFFTB, Northern Foothills fold and thrust belt.

FAULT SCARP PHOTOGRAPHS



Castle Mtn. fault extends between red arrows on all photos. (1) View west of Castle Mtn. fault near profile 19, deciduous trees on upthrown side. (2) Fault scarp 2.5-m-high in Area D. (3) Vertically offset margin of abandoned channel in Area B, scarp height 2.5 m. (4) 3.2-m-high scarp in Area D, additional splay north of scarp is ~1 m high giving a total displacement of over 4 m (5) Fault scarp near profile 20, height 2.6 m. (6) Vertically offset dune crest (1.8 m) in area D.

AERIAL IMAGE, LIDAR HILLSHADE, AND SURFICIAL-GEOLOGIC MAP OF THE CASTLE MOUNTAIN FAULT



Pleistocene

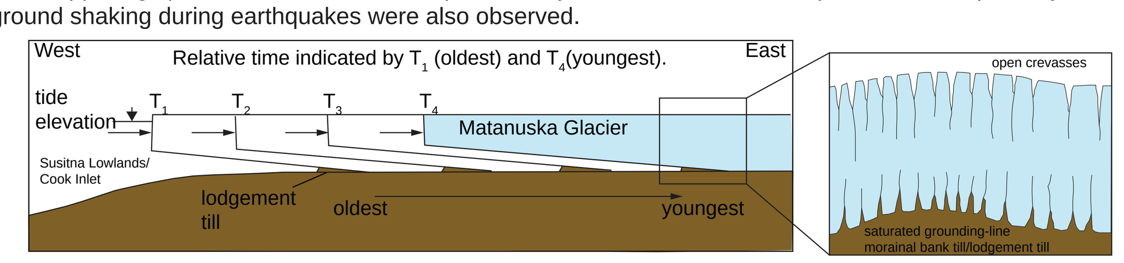
Unit	Description
Qfd1	Relatively younger estuarine fan-delta sands underlain by fine-grained Bootlegger Cove Formation: composed of fine to medium estuarine sands.Surface characterized by abandoned channels and longitudinal sand dunes.
Qfd2	Relatively older estuarine fan-delta sands in low terrace between Elmendorf terminal moraine and younger estuarine fan-delta. Fine to medium grained estuarine sand. Escarpment on west possibly cut by tide waters when region was isostatically depressed.
Qf	Flood deposits. Pebble-cobble gravels with sand and trace silt deposited in the Little Susitna River drainage by late Elmendorf floods emanating from lower Matanuska Valley to the east.
Qog	Outwash gravels. Overconsolidated pebble-cobble gravels. Surface was overridden by the Elmendorf advance producing drumlin-like landforms.
Qdm	Grounding-line morainal-ridge complex. Polymictic pebble-cobble gravels with scattered subangular boulders deposited beneath expanding Matanuska glacial lobe during waxing phase of Elendorf advance. Surface has variously oriented, intersecting linear to arcuate, basal crevasse-fill ridges up to 3 m high composed of that consist of massive, poorly sorted, medium to coarse grained sand with pebble-cobble gravels.
Qm	Glacial end moraine of the Elmendorf advance of the Naptowne glaciation. Pebble-cobble gravel with scattered subrounded boulders.

QUATERNARY GEOLOGY/TECTONIC GEOMORPHOLOGY

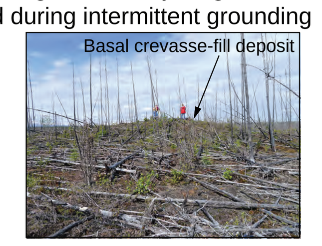
Surficial-geologic mapping across the Susitna Lowland indicates that the fault is associated with a clear scarp that displaces late Elmendorf (14-15 ka) glacial and Holocene deposits including glacial drift, sandy fan deltas, outwash plains, grounding-line moraines, basal-crevasse-fill complexes, stream terraces, oxbow lakes, and swamps (See map above). Where the scarp cuts these deposits it varies in height from ~ 0.5-4 m consistent with observations in Detterman et al. (1974). As noted by previous workers, much of the trace of the fault is identifiable by distinct vegetation lineaments characterized by large deciduous trees growing along the uplifted north side of the fault and stunted black spruce growing south of the fault (Photo 1).

The fault is characterized by two relatively straight traces separated by a broad ~ 2-km-wide bend in the vicinity of Fish Creek (Area C). In the vicinity of the bend, the fault trace lacks a well-defined scarp and is delineated by vegetation and a gentle south-facing slope. In some areas, the scarp is confined to a narrow zone (Area D). However, much of the fault trace is characterized by a wide zone of deformation consisting of left-stepping en echelon surface scarps oblique to the trace of the fault and left-stepping grabens up to 400 meters north of the scarp (Areas A and B).

Numerous abandoned channels, stabilized sand dunes, and terrace margins oriented orthogonal to the scarp are vertically offset and have negligible strike-slip displacement (See Photos 3 and 6 and enlarged maps of detailed study areas upper right). In addition to surface rupture, many landslides and lateral spread features possibly due to strong ground shaking during earthquakes were also observed.



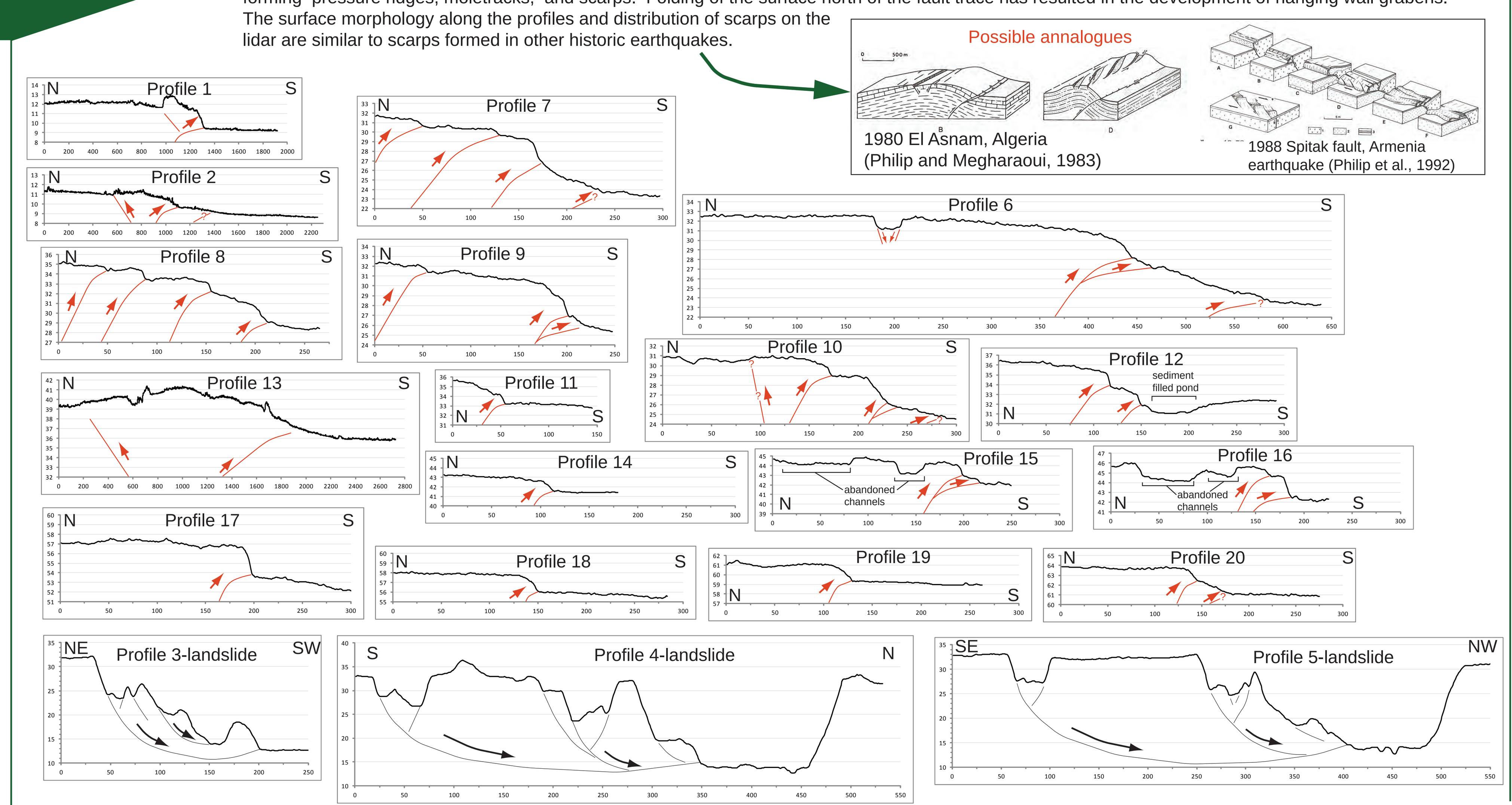
Model for formation of a series of grounding-line moraines (Area E) composed of lodgement till by stagnant or thinning and receding tidewater Matanuska Glacier. Basal crevasse-fill deposited during intermittent grounding and floating of intensely crevassed, receding tidewater Matanuska glacier. Sediment is squeezed upward due to downward pressure on the saturated grounding-line moraine.



TOPOGRAPHIC PROFILES

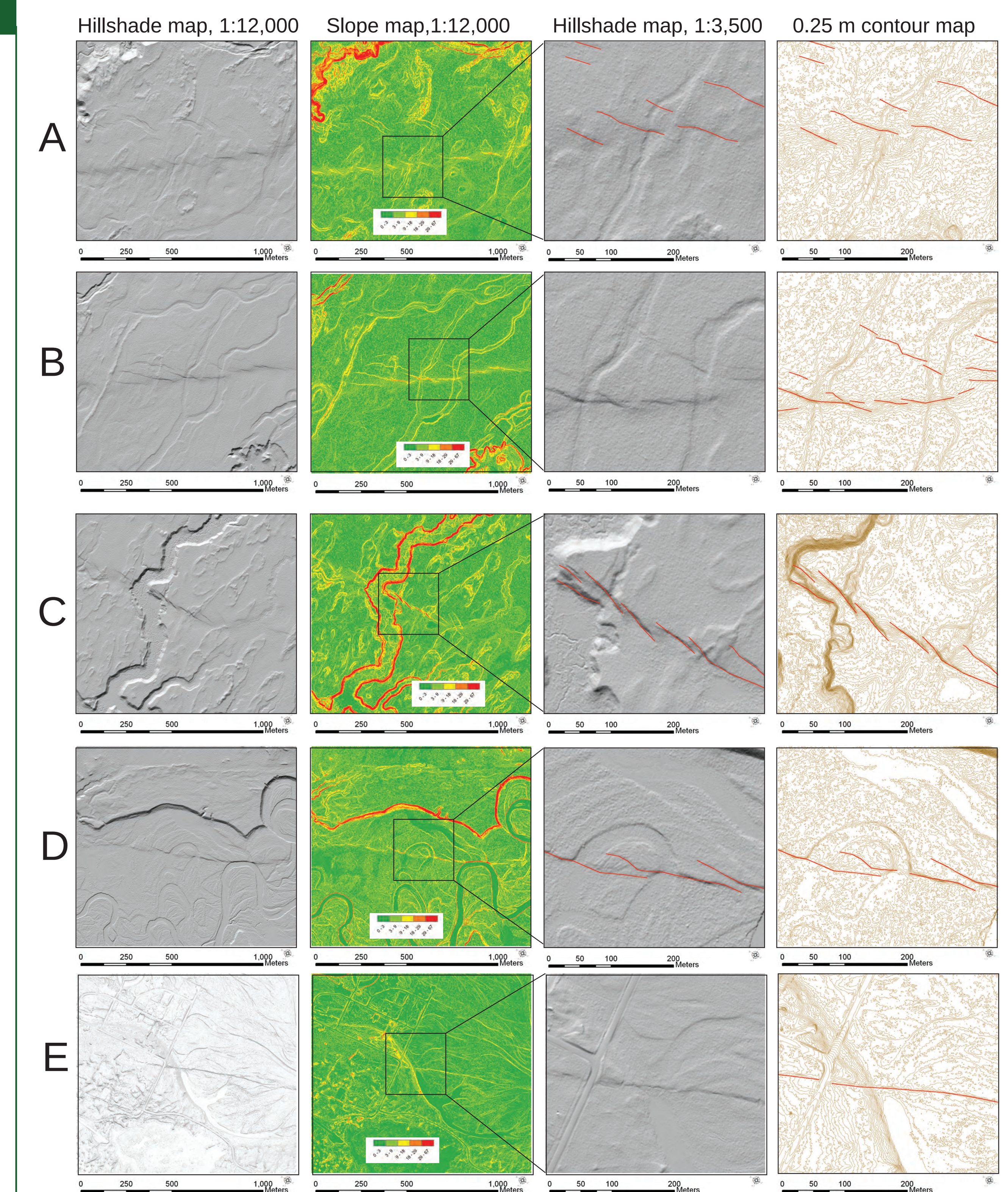
From the lidar data, we constructed 17 topographic profiles across the Castle Mountain fault and 3 profiles across lateral spread/ landslide features north of the fault (See hillshade map for locations). The cross fault profiles consistently show surface faulting and broad warping of sand delta, alluvial flood plain, and abandoned stream channels. Based on the distribution of fault scarps on the lidar, we present subsurface schematic interpretations of the faulting below each profile.

The surface expression is consistent with a high angle reverse fault model where the hanging wall block is thrust up and "bulldozed" out over the footwall block forming pressure ridges, moletracks, and scarps. Folding of the surface north of the fault trace has resulted in the development of hanging wall grabens. The surface morphology along the profiles and distribution of scarps on the lidar are similar to scarps formed in other historic earthquakes.



DETAILED STUDY AREAS

Maps showing little to no lateral displacement of Holocene landforms



CONCLUSIONS AND IMPLICATIONS

Sense of motion on the Castle Mountain fault

Based on scarp and fault zone morphology, rupture trace geometry, and continuity of geomorphic features across the fault, we suggest that earthquakes along the Castle Mountain fault are characterized by reverse faulting above a north-dipping fault. We further suggest that the grabens north of the fault are the product of folding and extension (bending moment deformation) in the crest of an anticline developing in the hanging wall. The left-stepping en echelon pattern of scarps suggests a minor oblique component of slip, however, we did not observe lateral displacement of geomorphic markers.

Our observations on the style of deformation are consistent with Detterman et al. (1974) and Hauessler et al. (2002), however differ from the view of Willis et al. (2007) in terms of the amount of lateral displacement. Our lidar and field observations clearly indicate:

- There has been negligible lateral slip in the Holocene, and
- Surface deformation is the product of high-angle reverse faulting and possibly a minor component of right-oblique slip.

Implications for seismic hazard assessments

Estimation of the size and recurrence of earthquakes in seismic hazard analyses depend on geologic description of the geometry and slip rates of active faults. Seismic hazards assessments for southcentral Alaska presently use a strike-slip sense of motion and a slip rate of 3 mm/yr for the Castle Mountain fault.

Our data suggest that these parameters are not accurate and that the fault is better characterized as a right oblique, high angle reverse fault.

We speculate that the Holocene offsets across the Susitna Lowland (~1-5 m) indicate a vertical displacement rate of ~0.5 mm/yr. The lateral displacement rate may be similar to the long term bedrock rate of <0.3 mm/yr.

Future paleoseismic studies aimed at refining the current slip rate are necessary. These data are critical to insure that the upcoming USGS Seismic Hazard Map update for Alaska shows realistic ground motions related to earthquakes on the Castle Mountain fault.

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