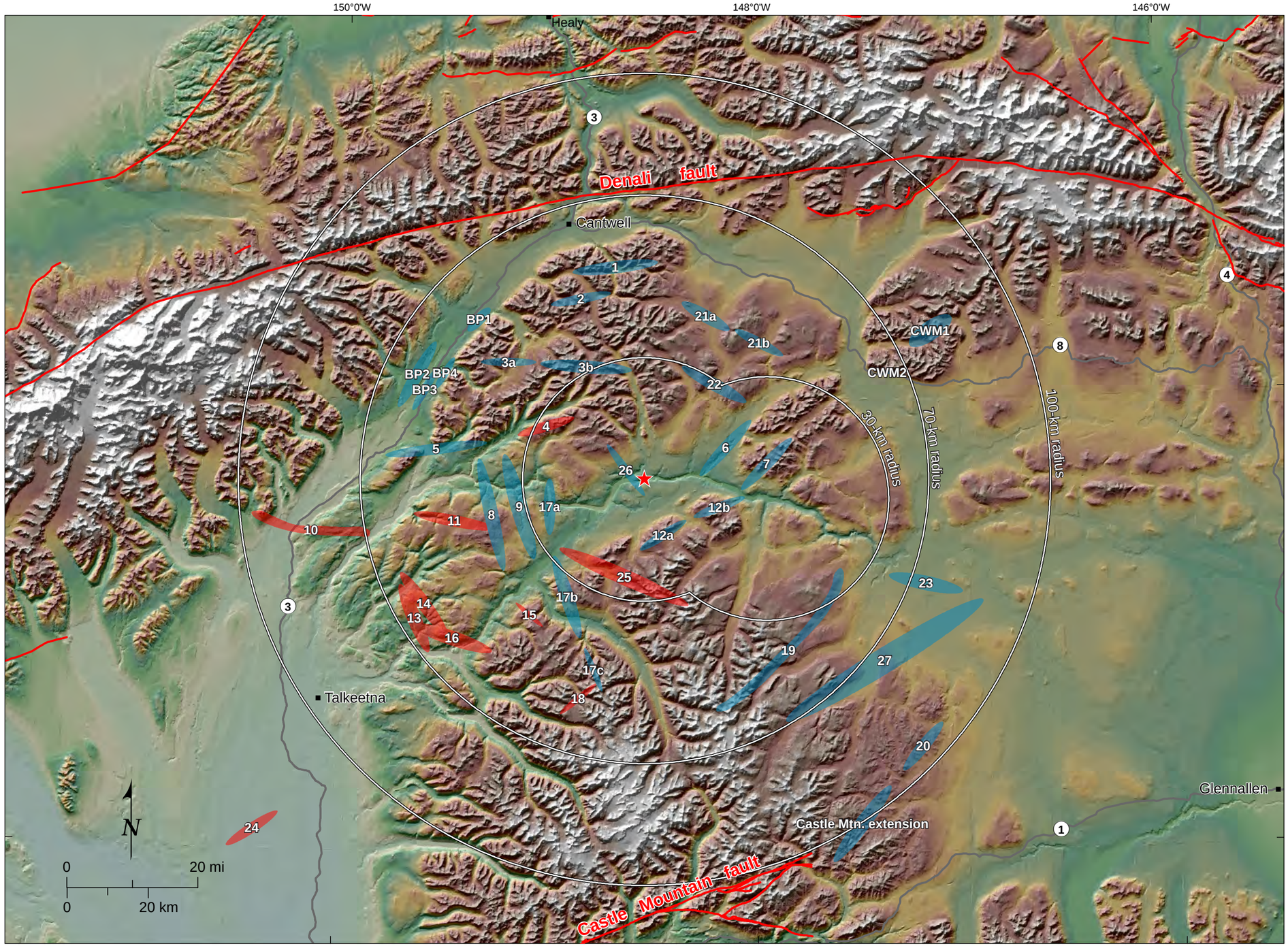
This attachment includes some figures that contain Critical Energy Infrastructure Information (CEII), which are being withheld from public viewing, in accordance with FERC's Order No. 630-A.

DO NOT RELEASE.

Figures

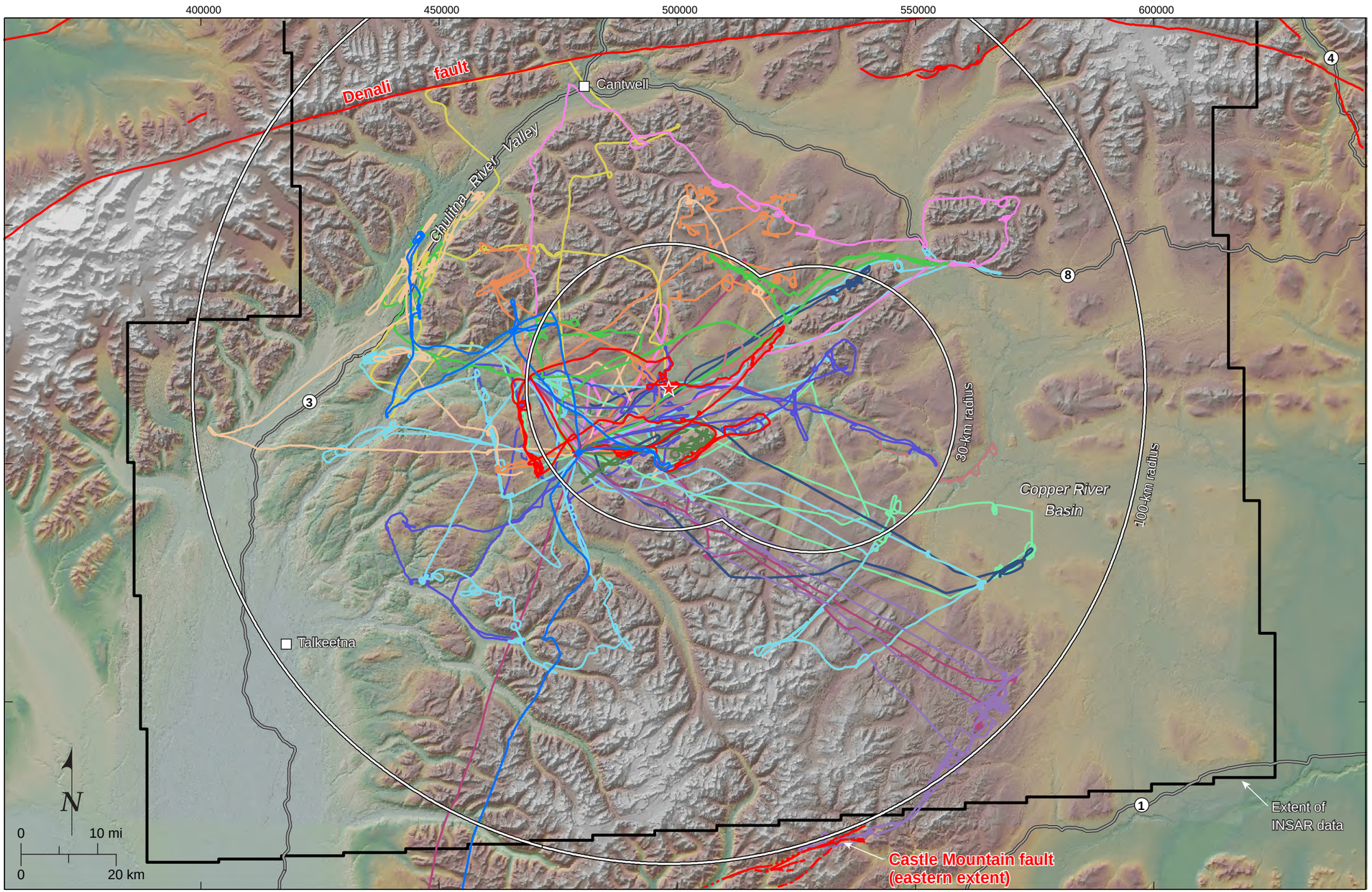


Explanation

- Quaternary fault (Koehler et al., 2012)
- Field work planned in 2013 based on results of TM-8 (FCL, 2013)
- No field work planned in 2013 based on results of TM-8 (FCL, 2013)
- ★ Proposed Watana site

Date 02/11/15	STATE OF ALASKA ALASKA ENERGY AUTHORITY	SUSITNA-WATANA HYDROELECTRIC PROJECT LOCATION MAP AND LINEAMENT GROUPS	FIGURE 1-1

fwla-wc-file1/project/Projects/79_2000/79_218900_Alaska_Railbelt/05_Graphics/79_218900 Combined Crustal Source Surface Fault Rupture Evaluation



Explanation

- Quaternary fault (Koehler et al., 2012)
- ★ Proposed Watana site

GPS Tracks (by reconnaissance date)

- 7/11/2013
- 7/12/2013
- 7/13/2013
- 7/14/2013
- 7/15/2013
- 7/16/2013
- 7/17/2013
- 7/18/2013
- 7/19/2013
- 7/21/2013
- 7/22/2013
- 7/23/2013
- 7/24/2013
- 9/4/2013
- 9/5/2013

Coordinates on NAD83 UTM 6 North.
Elevation from INSAR data and USGS SRTM data.

fwla-wc-file1/project/Projects/79_2000/79_218900_Alaska_Railbelt/05_Graphics/79_218900_TM14 Janurary 2014 Lineament Report

FUGRO Date 02/11/15	STATE OF ALASKA ALASKA ENERGY AUTHORITY ALASKA ENERGY AUTHORITY	SUSITNA-WATANA HYDROELECTRIC PROJECT JULY AND SEPTEMBER 2013 FIELD RECONNAISSANCE GPS TRACKS	FIGURE 2-1A

460000

500000

540000

7000000

6960000

30-km radius

High Lake
fuel station

Susitna River

Susitna River

Stephan
Lake Camp

N

0 5 mi

0 10 km

Explanation

★ Proposed Watana site

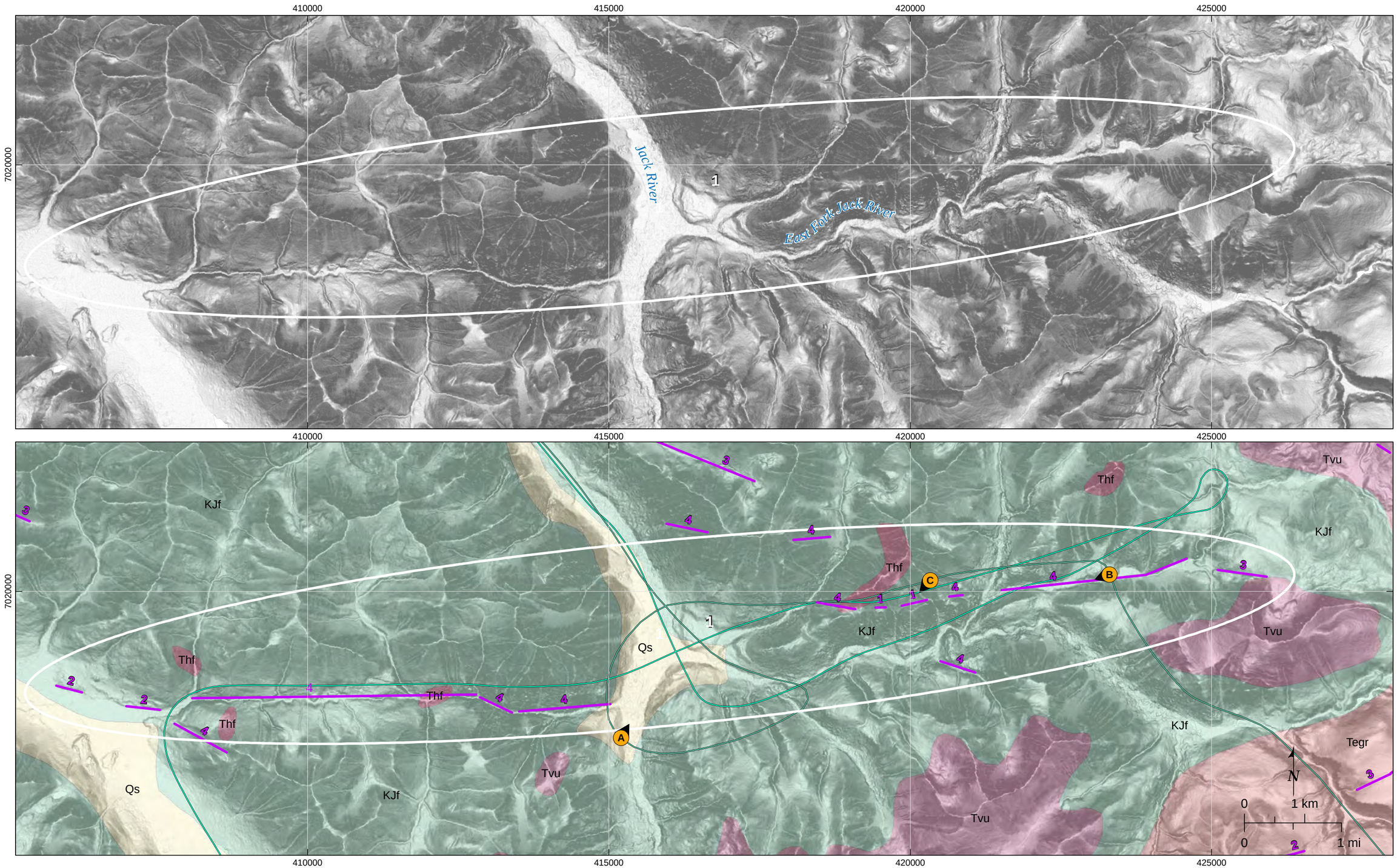
GPS Tracks
(by reconnaissance date)

- 7/12/2014
- 7/13/2014
- 7/14/2014
- 7/15/2014
- 7/16/2014
- 7/17/2014
- 7/18/2014
- 7/19/2014
- 7/20/2014
- 9/11/2014
- 9/12/2014
- 9/13/2014
- 9/14/2014
- 9/15/2014
- 9/16/2014
- 9/17/2014
- 9/18/2014

Coordinates on NAD83 UTM 6 North.
Elevation from IFSAR data.

fwla-wc-file1/project/Projects/79_2000/79_218900_Alaska_Railbelt/05_Graphics/79_218900_TM14 Janurary 2014 Lineament Report

FUGRO Date 02/11/15	STATE OF ALASKA ALASKA ENERGY AUTHORITY ALASKA ENERGY AUTHORITY	SUSITNA-WATANA HYDROELECTRIC PROJECT JULY AND SEPTEMBER 2014 FIELD RECONNAISSANCE GPS TRACKS	FIGURE 2-1B

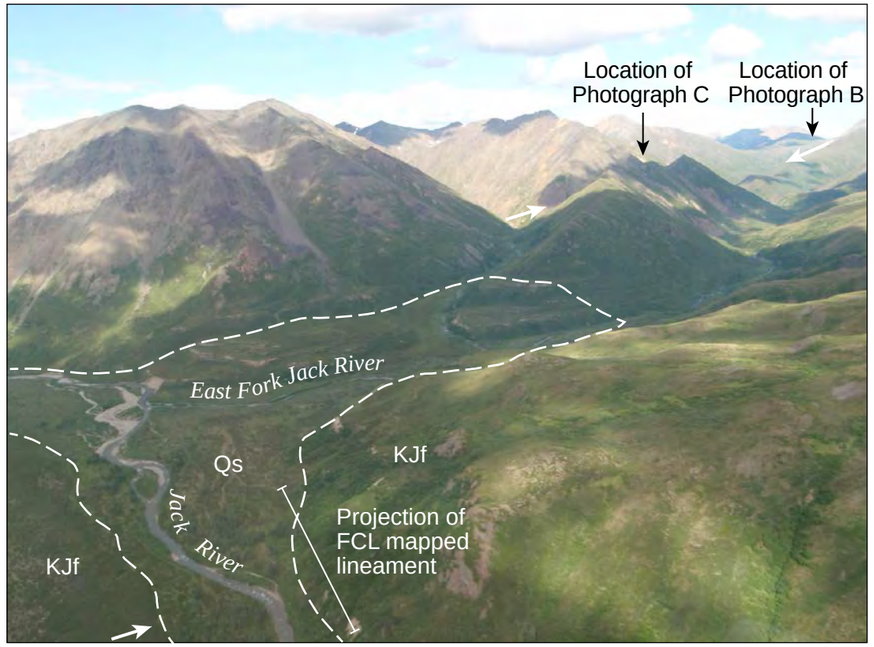


Notes: 1. See Figures A0.2, A0.3, A0.4, and A0.5 for explanation.
2. Geology by Wilson et al., 1998

TUGRO Date 02/11/15	STATE OF ALASKA ALASKA ENERGY AUTHORITY ALASKA ENERGY AUTHORITY	SUSITNA-WATANA HYDROELECTRIC PROJECT EXAMPLE OF LINEAMENT GROUP MAP DATA	FIGURE 2-2

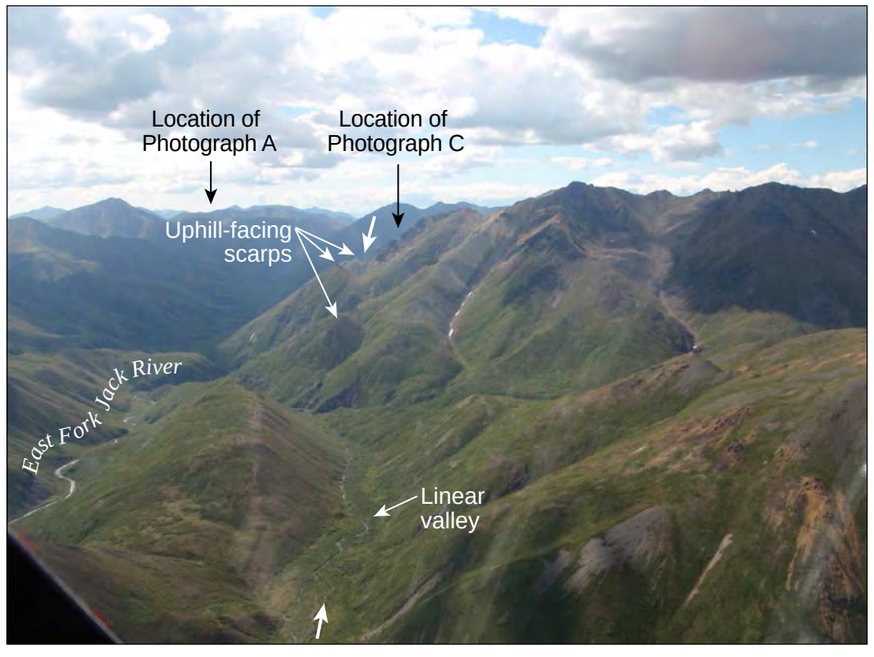
fwla-wc-file1/project/Projects/79_2000/79_218900_Alaska_Railbelt/05_Graphics/79_218900 Combined Crustal Source Surface Fault Rupture Evaluation

A)



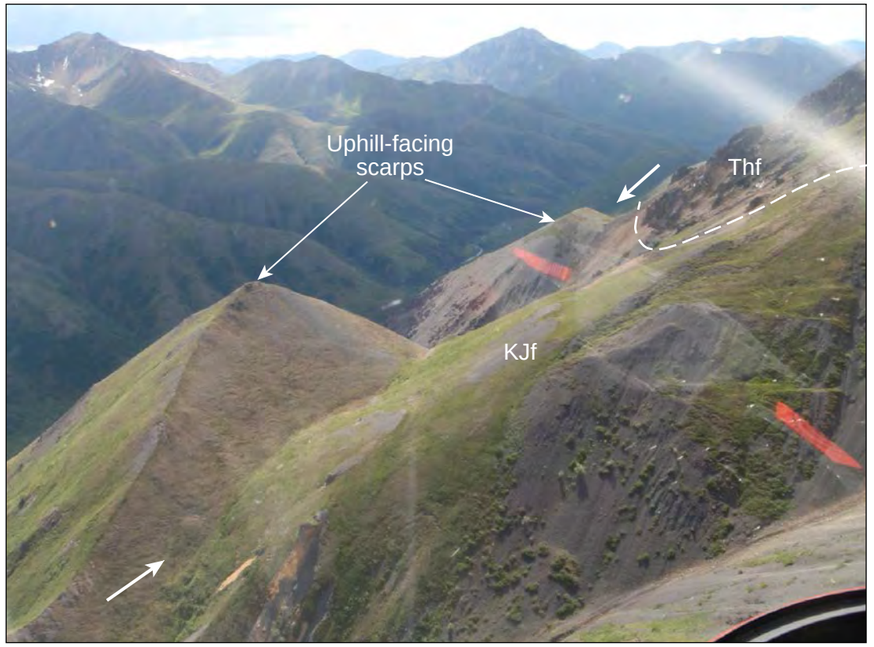
View looking northeast from location A towards the confluence of the Jack River and the East Fork Jack River. Arrows point along the alignment of mapped lineaments. Note absence of linear expression in Quaternary deposits.

B)



View looking southwest from location B along alignment of linear features. Arrows indicate the alignment of the mapped lineaments.

C)



View looking southwest from location C at a detailed view of aligned uphill-facing scarps. Note Thf contact is up-slope from the scarp in the distance.

Date 02/11/15	STATE OF ALASKA ALASKA ENERGY AUTHORITY	SUSITNA-WATANA HYDROELECTRIC PROJECT EXAMPLE OF LINEAMENT GROUP PHOTOGRAPHS	FIGURE 2-3

fwla-wc-file1/project/Projects/79_2000/79_218900_Alaska_RailbeltI05_Graphics/79_218900 Combined Crustal Source Surface Fault Rupture Evaluation

Attributes of lineaments mapped by FCL (2013) that apply to all figures and plates in Appendix A

Reconnaissance (INSAR)

1 - 5
10
77
88

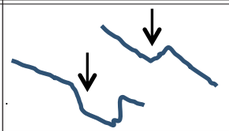
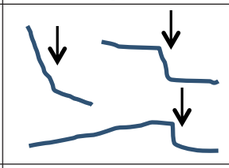
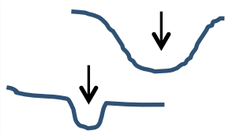
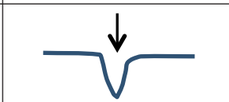
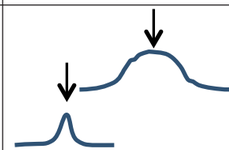
Detail (LiDAR)

1 - 5
10
77
88

Lineament Groups

17a — Lineament group mapped for this study coinciding with previously mapped fault or lineament

25 — No previously mapped fault or lineament coincides with lineament group

Attribute	Cross Section Morphology*	Description	Examples
1		Linear break-in-slope bisecting a planar surface	Uphill- or downhill-facing scarps, ateral moraines or kame deposits along lateral margins of valley glaciers
2		Abrupt changes in slope adjacent to otherwise relatively horizontal (and planar) surfaces	Linear range fronts, faceted ridges, terrace risers, steep downstream faces of rouche mountonees
3		Linear U-shaped trough	Glacial valleys, ice-scoured flutes, flood-scoured flutes,
4		Linear V-shaped trough	Active stream channels
5		Linear ridges	Drumlins, water-scoured terrain, eskers
6 (also 77)	n/a	A series of aligned features	Could include attributes #1 -5 above and/or aligned saddles, tonal lineaments, etc.
66	n/a	Data artifacts	Linear seams between data sets collected on different dates
88	n/a	A series of aligned features, which are too small to individually map at the given scale	Could include features with attributes #1-5 above and/or aligned saddles, tonal lineaments, etc.
99	n/a	A line which encloses a broad expanse of features all having the same orientation	An area of jointing or of glacial striae all having the same, parallel orientation
10	n/a	Anthropogenic lineaments	Roads, rail roads, power lines and other linear clearings, etc.

Notes: *Arrow points to location of the mapped feature.

Explanation for relevant geologic units of Williams and Galloway (1986) shown on Figure A20.5 and A23.1

Geologic Units

Bottom deposits of 914 - 975 m lake
Overprint denoting glacial drift that is mantled by bottom sediments of glacial lake that extended to 914 - 975 m abovemodern sea level, largely confined to middle Susitna valley, above ice dam below Fog Lake (off map) and apparently bounded on east and south side by glacier ice. Does not cover late(st) Wisconsin (last major) morainal systems. No shoreline features are mapped.

Bottom deposits intermediate (777 - 747) lake
Overprint denoting bottom deposits of a local lake that covered melting glacier ice between Tyone Lake and Lake Louise, apparently behind Tyone Spillway, and drained as the elevation of the spillway was cut down from 777 m to 747 m above sea level while stagnant ice was still in valley bottom.

Bottom deposits of last regional lake
Overprint denoting drape of bottom deposits over drift and thick lake sediments that persisted in Copper River drainage basin from just before deposition of Old Man moraines to a time when glaciers had retreated to within 16 to 24 km of present glaciers: older than 13,000 years.

Symbols

AA — Location and letter designation of radiocarbon-dated stratigraphic section in accompanying text.

Ice boundary, morainal ridge, kame terrace, delta, or other ice contact feature marking edge of glacier: hachures toward glacier.

Shoreline of regional lake: mapped for the lake in Copper River basin where at 747 m (maximum elevation); the elevation to which Tyone Spillway was eroded, and successively lower levels in the northern part of area between 747 m and 701 m above sea level. Lesser recessional shorelines mapped by Nichols and Yehle (1969) not shown.

Upper limit of post-glacial (Holocene, in part) shoreline of Tazlina Lake from elevation 564 m down to present lake level 544 m caused by lowering of lake as Tazlina River has deepened its canyon.

d — Delta of glacial lake, including those of modern glacial lakes such as Tazlina Lake.

Linear or drumlinoid feature, due to ice scour, direction of ice movement indicated by arrow.

Spillway for glacial meltwater, including that stored in large glacial lakes.

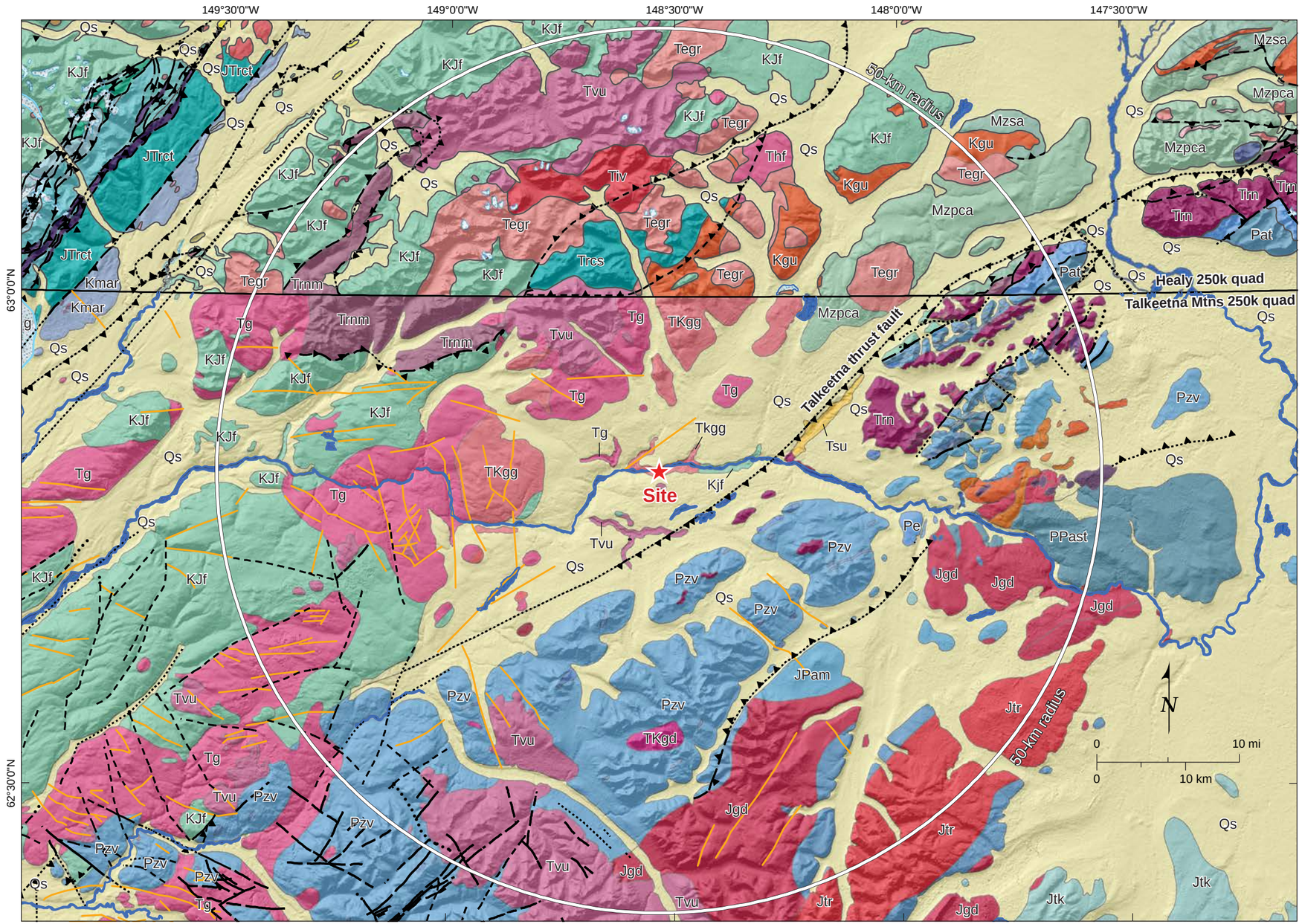
Contact between map units where not glacial boundary, most commonly between different levels of lake deposits.

D / U — Active (?) fault, lower Sonona Creek, offsetting unconsolidated deposits.

Location of selected erratic boulders, mountain top erratic stones transported by glaciers, e.g. Sheep Mountain; many occurrences on mountains lower than 1829 m not shown.

FUGRO Date 02/11/15	STATE OF ALASKA ALASKA ENERGY AUTHORITY ALASKA ENERGY AUTHORITY	SUSITNA-WATANA HYDROELECTRIC PROJECT EXAMPLE OF STRIP MAPS EXPLANATION	FIGURE 2-4

fwla-wc-file1/project/Projects/79_2000/79_218900_Alaska_Railbelt/05_Graphics/79_218900 Combined Crustal Source Surface Fault Rupture Evaluation



Geology from Wilson et al., 1998 (USGS Open-file Report 98-133 Healy and Talkeetna Mountains 250,000 quadrangles)

See Figure 2-5B for map legend

FUGRO Date 02/11/15	STATE OF ALASKA ALASKA ENERGY AUTHORITY ALASKA ENERGY AUTHORITY	SUSITNA-WATANA HYDROELECTRIC PROJECT SITE REGION GEOLOGY FROM TM-8	FIGURE 2-5A

fwla-wc-file1/project/Projects/79_2000/79_218900_Alaska_Railbelt/05_Graphics/79_218900 Combined Crustal Source Surface Fault Rupture Evaluation

g Ice fields or glaciers

QUATERNARY DESPOSITS

Qs Surfical deposits, undifferentiated

TERTIARY ROCKS
Sedimentary Rocks

Tsu Sedimentary rocks, unidivided

Tn Nenana Gravel

Tcb Coal-bearing rocks

Tfv Fluviatile sedimentary rocks and subordinate volcanic rocks

Igneous Rocks
Volcanic and Hypabyssal Rocks

Tvu Tertiary volcanic rocks, undivided

Thf Hypabyssal felsic and intermediate intrusions

Thm Hypabyssal mafic intrusions

Intrusive Rocks

Tiv Granite and volcanic rocks, undivided

EOCENE

Tegr Granite and granodiorite

PALEOCENE

Tg Granitic rocks

TERTIARY AND/OR CRETACEOUS
Igneous Rocks
Intrusive Rocks

TKg Granitic rocks

TKgd Granodiorite, tonalite and monzonite dikes, and stocks

Metamorphic Rocks

TKgg Gneissose granitic rocks

UNDIVIDED MESOZOIC ROCKS
METAMORPHIC ROCKS

Mzsa Schist and amphibolite

Mzpca Phyllite, pelitic schist, calc-schist, and amphibolite of the McClaren metamorphic belt

CRETACEOUS
Melange

Kmar Melanges of the Alaska Range

TrSl Limestone blocks

Igneous Rocks
Volcanic and hypabyssal rocks

Ksva Andesite subvolcanic rocks

Intrusive Rocks

Kgu Granitic rocks

Kgk/Keg Granitic rocks younger than 85 Ma

Kmum Ultramafic rocks

CRETACEOUS AND/OR JURASSIC
Sedimentary Rocks

KJs Argillite, chert, sandstone, and limestone

KJf Kahiltna flysch sequence

KJcg Conglomerate, sandstone, siltstone, shale, and volcanic rocks

JURASSIC
Igneous Rocks

Jmu Mafic and ultramafic rocks

Jgd Alaska-Aleutian Range and Chitina Valley batholiths, undifferentiated

Metamorphic Rocks

JPaur Uranatina metaplutonic complex

Sedimentary Rocks

JTrlm Limestone and marble

Jtk Talkeetna Formation

TRIASSIC
Sedimentary Rocks

Trcs Calcareous sedimentary rocks

Trk Kamishak limestone

Plutonic Rocks

Trgb Gabbro, diabase, and metagabbro

Volcanic Rocks

Trn Nikolai Greenstone and related similar rocks

Metamorphic Rocks

Trnm Metavolcanics and associated metasedimentary rocks

MESOZOIC AND PALEOZOIC
Assemblages and Sequences

JTrsu Red and brown sedimentary rocks and basalt

JTrct Crystal tuff, argillite, chert, graywacke, and limestone

Trr Red beds

TrDv Volcanic and sedimentary rocks

Dmgs Serpentinite, basalt, chert and gabbro

PALEOZOIC
Assemblages and Sequences
(Skolai Group)

Pe Eagle Creek Formation

Pzv Station Creek and Slana Spur Fm., and equivalent rocks

Pat Teteina Volcanics

Jpmu/Jpam PPast Streina metamorphic complex

JPzmb Marble

Stratigraphic contact

Shoreline or riverbank

Ice contact (glacier limit)

Lineament

Fault - certain

Fault - approximate

Fault - inferred

Fault - concealed

Thrust fault - certain

Thrust fault - approximate

Thrust fault - inferred

Thrust fault - concealed

Geology from Wilson et al., 1998 (USGS Open-file Report 98-133)

fwla-wc-file1/project/Projects/79_2000/79_218900_Alaska_Railbelt/05_Graphics/79_218900 Combined Crustal Source Surface Fault Rupture Evaluation

FUGRO

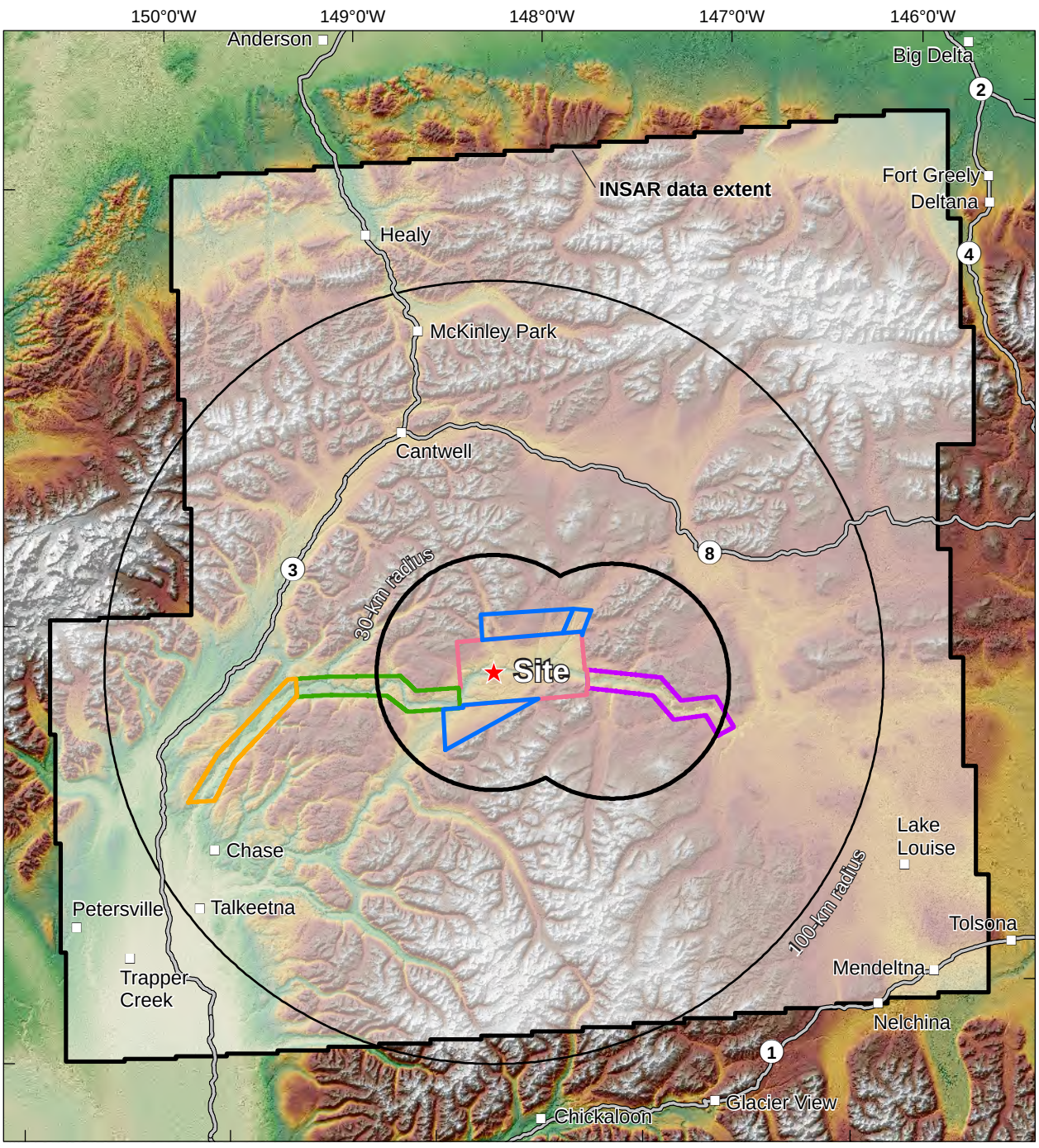
Date 02/11/15

STATE OF ALASKA
ALASKA ENERGY AUTHORITY
ALASKA ENERGY AUTHORITY

SUSITNA-WATANA HYDROELECTRIC PROJECT

SITE REGION
GEOLOGY LEGEND

FIGURE
2-5B



Base data from ASTER Global Digital Elevation Model (ASTER GDEM is a product of METI and NASA)

Explanation

Extent of INSAR data

Extent of LiDAR Data

- Area A
- Area B
- Area C
- Area D
- Area E

Note: Extent of Landsat imagery and ASTER GDEM elevation data are greater than the area shown in figure.

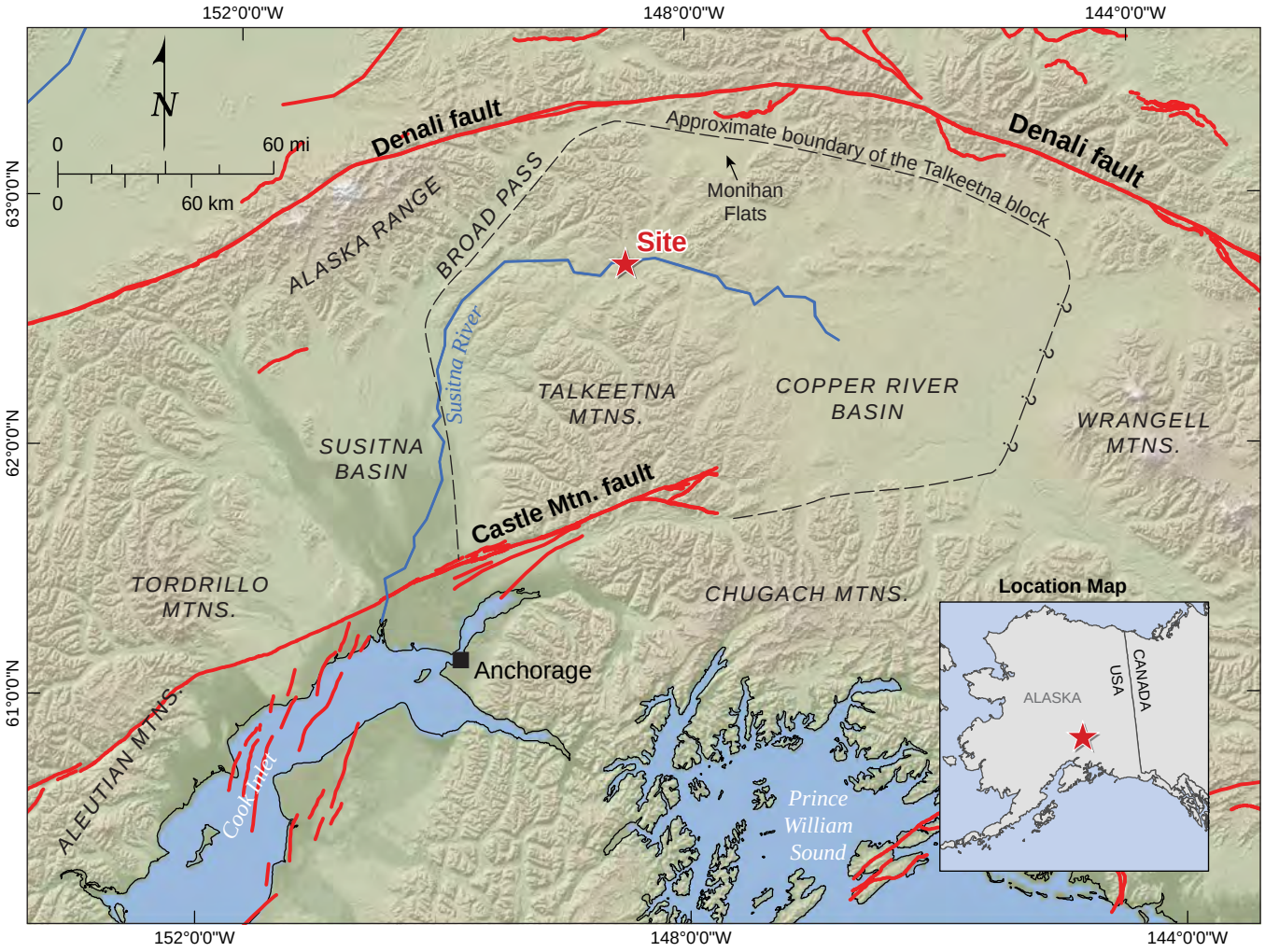
N

0 20 mi

0 40 km

FUGRO Date 02/11/15	STATE OF ALASKA ALASKA ENERGY AUTHORITY ALASKA ENERGY AUTHORITY	SUSITNA-WATANA HYDROELECTRIC PROJECT EXTENT OF GEOSPATIAL DATA	FIGURE 2-6

fwla-wc-file1/project/Projects/79_2000/79_218900_Alaska_Railbelt/05_Graphics/79_218900 Combined Crustal Source Surface Fault Rupture Evaluation



Explanation

Quaternary fault (Koehler et al., 2012)

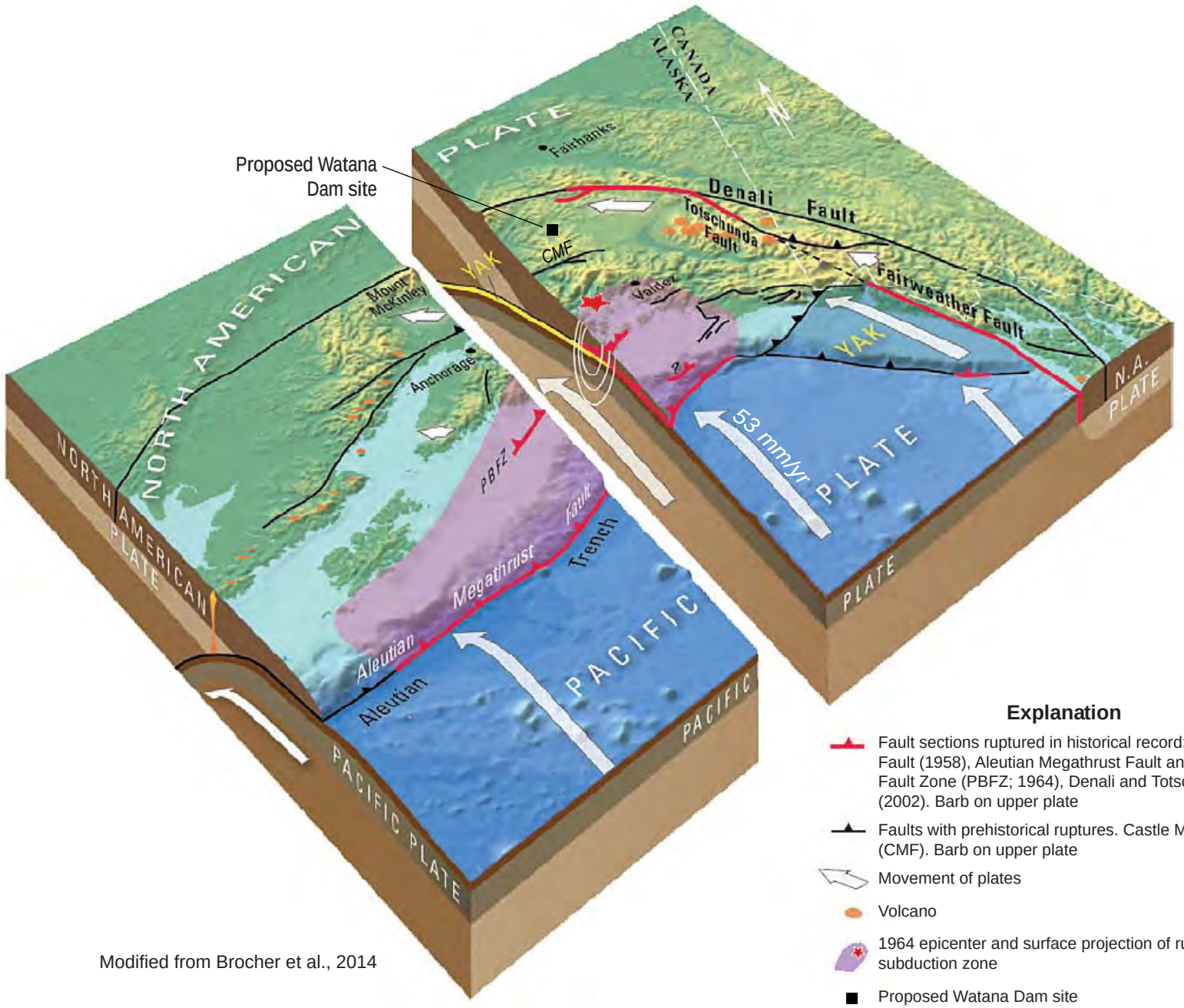
Date 02/11/15

STATE OF ALASKA
ALASKA ENERGY AUTHORITY

SUSITNA-WATANA HYDROELECTRIC PROJECT

BLOCK DIAGRAM OF SOUTH-CENTRAL ALASKA SHOWING TECTONIC SETTING OF THE 1964 EARTHQUAKE

FIGURE 3-2



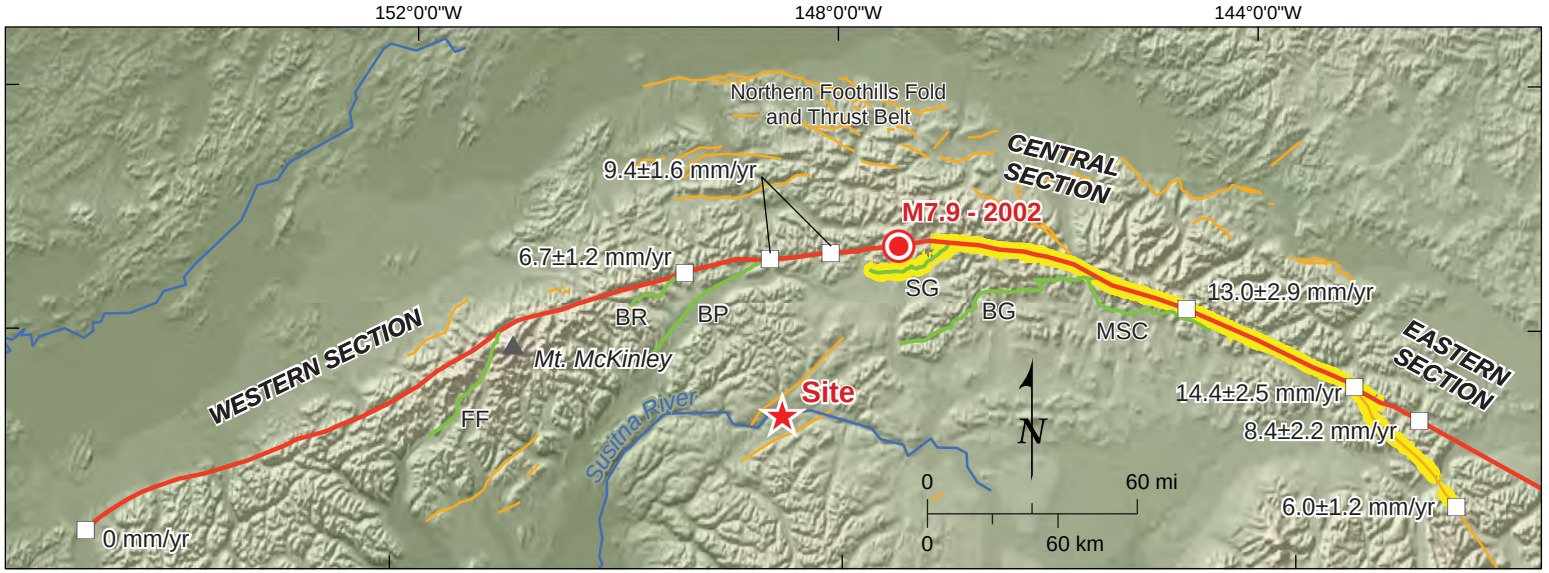
Date 02/11/15

STATE OF ALASKA
ALASKA ENERGY AUTHORITY

SUSITNA-WATANA HYDROELECTRIC PROJECT

DENALI FAULT CHARACTERIZATION

FIGURE 3-3



Explanation

Symbols

- Earthquake epicenter
- Slip rate (sources discussed in text)

Faults

- Denali fault
- 2002 Denali fault rupture, Haeussler (2008)
- Southern Denali faults
- Other fault or feature

Abbreviations

BR - Bull River fault
BP - Broad Pass fault
BG - Broxson Gulch fault
FF - Foraker fault
MSC - McCallum-Slate Creek fault
SG - Susitna Glacier fault

fwla-wc-file1/project/Projects/79_2000/79_218900_Alaska_Railbelt/05_Graphics/79_218900 Combined Crustal Source Surface Fault Rupture Evaluation

Date 02/11/15

FUGRO

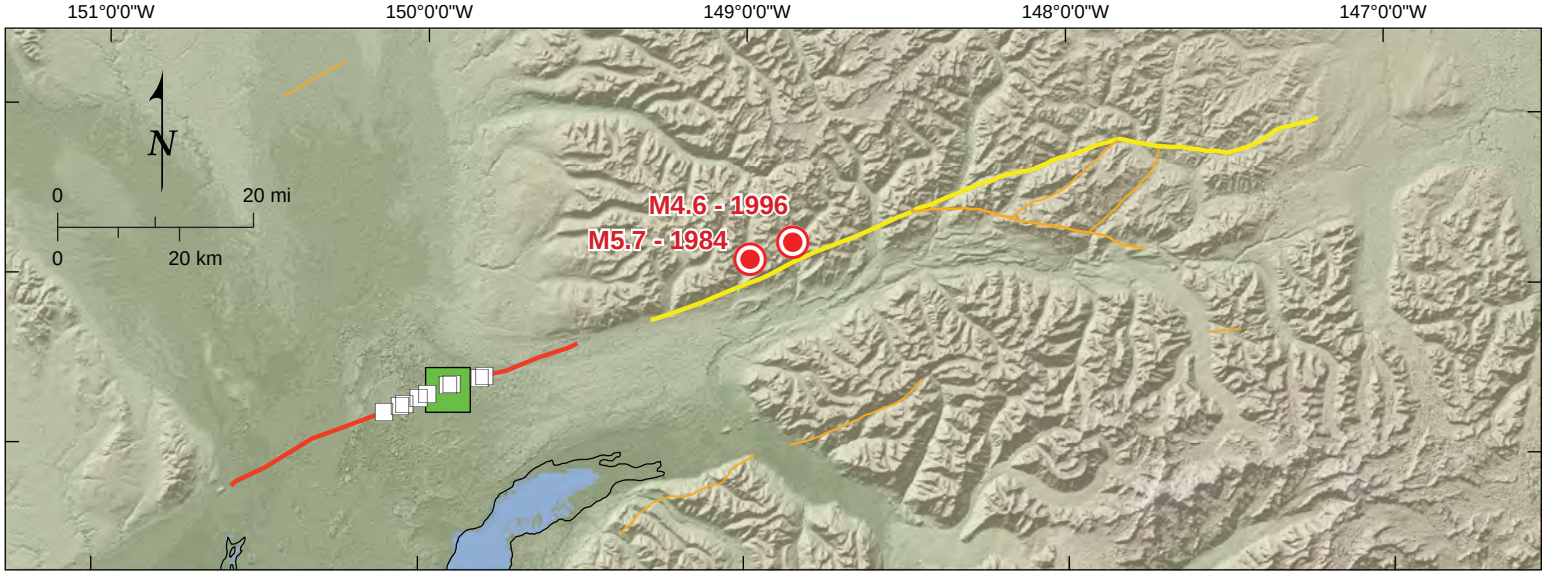
STATE OF ALASKA
ALASKA ENERGY AUTHORITY

ALASKA ENERGY AUTHORITY

SUSITNA-WATANA HYDROELECTRIC PROJECT

CASTLE MOUNTAIN FAULT CHARACTERIZATION

FIGURE 3-4



Explanation

- Earthquake epicenter

Paleoseismic Investigations

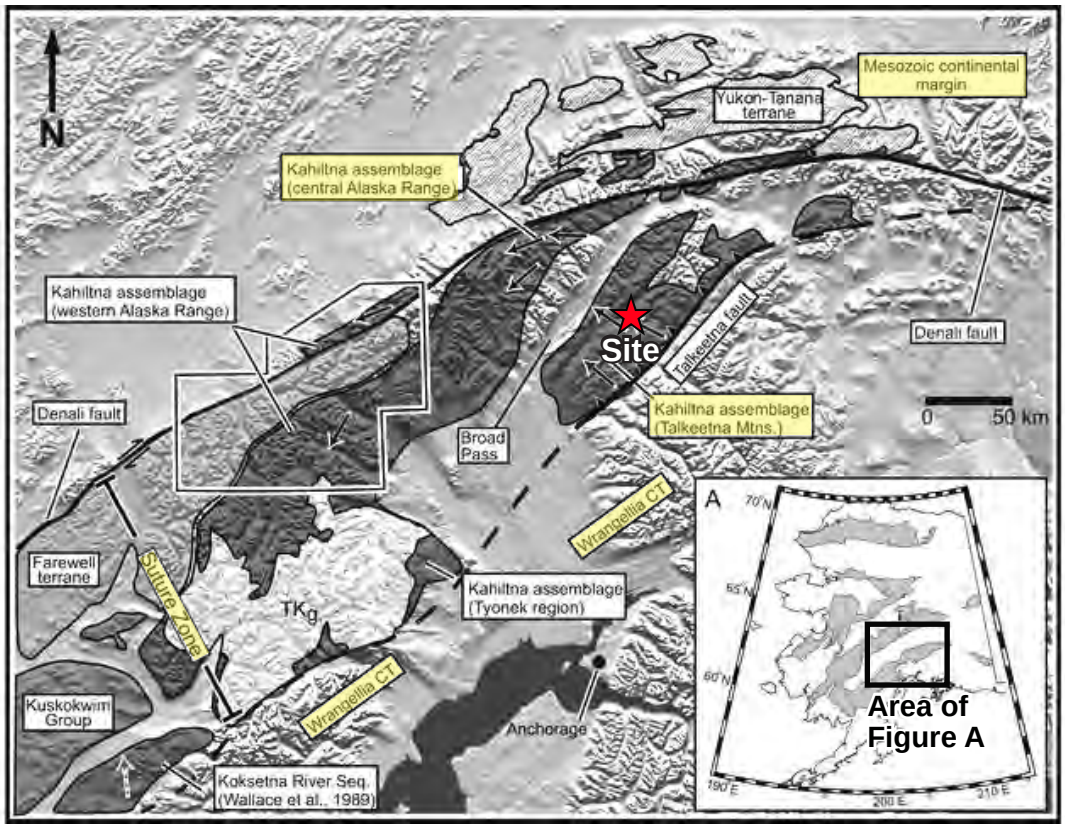
- Hausler et al., 2002
- Willis et al., 2007

Faults

- Castle Mtn. fault, western segment
- Castle Mtn. fault, eastern segment and Caribou fault
- Other fault

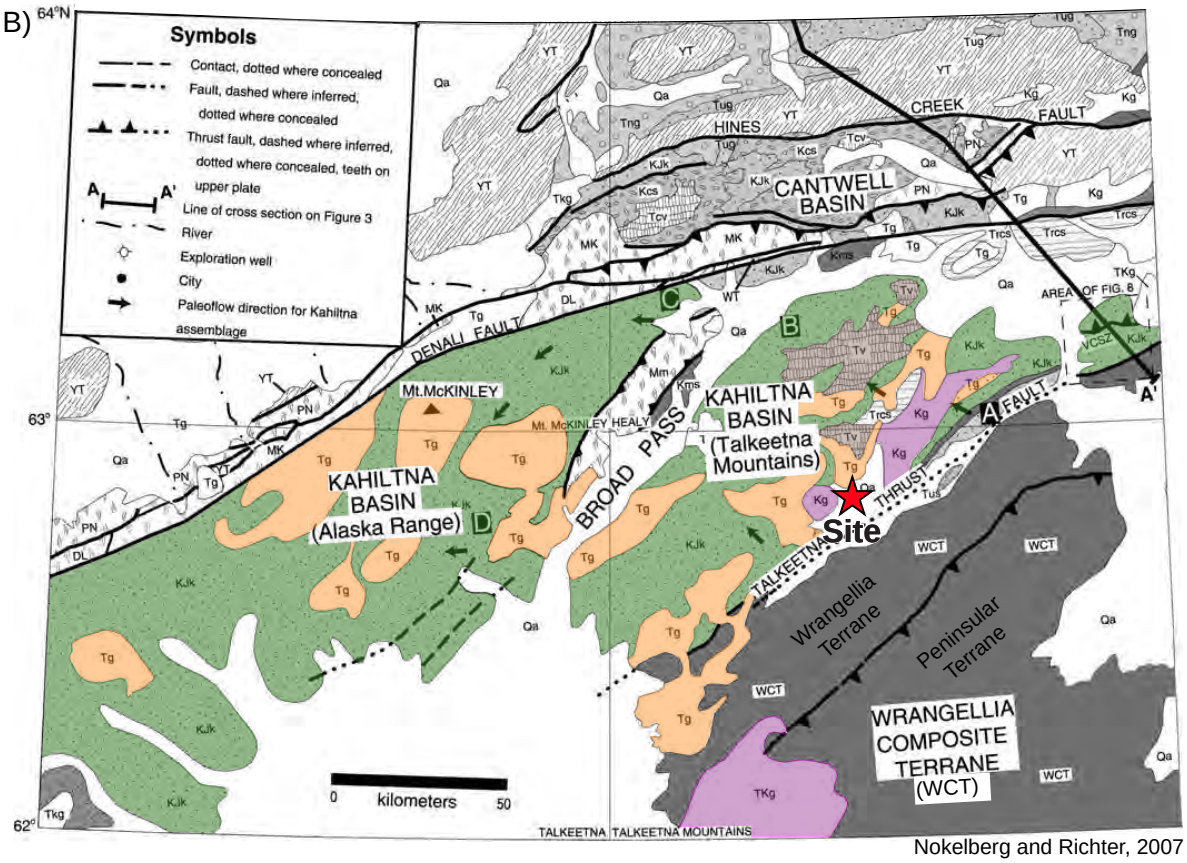
Note: Site is ~100 km to the north

A)



Kalbas et al., 2007

B)



Nokelberg and Richter, 2007

KJK	Late Jurassic – early Cretaceous Kahiltna assemblage	Tg	Tertiary plutonic intrusions
TKg	Cretaceous – Tertiary plutonic intrusions	Tv	Tertiary volcanics

fwla-wc-file1/project/Projects/79_2000/79_218900_Alaska_Railbelt/05_Graphics/79_218900 Combined Crustal Source Surface Fault Rupture Evaluation

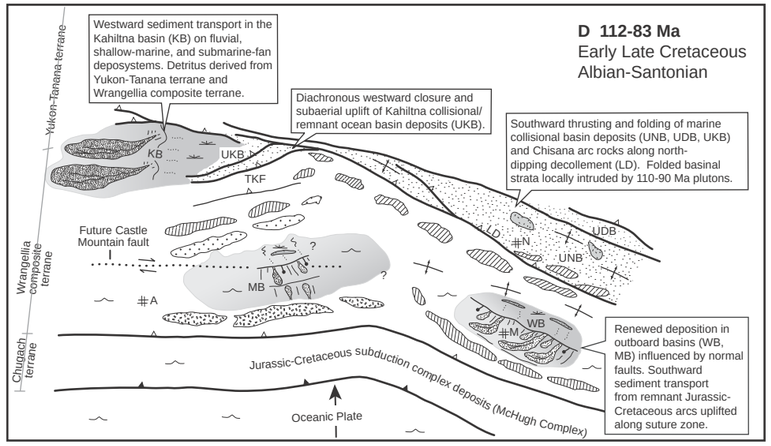
Date 02/11/15

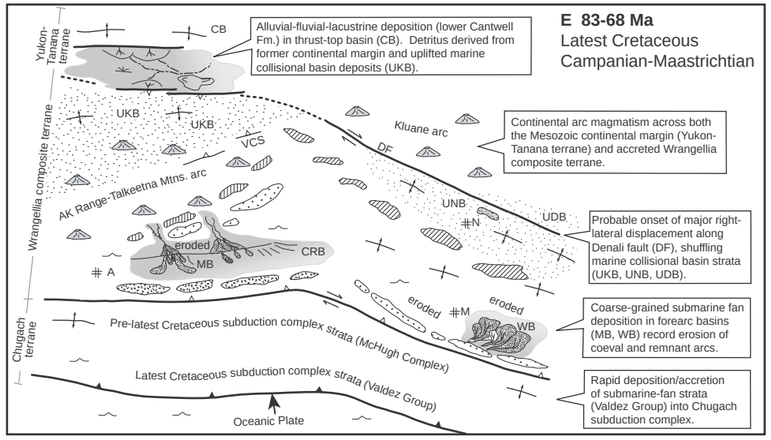
STATE OF ALASKA
ALASKA ENERGY AUTHORITY

SUSITNA-WATANA HYDROELECTRIC PROJECT

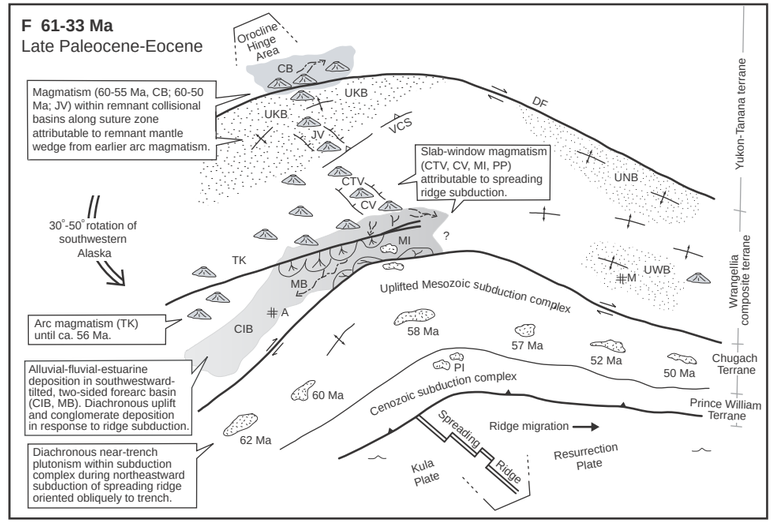
REGIONAL TECTONIC TERRANES AND BASINS

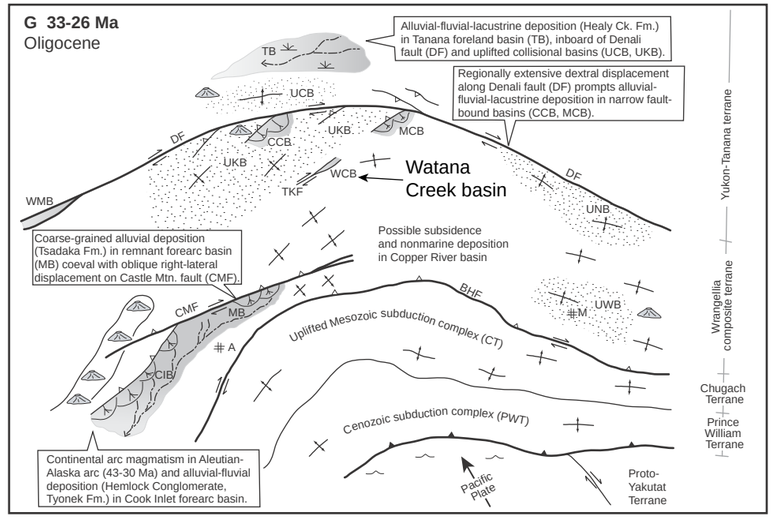
FIGURE
3-5

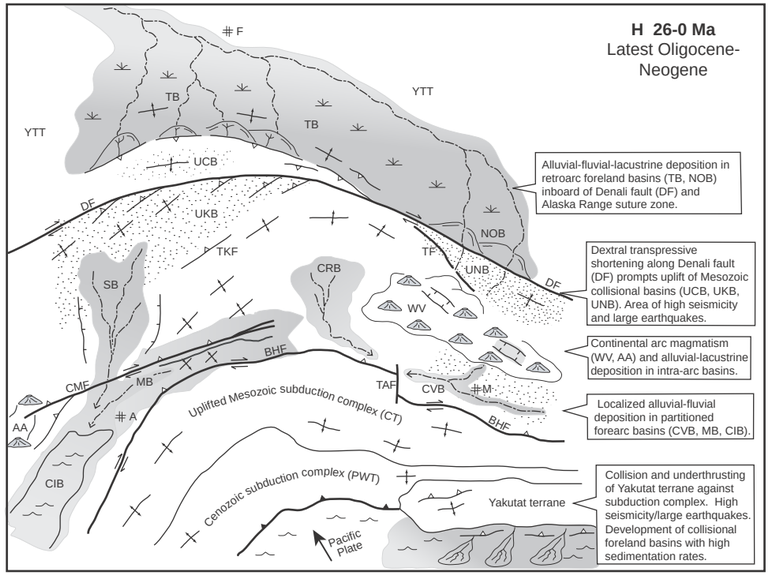




Trop and Ridgeway, 2007.







Magmatism

- Locus of active volcanism
- Paleocene-Eocene intrusives
- Mid-Cretaceous Chisana arc rocks
- Upper Jurassic Talkeetna-Chitina arc rocks
- Middle Jurassic Talkeetna arc rocks
- Lower Jurassic Talkeetna arc rocks

Deformational Features

- Active subduction zone (barb on downgoing plate)
- Active crustal shortening (barb on thrust sheets)
- Regional topographic uplifts via folding/faulting
- Active crustal extension via normal faults
- Regional dextral strike-slip fault
- Strike-slip movement away (⊗) or toward (⊙)

Depositional Features

- Alluvial
- Fluvial
- Lacustrine
- Fan-Delta/ Prodelta Slope
- Marine Shelf
- Submarine Fans
- Marine environments
- Active depositional basin
- Uplifted basinal strata

Explanation

Geographic references

- ╪A - Anchorage
- ╪F - Fairbanks
- ╪M - McCarthy
- ╪N - Nabesna

Terranes

AT - Alexander
CT - Chugach
PT - Peninsular
PWT - Prince William
WT - Wrangellia
YT - Yakutat
YTT - Yukon-Tanana

Outboard Margin Basins

CIB - Cook Inlet
CRB - Copper River
CVB - Chitina Valley
MB - Matanuska - S. Talkeetna Mtns.
SB - Susitna
WB - Wrangell Mountains
(Prefixed with U=Uplifted)
(Prefixed with F=Future position)

Volcanic Fields, Plutonic Belts

AA - Aleutian-Alaska arc
CV - Caribou Creek volcanics
CTV - Central Talkeetna Mtns. volcanics
JV - Jack River volcanics/plutons
MI - Matanuska Valley intrusives
PI - Prince William Sound intrusives
TK - Talkeetna Mountains-Kluane arc
WV - Wrangell volcanic field

Inboard Margin Basins

CB - Cantwell
CCB - Colorado Creek
DB - Dezadeash
KB - Kahiltna
MCB - MacCallum Creek
NOB - Northway
NB - Nutzotin
TB - Tanana
WCB - Watana Creek
(Prefixed with U=Uplifted)
(Prefixed with F=Future position)

Faults, Shear Zones

BHF - Border Ranges-Hanagita fault
BLF - Bruin Bay-Little Oshetna fault
CMF - Castle Mountain fault
CTB - Chitina thrust belt
DF - Denali fault
HCF - Hines Creek fault
LD - Lost Creek decollement
TF - Totschunda fault
TAF - Taral fault
TKF - Talkeetna fault
VCS - Valdez Creek shear zone

fwla-wc-file1/project/Projects/79_2000/79_218900_Alaska_Railbelt/05_Graphics/79_218900 Combined Crustal Source Surface Fault Rupture Evaluation

FUGRO
Date 02/11/15

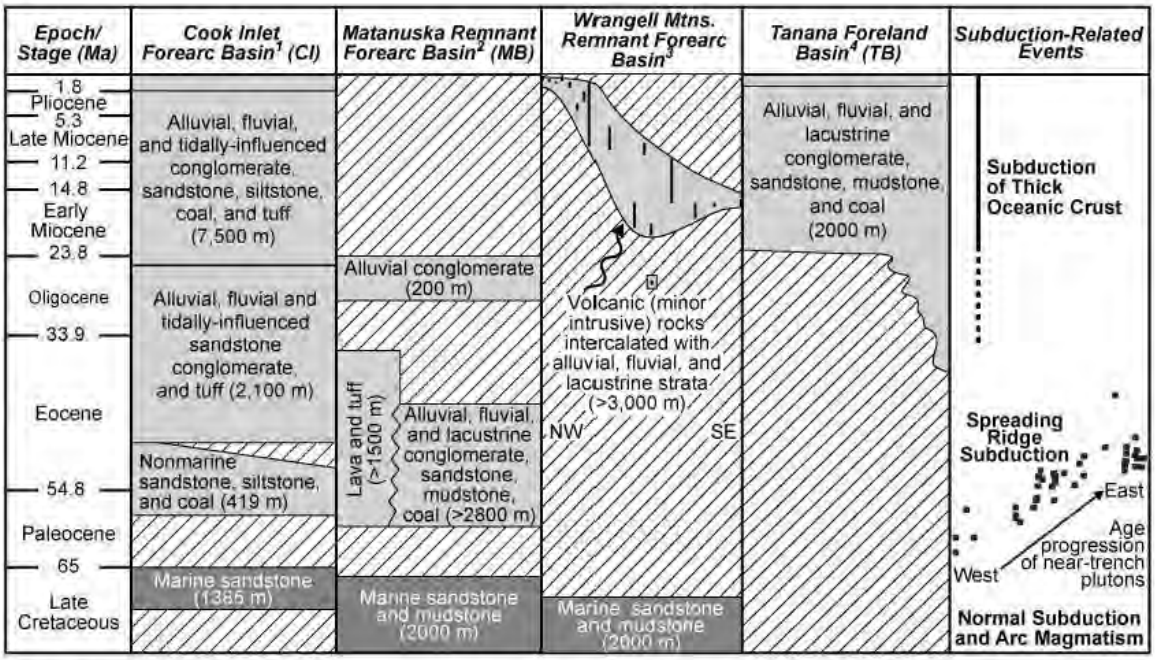
STATE OF ALASKA
ALASKA ENERGY AUTHORITY
ALASKA ENERGY AUTHORITY

SUSITNA-WATANA HYDROELECTRIC PROJECT

SCHEMATIC EVOLUTION OF SOUTH-CENTRAL ALASKA

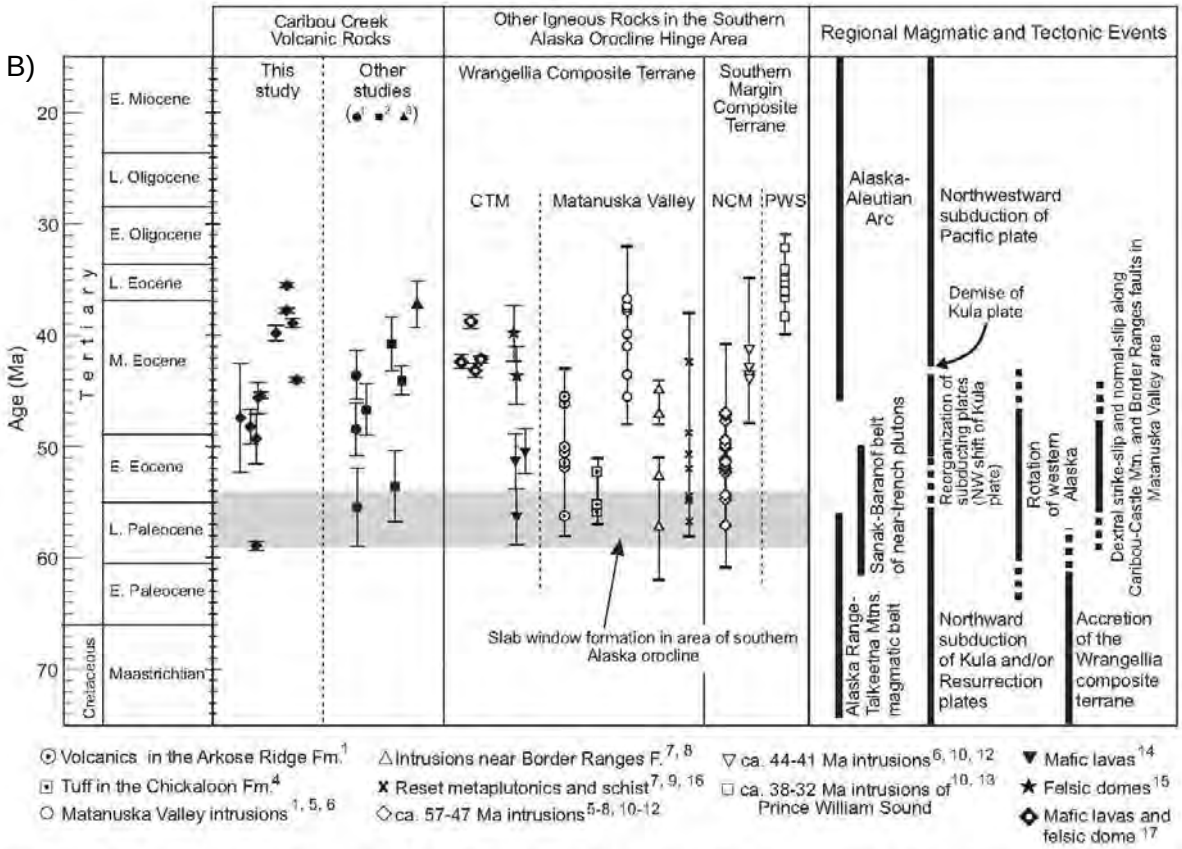
FIGURE
3-6

A)



From Ridgeway et al., 2011

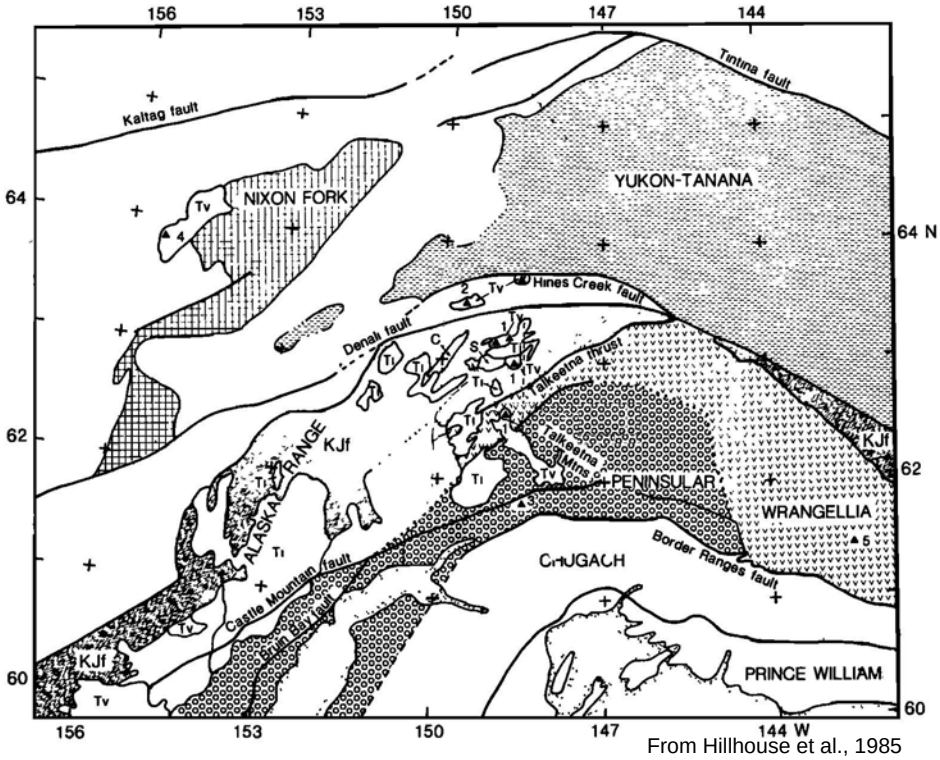
B)



From Cole et al., 2007

Age-event diagram showing radiometric ages of volcanic rocks in the Caribou Creek volcanic field.

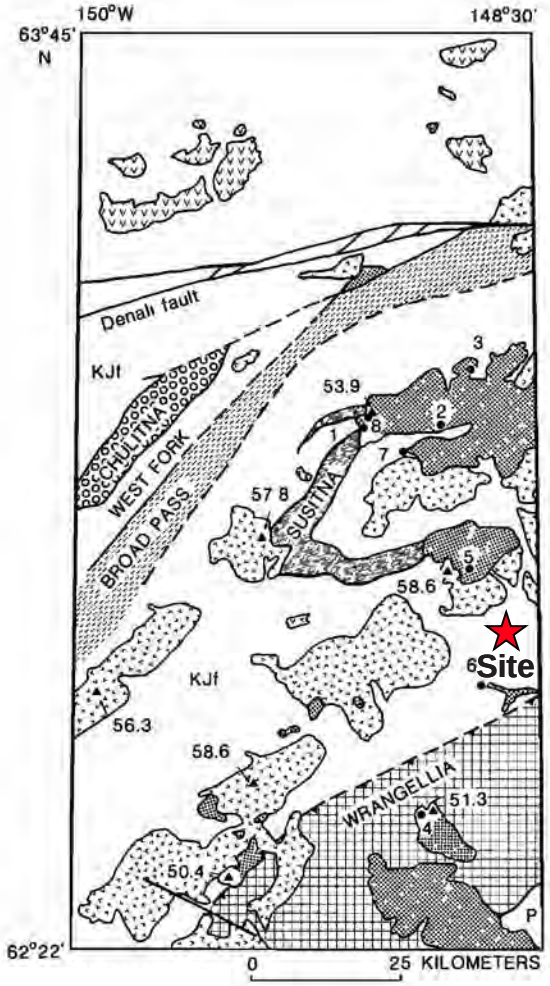
A)



From Hillhouse et al., 1985

Map of selected terranes of south-central Alaska.

B)



From Hillhouse et al., 1985

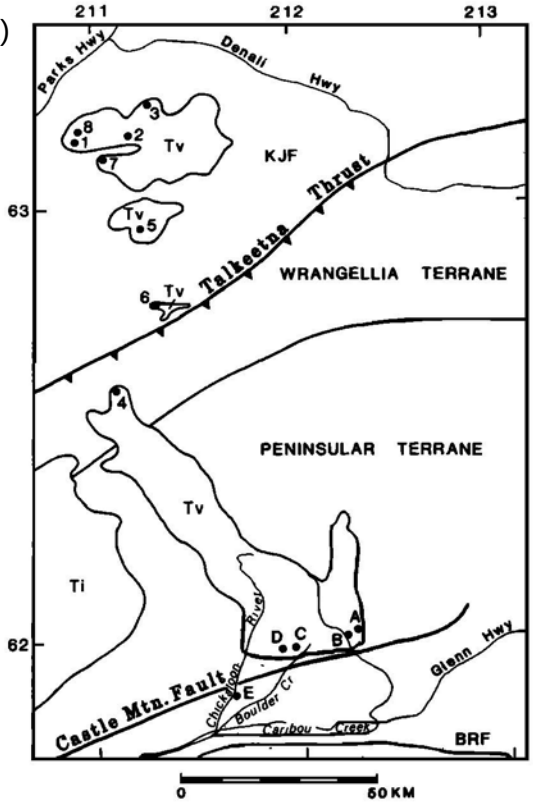
N

Outline geologic map with selected terranes showing localities dated by potassium-argon (triangles) and paleomagnetic sample sites (dots).

fwla-wc-file1/project/Projects/79_2000/79_218900_Alaska_Railbelt/05_Graphics/79_218900 Combined Crustal Source Surface Fault Rupture Evaluation

FUGRO Date 02/11/15	STATE OF ALASKA ALASKA ENERGY AUTHORITY ALASKA ENERGY AUTHORITY	SUSITNA-WATANA HYDROELECTRIC PROJECT MAP OF TERRANES, POTASSIUM-ARGON DATES, AND PALEOMAGNETIC SAMPLES	FIGURE 3-8

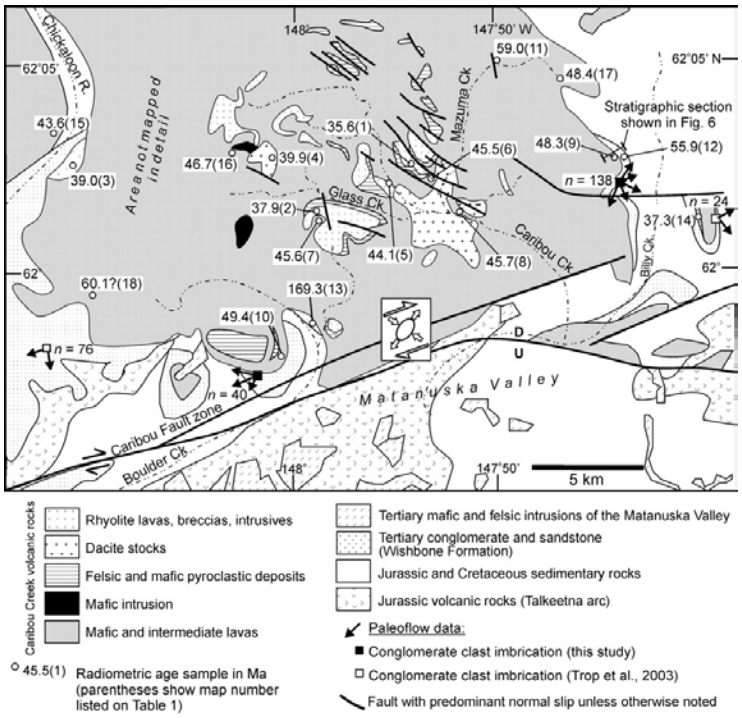
A)



From Panuska et al., 1990

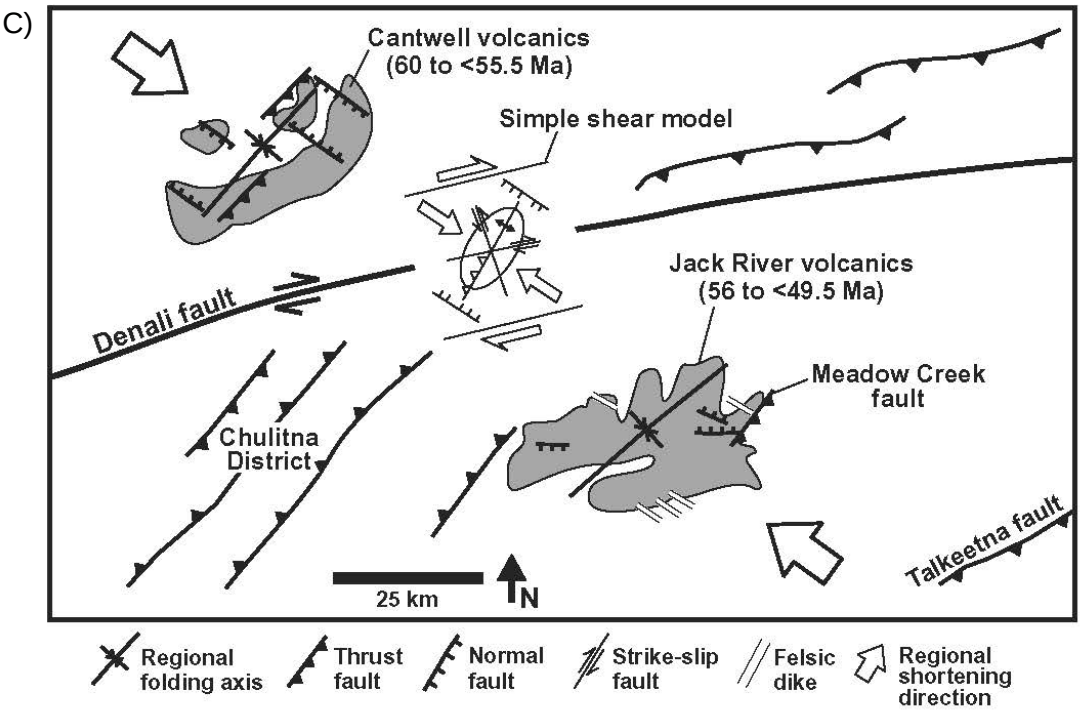
Sample locality map for Eocene volcanic rocks in the Talkeetna Mountains.

B)



Simplified geologic map of the Caribou Creek volcanic field.

C)



Synthesis of deformation pattern in the Jack River and Cantwell Formation volcanic rocks and surrounding regions (Cole et al., 2007).

fwla-wc-file1/project/Projects/79_2000/79_218900_Alaska_Railbelt/05_Graphics/79_218900 Combined Crustal Source Surface Fault Rupture Evaluation

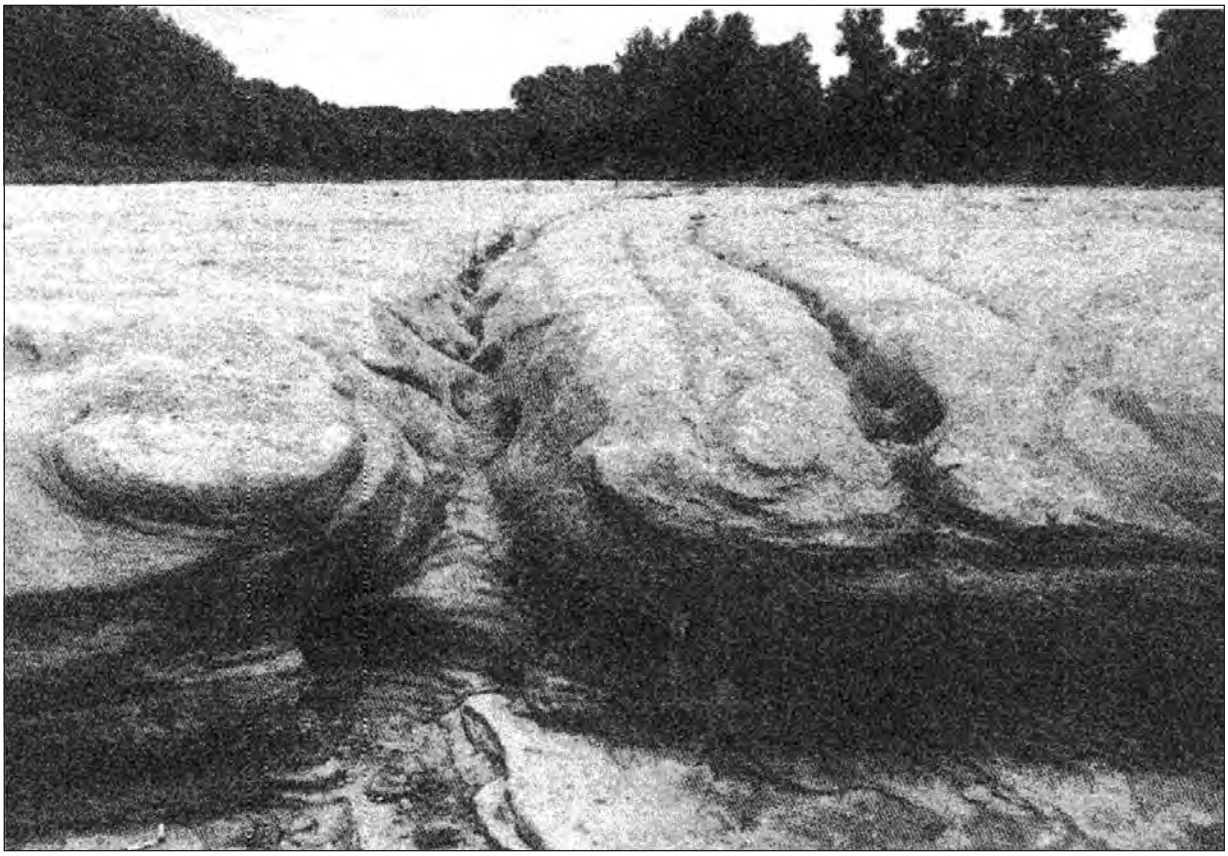
FUGRO
Date 02/11/15

STATE OF ALASKA
ALASKA ENERGY AUTHORITY
ALASKA ENERGY AUTHORITY

SUSITNA-WATANA HYDROELECTRIC PROJECT

GEOLOGIC AND PALEOMAGNETIC EVIDENCE FOR SIMPLE SHEAR IN THE TALKEETNA RANGE

FIGURE
3-9



From Gray, 2001.

Note linearity of channels, lack of contributing watershed area, and steep sidewalls.



From http://www.landforms.ca/cairngarms/meltwater%20channels.htm, last accessed 1 October, 2013.

These sub-ice channels are cut through interfluves, seen as notches on the skyline.



Source: http://www.graenslandet.se/en/traces-of-the-ice-age/meltwater-ridges-meltwater-channels-or-glacial-grooves

Sub-ice channels at Grövelsjön.

FUGRO Date 02/11/15	STATE OF ALASKA ALASKA ENERGY AUTHORITY ALASKA ENERGY AUTHORITY	SUSITNA-WATANA HYDROELECTRIC PROJECT EXAMPLE SUB-ICE CHANNELS, GREENLAND	FIGURE 3-11

fwla-wc-file1/project/Projects/79_2000/79_218900_Alaska_Railbelt/05_Graphics/79_218900 Combined Crustal Source Surface Fault Rupture Evaluation



White arrows denote locations of linear to sub-linear incised creeks that enter at high angles to Seneca Valley and Lake.

fwla-wc-file1/project/Projects/79_2000/79_218900_Alaska_Railbelt/05_Graphics/79_218900 Combined Crustal Source Surface Fault Rupture Evaluation

150°0'W
148°0'W
146°0'W
63°0'N
62°0'N
9 samples; dates ranging from 2.5±0.3 to 146.4±10.4 ka
Denali fault
5 samples; dates ranging from 14.9±1.6 to 16.0±1.7 ka
2.1±0.2 ka
2.4±0.4 ka
Cantwell
8 samples; dates ranging from 11.2±1.4 to 16.7±4.1 ka
3 samples; dates ranging from 11.8±1.9 to 12.5±1.9 ka
6 samples; dates ranging from 1.2±0.2 to 31.0±3.5 ka
Alaska Range
Northern Talkeetna Mountains
Susitna River
Site
Watana Creek
Copper River Basin
30-km radius
100-km radius
Talkeetna
Talkeetna Mountains
N
0
10 mi
0
20 km
3
8
1

Base data from ASTER Global Digital Elevation Model (ASTER GDEM is a product of METI and NASA)

Explanation

Alaska Paleo-Glacier Atlas v. 2 Data (Kaufman et al., 2011)

Limit of late Wisconsin glaciers

Cosmogenic Exposure Sample Locations

- Dortch et al., 2010a
- Dortch et al., 2010b
- Matmon et al., 2006

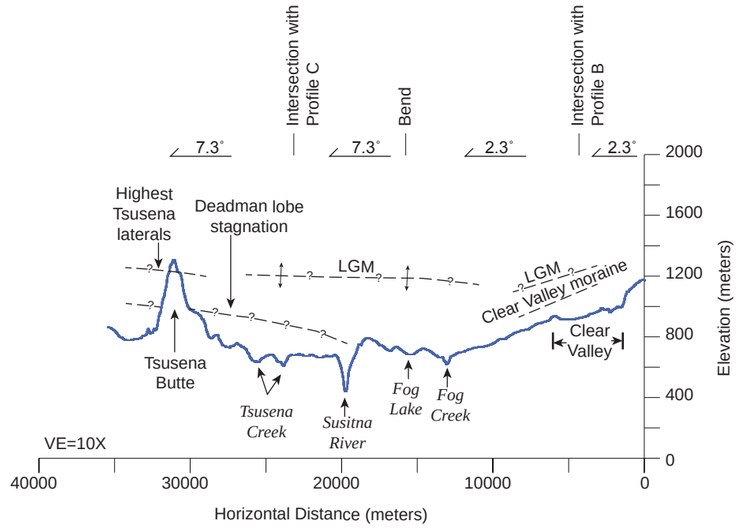
Glacial Lake Elevation Extents (meters)

- 800 m
- 975 m

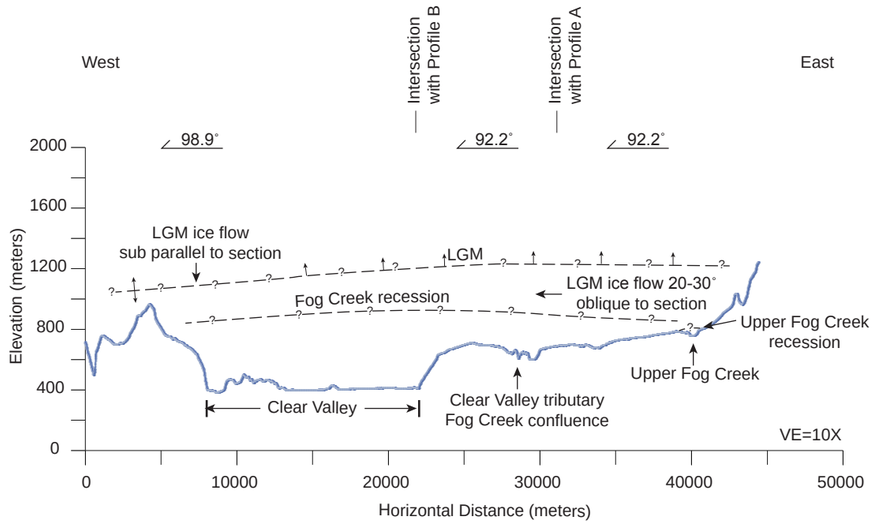
Quaternary fault (Koehler et al., 2012)

fwia-wc-file1/project/Projects/79_2000/79_218900_Alaska_Railbelt/05_Graphics/79_218900 Combined Crustal Source Surface Fault Rupture Evaluation

FUGRO Date 02/11/15	STATE OF ALASKA ALASKA ENERGY AUTHORITY ALASKA ENERGY AUTHORITY	SUSITNA-WATANA HYDROELECTRIC PROJECT LATE WISCONSIN GLACIAL LIMITS AND AGE CONTROL	FIGURE 3-13



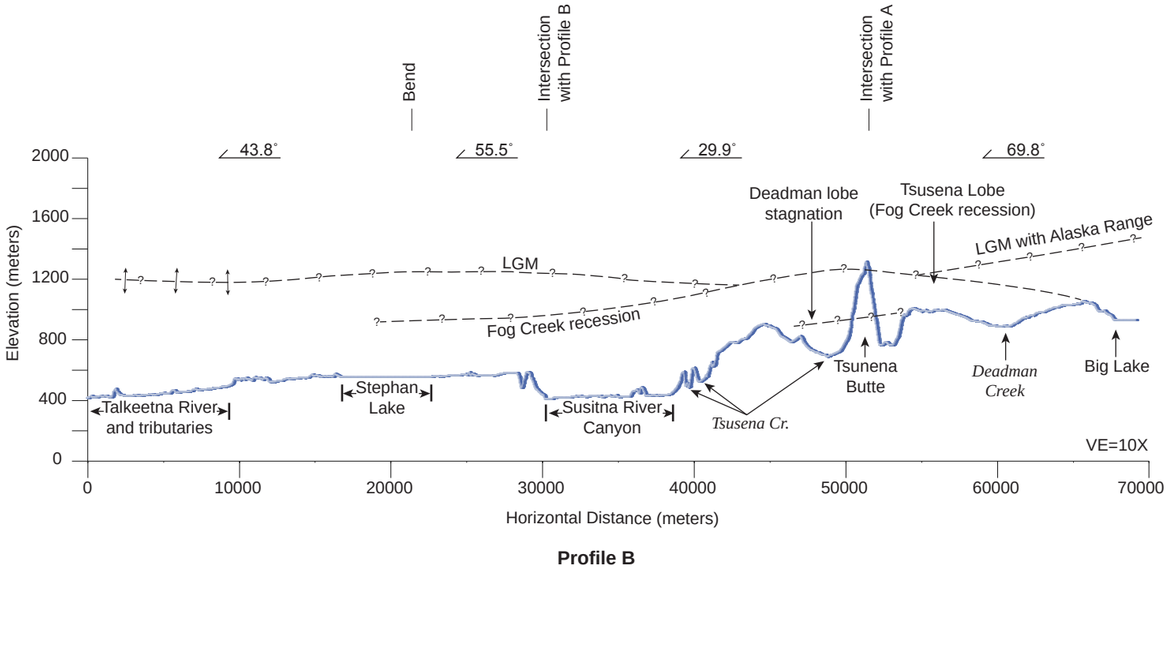
Profile A



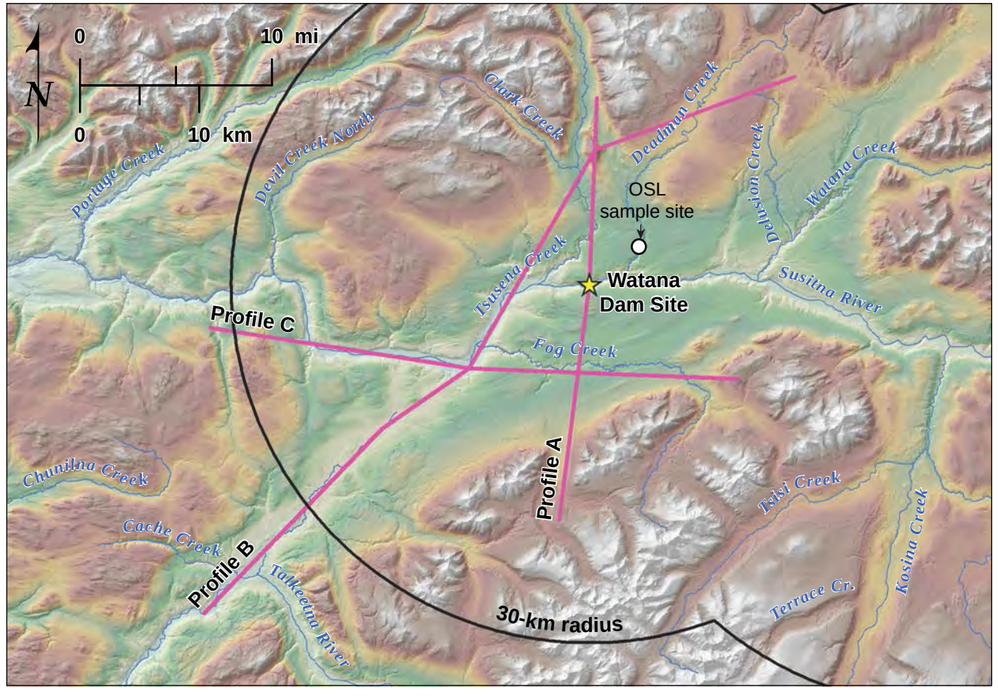
Profile C

Explanation

98.9° Bearing

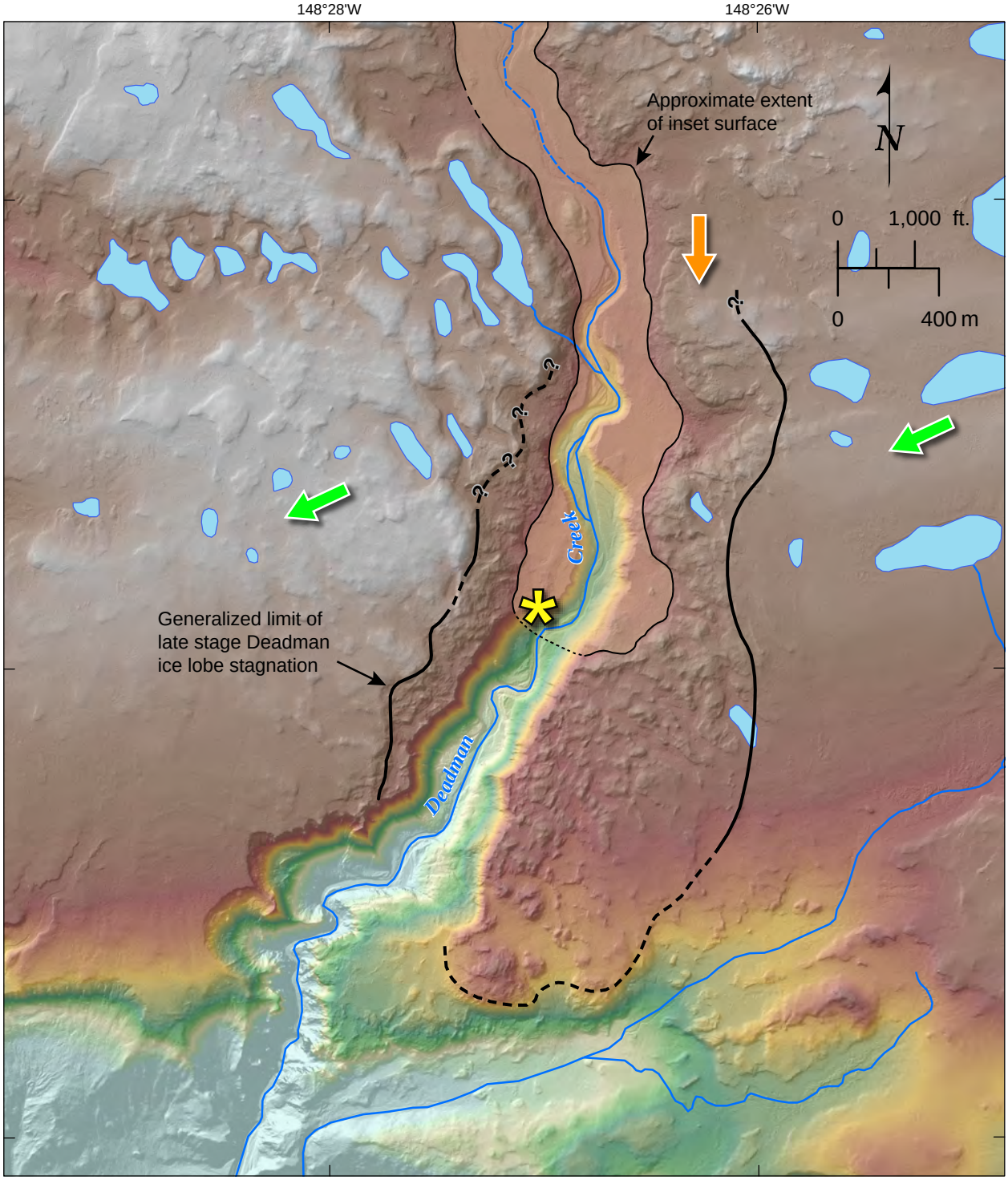


Profile B



FUGRO Date 02/11/15	STATE OF ALASKA ALASKA ENERGY AUTHORITY ALASKA ENERGY AUTHORITY	SUSITNA-WATANA HYDROELECTRIC PROJECT GLACIAL ICE RECONSTRUCTION PROFILES	FIGURE 3-14

fwla-wc-file1/project/Projects/79_2000/79_218900_Alaska_Railbelt/05_Graphics/79_218900 Combined Crustal Source Surface Fault Rupture Evaluation



Base data from Matanuska-Susitna LiDAR data, 2012.

Explanation

- Older, regional ice flow direction
- Late stage Deadman ice lobe direction
- OSL sample site

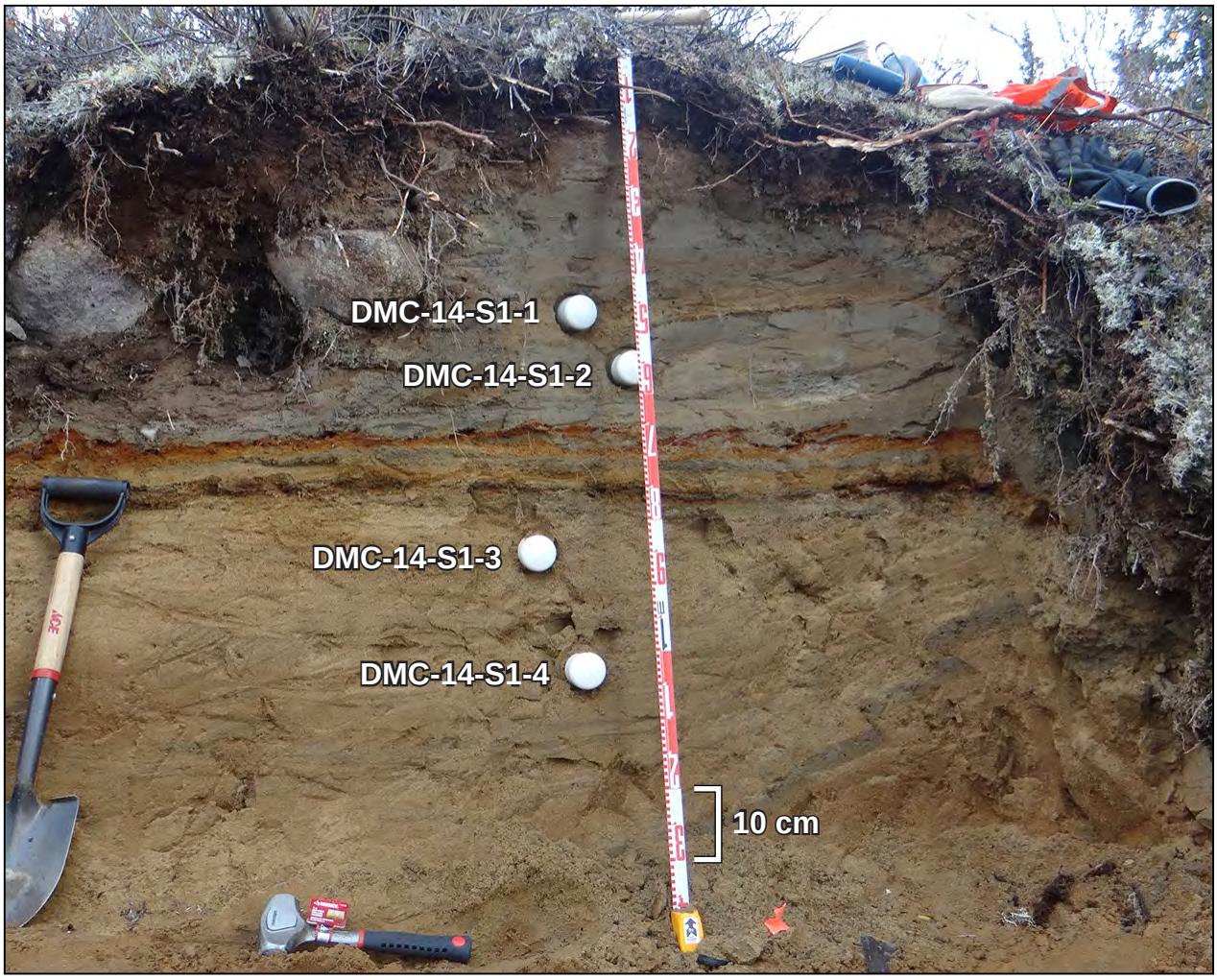
Elevation Value

2485

1540

fwla-wc-file1/project/Projects/79_2000/79_218900_Alaska_Railbelt/05_Graphics/May 2015 CSSE with SFR Final Rep 14-33

FUGRO Date 05/15/15	STATE OF ALASKA ALASKA ENERGY AUTHORITY ALASKA ENERGY AUTHORITY	SUSITNA-WATANA HYDROELECTRIC PROJECT DEADMAN CREEK OSL SAMPLE SITE	FIGURE 3-15



Date 05/15/15

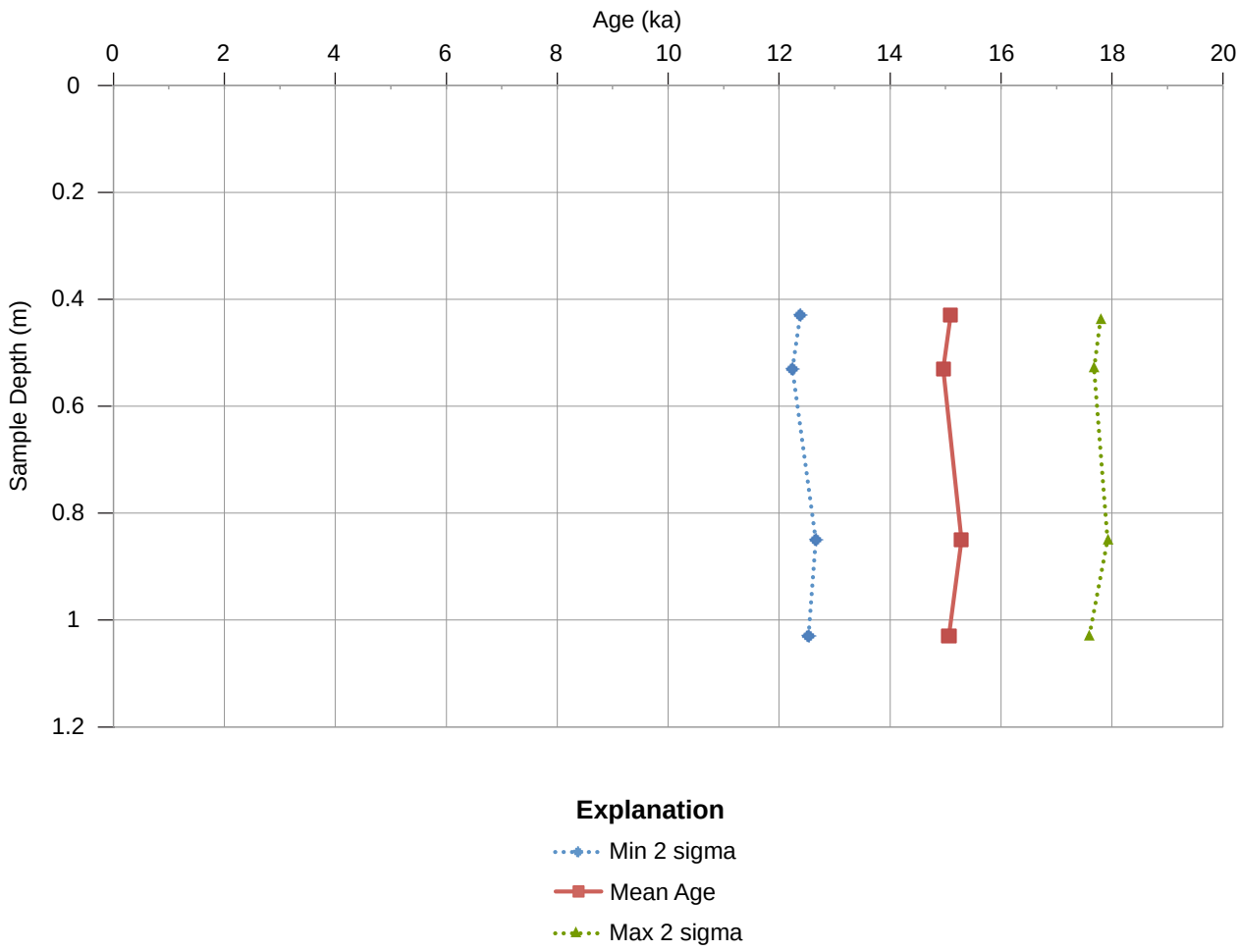
STATE OF ALASKA
ALASKA ENERGY AUTHORITY

SUSITNA-WATANA HYDROELECTRIC PROJECT

PHOTOGRAPH OF OSL SAMPLES COLLECTED
AT DEADMAN CREEK EXPOSURE

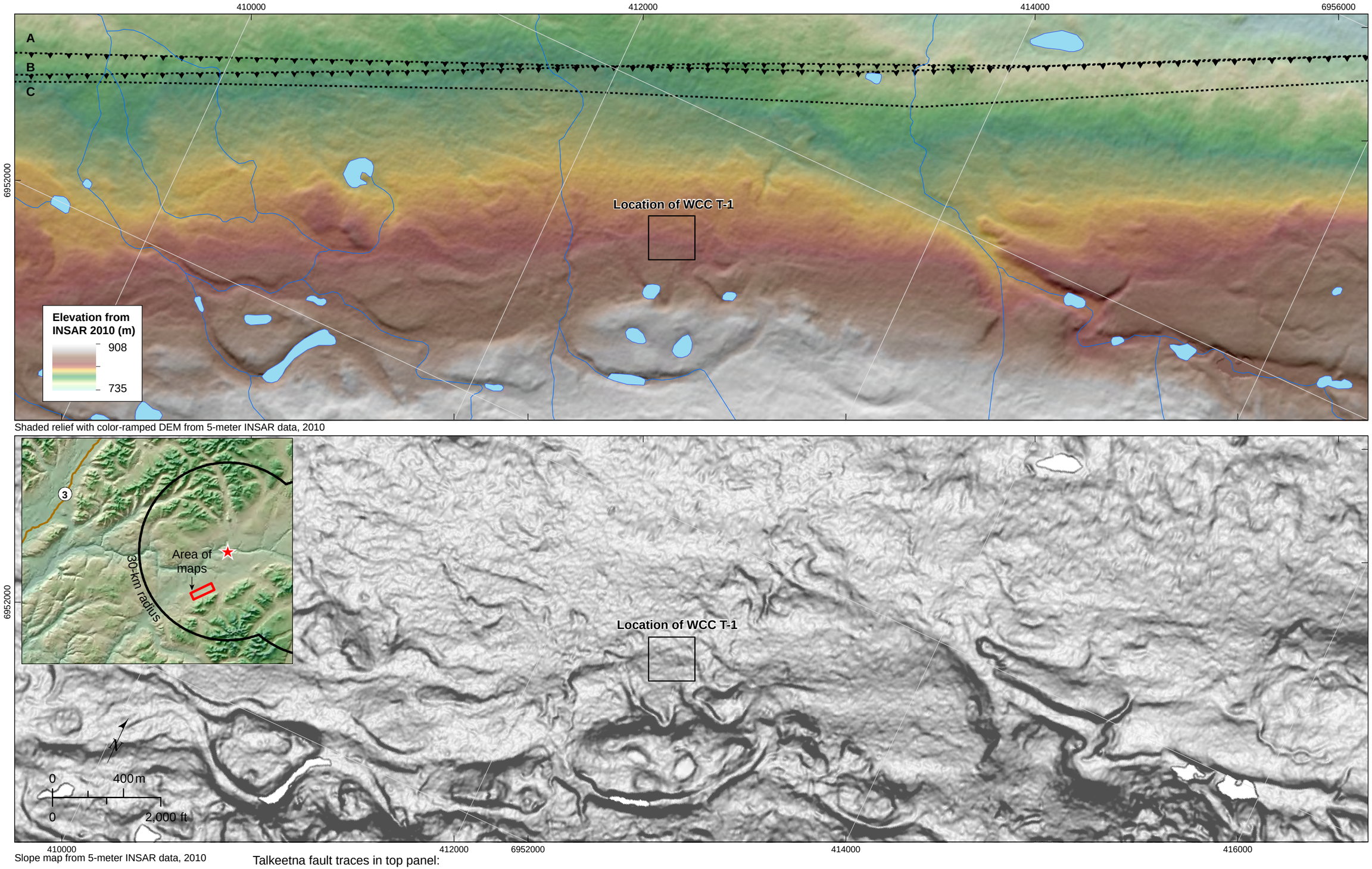
FIGURE
3-16

fwla-wc-file1/project/Projects/79_2000/79_218900_Alaska_Railbelt/05_Graphics/May 2015 CSSE with SFR Final Rep 14-33



fwla-wc-file1/project/Projects/79_2000/79_218900_Alaska_Railbelt/05_Graphics/May 2015 CSSE with SFR Final Rep 14-33

FUGRO Date 05/15/15	STATE OF ALASKA ALASKA ENERGY AUTHORITY ALASKA ENERGY AUTHORITY	SUSITNA-WATANA HYDROELECTRIC PROJECT OSL AGE-DEPTH PLOT	FIGURE 3-17



DATA FRAME HAS BEEN ROTATED
25 DEGREES EAST OF NORTH

Talkeetna fault traces in top panel:

- **A** Csejtey et al., 1978
- **B** WCC report, 1982
- **C** Wilson et al., 2009

FUGRO
Date 02/11/15

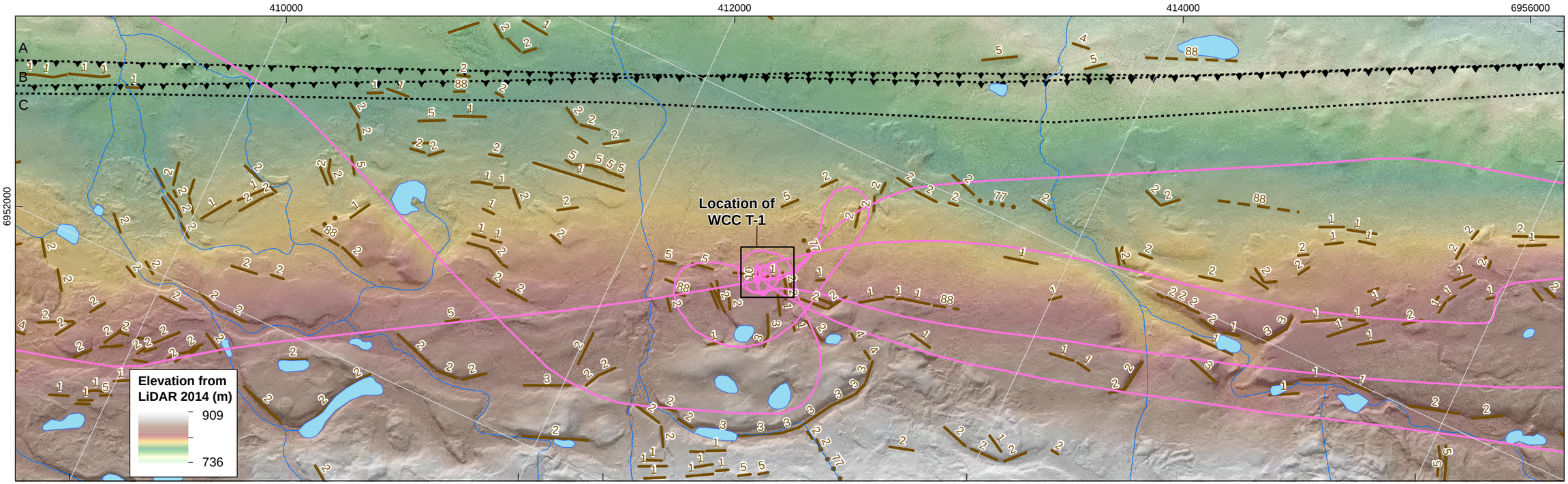
STATE OF ALASKA
ALASKA ENERGY AUTHORITY
ALASKA ENERGY AUTHORITY

SUSITNA-WATANA HYDROELECTRIC PROJECT

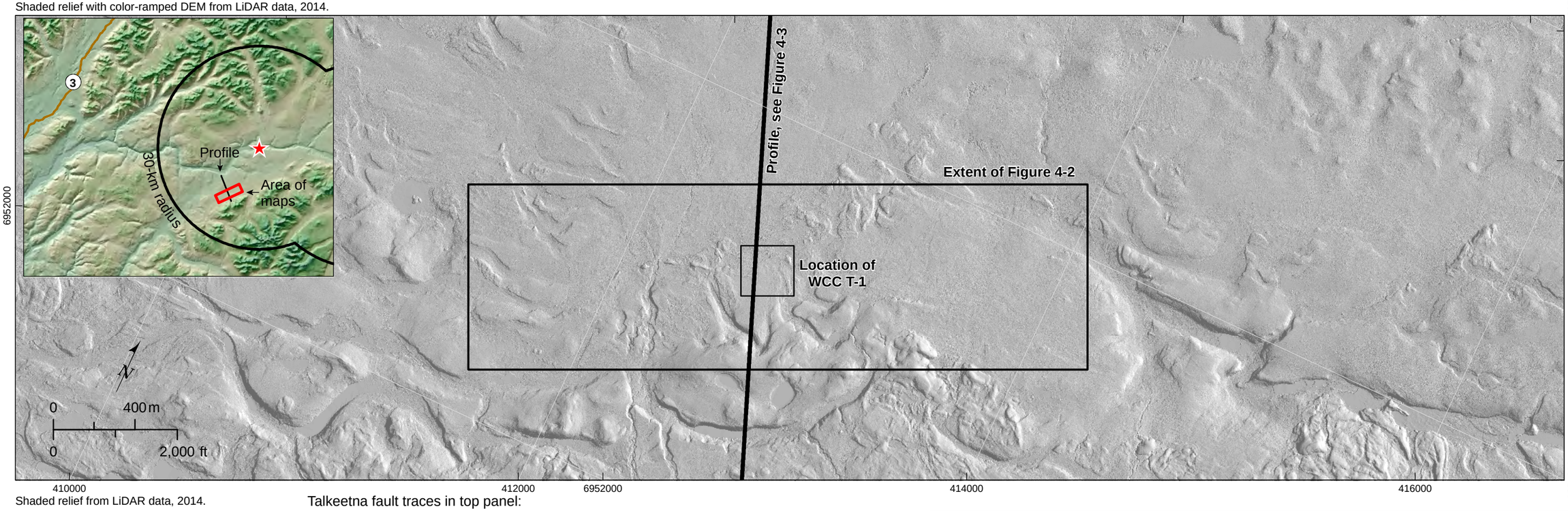
WCC TRENCH T-1 AREA
LOCATION MAP (INSAR BASE)

FIGURE
4-1A

fwla-wc-file1/project/Projects/79_2000/79_218900_Alaska_Railbelt/05_Graphics/79_218900 Combined Crustal Source Surface Fault Rupture Evaluation



Shaded relief with color-ramped DEM from LiDAR data, 2014.



Shaded relief from LiDAR data, 2014.

DATA FRAME HAS BEEN ROTATED
25 DEGREES EAST OF NORTH

Talkeetna fault traces in top panel:

- **A** Csejtey et al., 1978
- **B** WCC report, 1982
- **C** Wilson et al., 2009

Date 02/11/15

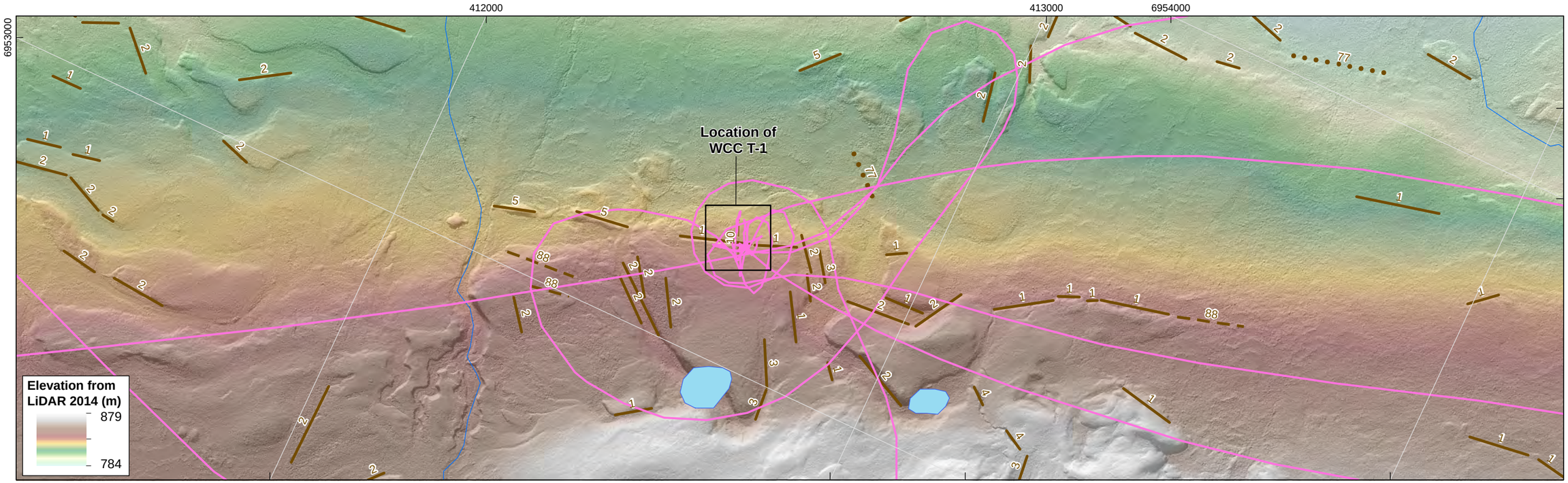
STATE OF ALASKA
ALASKA ENERGY AUTHORITY
ALASKA ENERGY AUTHORITY

SUSITNA-WATANA HYDROELECTRIC PROJECT

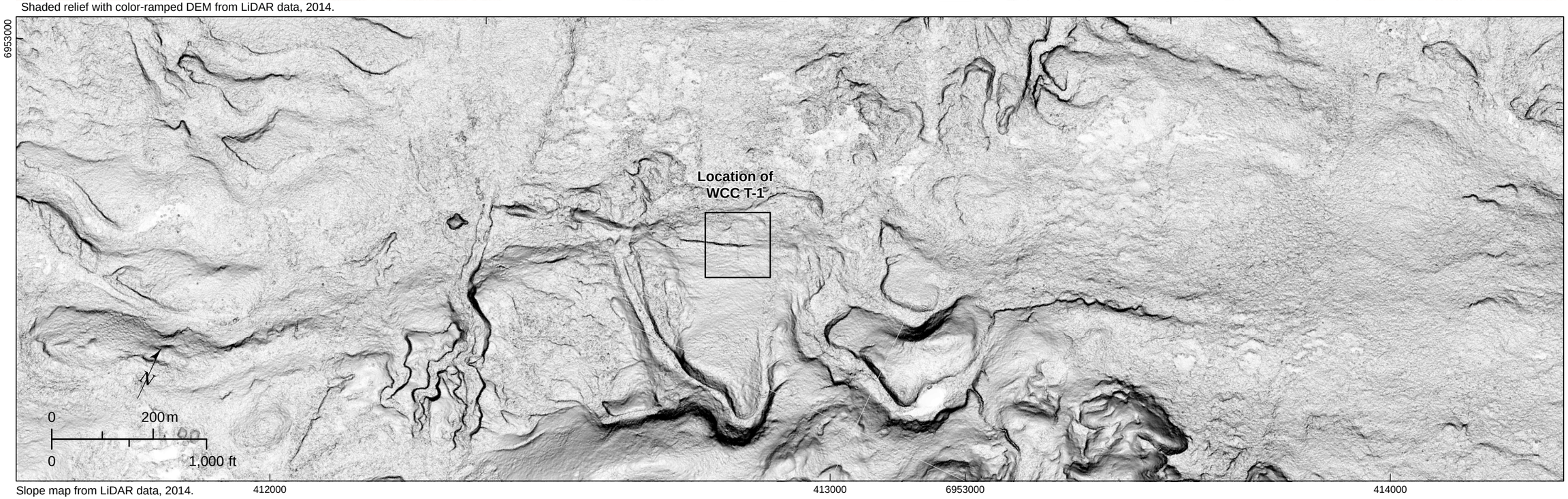
WCC TRENCH T-1 AREA
LOCATION MAP (LIDAR BASE)

FIGURE
4-1B

fwla-wc-file1/project/Projects/79_2000/79_218900_Alaska_Railbelt/05_Graphics/79_218900_TM14 Janurary 2014 Lineament Report /79_218900 CSSE Update/



Shaded relief with color-ramped DEM from LiDAR data, 2014.



Slope map from LiDAR data, 2014.

412000 413000 6953000 414000

DATA FRAME HAS BEEN ROTATED
25 DEGREES EAST OF NORTH

FUGRO
Date 02/11/15

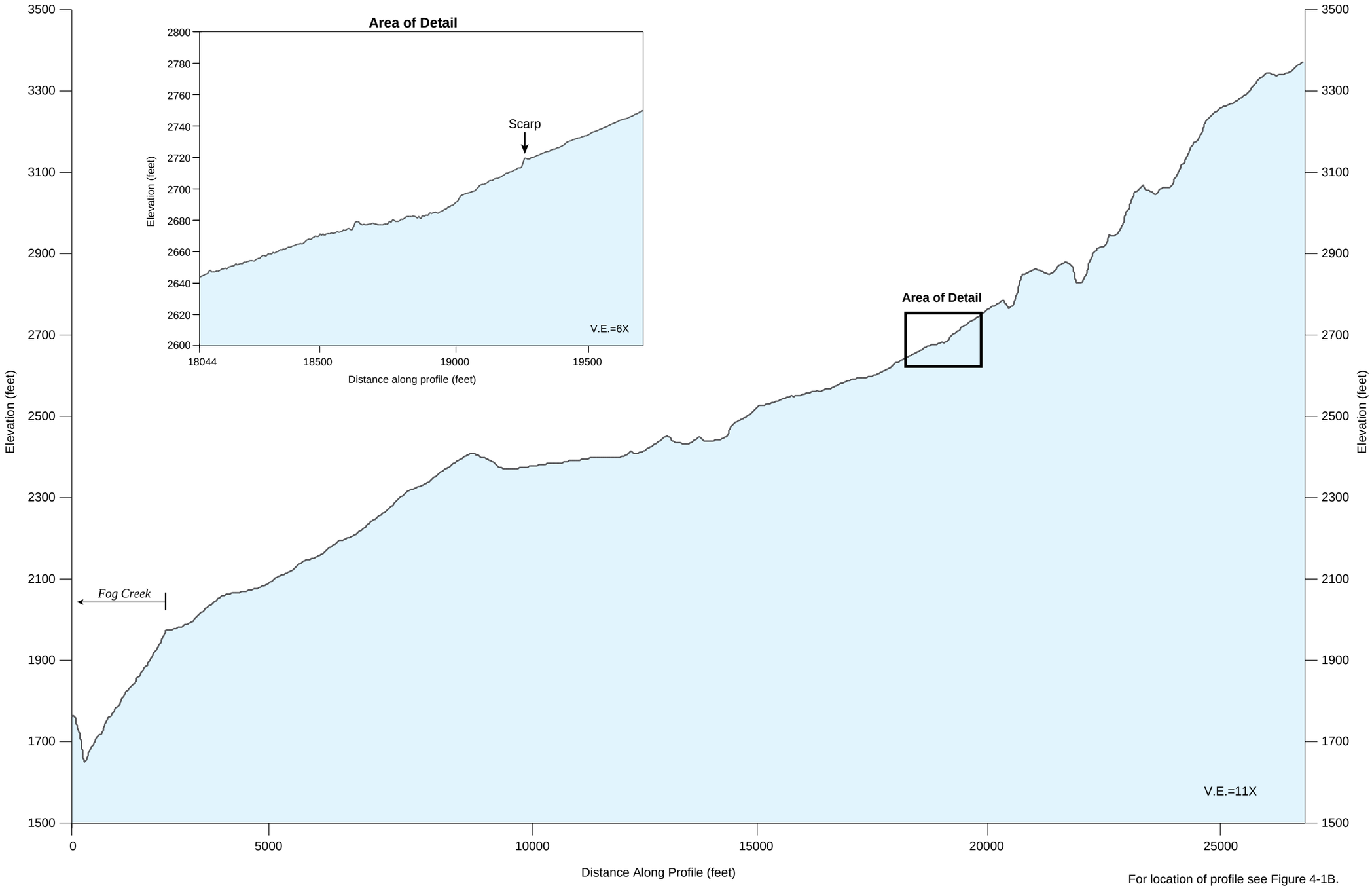
STATE OF ALASKA
ALASKA ENERGY AUTHORITY
ALASKA ENERGY AUTHORITY

SUSITNA-WATANA HYDROELECTRIC PROJECT

WCC TRENCH T-1 AREA
DETAIL VIEW (LIDAR BASE)

FIGURE
4-2

fwla-wc-file1/project/Projects/79_2000/79_218900_Alaska_Railbelt/05_Graphics/79_218900 Combined Crustal Source Surface Fault Rupture Evaluation

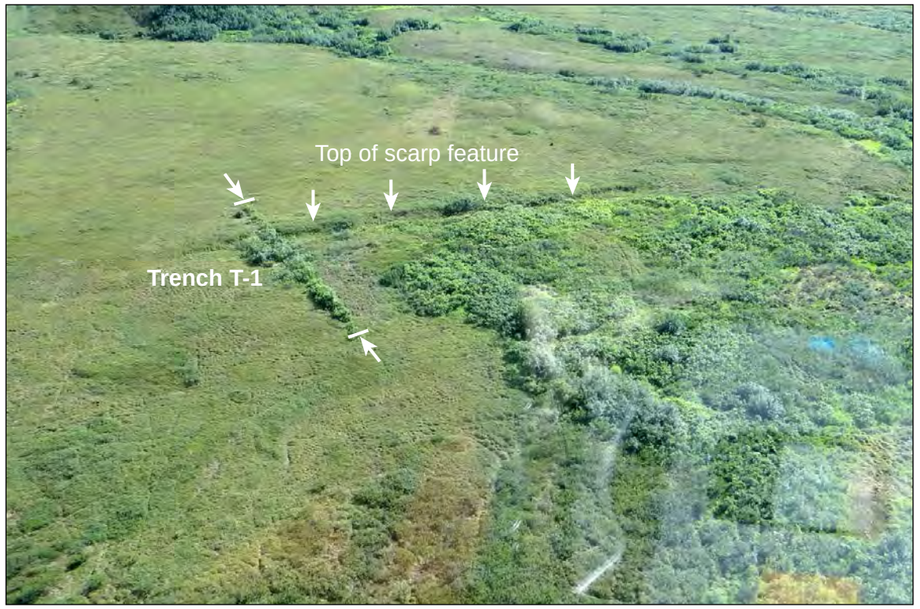


For location of profile see Figure 4-1B.

fwla-wc-file1/project/Projects/79_2000/79_218900_Alaska_Railbelt/05_Graphics/79_218900 Combined Crustal Source Surface Fault Rupture Evaluation

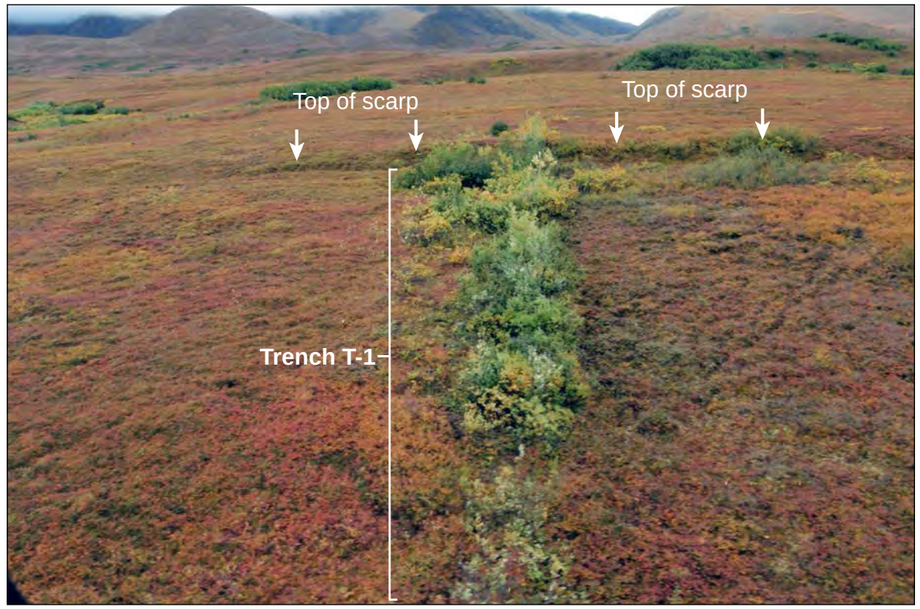
FUGRO Date 02/11/15	STATE OF ALASKA ALASKA ENERGY AUTHORITY ALASKA ENERGY AUTHORITY	SUSITNA-WATANA HYDROELECTRIC PROJECT TOPOGRAPHIC PROFILE ACROSS T-1 SCARP TO FOG CREEK	FIGURE 4-3

A)



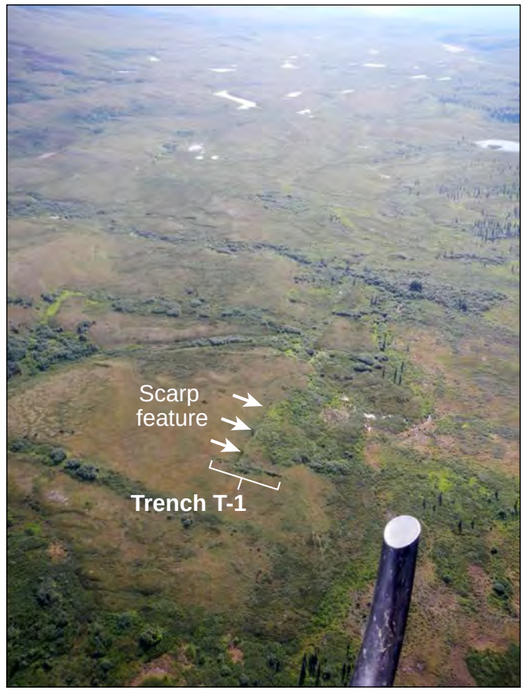
View of WCC T-1 location (marked by tree line), looking slightly east of south.

B)



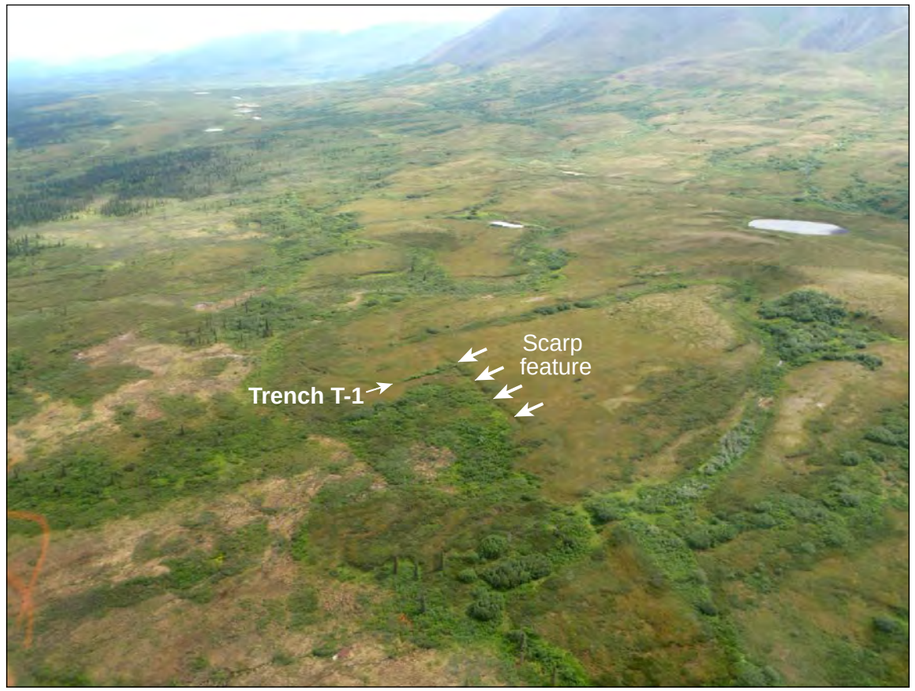
Very low altitude view of tree line that corresponds to backfilled Trench T-1, with scarp-like feature in mid-background.

C)



View of WCC T-1 looking southwest. Note how the expression of the scarp feature dies out along the projected trend of the feature.

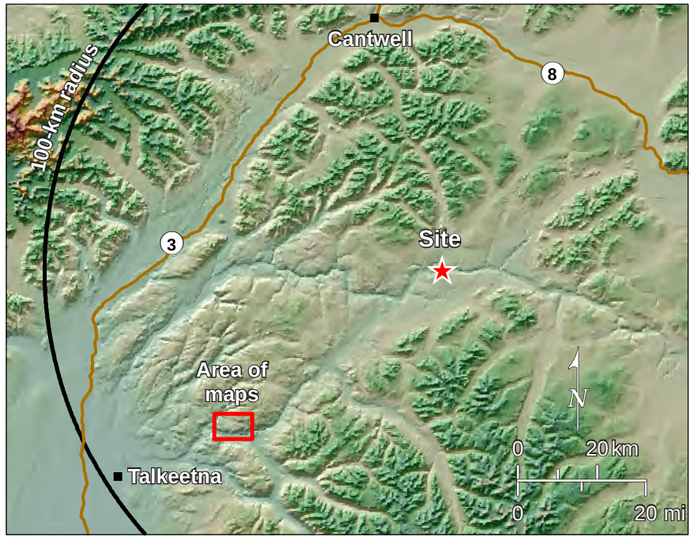
D)

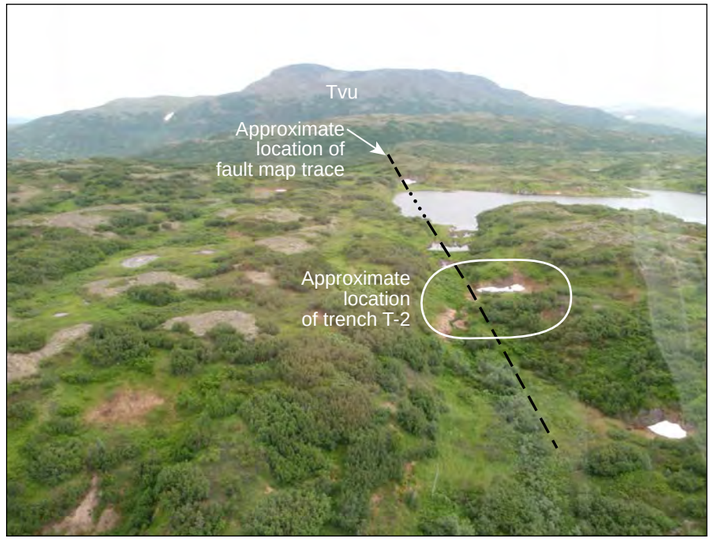


View of WCC T-1 looking northeast.

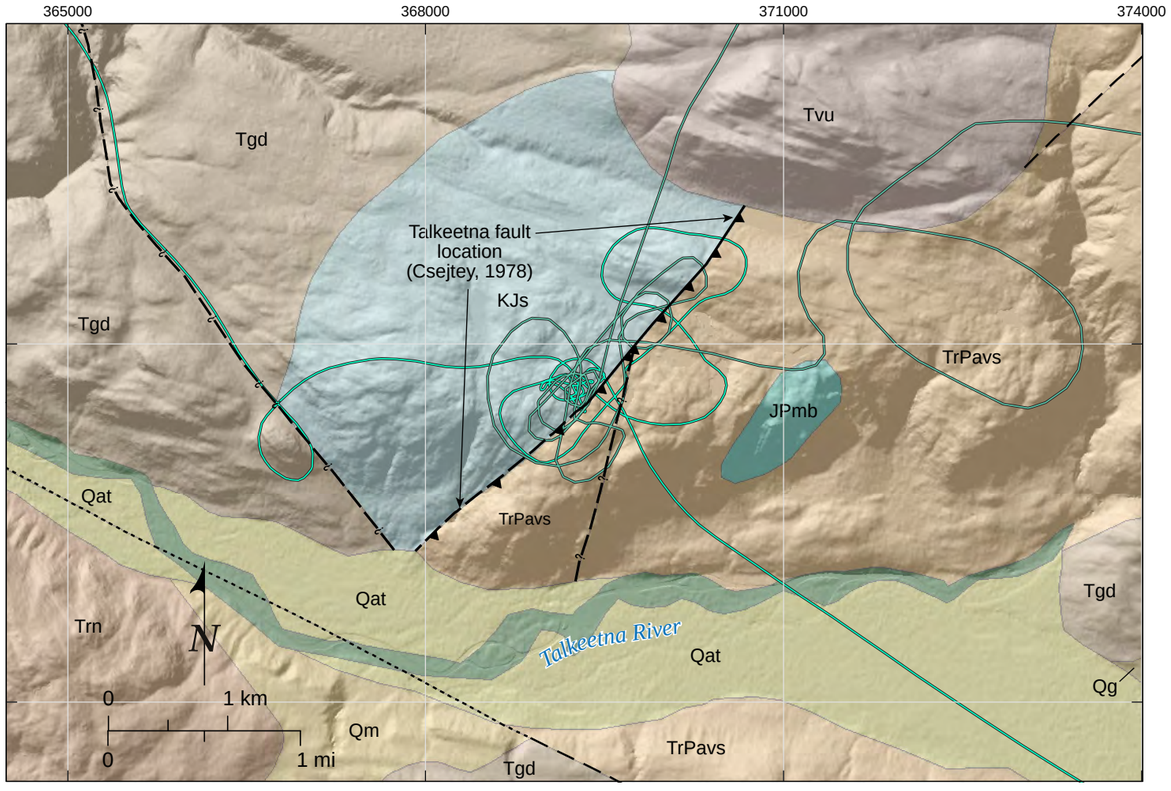
Date 02/11/15	STATE OF ALASKA ALASKA ENERGY AUTHORITY ALASKA ENERGY AUTHORITY	SUSITNA-WATANA HYDROELECTRIC PROJECT PHOTOGRAPHS OF WCC TRENCH T-1 SITE	FIGURE 4-4

fwla-wc-file1/project/Projects/79_2000/79_218900_Alaska_Railbelt/05_Graphics/79_218900 Combined Crustal Source Surface Fault Rupture Evaluation

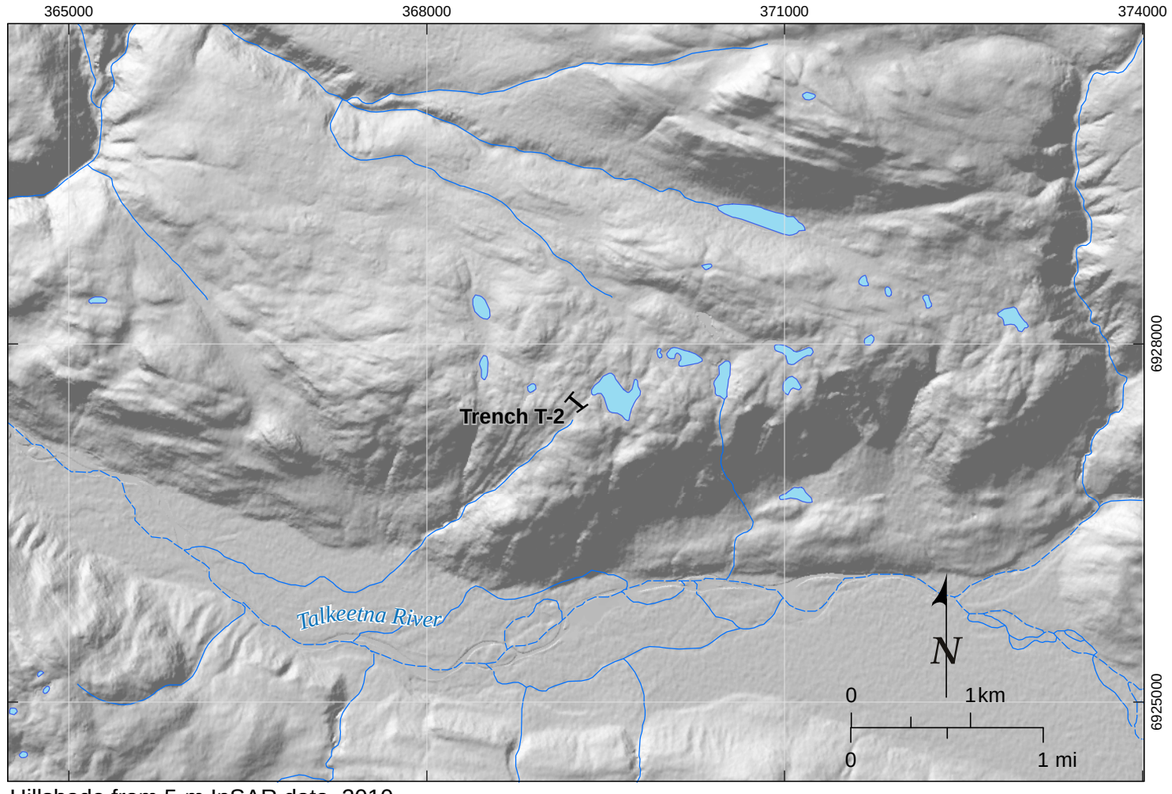




View looking north-northeast along trend of mapped Talkeetna fault trace with unfaulted volcanic intrusives (Tvu) in the background.



Geology from Wilson et al., 2009



Hillshade from 5-m InSAR data, 2010.

Notes: 1. See Figures A0.2, A0.3, A0.4, and A0.5 for explanation.

fwla-wc-file1/project/Projects/79_2000/79_218900_Alaska_Railbelt/05_Graphics/79_218900 Combined Crustal Source Surface Fault Rupture Evaluation

FUGRO
Date 02/11/15

STATE OF ALASKA
ALASKA ENERGY AUTHORITY
ALASKA ENERGY AUTHORITY

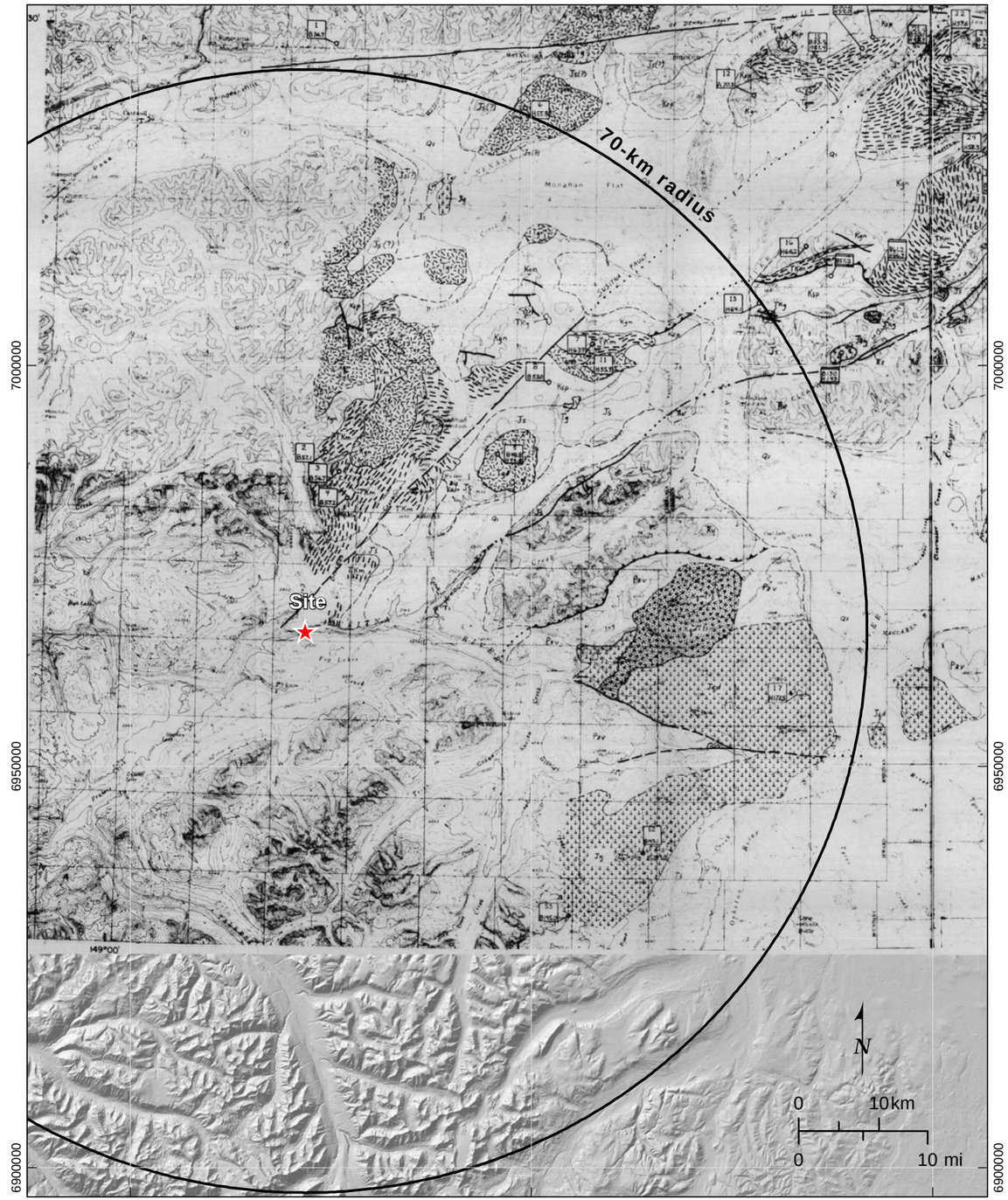
SUSITNA-WATANA HYDROELECTRIC PROJECT

MAPS AND PHOTOGRAPHS OF WCC TRENCH T-2 AREA

FIGURE
4-5



Imagery from Landsat, 2010.



Geologic map from Turner and Smith,(**1974**), original map scale=1:250,000.

fwla-wc-file1/project/Projects/79_2000/79_218900_Alaska_Railbelt/05_Graphics/79_218900 Combined Crustal Source Surface Fault Rupture Evaluation

Date 02/11/15	STATE OF ALASKA ALASKA ENERGY AUTHORITY ALASKA ENERGY AUTHORITY	SUSITNA-WATANA HYDROELECTRIC PROJECT SUSITNA FEATURE, SATELLITE IMAGERY, AND GEOLOGIC MAP	FIGURE 4-6

435000 440000 445000 450000

6995000

Deadman Creek

Deadman Mountain

22

21b

14-027

14-026

S-1, WCC

A B C D

Qs Thf Thf Trcs Kgu Kgu Tegr Tegr Kgu Kgu Tegr Qs Tegr Deadman Mountain 105 106 103 104 Tegr Qs Mzpca Tegr

WCC (1982)

Turner and Smith (1974)

N

0 1 km

0 1 mi

Bottom: geology by Wilson et al., 2009

Explanation

Fault, Certain

Fault, Approximate

FUGRO Date 02/11/15

STATE OF ALASKA
ALASKA ENERGY AUTHORITY
ALASKA ENERGY AUTHORITY

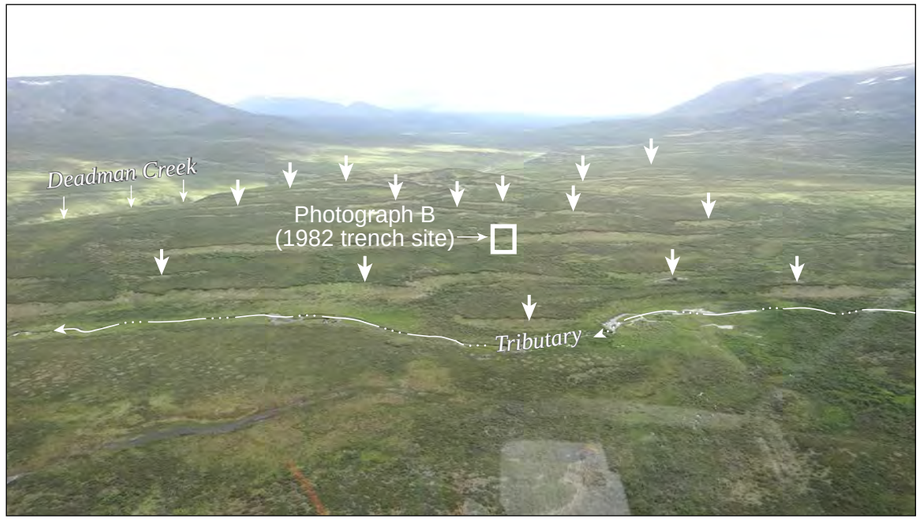
SUSITNA-WATANA HYDROELECTRIC PROJECT

SUSITNA FEATURE
FIELD DATA AND GEOLOGIC MAPS

FIGURE
4-7

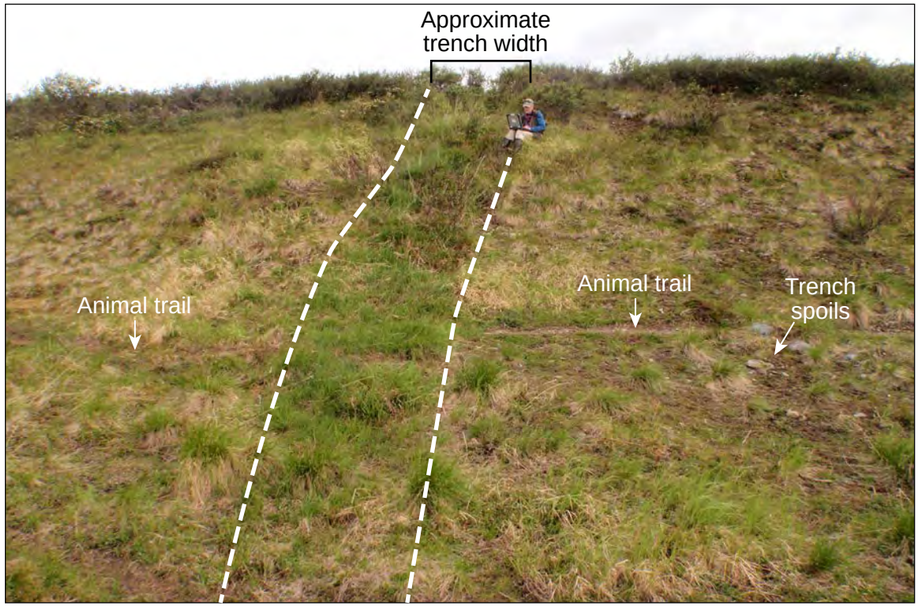
fwla-wc-file1/project/Projects/79_2000/79_218900_Alaska_Railbelt/05_Graphics/79_218900 Combined Crustal Source Surface Fault Rupture Evaluation

A)



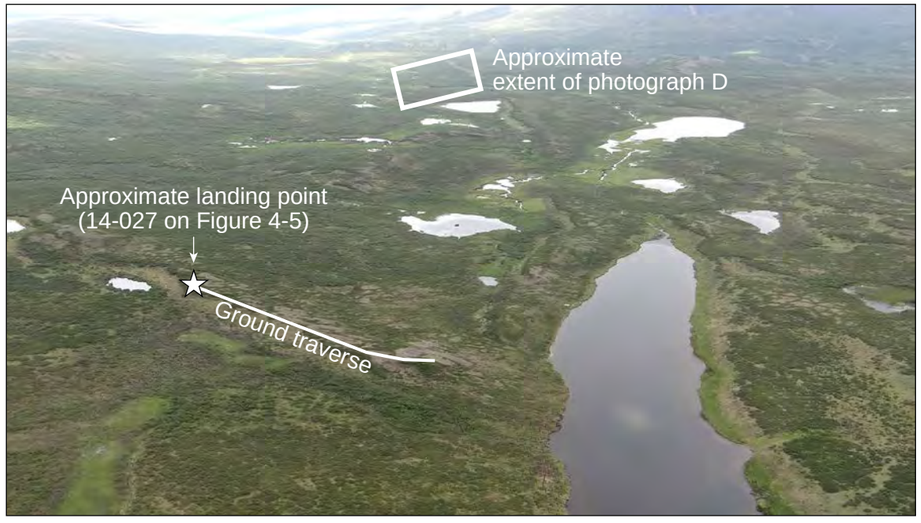
View looking northwest at slope breaks along postulated Susitna feature.
1982 trench site is also shown on Figure 4-5. Numerous slope breaks of similar size are present along Deadman Creek and in background.

B)



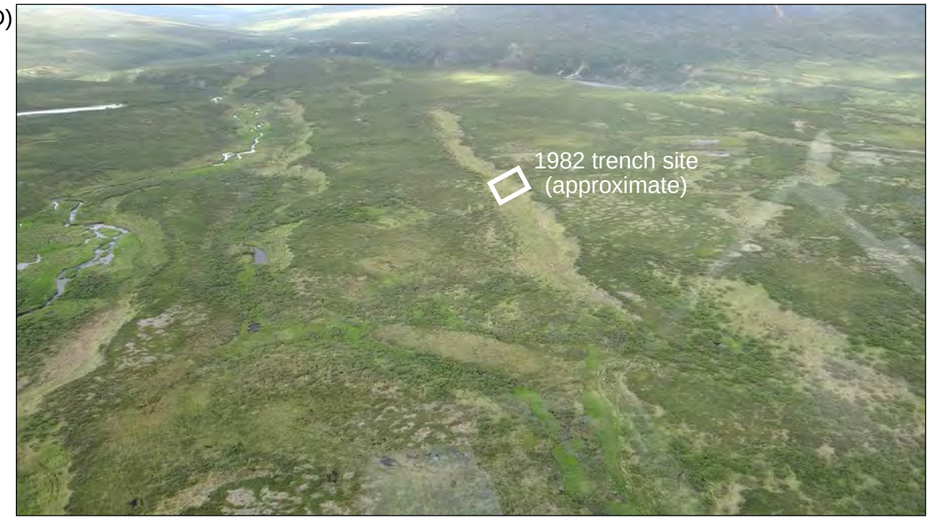
Ground-level view of 1982 trench site.

C)



View looking south at moraines and location of moraine crest ground traverse.

D)



View looking south along Susitna feature.

FUGRO Date 02/11/15	STATE OF ALASKA ALASKA ENERGY AUTHORITY ALASKA ENERGY AUTHORITY	SUSITNA-WATANA HYDROELECTRIC PROJECT SUSITNA FEATURE PHOTOGRAPHS OF WCC TRENCH S-1 SITE	FIGURE FIGURE 4-8

fwla-wc-file1/project/Projects/79_2000/79_218900_Alaska_Railbelt/05_Graphics/79_218900 Combined Crustal Source Surface Fault Rupture Evaluation

495000 500000 505000 510000

6970000 6965000 6960000

Qt Qo Qa Qid Tbgd Tqd Tvs Kag Tap Qu Tgd Tsu TRvs Pzv

Susitna River

Tsusena Creek

Deadman Creek

Shear zone

Absence of rock exposures

Absence of rock exposures

Heavily vegetated and steep; No visual evidence to confirm this structure

Contact between Qo and Qid is transcribed from original source

Tqd/Kag contact?

3 meter thick andesite dike

Well exposed

Well exposed

Site

Cyrstalline rock

Exposures not accessible due to waterline

No exposures

Volcaniclastic?

Mafic intrusion (?) exposed along waterline

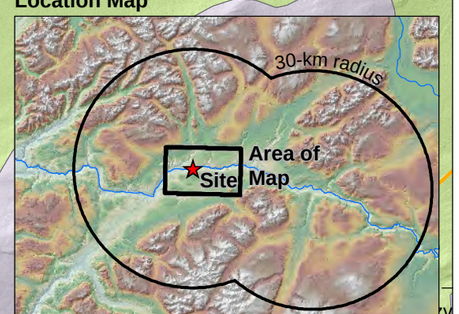
Talkeetna fault (Acres, 1982)

N

0 3,000 ft

0 1,000 m

Location Map



Explanation

Annotations from this Study

Symbols

- Trend and plunge of anticline hinge
- Trend and plunge of syncline hinge
- Arrows point to outcrop observations
- Brackets are an approximation of lateral extent of exposure outcrop
- Observation from ground or aerial hover

Strike and Dip

- Strike/dip from USACE 1979, map D-3
- Strike/dip from Acres, 1982
- Fault locations, this study
- Strike/dip Kag, this study
- Strike/dip Tsu, this study
- Strike/dip Tsu WCC, 1982

Acres Mapping

- Shear
- Thrust

Geologic Units (Acres, 1982)

Qa	Alluvium, alluvial terraces and fans
Qid	Ice disintegration deposits
Qt	Till
Qo	Outwash
Qu	Surficial deposits, undifferentiated, generally thin
Tvs	Tertiary volcaniclastic sandstone, siltstone and shale
Tap	Tertiary andesite porphyry, minor basalt
Tqd	Tertiary diorite to quartz diorite, minor granodiorite
Tbgd	Cretaceous biotite granodiorite
Kag	Triassic argillite and graywacke (Kahiltna)
TRvs	Paleozoic basaltic metavolcanic rocks, metabasalt and slate
Pzv	Cretaceous basaltic to andesitic metavolcanic rocks

Notes:
1. See text for description of compiled data sources.
2. Registration artifacts from original Acres (1982) map are not corrected.
3. This layout is in color at 11x17 size.

Coordinates on NAD83 UTM 6 North.
Elevation from LiDAR and IfSAR data.

fwla-wc-file1/project/Projects/79_2000/79_218900_Alaska_Railbelt/05_Graphics/79_218900 Combined Crustal Source Surface Fault Rupture Evaluation

FUGRO Date 02/11/15	STATE OF ALASKA ALASKA ENERGY AUTHORITY ALASKA ENERGY AUTHORITY	SUSITNA-WATANA HYDROELECTRIC PROJECT SUSITNA RIVER GEOLOGIC MAP TRANSECT	FIGURE 5-1A

505000 510000 515000 520000

6975000

6970000

Explanation

Annotations from this Study

Symbols

- Trend and plunge of anticline hinge
- Trend and plunge of syncline hinge
- Arrows point to outcrop observations
- Brackets are an approximation of lateral extent of exposure outcrop
- Observation from ground or aerial hover

Strike and Dip

- Strike/dip from USACE 1979, map D-3
- Strike/dip from Acres, 1982
- Fault locations, this study
- Strike/dip Kag, this study
- Strike/dip Tsu, this study
- Strike/dip Tsu WCC, 1982

Acres Mapping

- Shear
- Thrust

Geologic Units

Acres (1982)

Qa	Alluvium, alluvial terraces and fans
Qid	Ice disintegration deposits
Qt	Till
Qo	Outwash
Tsu	Tertiary conglomerate, sandstone and claystone
Kag	Cretaceous argillite and graywacke (Kahiltna)
TRvs	Triassic basaltic metavolcanic rocks, metabasalt and slate

Wilson et al. (2009)

Qs	Quaternary sediment (undivided)
Tsu	Tertiary sediment (undivided)
Trn	Triassic Nikolai greenstone
JPmb	Jurassic/Paleozoic metabasalt

Notes:
1. See text for description of compiled data sources.
2. Registration artifacts from original Acres (1982) map are not corrected.
3. This layout is in color at 11x17 size.

Wilson et al. (2009) mapping
Limit of Acres (1982) mapping

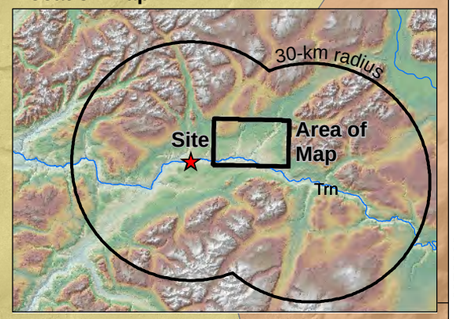
Talkeetna fault (Wilson et al., 2009)
Talkeetna fault (Acres, 1982)
Bend in Watana Creek
Delusion Creek
Susitna River
Watana Creek
Downstream extent of Tsu exposure (south bank)
Downstream extent of Tsu exposure (north bank)
Exposed but no landing area
Volcaniclastic?
Quaternary gravels
Fault zone in TRvs
Vertical fault (NE) exposed in TRvs (inaccessable due to river)
TRvs on hill
Not accessible

Qa Qid Qt Qo Qs Tsu Trn TRvs Kag JPmb

N

0 3,000 ft
0 1,000 m

Location Map



Coordinates on NAD83 UTM 6 North.
Elevation from LiDAR and IfSAR data.

Date 02/11/15	STATE OF ALASKA ALASKA ENERGY AUTHORITY ALASKA ENERGY AUTHORITY	SUSITNA-WATANA HYDROELECTRIC PROJECT WATANA CREEK GEOLOGIC MAP TRANSECT	FIGURE 5-1B

fwla-wc-file1/project/Projects/79_2000/79_218900_Alaska_Railbelt/05_Graphics/79_218900 Combined Crustal Source Surface Fault Rupture Evaluation



Vertical faults exposed in Triassic rocks, at the mouth of Watana Creek.



Vertical faults exposed in Triassic rocks, across from the mouth of Watana Creek.

FUGRO

Date 02/11/15

STATE OF ALASKA
ALASKA ENERGY AUTHORITY

ALASKA ENERGY AUTHORITY

SUSITNA-WATANA HYDROELECTRIC PROJECT

FAULTS IN TRIASSIC ROCK
NEAR WATANA CREEK

FIGURE

5-2

fwla-wc-file1/project/Projects/79_2000/79_218900_Alaska_Railbelt/05_Graphics/79_218900 Combined Crustal Source Surface Fault Rupture Evaluation



Triassic shear (140, 45 SW) outcrop.



Close up of a shear feature.

fwla-wc-file1/project/Projects/79_2000/79_218900_Alaska_Railbelt/05_Graphics/79_218900 Combined Crustal Source Surface Fault Rupture Evaluation





fwla-wc-file1/project/Projects/79_2000/79_218900_Alaska_Railbelt/05_Graphics/79_218900 Combined Crustal Source Surface Fault Rupture Evaluation

Date 02/11/15

STATE OF ALASKA
ALASKA ENERGY AUTHORITY

SUSITNA-WATANA HYDROELECTRIC PROJECT

SHEAR IN TERTIARY VOLCANICLASTIC (?) DEPOSITS, SOUTH BANK SUSITNA RIVER

FIGURE

5-4



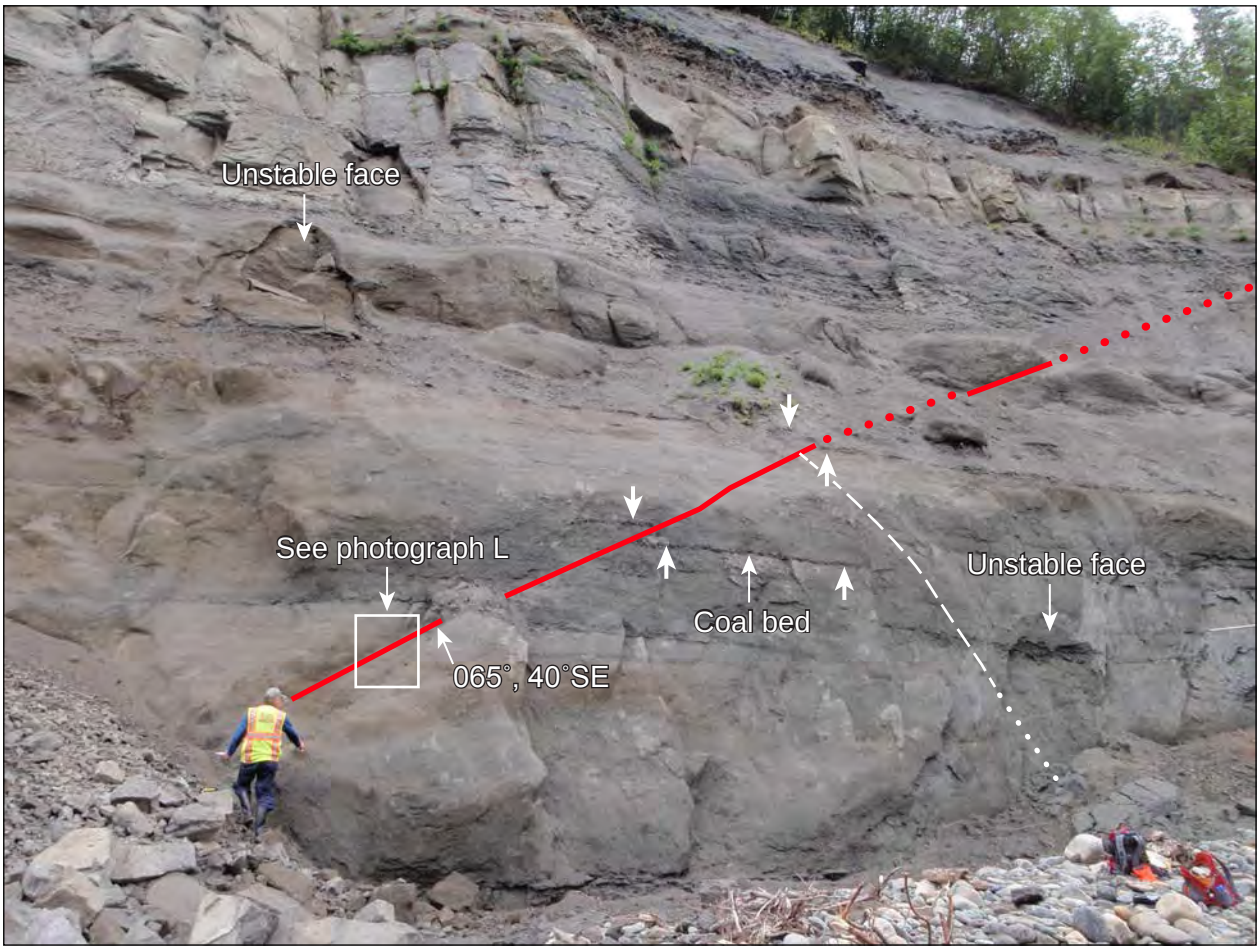
Fault S1 outcrop.



Fault S2 outcrop.

fwla-wc-file1/project/Projects/79_2000/79_218900_Alaska_Railbelt/05_Graphics/79_218900 Combined Crustal Source Surface Fault Rupture Evaluation

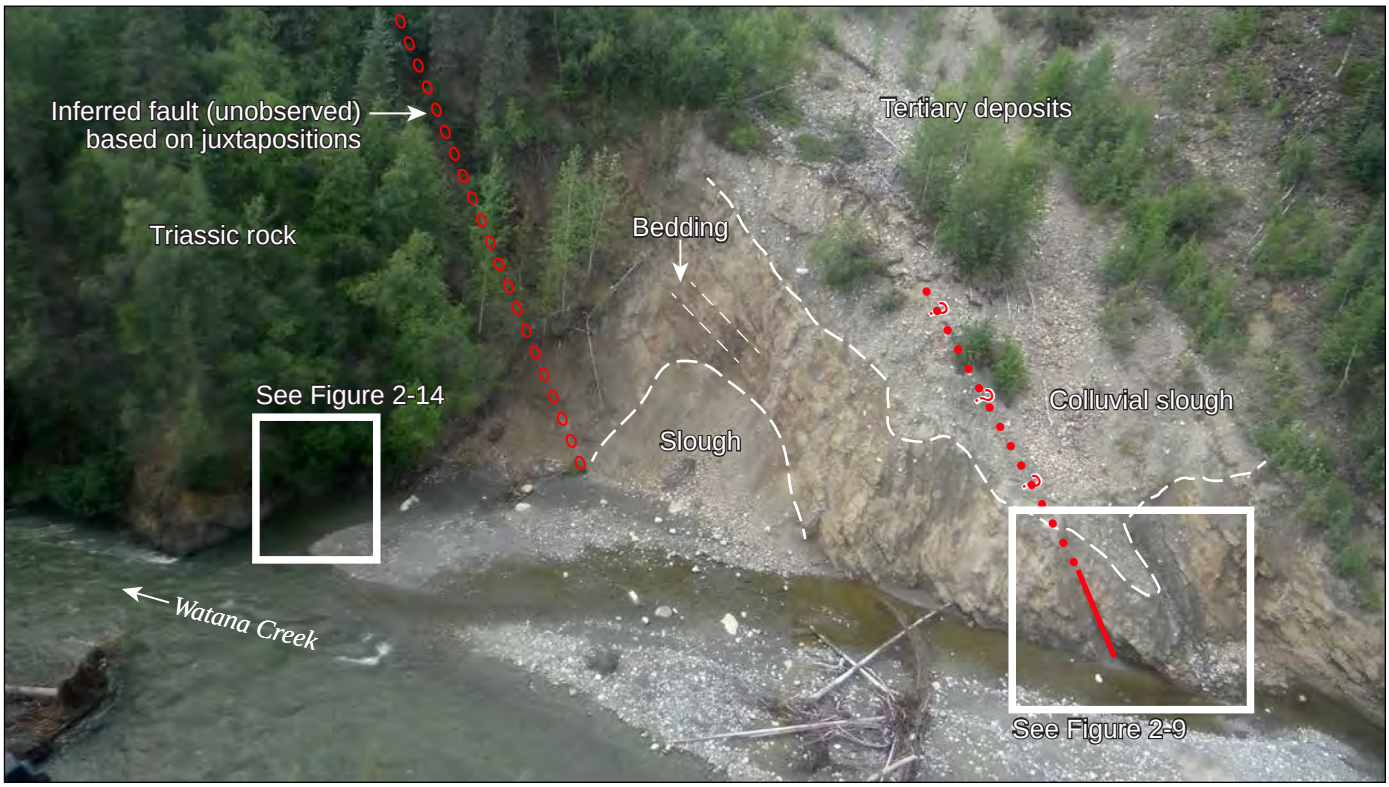
FUGRO Date 02/11/15	STATE OF ALASKA ALASKA ENERGY AUTHORITY ALASKA ENERGY AUTHORITY	SUSITNA-WATANA HYDROELECTRIC PROJECT FAULTS EXPOSED IN CRETACEOUS ROCK, NORTH BANK SUSITNA RIVER	FIGURE 5-5



Photograph of faulted outcrop with coal bed. Visually estimated 60-80 cm of separation along the fault plane. Second fault (221, 27˚ NW)appears to terminate against primary fault (065, 40˚SE) extends across the outcrop.

fwla-wc-file1/project/Projects/79_2000/79_218900_Alaska_Railbelt/05_Graphics/79_218900 Combined Crustal Source Surface Fault Rupture Evaluation

FUGRO Date 02/11/15	STATE OF ALASKA ALASKA ENERGY AUTHORITY ALASKA ENERGY AUTHORITY	SUSITNA-WATANA HYDROELECTRIC PROJECT FAULTS EXPOSED IN TERTIARY SEDIMENTS, UPPER WATANA CREEK	FIGURE 5-6



Aerial view looking approximately south-southwest. Triassic rocks are densely vegetated.

fwla-wc-file1/project/Projects/79_2000/79_218900_Alaska_Railbelt/05_Graphics/79_218900 Combined Crustal Source Surface Fault Rupture Evaluation

FUGRO Date 02/11/15	STATE OF ALASKA ALASKA ENERGY AUTHORITY ALASKA ENERGY AUTHORITY	SUSITNA-WATANA HYDROELECTRIC PROJECT OVERVIEW OF FAULT LOCATIONS, LOWER WATANA CREEK	FIGURE 5-7



View looking west at lower part of Tertiary deposit toward uncleaned exposure of fault (065-080˚ strike; 65˚N dip). Left-lateral oblique relative movement.

fwla-wc-file1/project/Projects/79_2000/79_218900_Alaska_Railbelt/05_Graphics/79_218900 Combined Crustal Source Surface Fault Rupture Evaluation

FUGRO

Date 02/11/15

STATE OF ALASKA
ALASKA ENERGY AUTHORITY
ALASKA ENERGY AUTHORITY

SUSITNA-WATANA HYDROELECTRIC PROJECT

FAULT IN TERTIARY DEBRIS-FLOW/TORRENT DEPOSIT, LOWER WATANA CREEK

FIGURE
5-8



View looking south at vertical fault in Triassic rocks; visually estimated apparent strike is northeast.

Date 02/11/15

STATE OF ALASKA
ALASKA ENERGY AUTHORITY

SUSITNA-WATANA HYDROELECTRIC PROJECT

FAULT EXPOSED IN TRIASSIC ROCK, LOWER WATANA CREEK

FIGURE 5-9

fwla-wc-file1/project/Projects/79_2000/79_218900_Alaska_Railbelt/05_Graphics/79_218900 Combined Crustal Source Surface Fault Rupture Evaluation

Figure 5-10. Dam Site Bedrock Geology

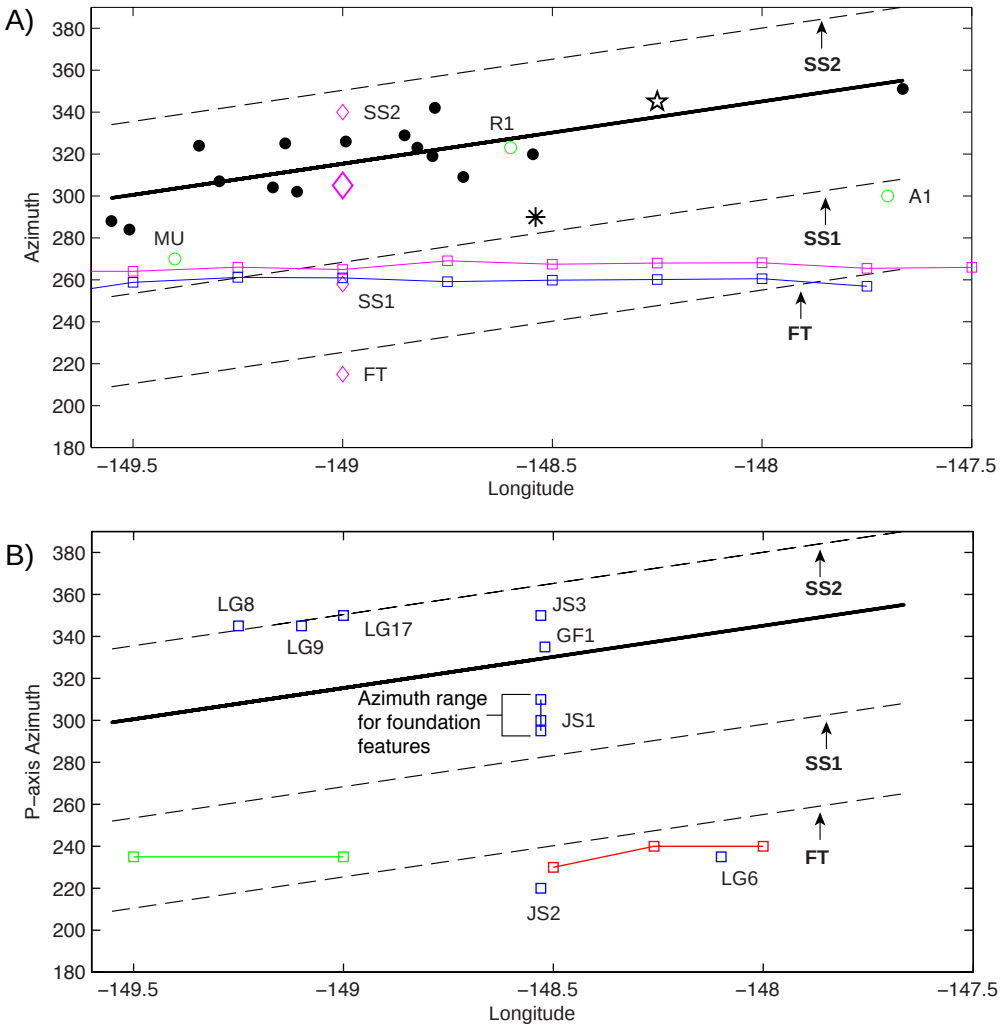
This figure contains Critical Energy Infrastructure Information (CEII), which is being withheld from public viewing, in accordance with FERC's Order No. 630-A.

DO NOT RELEASE.

Figure 5-11. Crustal Stress Orientations and Strain Ellipses

This figure contains Critical Energy Infrastructure Information (CEII), which is being withheld from public viewing, in accordance with FERC's Order No. 630-A.

DO NOT RELEASE.



Explanation

Earthquake Focal Mechanism and GPS-based Data

- P-axis (focal mechanisms from Watana Seismic Network)
- Best fit line to WSN P-axis data
- P-axis (focal mechanisms from Doser, 2004) groups MU, R1, A1
- WAT 1 GPS vector (relative to fixed North America) AEC (2014)
- Pacific Plate motion relative to North America (arbitrarily plotted at -148.5 longitude) DeMets et al. (2010)

Average Fault and Geologic Structure Strike Data

- Denali fault
- Castle Mountain fault
- Talkeetna fault
- Broad Pass faults
- Lineament groups (LG6, LG8, LG9, LG17)
- Geologic features and joints at Watana damsite (GF1, JS1, JS2, JS3) MWH (2014)

Denali Fault Simple Shear Model

- Regional shortening direction (Cole et al., 2007)
- Fault strike for principal elements SS1 = strike-sllip (1st plane), SS2=strike-slip (2nd plane), FT=fold/thrust planes
- Extrapolation of simple shear model planes (SS1, SS2, FT) shifted to slope of best fit line of network focal mechanism data

FUGRO Date 02/11/15	STATE OF ALASKA ALASKA ENERGY AUTHORITY ALASKA ENERGY AUTHORITY	SUSITNA-WATANA HYDROELECTRIC PROJECT PRINCIPAL STRESS ORIENTATION AND GEOLOGIC STRUCTURE STRIKE VARIATION WITH LONGITUDE	FIGURE 5-12

fwla-wc-file1/project/Projects/79_2000/79_218900_Alaska_Railbelt/05_Graphics/79_218900 Combined Crustal Source Surface Fault Rupture Evaluation