[PS]Tectonic Implications of New Geological and Geophysical Results from the Susitna Basin, South-Central Alaska*

Richard G. Stanley[1], Peter J. Haeussler[2], Jeffrey A. Benowitz[3], Kristen A. Lewis[4], Diane P. Shellenbaum[5], Richard W. Saltus[4], Anjana K. Shah[4], Jeffrey D. Phillips[4], and Christopher J. Potter[6]

Search and Discovery Article #10608 (2014)
Posted July 7, 2014

*Adapted from poster presentation given at Pacific Section AAPG, SEG and SEPM Joint Technical Conference, Bakersfield, California, April 27-30, 2014

[1]United States Geological Survey, Menlo Park, CA (rstanley@usgs.gov)
[2]United States Geological Survey, Anchorage, AK
[3]Geophysical Institute, University of Alaska Fairbanks, Fairbanks, AK
[4]United States Geological Survey, Denver, CO
[5]Alaska Division of Oil and Gas, Anchorage, AK
[6]United States Geological Survey, Piscataway, NJ

Abstract

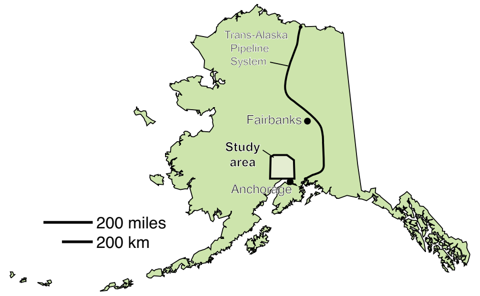
Exploratory wells, seismic reflection, gravity, and aeromagnetic data provide new insights into the tectonic history of the Susitna basin, about 80 km NW of Anchorage. Seven exploratory wells drilled in the Susitna basin from 1964 to 2005 found no commercial quantities of oil or gas, but at least one company has announced plans to drill more wells in the near future. Three wells in the Susitna basin bottomed in a package of Paleogene volcanic and sedimentary rocks. The ages of these rocks are based on Paleocene palynomorphs and five $^{40}Ar/^{39}Ar$ step-heating ages on whole-rock samples, as follows: 57.3 ± 0.2 Ma on basalt from the Trail Ridge Unit 1 well; 54.3 ± 0.4 on andesite (?) and 56.9 ± 0.4 Ma on basalt from the Pure Kahiltna Unit 1 well; and 56.4 ± 0.8 and 56.7 ± 1.1 Ma on basalt from the Sheep Creek 1 well. This package is about the same age as the Arkose Ridge Formation in the nearby Talkeetna Mountains. The volcanic package is overlain by a nonmarine sequence of sandstone, siltstone, and coal that contains Eocene palynomorphs and is more than 1,300 m thick in the Trail Ridge and Pure Kahiltna wells. The Eocene strata, in turn, are unconformably overlain by Miocene and younger strata. In the western part of the Susitna

basin, seismic reflection and aeromagnetic data reveal the presence of a prominent syncline flanked by N-striking reverse faults. The Trail Ridge well is located on the western limb of this syncline and penetrated a sequence of conglomerate and sandstone, about 2,500 m thick, that contains early Miocene to Quaternary palynomorphs. We hypothesize that Miocene and younger folding and faulting created a synclinal depocenter that accommodated the thick sedimentary pile at the Trail Ridge well. In the eastern part of the basin, seismic profiles show that Tertiary strata are deformed into open folds and cut by reverse faults. Subtle NE-striking aeromagnetic lineations are coincident with anticlinal crests in the Paleogene volcanic package. Gravity modeling indicates that the southwestern margin of the basin is the Beluga Mountain fault, a NW-striking, SW-dipping thrust fault. We suggest that Paleogene strata in the Susitna basin record volcanism, subsidence, and sedimentation that accompanied eastward passage of a slab window related to subduction of the Resurrection-Kula spreading ridge. The Miocene-on-Paleogene unconformity is not precisely dated but may record uplift and erosion that accompanied the initiation of Yakutat microplate subduction beneath south-central Alaska. Compressional deformation associated with microplate subduction resulted in folding, faulting, and subsidence of at least one synclinal depocenter during the Neogene and Quaternary.

Tectonic implications of new geological and geophysical results from the Susitna basin, south-central Alaska

By Richard G. Stanley, Peter J. Haeussler, Jeffrey A. Benowitz, Kristen A. Lewis, Diane P. Shellenbaum, Richard W. Saltus, Anjana K. Shah, Jeffrey D. Phillips, and Christopher J. Potter

USGS science for a changing world



Summary

Exploratory wells, seismic reflection, gravity, and aeromagnetic data provide new insights into the tectonic history of the Susitna basin, located about 80 km NW of Anchorage, Alaska. Seven exploratory wells drilled in the Susitna basin from 1964 to 2005 found no commercial quantities of oil or gas. However, at least one company has announced plans to drill more wells in the near future.

Three wells in the Susitna basin bottomed in a package of Paleogene volcanic and sedimentary rocks. The ages of these rocks are based on Paleocene palynomorphs and five $^{40}Ar/^{39}Ar$ step-heating ages on whole-rock samples, as follows: 57.3 ± 0.2 Ma on basalt from the Trail Ridge Unit 1 well; 54.3 ± 0.4 Ma on andesite(?) and 56.9 ± 0.4 Ma on basalt from the Pure Kahiltna Unit 1 well; and 56.4 ± 0.8 Ma and 56.7 ± 1.1 Ma on basalt from the Sheep Creek 1 well. This package is about the same age as the Arkose Ridge Formation in the nearby Talkeetna Mountains.

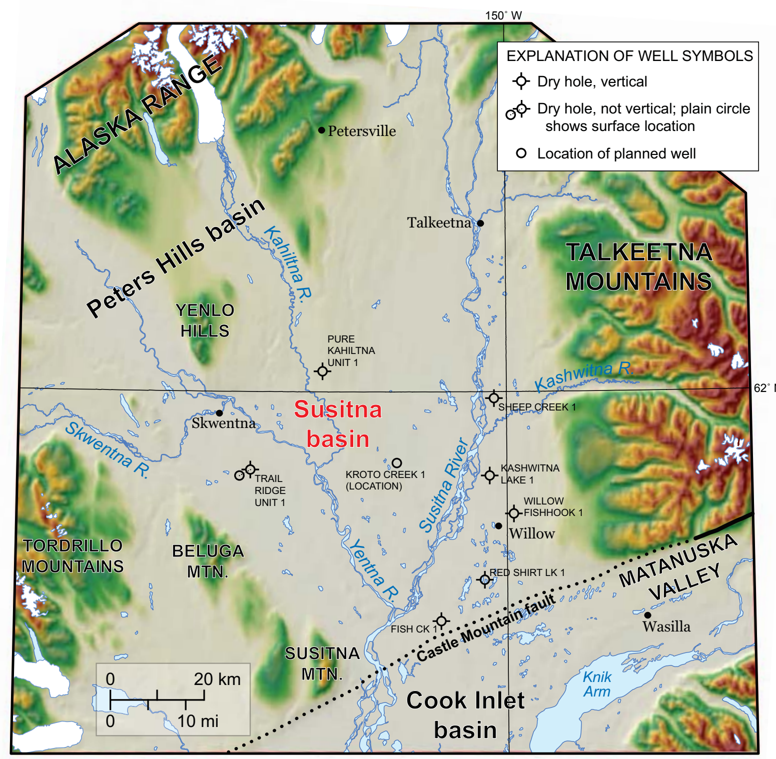
The volcanic package is overlain by a nonmarine sequence of sandstone, siltstone, and coal that contains Eocene palynomorphs and has an apparent thickness of more than 1,300 m in the Trail Ridge and Pure Kahiltna wells. The Eocene strata, in turn, are unconformably overlain by Miocene and younger nonmarine strata. Nonmarine deposition is indicated by the presence of coal and terrestrial palynomorphs and the absence of marine fossils.

In the western part of the Susitna basin, seismic reflection and aeromagnetic data reveal the presence of a prominent syncline flanked by N-striking reverse faults. The Trail Ridge well is located on the western limb of this syncline and penetrated a sequence of conglomerate and sandstone, about 2,500 m thick, that contains early Miocene to Quaternary palynomorphs. We hypothesize that Miocene and younger folding and faulting created a synclinal depocenter that accommodated the thick sedimentary pile at the Trail Ridge well.

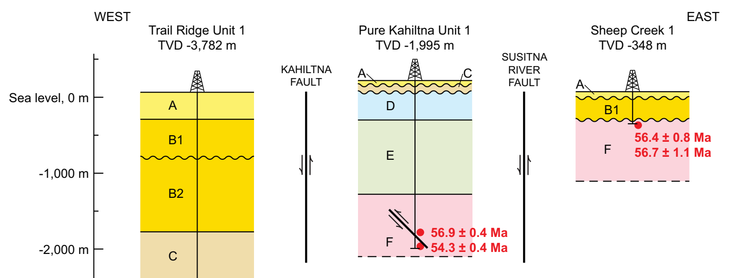
In the eastern part of the basin, seismic profiles show that Tertiary strata are deformed into open folds and cut by reverse and thrust faults. Subtle NE-striking aeromagnetic lineations are coincident with anticlinal crests in the Paleogene volcanic package. Gravity modeling indicates that the southwestern margin of the basin is the Beluga Mountain fault, a NW-striking, SW-dipping thrust fault.

We suggest that Paleogene strata in the Susitna basin record volcanism, subsidence, and sedimentation that accompanied eastward passage of a slab window related to subduction of the Resurrection-Kula spreading ridge. The Miocene-on-Paleogene unconformity is not precisely dated but may record uplift and erosion that accompanied the initiation of Yakutat microplate subduction beneath south-central Alaska. Compressional deformation associated with microplate subduction resulted in folding, faulting, and subsidence of at least one synclinal depocenter during the Neogene and Quaternary.

Susitna basin location map

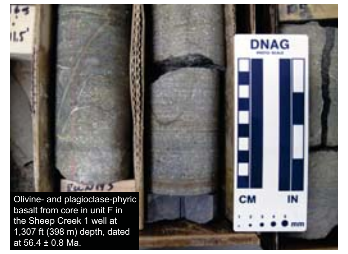

EXPLANATION OF WELL SYMBOLS
Dry hole, vertical
Dry hole, not vertical; plain circle shows surface location
Location of planned well
ALASKA RANGE
Petersville
Peters Hills basin
Kahiltna R.
Talkeetna
TALKEETNA MOUNTAINS
YENLO HILLS
PURE KAHILTNA UNIT 1
Susitna basin
Skwentna
Skwentna R.
Kashwitna R.
SHEEP CREEK 1
TRAIL RIDGE UNIT 1
KROTO CREEK 1 (LOCATION)
KASHWITNA LAKE 1
WILLOW FISHHOOK 1
Willow
TORDRILLO MOUNTAINS
BELUGA MTN.
Susitna River
Yentna R.
RED SHIRT LK 1
MATANUSKA VALLEY
Wasilla
FISH CK
Castle Mountain fault
SUSITNA MTN.
Cook Inlet basin
Knik Arm
150° W
62° N
0 20 km
0 10 mi

Correlation and volcanic geochronology of wells



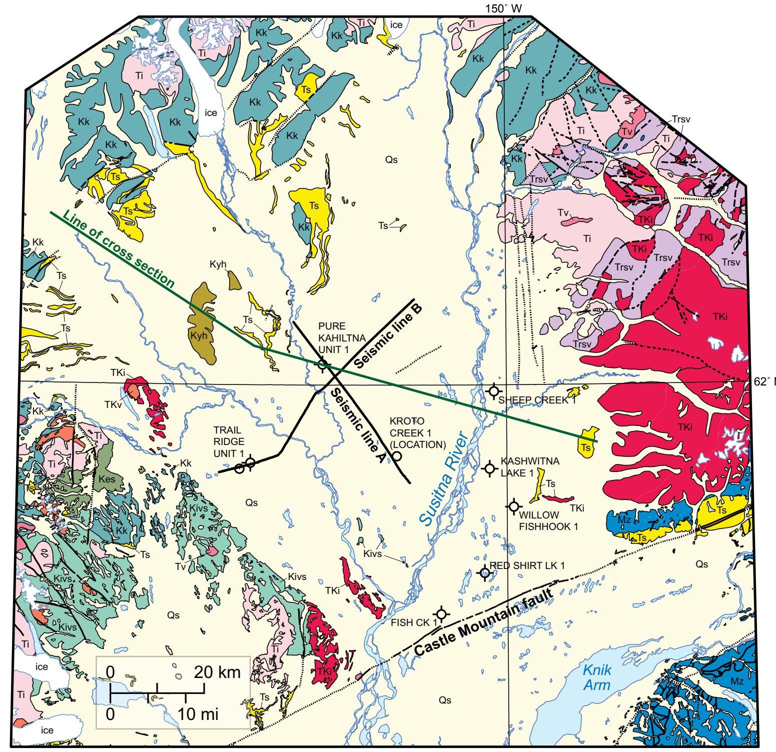
EXPLANATION (modified from Stanley & others, 2013, 2014)
A, Boulder gravel, sand, & clay; Quaternary, glacial & fluvial (59-364 m thick)
B1, Sandstone, conglomerate, siltstone, claystone, & coal; late Pliocene to late Miocene or middle Miocene, nonmarine (0-497 m thick)
B2, Conglomerate, sandstone, siltstone, & claystone; middle Miocene to early Miocene, nonmarine (0-1,014 m thick)
C, Sandstone, siltstone, claystone, & coal; middle Miocene to early Miocene, nonmarine (90-608 m thick)
D, Sandstone, siltstone, claystone, & coal; middle Eocene, nonmarine (375-683 m thick)
E, Sandstone, siltstone, coal, & claystone; early Eocene, nonmarine (626-979 m thick)
F, Basalt/andesite, conglomerate, sandstone, siltstone, claystone, & coal; early Eocene to late Paleocene, nonmarine (>500 m thick)

Andesitic(?) tuff with near-vertical flow banding, from core in unit F in the Pure Kahiltna 1 well at 7,243-7,265 ft (2,208-2,214 m) depth, dated at 54.3 ± 0.4 Ma.



Olivine- and plagioclase-phyric basalt from core in unit F in the Sheep Creek 1 well at 1,307 ft (398 m) depth, dated at 56.4 ± 0.8 Ma.

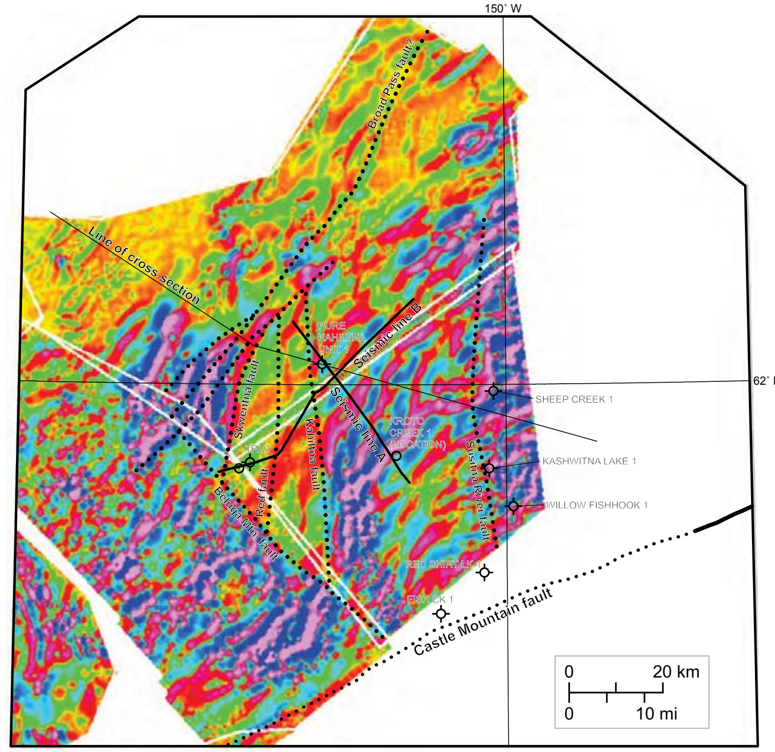
Susitna basin surface geology (modified from Wilson and others, 2012)


150° W
62° N
Line of cross section
Seismic line B
Seismic line A
PURE KAHILTNA UNIT 1
TRAIL RIDGE UNIT 1
KROTO CREEK 1 (LOCATION)
SHEEP CREEK 1
KASHWITNA LAKE 1
WILLOW FISHHOOK 1
RED SHIRT LK 1
FISH CK
Susitna River
Castle Mountain fault
Knik Arm
0 20 km
0 10 mi

SURFACE GEOLOGIC MAP UNITS

Unit	Description
Qs	Quaternary deposits
Ts	Tertiary sedimentary rocks
Tv	Tertiary volcanic rocks
Ti	Tertiary intrusive rocks
TKv	Tertiary & Cretaceous volcanic rocks
TKi	Tertiary & Cretaceous intrusive rocks
Kivs	Metavolcanic & sedimentary rocks (Cretaceous and/or Paleogene)
Kk	Kahiltna flysch sequence (Cretaceous)
Kyh	Graywacke of the Yenlo Hills (Cretaceous & Jurassic)
Kes	Flysch of the Tordrillo Mountains (Cretaceous & Jurassic)
Trsv	Triassic igneous, sedimentary, & metamorphic rocks, undivided
Mz	Mesozoic rocks, undivided

High pass filtered magnetic map, inferred faults (dotted), seismic lines (solid), and wells



References cited

Doser, D. I., 2004, Seismicity of the Denali–Totschunda fault zone in central Alaska (1912-1988) and its relation to the 2002 Denali fault earthquake sequence: Bulletin of the Seismological Society of America, v. 4, no. 6B, p. S132–S144.

Haeussler, P. J., 2008, An overview of the neotectonics of interior Alaska—far-field deformation from the Yakutat microplate collision, *in* Freymueller, J.T., and others, eds., Active Tectonics and seismic potential of Alaska: AGU Monograph 179, p. 83-108.

Hults, C.P., Wilson, F.H., Donelick, R.A., and O'Sullivan, P.B., 2013, Two flysch belts having distinctly different provenance suggest no stratigraphic link between the Wrangellia composite terrane and the paleo-Alaskan margin: Lithosphere, v. 5, no. 6, p. 575-594.

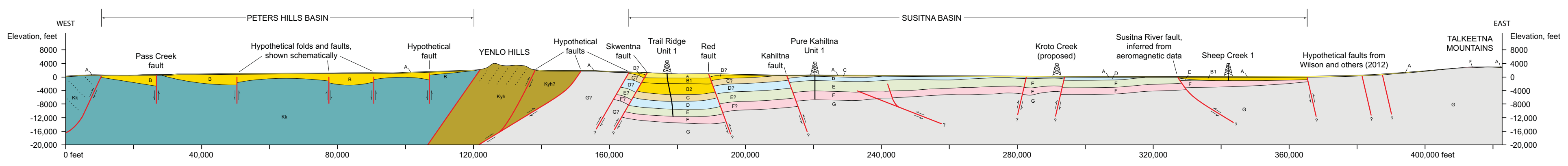
Nokleberg, W.J., Plafker, George, and Wilson, F.H., 1994, Geology of south-central Alaska, *in* Plafker, G., and Berg, H. C., eds., The geology of Alaska: GSA, The geology of North America, v. G-1, p. 311–366.

Stanley, R.G., Haeussler, P.J., Benowitz, J.A., Goodman, D.K., Ravn, R.L., Shellenbaum, D.P., Saltus, R.W., Lewis, K.A., and Potter, C.J., 2013, New stratigraphic revelations in the subsurface Susitna basin, south-central Alaska, from geochronology and biostratigraphy [poster]: Alaska Division of Geological & Geophysical Surveys, 1 sheet, http://www.dggs.alaska.gov/pubs/id/26887

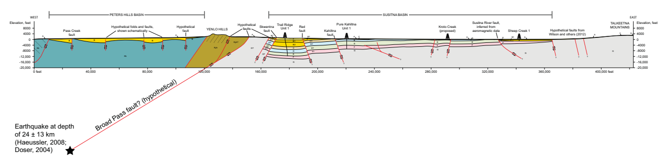
Stanley, R.G., Lillis, P.G., Pawlewicz, M.J., and Haeussler, P.J., 2014, Rock-Eval pyrolysis and vitrinite reflectance results from the Sheep Creek 1 well, Susitna basin, south-central Alaska: U.S. Geological Survey Open-File Report 2013-1307, 12 p.

Wilson, F.H., Hults, C.P., Schmoll, H.R., Haeussler, P.J., Schmidt, J.M., Yehle, L.A., and Labay, K.A., compilers, 2012, Geologic map of the Cook Inlet region, Alaska: U.S. Geological Survey Scientific Investigations Map 3153, 76 p., 2 sheets, scale 1:250,000, http://pubs.usgs.gov/sim/3153/

Preliminary cross section of Peters Hills and Susitna basins (location shown on geologic map)


WEST
EAST
PETERS HILLS BASIN
SUSITNA BASIN
Elevation, feet
Pass Creek fault
Hypothetical folds and faults, shown schematically
Hypothetical fault
YENLO HILLS
Hypothetical faults
Skwentna fault
Trail Ridge Unit 1
Red fault
Kahiltna fault
Pure Kahiltna Unit 1
Kroto Creek (proposed)
Susitna River fault, inferred from aeromagnetic data
Sheep Creek 1
Hypothetical faults from Wilson and others (2012)
TALKEETNA MOUNTAINS
Kk
Kyh
G
0 feet
40,000
80,000
120,000
160,000
200,000
240,000
280,000
320,000
360,000
400,000 feet

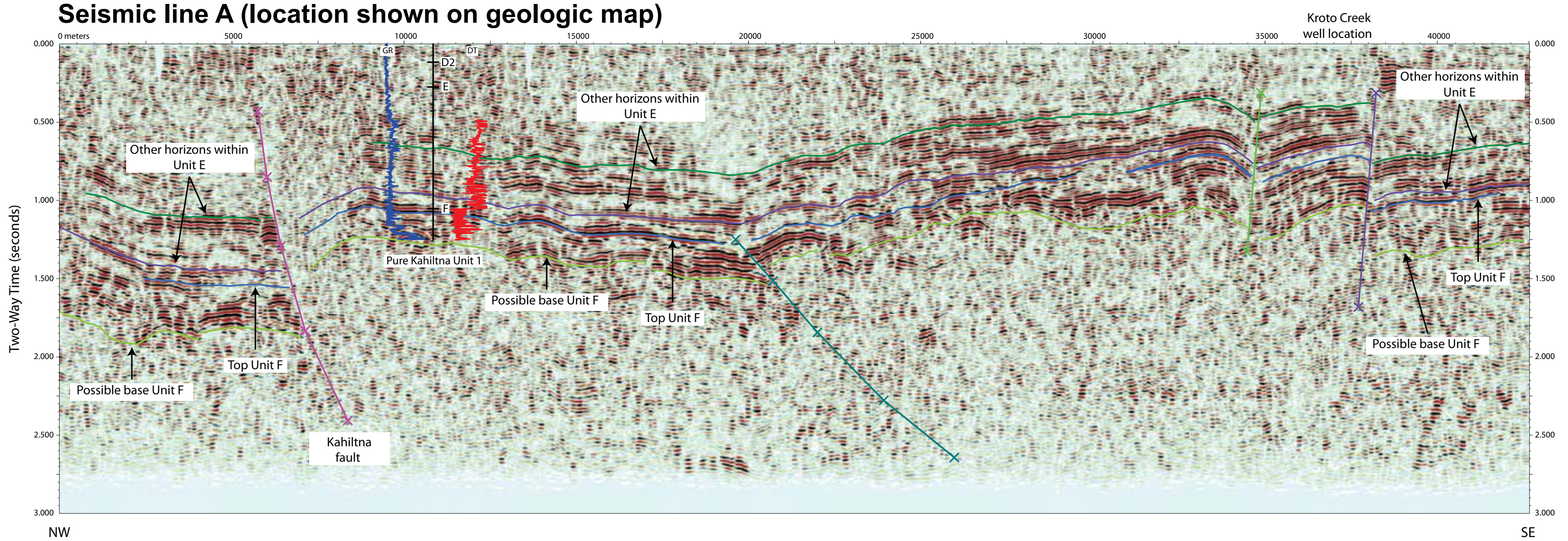
Cross section at same scale as geologic map (1:500,000)



EXPLANATION

Unit	Description
A	A, Boulder gravel, sand, and clay; Quaternary, glacial and fluvial
B	B, Sandstone, conglomerate, siltstone, claystone, & coal; Pliocene & Miocene, nonmarine. Locally divided into:
B1	B1, Sandstone, conglomerate, siltstone, claystone, and coal; late Pliocene to late Miocene or middle Miocene
B2	B2, Conglomerate, sandstone, siltstone, and claystone; middle Miocene to early Miocene
C	C, Sandstone, siltstone, claystone, and coal; middle Miocene to early Miocene, nonmarine
D	D, Sandstone, siltstone, claystone, and coal; middle Eocene, nonmarine
E	E, Sandstone, siltstone, coal, and claystone; early Eocene, nonmarine
F	F, Basalt/andesite, conglomerate, sandstone, siltstone, claystone, and coal; early Eocene to late Paleocene, nonmarine
G	G, Igneous, metamorphic, and sedimentary rocks (Triassic and older) of the Wrangellia composite terrane of Nokleberg and others (1994) and igneous intrusions (Tertiary and Cretaceous)
Kk	Kk, Kahiltna flysch sequence (of Wilson and others, 2012); sandstone, siltstone, and argillite; Cretaceous (Hults and others, 2013); marine, deformed, and locally metamorphosed
Kyh	Kyh, Graywacke of the Yenlo Hills (of Wilson and others, 2012); Cretaceous and Jurassic (Hults and others, 2013); marine

Seismic line A (location shown on geologic map)



Author affiliations and contact information:

Benowitz: Geophysical Institute, University of Alaska Fairbanks, P.O. Box 755940, Fairbanks, AK 99775, 907-457-7010, jbenowitz@alaska.edu

Haeussler: U.S. Geological Survey, U.S. Geological Survey, 4210 University Drive, Anchorage, AK 99508, 907-786-7447, pheuslr@usgs.gov

Lewis: U.S. Geological Survey, Box 25046, MS 939, Denver, CO 80225, 303-236-5572, klewis@usgs.gov

Phillips: U.S. Geological Survey, Box 25046, MS 964, Denver, CO 80225, 303-236-1206, jeff@usgs.gov

Potter: U.S. Geological Survey (at Rutgers University), Piscataway, NJ 08854, 303-506-1405, cpotter@usgs.gov

Saltus: U.S. Geological Survey, Box 25046, MS 964, Denver, CO 80225, 303-236-1375, saltus@usgs.gov

Shah: U.S. Geological Survey, Box 25046, MS 964, Denver, CO 80225, 303-236-1218, ashah@usgs.gov

Shellenbaum: Alaska Division of Oil and Gas, 550 W. 7th Ave, Suite 1100, Anchorage, AK 99501, 907-375-8241, diane.shellenbaum@alaska.gov

Stanley: U.S. Geological Survey, 345 Middlefield Road, MS 969, Menlo Park, CA 94025, 650-329-4918, rstanley@usgs.gov

Seismic line B (location shown on geologic map)