Thrust Faults in Transpressive Strike-slip Environments: Role of the Susitna Glacier Fault in the M_w 7.9 Denali Fault Earthquake Sequence, Alaska

Anthony J. Crone [1], Stephen F. Personius [1],
Patricia A. Craw [2], Peter J. Haeussler [1]
and Lauren A. Staft [2]

U.S. Geological Survey [1]
and Alaska Dept. of Geological and Geophysical Surveys [2]

The Denali Fault Earthquake

- M_w 7.9 earthquake on 3 November 2002
- Produced 341 km of surface rupture on parts of three faults:
  Susitna Glacier (48 km), Denali (226 km) and Totschunda (66 km) faults
- Epicenter:
  - 63.5175° N.; 147.444° W.; on trace of Denali fault
  - Depth: ~6 km
- Preceded by M_w 6.7 strike-slip earthquake on 23 October 2002
- Composed of at least three subevents
  - Initial event: reverse faulting N. 82°E., 48° N. nodal plane
  - Second and third events:
    - Right-lateral slip on SE-NW nodal planes
    - Located about 90-100 km and 160-230 km east of mainshock epicenter

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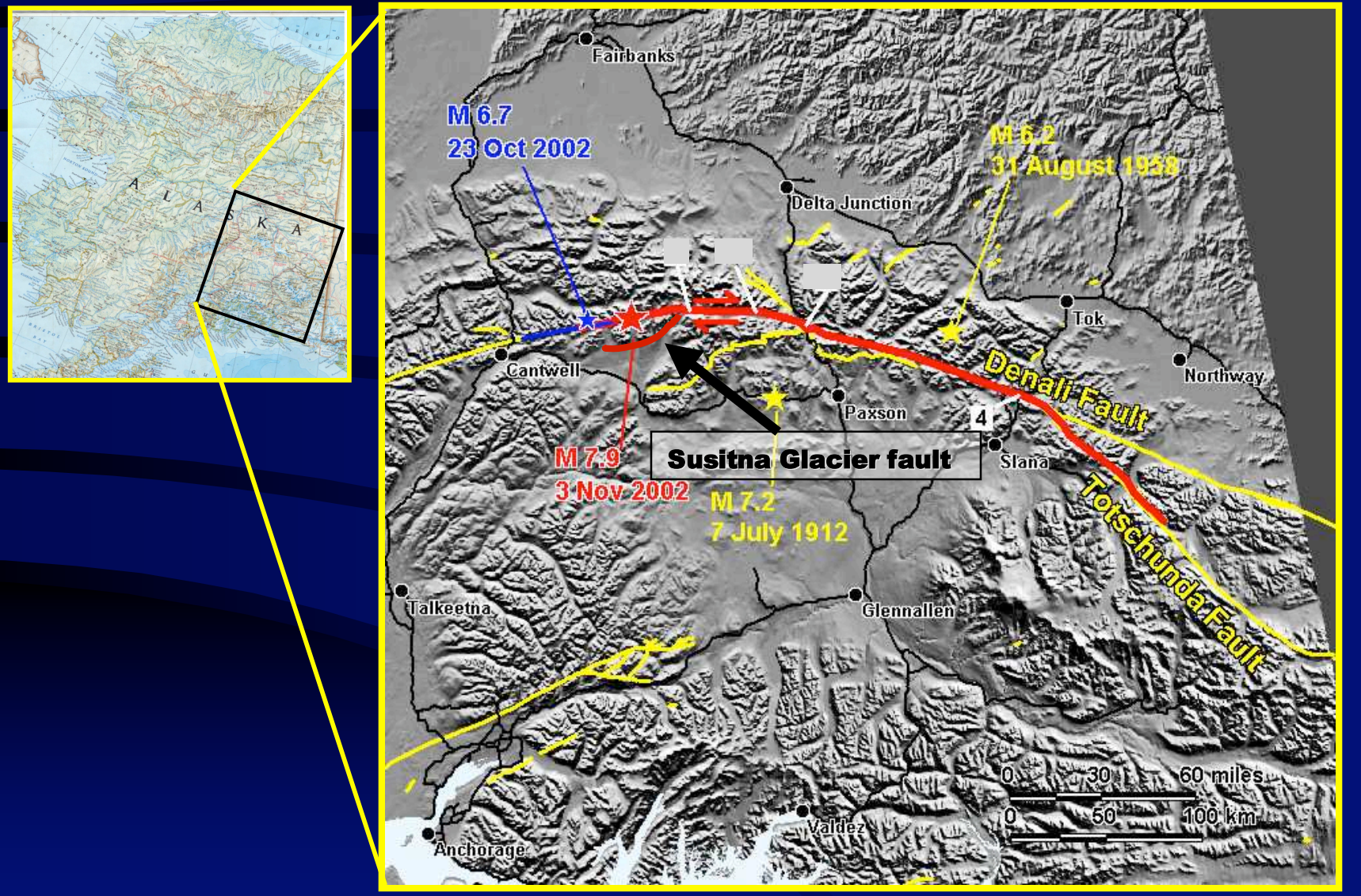
General Location Map



Denali Fault and 2002 Earthquake Epicenters

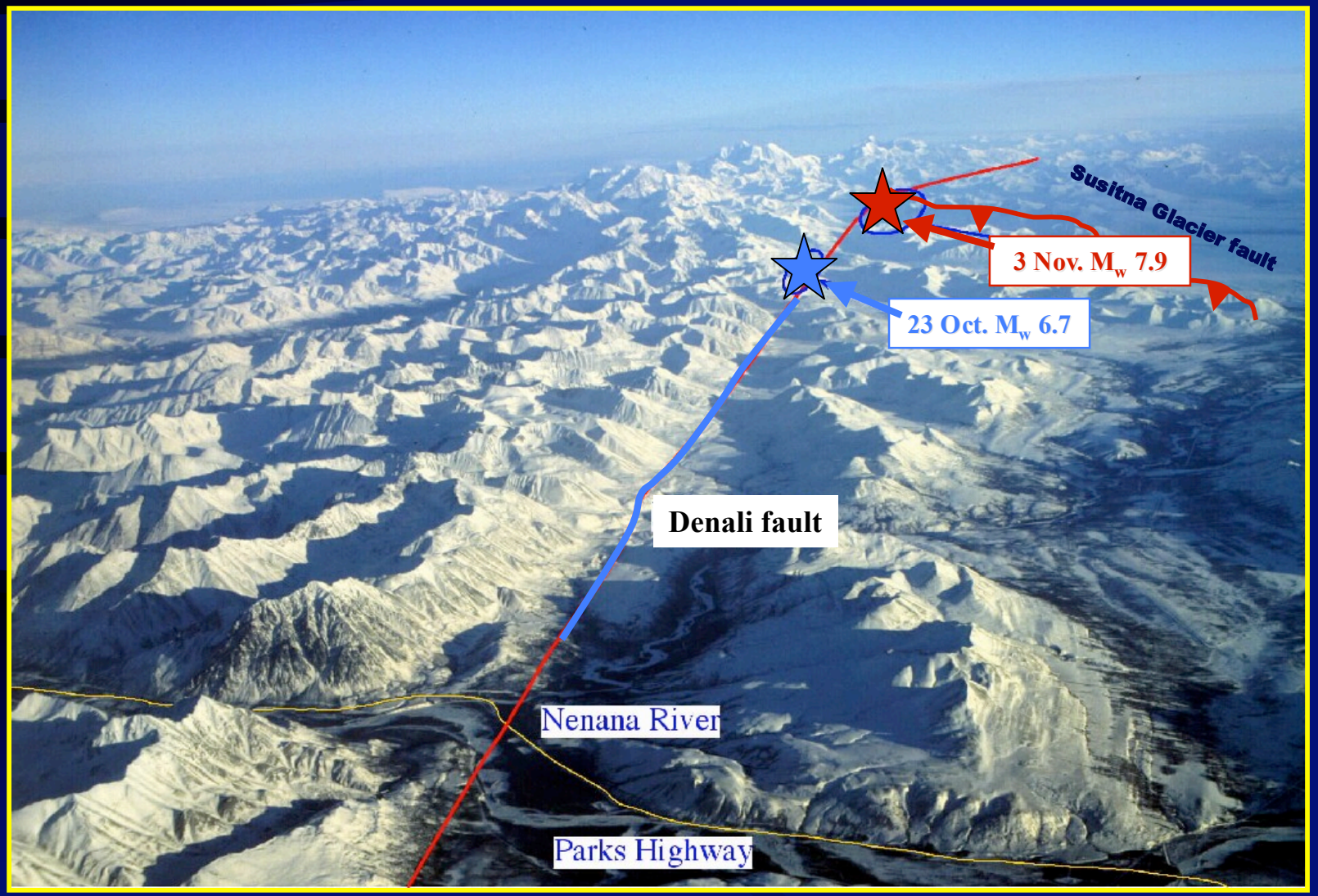


Photo by Wes Wallace, Univ. of Alaska, Fairbanks

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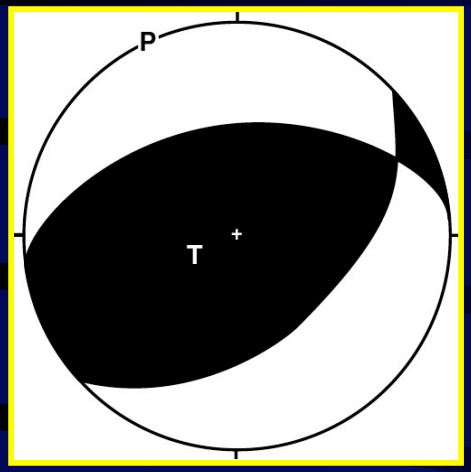
Susitna Glacier Rupture: Subevent 1

Focal Mechanism



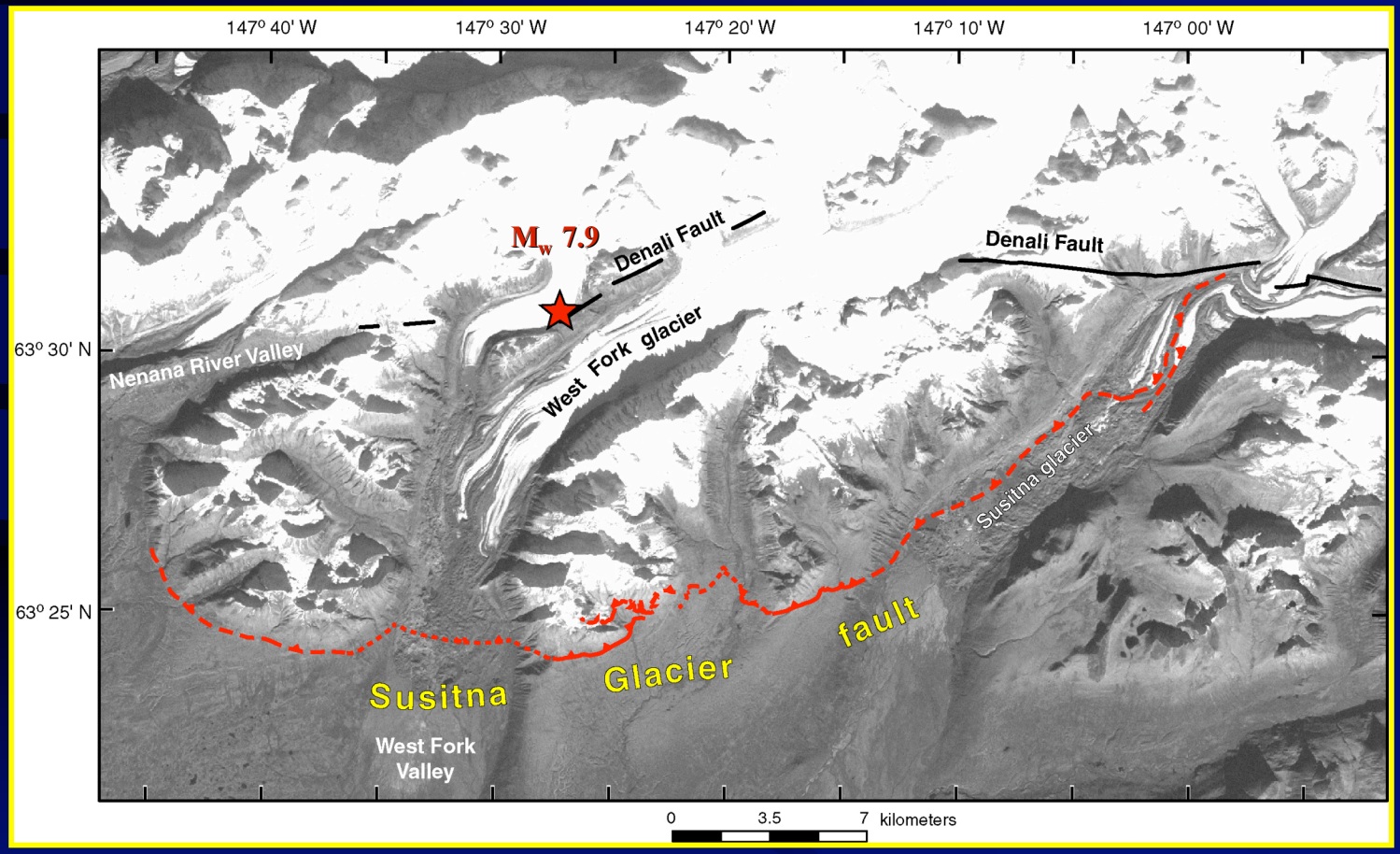
Thrust faulting with minor strike slip;
N 82°E, 48° N

M_w 7.2 event

Surface rupture on previously unknown Susitna Glacier fault

Susitna Glacier Fault: Surface Faulting Parameters

- Surface Rupture: 48 km long
- Typical vertical tectonic displacements: 1-3 m
- Maximum vertical tectonic displacement: 5.4 m



Ruptures extend from southern margin of the Alaska Range to upper part of Susitna Glacier

Susitna Glacier Fault Surface Rupture

Thrust fault, Susitna Glacier
Nov. 2002

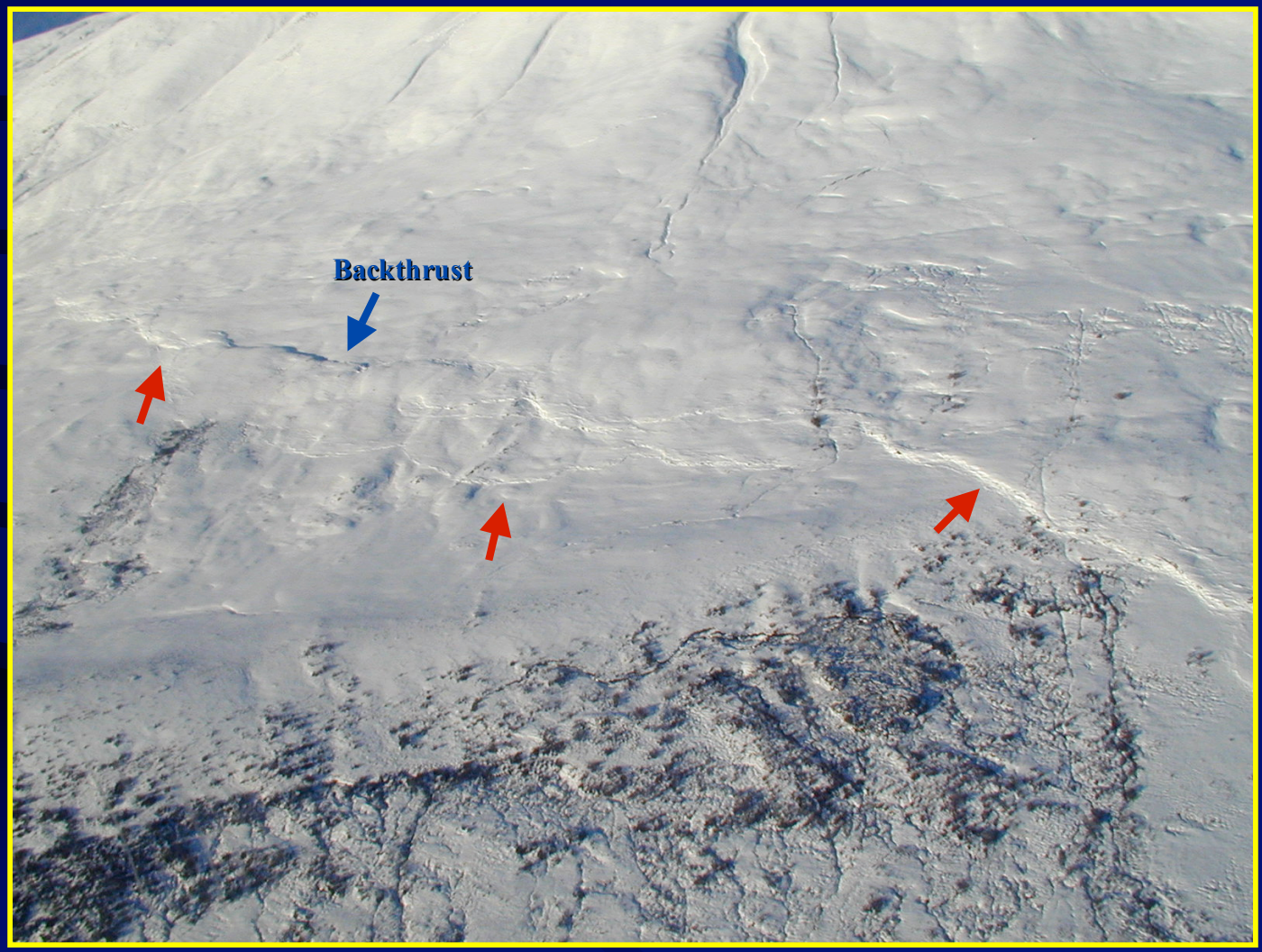
Photograph by P. Haeussler

Brittle failure in glacial ice created thrust-fault scarps

Photograph by P. Craw

Susitna Glacier Fault Surface Rupture

- Southeast-directed thrust fault
- Typical multiple strands and sinuous trace of thrust fault rupture



View to the north-northwest

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Susitna Glacier Fault Surface Rupture

Locally backthrusts are greater than 4 m high

View to the east

North

South

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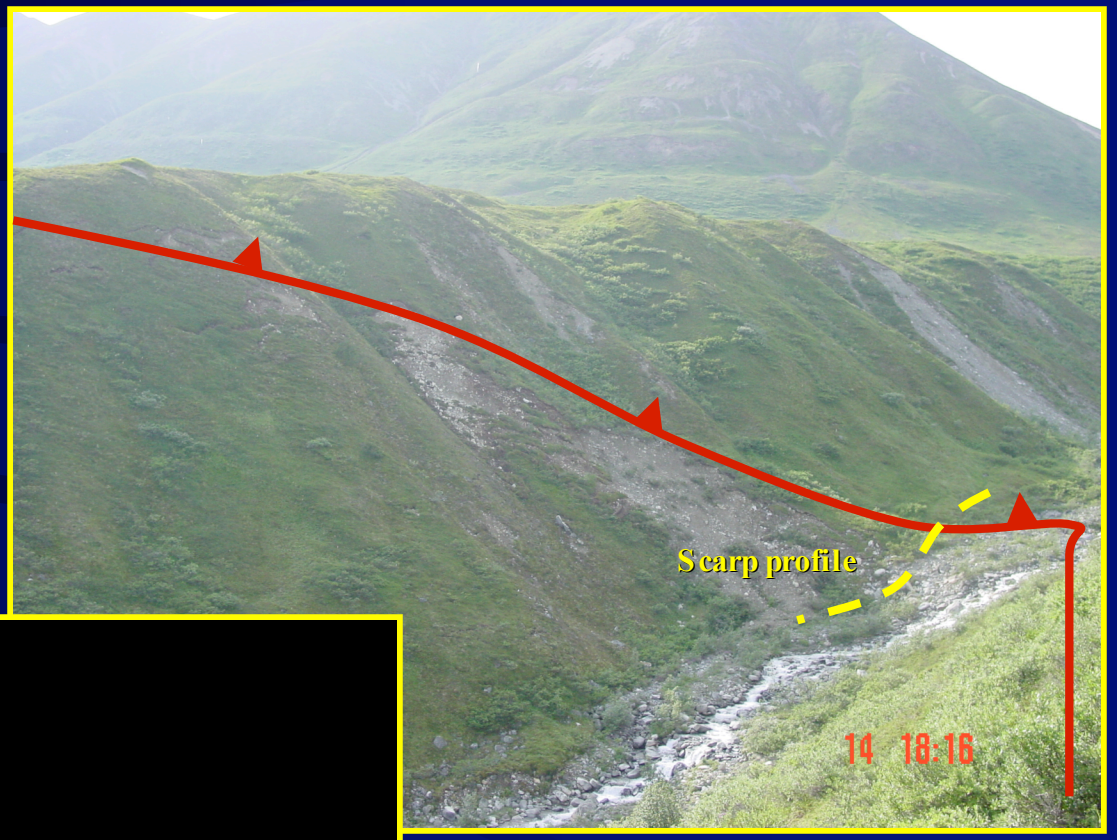
Sustina Glacier Fault Surface Rupture

Best constrained near-surface dip: 19°±3°

Seismological and InSAR data indicate 35°-48° dips



19°±3°

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Susitna Glacier Fault Surface Rupture

- Fault dips to NNW (into the hillside)
- Locally large scarps; 5-7 m high
- Large scarps are generally compound scarps from 2002 rupture superimposed on previous event and from near-fault warping in footwall.

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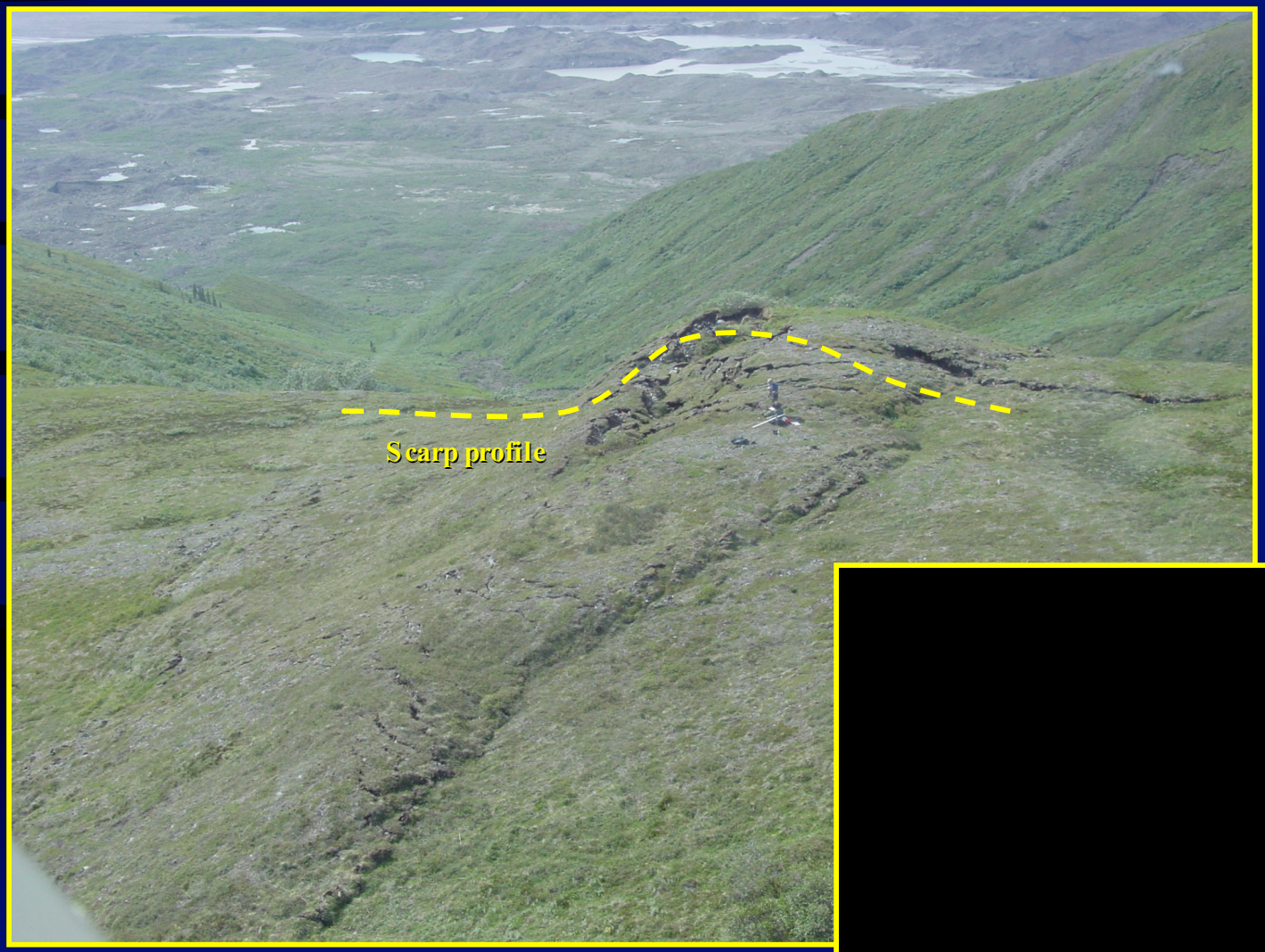
Susitna Glacier Fault Surface Rupture



Complex rupture patterns on old scarps

Susitna Glacier Fault Paleoseismology

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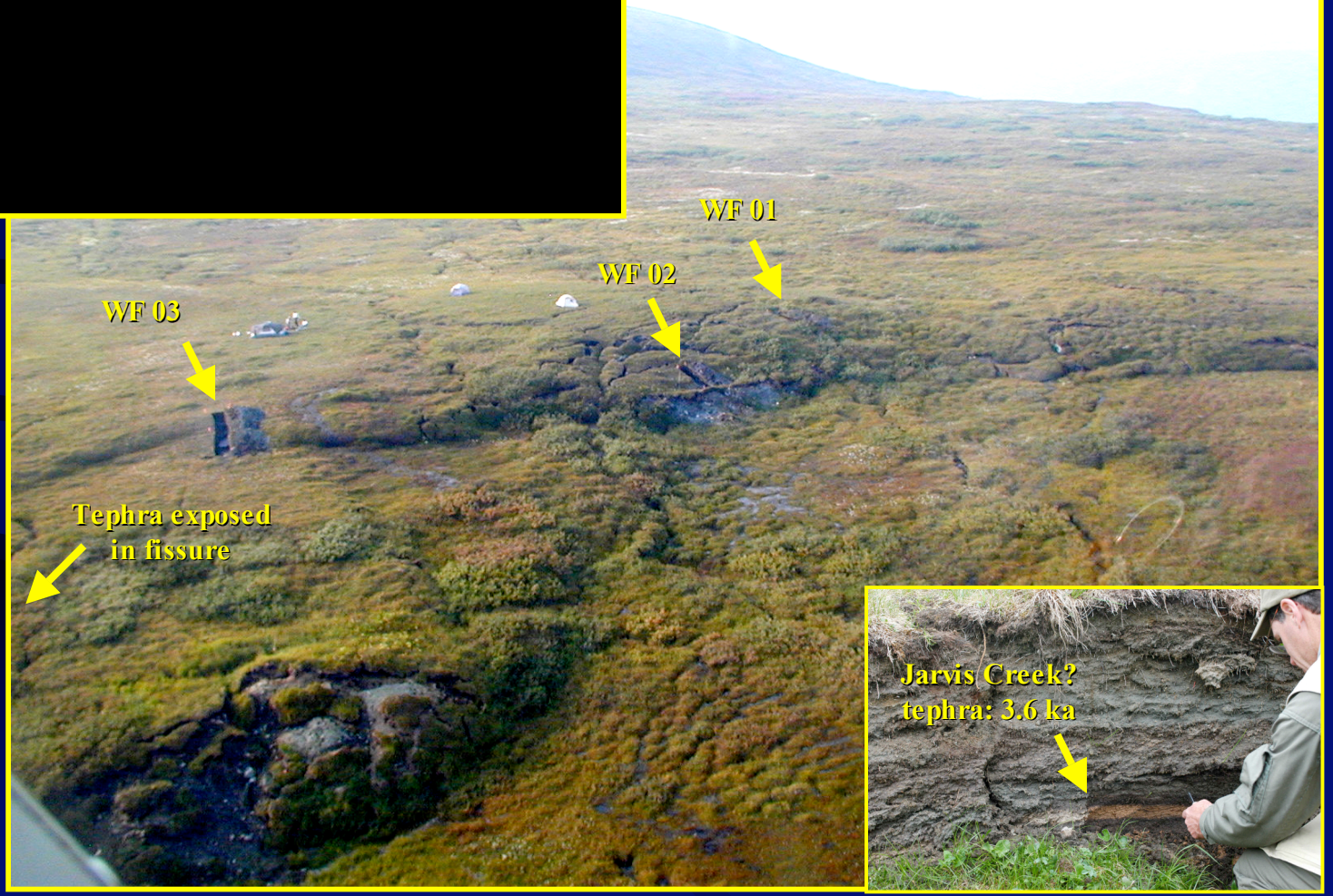
Three trenches across prehistoric scarp at "Wet-fan" site



2002 ruptures superimposed on prehistoric fault scarp

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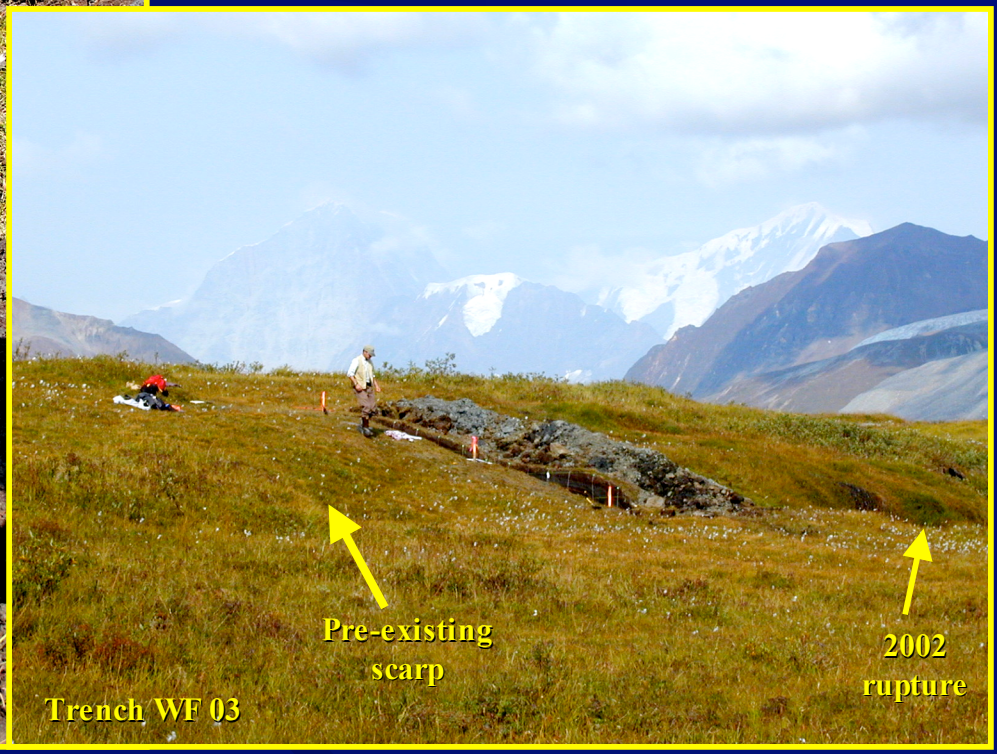
Susitna Glacier Fault Paleoseismology: "Wet-fan" Site

Tephra extensively deformed in all trenches



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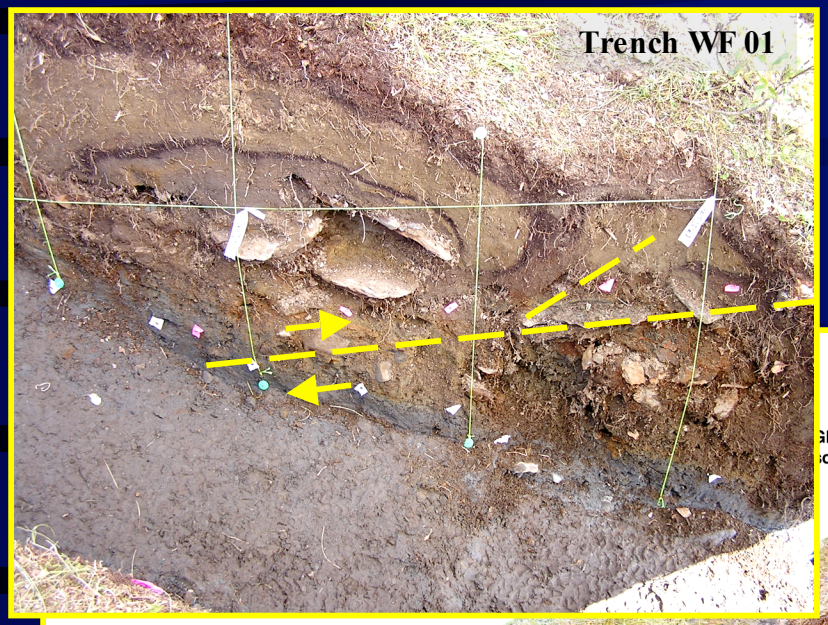
Susitna Glacier Fault Paleoseismology: "Wet-fan" Site

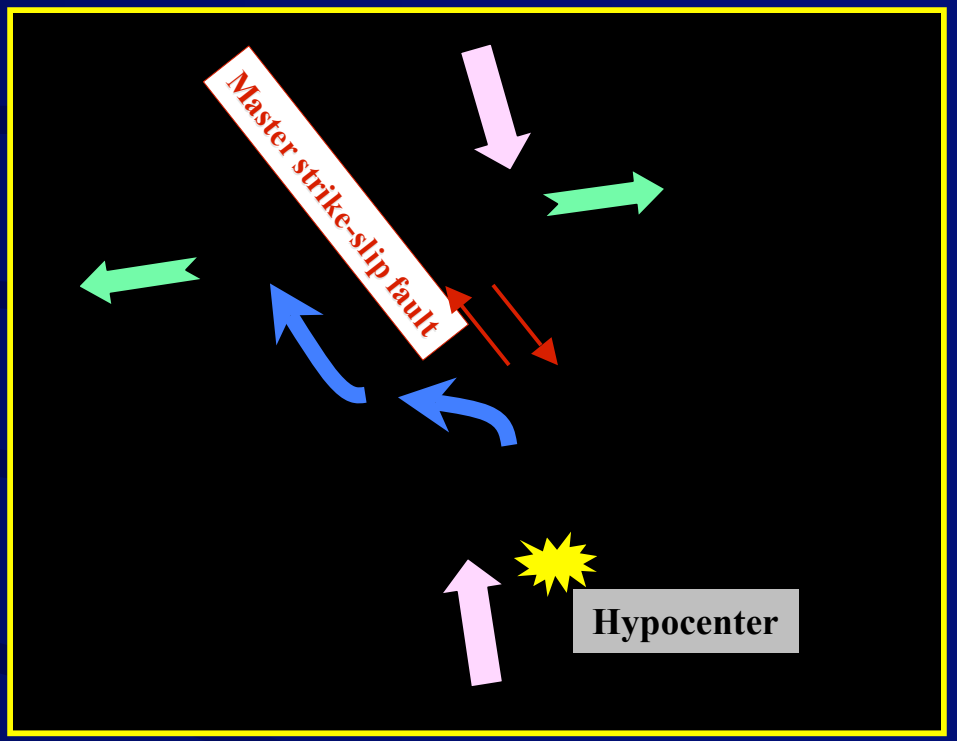


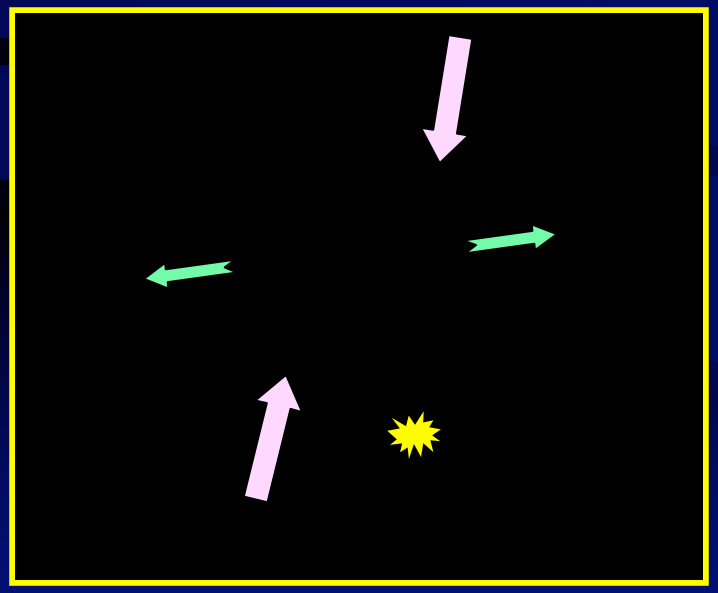
- Convoluted bedding and recumbent folding of Jarvis Creek? tephra (3650 yr BP)
- Deformation predates 2002 earthquake
- Penultimate event < 3.6 ka; older than MRE on Denali fault (450-650 yr BP)

Trench WF 03

Thrust Faults in Transpressional Settings

- Rupture of thrust fault reduces fault-normal compression
- Encourages failure of strained strike-slip master fault





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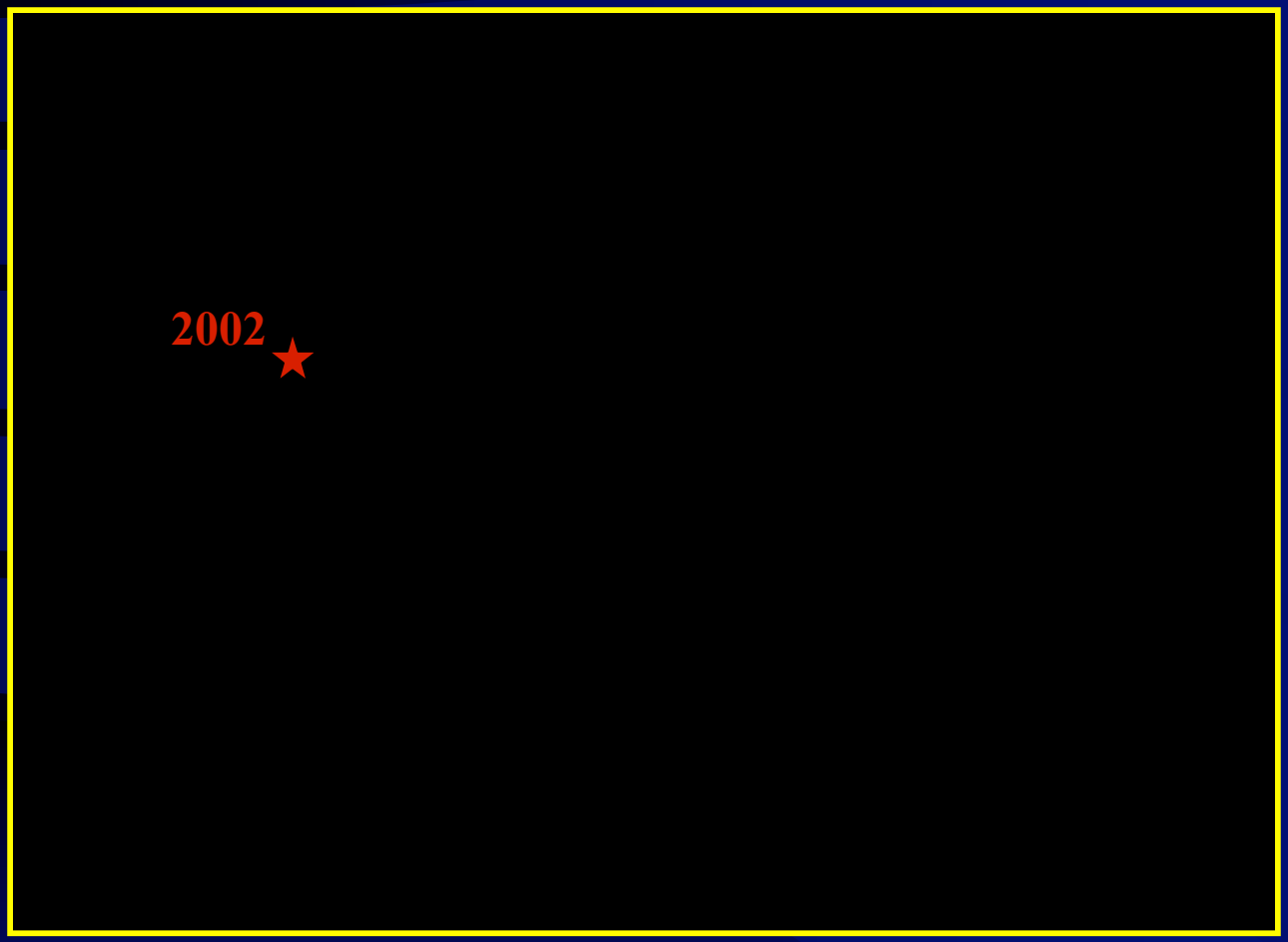
Denali Fault System – Related Thrust Faults



Poorly studied reverse faults of Denali fault system reported to have Quaternary movement

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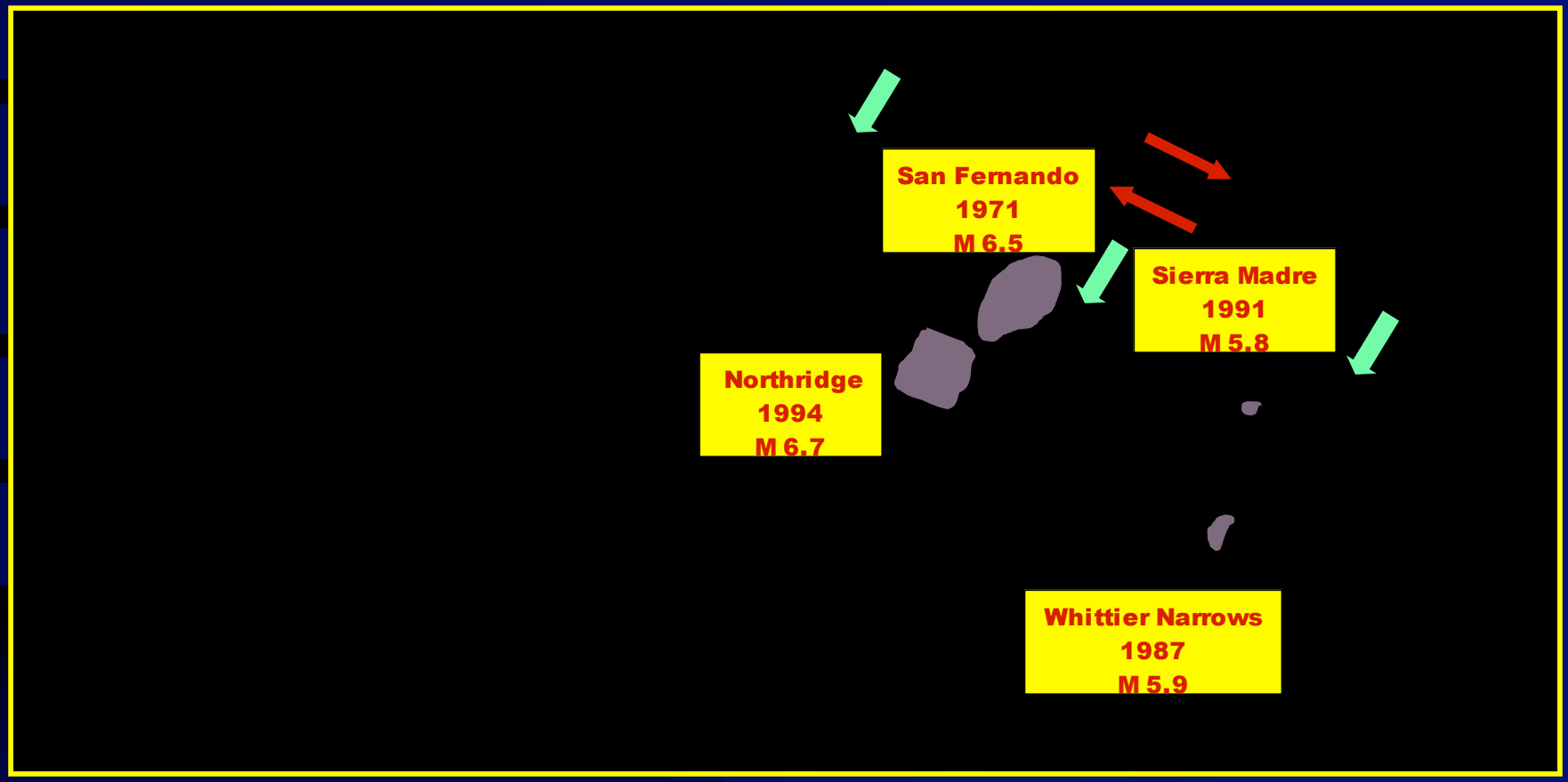
Transpressive Faults: Southern California



Recent damaging thrust-fault earthquakes associated with the southern San Andreas system

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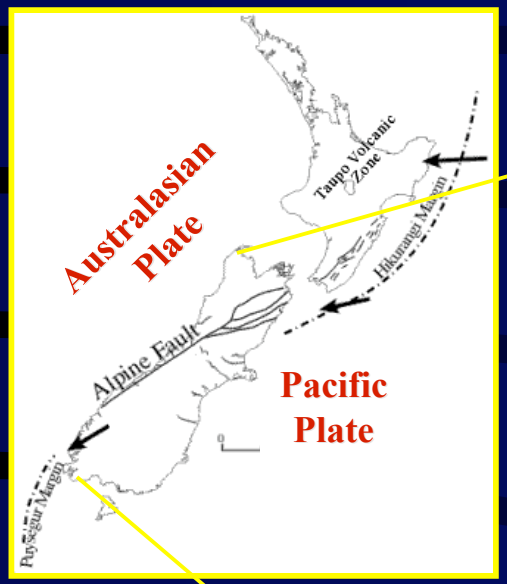
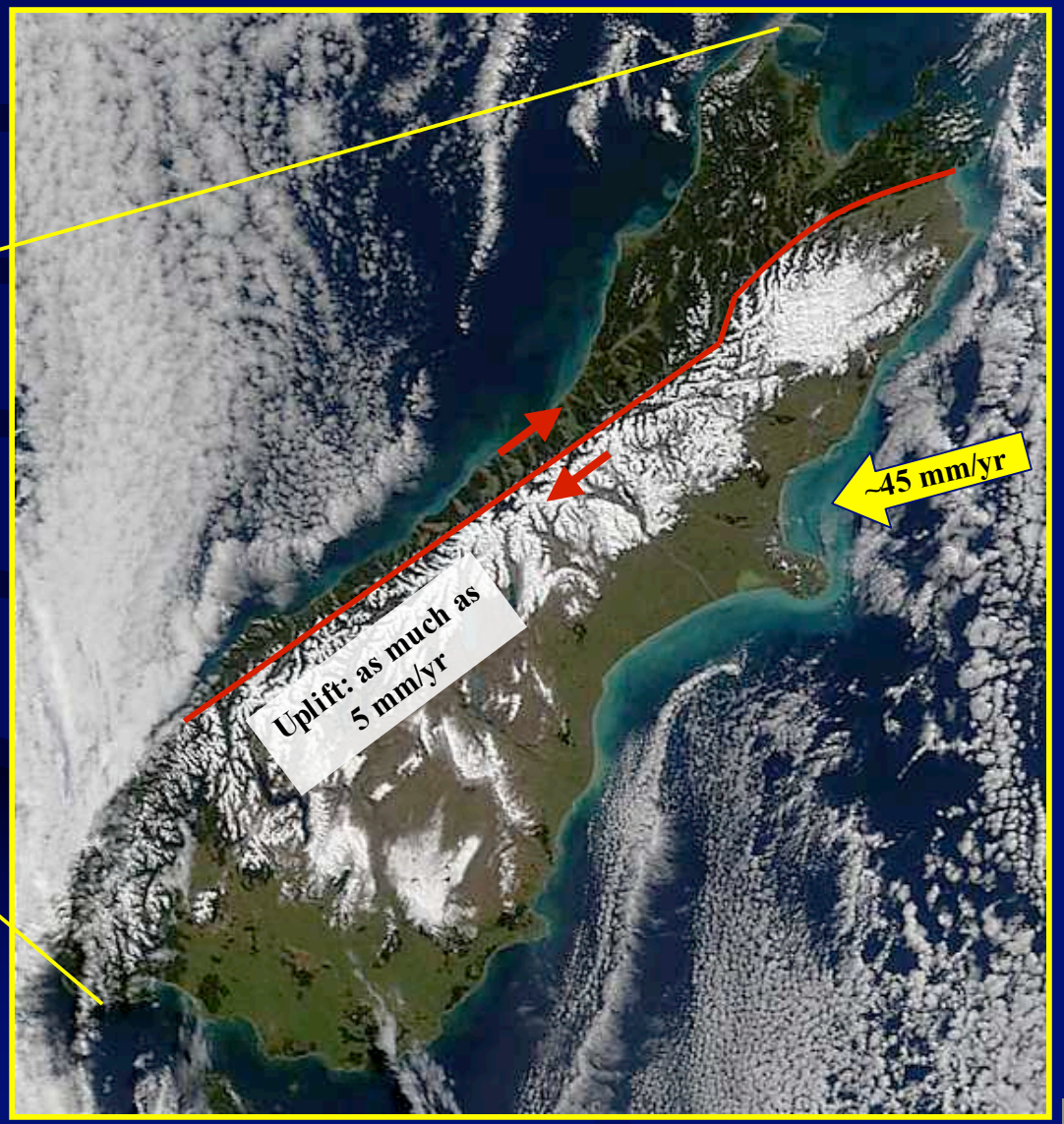
Transpressive Faults: Alpine Fault, New Zealand





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Susitna Glacier-Denali Fault System: Remaining Questions

- Surface rupture on Denali fault is more frequent than on the Susitna Glacier fault.
- Does the thrust fault always rupture in conjunction with slip on master strike-slip fault?
- What is the role of thrust faults on initiating or inhibiting ruptures on the Denali fault?

Seismic Hazard Assessments

- Accurate assessment of seismic hazards of transpressive fault systems requires understanding of role of entire fault system.
- Thrust faults contribute significantly to the hazard.
- Paleoseismological data is useful in characterizing the interaction of fault and behavior of the system.

Comments or Questions