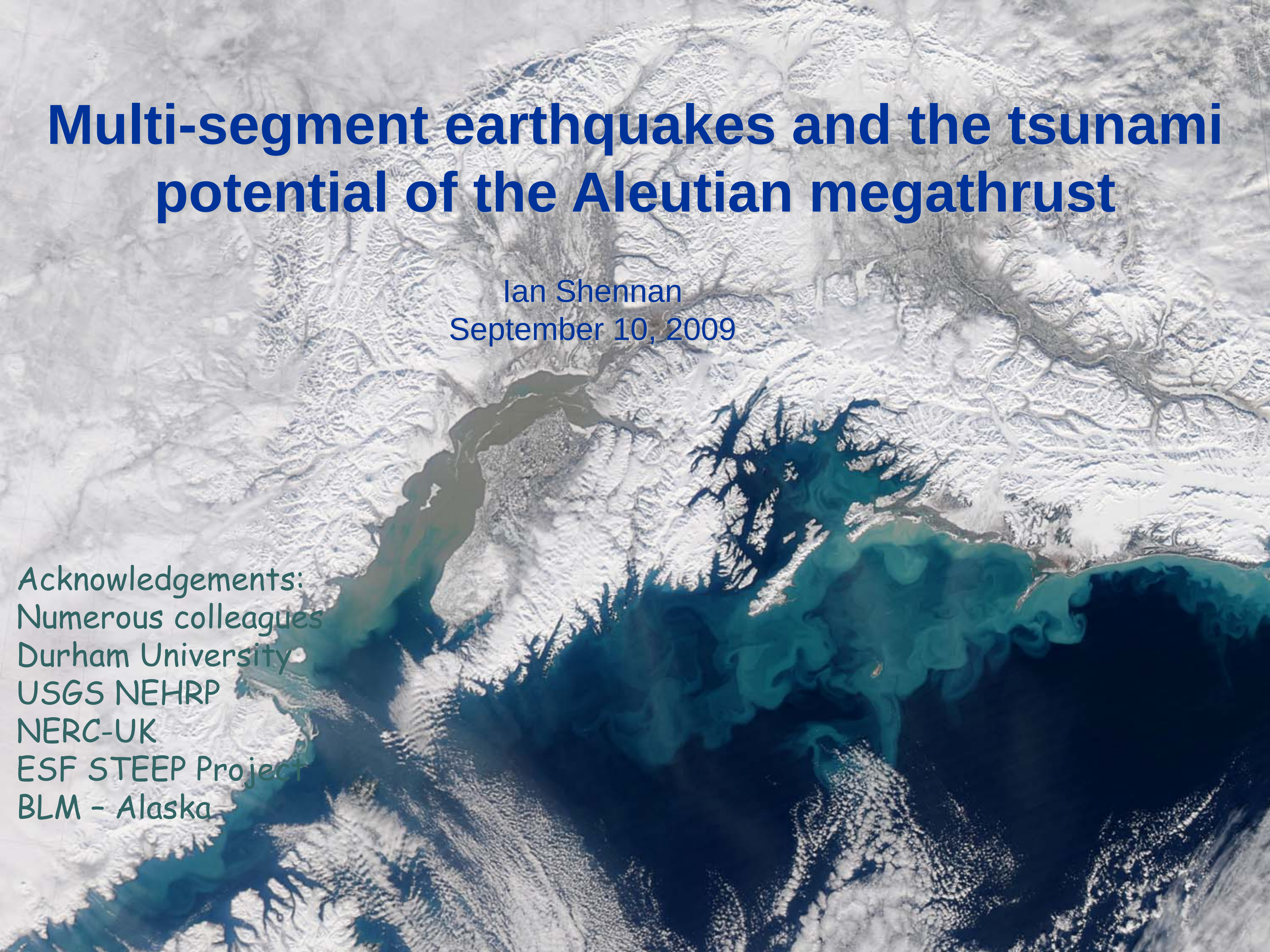
Multi-segment earthquakes and the tsunami potential of the Aleutian megathrust

Ian Shennan

September 10, 2009



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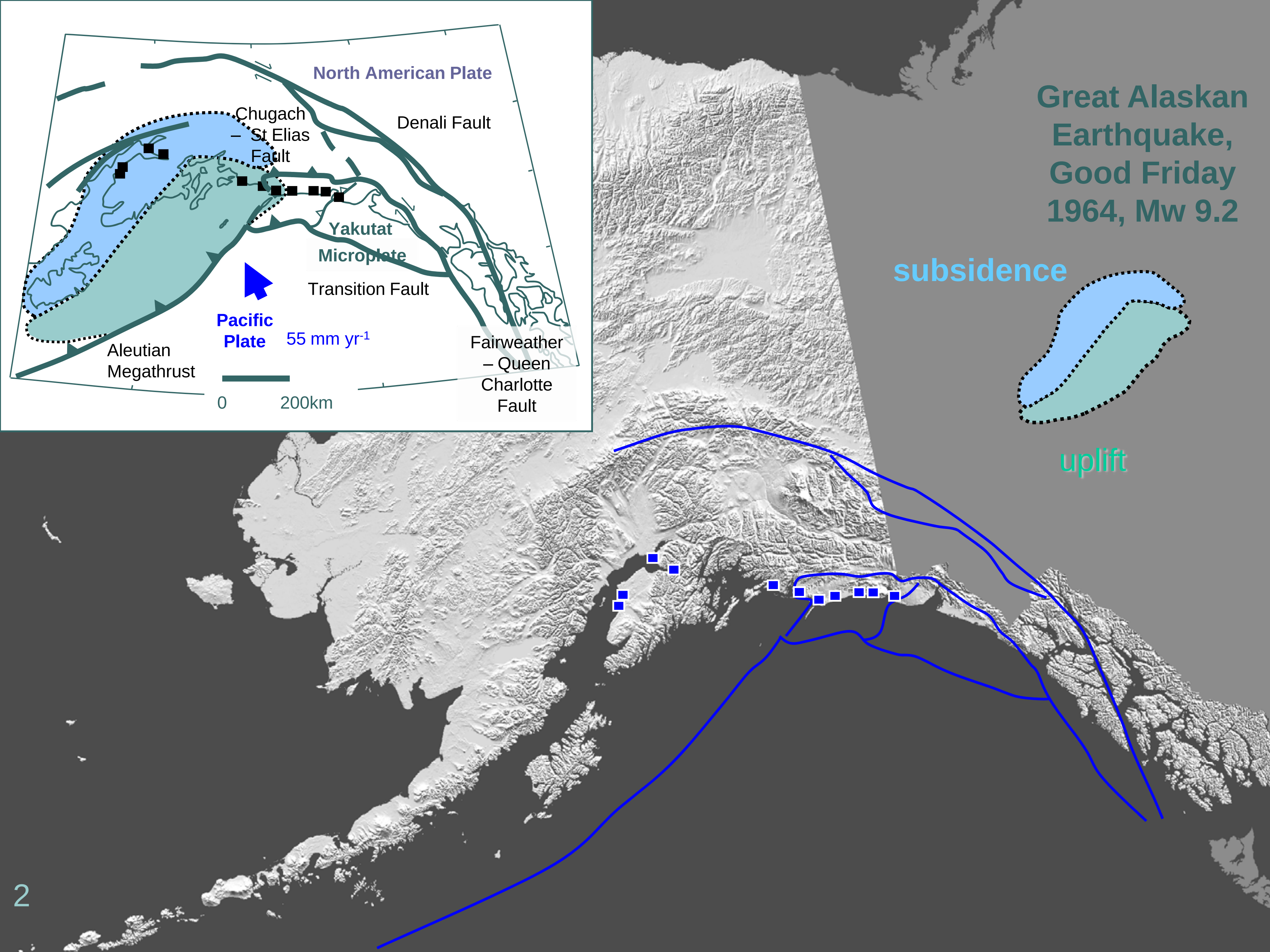
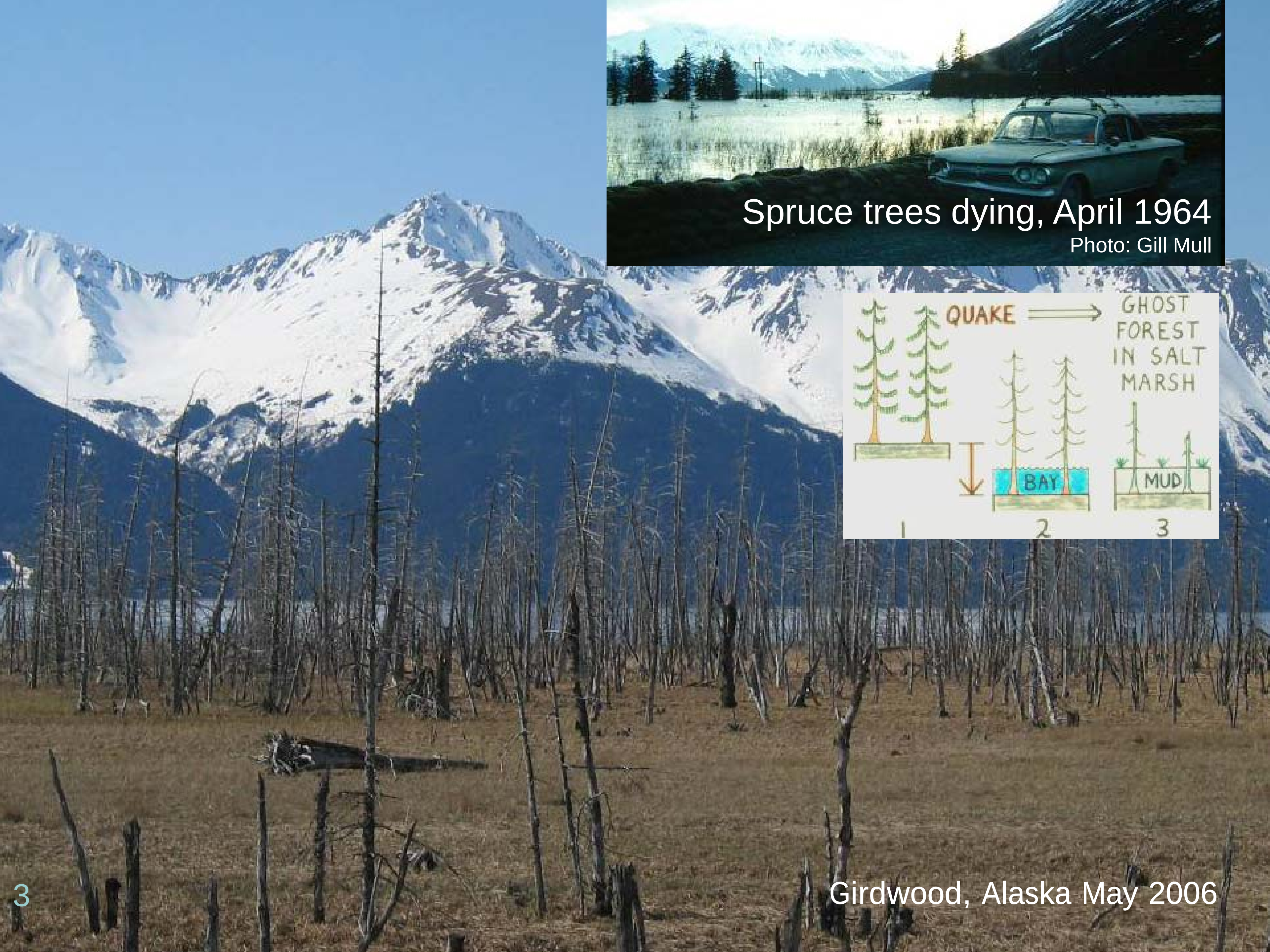
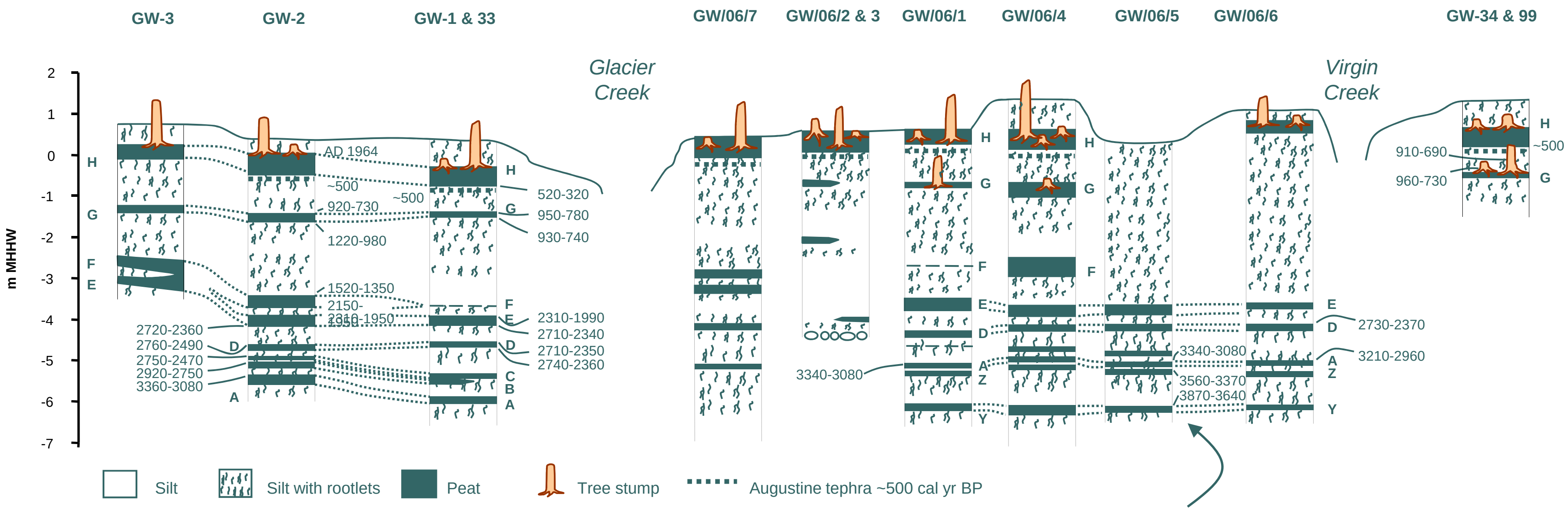
ESF STEEP Project
BLM – Alaska


Great Alaskan Earthquake, Good Friday 1964, Mw 9.2
subsidence
uplift
North American Plate
Chugach – St Elias Fault
Denali Fault
Yakutat Microplate
Transition Fault
Pacific Plate
55 mm yr-1
Aleutian Megathrust
Fairweather – Queen Charlotte Fault
0
200km



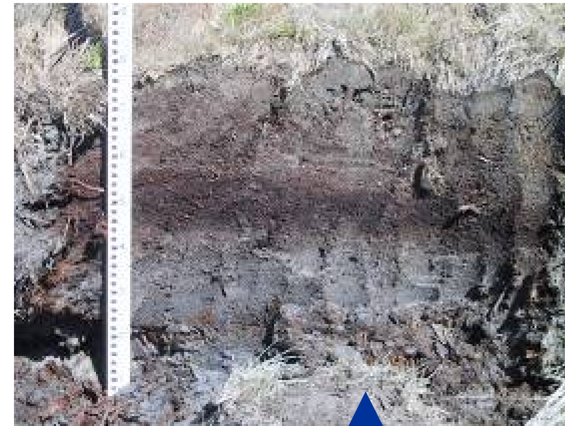
Girdwood, Alaska May 2006

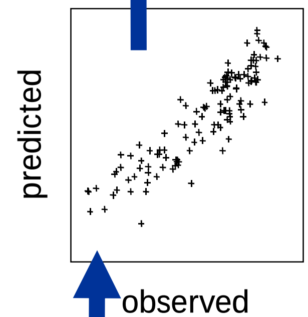
Girdwood: 10 peat-mud couplets, 7 great earthquakes

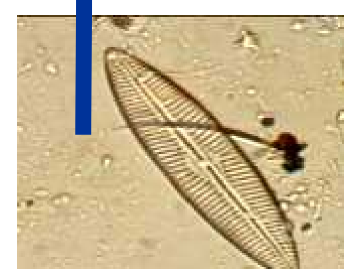


3870-3640 cal yr BP

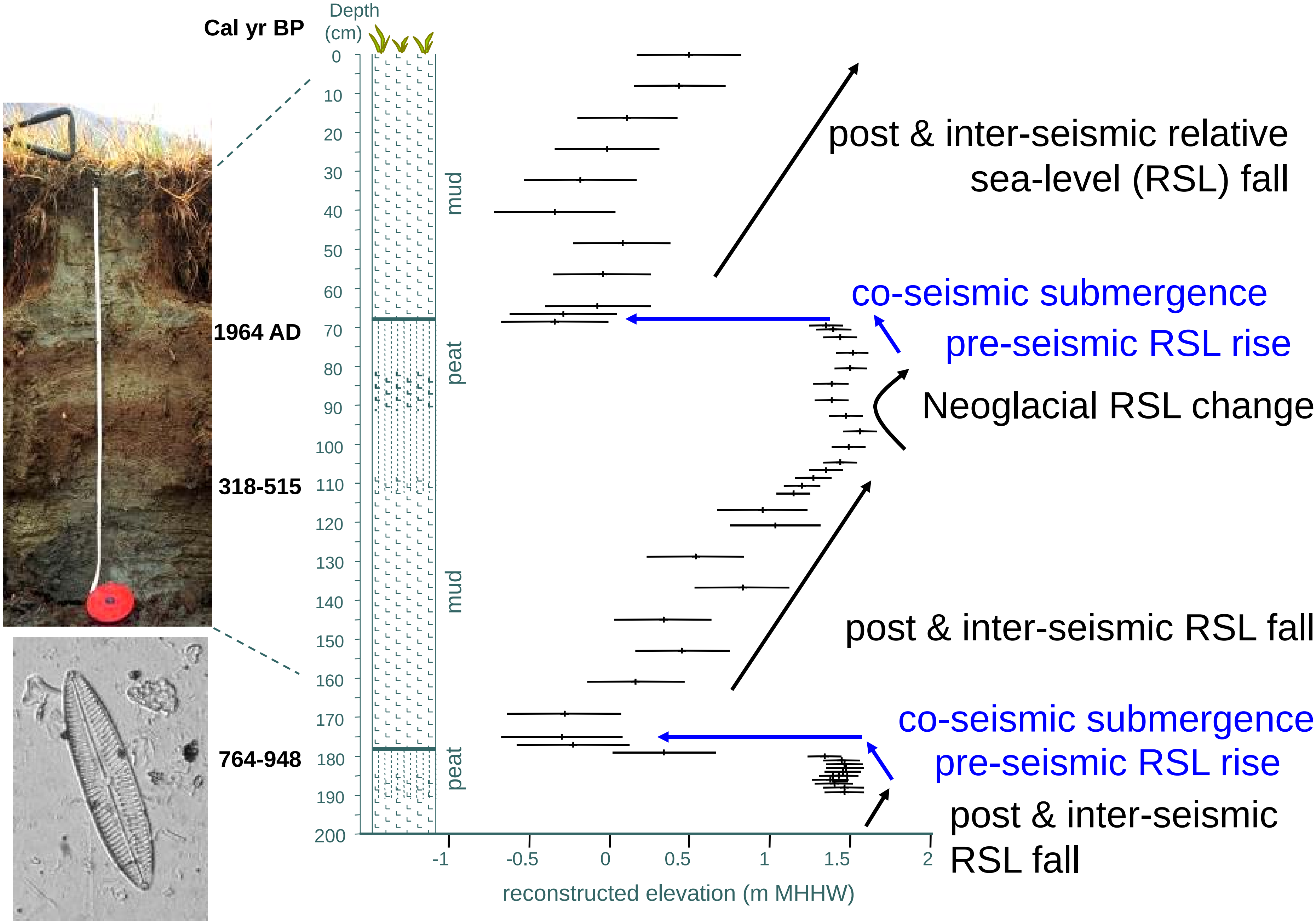
Diatoms in environmental reconstruction



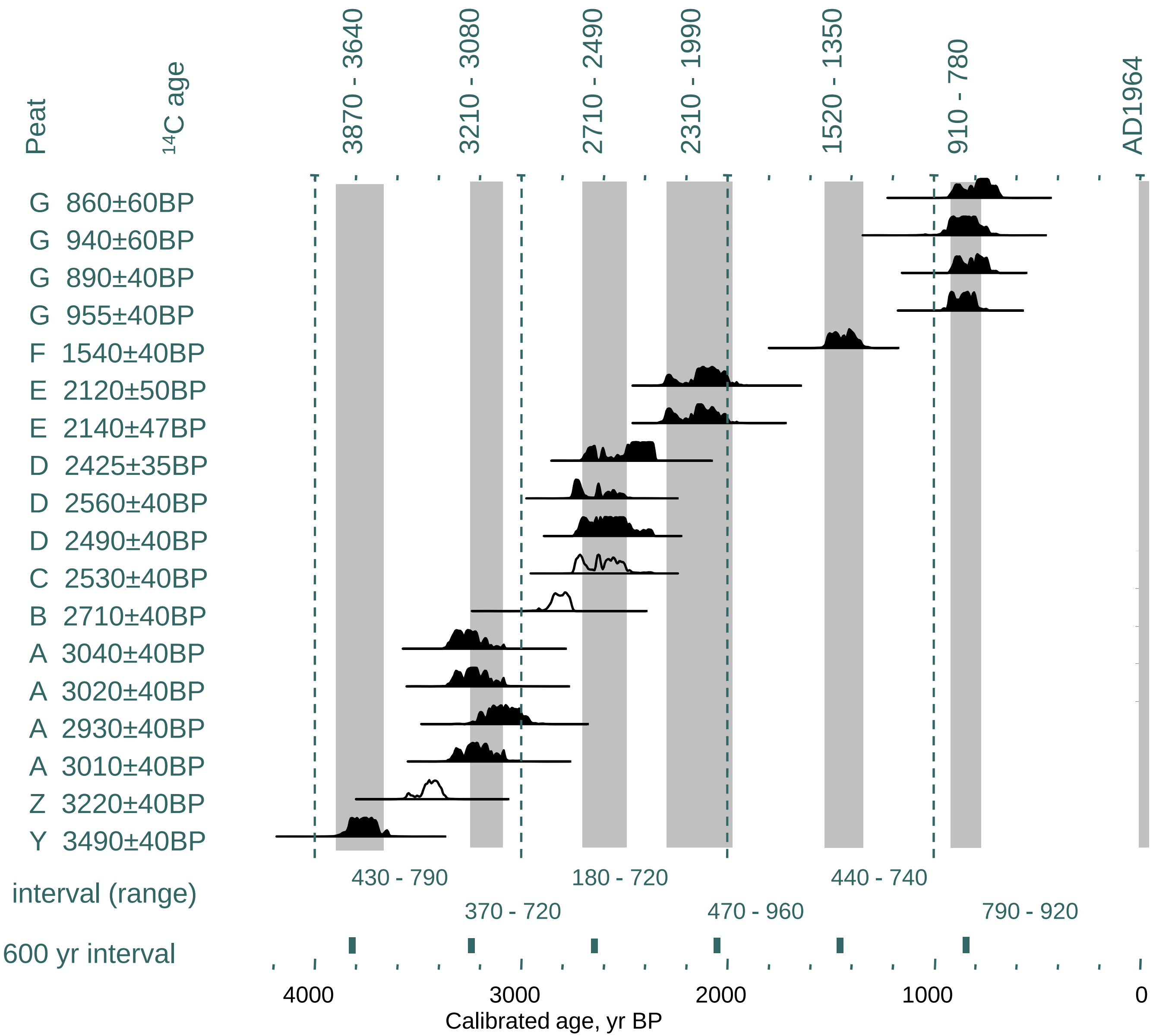




Girdwood reconstructed land / sea-level change



Last 4000yr: 7 great earthquakes

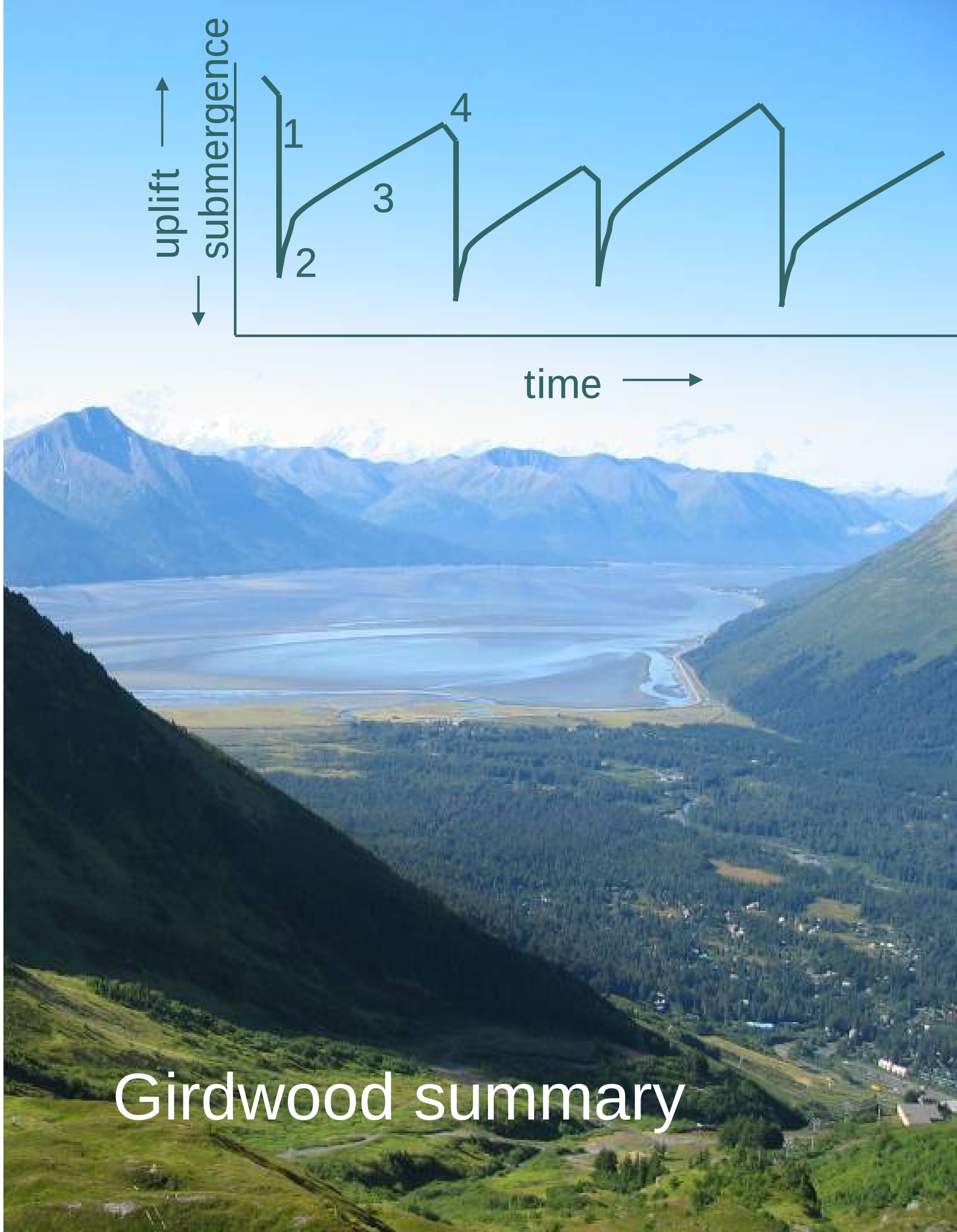


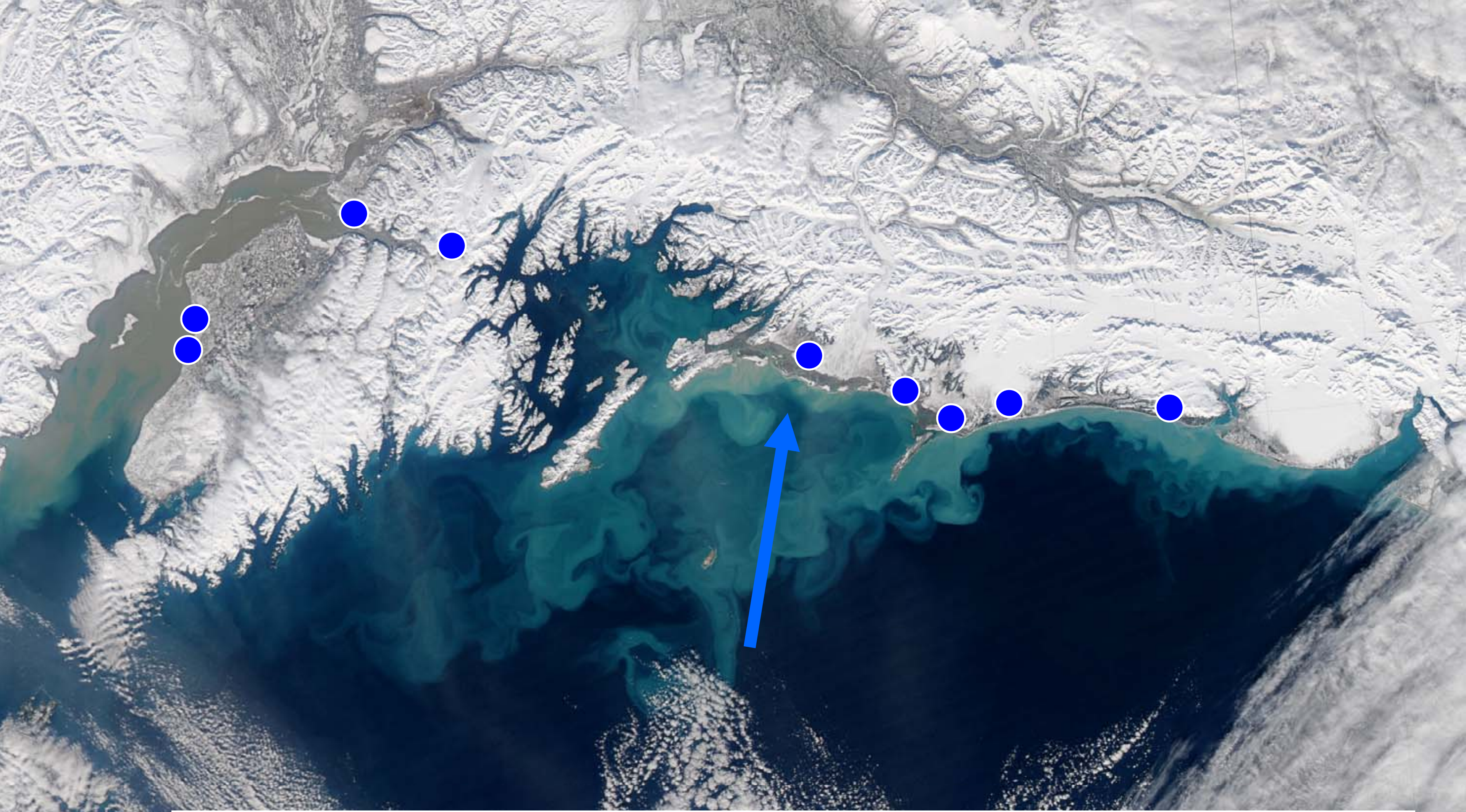
Girdwood summary

- ~7m net subsidence superimposed on seven earthquake cycles in the past 4000 years.

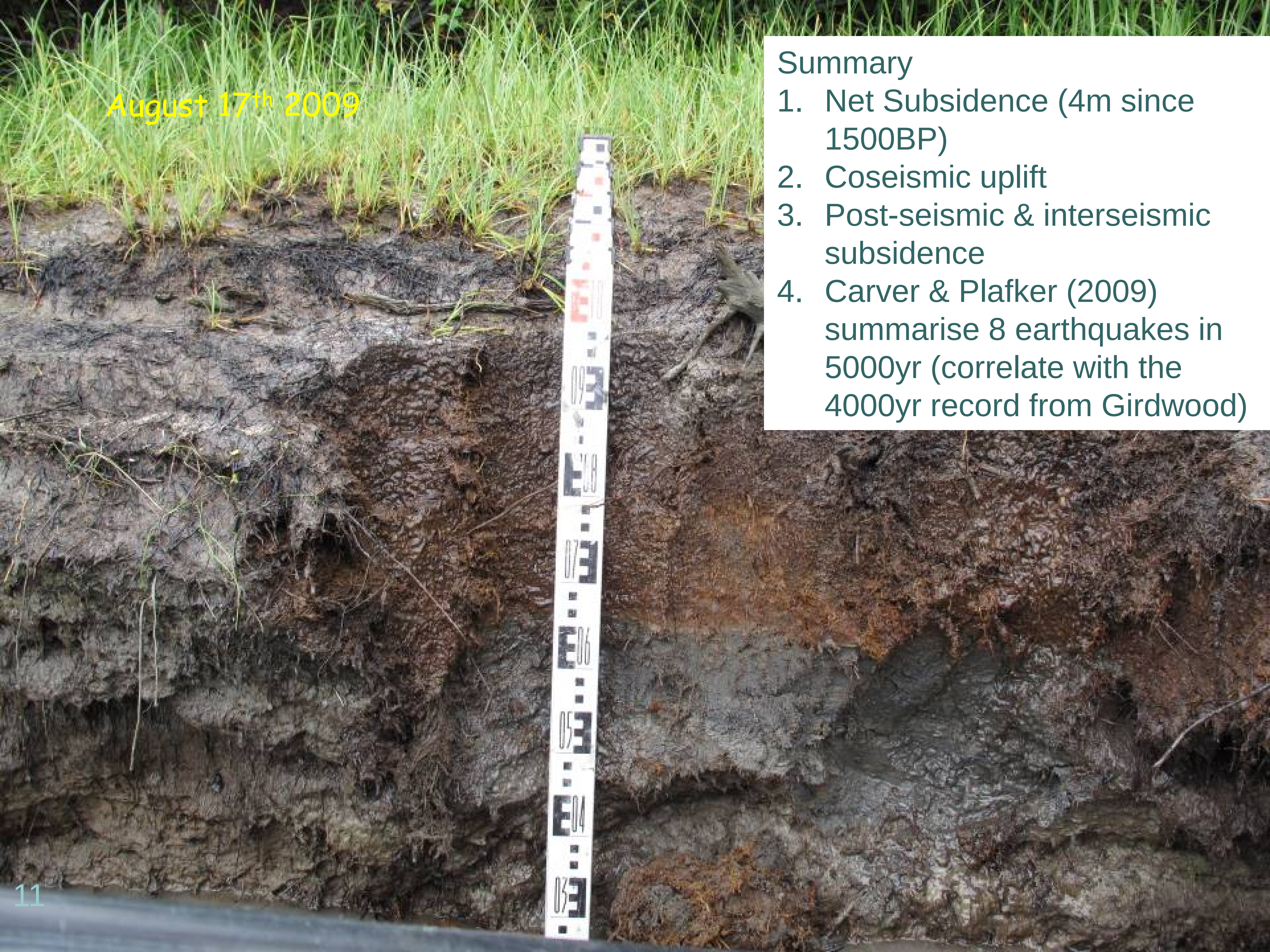
- EDC model for the Girdwood area with coseismic subsidence (1), followed by rapid post-seismic uplift in the decades after the earthquake (2). This merges into centuries of slower inter-seismic uplift (3) before a period of pre-seismic subsidence (4).

- Great earthquakes: no fixed recurrence interval between great. The shortest interval is between ~180 and 720 years. The longest interval is 790 – 920 years, which is between the penultimate earthquake and the Mw9.2 Alaska earthquake of March 1964.



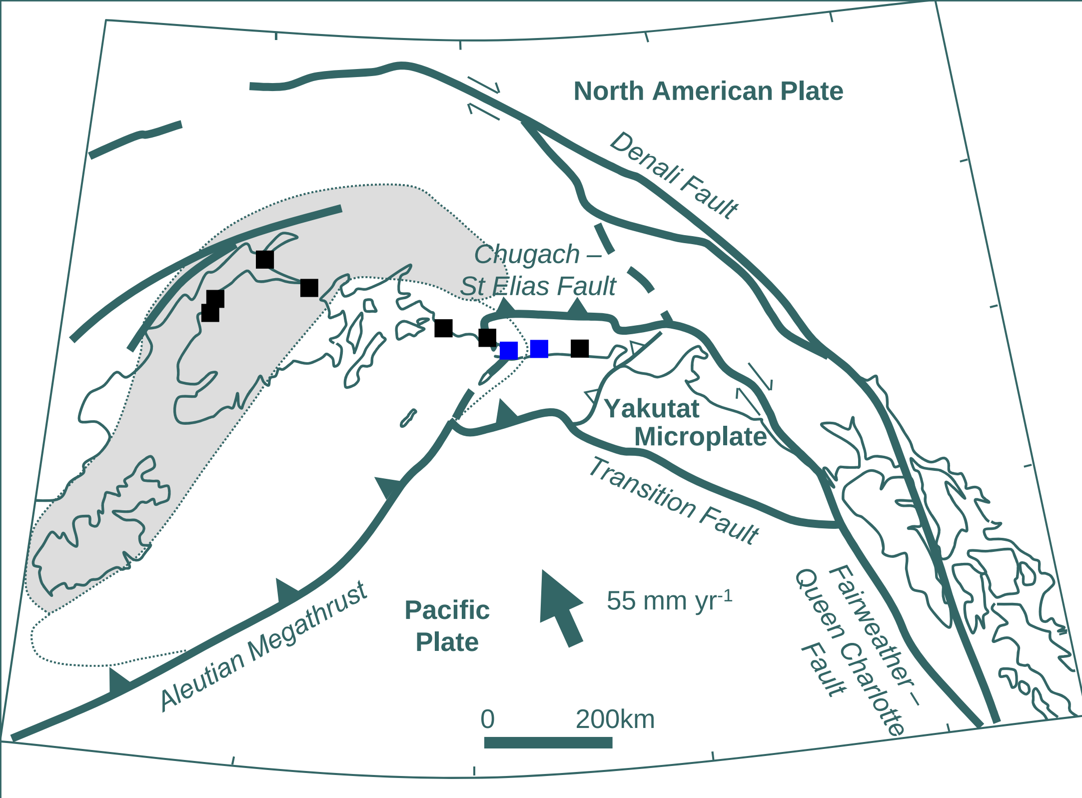


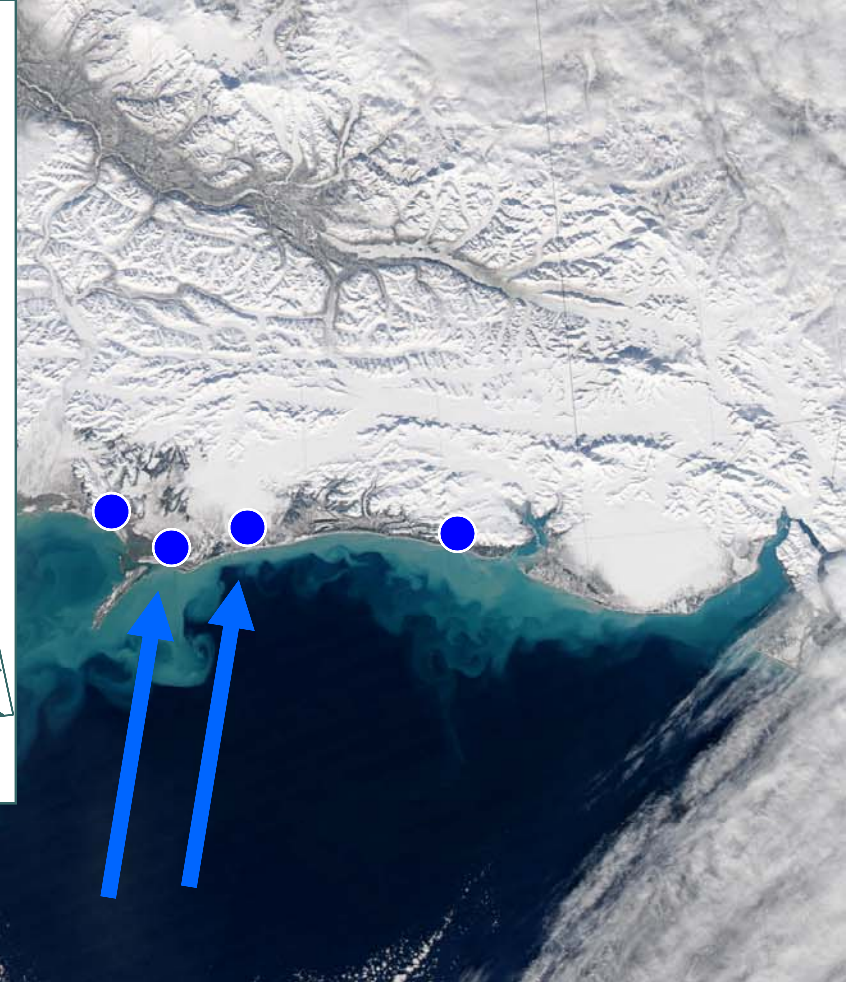
Zone of co-seismic uplift 1964: Alaganik Slough



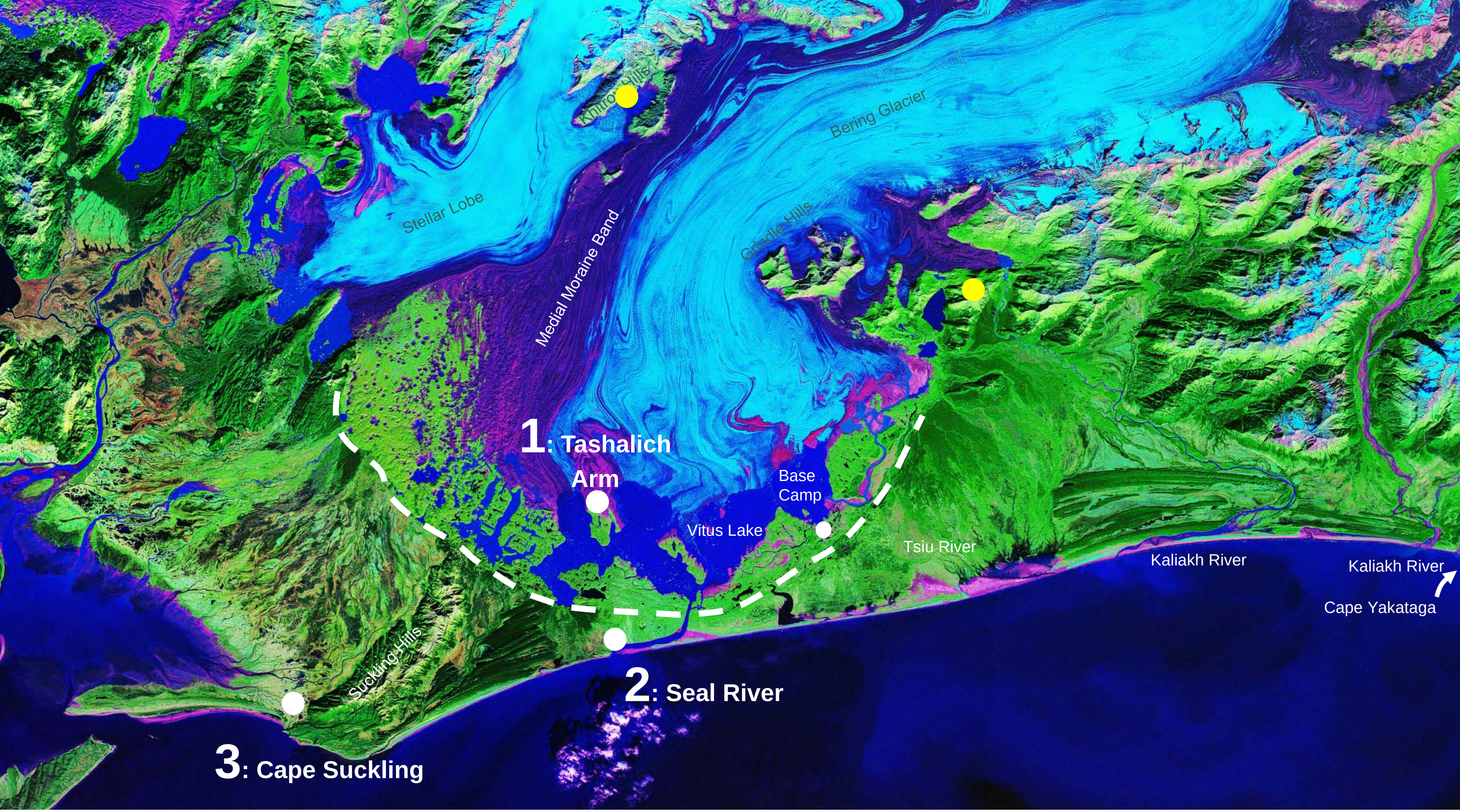
Summary

1. Net Subsidence (4m since 1500BP)
2. Coseismic uplift
3. Post-seismic & interseismic subsidence
4. Carver & Plafker (2009) summarise 8 earthquakes in 5000yr (correlate with the 4000yr record from Girdwood)





Near the eastern limit of co-seismic uplift 1964: Cape Suckling & Bering Glacier



Since the Little Ice Age maximum, ~AD 1900 (dashed line), Bering Glacier has undergone multiple surge and retreat cycles, ~1920, ~1938-1940, 1957-1960, 1965-1967 and 1993-1995.

Continued retreat since 1995 exposes new sediment sequences each year.

Cape Suckling marsh

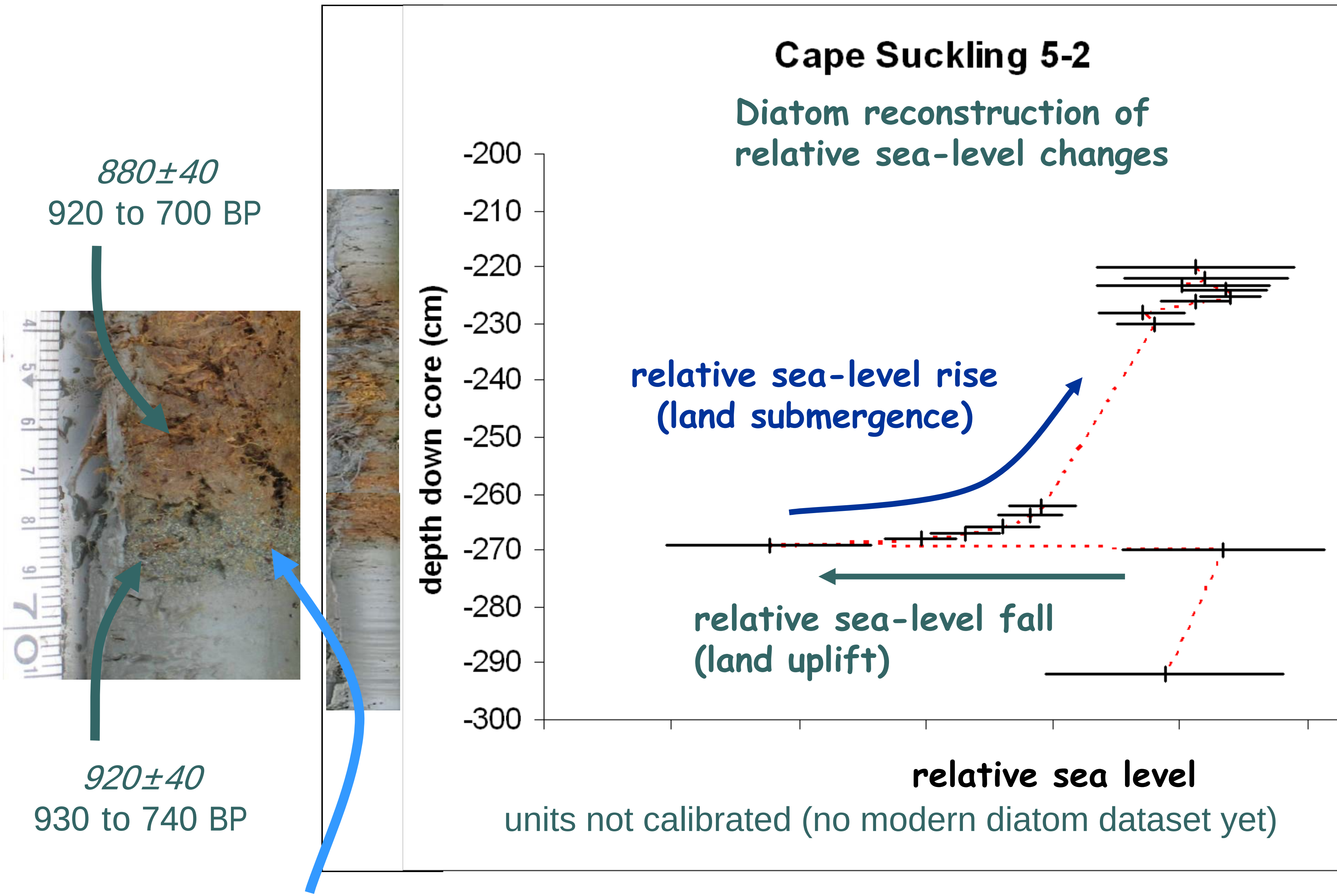
2004

1,2,5,7,8

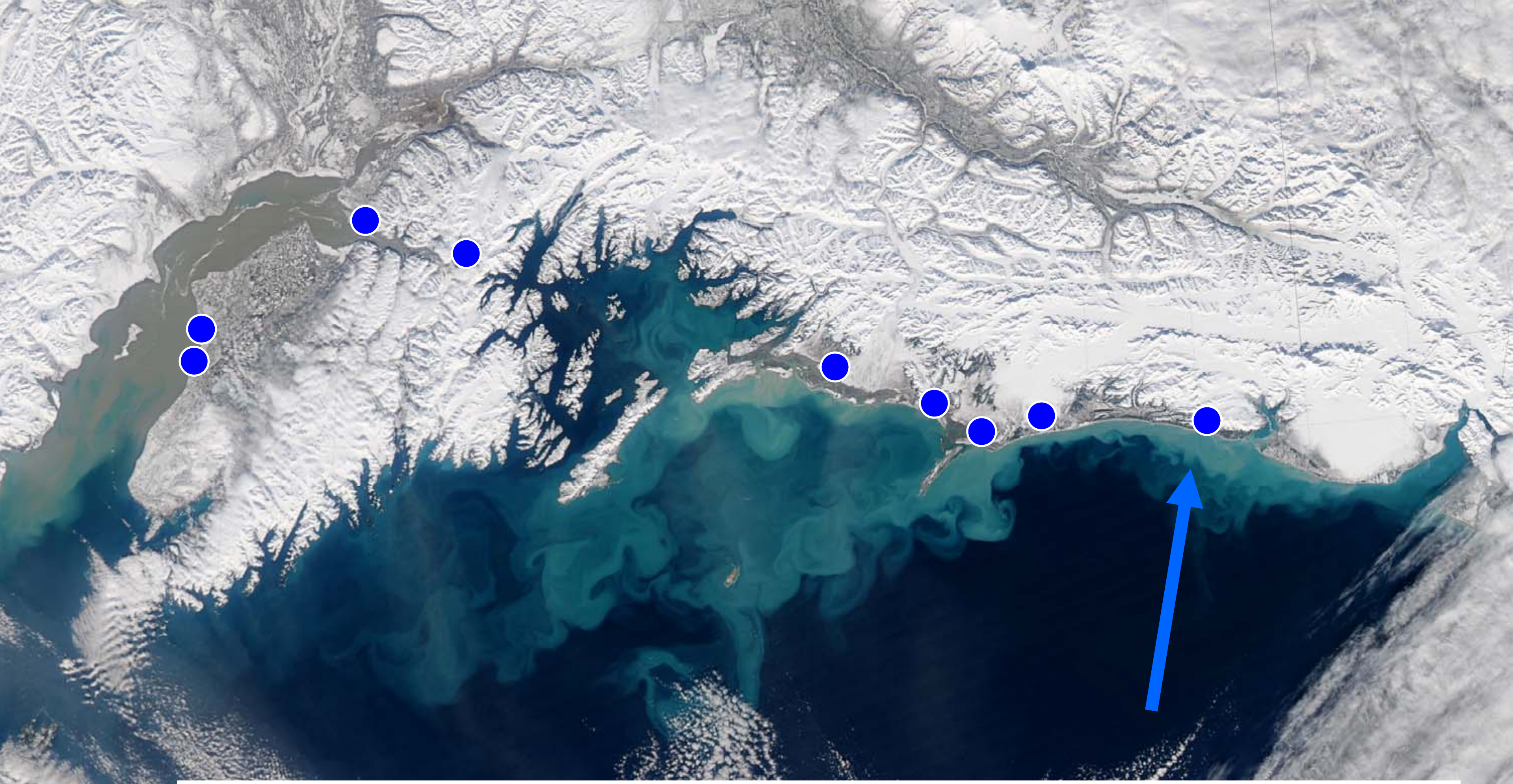
2005

1-5


Cape Suckling CS/0/2 8th August 2005 16-310cm
1964?
60
60
~110 BP
110
110
~300 BP
160
160
210
210
260
260
310



Possible tsunami sand



Beyond the eastern limit of co-seismic uplift 1964: Yakataga to Icy Bay, the Forgotten Coast

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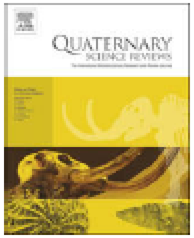

Rapid Communication

Multi-segment earthquakes and tsunami potential of the Aleutian megathrust

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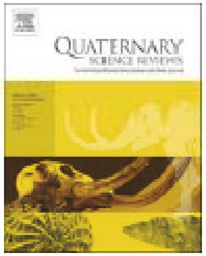

Late Quaternary sea-level changes and palaeoseismology of the Bering Glacier region, Alaska

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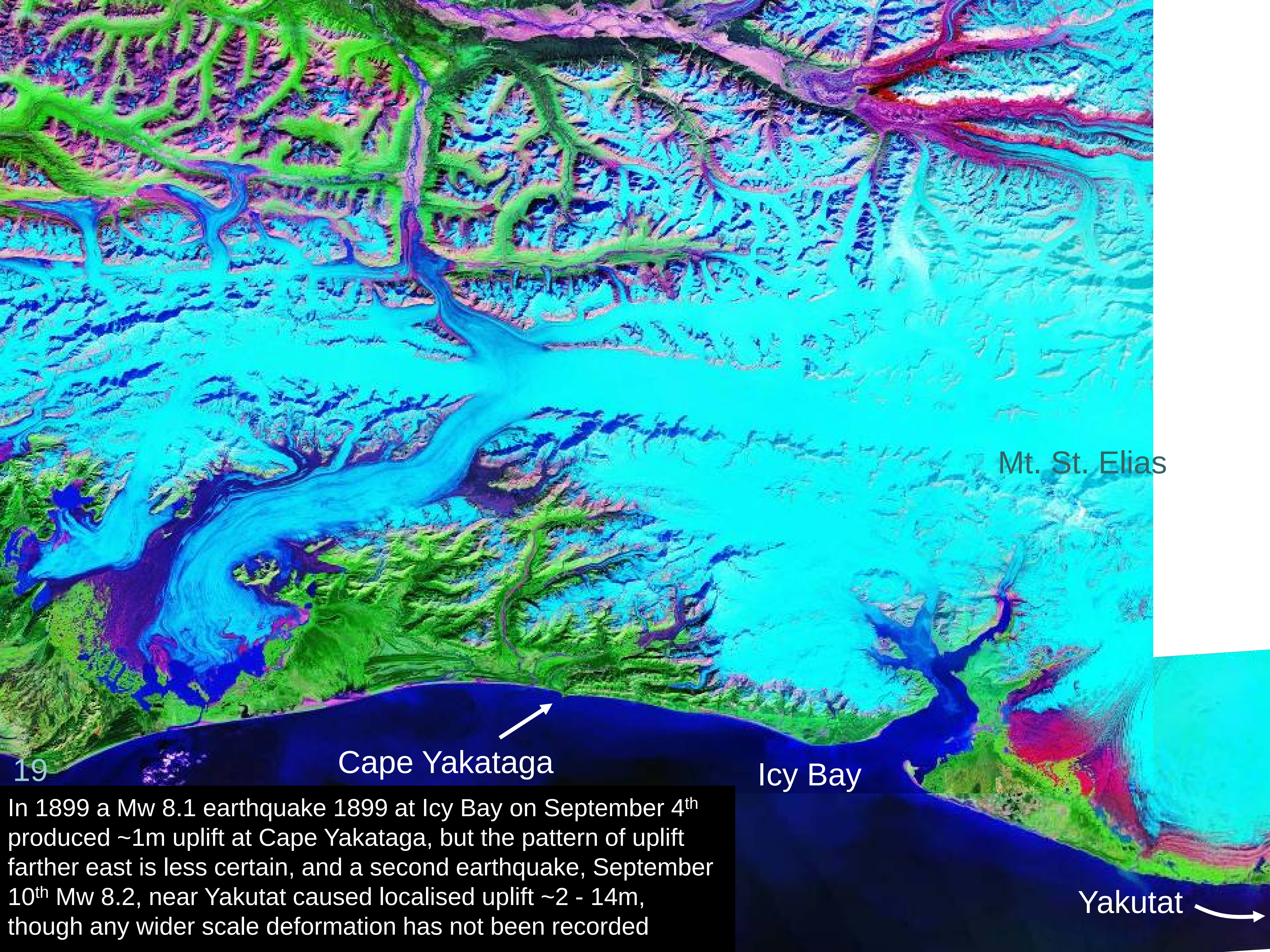
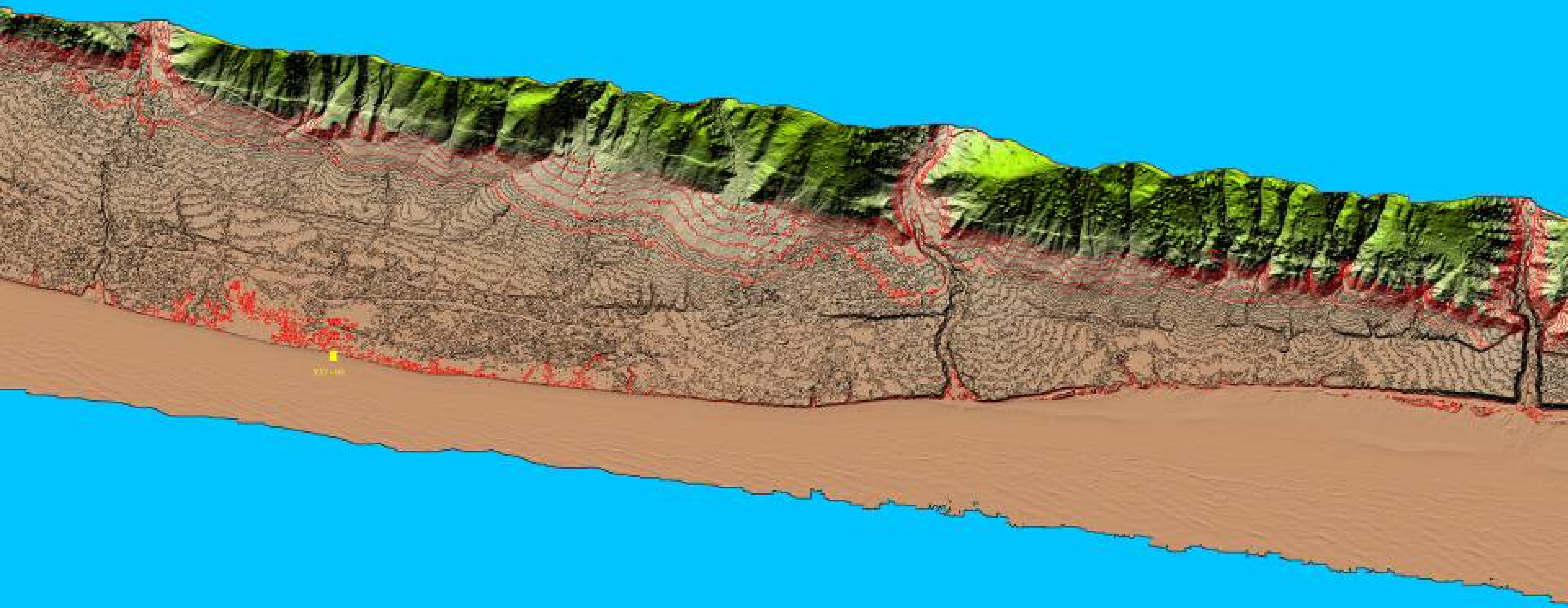
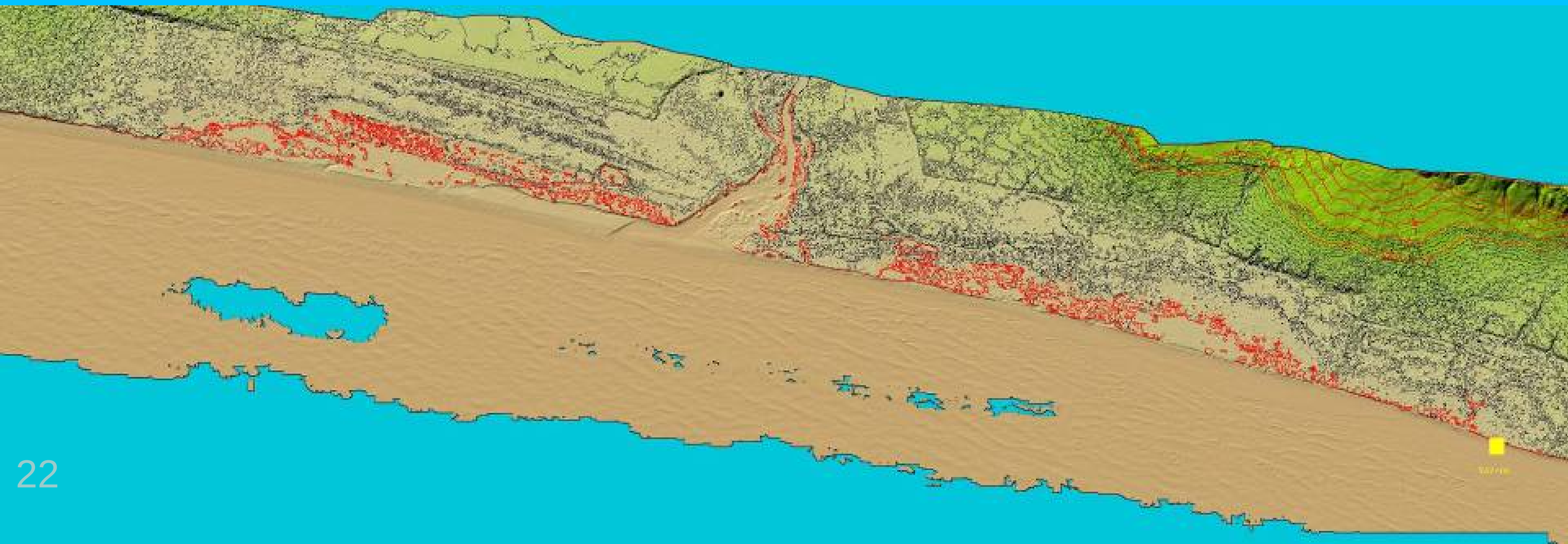
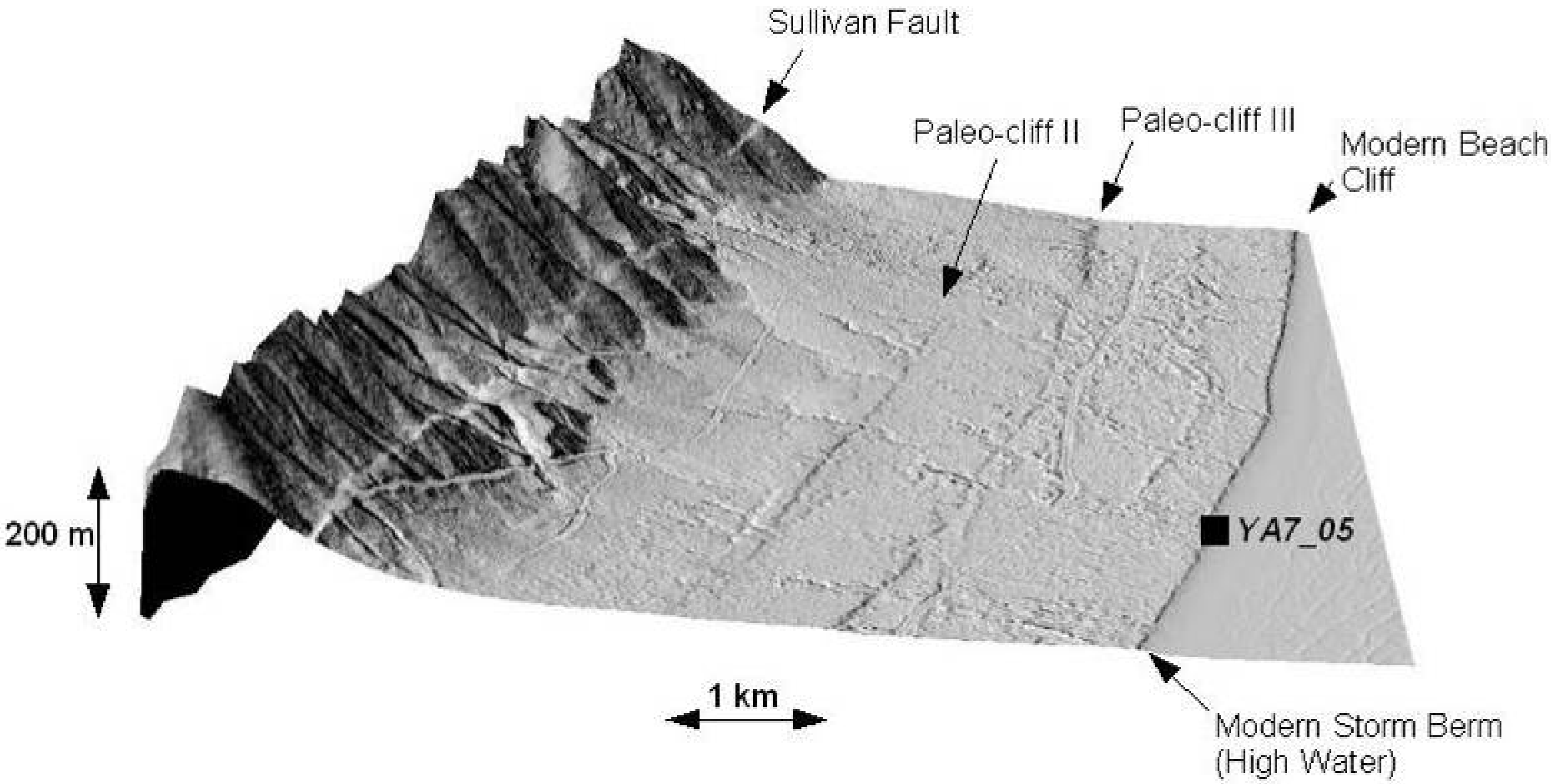


In 1899 a Mw 8.1 earthquake 1899 at Icy Bay on September 4th produced ~1m uplift at Cape Yakataga, but the pattern of uplift farther east is less certain, and a second earthquake, September 10th Mw 8.2, near Yakutat caused localised uplift ~2 - 14m, though any wider scale deformation has not been recorded



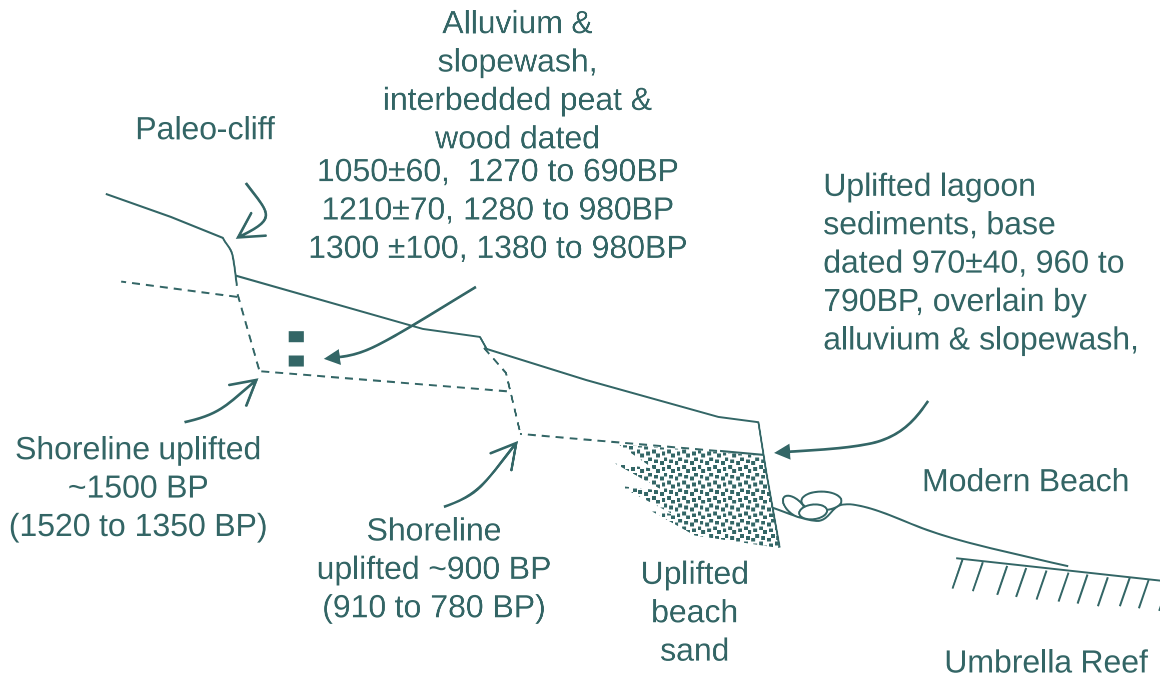


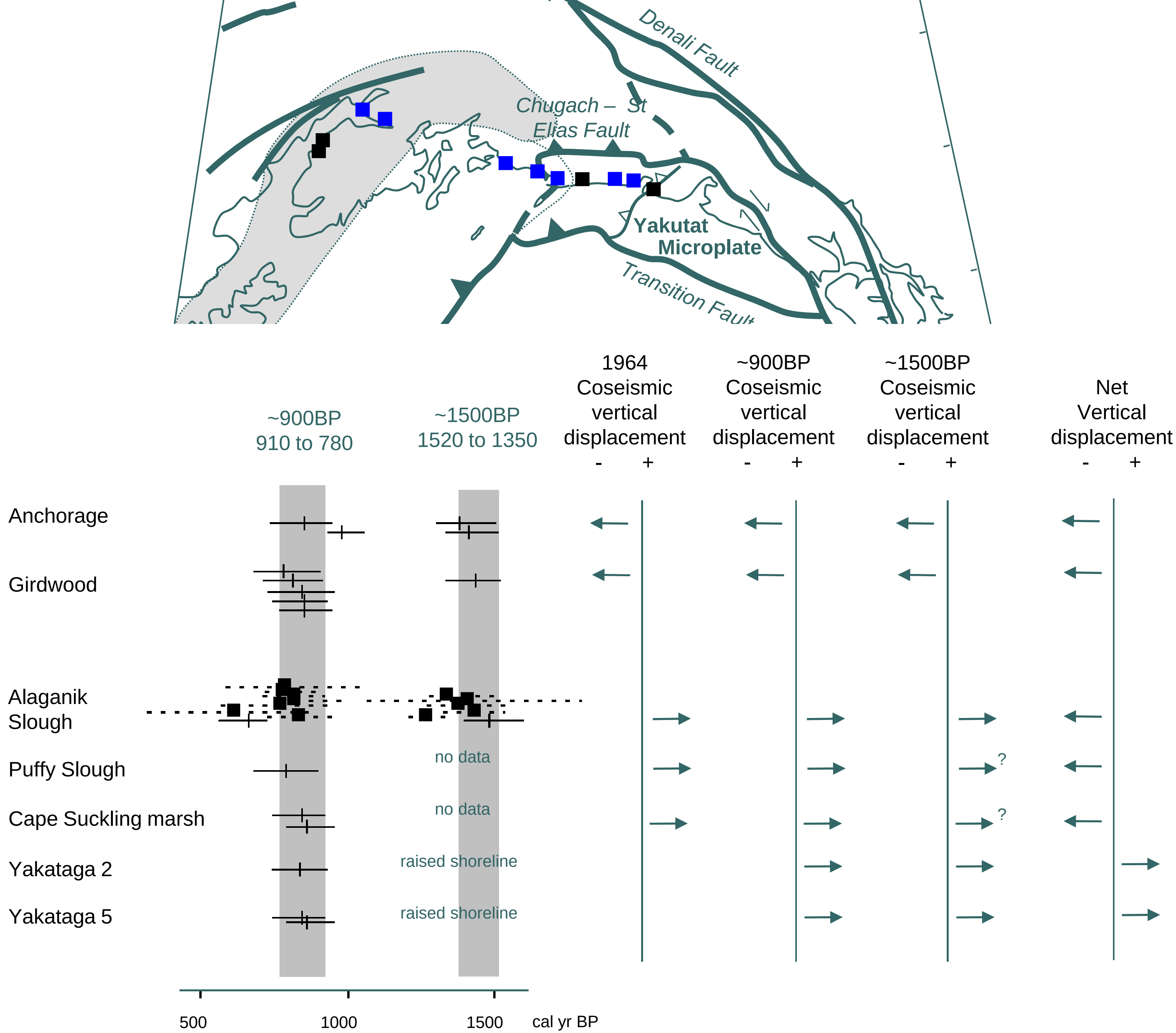

Sullivan Fault
Paleo-cliff II
Paleo-cliff III
Modern Beach Cliff
200 m
YA7_05
1 km
Modern Storm Berm (High Water)


N
F


970±40,
960 to 790BP

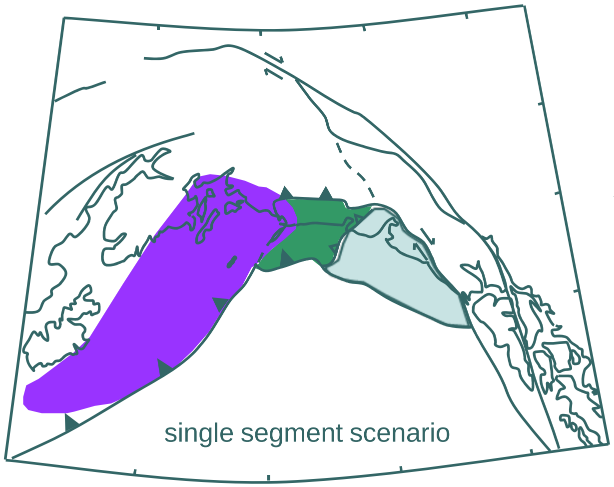

17-19 m surface inset into Terrace Surface III on east side of White River
White River
900 BP uplift escarpment?
Terrace Surface III (21 – 24 m, say)
17 – 19 m surface inset below Terrace Surface III


Alluvium & slopewash, interbedded peat & wood dated
1050±60, 1270 to 690BP
1210±70, 1280 to 980BP
1300 ±100, 1380 to 980BP
Paleo-cliff
Uplifted lagoon sediments, base dated 970±40, 960 to 790BP, overlain by alluvium & slopewash,
Shoreline uplifted ~1500 BP (1520 to 1350 BP)
Shoreline uplifted ~900 BP (910 to 780 BP)
Uplifted beach sand
Modern Beach
Umbrella Reef

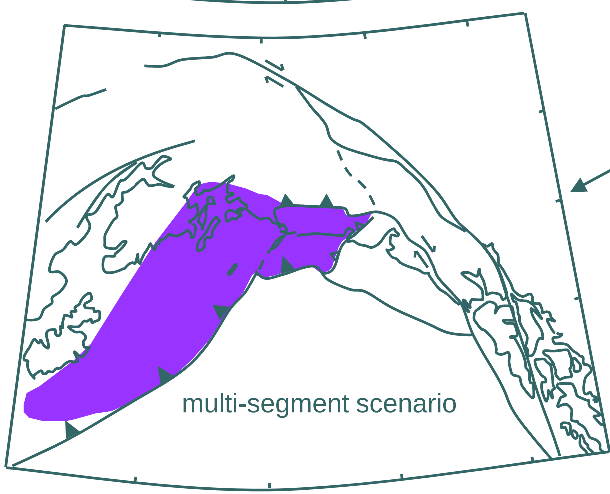

Denali Fault
Chugach – St Elias Fault
Yakutat Microplate
Transition Fault
~900BP
910 to 780
~1500BP
1520 to 1350
1964 Coseismic vertical displacement
~900BP Coseismic vertical displacement
~1500BP Coseismic vertical displacement
Net Vertical displacement
- +
Anchorage
Girdwood
Alaganik Slough
Puffy Slough
Cape Suckling marsh
Yakataga 2
Yakataga 5
no data
raised shoreline
?
500
1000
1500
cal yr BP

Given the structural setting and historical earthquake history of the region we must two scenarios :

1) a rupture scenario like that of the 1899 Yakataga and 1964 earthquakes, where the Yakataga seismic gap and eastern segment of the Aleutian megathrust ruptured independently and

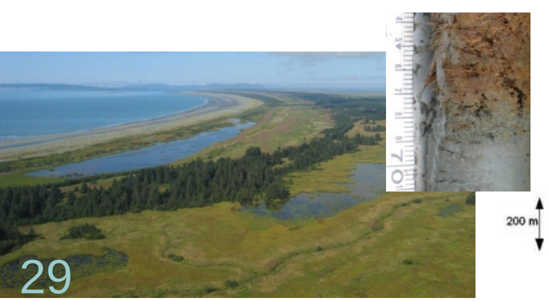


2) simultaneous rupturing of the megathrust from Cook Inlet in the west to the Pamplona – Malaspina thrust front in the east in which the Yakataga seismic gap ruptures in conjunction with the eastern segment of the Aleutian megathrust.

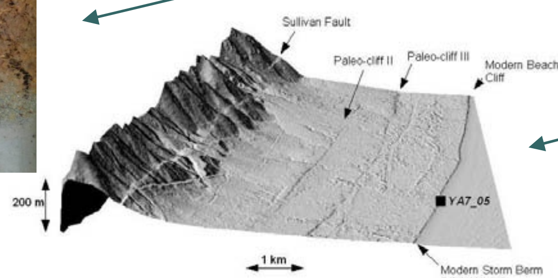


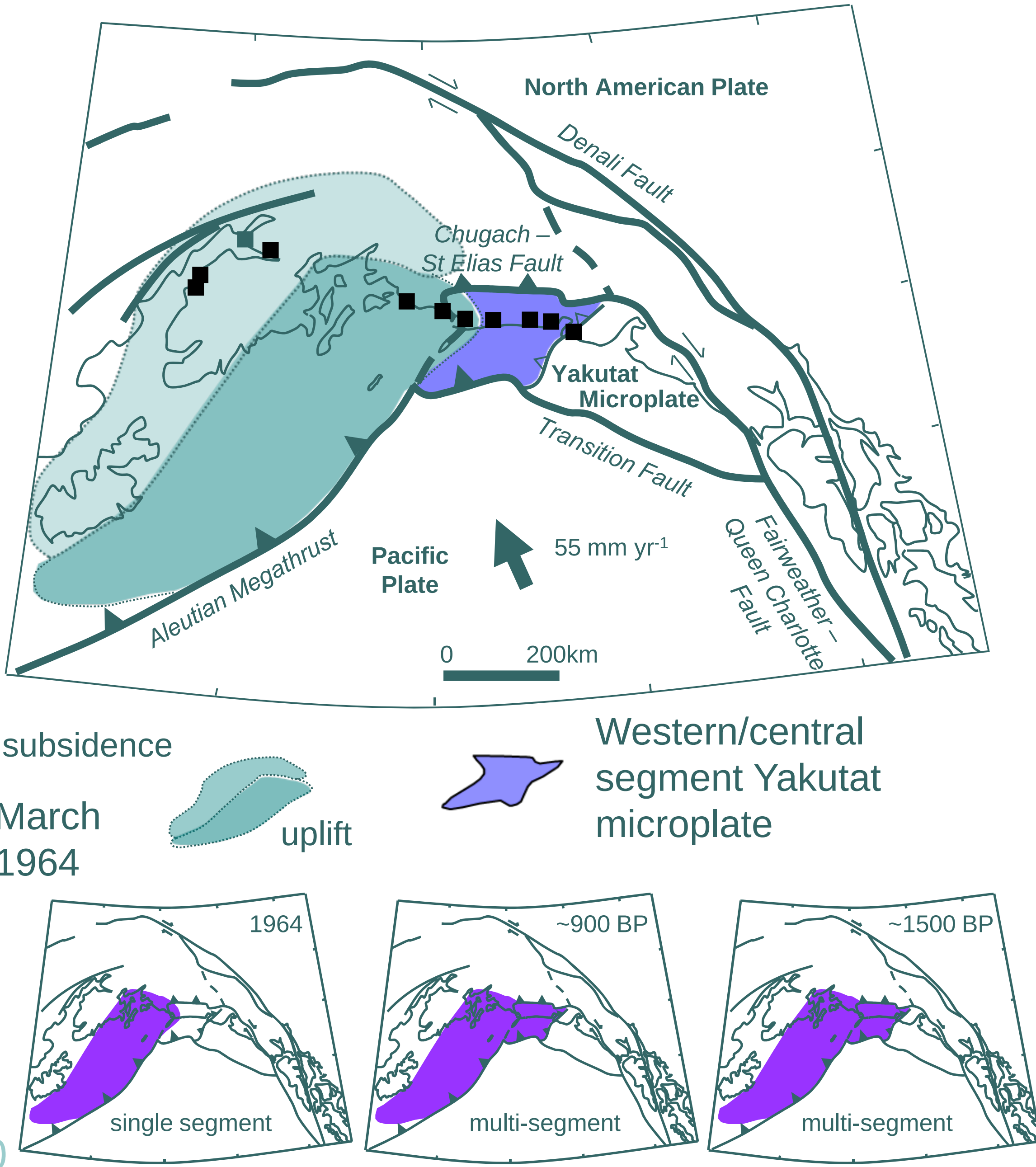
Two lines of evidence support 2) ~900 BP and ~1500 BP great earthquakes

First, greater coseismic deformation at Cape Suckling in ~900 BP than in 1964 suggests that the area of surface deformation extended farther east.



Second, the more widespread evidence for uplift east of Cape Yakataga in both ~900 BP and ~1500 BP than in 1899





Multi-segment earthquakes

Earthquakes ~900 and ~1500 years ago involved rupture of the western/ central segment of the Yakutat microplate along with the 1964 rupture zone

We calculate an additional 23,000 km^2 to the rupture area and ~15% increase in seismic moment, from Mw 9.2 in 1964 to ~Mw 9.25 for the multi-segment earthquakes.

Modelling of tsunami generation and coastline inundation for single-segment and multi-segment earthquakes at other subduction zones suggests that an increased area of sea-floor uplift with a multi-segment earthquake produces a tsunami with greater wavelength that penetrates farther inland, even though the height of the wave at the coast may be similar

Summary

1. Seven great earthquake cycles in the past 4000 years.
2. Not a fixed recurrence interval between great, >Mw9, earthquakes. Shortest ~180 – 720 years, longest interval is 790 – 920 years,
3. Earthquake Deformation Cycle Model for the area of subsidence: coseismic subsidence, rapid post-seismic uplift in the decades after the earthquake; centuries of slower inter-seismic uplift before a period of pre-seismic subsidence.
4. Multi-segment earthquakes ~900 and ~1500 years ago involved rupture areas ~15% greater than in 1964, indicating greater magnitude, >Mw 9.2, and increased tsunamigenic potential.
5. Complex deformation within the Yakutat microplate, influenced by both subduction and transform fault motion, controls recurrence of these largest earthquakes.
6. Through multiple seismic cycles this leads to net uplift in the Yakataga microplate, part of the Saint Elias orogen.