What information for tsunami sources can we obtain from Paleotsunami Research in Alaska?

Dmitry Nicolsky

with a lot of input from

Rob Witter, and Rich Briggs

1University of Alaska Fairbanks
2 U.S. Geological Survey Anchorage, Alaska
3 U.S. Geological Survey Golden, Colorado

January 30, 2019
Field investigations along the Alaska-Aleutian subduction zone

Ten investigations from 2010–2018

- Umnak Island
- Unga Island
- Sitkinak Island
- Sedanka Island
- Simeonof Island
- Sanak Island
- Chirikof Island
- Sitkalidak Island
- Kenai Fjords
What information about Alaskan tsunami sources can we glean from field studies?

- How persistent are rupture boundaries of historic earthquakes?
- How do field observations help define megathrust rupture patches?
- How often do great megathrust ruptures and tsunamis occur in the Aleutians?
How persistent are rupture boundaries of historic earthquakes?

Resistant beds in saltmarsh

Sitkinak Island, Alaska

Briggs et al., 2014
How persistent are rupture boundaries of historic earthquakes?
How do field observations help define megathrust rupture patches?

Fox Islands

*Unusually large tsunamis frequent a currently creeping part of the Aleutian megathrust.*

(Witter et al., 2016, Nicolsky et al., 2016 Witter et al., 2018)

164–157 year recurrence
Analysis of the sediment core and runup data in Stardust Bay can be used to constrain the worst case tsunami scenarios.


**Inundation up to 18m (60ft) in 1957**
Tsunami models imply near-trench rupture in 1957

Tsunami models imply near-trench rupture in 1957.
Modeling runup of the 1957 tsunami at Stardust Bay

A shallow rupture, such as we illustrate in model D, with about 20m of maximum slip can generate a tsunami that explains both the tsunami runup in Stardust Bay and the tide gauge record at Dutch Harbor.
Driftwood Bay

Drift logs at 19–23 m above sea level Driftwood Bay.
Umnak Island

- 9 sand sheets in ~2200 yrs
- Sand sheets meet tsunami criteria
- Youngest sand sheet deposited in 1957
- Stranded drift logs indicate >23 m runup in 1957
- 270–340 yr average tsunami recurrence interval
How do field observations help define megathrust rupture patches?

Fox Islands

*Unusually large tsunamis frequent a part of the Aleutian megathrust.*

(Witter et al., 2016

Nicolsky et al., 2016

Witter et al., in 2018)

Sanak Island

*In addition to the great 1946 tsunami, ancient tsunamis occurred prior to ~2000 yr ago, but not in 1788.*

(Engelhart et al., unpublished data)
Sanak Island

Evidence for 1946 tsunami

FINDINGS:

– 5 sand sheets in ~4200 yrs
– Youngest sand sheet deposited in 1946
– Drift logs indicate high runup in 1946
– 4 sand sheets between 2000–4200 yrs ago
– No evidence for a 1788 tsunami

Engelhart et al., 2015
GSA
Tsunami sources for Cold Bay and King Cove

At Sanak - in addition to the great 1946 tsunami, ancient tsunamis occurred prior to ~2000 yr ago, but not in 1788.
How do field observations help define megathrust rupture patches?

**Shumagin Islands**
Absence of evidence for great earthquakes or tsunamis implies that creep has relieved strain for thousands of years.
(Witter et al., 2014)

**Fox Islands**
Unusually large tsunamis frequent a currently creeping part of the Aleutian megathrust.
(Witter et al., 2015)

**Sanak Island**
In addition to the great 1946 tsunami, ancient tsunamis occurred prior to ~2000 yr ago, but not in 1788.
(Engelhart et al., unpublished data)
Simeonof Island
Surprisingly stable

**FINDINGS:**
- Glaciers retreated after 10.4 ka
- No uplifted shorelines
- No marine deposits above modern tides
- Storms likely source of low, thin sands
- Earthquake models allow M 7.7–8.5 ruptures near trench

*Witter et al., 2014*
Tsunami sources for Sand Point

Simeonof Island has been surprisingly stable over the past 3500 years.
How often do great megathrust ruptures and tsunamis occur in the Aleutians?

**Fox Islands**
Unusually large tsunamis frequent a currently creeping part of the Aleutian megathrust.
(Witter et al., 2016)

**Sanak Island**
In addition to the great 1946 tsunami, ancient tsunamis occurred prior to ~2000 yr ago, but not in 1788.
(Engelhart et al., unpublished data)

**Shumagin Islands**
Absence of evidence for great earthquakes or tsunamis implies that creep has relieved strain for thousands of years.
(Witter et al., 2014)

**Chirikof Island**
Ruptures of the megathrust probably launched large tsunamis every 180–270 yrs over the past 3500 yrs, including in 1788.
(Nelson et al., 2015)
Chirikof Island

Dropping like a stone

FINDINGS:
- Multiple sand sheets in past 3,500 yrs
- Sand sheets deposited by tsunamis in 1788 and 1938
- 180–270 yr average tsunami recurrence

Nelson et al., 2015
What could GPS observations tell us?

Freymueller et al. (2008)
Sources near Chirikof Island currently, it is subsiding
Developing tsunami sources for Kodiak

Scenario 9: Mw 9.25 earthquake in the area of Kodiak Island with 50 m of maximum slip.

Scenario 4: Mw 9.0 earthquake in the area of Kodiak Island, 20 km depth.

Scenario 2: Mw 9.1 earthquake in the area of Kodiak Island, 10 km depth.
Insights from the field:

- **Field evidence implies varied rupture behavior without fixed segment boundaries**
- **Currently creeping parts of the megathrust may have ruptured in the past (or not!).**
- **Evidence for a 1788 megaquake does not exist.**
2007 USGS Seismic Hazard Map: Alaska-Aleutian Subduction Zone
2007 Hazard Maps:
Defined by earthquake magnitude & recurrence

Prince William Sound
Magnitude 9.2
650 yr recurrence
Ruptures with Kodiak

Yakataga
Magnitude 8.1
1640 yr recurrence

Semidi Islands
Magnitude 8.5
4320 yr recurrence

Kodiak (breaking alone)
Magnitude 8.8
650 yr characteristic

Shumagin Islands
Magnitude 8
95 yr recurrence

Aleutians
Magnitude 9.2
820 yr recurrence

Wesson, Boyd, Mueller, Bufe, Frankel, and Petersen, 2007
New findings will guide revisions.

Prince William Sound
New: ~595 yr recurrence
Kenai independent?
Old: 650 yr recurrence

Semidi Islands
New: 180–270 yr tsunami recurrence
1788 earthquake
Old: M 8.5
4320 yr recurrence

Yakataga
New: M 9+
Ruptures with PWS
Old: M 8.1
1640 yr recurrence

Kodiak
New: 200–300 yr recurrence
Earthquakes in 1788 and 1964
Ruptures with PWS and alone
Old: M 8.8
650 yr recurrence

Sanak
New: Near trench ruptures?
Old: Mmax 8
95 yr recurrence

Fox Islands
New: 164–257 yr tsunami recurrence
Old: M 9.2
820 yr recurrence

Shumagins
New: Persistent creep?
Old: Mmax 8
95 yr recurrence
Summary of paleoseismology in the 1964 rupture zone

Hutchinson and Crowell, 2007

Fig. 3. Zones of coseismic uplift and subsidence in 1964 (after Plafker, 1969), present-day velocities (http://www.gps.alaska.edu/jeff/Chapman_GPS_velocities.html accessed 13 July 2015) and location of coastal marsh sites providing paleoseismic records (circles).

Fig. 4. Probability density functions for earthquake ages from sites in the Prince William Sound segment (data from Shennan et al., 2014b, 2014c).
Kenai
Kodiak
YKT
PWS
Semidi
Shumagin
Sanak

1788
(Soloviev)
~1500 BP

Kenai

Kodiak

PWS

YKT

Semidi

Sanak

Shumagin
~2100 BP

Kenai

PWS

YKT

Kodiak

Semidi

Shumagin

Sanak
Applications to the Gulf of Alaska sources

- **Model based on the 1964 earthquake**
  - Johnson and others (1996)

- **Model incorporating paleoseismic data**
  - Multi-Segment Great Alaska Earthquake (Suleimani et al.)
Conclusions

• Active paleoseismic research brings new data to define credible tsunami sources
• Data is incorporated into multiple activities (e.g. Powell Center workgroup, Seismic Hazard Map updates)
• Information is actively used by states to develop potential tsunami sources