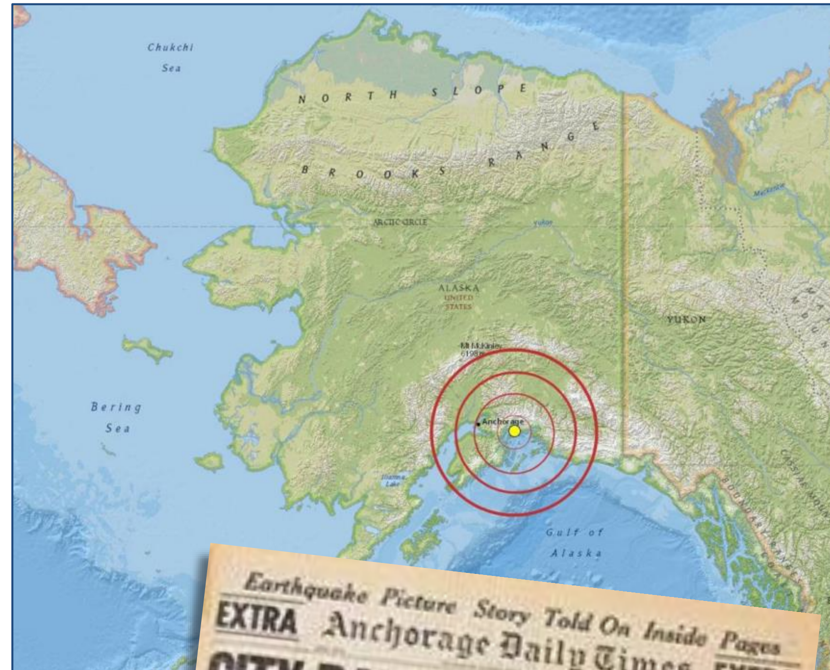
HISTORICAL Magnitude 9.2 ALASKA

Friday, March 27, 1964 at 5:36:16 PM Alaska Time

Over the last 60 years, no earthquake has surpassed the magnitude of the March 27, 1964 Great Alaska Earthquake. This Magnitude 9.2, the second-largest ever recorded, radically transformed Alaska and, as a result of research done in the aftermath, transformed our understanding of plate tectonics, tsunami generation, and earthquakes.

The earthquake struck at 5:36 p.m. local time on Good Friday. The epicenter was 120.7 km (75 miles) east of Anchorage on the north shore of Prince William Sound. The ground shook across southern Alaska for more than 4 minutes. In Anchorage, the ground opened giant fissures. Even before the shaking ended, landslides launched tsunamis that swept away coastal villages, contributing to the development of national programs to reduce earthquake and tsunami risk.




Earthquake Picture Story Told On Inside Pages
EXTRA Anchorage Daily Times EXTRA
CITY RALLIES FROM QUAKE
SHOCKWAVE ONE OF MIGHTIEST
Loss Estimated By Governor At $250 Million

Front page of the Anchorage Daily Times the day after the 1964 earthquake.

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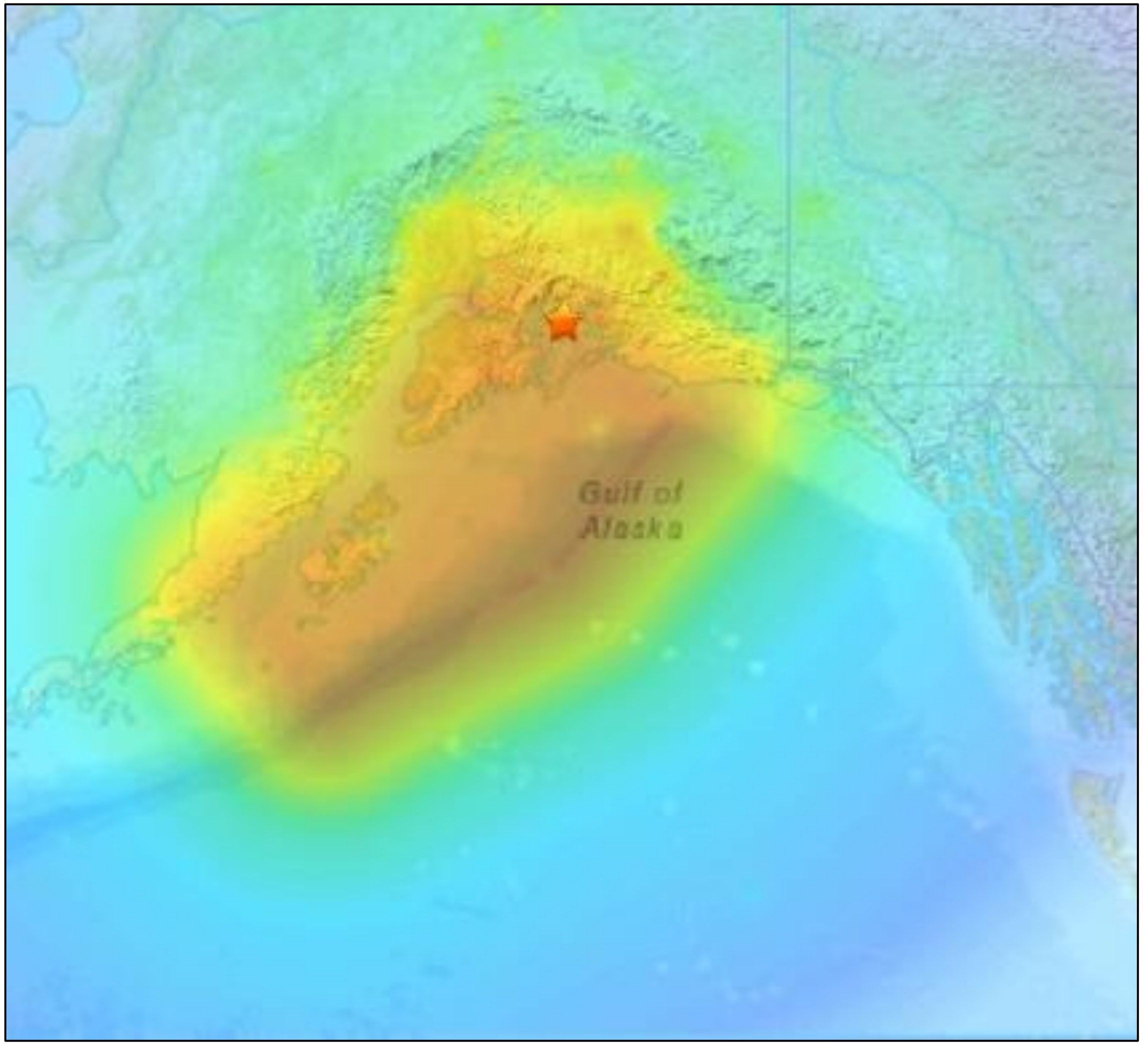
This earthquake caused strong to violent shaking over a wide area of southern Alaska. The map shows where the most intense shaking occurred, and the colors correspond to the shaking intensities and damage listed in the legend.

Shaking intensities up to level 9 (IX) were reported during the event, which corresponds to perceived violent shaking and heavy damage to structures.

MMI	Perceived Shaking
X	Extreme
IX	Violent
VIII	Severe
VII	Very Strong
VI	Strong
V	Moderate
IV	Light
II-III	Weak
I	Not Felt



USGS estimated shaking intensity from M 9.2 Earthquake

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In all, 131 people were killed: 115 in Alaska and 16 in Oregon and California. Although tragic, for an earthquake this size, the death toll was low. Despite massive and widespread destruction of buildings, homes, roads, bridges and railways, only nine of the 131 fatalities were directly caused by the earthquake. Authorities attributed this to three factors:

- most of the affected area was sparsely populated
- most structures were built of wood
- the earthquake struck during the fishing offseason and on a Friday evening before the Easter holiday weekend when most schools and offices were empty.

The larger death toll was caused by the subsequent tsunamis, both local ones generated by landslides and the main open-ocean tsunami generated by seafloor uplift.

Video courtesy @AlaskaDHSEM

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This earthquake caused hundreds of damaging landslides, submarine slumps, and other ground failures.

Alaska's largest city, Anchorage, experienced severe ground shaking and sustained heavy property damage.

Above: Collapse of Fourth Avenue near C Street, Anchorage. Before the earthquake, the sidewalk and street at left was at the street level on the right. The ground on the left subsided 3.4 m (11 ft) in response to 4.3 m (14 ft) of horizontal movement to the left.
USGS photographs by Joseph K. McGregor and Carl Abston.

Left: Wreckage of Government Hill School in Anchorage.

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One span of the Million Dollar Bridge in the Copper River Delta slipped off its pier, and other spans shifted on their piers due to liquefaction of soils during the strong ground shaking of the Great Alaska Earthquake. In other places, railroad tracks buckled and were torn from their ties. USGS photographs by R. Kachadoorian and M.G. Bonilla.

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Parts of the coast sank, or subsided, as much as 8 feet (2.4 m), and other parts rose by as much as 38 feet (11.58m). This photo shows the ground offset or "fault scarp" produced by reactivation of the Hanning Bay fault on Montague Island in Prince William Sound. Vertical displacement is about 12 feet (3.65 m) in the foreground and up to 15 feet (4.57 m) near the trees in the background.

Photo from U.S. Geological Survey Professional Paper 541 *The Alaska Earthquake March 27, 1964 Field Investigations and Reconstruction Effort, US Government Printing Office, 1966*.

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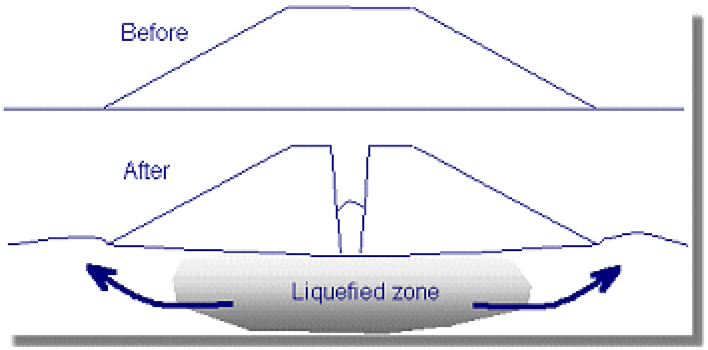
Research in the years following the earthquake resulted in:

- Support for the new theory of plate tectonics
- Better understanding of earthquake ground deformation (including soil liquefaction)
- Tsunami hazard assessments and warnings
- Lessons for earthquake zones worldwide

Above: A section of the Seward Highway on Turnagain Arm is destroyed after the earthquake. Lateral spreading in the soil beneath the roadway caused the embankment to be pulled apart, producing the large crack down the center of the road.



Right: A drawing of the raised highway before and after the earthquake. Research following the earthquake opened the door to new information on the effects of soil liquefaction, the phenomenon to blame for much of the damage throughout Southcentral Alaska.

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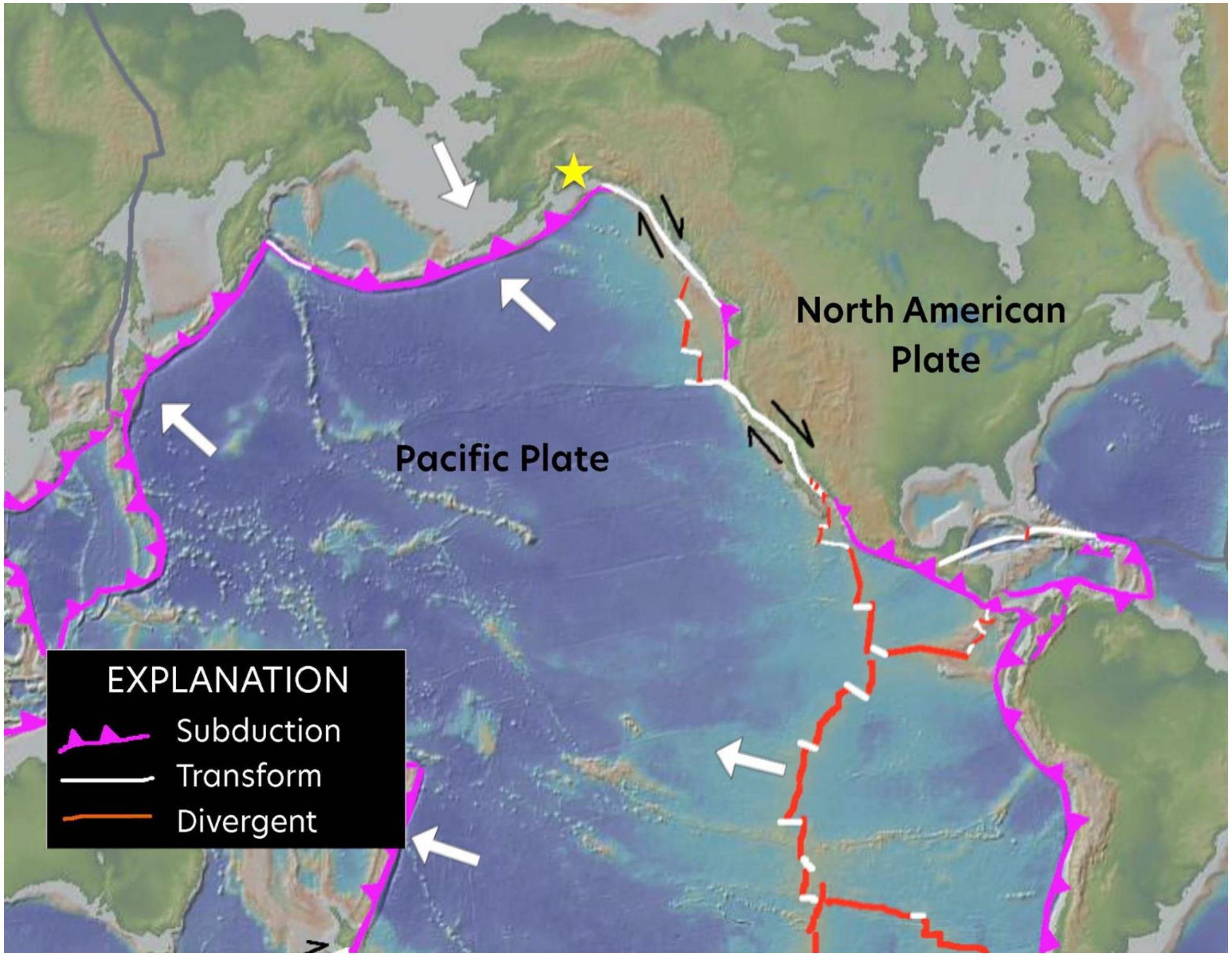
At first, scientists did not know how a M 9.2 earthquake could have happened, because the prevailing theories of the day could not explain such large displacements. It was understood that earthquakes occur along known fault lines where sections of earth rub against each other.

Those events—like the 1906 San Francisco quake — often leave cracks in the ground, sometimes visible over long distances. But the prevailing theory of a counter-clockwise rotation of the Pacific Plate, didn't account for new crust being created at underwater ridges, nor did it imagine that old crust could be subducted under continents.

We now know that this earthquake occurred where the Pacific Plate subducts beneath the North American Plate, resulting in great earthquakes, > M 8.



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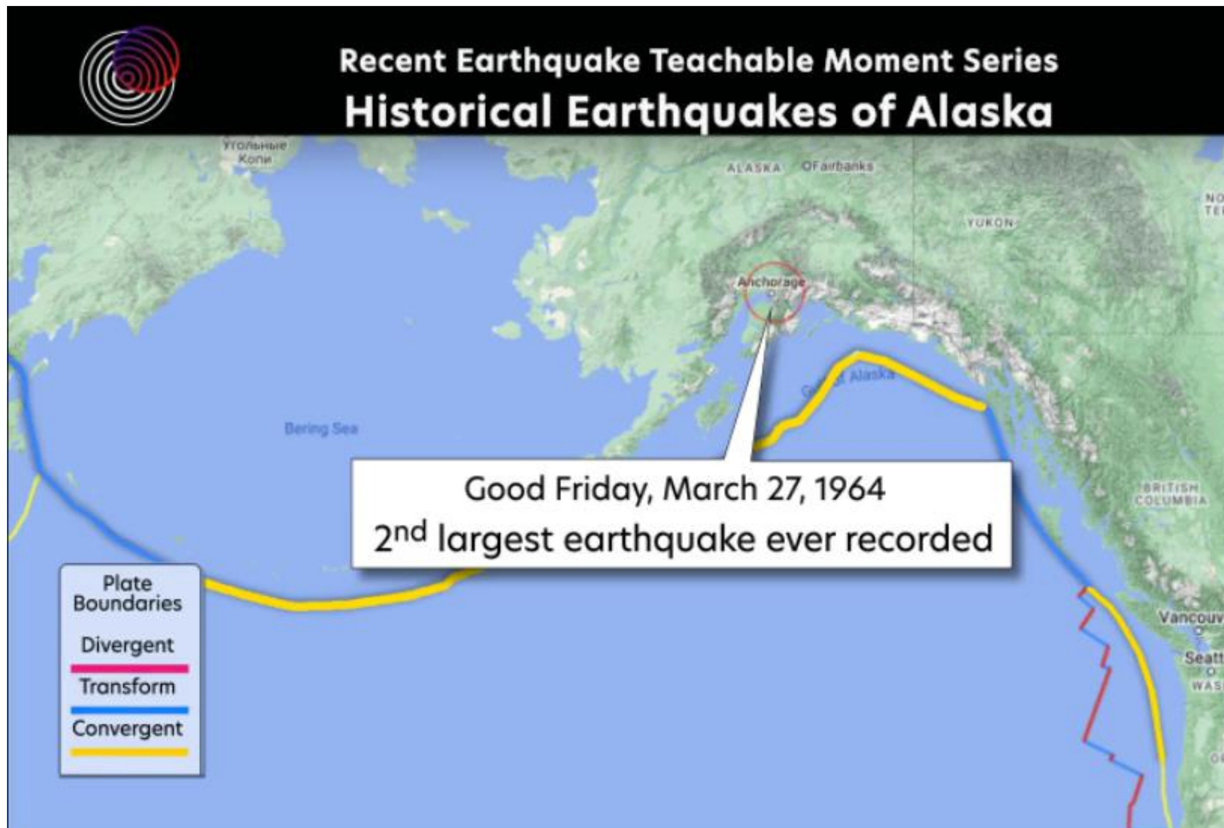
Alaska is the most seismically active state in the United States. The Alaska - Aleutian subduction zone (where the Pacific Plate dives beneath the North American Plate) produces more earthquakes >M 8 than any other subduction zone. This 1964 historical M 9.2 earthquake is the second largest earthquake ever recorded (the 1960 M 9.5 Chile earthquake was the largest).

Between 1899 and 2021, nine earthquakes of magnitude 8 or greater have struck along the subduction zone.

Earthquakes are distributed broadly across the plate boundary and occur at a range of depths, due to contact between the plates and compression and bending of the plates.

Since 1964 scientists, have learned that the world's most powerful earthquakes are subduction events in which one tectonic plate slips under another.



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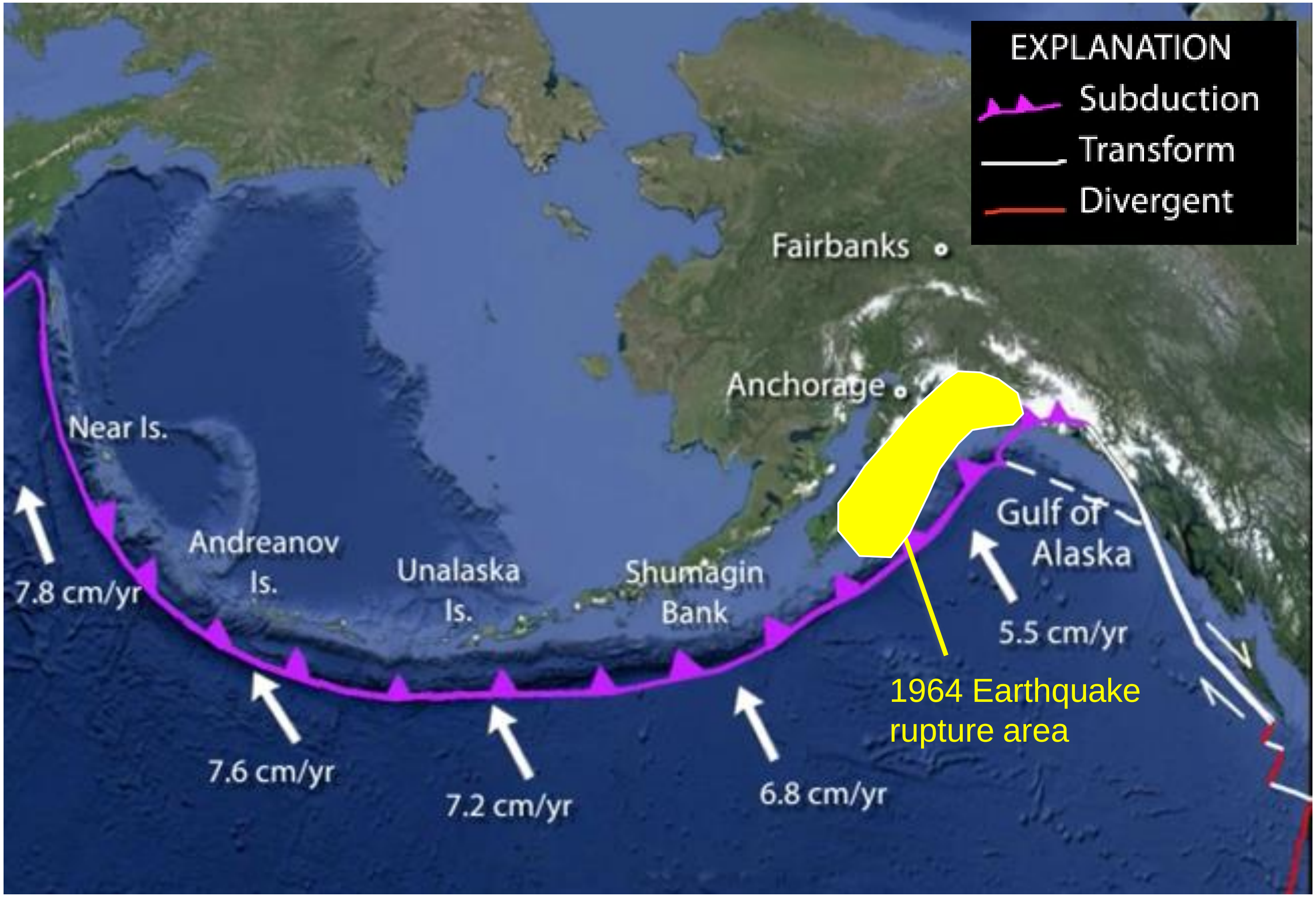

The Pacific Plate converges with, and subducts beneath the North American Plate and begins its descent into the mantle at the Alaska - Aleutian Trench. The rates of relative plate motion range from 5.5 cm/yr (2.2 in/yr) in the Gulf of Alaska to 7.8 cm/yr (3 in/yr) at the western end of the Aleutian Island chain. The 1964 earthquake rupture occurred between the two tectonic plates.

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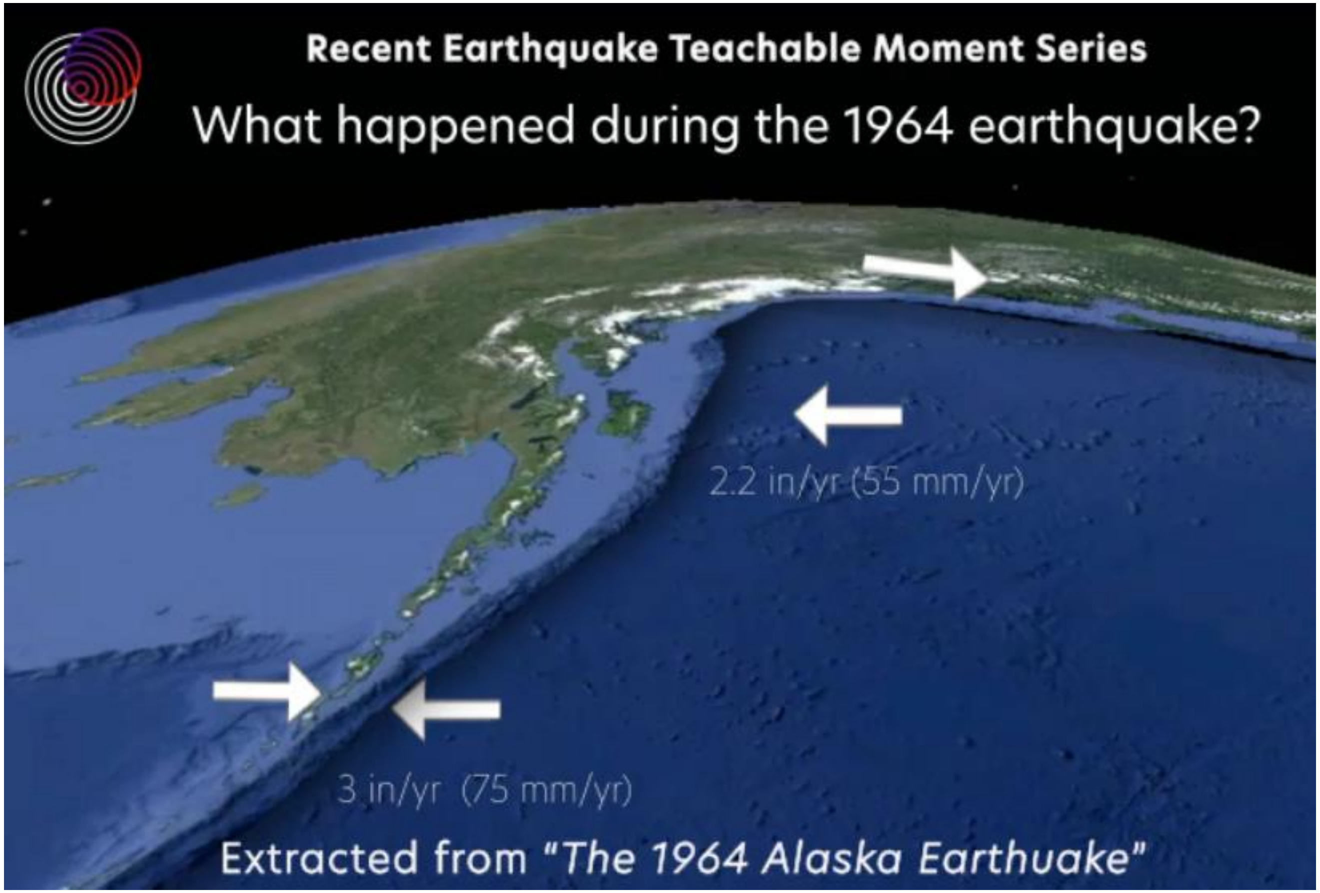
During the earthquake, the fault rupture displaced an area more than 800 km (500 miles) long, releasing immense seismic energy. This animation depicts the rupture process and plate interaction during this earthquake.



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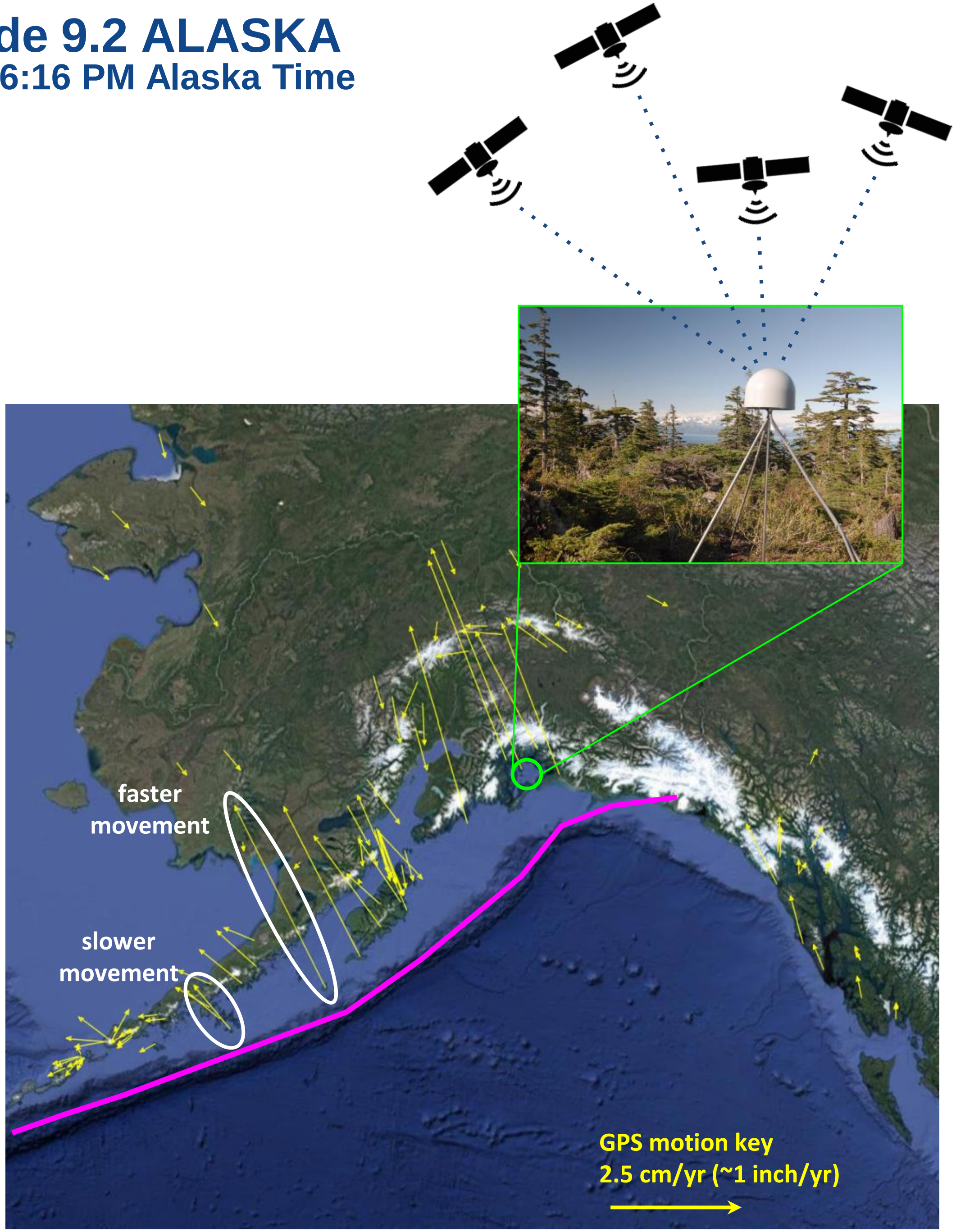
One of the current methods used to determine rates of plate motion is GPS observations.

To determine distance, GPS stations receive signals from satellites and use the time offset between when the signal leaves the satellite and when it arrives at the station. If a station receives signals from 4 or more stations, that data can determine its location. (Six or more satellites is more accurate).

This is the same way GPS works in phones and other devices. But the high-precision stations can determine location within millimeters (<¼ inch) rather than 5-10 meters (15-30 feet).

Over time, movement of GPS stations caused by plate tectonics can be determined. The yellow vectors show motions of GPS stations in southern Alaska (arrows).



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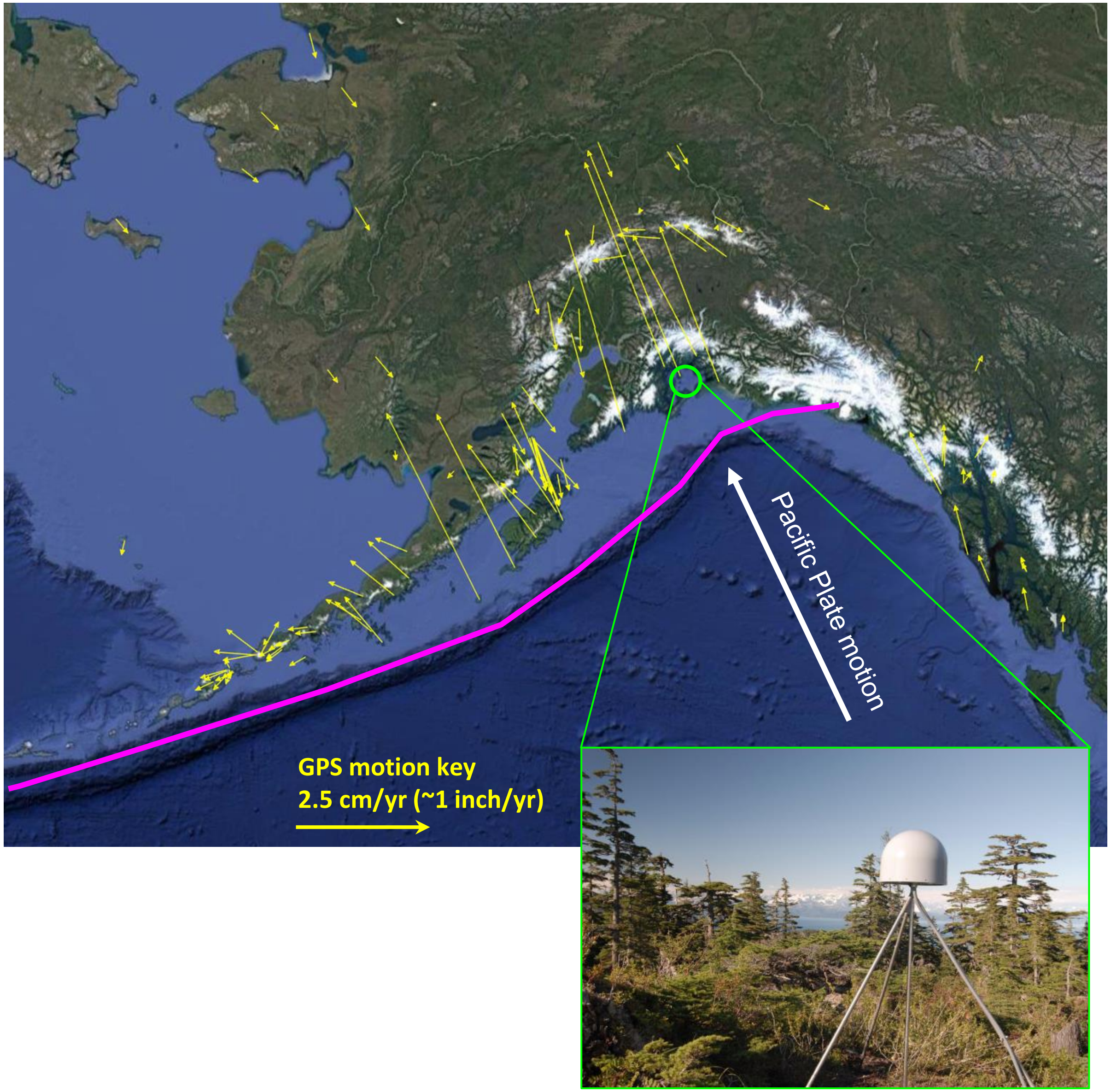
There were no GPS stations in 1964 but modern stations can teach us a lot about stress build up from plate tectonics that both led to the 1964 earthquake and will cause future earthquakes.

Stations in south central Alaska, where the M 9.2 earthquake occurred, today record northwest motion as the Pacific Plate pushes into North America. These rates are up to 4.3 cm/yr (1.7 inches/yr).

Over decades and centuries this compression will accumulate leading to future Magnitude +9 earthquakes with ground displacements of 10s of meters, like those that occurred during the 1964 earthquake.



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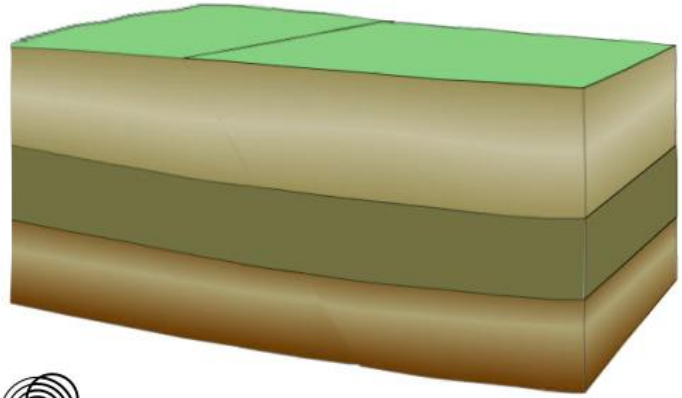
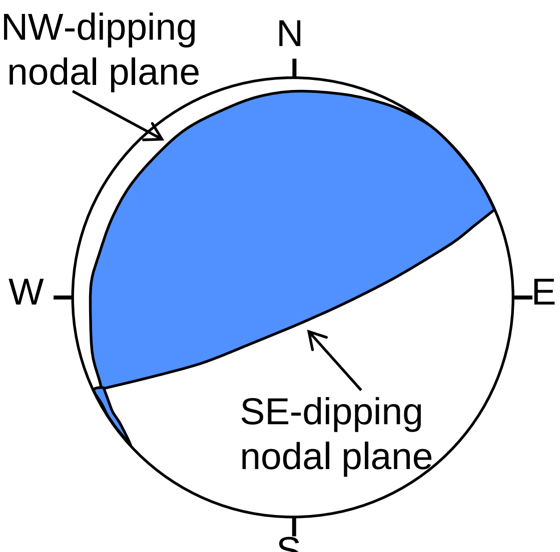
Because an earthquake occurs as slip on a fault, it generates primary (P) waves in quadrants where the first pulse is compressional (shaded) and quadrants where the first pulse is dilational (white). Orientation of these quadrants determines the type of fault that produced the earthquake.

Focal Mechanism for a Reverse Fault



EarthScope Consortium

www.iris.edu/hq/inclass/animation/204



1964 Alaska Focal Mechanism

Left: The focal mechanism of the Alaska 1964 earthquake has the signature of a reverse (or thrust) faulting earthquake.

One nodal plane dips steeply to the southeast and the other dips at a shallow angle to the northwest. But which nodal plane is the fault plane?

In 1964, plate tectonics was in its infancy and we did not understand subduction zones. Not surprisingly, an argument ensued about which of the two nodal planes was the fault plane.

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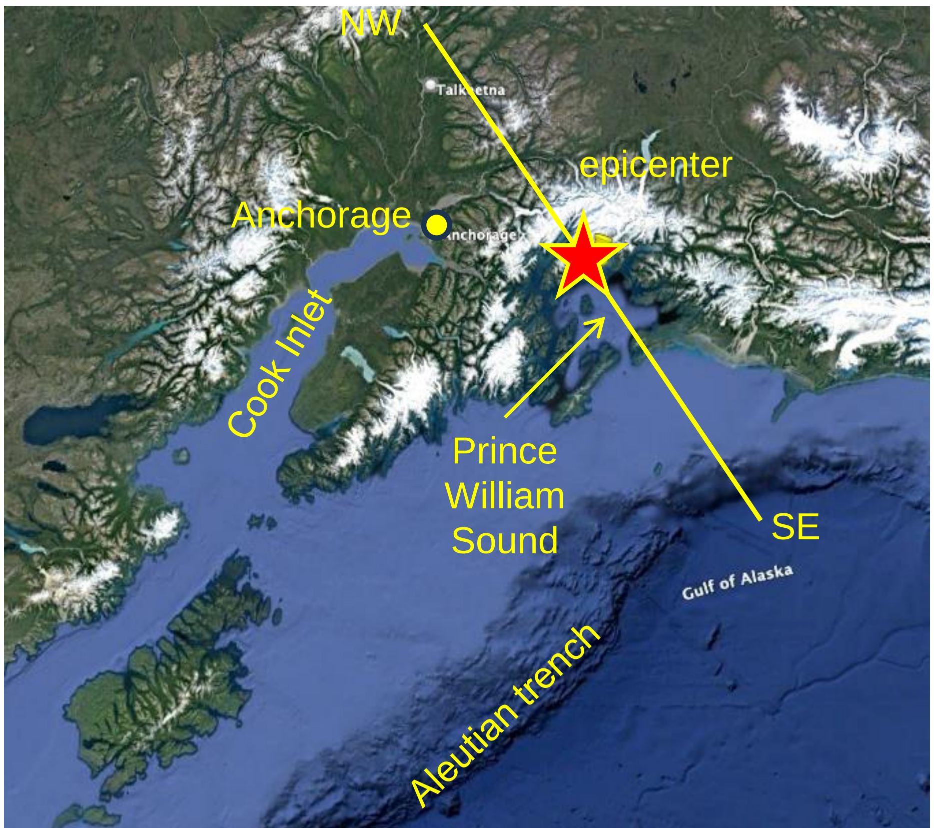
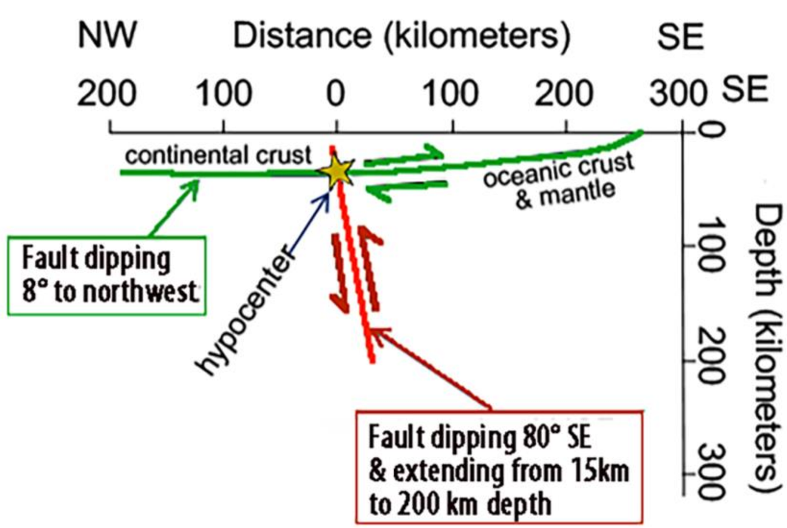
On the map below, the line of a cross section is drawn from northwest to southeast through the epicenter of the 1964 Alaska earthquake. The cross section on the lower right illustrates the two fault models proposed to account for the focal mechanism. Seismologists initially interpreted the nodal plane dipping 80° SE to be the fault plane. They proposed 6 to 9 meters of southeast-side-up displacement on a fault extending from 15 to 100 or 200 kilometers deep. From our modern plate tectonics perspective, this steeply-dipping reverse fault reaching over 100 km deep is quite strange.



Geologists studying surface faulting and land level changes along shorelines of Cook Inlet and Prince William Sound favored a thrust fault dipping just 8° to the northwest. That “megathrust” fault was thought to extend to the Aleutian Trench. So, how was the debate between these two fault models resolved?



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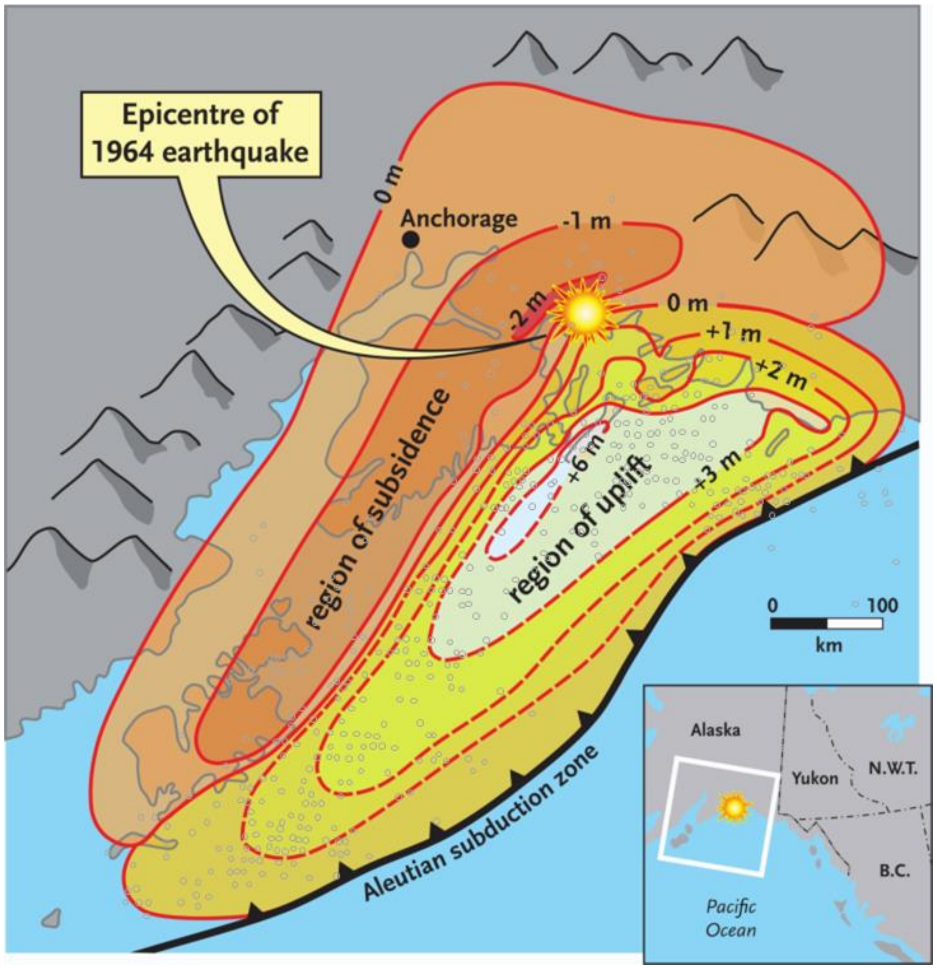
To answer the fault-plane question, we can look at the effect of this earthquake on changes in land level. In the *region of subsidence*, land dropped by as much as 2 meters. Land uplifted by as much as 6 meters in the *region of uplift*.



The following observations strongly favored the megathrust fault model.

- Megathrust faulting nicely accounts for the regions of subsidence and uplift while the steeply-dipping fault model yields regions much narrower than observed.
- Aftershocks of $\leq$ 50 km depth occurred beneath the regions of subsidence and uplift. This is expected for the megathrust model but inconsistent with the steeply-dipping fault model that predicts a narrow band of aftershocks extending to > 100 km depth.
- Broad uplift of the continental shelf produced by megathrust faulting can generate the observed tsunami much more effectively than a steeply-dipping fault.

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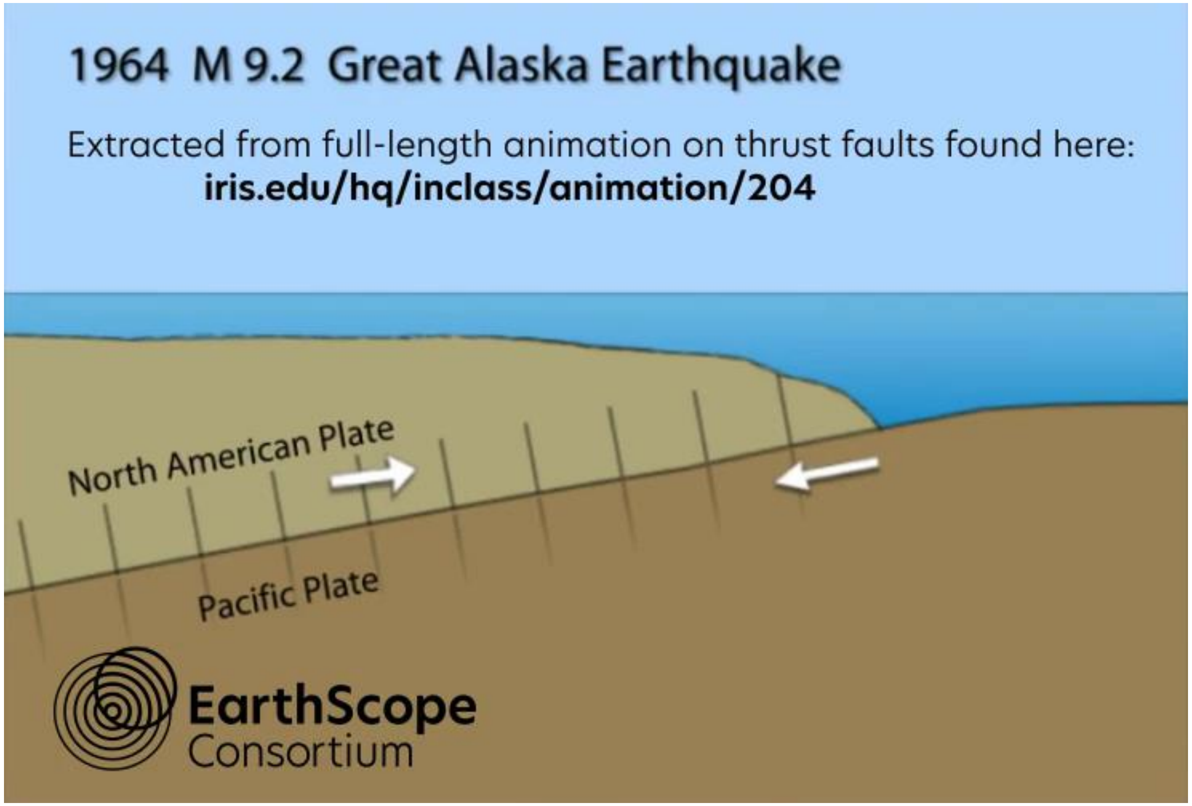
Shallow great earthquakes in subduction zones often cause tsunamis because they offset the ocean floor. The 1964 M 9.2 earthquake generated a massive tsunami because it uplifted the ocean floor more than 9 meters (29.5 ft). Today's tsunami warning and forecast capability involves detection and modeling components that were not available in 1964.



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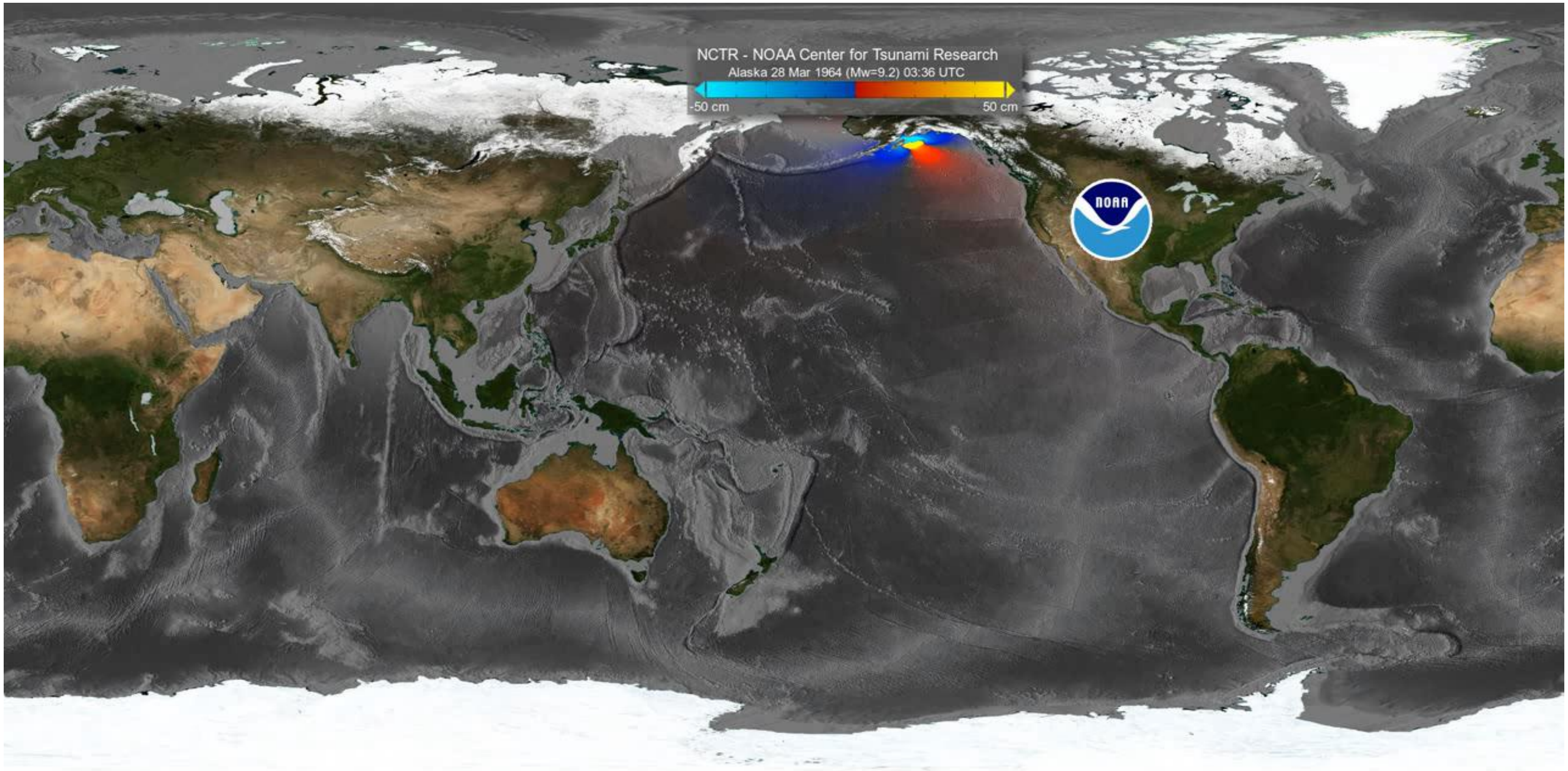

Animation of the global propagation of the tsunami. The tsunami traveled across the Pacific Ocean affecting twenty countries and causing damage as far away as Japan. Gigantic waves were generated locally, with the maximum wave run-up height of 220 feet (67 m) recorded in Valdez, Alaska. Most of the 131 deaths from this disaster were caused by the effects of ocean waves, including people drowning as far away as Crescent City, California.

Tsunamis can travel at speeds up to 800 km per hour (500 miles per hour), as fast as a jet plane. In the open ocean, ocean floor bathymetry affects the wave because a tsunami moves the seawater all the way to the floor of the ocean.

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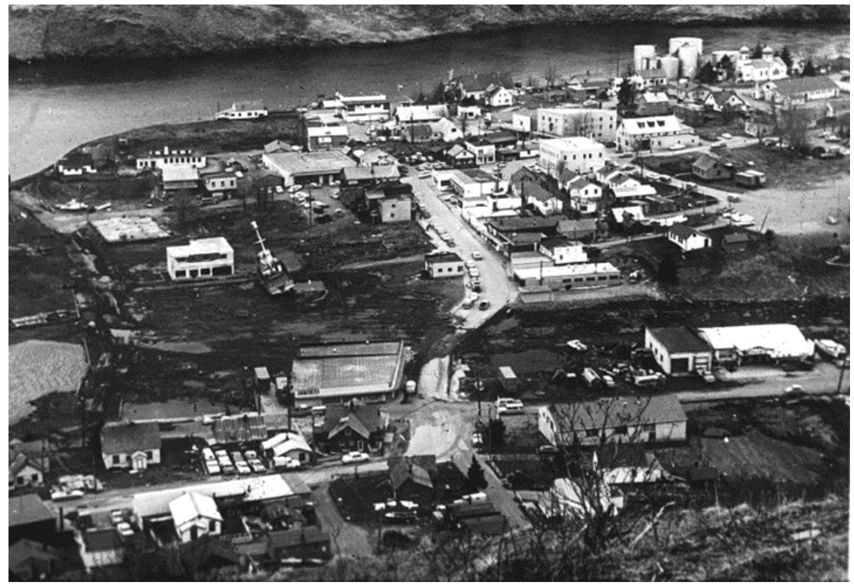
This pair of photos of downtown Kodiak, Alaska, was taken before and after the tsunami which followed the 1964 Alaska earthquake.

The tsunami severely damaged homes, shops, and naval-station structures but also temporarily crippled the fishing industry in Kodiak by destroying the processing plants and most of the fishing vessels.



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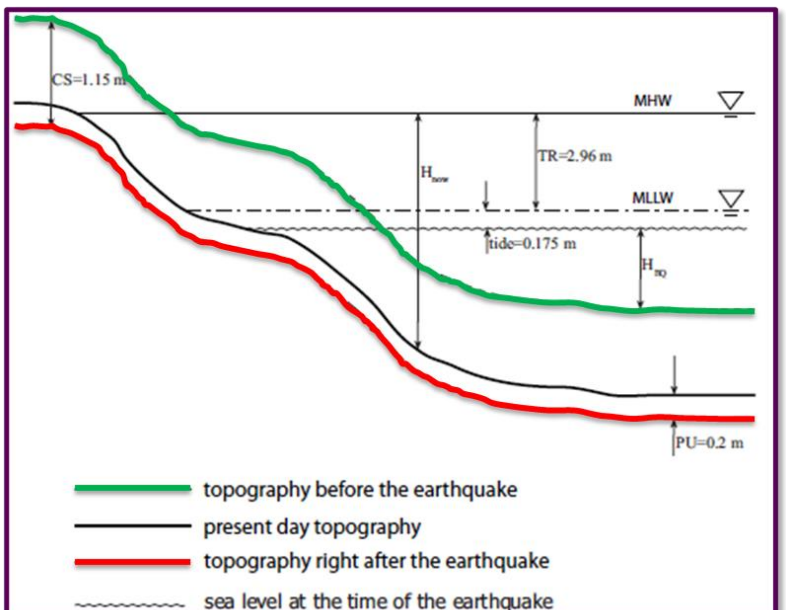
In addition to the 'tectonic' tsunami generated by the earthquake, coastal Alaskan communities also experienced subsidence and landslide-generated tsunamis.

Land dropped 1.1 meters (3.5 ft) at Seward during the 1964 earthquake and land subsidence increased tsunami inundation. However, one fortunate coincidence is that the earthquake occurred at low tide. Because tsunamis "ride the tides", tsunami inundation was much less than it would have been if the earthquake had occurred during high tide.

Seward Coseismic Subsidence



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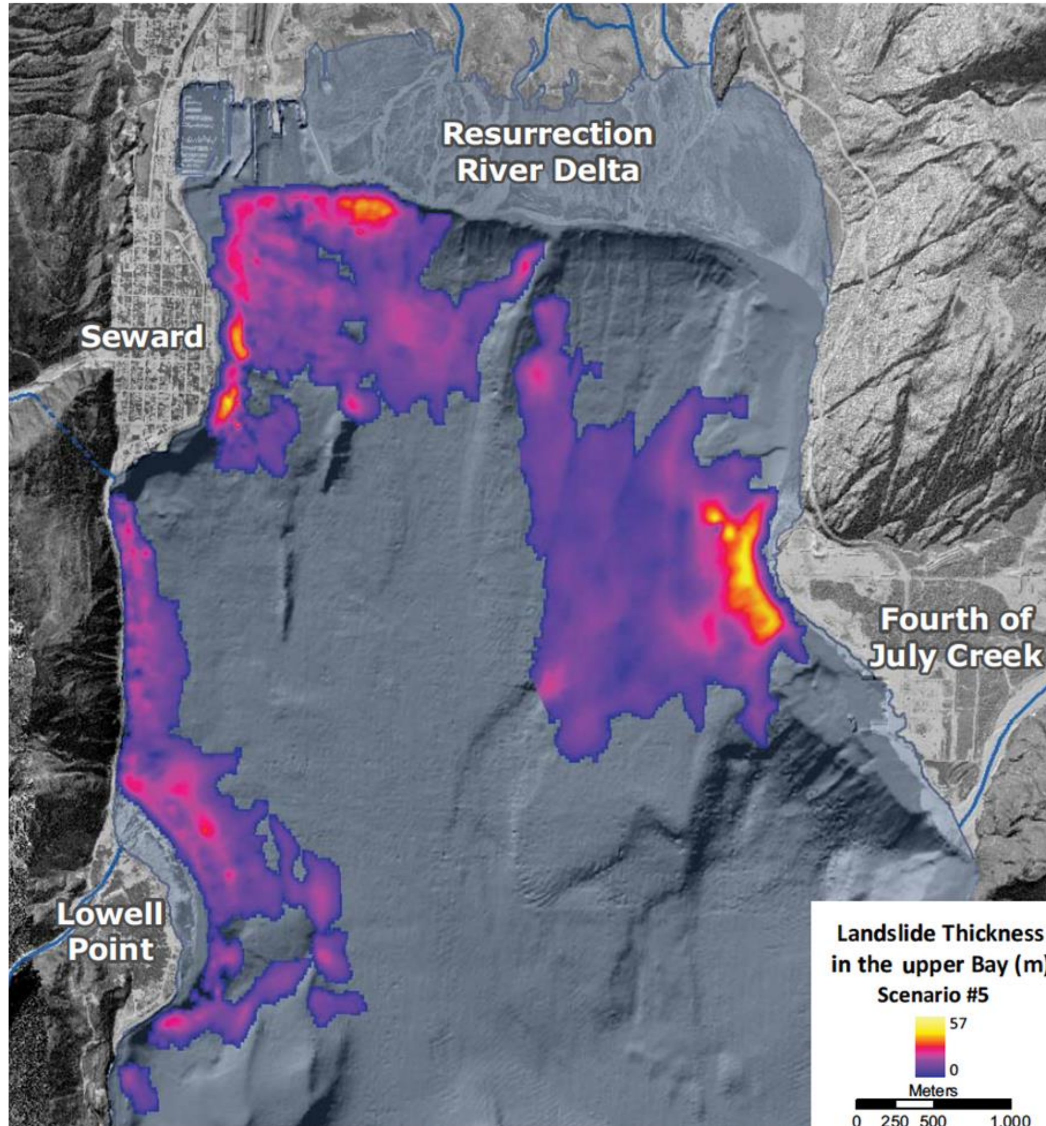
Seward 1964 Landslides

Detailed bathymetric studies allowed reconstruction of the sizes of the landslides.

Modeling of the tsunami generated by three submarine landslides at the head of Resurrection Bay reproduced the observed wave heights and sequence.

Modeling of the tectonic tsunami reproduced arrival times and height of the longer period waves.



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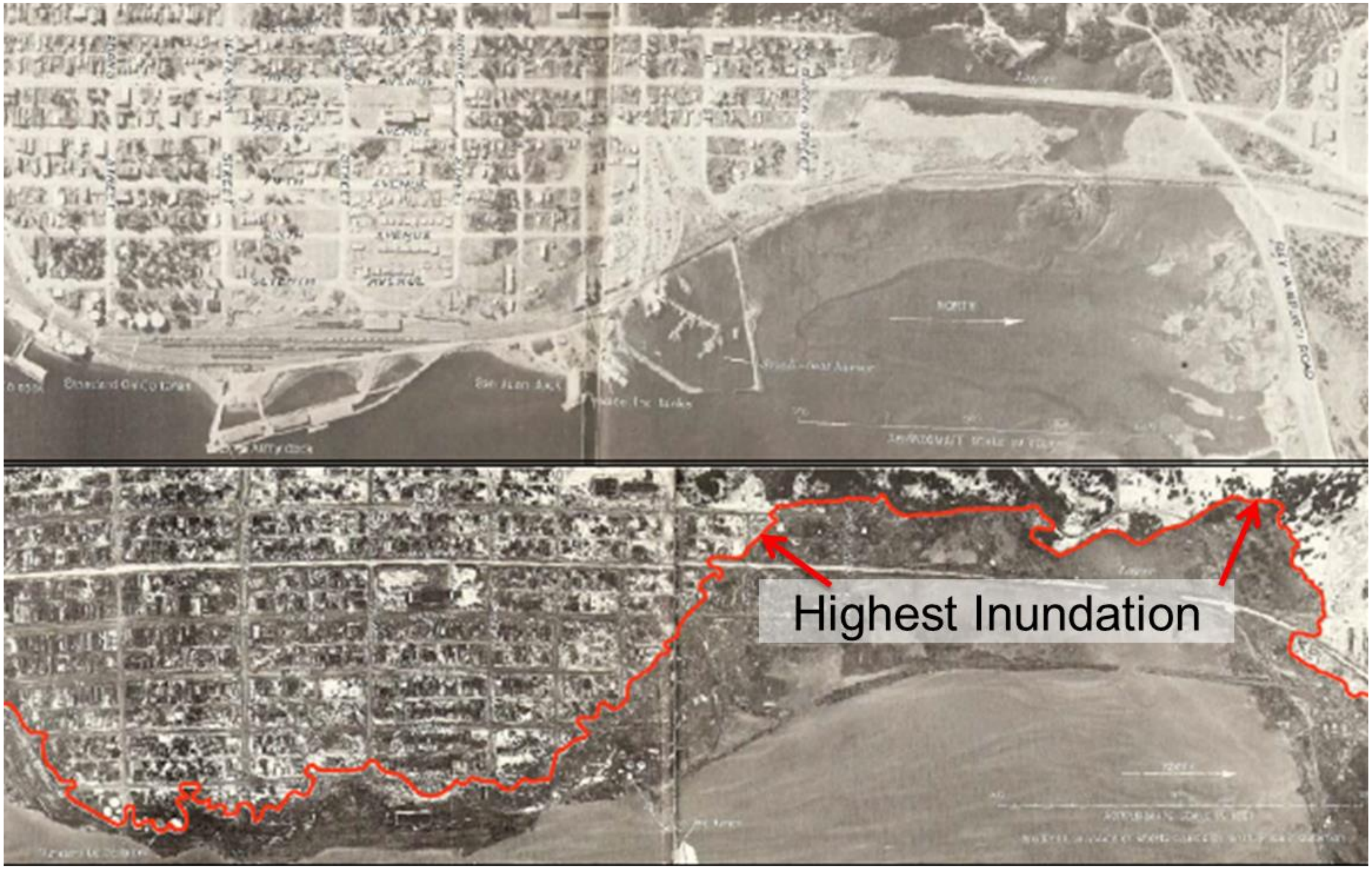
Seward Before & After Tsunami



After 30 seconds of shaking, a landslide that included much of the waterfront slid into the bay rupturing fuel tanks and igniting oil. Two underwater landslides occurred at same time. The series of three landslide-generated waves up to 6 meters (19.7 ft) high arrived during first 3 minutes of shaking. The tectonic tsunami, covered in burning oil, arrived ~20 minutes after ground shaking stopped. The third tectonic tsunami wave was highest at ~8 meters (26 ft) height. Wind blowing toward bay prevented entire town from burning. 13 people were killed.

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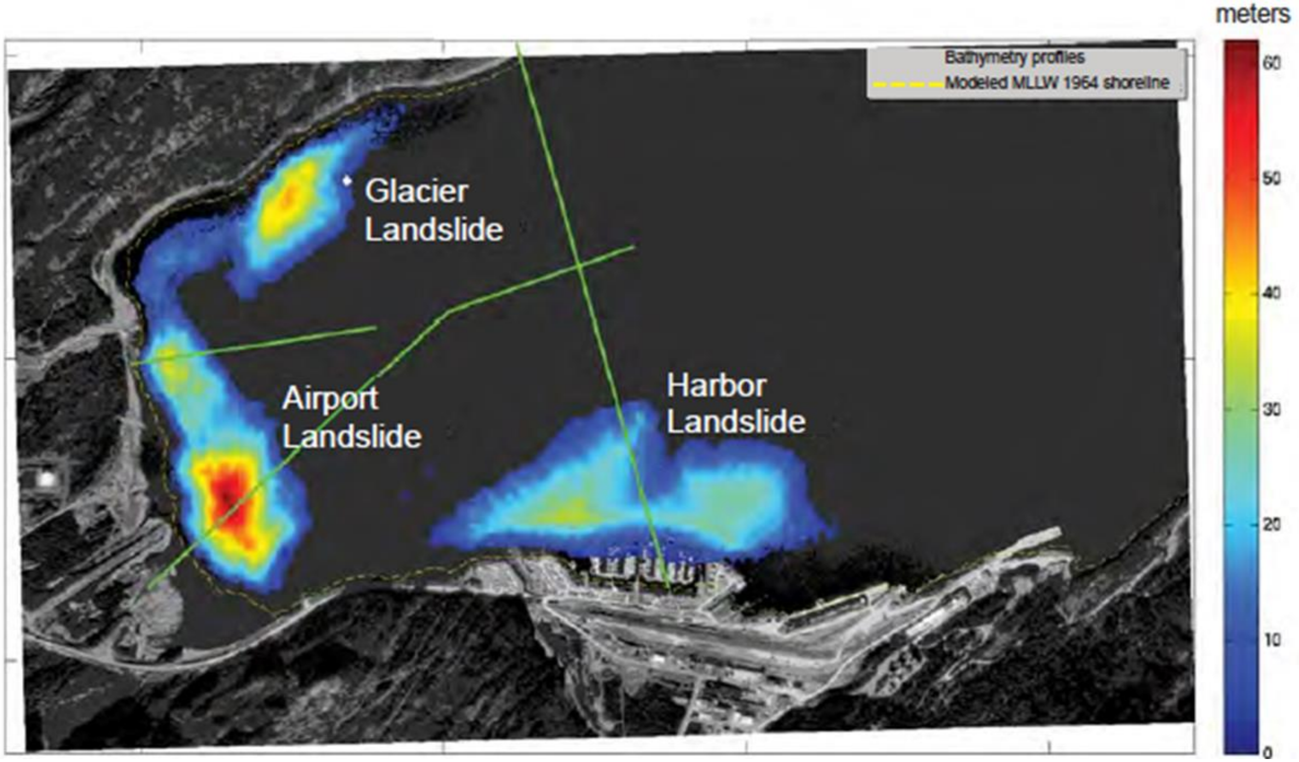
Detailed bathymetric studies of Passage Canal, Whittier allows reconstruction of sizes of the landslides that generated tsunami waves. This modeling reproduced the landslide-generated tsunami wave heights that were observed in 1964.



Left: Whittier 1964 Landslides

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Whittier After 1964 Tsunami

Whittier subsided 1.6 m (5 ft) during the earthquake. Thirteen out of 70 people in Whittier died in the tsunamis. Three waves generated by landslides arrived during ground shaking and completely destroyed the buildings of two lumber companies. Fire destroyed fuel-storage tanks at the waterfront.

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