Introduction and Importance of 1964 Alaska Earthquake

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Abstract. The 1964 Alaska Earthquake is the largest earthquake in U.S. history. Even after decades, it still has a huge impact in the field of geology and seismology. This disaster and following consequences in the local area and around the world had made great contributions to science society as an outstanding example. It is not only a strong support of the Theory of Plate Tectonics and convincing observation and explanation of earthquake ground deformation, but also a unique case to increase understanding of liquefaction and earthquake hazards in Alaska and elsewhere. This is an introduction of this catastrophe and a statement of importance in the field of geology.

Keywords: Earthquake · Alaska · Natural Disaster · Tsunami

1 Introduction

On Good Friday, March 27th, 1964, an earthquake of magnitude 9.2 struck south-central Alaska at 17:36 local time. This disaster, 1964 Alaska earthquake, also known as the Good Friday earthquake, is the largest earthquake recorded in U.S. history and 3rd largest around the world. This event caused ground fissures, collapsing structures and tsunamis resulting in 131 killed and total damage of 311 million dollars.

2 Geology

This earthquake is a megathrust earthquake caused by the subduction zone between North American Plate and Pacific Plate with the moment magnitude of 9.2 Mw. Figure 1 is the map of southern Alaska showing the epicenter of the 1964 Alaska Earthquake (red star in Fig. 1). Pacific plate (oceanic) moved northward and went underneath the North American Plate (continental), causing the rupture at Aleutian Megathrust Fault resulting in an uplift on the south, and a subsidence on the north. Between the uplift and subsidence is the epicenter at Prince William Sound. The depth of the focus of this earthquake is 25 km below the surface, which was relatively close to the ground, releasing huge amounts of energy. With the duration of 4–5 min, ocean floor shifts created large tsunamis up to 67 m in height and large rockslides. Vertical displacement up to 12 m occurred and affected a total area more than 250,000 km^2 within Alaska.

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Fig. 1. The outline of Pacific Plate and North American Plate [1]

The 1964 Alaska Earthquake spawned thousands of lesser aftershocks and hundreds of damaging landslides, submarine slumps, and other ground failures. There were more than 20 big aftershocks (>6.0 Mw) within one month after the main earthquake, eleven of them happened the next day and nine happened in three weeks. Alaska's largest city, Anchorage, located west of the fault rupture, sustained heavy property damage. Tsunamis produced by the earthquake resulted in deaths and damage as far away as Oregon and California. Altogether the earthquake and subsequent tsunamis caused 131 fatalities and an estimated $311 billion (1964).

Figure 2 shows the travel time for tectonic tsunami calculated and the contour lines represents the travel time in hours. There was a tectonic tsunami produced following with about 20 smaller and local tsunamis produced by submarine and subaerial landslides and were responsible for the majority of the tsunami damage. The largest tsunami wave was recorded in Shoup Bay, Alaska, with a height of about 67 m. Globally, the 1964 Alaska Earthquake generated tsunamis not only affected North America. More than 20 countries including Peru, New Zealand, Papua New Guinea, Japan, Mexico, and in the continent of Antarctica noted the tsunamis and caused property damage.

3 Academic Importance

The 1964 Alaska Earthquake was a huge tragedy because of the loss of life and property, leaving negative effects locally and globally. However, it also provided a legacy of data about subduction zone earthquakes and the hazards they brought. "It was the largest U.S. earthquake ever recorded, and a turning point in earth science. Learn about the great leaps in research over the past 50 years." [3] This event caused a leap in scientific

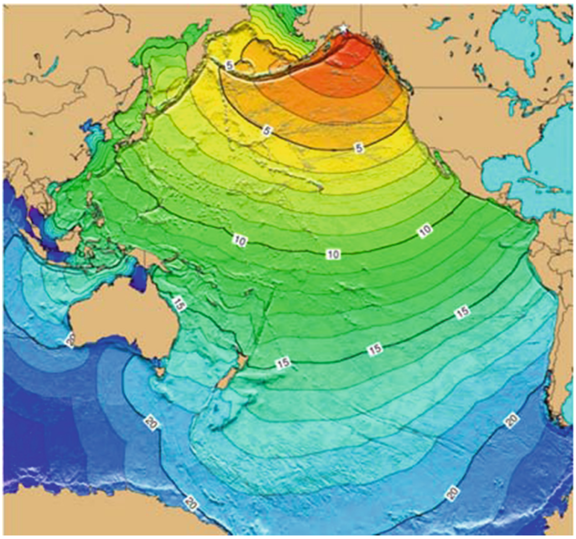

Fig. 2. Color coded diagram of travel time in hours [2]

understanding, contributing remarkable breakthroughs in geology, seismology, and other earth science research around the world until now, especially as the support for the Theory of Plate Tectonic and enhanced understanding of liquefaction and subduction zone.

The 1964 Alaska Earthquake helped scientists to understand the Theory of Plate Tectonic and provided an outstanding example. Theory of Plate Tectonic originated from the hypothesis back to 1912, but was not widely accepted until 1962. Back to 1964, at first, geologists did not know how such a huge earthquake could have happened, because the prevailing theories of the day could not explain such a large movement, and then they turned to a relatively new theory, the Theory of Plate Tectonics. Academic society has compelling evidence for this theory that most earthquakes occurred near the boundaries of plates and the movement direction of plates is consistent with observed events. Also, the 1964 Alaska Earthquake served as a strong proof of this theory. The 1964 Alaska Earthquake resulted from plate convergence, where the Pacific Plate went underneath the North American Plate because of the difference from densities of oceanic and continental crust. Since 1964, subduction zones have been recognized elsewhere, including Japan and Chile, where great earthquakes have also occurred during past years. Understanding gained in this earthquake became the foundations of the geological framework for assessing the earthquake and tsunami hazards around the world, pushing the entire field of geology and seismology forward a lot. Also, the 1964 Alaska Earthquake was one of the first events to demonstrate to scientists that an earthquake may cause changes of seafloor depth that generate transoceanic tsunamis, explaining some "orphan" tsunamis and broadening the horizon for seismic analysis.

Besides helping understand the Theory of Plate Tectonics, the 1964 Alaska Earthquake also helped recognize hazards due to movement on secondary faults. It showed that secondary faults spreading out or splaying upward from the main rupture plane can accommodate much of the horizontal and vertical movement associated with the sudden plate motion. After the 1964 earthquake, vertical uplifts of 36 ft were mapped along splay faults on Montague Island, and vertical uplifts along related faults were inferred to extend as far south as Kodiak Island. These uplifts produced large tsunamis on the Kenai Peninsula near Seward and on Kodiak Island. Such secondary faulting is likely also responsible for the tsunami disaster in Aceh, Indonesia, during the 2004 Great Aceh-Andaman Earthquake.

Additionally, the 1964 Alaska raised the understanding of liquefaction and the hazard it brought. Liquefaction takes place when loosely packed, water-logged sediments at or near the ground surface lose their strength in response to strong ground shaking. Liquefaction occurring beneath buildings and other structures can cause major damage during earthquakes. During this disaster, most of the buildings were destroyed by soil liquefaction caused by the earthquake. Catastrophic soil failure in the Alaskan and Niigata, Japan, earthquakes in 1964 provided a new insight that liquefaction of sandy soils caused by earthquake shaking poses a major threat to the stability of engineered structures. During strong earthquake shaking, geologically young, water-saturated sandy deposits can act like a liquid, causing them to flow downhill and to lose their ability to support man-made structures during the shaking. More than $30 million in damage, from both liquefaction and tsunamis, was sustained by the federally owned Alaska Railroad. Many important railroad bridges were destroyed when their pilings and piers sank or spread apart because the underlying soils flowed. Parts of the railroad were out of service for nearly six months. The 1964 Alaskan and Japanese earthquakes prompted extensive government-funded research by geotechnical engineers in both countries on the physics of liquefaction and implications for structural stability. Their findings led to the development of field based methods to determine liquefaction potential of coarse-grained soils; these methods are used around the world by civil engineers to ensure the safety of structures in earthquake-prone areas.

Different models have been developed after the 1964 Alaska Earthquake. Suito and Freymueller [4] performed a 3-D viscoelastic model, with an afterslip model, to describe the postseismic deformation following the 1964 Alaska Earthquake, which is quite triggering and enlightening. Their modeling showed that no single mechanism could explain both the 30-year cumulative uplift and the present velocities, but a combination of viscoelastic relaxation, afterslip and interseismic slip deficit explain all first order features of observed postseismic deformations. In their opinion, even decades have passed, velocities in present still contain a significant component of postseismic deformation, showing that very long lived postseismic deformation plays an important role in the subduction zone earthquake cycle for huge earthquakes.

Another research performed by Piersanti et al. [5] is also eye-opening. They have verified that viscoelastic relaxation produces noticeable amplification of the coseismic horizontal and vertical displacements, especially in the case of deep seismic sources. The major conclusion of their study is that in the presence of a low-viscosity zone beneath the lithosphere, the rates of deformation predicted by their model are comparable with those observed along some of the Alaska baseline.

4 Discussion

Earthquake is one of the most destructive natural disasters costing life and property. It is extremely difficult to precisely predict earthquakes and prevent damage. There are two reasons why earthquakes are hard to prevent. The first is there are always seismic waves generated at faults and the difference between abnormal ones and regular ones are not significant before the event happens. Once it was observed, there is very limited time from releasing moment and arriving moment because the velocity of seismic waves is high, normally around several kilometers per second, leaving limited time to take reaction. The second reason is with modern technology and data acquired from the past, it is hard to predict the time precisely, in minutes or seconds. Earthquake is a sudden disaster, which only lasts for minutes, releasing huge amounts of energy to cause destruction. If the prediction can only be precise as the date, it is not a trustworthy prediction because the time range is too broad to take action on time. However, according to the first fundamental principle of this class, which is "hazards are predictable from scientific evaluation." once we achieve more advanced technology which can sense the seismic waves more accurately and sensitively, and generate more adequate models which can predict earthquake more precisely, the hazard of earthquake would be able to predict and to prevent further loss of life and property. Since we cannot actually get the precise arriving moment of an earthquake, it is more and more important to get prepared before the actual event happens. Making a plan ahead and staying calm would be the most correct response for a disaster like earthquakes (Fig. 3).

5 Conclusion

The 1964 Alaska Earthquake, the largest earthquake recorded in U.S. history, has caused huge damage including loss of life and property and geological deformation in the local area. However, this disaster also provided huge academic value as the legacy to help the society of geology and seismology to fulfill understanding and experience of earthquakes in Alaska and elsewhere. With the help of the 1964 Alaska Earthquake, further understanding about secondary faults and liquefaction was acquired and proof of the Theory of Plate Tectonics was provided. Even though with modern technology, a precise forecast of earthquakes is hard to achieve, with more and more cases like the 1964 Alaska Earthquake, it is not impossible to achieve a precise forecast of earthquakes in the future and to prevent loss of life and property.

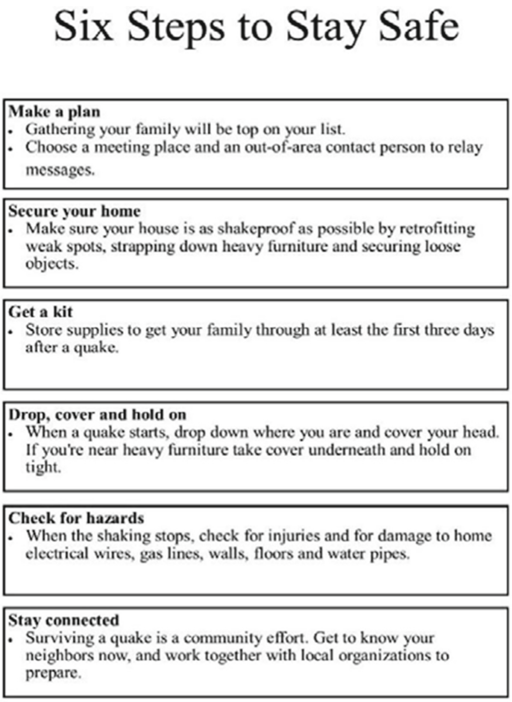

Fig. 3. Six Steps to stay safe Before, During and After Earthquake [Owner-draw] [6]

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