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1964 Great Alaska Earthquake—A Photographic Tour of Anchorage, Alaska

Open-File Report 2014–1086

U.S. Department of the Interior
U.S. Geological Survey

Cover:
Comparison photographs taken from the same location on 4th Avenue looking east through the intersection with C Street, Anchorage, Alaska. (Top photograph taken by U.S. Army, 1964; bottom photograph taken by Robert G. McGimsey, 2013)

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By Evan E. Thoms, Peter J. Haeussler, Rebecca D. Anderson, and Robert G. McGimsey

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SALLY JEWELL, Secretary

U.S. Geological Survey
Suzette M. Kimball, Acting Director

U.S. Geological Survey, Reston, Virginia: 2014

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Conversion Factors

Inch/Pound to SI

Multiply	By	To obtain
	Length	
inch (in.)	2.54	centimeter (cm)
inch (in.)	25.4	millimeter (mm)
foot (ft)	0.3048	meter (m)
mile (mi)	1.609	kilometer (km)
	Area	
acre	4,047	square meter (m^2)
acre	0.4047	hectare (ha)
acre	0.4047	square hectometer (hm^2)
acre	0.004047	square kilometer (km^2)

Datum

Horizontal coordinate information is referenced to the North American Datum of 1983 (NAD 83).

1964 Great Alaska Earthquake—A Photographic Tour of Anchorage, Alaska

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Introduction

On March 27, 1964, at 5:36 p.m., a magnitude 9.2 earthquake, the largest recorded earthquake in U.S. history, struck southcentral Alaska (fig. 1). The Great Alaska Earthquake (also known as the Good Friday Earthquake) occurred at a pivotal time in the history of earth science, and helped lead to the acceptance of plate tectonic theory (Cox, 1973; Brocher and others, 2014). All large subduction zone earthquakes are understood through insights learned from the 1964 event, and observations and interpretations of the earthquake have influenced the design of infrastructure and seismic monitoring systems now in place. The earthquake caused extensive damage across the State, and triggered local tsunamis that devastated the Alaskan towns of Whittier, Valdez, and Seward. In Anchorage, the main cause of damage was ground shaking, which lasted approximately 4.5 minutes. Many buildings could not withstand this motion and were damaged or collapsed even though their foundations remained intact. More significantly, ground shaking triggered a number of landslides along coastal and drainage valley bluffs underlain by the Bootlegger Cove Formation, a composite of facies containing variably mixed gravel, sand, silt, and clay which were deposited over much of upper Cook Inlet during the Late Pleistocene (Ulery and others, 1983). Cyclic (or strain) softening of the more sensitive clay facies caused overlying blocks of soil to slide sideways along surfaces dipping by only a few degrees.

This guide is the document version of an interactive web map that was created as part of the commemoration events for the 50th anniversary of the 1964 Great Alaska Earthquake. It is accessible at the U.S. Geological Survey (USGS) Alaska Science Center website: *http://alaska.usgs.gov/announcements/news/1964Earthquake/*. The website features a map display with suggested tour stops in Anchorage, historical photographs taken shortly after the earthquake, repeat photography of selected sites, scanned documents, and small-scale maps, as well as links to slideshows of additional photographs and Google Street View™ scenes. Buildings in Anchorage that were severely damaged, sites of major landslides, and locations of post-earthquake engineering responses are highlighted. The web map can be used online as a virtual tour or in a physical self-guided tour using a web-enabled Global Positioning System (GPS) device. This publication serves the purpose of committing most of the content of the web map to a single distributable document. As such, some of the content differs from the online version.

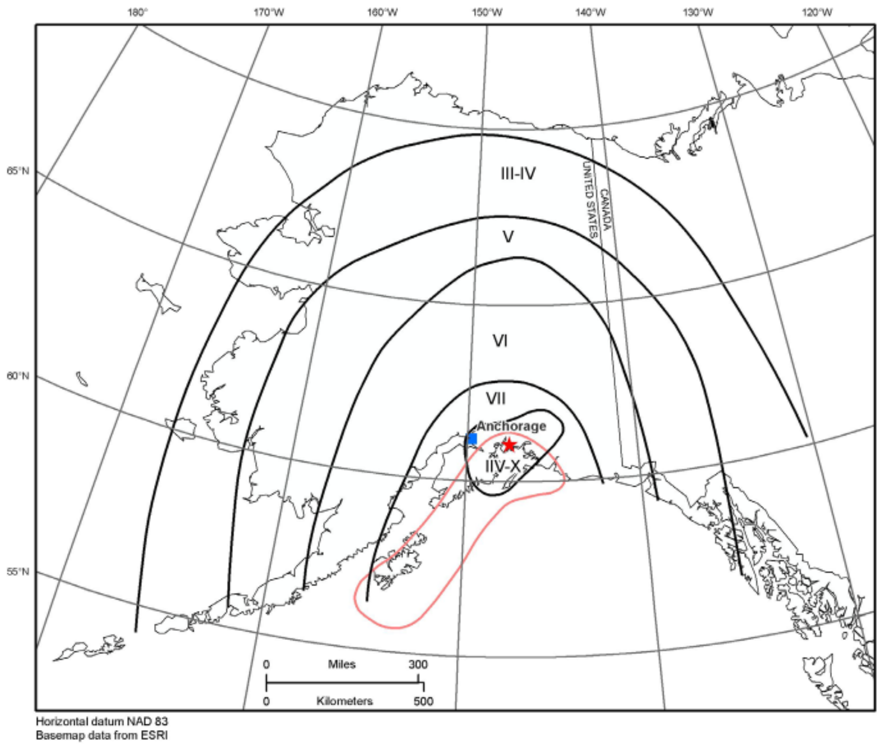


Figure 1. Overview map showing epicenter of the 1964 Great Alaska Earthquake (red star), the area on the megathrust contact that ruptured (red polygon), and lines enclosing areas of similar Modified Mercalli Intensity (Roman Numerals; Stover and Coffman, 1993), Alaska.

How to Use This Guide

The tour area only covers the City of Anchorage. An overview map (fig. 2) shows the three areas covered by the tour with numbered icons for each tour stop described in the "Photographic Tour Stops" section. For simplicity, the stops have been sorted from east to west, so the numbers do not imply the order in which they should be visited, and directions to the stops are not given in this guide. Although the map uses high-resolution and accurate base layers, it should not be used as the sole source of navigation. Many of the stops are at locations where nearby parking is available or at public parks, but some are on private land where businesses are operating. Please be considerate of their business; park away from entrances and exits, make your visit short, and be polite if approached.

The stops are broadly organized into two groups: (1) sites where there was notable damage as a result of the earthquake, and (2) sites that illustrate the post-earthquake response in terms of engineering meant to reduce the potential for further damage or instrumentation that collects data used by scientists and engineers to better understand seismic hazards. Many sites of historic damage show no present-day (2013) evidence of the earthquake as most of the massive landslides have been re-graded and developed, and some buildings that were damaged have been repaired whereas others have been removed for other reasons.

Many of the images used in the guide can be accessed at the USGS Photographic Library (USGS PL) website (*http://libraryphoto.cr.usgs.gov/*) on the Key Word Search page by searching for the photograph identification (ID) given in figure captions (for example, USGS PL, ID aeq00025, search for "aeq00025"). Tour stop and photograph descriptions come verbatim from Hansen (1965), photograph captions accessed at the USGS Photographic Library, or modified from other sources.

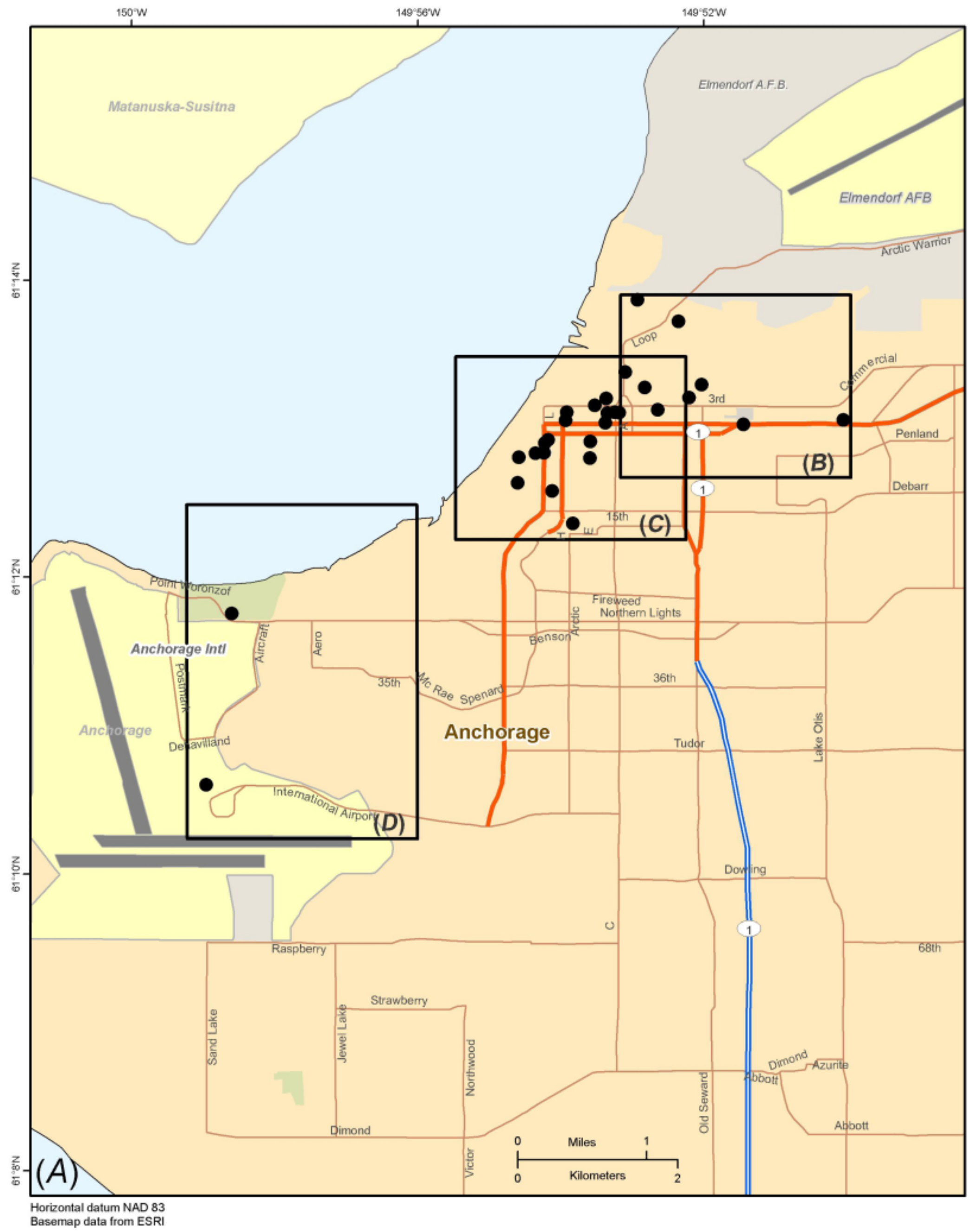


Figure 2. Overview map (*A*) of Anchorage, Alaska, showing locations of photographic tour stops and boundaries of three larger scale maps (*B*, *C*, and *D*).The larger scale maps include numbered icons that refer to tour stop headings in the text where the sites are described and include the generalized extents of the more notable landslides, shown with cross-hatching (generalized from Hansen [1965]). (FA, Fourth Avenue Slide; GH, Government Hill Slide; LS, L Street Slide; NH, Native Hospital Slide; TH, Turnagain Heights Slide.)

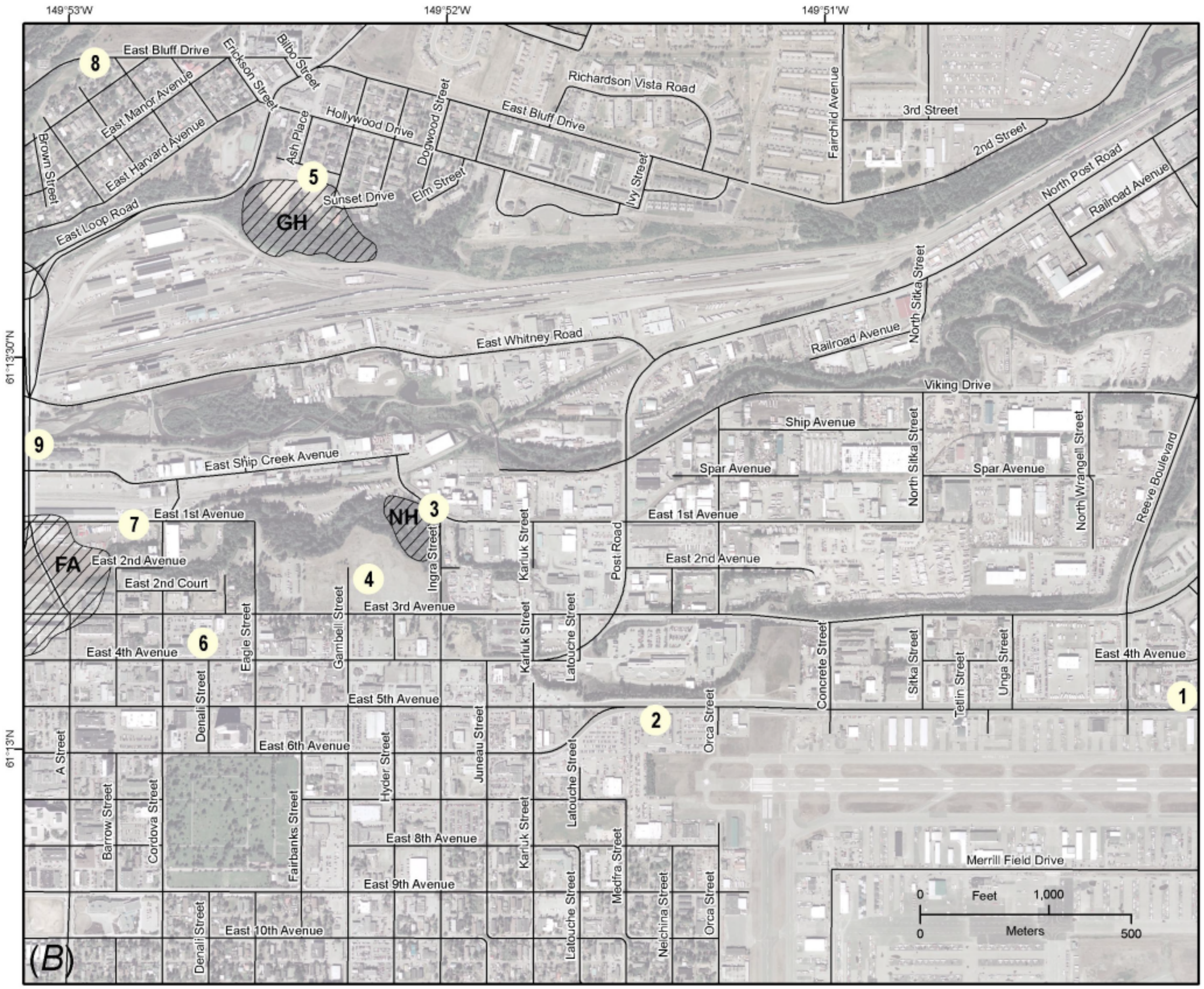
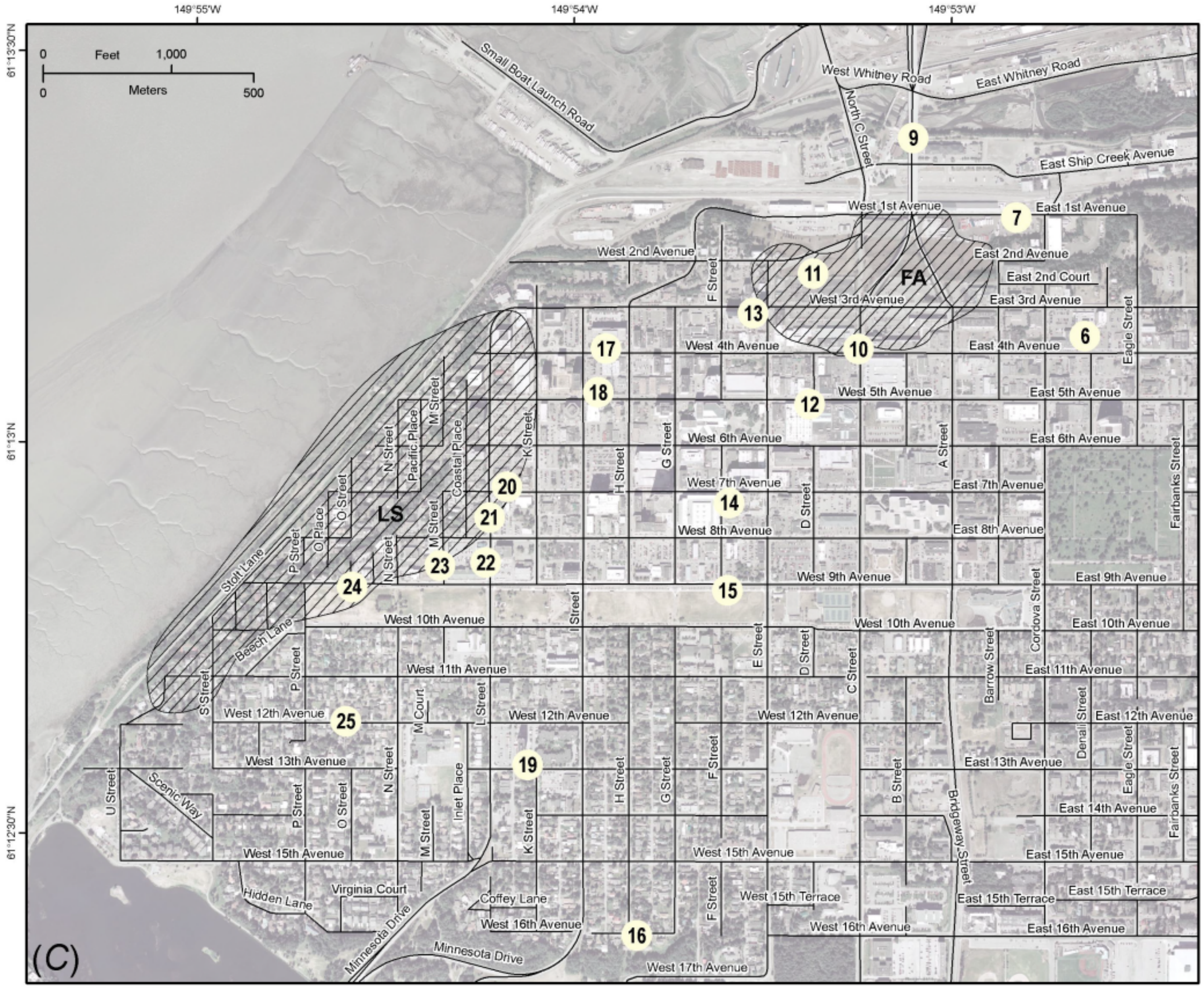


Figure 2.—Continued.



Horizontal datum NAD 83
2013 satellite imagery from USGS
Street data from Municipality of Anchorage

Figure 2.—Continued.

Horizontal datum NAD 83
2013 satellite imagery from USGS
Street data from Municipality of Anchorage

Figure 2.—Continued.

Photographic Tour Stops

1. 5th Avenue Chrysler Building

“The one-story 5th Avenue Chrysler Center just north of Merrill Field was a total loss. It had a precast- and prestressed-concrete T-beam roof supported by concrete-block walls. The front of the building collapsed and the T-beam roof fell in on the showroom. The hollow-core concrete block side walls failed at the rear corners of the building” (Hansen, 1965, p. A24) (fig. 3).

Figure 3. The 5th Avenue Chrysler Building, Anchorage, Alaska, 1964. (Photograph from U.S. Geological Survey Photographic Library, ID aeq00025.)

2. Alaska Sales and Service Building

"The one-story Alaska Sales and Service Building on East 5th Avenue at Medfra Street was under construction but was structurally almost complete at the time of the earthquake; it was a total loss. Collapse is attributed chiefly to failure of melded connections between T-shaped precast-concrete columns and roof beams, caused either by the breaking of welds or tearing out of bar inserts. The exterior precast-concrete walls of the building partly collapsed when the roof gave way" (Hansen, 1965, p. A23; fig. 4).

Figure 4. The Alaska Sales and Service Building, Anchorage, Alaska, 1964. (Photograph from U.S. Geological Survey Photographic Library , ID aeq00024.)

3. Compressional Fold at Toe of Native Hospital Slide

Like a rug being pushed along a floor, landslides can cause folding of the ground in front of them as they slide. A fuel tank (fig. 5) at the toe of the Native Hospital Slide (stop 4) was damaged by this type of folding because of shortening when the bluff upslope failed and slid downhill (Hansen, 1965). Deformation like this also caused damage to buildings at the toes of the 4th Avenue and L Street Slides (Hansen, 1965, p. A23).

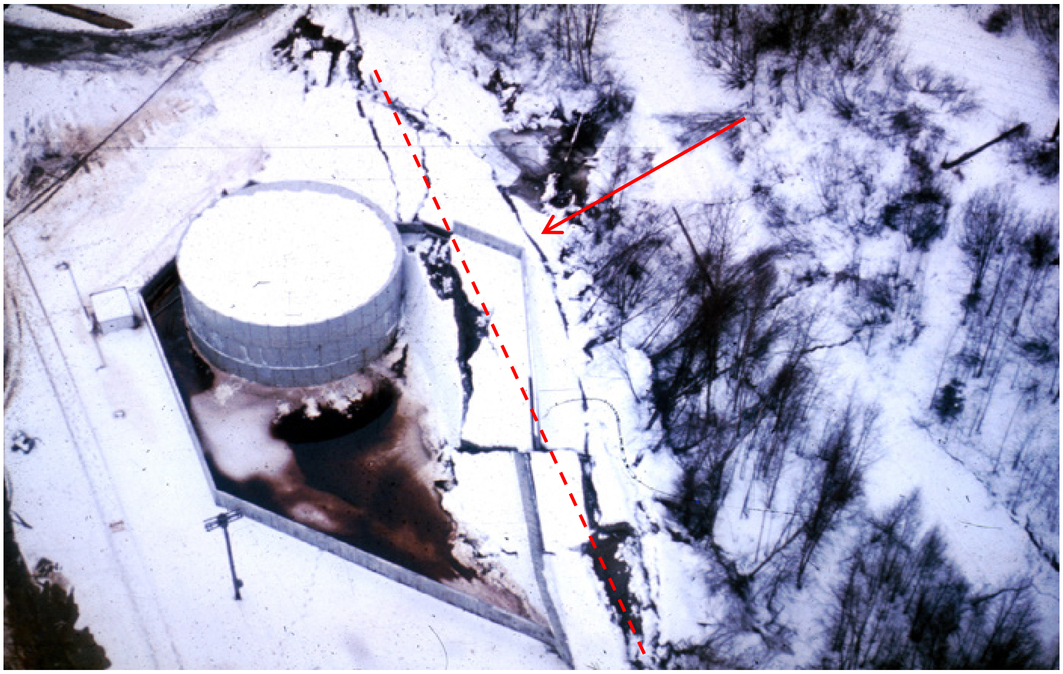


Figure 5. Fuel tank damaged by compressional folding at the toe of the Native Hospital Slide, Anchorage, Alaska, 1964. Red arrow indicates the direction of push from the landslide and the dashed red line indicates the crest of the resulting fold in the ground. (Photograph from U.S. Geological Survey Photographic Library, ID aeq00053.)

4. Native Hospital Slide

"The Native Hospital Slide, or 1st Avenue Slide as it has occasionally been called, disrupted part of the grounds of the Alaska Native Service Hospital and wrecked a fuel-storage tank at the foot of the bluff. Although it was a small slide and not a very destructive one, it was of unusual scientific interest because of its clear portrayal of repeated translatory landsliding in the same area. The slide of March 27, 1964, transected an earlier slide of identical habit and exposed the older graben in full cross section in the headward scarp of the present graben. This site of failure, therefore, seems to answer the question as to whether natural remolding and consolidation of the clay after sliding is sufficient in itself to forestall further sliding—it obviously was not, in the Native Hospital Slide. Most other slide areas at Anchorage and vicinity also presented evidence of multiple sliding, but none did it as clearly as the Native Hospital Slide" (Hansen, 1965, p. A49; fig. 6).

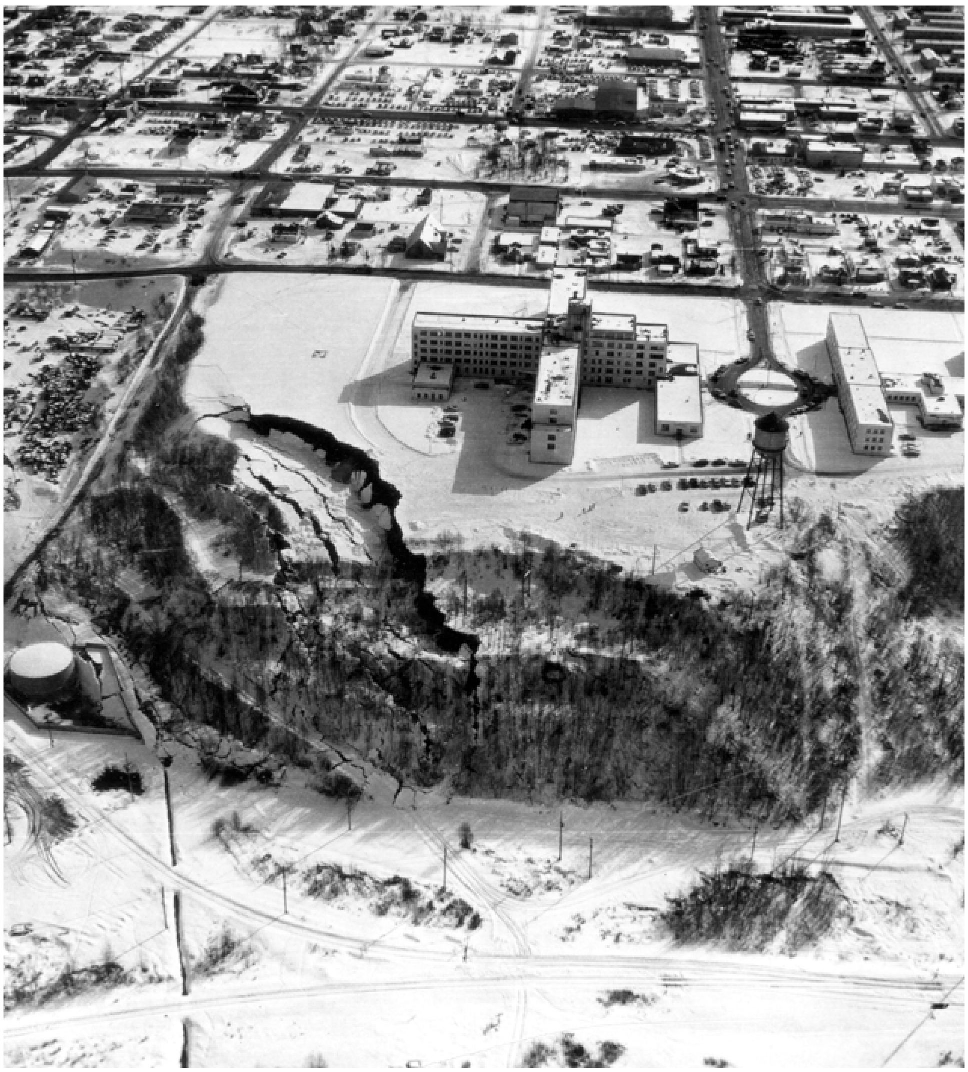


Figure 6. Oblique aerial view looking south of the Native Hospital Slide and the former Alaska Native Service Hospital , Anchorage, Alaska, 1964. The damaged fuel tank from Stop 3 (fig. 5) can be seen below the middle of the left margin of the photograph. (Photograph from U.S. Geological Survey Photographic Library, ID ake00065.)

The hospital remained in service until the occupation of a new building in 1997 and was demolished shortly thereafter (Rife and Dellapenna, 2009). The scars of both the 1964 landslide and the undated landslide before 1964 are visible at the present day (2013) (fig. 7).

Figure 7. Re-creation of the view south of the Native Hospital Slide and the former Alaska Native Service Hospital from satellite imagery and 2011 lidar elevation data, Anchorage, Alaska. (Satellite imagery from 2014, ©Digital Globe, NextView License; 2011 lidar data from Federal Emergency Management Agency, project number 400000072.)

5. Government Hill Slide–Sunset Park

The Government Hill Elementary School was destroyed when part of the bluff on which it was built slid southward about 35 feet toward Ship Creek and caused lowering of the ground in the form of two major troughs, or grabens, and many smaller fractures (fig. 8; Hansen, 1965, p. A54). The surface along where the sliding occurred was within a sensitive facies of the underlying Bootlegger Cove Formation (Hansen, 1965, p. A58). Because school was not in session (the earthquake occurred in the evening and March 27, 1964, fell on Good Friday, observed as a holiday in Alaska at the time) and the building was empty, no lives were lost (Hansen, 1965). The school was rebuilt two blocks to the north in 1965 and the former school site was developed into a park in 1985 (Municipality of Anchorage, 2013; fig. 9).

Figure 8. Annotated March 30, 1964, aerial photograph of the Government Hill Slide, Anchorage, Alaska, 1964. (Photograph taken by Air Photo Tech.)

Figure 9. Comparison photographs taken from the same location at the Government Hill Slide area, Anchorage, Alaska, in 1964 (top) and 2013 (bottom) looking west near the middle of the uppermost occurrence of the word “graben” in figure 8. The same watertower is visible in the background of both images. (Top photograph from U.S. Geological Survey Photographic Library, ID ake00067; bottom photograph taken by R.G. McGimsey, U.S. Geological Survey, 2013.)

6. McKinley Tower

The McKinley Tower (historically known as the Mount McKinley Building and the MacKay Building) and the Inlet Tower (historically known as the 1200 L Street Building) (Stop 19) are identical 14-story apartment buildings completed in 1951 about 1 mi apart. Both towers sustained similar damage, the most obvious being classic x-shaped shear cracks in the exterior stucco below many of the windows (fig. 10; Hansen, 1965, p. A26). During retrofitting, beginning in the late 1990s, structural elements in the Mckinley Tower building were reinforced with an epoxy-saturated carbon fabric in order help meet seismic building codes (Martin, 2005).

Figure 10. Damage to the McKinley Tower (Mount McKinley Building at the time of the earthquake), Anchorage, Alaska, 1964. Compare the x-shaped cracks below the windows with those on the Inlet Tower (Stop 19). (Photograph from Judith and Malcolm McDonald papers, Archives and Special Collections, Consortium Library, University of Alaska Anchorage ID uaa-hmc-0619-s2-f22-20.)

7. Compressional Folding at Toe of 4th Avenue Slide

While tensional fractures and deep grabens characterized the 4th Avenue Slide between 2nd and 4th Avenue, warehouses along 1st Avenue were heavily damaged by compressional deformation at the toe of the slide (Hansen, 1965, p. A23; fig. 11). This area remains an important distribution center for goods, but the risk of damage similar to that incurred in 1964 is ostensibly reduced by the construction of Buttress Park (Stop 11).

Figure 11. View looking southwest from 1st Avenue of warehouses damaged by compressional deformation at the toe of the 4th Avenue Slide, Anchorage, Alaska, 1964. The Westward Hotel (Stop 13) can be seen in the background. (Photograph from U.S. Geological Survey Photographic Library, ID aeq00051.)

8. Port of Anchorage Overlook–Suzan Nightingale McKay Park

"Much of the damage in the Port of Anchorage area was caused by ground displacements along fractures, but some damage is attributable to direct seismic shaking. The main pier lurched laterally 5 to 19 inches. Large longitudinal cracks and several transverse ones opened up, and the walls of several buildings were cracked. All four gantry cranes were damaged. Steel piles penetrated the deck of a subordinate pier. Approach roads and railroads settled as much as 18 inches. Two cement-storage tanks were toppled, one at the property of the Permanente Cement Co. at the entrance to the U.S. Army Dock and one at the Alaska Aggregate Corp. facility just north of Ship Creek. Oil-storage tanks in the dock area were mostly superficially damaged, but some tanks were bulged outward at the bottom, probably by rocking and pounding back and forth as the contents sloshed to and fro" (Hansen, 1965, p. A27; fig. 12).

Figure 12. Anchorage municipal wharf area at low tide, shortly after the earthquake, Anchorage, Alaska, 1964. The main dock was slightly damaged, but the older U.S. Army dock (upper left) was ruined. Vibration and ground fractures damaged some structures in the port area, including the fuel tank seen in the lower right. (Photograph from U.S. Geological Survey Photographic Library, ID ake00243.)

9. Instrumentation of the Port Access Bridge

In an effort to understand more about how bridges react to earthquakes, the Port Access Bridge, constructed in 1975 and retrofitted through the years, was instrumented with accelerometers beginning in 2003 (Yang and others, 2004; Yang, 2006). In all, 39 sensors along its length record earthquake- and train-induced vibrations and collect data used by scientists and engineers (Yang, 2006).

Figure 13. View looking north from Buttress Park of the Port Access Bridge (photograph from Yang, 2006, p. 4), Anchorage, Alaska. Accelerometers are installed near the tops of many of the support columns.

10. 4th Avenue Slide

“The 4th Avenue Slide involved all or parts of 14 city blocks in a roughly oval area of about 36 acres, containing perhaps 2 million cubic yards of earth, centered at the northern side of downtown Anchorage. It was bounded headward on the south by 4th Avenue, on the west by E Street, on the north approximately by 1st Avenue, and on the east somewhat indefinitely by Barrow Street. Its length north to south in the direction of slippage was about 1,050 feet; east to west it was about 1,800 feet across. Strong fracturing and related ground displacements extended 1-1/2 blocks (about 450 feet) or so south of the slide proper, where considerable damage was inflicted on buildings, streets, and sidewalks. Minor displacements extended as far south as 600 feet. Eyewitnesses reported that sliding began about 2 minutes after the earthquake started and stopped about the same time as the earthquake” (Hansen, 1965, p. A41; figs. 14, 15, and 16).

Figure 14. Comparison photographs taken from the same location on 4th Avenue about 1 block east of the main area of damage, Anchorage, Alaska. In 1964 (top), the ground just to the left of the sidewalk dropped about 8 feet bringing the marquee of the Denali Theater down to street-level. (Top photograph from U.S. Geological Survey Photographic Library, ID aeq00046, 1964; bottom photograph taken by R.G. McGimsey, U.S. Geological Survey, 2013.)

Figure 15. Comparison photographs taken from the same location on 4th Avenue near the intersection with C Street and looking west. Red arrows point to the west wall of the Army Navy store in both images. (Top photograph [1964] from U.S. Geological Survey Photographic Library, ID aeq00045; bottom photograph [2013] taken by R.G. McGimsey, U.S. Geological Survey, 2013.)

Figure 16. Comparison photographs taken from the same location on 4th Avenue looking east through the intersection with C Street, Anchorage, Alaska. Red arrows point to the McKinley Tower (Stop 6) in both images. (Top photograph [1964] taken by U.S. Army, U.S. Geological Survey Photographic Library, ID ake00144; bottom photograph [2013] taken by R.G. McGimsey, U.S. Geological Survey.)

11. Buttress Park

Much of the 4th Avenue Slide area north of 3rd Avenue has been re-graded since the earthquake and turned into Buttress Park. The north-facing slope dropping into Ship Creek has been reinforced at its toe with a buried gravel buttress, giving the park its name (fig. 17). Details of the design can be found in Long and George (1966).

Immediately following the earthquake, 25 boreholes in and around a number of the major Anchorage landslides were installed with slope-inclinometer casings. Measurements were taken frequently through 1965, but rarely thereafter. All recoverable casings were resurveyed in 1979 and a comparison was made between the old and new data. Updike (1983) reported that negligible strain had occurred in the area of the L Street and Turnagain Heights Slides since the earthquake. There were, however, three zones of up to 3 inches of deflection in the Buttress Park area of the 4th Avenue Slide. The zones of strain have strong correlations with known weak layers in the Bootlegger Cove Formation which were probably the zones of failure for the landslide. Nearly all of the strain apparently happened before 1976, but Updike (1983) still expressed concern about the potential for movement in this area.

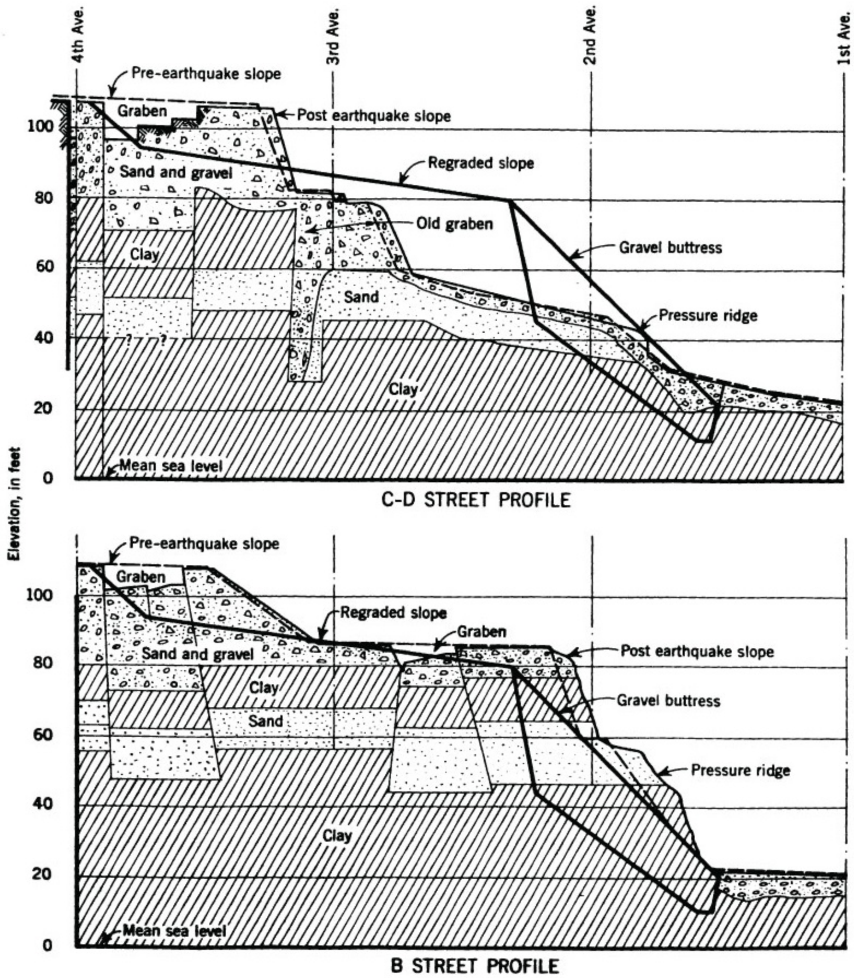


Figure 17. Figure 4 from Long and George (1966), showing cross-section views of the 4th Avenue Slide and the post-earthquake design of the stabilizing gravel buttress. (Used with permission from American Society of Civil Engineers.)

12. J.C. Penny Store

At the time of the earthquake, the J.C. Penney store was five stories tall. The building was damaged beyond repair and torn down (figs. 18 and 19). The principal cause of damage is attributed to rotational motion of the foundation which caused the shearing of various support walls throughout the building (Hansen, 1965, p. A26). At least one death occurred when the north wall of the building fell on a parked car as the owner was attempting to move it to safety (Hansen, 1965, p. A27).

Figure 18. Comparison photographs of the J.C. Penney Building from D Street looking southwest, Anchorage, Alaska. (Top photograph [1964] taken by George Plafker, U.S. Geological Survey Photographic Library, ID ake00055; bottom photograph [2013] taken by R.G. McGimsey, U.S. Geological Survey.)

Figure 19. Comparison photographs of the J.C. Penney Building from 5th Avenue looking west, Anchorage, Alaska. (Top photograph [1964] taken by U.S. Geological Survey; bottom photograph [2013] taken by R.G. McGimsey, U.S. Geological Survey.)

13. Westward (Hilton) Hotel

There was little visible damage to the 14-story Westward Hotel, but damage to the interior structural elements was severe (Hansen, 1965, p. A23; fig. 20). The building was repaired, expanded to the west in the 1980s, and is now known as the Hilton Anchorage West Tower (Tundra Times, 1984).

Figure 20. View looking east in late 1964 of the Westward Hotel. The lower building in the foreground sits where the Hilton Anchorage East Tower is presently located (2014). (Photograph from Alaska's Digital Archives, Ward Wells Collection, ID AMRC-wws-4231-1.)

14. Robert Atwood Government Building

Through the direction of the Advanced National Seismic System (ANSS), seismometers were installed throughout the 20-story Atwood Building in 2003 (fig. 21) to provide improved information about how some buildings respond to earthquakes (Çelebi and others, 2004). The sensors record lateral swaying, twisting, rocking, and drift (displacement) between floors. For comparison with ground motion at sites unaffected by infrastructure, the array in the Atwood Building is complemented by the Delaney Park borehole array two blocks south (Stop 15).

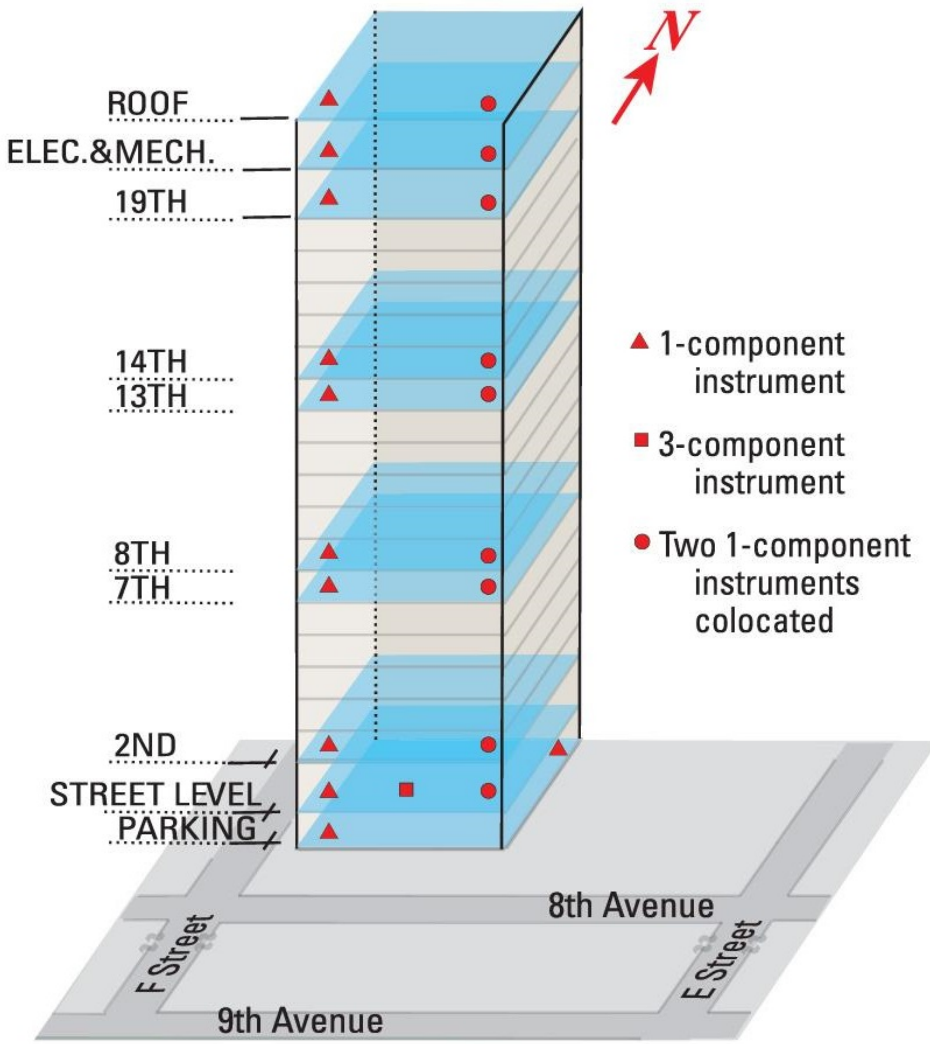


Figure 21. Schematic of the Atwood Building depicting the general locations of seismometers that have been installed to record motion from seismicity (from Çelebi and others, 2004).

15. Delaney Park Borehole Array

Seven accelerometers at Delaney Park, along with accelerometers installed throughout the Atwood Building (Stop 14) two blocks to the north, make up one of the first monitoring systems of its kind (Çelebi and others, 2004; Delaney Park Alaska Digital Array, 2014; fig. 22). The sensors have been installed at depths between the surface and 200 feet, within the undisturbed glacial stratigraphy, to give engineers detailed information on the interaction between the soil and infrastructure.

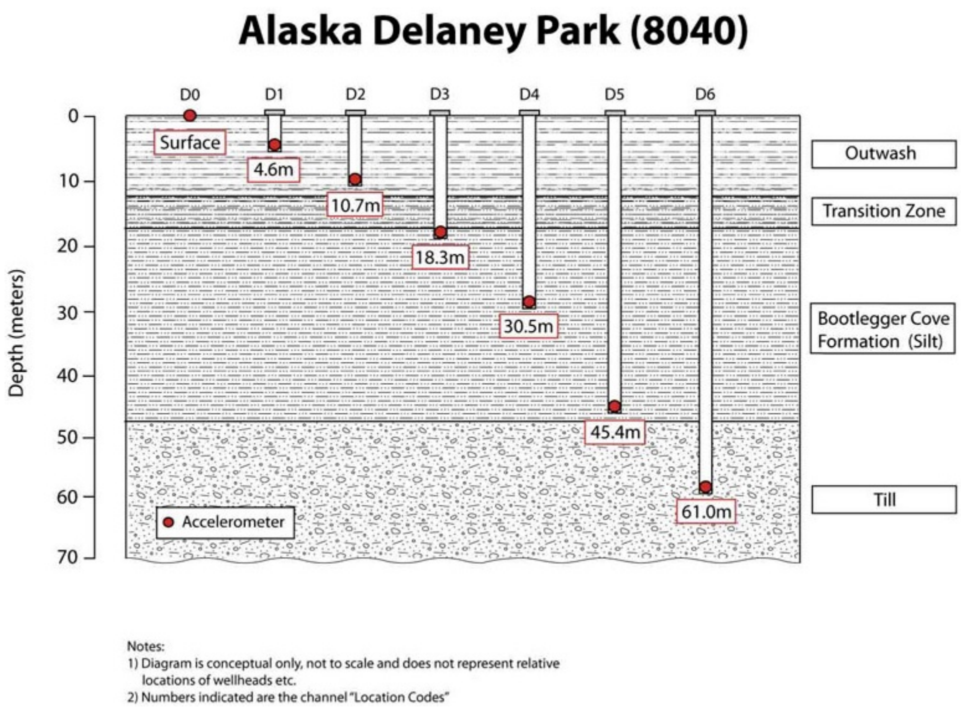


Figure 22. Generalized cross-section view of the seven accelerometers in the Delaney Park borehole array and the local stratigraphy (Delaney Park Alaska Digital Array, 2014).

16. Hillside Apartment Building

"The Hillside Apartments were on the south side of 16th Avenue between G and H Streets on a bluff overlooking Chester Creek. They were damaged beyond repair and have since been dismantled. This was a split-level building, five stories high on the south side and three stories high on the street side. It had a post-and-lintel frame with steel-pipe columns, rolled-steel beams and concrete floor slabs on steel joists. Walls were unreinforced hollow concrete block. The building was sheared in an east-west direction at the third-story level on the south side and in the lower two stories on the north side—the upper stories lurched west relative to the lower stories" (Hansen, 1965, p. A25–A26; fig. 23). Although built on a bluff, there was no landsliding here; the building was damaged as a result of ground shaking alone.

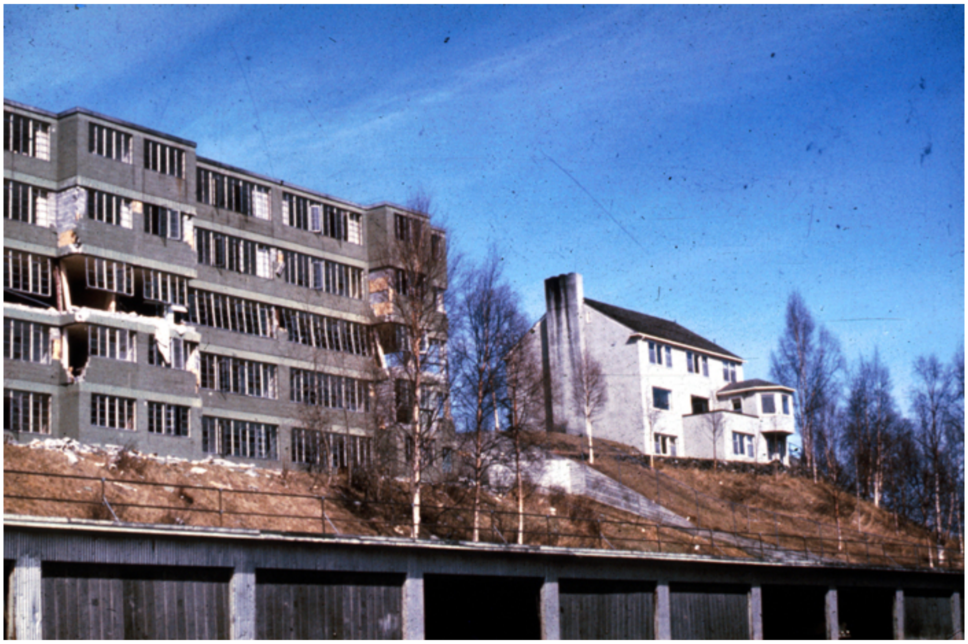


Figure 23. View looking northeast of the Hillside Apartment Building, Anchorage, Alaska. The adjacent white wood-framed house received little damage and is standing at the present day (2014). (Photograph from U.S. Geological Survey Photographic Library, ID aeq00021.)

17. Nesbett Courthouse

The Nesbett Courthouse is a 6-story building designed according to the 1991 Uniform Building Code and constructed in the mid-1990s. The site lies within Anchorage's Seismic Hazard Zone 4, which means it has a "high" potential for earthquake-induced ground failure. The building was designed to fail in a controlled way in order to accommodate ground displacements up to 4 feet horizontally and almost 3 feet vertically (fig. 24). The main structural support for the building is on steel beams, girders, and columns bearing on a continuous 3-foot thick reinforced concrete slab foundation. Wind and seismic forces (that is, lateral loads on the building) are resisted by a dual system of eccentric braced frames and special moment frames. These lateral loads are transmitted to the slab foundation through concrete shear walls in the basement. The predicted lateral and vertical displacements during a major earthquake-induced landslide were designed to be taken up by rotation and deflection within unbraced sections of the building frame, or "flexible bays," in order to avoid complete collapse. Figures 25 and 26 are examples of the structural and foundation details in the construction plans for this building.

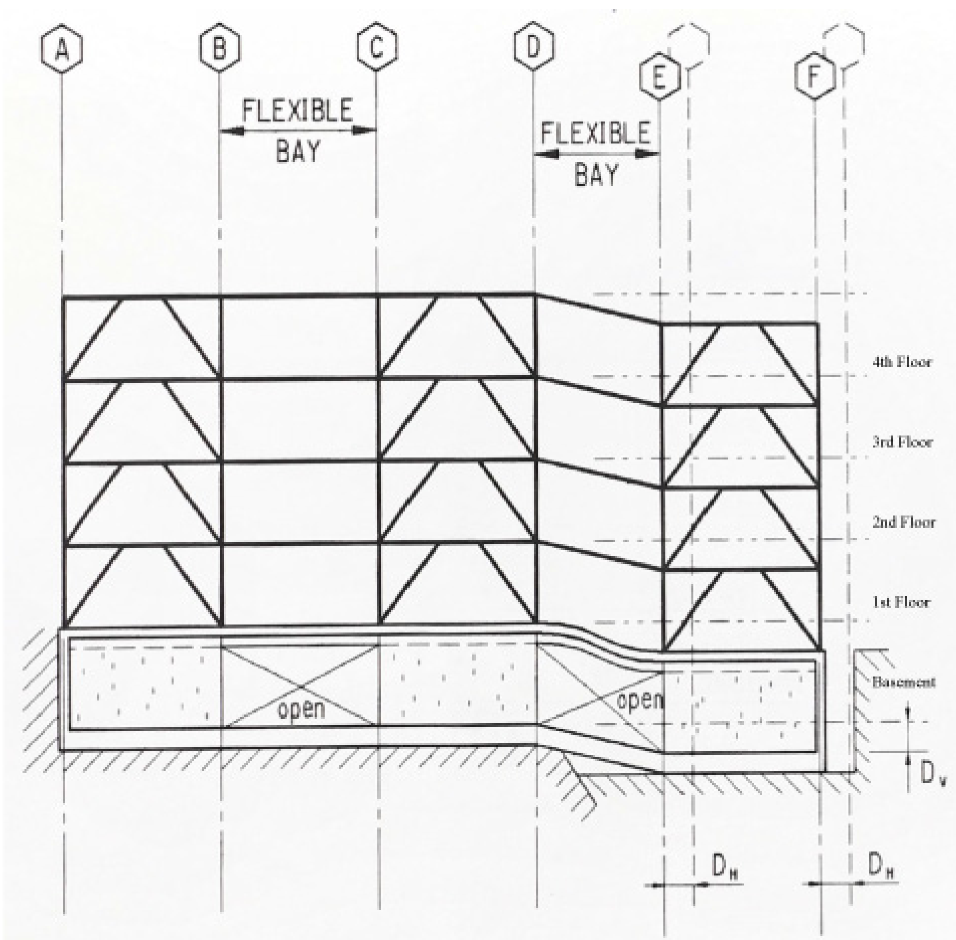


Figure 24. Simplified diagram showing how the Nesbett Courthouse is meant to accommodate ground motion below or beside the foundation without collapsing completely (Coffman Engineers, Inc., 1987). Unbraced "flexible bays" are designed to take up displacements (D_H = 4 feet, $D_V \approx$ 3 feet) while allowing other sections of the building to remain intact. Letters A-F are reference names for the sides of the frames in the building. D_H and D_V are the vertical and horizontal, respectively, projected displacement due to landsliding.

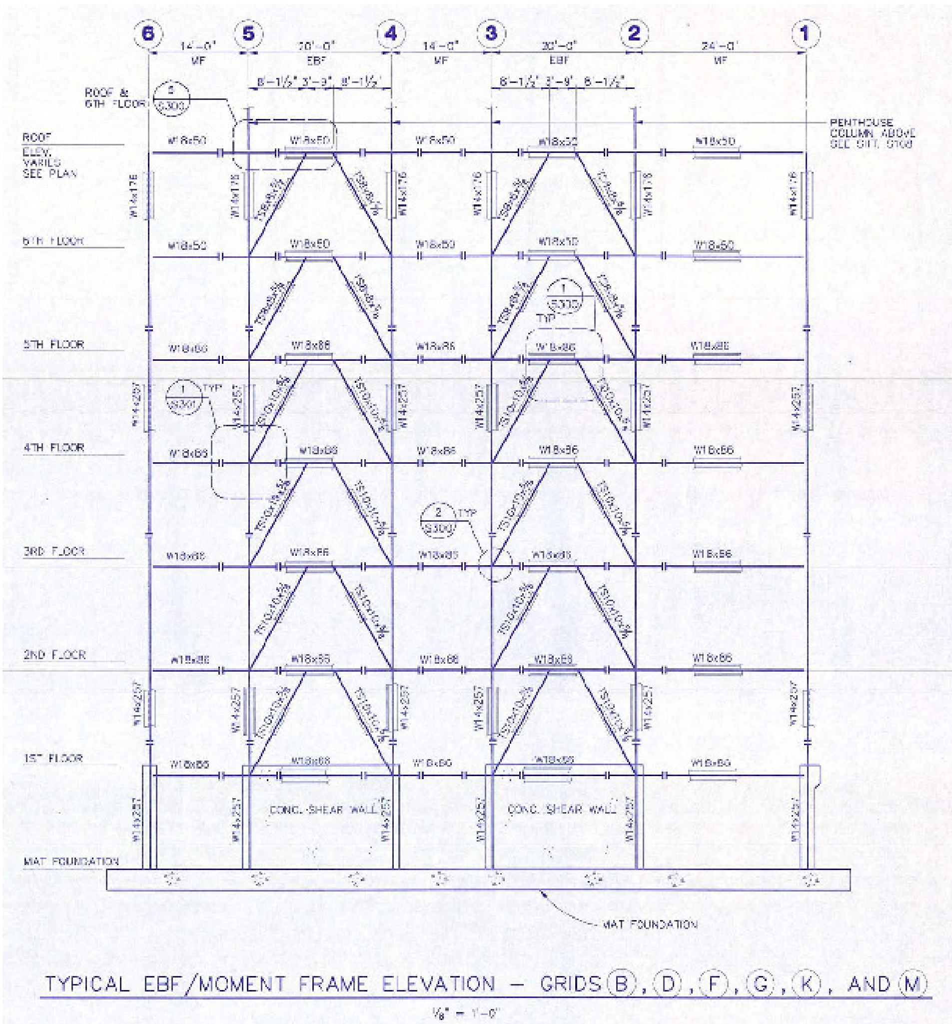


Figure 25. Detailed diagram of moment frame component within the Nesbett Courthouse (McCool Carlson Green, 1993).

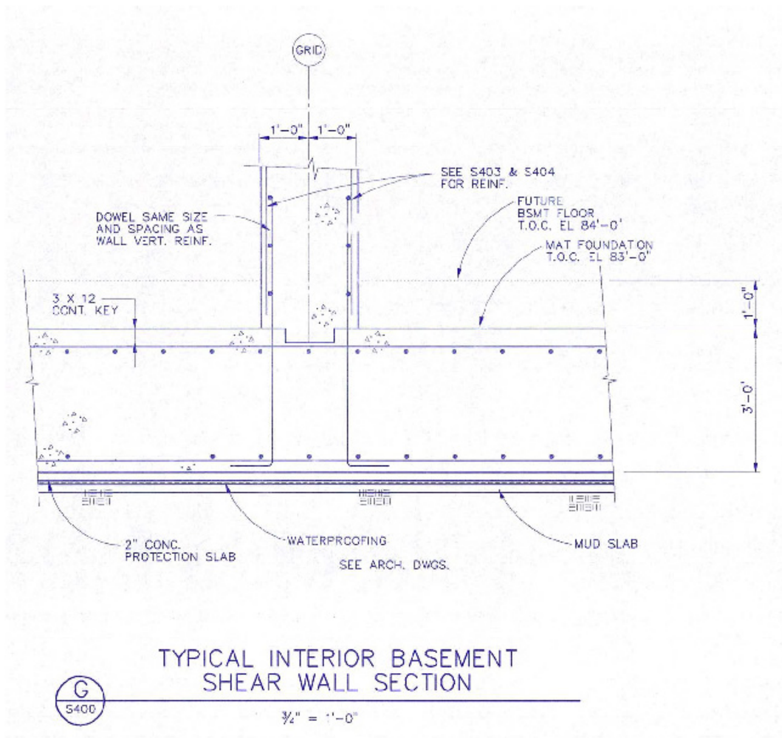


Figure 26. Detailed diagram of foundation mat and shear wall connection (McCool Carlson Green, 1993).

18. Earthquake Warning Signs at Unreinforced Masonry Wall

Unreinforced masonry walls consist of brick, concrete block, or other masonry material that is stacked and mortared without steel reinforcement, such as a grid of rebarthem. Although most unreinforced masonry structures in Anchorage fared well during the earthquake (Hansen, 1965, p. A23), they are of great concern worldwide because of the high rate of injury and property damage caused by their collapse during earthquakes (Reitherman, 2009; fig. 27). Retrofitting of existing buildings, however, is expensive and not required by most municipalities.

Figure 27. Signs along a wall adjacent to a parking lot warn motorists and passersby about the hazard presented by unreinforced masonry walls, Anchorage, Alaska. (Photograph courtesy of Robert Scher, Anchorage Geotechnical Advisory Commission [2013].)

19. Inlet Tower

The Inlet Tower was moderately damaged because of ground shaking (fig. 28) in much the same way as its twin, the McKinley Tower (Stop 6; Hansen, 1965, p. A26).

Figure 28. Comparison photographs of the Inlet Tower taken from the same location on 13th Avenue. (Left photograph [1964] from U.S. Geological Survey Photographic Library, ID aeq00019; right photograph [2013] taken by R.G. McGimsey, U. S. Geological Survey.)

20. L Street Slide–715 L Street Apartment Building

Perhaps the most notable feature of the L Street Slide was the long arcuate graben that formed at its head (fig. 29). It was concave toward the shoreline, about 3,600 feet long, with a maximum width of about 250 feet (Hansen, 1965, p. A43). There were fractures on both sides of the graben and pressure ridges at the toe of the slide which were damaging, but much of the slide mass showed little disturbance despite moving toward the shoreline at distances of up to 14 feet (Hansen, 1965, p. A43). Much of the damage occurred at the graben where the ground under foundations subsided as much as 10 feet (Hansen, 1965, p. A43), as it did underneath the apartment building in figure 30.

Figure 29. Annotated aerial photograph of most of the area affected by the L Street Slide, Anchorage, Alaska. Photographic tour stops are marked by number: (20) 715 L Street Apartment Building, (21) L Street Bend, (22) St. Mary's Residence, (23) Four Seasons Apartment Building, and (24) L Street Slide scarp. (Photograph taken by Air Photo Tech, 1964.)

Figure 30. The apartment building behind the largely undamaged house in the foreground was sheared almost equally in two when the western half dropped 7 feet down the main scarp at the head of the L Street Slide, Anchorage, Alaska, 1964. The apartments have been removed but the Anchorage Medical and Surgical Building to the east was undamaged. (Photograph from U.S. Geological Survey Photographic Library, ID ake00327.)

21. L Street Bend

The main scarp of the L Street Slide cut across L Street between 7th and 8th Avenues. Because the slide mass west and north of the scarp moved seaward while the ground headward of the scarp remained in place, the centerline of L Street now bends about 12 feet to the east, just south of 7th Avenue (fig. 31).

Figure 31. View looking south down L Street from a just south of 6th Avenue, Anchorage, Alaska. The two subtle but distinct kinks in the centerline, as it is traced from lower left toward the upper right, represent the re-alignment of L Street where it crossed the main scarp at the head of the L Street Slide. (Photograph taken by Evan Thoms, U.S. Geological Survey [2014].)

22. St. Mary's Residence – Old Providence Hospital

Completed in 1939, the original Providence Hospital became a nursing home known as St. Mary's Residence in 1962 and was a well-known landmark at the time of the earthquake. Despite its proximity to the graben that formed at the head of the L Street Slide (fig. 32), the building survived the earthquake with minimal damage and remained in use until it was demolished in the mid-1970s.

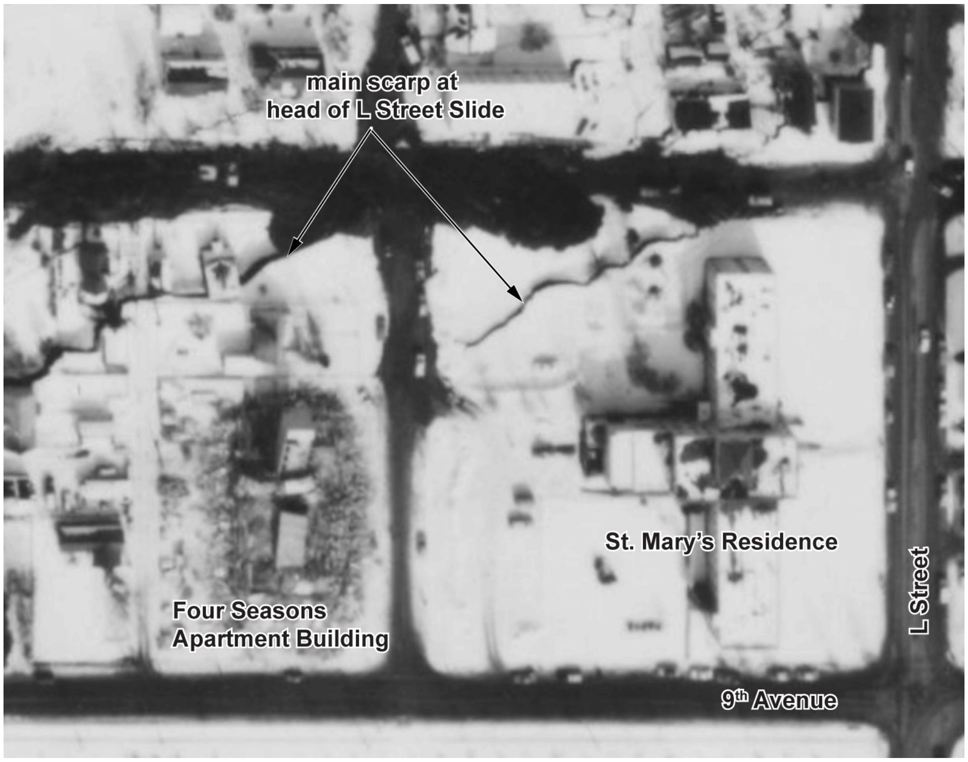


Figure 32. 1964 aerial photograph of St. Mary's Residence and the nearby Four Seasons Apartment Building (Stop 23), Anchorage, Alaska. (Photograph taken by Air Photo Tech, 1964.)

23. Four Seasons Apartment Building

The Four Seasons Apartment Building was a new 6-story lift-slab reinforced concrete building nearing completion in 1964 (fig. 33). It reportedly withstood 2–3 minutes of shaking before collapsing just before the end of the earthquake. The main shear-resistant structural elements of the building, a poured-in-place reinforced concrete stairwell and a combined elevator shaft and stairwell, fractured at the first floor, toppled over, and came to rest on top of building rubble, all the while remaining largely intact (Hansen, 1965, p. A24–A25).

Figure 33. The remains of the Four Seasons Apartment Building, Anchorage, Alaska, 1964. The tilted column on the right was the combined elevator shaft and stairwell. (Photograph from U.S. Geological Survey Photographic Library, ID aeq00026.)

24. Graben and Main Scarp at the Head of the L Street Slide

At this location, the graben at the head of the L Street Slide cut across 9th Avenue and continued to the southwest across the Delaney Park Strip (fig. 34). The degraded main scarp is visible today as the small rise in slope to the east between here and the Centennial Rose Garden.

Figure 34. In this annotated view looking east, the graben at the head of the L Street Slide, Anchorage, Alaska, 1964 cuts through properties between 8th and 9th Avenues from upper left to lower right. The collapsed Four Seasons Apartment Building (Stop 23) and the relatively undamaged St. Mary's Residence (Stop 22) lie beyond the graben on undisturbed ground. The present-day Centennial Rose Garden is just off the right margin of this photograph, near the N Street easement. (Photograph from U.S. Geological Survey Photographic Library, ID aeq00043.)

25. Pre-1964 Landslide Scarp at the Maxine and Frank Reed Family Staircase

The staircase at this stop (named in 2007 in honor of the philanthropic residents who lived at the top of the staircase for more than 60 years) was built to accommodate pedestrian traffic over a steep bluff that some (Hansen, 1965, p. A67; Schmoll and Dobrovolny, 1972) interpreted to be evidence of landsliding during a pre-1964 earthquake of unknown age (fig. 35). Similar steep and arcuate bluffs exist throughout the Anchorage area indicating that landsliding is a common process in this area. There was no reported sliding on this feature in 1964 (Hansen, 1965, p. A67).

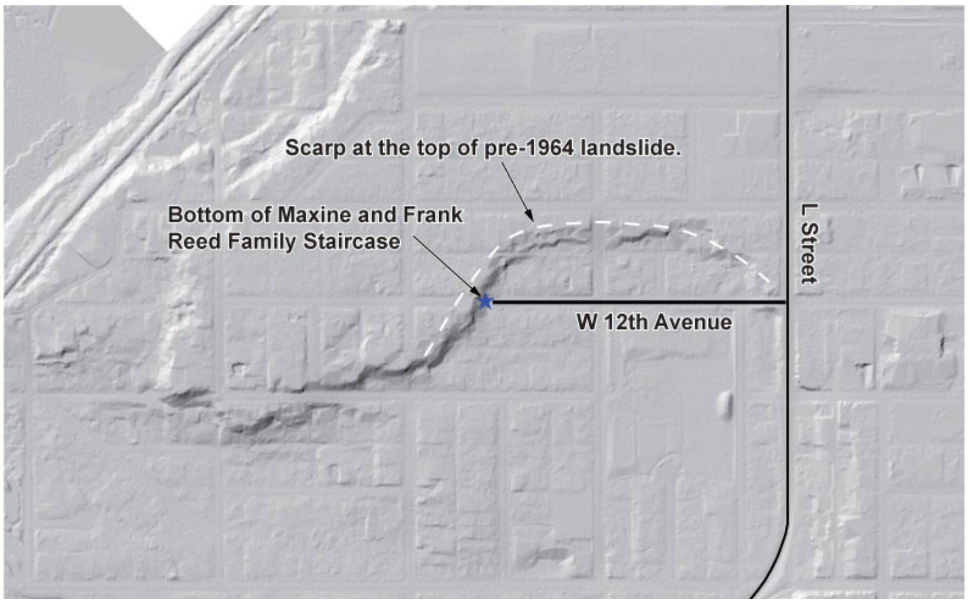


Figure 35. Annotated lidar-based hillshade elevation model of the probable landslide scar in the South Addition neighborhood, Anchorage, Alaska. (2011 lidar data from Federal Emergency Management Agency, project number 400000072.)

26. Turnagain Heights Slide at Earthquake Park

The Turnagain Heights Slide occurred along a steep bluff fronting Knik Arm on Cook Inlet. Its length east to west, parallel to the former shoreline, was about 1.5 miles, and the bluff retreated southward a maximum of 1,200 feet into the Turnagain Heights neighborhood (fig. 36; Hansen, 1965 p. A59). In all, about 130 acres were completely disrupted and 75 homes were reportedly destroyed (Hansen, 1965, p. A59; figs. 36–41). Failure here and in the L Street, 4th Avenue, and Government Hill landslides in Anchorage occurred on horizontal or near horizontal slip surfaces in a sensitive clay facies of the underlying Bootlegger Cove Formation, prone to cyclic softening (Hansen, 1965, p. A65) . The Tony Knowles Coastal Trail passes along the toe of the slide mass, where relics of the disturbed ground surface are still visible near Earthquake Park, just north of the Ted Stevens Anchorage International Airport.

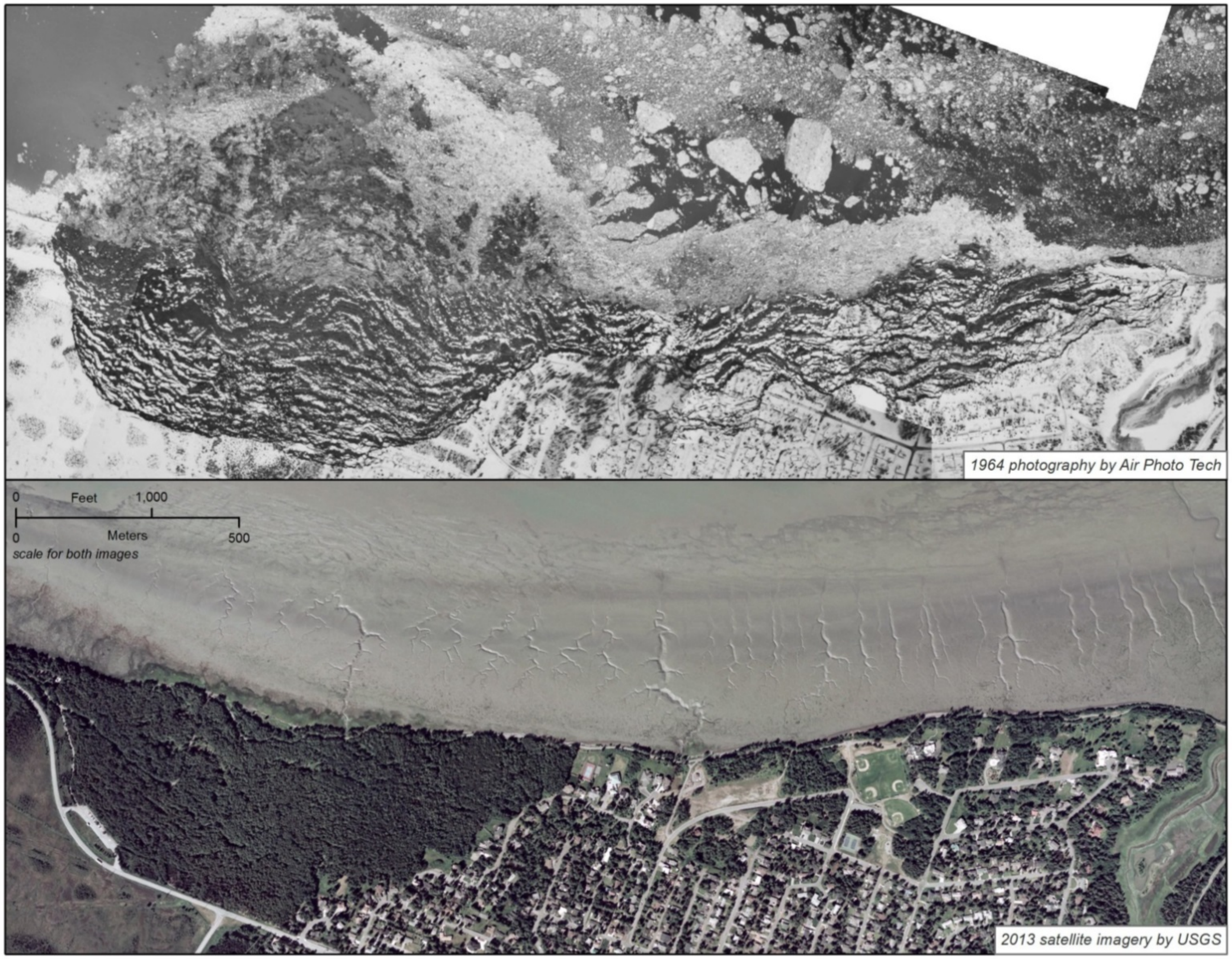


Figure 36. 1964 photo-mosaic showing the extent of the Turnagain Height Slide (top) and 2013 satellite imagery (bottom) for comparison, Anchorage, Alaska. A portion of the area covered by the landslide has been turned into parks, but the rest remains residential in use. (Top photograph taken by Air Photo Tech, 1964; bottom satellite imagery by U.S. Geological Survey, 2013.)

Figure 37. View of part of the Turnagain Heights Slide looking roughly southeast shortly after the earthquake, Anchorage, Alaska, 1964. (Photograph from U.S. Geological Survey Photographic Library, ID ake00087.)

Figure 38. View from within the Turnagain Heights Slide mass looking roughly south, Anchorage, Alaska, 1964. Note the structures on the new bluff in the background. The ground surface was lowered about 35 feet from the pre-quake level. After the earthquake this area was regraded and gradually redeveloped with single-family residences. (Photograph from U.S. Geological Survey Photographic Library, ID eib00337.)

Figure 39. Tree split in half by a crack in frozen ground near in the Turnagain Heights Slide area, Anchorage, Alaska, 1964. (Photograph from U.S. Geological Survey Photographic Library, ID ake00070.)

Figure 40. Part of a sand boil in the Turnagain Heights Slide area, Anchorage, Alaska, 1964. Ridges 2–3 feet high and 100 feet or more long were formed as fountains of water ejected through frozen ground. (Photograph from U.S. Geological Survey Photographic Library, ID ake00060.)

Figure 41. Slip surface in the Bootlegger Cove Formation exposed near the west margin of the Turnagain Heights Slide, Anchorage, Alaska. View is roughly to the west with Point Woronzof in the distance. (Photograph from Hansen, 1965, fig. 43, p. A63).

27. Anchorage International Airport Control Tower

The control tower at the Anchorage International Airport (now the Ted Stevens Anchorage International Airport) collapsed because of ground shaking, killing one occupant (fig. 42) (Hansen, 1965, p. A23) . At seven stories high, this was the tallest structure in Anchorage that was completely destroyed.

Figure 42. The destroyed control tower at the Anchorage International Airport, Anchorage, Alaska, 1964. (Photograph from U.S. Geological Survey Photographic Library, ID aeq00027.)

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Glossary

accelerometer A device that measures the change in acceleration, as opposed to displacement, of a structure or device as a result of dynamic loads such as wind or earthquakes. The acceleration that is measured can be thought of as what is commonly called g-force, felt during vibration, shock, or when changing direction in a vehicle.

compressional stress The stress that squeezes something. It is the stress component perpendicular to a given surface, such as a fault plane or a wall in a building.

concrete block A large, usually hollow, rectangular brick of concrete commonly used in construction.

cyclic (strain) softening The characteristic of cohesive soils (for example, clay and plastic silt) to experience a reduction in shear strength and stiffness, sometimes significant, when subject to cyclic straining.

earthquake Earthquake is a term used to describe both sudden slip on a fault, and the resulting ground shaking and radiated seismic energy caused by the slip, or by volcanic or magmatic activity, or other sudden stress changes in the Earth.

epicenter The epicenter is the point on the Earth’s surface vertically above the hypocenter (or focus); point in the crust where a seismic rupture begins.

graben A graben is a down-dropped block of the Earth’s crust resulting from extension, or pulling, of the crust.

ground motion Ground motion is the horizontal and vertical shaking, and rolling movement of the earth's surface caused by the various forms of energy waves created from earthquakes or explosions.

inclinometer A device which measures the angle or the tilt relative to a vertical or horizontal datum.

Late Pleistocene The period in the Earth’s history from roughly 126,000 to 11,700 years ago characterized as a time dominated by glaciation.

magnitude The magnitude is a number that characterizes the relative size of an earthquake. Magnitude is based on measurement of the maximum motion recorded by a seismometer. Several scales have been defined, but the most commonly used are: (1) local magnitude (ML), commonly referred to as "Richter magnitude:" (2) surface-wave magnitude (Ms): (3) body-wave magnitude (Mb): and (4) moment magnitude (Mw). Scales 1–3 have limited range and applicability and do not satisfactorily measure the size of the largest earthquakes. The moment magnitude (Mw) scale, based on the concept of seismic moment, is uniformly applicable to all sizes of earthquakes but is more difficult to compute than the other types. All magnitude scales should yield approximately the same value for any given earthquake.

Modified Mercalli Intensity Scale The intensity is a number (written as a Roman numeral) describing the severity of an earthquake in terms of its perceived effects on the Earth's surface and on humans and their structures. Several scales exist, but the ones most commonly used in the United States are the Modified Mercalli scale and the Rossi-Forel scale. The intensity value varies depending upon the number of people who feel the event, the age of the building and type of construction, the surficial geology at the site, as well as with distance from the earthquake rupture. In contrast, a magnitude is unique to the same earthquake, regardless of distance.

subduction zone The subduction zone is the place where two lithospheric plates come together, one riding over the other. Most volcanoes on land occur parallel to and inland from the boundary between the two plates.

tectonic plates The large, thin, relatively rigid plates that move relative to one another on the outer surface of the Earth.

tsunami A sea wave of local or distant origin that results from large-scale seafloor displacements associated with large earthquakes, major submarine slides, or exploding volcanic islands.

landslide A movement of surface material down a slope.

lidar A remote sensing technology that uses a laser to collect 3-dimensional point clouds of the Earth's surface.

liquefaction A process by which cohesionless sediment, such as sand or gravel, temporarily loses strength and acts as a fluid, like wiggling your toes in the wet sand near the water at the beach. This effect can be caused by earthquake shaking.

moment frame Moment frames consist of structural load-bearing beams and columns connected rigidly at the corners by welding and (or) bolts.

post-and-lintel A system of construction using a horizontal lintel or header to span a gap by being supported on its ends by two vertical columns or posts.

precast concrete Concrete that has been prepared as a construction component by being poured and cured within a mold or form in a controlled location, then moved and lifted into place at the site of construction.

prestressed concrete Concrete which has been formed into a shape so that when installed it provides some resistance to its normal weakness. For instance, a bridge beam might be formed so that when installed there is a slight upward camber or bend along its length to reduce the amount of bending when loaded.

seismometer An instrument used to detect and record earthquakes. Generally, it consists of a mass attached to a fixed base. During an earthquake, the base moves and the mass does not. The motion of the base with respect to the mass is commonly transformed into an electrical voltage. The electrical voltage is recorded on paper, magnetic tape, or another recording medium. This record is proportional to the motion of the seismometer mass relative to the earth, but it can be mathematically converted to a record of the absolute motion of the ground.

scarp A small step in the ground formed when the surface along one side of a crack or fault moves vertically with respect to the other side.

shear stress The stress component parallel to a given surface, such as a fault plane, the wall of a building, or the contact between two strata of rock.

shear wall A wall composed of braced panels to counter the effects of lateral or side-to-side load acting on a structure. In typical wood-framing, for example, the construction of a shear wall is accomplished by fastening plywood to a stud wall.

strain The small changes in length and volume associated with deformation of the earth or structural materials by outside forces or stresses.

stress Stress is the force per unit area acting on a plane within a body. Six values are required to characterize completely the stress at a point: three normal components and three shear components.

T-beam A load-bearing structure of reinforced concrete, wood, or metal with a t-shaped cross section. Usually installed as a column upon which roof beams or rafters are placed.

tensional stress The stress that tends to pull something apart.

unreinforced Within the context of construction using poured concrete, concrete blocks, or other masonry material, unreinforced refers to the lack of reinforcement such as an internal grid of rebar.

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