Earthquake Hazards in Utah

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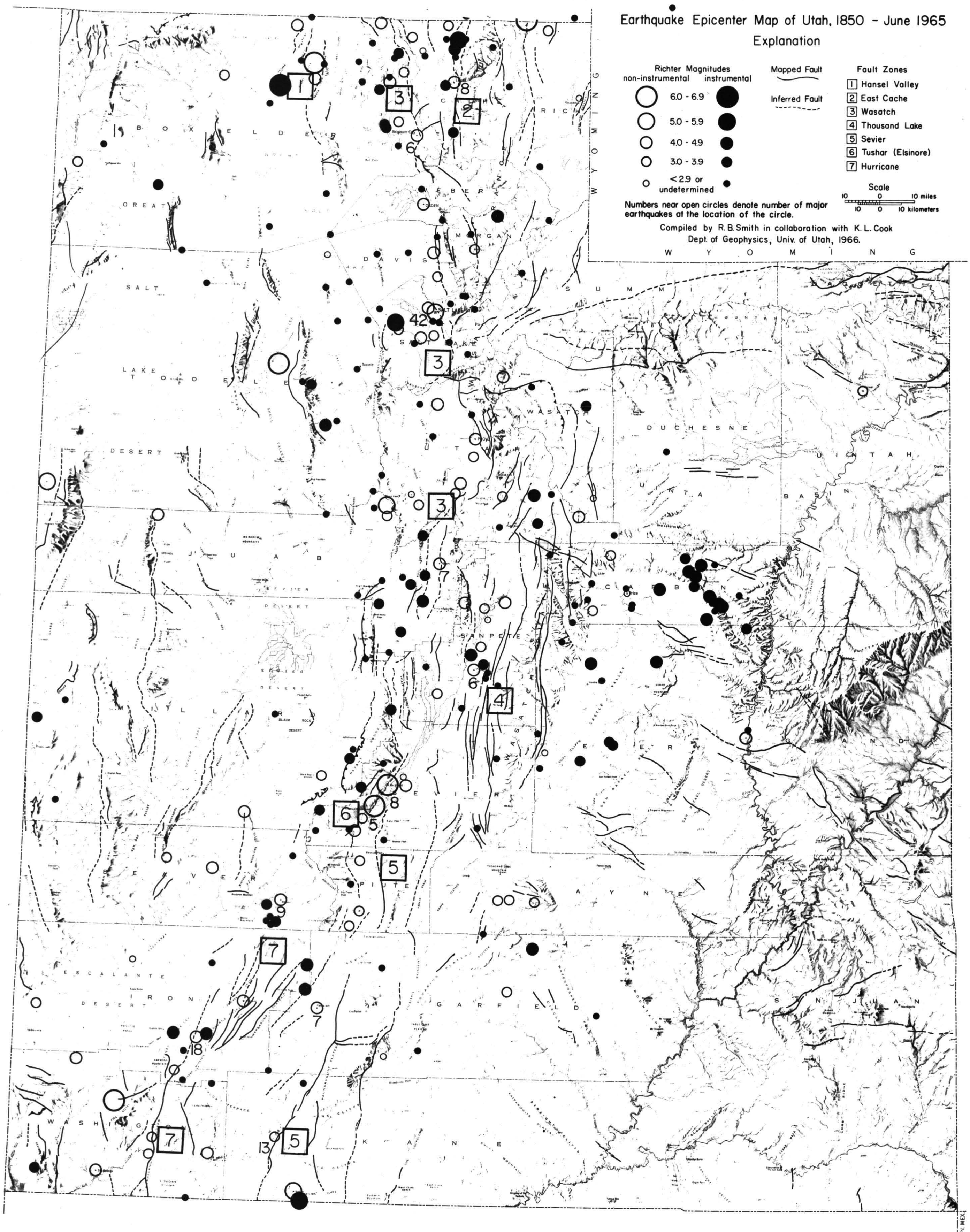
Earthquake Epicenter Map of Utah, 1850 - June 1965
Explanation
Richter Magnitudes
non-instrumental instrumental
6.0 - 6.9
5.0 - 5.9
4.0 - 4.9
3.0 - 3.9
< 2.9 or undetermined
Mapped Fault
Inferred Fault
Fault Zones
1 Hansel Valley
2 East Cache
3 Wasatch
4 Thousand Lake
5 Sevier
6 Tushar (Elsinore)
7 Hurricane
Scale
10 0 10 miles
10 0 10 kilometers
Numbers near open circles denote number of major earthquakes at the location of the circle.
Compiled by R. B. Smith in collaboration with K. L. Cook
Dept. of Geophysics, Univ. of Utah, 1966.
W Y O M I N G
B O X E L D E R
G R E A T
S A L T
L A K E
D E S E R T
T O O E L E
J U A B
M I L L A R D
B E A V E R
I R O N
W A S H I N G T O N
K A N E
G A R F I E L D
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U T A H
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C A R B O N
E M E R Y
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S A N J U A N
S U M M I T
W A S A T C H
D A V I S
M O R G A N
W E B E R
R I C H
C A C H E
S A L T L A K E
ESCALANTE DESERT
SEVIER DESERT
BLACK ROCK DESERT
UINTA BASIN

EARTHQUAKE HAZARDS IN UTAH

by Kenneth L. Cook [a]

In discussing the earthquake hazards in Utah, the following questions will be treated:

1) Why do earthquakes occur in Utah?

2) Where do earthquakes occur in Utah?

3) How large and dangerous are the earthquakes?

4) What are we now doing about the earthquake problem?

5) What more should we be doing?

WHY DO EARTHQUAKES OCCUR IN UTAH?

A belt of seismicity extends northward from the East Pacific Rise, along the Gulf of California and through western Arizona, central Utah (figure 1), southeast Idaho, western Wyoming, western Montana, and into British Columbia. This active seismic belt coincides with a branch of the great world-encircling rift system, in which the earth's crust is being extended or stretched. Utah lies on this belt of seismicity.

Extensions of the earth's crust result in its breakage into large and small blocks of rocks which move relative to each other along the faults or fracture zones between adjacent blocks. Earthquakes occur when the built-up stresses along these fault zones exceed the resistance of movement. During and after sudden release of the stress, displacements of the ground can often be observed and measured. The energy that is released at or near the fault zone travels away from it and gives rise to seismic waves which can cause damage. In Utah the earthquakes are related to the fault zones, and most of the major earthquake damage can be expected at or near them. The point of origin at depth of the earthquake is the focus or hypocenter; the point on the surface of the earth vertically above the focus is the epicenter.

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Figure 1. Earthquake epicenter map of Utah. Scale 1:1,000,000. Arabic numbers near some of the circles denote approximate number of major earthquakes reported at the location and does not include minor aftershocks. From Cook and Smith, Bulletin of the Seismological Society of America, v. 57 (4), p. 689-718, Aug. 1967, with permission. Base map taken from U. S. Geological Survey shaded relief map of state of Utah, 1959.

The forces causing the movement of the large crustal blocks probably originate within the earth's mantle. Along the belt of seismicity in Utah, the top of the mantle is about 25 to 30 km (15-18 miles) below the earth's surface. The movements of the blocks are continuing today; therefore the earthquakes continue to occur. Most of the earthquakes in Utah probably have a depth of focus of 33 km or less, with some as deep as 40 km.

WHERE DO EARTHQUAKES OCCUR IN UTAH?

Figure 1 shows the earthquake epicenter map of Utah (Cook and Smith, 1967). The northerly trend of the earthquake epicenter belt through central Utah should be noted. The six most active fault zones in Utah, with the approximate number of earthquakes documented from 1850 through June 1965 in parentheses (Cook and Smith, 1967), are:

Hansel Valley fault zone (9), north of Great Salt Lake,

East Cache fault zone (18), along the eastern margin of Cache Valley in northern Utah,

Wasatch fault zone (105), extending for about 160 miles along the western foot of the Wasatch Mountains between Collinston and Levan,

Table 1. Largest damaging earthquakes in Utah, 1850 through June 1965 (Cook and Smith, 1967).

Date (GCT)	Approximate Magnitude (Richter scale)	Location of Greatest Damage
1884 Nov. 10	6.1	Northern Utah-Southeastern Idaho; severe damage
1901 Nov. 14	6.7	Richfield; about 35 shocks
1902 Nov. 17	6.1	Pine Valley; 2 shocks
1909 Oct. 6	6.7	Garland, Hansel Valley
1921 Sept. 29	6.1	Elsinore; ($100,000 damage)
1921 Oct. 1	6.1	Elsinore; ($100,000 damage)
1934 Mar. 12	6.1	Kosmo (Hansel Valley)
1962 Aug. 30	5.7	Logan ($1 million damage)

Table 2. Approximate vertical displacements along recent (within probably 300 years) fault scarps and Richter magnitudes (actual or estimated) of certain large earthquakes in western United States.

Date (GCT)	Magnitude (Richter scale)	Approximate amount of vertical displacement (feet)	Location of fault scarp or name of earthquake
Probably less than 300 years ago	Probably at least 7.1 to 7.2	15[a]	Wasatch fault[e] (at mouth of Big Cottonwood Canyon)
"	"	20[b]	Wasatch fault[e] (at mouth of Little Cottonwood Canyon)
"	"	18-20(early)[c] 10-12(latest)[c]	Wasatch fault[e] (at mouth of ravine north of Nephi)
1934 Mar. 12	6.1	2	Kosmo (Hansel Valley)
1954 Dec. 16	7.2	12[d]	Dixie Valley-Fairview Peak, Nevada
1959 Aug. 17	7.1	15	Hebgen Lake, Montana

a. Maximum of 60 feet in three separate movements. The last movement, which is listed above, was about 15 feet.

b. One movement only, which amounted to 20 feet.

c. Two movements at mouth of ravine, including one that cut the flood plain.

d. On east side of Fairview Peak, there occurred 12 feet of vertical and 12 feet of horizontal displacement. On the west side of Dixie Valley, there occurred 7 feet of vertical displacement. These movements occurred during the same earthquake episode.

e. Estimates of number of movements and approximate amount of vertical displacement of Wasatch fault are from R. E. Marsell, oral communication, December 1968.

Thousand Lakes fault zone (15), in central Utah,

Sevier-Tushar (or Elsinore) fault zone (51), which includes Sanpete Valley in central Utah,

Hurricane fault zone (40), extending southward from the Cedar City area to the Grand Canyon of Arizona.

The largest damaging earthquakes in Utah from 1850 to 1965 are listed in table 1.

Fresh fault scarps at the mouths of Big and Little Cottonwood canyons and along the Wasatch front north of Nephi are evidence of recent (probably within 300 years) earthquakes of a Richter magnitude of probably at least 7.1 or 7.2. Table 2 shows the approximate vertical displacements along the fault scarps and the probable Richter magnitudes of the earthquakes. The writer assumes that each of these fresh fault scarps, which are 10 to 20 feet in height, was formed during a single earthquake. This assumption is reasonable in view of the similar fault scarps that were formed during (1) the Dixie Valley-Fairview Peak earthquake, Nevada (in 1954, with a Richter magnitude of 7.2) and (2) the Hebgen Lake earthquake, Montana (in 1959, with Richter magnitude of 7.1). The vertical displacement along the faults during these earthquakes (table 2) was of the same order of magnitude as the amount of vertical displacement observed along the recent fault scarps along the Wasatch fault. It can therefore be assumed that these earthquakes were of comparable magnitude.

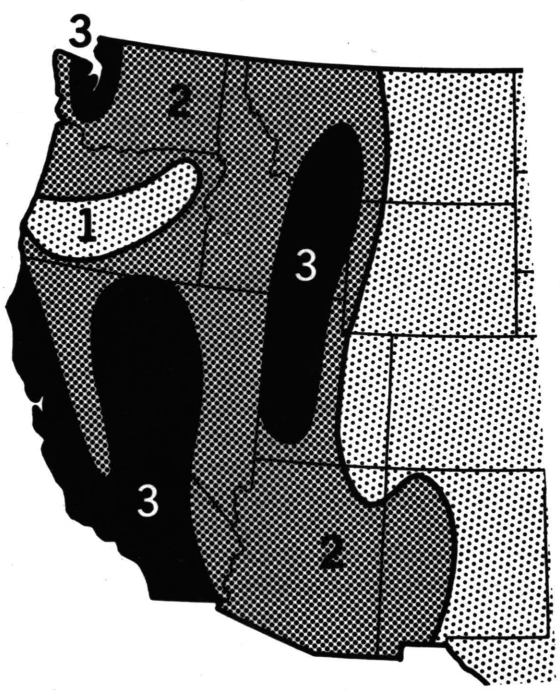

Figure 2. Seismic risk map of western U. S., ESSA/Coast and Geodetic Survey. Zone 1: expected minor damage. Zone 2: expected moderate damage. Zone 3: major destructive damage may occur. From U. S. Dept. of Commerce News, January 14, 1969.

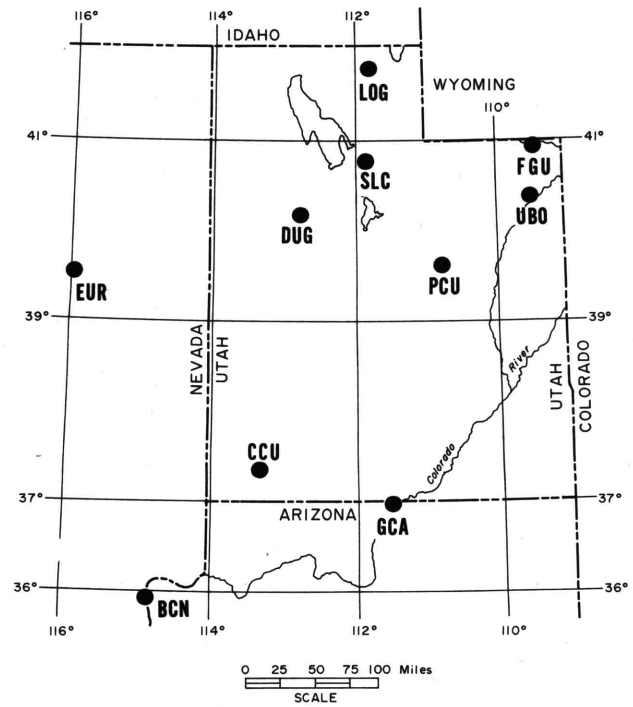

Figure 3. Seismograph stations in Utah and adjacent areas that provided data for this study. Locality symbols are explained in table 3. After Cook and Smith, Bulletin of the Seismological Society of America, v. 57 (4), p. 689-718, Aug. 1967, with permission.

HOW LARGE AND DANGEROUS ARE EARTHQUAKES IN UTAH?

From 1850 through June 1965, at least 609 earthquakes occurred in Utah; at least 38 of these were damaging, that is, at least dishes or windows were broken, plaster was cracked, or bricks toppled from chimneys (Cook and Smith, 1967). More than 90 percent occurred along or in association with the known fault zones. At least 15 earthquakes had an estimated Richter magnitude of 6.0 or greater. Two earthquakes (Richfield in 1901 and Hansel Valley in 1909) had an approximate Richter magnitude of 6.7 (table 1). During the Hansel Valley earthquake of 1934 (magnitude of 6.1), near Kosmo on the north shore of Great Salt Lake, a two-foot fault scarp was formed. From 1950 through June 1965, Utah experienced 13 damaging earthquakes, an average of nearly one per year.

The Logan earthquake in 1962 (magnitude of 5.7) caused about $1 million in property damage in that densely populated area; fortunately there was nc injury to the people.

Since 1962, when a more complete seismograph network was installed in Utah, many more earthquakes were recorded than in any previous comparable time. The increase in number is doubtless primarily the result of improved detection and interpretation techniques rather than an increase in seismicity in the region. The data show recent earthquake activity in the Ephraim (1961), Cache Valley (1962) and Levan (1963) areas, and earthquake swarms (many small earthquakes) in the Lehman Caves (1963), Southern Utah-Nevada border (west of Enterprise, 1966), Richfield (1967), and Scipio (1968) areas.

The zone of seismicity through central Utah, the area in which 85 percent of the state's population lives, is currently classified zone 2 by the Uniform Building Code. The Coast and Geodetic Survey (ESSA) of the U.S. Government released a map on January 14, 1969 (Algermissen, 1969), showing areas in the United States where earthquake damage could occur (figure 2). This map reclassifies the zone of seismicity through central Utah as zone 3. This zone has greater potential seismic risk than zone 2 and is subject to earthquakes of approximately magnitude 7.1 on the Richter scale (Karl Steinbrugge, 1968, oral communication).

WHAT ARE WE NOW DOING ABOUT EARTHQUAKES?

Installation of a more complete network of permanent seismograph stations throughout the state in 1962 is a major step in detection of earthquakes and in studying their effects by defining the active seismic areas. Figure 3 shows the locations of the permanent seismograph stations in Utah.

Table 3 shows the organizations which operate the stations. For most seismograph stations in the state, the University of Utah has a cooperative arrangement with other universities, colleges and the federal government for the operation, repair and maintenence of the stations. Some stations are operated independently by the federal government; however, the data from these stations are obtained and used for the determination of the epicenters of earthquakes in Utah.

The epicenters are determined for all earthquakes in Utah of sufficient magnitude to be detected at three or more stations. These data and other information such as date, time, latitude and longitude, Richter magnitude, and depth of focus if available, are published quarterly in the University of Utah Seismological Bulletin. The UNIVAC computer at the University of Utah permits immediate computation of epicenters of earthquakes as the data are obtained from the stations in the network.

A set of portable seismograph equipment is being assembled from components purchased by the Utah Geological and Mineralogical Survey. This equipment will be used to monitor earthquakes, aftershocks and earth movements along and in the vicinity of the active faults in Utah.

A study of possible small displacements (creep) along the Wasatch fault in the Salt Lake City region was initiated several years ago. The study is a cooperative project between Professor Clifford G. Bryner of the Civil Engineering Department of the University of Utah and the Coast and Geodetic Survey, Environmental Science Services Administration. Many survey markers installed on either side of the Wasatch fault are observed yearly. The purpose of the study is to ascertain whether small movements are taking place.

To study the earth movement caused by local earthquakes and announced underground nuclear explosions in Nevada, strong-motion seismographs have been placed intermittently in different parts of Salt Lake City. It is anticipated that the earth movement from the same seismic event (earthquake, underground nuclear explosion, etc.) would vary considerably over the same city, depending on such factors as type of soil, depth to bedrock, etc.

Table 3. Permanent seismograph stations in Utah.

Name	Location	Organization
Cedar City (CCU)[a]	Cedar City	Univ. of Utah and College of Southern Utah
Dugway (DUG)	Dugway	Univ. of Utah and CGS[b]
Flaming Gorge (FGU)	Flaming Gorge dam area	CGS
Glen Canyon (GCA)	Glen Canyon dam area	CGS
Logan (LOG)	Logan	Utah State Univ. and Univ. of Utah
Price (PCU)	Price	Univ. of Utah and College of Eastern Utah
Salt Lake City (SLC)	Salt Lake City	Univ. of Utah and CGS
Uintah Basin Observatory (UBO)	Vernal area	Advanced Research Projects Agency, U.S. Department of Defense

a. Letter designations (CCU, etc.) correspond with those on map in figure 3.
b. CGS indicates Coast and Geodetic Survey, Environmental Science Services Administration, U.S. Department of Commerce.

WHAT MORE SHOULD WE BE DOING ABOUT EARTHQUAKES?

The first step should be to protect the water supply of Salt Lake City. About 90 percent of all the water used by the city flows across the Wasatch fault in pipes that would be broken by a major earthquake. Fire, an inevitable companion of earthquakes in a populated area, would be out of control without water to fight it. More lives were lost and more property damage occurred in the San Francisco earthquake in 1906 as a result of fire than directly from the shaking incident to the earthquake. Specially designed flexible water pipes should be laid across the Wasatch fault to help insure a water supply. Such pipes have been laid in areas in California where pipes cross the San Andreas fault.

All public and private buildings where large numbers of people gather–schools, churches, theaters, hotels, apartment houses, office buildings, etc.,–should have earthquake-resistant features incorporated into their design by the architects in accordance with the zone 3 rating for this region.

Studies that involve research in earthquake prediction should be encouraged and supported by the people of Utah.

The Wasatch fault zone should have first priority. The research should include the following:

1. Various types of geologic mapping should be done and geophysical surveys made to locate the traces of the Wasatch fault zone more accurately. The geophysical surveys should include seismic refraction and reflection methods, and gravity and magnetic surveys.
2. The Wasatch fault zone should be instrumented with:
   a. Portable seismographs to detect small tremors.
   b. Strainmeters, to measure buildup in cumulative strain that may occur before an earthquake.
   c. Tiltmeters.
   d. Instruments for measuring creep along the fault.
   e. Measurements of telluric currents and earth resistivity which may change before an earthquake.
   f. Magnetometers, to measure the changes in magnetic flux that are associated with earth movements.
   g. Tidal gravity meter. The possible correlation between earth tides and earthquakes should be studied further.
3. Strong-motion seismographs should be installed in new high-rise buildings in Salt Lake City to record their response to earth movements during an earthquake. This information will assist in the design of future buildings in the same general area.

The permanent statewide seismograph station network in Utah should be expanded.

We should not panic but should start immediately to take steps to alleviate the severity of earthquakes when they occur, to support earthquake research with the end to predicting their occurrence, and to design buildings, dams, and bridges to resist the effects of earthquakes.

ADDENDUM

Since this paper was presented in 1967, two horizontal quartz-type 100-foot-long strainmeters (oriented north-south and east-west) were installed in the Granite Mountain Records Vault, Little Cottonwood Canyon, Salt Lake County, in a cooperative project between the writer and Dr. Maurice W. Major of the Colorado School of Mines. The project is supported by the Environmental Science Services Administration. The large cumulative buildup in strain (up to 50×10^{-8}) that was measured on the strainmeter during several days prior to two earthquakes (during January 23 and February 16, 1969) in the Salt Lake City area is encouraging evidence that it may be possible to predict earthquakes along the Wasatch fault at some time in the future. (Cook and Major, 1969).

The following additional equipment is planned for installation in the Granite Mountain Records Vault during 1970:

1. A 45° leg on the present strainmeter to help resolve the measurements of strain.
2. Two tiltmeters (designed by the Timmin Research Corporation) each 100 feet long, oriented north-south and east-west, respectively.
3. A three-component seismograph, to monitor seismically the strain steps that have been observed and tilts which are expected to be observed in association with earthquakes (or microearthquakes) in the vicinity of the vault.

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