REGIONAL CONDITIONS FOR GROUND-FAILURE HAZARDS,
WEST HALF OF THE PRESTON 1° X 2° QUADRANGLE,
IDAHO AND WYOMING

Kurt L. Othberg

Idaho Geological Survey
University of Idaho
Moscow, Idaho 83843

Technical Report 84-2
July 1984
# TABLE OF CONTENTS

<table>
<thead>
<tr>
<th>Section</th>
<th>Page</th>
</tr>
</thead>
<tbody>
<tr>
<td>INTRODUCTION</td>
<td>1</td>
</tr>
<tr>
<td>PLATE 1: GENERAL PHYSIOGRAPHY AND TOTAL PRECIPITATION</td>
<td>3</td>
</tr>
<tr>
<td>PLATE 2: GENERAL PHYSIOGRAPHY AND PREDICTED INTENSITY OF PRECIPITATION</td>
<td>5</td>
</tr>
<tr>
<td>PLATE 3: TECTONIC LANDFORMS OF PROBABLE QUATERNARY AGE</td>
<td>7</td>
</tr>
<tr>
<td>PLATE 4: LITHOLOGIC ASSEMBLAGES WITH PHYSIOGRAPHIC SIGNIFICANCE</td>
<td>8</td>
</tr>
<tr>
<td>PLATE 5: SELECTED EARTHQUAKE EPICENTERS, POTENTIALLY ACTIVE FAULTS, AND MAXIMUM PROBABLE EARTHQUAKE ACCELERATIONS IN BEDROCK.</td>
<td>12</td>
</tr>
<tr>
<td>PLATE 6: DEVELOPMENTAL FEATURES POTENTIALLY AFFECTED BY GROUND-FAILURE HAZARDS.</td>
<td>16</td>
</tr>
<tr>
<td>PLATE 7: PHOSPHATE AND PETROLEUM RESOURCES</td>
<td>18</td>
</tr>
</tbody>
</table>

## Figure

**Figure 1.** Locations of earthquakes that were large enough to cause intensities of IV or greater within the project area. ............... 13
REGIONAL CONDITIONS FOR GROUND-FAILURE HAZARDS,  
WEST HALF OF THE PRESTON 1° x 2° QUADRANGLE,  
IDAHO AND WYOMING  

by  
Kurt L. Othberg

INTRODUCTION

The dynamic physiography of Idaho is susceptible to ground failures that can cause costly property damage and threaten health and life. The types of hazardous ground failures in the west half of the Preston 1° x 2° quadrangle, Idaho and Wyoming, are landslides, subsidence, liquefaction, and ground rupture along active faults.

For this report information has been compiled about the regional geomorphology and the activities of people that affect ground-failure hazards. The significant regional conditions studied in this report are physiography, climate, Quaternary tectonics, lithologies, structure, and the features of human development that may interact adversely with ground failures.

Although the region is sparsely populated, large phosphatic-rock reserves and active phosphate mining and processing, along with the possibility of oil and gas potential, make it an area of major resource development. This actual and potential utilization of resources is the primary justification for studying the ground-failure hazards in the region.

Seven preliminary maps have been prepared to portray the regional conditions pertinent to ground-failure hazards:

Plate 1: General Physiography and Total Precipitation

1Idaho Geological Survey, University of Idaho, Moscow, Idaho 83843.
Plate 2: General Physiography and Predicted Intensity of Precipitation
Plate 3: Tectonic Landforms of Probable Quaternary Age
Plate 4: Lithologic Assemblages with Physiographic Significance
Plate 5: Selected Earthquake Epicenters, Potentially Active Faults, and Maximum Probable Earthquake Accelerations in Bedrock
Plate 6: Developmental Features Potentially Affected by Ground-Failure Hazards
Plate 7: Phosphate and Petroleum Resources

The text gives background information, explanations, significant interpretations, and interrelationships appropriate to each plate.
PLATE 1: GENERAL PHYSIOGRAPHY AND TOTAL PRECIPITATION

Landslides are probably the most prevalent type of ground-failure in the Preston quadrangle. Three geomorphic factors that affect landsliding are relief, elevation, and the relative saturation of earth materials. The informal physiographic subdivisions shown on this map portray the great relief and accompanying contrasts in elevation in the project area; the isohyetalis indicate the moisture available for an average year.

The portion of the Preston quadrangle west of the Bear River Range and Blackfoot Reservoir is included in the Basin and Range Province (Fenneman, 1946). The remainder of the project area is within the Middle Rocky Mountain Province, but includes basins similar to those of the Basin and Range Province. Much of the contrasts in relief and elevation are due to low, relatively flat basins juxtaposed with mountains. Local climatic conditions differ considerably because of the variations in elevation, relief, and the exposure of slopes to the sun (aspect). Precipitation is significantly affected by elevation and the major landforms. Total precipitation ranges from 10 to 45 inches per year. More than half of the precipitation at higher elevations falls as snow (U.S. Departments of the Interior and Agriculture, 1977). Infiltrating snowmelt is a major cause of the saturation of earth materials, and greater snow depths and slower melting can lead to increased saturation. As a result, north-facing slopes may have a greater chance of becoming unstable than south-facing slopes. In addition, spring rains falling on already saturated steep slopes can contribute to slope failures, depending on the steepness of the slope and the lithology and structure of the earth materials.

REFERENCES
Boundary of physiographic subdivision.

Isohyetal line showing average total precipitation per year in inches. (U.S. Departments of the Interior and Agriculture, 1977.)
PLATE 2: GENERAL PHYSIOGRAPHY AND PREDICTED INTENSITY OF PRECIPITATION

Thunderstorms accompanied by intense precipitation occur locally in the project area primarily during the summer. The mean annual number of days with thunderstorms is 30 to 40, generally increasing to the east (Baldwin, 1973). The isopluvials shown on this map (Miller and others, 1973) demonstrate the effect of the mountains on the intensity of precipitation. The values of the isopluvials do not necessarily reflect thunderstorm conditions but do serve to show the pattern and possible quantities of rainfall that may occur during thunderstorms.

Flash floods and debris flows due to intense rainfall have not been reported for the project area. The relief, steep slopes, and thunderstorm activity suggest, however, that a potential hazard could exist. Preliminary geomorphic evidence suggests that flash floods and rapid flows may have been more prevalent in the past. The Downey-Pocatello area just west of the Preston quadrangle seems to be particularly susceptible to flash flooding during thunderstorms. It is not known what factor or factors may change toward the east, thereby reducing the incidence of flash floods. One important factor to consider is the possibility of overgrazing by livestock during this century, which could result in increased runoff in some areas.

REFERENCES

LEGEND

- Boundary of physiographic subdivision.

- Isopluvial line showing 24-hour precipitation in tenths of an inch for a 100-year period. The pattern of isopluvials for
GENERAL PHYSIOGRAPHY AND
PREDICTED INTENSITY OF PRECIPITATION

by

Kurt L. Othberg

1984
shorter periods and a 6-hour duration stays essentially the same. Values for the shortest period, 2 years, are about one-third as large as those shown for a 6-hour duration, and about one-half as large as those shown for a 24-hour duration.
PLATE 3: TECTONIC LANDFORMS OF PROBABLE QUATERNARY AGE

Ground-failure hazards exist because of active geomorphic processes. The movement of earth materials tends to be more prevalent in areas of youthful tectonic activity. In the west half of the Preston quadrangle, late Cenozoic tectonism has consisted primarily of normal faulting in response to regional extension* and vulcanism probably associated with the nearby Snake River Plain. Much of this activity has continued in Quaternary time.

The salient features in the project area are (1) uplifted range fronts, (2) down-dropped valleys, (3) large lava fields, and (4) hot spring deposits and active hot springs.

*This is a simplistic description of what may in fact involve enigmatic low-angle faults at depth and shear as well as extensional forces.
TECTONIC LANDFORMS
OF PROBABLE QUaternary AGE

by

Kurt L. Othberg

1984
PLATE 4: LITHOLOGIC ASSEMBLAGES WITH PHYSIOGRAPHIC SIGNIFICANCE

Earth materials within the west half of the Preston quadrangle range from indurated and resistant quartzites to soft and landslide-prone lacustrine silts and clays (Cressman, 1964; Mansfield, 1927; Oriel and Platt, 1980). It is characteristic of the area that physiography closely reflects the lithologies and structures of earth materials. Although Mansfield (1927) inferred the existence of several old erosion surfaces in the mountains, the topography is so dependent on the differential erosion of folded and faulted rocks of varying lithologies that the detection of older surfaces of erosion is highly subjective (Cressman, 1964). With the exception of remnants of middle- to late-Tertiary depositional surfaces (unit "nh"), the mountains have erosional slopes that are primarily late Quaternary in age. The recency and types of processes responsible for erosion of the mountain slopes are conjectural and are being researched. It seems, however, that many mountain slopes are more stable today than they have been in the past.

Different assemblages of bedrock units underlying the mountains and hills render a few physiographically distinct categories. The relative amount of less resistant, more landslide-prone rocks interbedded with resistant rocks generally increases up the stratigraphic section. The Precambrian and lower Paleozoic rocks are the most homogeneously resistant (unit "r") strata within the mountains. The upper Paleozoic and lower Mesozoic rocks are characterized by interbedded resistant and nonresistant beds; furthermore, the percentage of nonresistant units is greater in the younger part of the section. The distribution of these rock units is greatly affected by structure. For the general categorization of this map, the upper plate (unit "cvu") of the Meade Overtrust has been distinguished by its higher percentage of Paleozoic limestone beds, and the lower plate (unit "cv1") of the Meade Overtrust has been distinguished by its lower percentage of Paleozoic limestone beds. A subdivision of the lower plate has been made for the apparently block-faulted Sublett Range (unit "cv1b"). The upper Mesozoic units are also interbedded with resistant and nonresistant rocks, but they are characterized by a relatively high percentage of nonresistant mudstones (unit "nm") which are prone to landsliding. Within the mountainous areas of bedrock
LITHOLOGIC ASSEMBLAGES
WITH PHYSIOGRAPHIC SIGNIFICANCE

by
Kurt L. Othberg

1984
lithologic assemblages, numerous deposits of alluvium in valleys and widespread colluvium, including landslide deposits, have not been mapped or are too small to show for the purpose of this map.

The filling of valleys has been a major process in the geologic history of the project area. Lower Quaternary basaltic lava flows (unit "bl") filled valleys in the northwest portion of the region, drastically altering drainage in the north. Early- to late-Pleistocene lakes Thatcher and Bonneville deposited thick and widespread lacustrine sediments (unit "I") in the west-central and southwest portion of the region, up to about the 5,000-foot elevation in northern Cache Valley and up to about the 5,500-foot elevation in Gentile Valley.

Upper Quaternary tufa and travertine comprise minor mounds and terraces in the vicinity of Soda Springs. They occur either in relatively close proximity to or in juxtaposition with lava fields. Their locations are generally coincident with a known or inferred fault. The presence of modern geothermal waters in the area makes it possible that renewed hot spring activity could occur at or near these mapped deposits.

All hillslopes have colluvium deposited on them to some degree. Many of the less resistant bedrock units are mappable only on the basis of the content of float. A surficial geologic map would describe the character, thickness, and distribution of bedrock-derived colluvium. Mapping surficial deposits is beyond the scope of this project, but those colluvial deposits (unit "c") are shown that are significantly thick and widespread.

Several valleys in the west half of the Preston quadrangle may be actively aggrading today and definitely have been sites of considerable alluvial deposition during Holocene and Pleistocene time. The best example of this is the aggradation of Bear Lake Valley by the Bear River. Other examples are Portneuf Valley, Lower Valley, Upper Valley, Star Valley, and Thomas Fork Valley. Many other smaller valleys have received late Quaternary alluvial deposition, especially in relationship to the modification of drainages marginal to the lava fields. For the purposes of this map, alluvial deposits (unit "a") of channels, floodplains, fans, and terraces have been grouped together. Relatively small areas of hillslope colluvium and eolian silt have been included.
REFERENCES

LEGEND

r Resistant, partially crystalline Precambrian to Devonian strata of the Bear River, Wasatch, and Portneuf Ranges. Primarily dolomite, quartzite, and limestone.

Cliff- and valley-forming Mississippian to Jurassic strata of mountains and foothills; primarily limestone in Paleozoic units and shale, siltstone, sandstone, and limestone in Mesozoic units: cvu, cvl, and cvlb.

cvu Comprises terrains of upper plate of Meade Overthrust which is underlain by a relatively high percentage of Paleozoic rocks.
cvl Comprises terrain of lower plate of Meade Overthrust which is underlain by a relatively low percentage of Paleozoic rocks.
cvlb Comprises the apparently block-faulted Sublett Range.

nm Nonresistant mudstone and siltstone with minor ridge-forming conglomerate, sandstone, and limestone of Jurassic and Cretaceous strata. Underlies mountains and foothills of the Caribou Range and Gannett Hills.

nh Nonresistant tuff, siltstone, sandstone, and conglomerate of Tertiary age. Underlies low hills and dissected flat and sloping surfaces along the flanks of mountains.
bl Basaltic lava fields discontinuously mantled with loess.

l Lacustrine clay, silt, sand, and gravel of Pleistocene Lakes Bonneville and Thatcher, and other lakes of possible pluvial origin. Comprises relict lake bottoms, shorelines, and deltas.

t Tufa and travertine deposits comprising mounds and terraces at the locations of former hot springs.

c Colluvial silt, sand, angular gravel, and diamictons comprising hillslope debris of Pleistocene age.

a Alluvial, colluvial, and eolian silt, sand, and gravel of Pleistocene and Holocene channels, floodplains, fans, terraces, and hillslopes.
The potential for active faulting and earthquakes is an important consideration in a study of ground-failure hazards. Ground-surface rupture during recurrent movement along faults is a significant hazard to many developmental features, including buildings, dams, roads, railroads, and pipelines (Plate 6). Strong ground motion (shaking) during earthquakes can initiate landslides, cause liquefaction of saturated silty, sandy sediment, and accelerate the differential settlement and collapse of ground into solution cavities. All of these hazards can impact people, their structures, and their resources.

Potentially active faults, the traces of which are shown on this map, are compiled with minor modifications from maps by Witkind (1975), Williams (1962), Greensfelder (1976), Othberg and Breckenridge (1980), and Oriel and Platt (1980). The interpretation of potentially-active faults is primarily based on findings by the first four sources. The relatively accurate placement of the fault traces is based primarily on Oriel and Platt (1980) and Williams (1962).

At least 120 earthquakes of approximate magnitude 3 or greater have occurred within the west half of the Preston quadrangle since 1873 (data obtained from the National Geophysical and Solar-Terrestrial Data Center, Boulder, Colorado, and the University of Utah Seismograph Stations, Salt Lake City, Utah). Probably more significant, nearly 200 earthquakes large enough to cause intensities of IV or greater within the project area have occurred in surrounding regions (Figure 1). The potential for earthquake strong motion comes not only from within the study region but also from four distant seismic source areas: Yellowstone/southwest Montana, south-central Idaho, north-central Nevada, and northern Utah (Algermissen and others, 1982).

Maximum probable earthquake accelerations in bedrock (expressed as a percent of gravity) are shown on Plate 5 as a measure of strong ground motion should a large earthquake occur (Greensfelder, 1976). The maximum probable accelerations were calculated with a probability of being exceeded $10^{-4}$ times per year (or, once every 10,000 years an earthquake will result in accelerations that exceed those shown). The
SELECTED EARTHQUAKE EPICENTERS, POTENTIALLY ACTIVE FAULTS, AND MAXIMUM PROBABLE EARTHQUAKE ACCELERATIONS IN BEDROCK

by

Kurt L. Othberg

1984
Figure 1. Locations of earthquakes that were large enough to cause intensities of IV or greater within the project area (National Geophysical Solar-Terrestrial Data Center, Boulder, Colorado).
use of such a low probability level results in rather high values for acceleration (.2g to .75g). For comparison, acceleration values from Algermissen and others' (1982) nationwide map, with a 50-year probability level, range from .15g to .28g. Greensfelder's (1976) map was used for this compilation for three reasons: (1) it provides greater detail; (2) acceleration contours are based on the locations of potentially active faults; and (3) the longer time period probability level may provide a more realistic view of the effect earthquakes have had on Holocene ground-failure processes.

Both the pattern of acceleration and the level of acceleration are significant to estimating risk. The pattern represents greater risk near potentially active faults. The value of the acceleration contour is a prediction of the strength of earthquake shaking that may have to be endured. The risk of the occurrence of the predicted acceleration is dependent on the time period one wishes to use. For the Holocene (last 10,000 years), it is very probable that earthquakes large enough to initiate and accelerate ground-failure processes have occurred. The probability of that happening within the next 50 years, however, is rather low.

REFERENCES


LEGEND

0 Precise epicenters of earthquakes of magnitude greater than or equal to 3. Located to 0.001 degrees of latitude and longitude.

/ Trace of potentially active fault. Location of potential hazard of ground-surface rupture.

.5 Contour of maximum probable earthquake acceleration in gravity (g) units. The probability of being exceeded is $10^{-4}$ times per year.
PLATE 6: DEVELOPMENTAL FEATURES POTENTIALLY AFFECTED BY GROUND-FAILURE HAZARDS

A primary reason for selecting the Idaho portion of the Preston quadrangle to study ground-failure hazards is its importance as an area of major resource development. The most significant mineral resource is phosphate, and large mines have been developed within a relatively small portion of the distribution of the resource (compare Plates 6 and 7). Given continued demand, the mining of phosphate should remain active for many decades.

Oil and gas are important potential resources within the study area (see Plate 7). Discoveries and development of petroleum reserves within the area will greatly affect industry and population growth. The region already contains a corridor for pipelines, and the future development of petroleum resources could lead to new pipeline construction.

Pipelines can be easily damaged by ground failures. The Pacific Northwest Pipeline Company's pipeline route, shown on Plate 7, is an example of a developmental feature, which if broken by a landslide, differential settlement, fault rupture, or other ground failure would disrupt energy resources outside of the region.

Damage to power transmission lines is another example of the potential effect of hazards in the Preston quadrangle on distant industries and populations. Within the study area itself, the disruption of electrical power could adversely affect several towns and three large phosphate processing plants. Although the spacing between power poles reduces the probability of impact from any one ground failure, powerlines traverse such highly diverse terrain that they are subject to virtually all types of ground failure.

Highways and railroads also traverse many different terrains and currently have chronic problems with ground failures in a number of locations. An expansion of the highway system, either by widening or by developing new routes, will tend to increase the exposure of the highways to ground-failure hazards.

Many dams exist in the study area, and they are diverse in their size and construction. Their site engineering has not been studied for this project. The quality of geotechnical applications for any one dam,
DEVELOPMENTAL FEATURES POTENTIALLY AFFECTED BY GROUND-FAILURE HAZARDS

by

Kurt L. Othberg

1984
therefore, is unknown. The dam foundations are set in many different lithologies and at varying distances from traces of potentially active faults. Their locations are shown on this plate in order to draw attention to the need to recognize the presence of dams when mapping ground-failure hazards.

Active phosphate mines are tremendous disrupters of topography, drainage, and earth materials. Maintaining an efficiently run mine in many cases requires operating with high metastable slopes in the mine pit. As a result, the over-steepened slopes are the sites of many rock slides. The diversion of drainages by mine construction can lead to unplanned concentrations of runoff water, which in turn can result in debris flow hazards. Enormous quantities of mine wastes are piled in fills, and the loading of lower strength bedrock units can lead to slumps and earth flowage. Geotechnical consideration of ground failure is necessary in planning such mines in mountainous terrain.

Phosphate processing plants are large industrial operations that also require careful planning to avoid ground-failure hazards. They are located on this map to show the proximity of the processing plants to the regional conditions affecting ground-failures.

Of the cities and towns in the Preston quadrangle, Montpelier, Preston, and Soda Springs are the largest. They range in population from 2,500 to 3,500. At present these population centers are located in areas relatively free of ground failures. If resource development were to expand in the future, however, population would surely grow and the construction of new dwellings and work places could occur in nearby sites in which a hazard from ground failures exists.

LEGEND

Active phosphate mine
Phosphate processing plant
Dam
Powerline
Highway
Railroad
City
PLATE 7: PHOSPHATE AND PETROLEUM RESOURCES

Phosphatic rocks constitute a major mineral resource for Idaho. Eighty percent of the phosphate reserves in the western United States is in Idaho. Nearly all of Idaho's reserves are contained within the Preston quadrangle, and amount to nearly 1 billion tons. Annual production is nearly 5 million tons and is expected to gradually increase throughout the remainder of this century (U.S. Departments of the Interior and Agriculture, 1977).

Phosphate reserves in the study area are contained within the Phosphatic Shale Meade Peak Member of the Permian phosphoria Formation. Mapped phosphoria Formation (unit "S") and identified phosphate resources (unit "I") (preliminary data from the Idaho Bureau of Mines and Geology's Phosphate Resources Evaluation Program) are widely distributed in the cliff- and valley-forming lithologic assemblage of the upper plate of the Meade Overthrust (see unit "cvu," Plate 4). Virtually all of the resource occurs in mountainous terrain. Current mining activities have already had significant interaction with ground-failure processes, and the potential for the impact of ground-failure hazards on phosphate mining will probably increase as mining expands throughout the area of the reserves.

Idaho has not experienced a drilling discovery of oil or gas to date. The potential for discovery is good in the Preston quadrangle, where leasing is active and some drilling is taking place. The Preston quadrangle is in the Idaho-Wyoming-Utah salient of the Rocky Mountain Overthrust belt. This major structural element has been the source of recent significant oil and gas discoveries in Utah and Wyoming.

Within the Idaho portion of the Preston quadrangle, three major tectonic units provide a lithologic and structural basis for assessing the oil and gas resource potential. From east to west these units are the Cache Unit, the Meade Peak Unit, and the Central Unit. The Cache Unit is considered to have low oil and gas potential and has received very little exploration. The other two units have a good potential for oil and gas discovery and have been explored by a number of wells.
PHOSPHATE AND PETROLEUM RESOURCES

by

Kurt L. Othberg

1984
REFERENCES

LEGEND

Surface distribution of the Phosphoria Formation, which includes the Meade Peak Phosphatic Shale Member.

Identified phosphate resources (preliminary data from the Idaho Bureau of Mines and Geology Phosphate Resources Evaluation Program).

Major tectonic units with both lithologic and structural significance for assessing oil and gas resource potential: CACHE UNIT, MEADE PEAK UNIT, CENTRAL UNIT.

Tectonic unit boundary established by the location of major thrust faults.

Major mapped thrust fault; dashed where extrapolated by inference.

Major pipeline.

Dry oil and gas exploration hole. Total depth shown in feet.