GEOLOGIC HAZARDS OF CASTLE VALLEY, GRAND COUNTY, UTAH

by

William E. Mulvey
Utah Geological Survey

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ABSTRACT

Castle Valley is in a rapidly developing region experiencing high growth rates. To address development in areas with the potential for geologic hazards, the Castle Valley Planning Commission requested the Utah Geological Survey (UGS) to conduct a geologic-hazards investigation of Castle Valley. This information will be used to help guide development and reduce losses from geologic hazards.

Geologic processes that created the rugged and scenic landscape of Castle Valley are still active today and can be hazardous to property and lives. Erosion by running water is the most active and potentially damaging process. Runoff from summer cloudburst storms along Porcupine Rim concentrates in drainages that flow into Castle Valley, causing debris flows and flooding on alluvial fans. The cliffs of Porcupine Rim are source areas for large rock falls which can travel far out onto the alluvial fans below the cliffs. Sandy soils along Castle and Placer Creeks are susceptible to piping and erosion. Large areas of the northeastern part of the valley contain expansive clay soils. Valley-floor alluvial deposits may be a source of radon gas. Collapsible and gypsiferous soils, and ground-water contamination may present problems for development in Castle Valley.

Maps of these hazards (1:24,000 scale) are designed to assist homeowners, planners, and developers in making informed decisions when building in Castle Valley. The maps show areas where hazards may exist and where site-specific studies are advisable prior to development. The maps are for planning purposes only, and do not preclude the necessity for site investigations. Site-specific studies should evaluate hazards and, if necessary, recommend hazard-reduction measures. The studies must be prepared by qualified professionals (engineering geologists, geotechnical engineers, hydrologists).

Because of the small scale of the maps, some small hazard areas may not be shown; complete hazard studies are therefore recommended for critical facilities (hospitals, schools, fire stations) even outside mapped hazard areas.

INTRODUCTION

Castle Valley is located in Grand County, in east-central Utah (figure 1). The valley trends northwest-southeast, and is 12 miles (19 km) long and averages 2 miles (3 km) wide. To the northwest, the valley ends at the Colorado River; to the southeast are the 12,000-foot (3600-m) high La Sal Mountains. Valley-floor elevations range from 4120 feet (1250 m) near the Colorado River to 5800 feet (1750 m) in the foothills of the La Sal Mountains. Vegetation is sagebrush and pinyon-juniper with cottonwoods along streams. Castle and Placer Creeks flow through the valley from southeast to northwest, with their headwaters in the La Sal Mountains to the southeast. On the southwest side of the valley alluvial fans and talus slopes rise to the shear cliffs of Porcupine Rim. To the northeast the Priest and Nuns, Castle Rock, and Adobe Mesa are prominent topographic features.

Many of the geologic processes which shaped Castle Valley's scenic and rugged landscape over millions of years are still active today. These processes and the resulting deposits are potentially hazardous to property and lives.

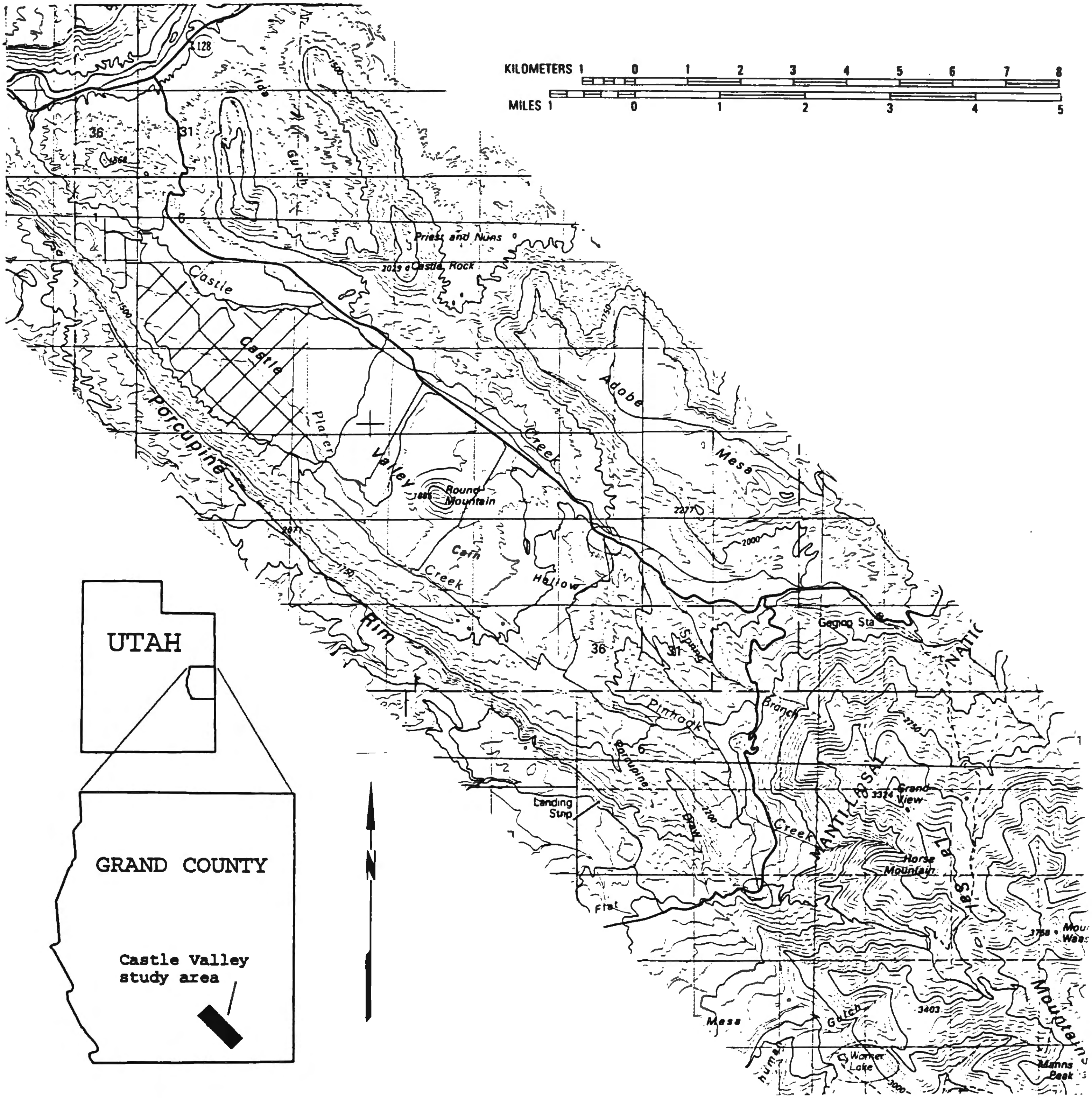

Figure 1. Location map.

Principal geologic hazards mapped in Castle Valley are: (1) expansive soil and rock, (2) gypsiferous soils, (3) alluvial-fan/stream flooding, (4) debris flows, (5) collapsible soils, (6) rock fall, and (7) soils subject to piping and erosion. Other possible hazards include: (8) radon, (9) potential for ground-water contamination, and (10) earthquakes. These hazards are all directly related to the geology of Castle Valley.

PURPOSE AND SCOPE

This report provides Castle Valley town officials, planners, and developers with information and maps concerning geologic hazards which may affect development in Castle Valley. The hazard maps are derived from geologic maps that are presently in preparation by M.L. Ross and H.H. Doelling of the UGS. The geology and geologic hazards were mapped at a scale of 1:24,000. The areal extent of many geologic hazards is based on the distribution of surficial and bedrock deposits associated with geologic hazards.

The scope of work for this report included meeting with local government officials and residents, literature and air-photo reviews, and field work. The report presents a detailed discussion of geologic hazards specific to Castle Valley, and will eventually be incorporated as part of a UGS Bulletin "Geology of Southern Grand County" to be published at a later date.

The report discusses geologic hazards in Castle Valley and lists: (1) their characteristics, (2) possible hazard-reduction measures, (3) scope of recommended site-specific hazards investigations, and (4) application of the maps to land-use planning. The maps are designed to stand alone, and include a summary discussion of each hazard depicted. Geological input is most important early in the planning process; redesigning subdivisions and other development around geologic problems or repairing damage from hazard events is costly and time consuming.

GEOLOGY

The geology of Castle Valley is unique and complex, with salt diapir development, salt dissolution and collapse, and erosion by running water being the dominant geologic processes. Rocks exposed in the valley range in age from Pennsylvanian to Quaternary. Appendix A shows these age relationships.

Geologic History

Geologic processes that shaped present-day Castle Valley began in Middle Pennsylvanian time with deposition of salts from seas that covered much of Utah during that time. These salts are the source for a salt diapir, or dome, beneath Castle Valley. Once horizontally bedded, upon burial the low density salts moved toward areas where overlying sediments were thinner (where overburden pressure was less) and flowed upward, causing growth of the diapir. As the diapir grew, its dome-like shape caused a topographic high and subsequent sediments were deposited along its flanks, causing an even greater difference in overburden pressure and squeezing more salt from beneath into the diapir, increasing its size. Because most of the sediment was deposited along the flanks of the diapir, sediments on top are much thinner. This process continued until all the salt was squeezed from beneath the surrounding sediments and into the diapir.

Growth of the diapir stopped during the Lower Triassic and a period of stability ensued. Sediments deposited over the diapir after this time are undeformed by salt movement. Igneous rocks that form Round Mountain (figure 1) crystallized from a molten mass that intruded into the sediments covering the diapir during the middle Tertiary (M.L. Ross, verbal communication, June 16, 1992). During the late Tertiary regional uplift of the Colorado Plateau began, initiating canyon cutting and erosion by rivers. As uplift slowed, erosion by rivers and streams eventually reached the diapir. Ground and surface waters began to dissolve the salt and remove it, causing overlying material to collapse into voids left by removal of the salt. This series of events began the formation of Castle Valley. Erosion by streams of the fractured rock over the diapir deepened and widened the valley, leaving the more resistant igneous rock of Round Mountain as an erosional remnant. During the Quaternary, deposition of sediment from glacial and perennial streams (Castle and Placer Creeks) originating in the La Sal Mountains began filling the valley and creating the topography present today.

The thick sediments deposited along the flanks of the diapir are still present today as Porcupine Rim, Priest and Nuns, Castle Rock, and Adobe Mesa (figure 1). Rocks that form the slopes of these features were deposited during the time of salt diapir movement, while the rocks that form the upper cliffs were deposited after diapir movement stopped.

Geologic Units

Numerous geologic units are exposed in the valley floor, lower slopes, and cliff walls. From oldest to youngest, they are the Paradox, Cutler, Moenkopi, and Chinle Formations (deposited during diapir movement), the Wingate Sandstone and Kayenta Formation (deposited after diapir movement); the La Sal Mountain granodiorite porphyry, and Quaternary deposits. All of the units form distinctive topographic features in the valley (figure 2).

The oldest unit is the Early Pennsylvanian Paradox Formation. It is composed of 75 to 90 percent sodium chloride (salt), with some potash and magnesium salts (Doelling, 1985). As the salts dissolve, they leave behind layers and contorted beds of gypsum, shale, and limestone. Gypsum and shale from this process form low hills in the southeastern end of Castle Valley. They are whitish-gray and easily eroded. The Permian Cutler Formation forms cliffs and slopes immediately above the valley floor. It contains red and maroon crossbedded sandstones and conglomerates with a few thin shale beds (Doelling, 1985). Sandstones of the Cutler Formation form cliffs at the extreme southwestern end of Castle Valley.

Slopes above the Cutler Formation are composed of the Lower Triassic Moenkopi Formation. The area around

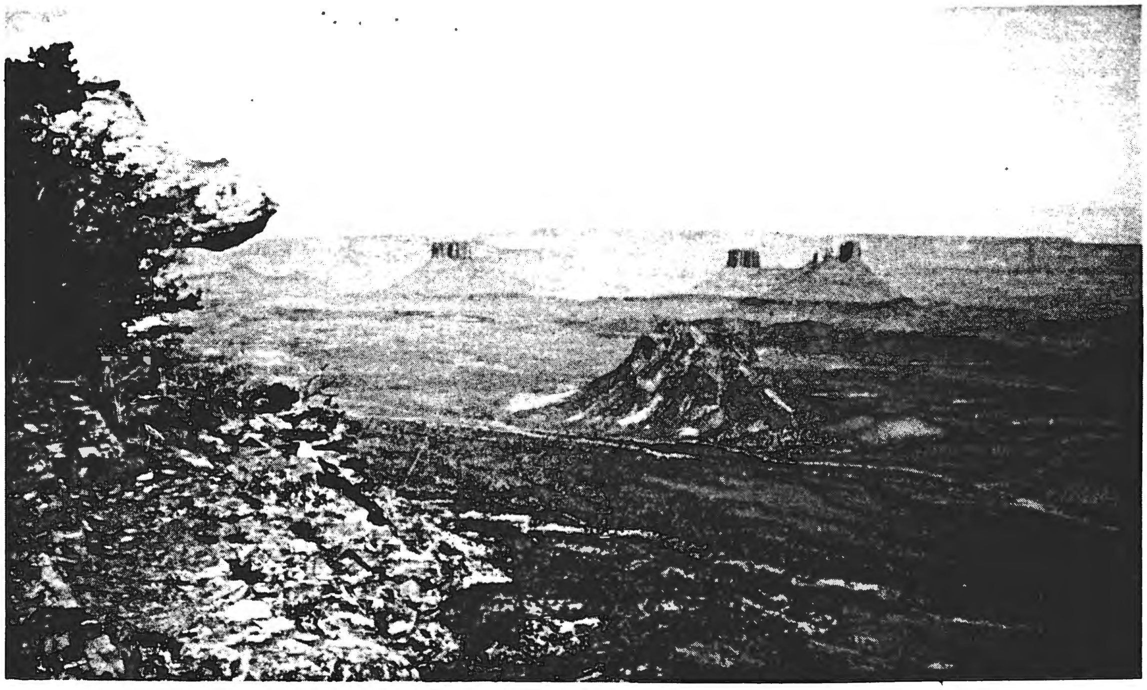

Figure 2. Relationship of geologic units in Castle Valley.
IPpg - Paradox Formation, Pc - Cutler Formation,
Ŧm - Moenkopi Formation, Ŧc - Chinle Formation,
Jw - Wingate Sandstone, Jk - Kayenta Formation,
Tpht - La Sal Mountain porphyry, Qal - Alluvium.

the La Sal Mountain Loop Road where it enters Castle Valley from Highway 128, Castle Rock, and the majority of slopes below Porcupine Rim are composed of the Moenkopi Formation. It is a brown, sandy shale and micaceous, silty sandstone with gypsum beds, which forms steep slopes with occasional ledges (Doelling, 1985). Above the Moenkopi is the Middle Triassic Chinle Formation, which also forms smooth slopes. The Chinle is composed of reddish-brown, silty, fine-grained sandstone, interbedded with considerable mudstone. Near the base of the unit is a poorly cemented gritstone (Doelling, 1985). This gritstone is visible on the slopes east of Castle Rock as a thin white to gray bed sloping up toward Adobe Mesa.

Capping these units are cliffs composed of the Upper Triassic Wingate Sandstone and Kayenta Formation. The Wingate Sandstone forms the massive cliffs of Porcupine Rim, Parriot Mesa, Castle Rock, and Adobe Mesa. It is composed of fine-grained, well-sorted sandstone which forms a dark-brown cliff. On top of the Wingate is the Kayenta Formation, a ledgy, step-like, lavender-gray, dark-brown sandstone. It caps many of the cliffs in the valley.

In the center of the eastern part of the valley, Round Mountain is composed of granodiorite porphyry that is similar to upper Tertiary age rocks in the La Sal Mountains to the east (M.L. Ross, verbal communication, June 16, 1992). The valley floor is covered by Quaternary alluvium eroded from the La Sal Mountains and lower valley slopes. Lower valley slopes are covered with talus and rock-fall material from the cliffs above. Talus and rock fall deposits overlie the Cutler, Moenkopi, and Chinle Formations in many areas.

EXPANSIVE AND GYPSIFEROUS SOIL AND ROCK

Expansive soil and rock in Castle Valley contain clay minerals capable of absorbing large quantities of water. As their moisture content changes, the clay minerals expand (water added) and contract (water removed) causing as much as a 10 percent change in soil volume (Sheldon and Prouty, 1979). The Moenkopi and Chinle Formations, and the soils derived from them, are the source of these expansive minerals (plate 1). As clay minerals expand when water is added, the expansion is both vertical and horizontal. This volume change may damage structures, roads, and utilities built on or buried in the expansive materials.

Clay soils may swell in two ways when wetted, either by absorption of water between clay particles or by incorporating water directly into the crystal lattice of individual clay minerals (figure 3). In both processes, the

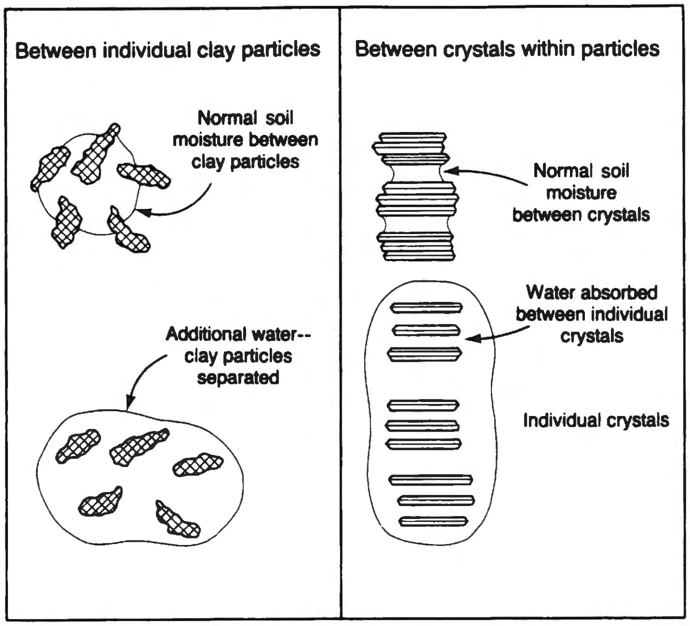

Figure 3. Schematic diagram of water-absorption process in clay minerals.

added water causes the soil or rock to expand. As the material dries, the loss of water causes shrinkage. The process of expanding and contracting churns and disturbs the surface of expansive deposits, giving some of them a characteristic puffy "popcorn" surface texture. This texture is a good field indicator of the presence of expansive soil and rock.

Problems commonly associated with expansive soil and rock are cracked foundations and other structural damage to buildings; heaving and cracking of roads, sidewalks, and driveways; damage to pipelines; and plugging of wastewater disposal drain fields. Single-family homes are particularly susceptible because foundation loads (1,500 to 2,500 lbs/ft^2 - 7,400 to 12,200 kg/m^2) may be less than the expansive pressures generated by the clays (3,000 to 11,200 lbs/ft^2 - 14,600 to 54,700 kg/m^2), making those structures subject to heave (Costa and Baker, 1981). Larger, heavier buildings are less susceptible to expansive soil problems.

Gypsiferous soil and rock are a very localized hazard in Castle Valley (plate 1). Those materials are subject to subsidence and collapse due to dissolution of gypsum, creating a loss of internal structure and volume within the deposit. Localized beds of gypsum are present in the Moenkopi Formation and in soils in the immediate vicinity of the gypsum beds. When water is introduced into the subsurface such as by irrigation for crops and landscaping or through wastewater disposal systems, gypsum may dissolve causing settlement. If thick gypsum beds are present, underground solution cavities may develop and collapse, causing sinkholes. Gypsum is also a weak material with low bearing strength, which can cause foundation problems for heavy structures. In addition, when gypsum weathers it forms sulfuric acid and sulfate, which may react with certain types of cement and weaken foundations.

Hazard-Reduction Measures

Drainage conditions affecting soil moisture content are important in areas of expansive soil and rock. Gutters and downspouts should direct water at least 10 feet (3 m) away from foundation slabs (Costa and Baker, 1981). Any vegetation that concentrates or draws water away from the soil should not be placed near foundations. Floors or walls near heating or cooling units should be insulated to prevent evaporation or condensation, which may cause local changes in soil moisture. House foundations can be strengthened by reinforcing the concrete with steel bars. Walls and floors can be supported on piles or footings placed in the soil to a depth below the active shrink/swell zone (Costa and Baker, 1981). Wide shoulders and good drainage along highways can minimize road damage. In highway foundations, a combination of hydrated lime, cement, and organic compounds can be added to road subgrade materials to stabilize the underlying soil (Costa and Baker, 1981). Wastewater disposal systems are not viable in areas of expansive soil and rock. The addition of water from disposal systems causes the soil to expand, clogging drainlines. Underground pipelines can be protected by backfilling around the pipe with sand and gravel, which increases permeability and permits expansion and contraction of the soil, without damage to the pipe.

Soil tests are required to determine the amount of gypsum present. If gypsum is present, the outer walls of foundations can be coated with impermeable membranes or bituminous coatings to protect them from deterioration. Special sulfate-resistant concrete can also be used. Because gypsum dissolves in water, runoff from roofs and gutters should be directed away from the structure. Landscaping close to the house should not include plants which require regular watering.

Scope of Recommended Site Investigations

Site investigations in areas of expansive and gypsiferous soil and rock (plate 1) should include a standard soil-foundation investigation to identify expansive clay or gypsum. If present, further specialized soil testing to determine clay mineralogy, expansive pressures, and gypsum content may be advisable to better understand the problem. The report should include recommendations on foundation design.

When building in an area of expansive soil or rock, additional costs for design and construction should be anticipated. A soil-foundation investigation may range in cost from $1,500 to $3,500 (1992 estimate). Additional costs in design and construction may be approximately 2 percent of the total building costs for a single-family home (J.R. Keaton; Sergent, Hauskins, and Beckwith; verbal communication, November, 1991). Though soil investigations and design modifications may seem costly, the cost is small when compared to that of repairing or replacing a structure.

ALLUVIAL-FAN FLOODING, STREAM FLOODING, AND DEBRIS FLOWS

Flooding in Castle Valley results from cloudburst storms and spring snowmelt. Cloudburst storms are the most common source of flood waters on alluvial fans; both cloudburst storms and spring snowmelt can cause flooding in Castle and Placer Creeks. The flooding potential of cloudburst rainstorms depends on numerous factors including: (1) the intensity or amount of rainfall per unit time, (2) the duration or length of time of rainfall, (3) the distribution of rainfall and direction storms move over a drainage basin, (4) soil characteristics, (5) antecedent (pre-existing) soil-moisture conditions, (6) vegetation conditions, (7) topography, and (8) drainage pattern (Lowe, 1990). Because many of these conditions are unknown until rain is falling on critical areas, the magnitude of flooding from a particular storm is difficult to predict. Snowmelt floods are characterized by high volume runoff, moderately high peak flows, and diurnal fluctuation in flow. They are more predictable because flood levels depend primarily on snow amounts in the mountains and temperature. Whether generated by cloudburst storms or snowmelt, three types of flooding may result: (1) alluvial-fan flooding, (2) stream flooding, and (3) debris flows.

Alluvial-Fan Flooding

Alluvial-fan flooding occurs with little advance warning and can be quite severe with unpredictable flow paths.

Flooding generally occurs as a result of cloudburst storms which drop large volumes of water in a short period of time. Storms generate high velocity flows that may occupy several different channels on the fan surface at once. Flood waters erode some channels, while depositing large volumes of sediment in others, making it difficult to predict flood paths on alluvial fans. Flood waters on alluvial fans usually contain large amounts of sediment, often including boulders and cobbles.

In Castle Valley, drainages on alluvial fans are generally incised at the apex of the fan and become shallower on lower parts of the fan. Where fans are deeply incised, flooding is contained in the channels. Because of this, these areas were excluded from the flood-hazard area. The hazard is greatest where drainages can not contain flood waters, and the water moves across the fan surface as sheet flow or in shallow channels. These areas are shown on plate 2.

Stream Flooding

Stream flooding in Castle and Placer Creeks is caused by cloudburst storms as well as by seasonal snowmelt. The primary cause is rapidly melting snow, usually from late April to early July. Flood waters are generally contained within the channels of Placer and Castle Creeks, which are incised to depths of 10 to 30 feet (3 to 10 m). Stream-flooding map designations (plate 2) are the boundaries of modern alluvium in the incised channels. Overbank flooding of areas outside the channels is most likely where depth of incision is least, or where the channel is obstructed and flow is constricted, such as at the culvert for main road over Castle Creek.

Debris Flows

Debris flows are mixtures of water, rock, soil, and organic material (70-90 percent solids by weight; Costa, 1984) that form a muddy slurry and flow downslope under gravity, commonly in surges or pulses. They generally remain confined to stream channels in mountainous areas, but may reach and deposit debris over large areas on alluvial fans at canyon mouths. Alluvial fans on the southwestern side of Castle Valley are particularly susceptible to debris-flow hazards (plate 2). This is because of the steep slopes below Porcupine Rim and the weathering characteristics of the bedrock (the Triassic Moenkopi, Chinle, and Wingate Formations) which provide unstable hillside debris.

Debris flows can form in at least two different ways: (1) heavy precipitation during cloudburst storms, and (2) directly from debris slides. In the La Sal Mountains and Castle Valley, cloudburst storms are common. Runoff from these storms can scour materials from the ground surface and stream channels, increasing the proportion of soil materials to water until the mixture becomes a debris flow. The size and frequency of debris-flow events generated by rainfall depend on several factors including the amount of loose material available for transport, the magnitude and frequency of the storms, the density and type of vegetative cover, and the moisture content of the soil (Campbell, 1975; Pack, 1985; Wieczorek, 1987).

Debris flows can also mobilize from debris slides. A debris slide is a type of landslide involving mainly coarse-grained debris, usually derived from colluvium. A debris flow may be generated when the debris slide reaches a stream, or when water content is increased by some other means until the moisture content is sufficient to cause viscous flow. Rapid melting of snow can increase water content in soils enough to cause debris slides and flows.

As the proportion of water to sediment increases with either the addition of more water or removal of sediment by deposition, debris flows become hyperconcentrated streamflows, commonly referred to as debris floods or mud floods. In hyperconcentrated streamflow, solids account for 40 to 70 percent of the material by weight (Costa, 1984). These streamflows can originate by progressive incorporation of materials into flood waters or dilution of debris flows (Waitt and others, 1983; Wieczorek and others, 1983). Much of the alluvial-fan flooding that takes place in Castle Valley damaging culverts, roads, and structures is most likely hyperconcentrated stream flow.

Hazard-Reduction Measures

Much of the flood damage to roads and culverts in Castle Valley is due to alluvial-fan flooding. This hazard is currently being reduced through drainage improvements such as larger culverts, gabions, and regrading of roads (Armstrong Consultants, Inc., 1988). However, these measures do not completely reduce the hazard on fan surfaces where channels are not deeply incised and are subject to sheet flow.

Methods for reducing alluvial-fan-flooding, stream-flooding, and debris-flow hazards and damage include: (1) avoidance, (2) drainage-basin improvement, (3) flow modification and detention, (4) floodproofing, and (5) flood-warning systems. Different methods or combinations of methods may be appropriate for individual drainages or types of development.

Alluvial-fan-flooding, stream-flooding, and debris-flow hazards may be reduced by avoiding areas at risk (source areas, stream channels, and alluvial fans) either permanently or at the time of imminent danger. Permanent avoidance is not possible in some areas, because existing development already occupies active alluvial fans and the flood plains along Placer and Castle Creeks. Permanent avoidance can be required for new development through zoning ordinances.

Channel modifications reduce erosion and improve the ability of the channel to pass debris downstream. Scour of unconsolidated material in stream beds and undercutting of unstable stream banks are two of the most important processes that contribute sediment to floods. Check dams (small debris- and water-retention structures in channels to prevent erosion by reducing velocity and causing deposition) are another method of reducing damage from flooding and debris flows. Stream beds may be stabilized by lining the channel. The potential for stream channels to pass flood waters and debris downstream can be improved by: (1) removal of channel irregularities, (2) enlargement of culverts combined with installation of upstream removable grates to prevent blockage, and (3) construction of flumes, baffles, deflection walls, and dikes (Jochim, 1986; Baldwin and others, 1987).

Structures crossing flood and debris-flow channels may be protected by: (1) bridges over channels having enough clearance to allow flood water or debris surges to pass underneath, (2) construction of debris sheds to allow debris flows to pass over structures, and (3) building structures to withstand flood water and debris-flow impact, burial, overtopping, and re-excavation (Hungr and others, 1987).

Defensive measures for debris flows in the deposition zone are designed to control both the areal extent of deposition and damage to any structures located there (Hungr and others, 1987). Defense measures include deflection devices, impact walls, and debris basins. Deflection devices are used to control direction and reduce the velocity of debris flows (Baldwin and others, 1987). Types of deflection devices include: (1) pier-supported deflection walls, (2) debris fences (a series of steel bars or cables placed horizontally at increasing elevations above the stream channel), (3) berms, (4) splitting-wedge walls (reinforced concrete wall in the shape of a "V" with the point facing uphill), and (5) gravity structures like gabions (hollow wicker-works or iron cylinders filled with earth) (Jochim, 1986; Baldwin and others, 1987).

Two types of debris basins, open and closed, are commonly employed to reduce debris-flow hazards. Both types are designed to constrain the area of debris deposition to predetermined limits laterally, upstream, or downstream (Hungr and others, 1987). Any suitable location along the lower part of the debris-flow path can be chosen to erect a barrier across the path and create a basin upstream. Open debris basins commonly have a basin-overflow spillway designed to direct water and excess material to a noncritical area or back into the stream channel. Open debris basins should be located where they utilize as much of the original natural deposition area as needed (Hungr and others, 1987).

Closed debris barriers and basins are provided with both straining outlets to pass water discharges and spillways to handle emergency debris overflows (Hungr and others, 1987). Closed debris barriers and basins can be located in the lower part of the transportation zone as well as in the deposition zone or on the alluvial fan (Hungr and others, 1987). Both types of debris basins require access for periodic removal of debris and maintenance.

Scope of Recommended Site Investigations

Site investigations in alluvial-fan-flooding, stream-flooding, and debris-flow hazard areas may include: (1) delineation of the most active alluvial-fan surfaces/segments and parts of the fan where channelized flow becomes sheet flow, (2) analysis of debris-flow potential based on the extent of debris slides, colluvium-filled slope concavities, and debris accumulation on slopes in the drainage, (3) examination of the stream channel to determine if it will supply debris, impede flow, or contain flows in the area of the proposed development, (4) analysis of existing upstream structures that might divert, deflect, or contain flows, and (5) recommendations concerning channel improvements, flow modification, catchment structures, direct protection structures, or floodproofing measures necessary to protect the proposed development. For critical facilities within alluvial-fan-flooding and debris-flow hazard areas, the storage capacity and design of any existing debris basins upstream from the site must be evaluated to ensure that they are strong enough to divert or contain the anticipated flood waters. Debris basins should be regularly maintained.

At present, predicting quantities of flow, extent of alluvial-fan flooding, and the volumes of debris flows is difficult at best, particularly in Castle Valley where few data on previous events are recorded. As a result, sizing of water-retention structures and debris basins should incorporate a considerable degree of conservatism to increase margins of safety.

COLLAPSIBLE SOILS

Collapsible soils are subject to volume reductions that can damage overlying structures. They are chiefly debris-flow, loess (wind-blown silt and fine sand), and alluvial-fan deposits. When wetted for the first time since deposition, collapsible soils lose the internal bonds holding them together in a process called hydrocompaction, causing the ground surface to subside or collapse. These soils are generally fine sands and silts held together by small amounts of clay (less than 12 percent). When the soil becomes saturated the clay bonds dissolve causing the soil to collapse. Collapsible soils are common in Utah, particularly in alluvial fans with shale in their source areas. The Moenkopi and Chinle Formations contain shale, and contribute sediments to alluvial fans on the northwest and southwest slopes of Castle Valley. Alluvial fans on the southwestern side of Castle Valley, that are mapped as debris-flow and alluvial-fan-flood hazard areas (plate 2), may also host collapsible soils.

Hazard-Reduction Measures

Although collapsible soils in Castle Valley are undocumented, the environment locally is favorable for their presence. Diagnostic field tests are not available to identify collapsible soils. Soil consolidation tests run in a laboratory are needed to determine their presence. If present, collapsible soils must be compacted, removed, or "collapsed" by presoaking. When the presence of collapsible soils is suspected, roof drainage and sprinkler systems should be kept away from structures to reduce potential damage. Wide shoulders and good drainage along highways can minimize road damage.

ROCK FALL

Rock falls occur along cliffs in Castle Valley. Since 1959, five rock falls on Porcupine Rim have been documented, four of these in the past six years (W.F. Case, Utah Geological Survey, verbal communication, November 25, 1991). As development advances higher on alluvial fans and slopes below cliffs, the risk from falling rocks will increase.

Rock falls originate when erosion and gravity dislodge rocks from cliffs or slopes. The most susceptible unit in Castle Valley is the Wingate Sandstone where outcrops are disrupted by bedding surfaces, joints, or other discontinuities that break rock into loose fragments, clasts, or slabs. Rocks in talus and cliffs may dislodge, fall onto steep slopes, and travel great distances by rolling, bouncing, and sliding. Runout distances for rock falls (plate 3) were determined by identifying and mapping rock-fall boulders and clasts visible on air photographs. The boundary of the rock-fall hazard areas on slopes below cliffs is based on the position of boulders on the photographs, with the top of the cliff being the source or upper boundary of the hazard area.

Primary causes of rock falls are weathering, freeze-thaw of water in outcrop discontinuities, and ground shaking during earthquakes. Keefer (1984) indicates that rock falls may occur in earthquakes as small as magnitude 4.0. In the August, 1988, San Rafael Swell earthquake (magnitude 5.3) near Castledale in central Utah, hundreds of rock falls occurred, temporarily obscuring the surrounding cliffs in clouds of dust (Case, 1988).

Rock falls present a hazard to structures and personal safety. In Grand County and Castle Valley, rock falls have blocked roadways and struck vehicles. Homes built on slopes below Porcupine Rim are particularly vulnerable (figure 4).

The primary factor in determining if an area is susceptible to rock falls is the presence of a source for the rocks. If there are no cliffs, outcrops, or rocks on a steep slope, the rock-fall hazard is negligible. The other major consideration is the distance and direction rocks will travel downslope.

Hazard-Reduction Measures

It is best to locate buildings outside of areas susceptible to rock falls. However, techniques are available for

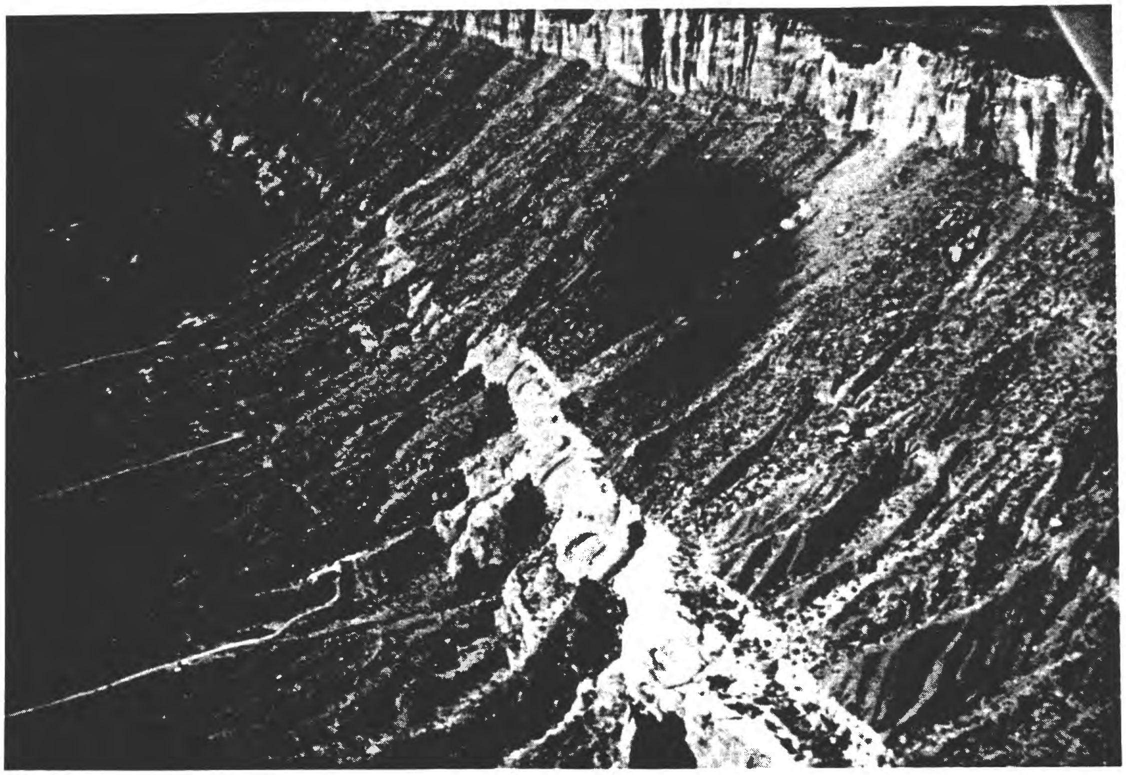

Figure 4. Rock fall from Porcupine Rim. Houses are visible in center of photo. Photo by W.F. Case.

reducing rock-fall hazards, including rock stabilization and removal or break-up of rock clasts. Deflection berms, slope benches, and rock-catch fences may all stop or at least slow down falling rocks. Structures may also be strengthened to withstand impact. Techniques for reducing landslide hazards including rock falls are described by Kockelman (1986). In areas where a rock-fall hazard is present but very low, disclosure of the hazard to landowners and residents with an acknowledgment on their part of the risk and a willingness to accept liability, may be acceptable at least for single-family residences.

Scope of Recommended Site Investigations

Site investigations in rock-fall hazard areas should define rock-fall sources and estimate runout paths and runout distances from each source in relation to the site. Rock-fall sources may be outcrops or individual clasts on a slope. Size, shape, depth of burial, and slope geometry are all factors to be considered in defining sources as well as runout path and distance. Computer models are available to simulate runout, but physical evidence such as extent of clast accumulations below sources, topography, damaged vegetation, and natural barriers are also important (Pfeiffer and Higgins, 1988).

SOIL SUBJECT TO PIPING AND EROSION

Soil susceptible to piping and erosion covers much of the floor of Castle Valley (plate 4). The soil consists of fine-grained Holocene-age alluvium (last 10,000 years), composed of sand, silt, and clay, and is at least 30-feet (10-m) deep where seen in exposures along Castle Creek.

Piping is subsurface erosion by ground water that moves along permeable, noncohesive layers in unconsolidated materials and exits at a free face that intersects the layer (figure 5). Removal of fine-grained particles (silt and clay) by this process creates voids that act as minute channels which further direct the movement of water. As channels enlarge, water moving through the voids increases velocity and removes more material forming a "pipe." The pipe becomes a preferred avenue for ground-water flow and enlarges as more water is intercepted. Increasing the size of the pipe removes support from the walls and roof, causing eventual collapse. Sinkholes form at the surface above the pipes, directing even more surface water into them. Eventually, total collapse forms a gully that concentrates erosion along the line of collapse features.

Piping is common in arid climates where fine-grained, uncemented Holocene-age alluvium is incised by streams. When water is introduced near incised streams, it soaks into the subsurface until reaching layers that conduct the water to a free face such as the stream bank.

Characteristics that make soil susceptible to piping also make it subject to rapid erosion. Erosion is the removal of material, particularly unconsolidated deposits, by running water (figure 6). In Castle Valley, sheetwash erosion during cloudburst storms is common, as is vertical and lateral cutting of stream channels and banks. During cloudbursts, sheetwash can affect talus slopes and alluvial fans.

Piping and erosion can damage roads, bridges, culverts, and structures. In Castle Valley, roads are the most susceptible because they parallel and cross-cut incised drainages. Roads can contribute to piping and erosion by

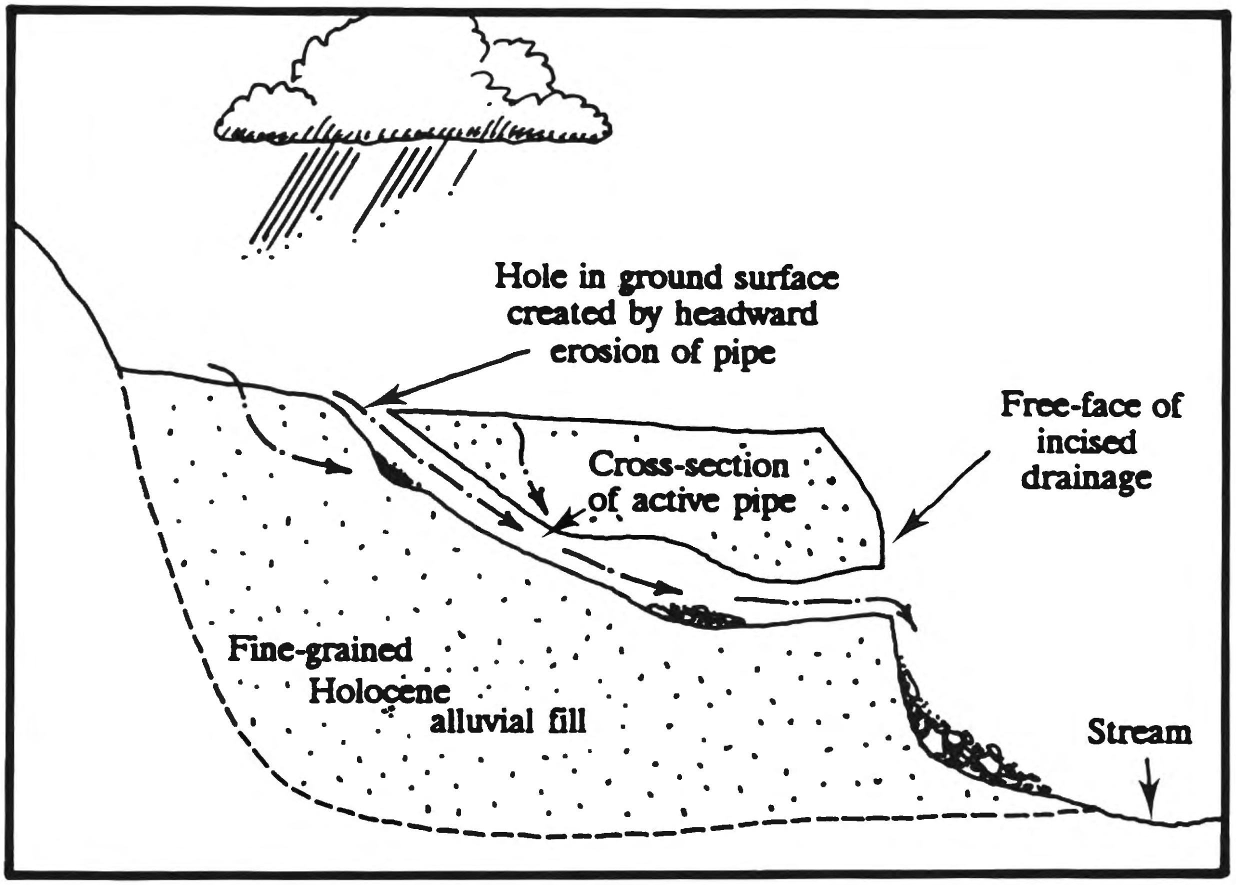

Figure 5. Schematic cross-section of pipe in Holocene alluvium.

altering natural runoff and channeling water. Channelized water can increase infiltration and the potential for pipes to develop, as well as erosion. Earthfill structures such as those impounding stock ponds on the southeastern side of Castle Valley may also be susceptible to piping.

Hazard-Reduction Measures

The best method of reducing piping and erosion hazards is to control drainage. Around culverts and bridge abutments, drainage should be channelized and directed through or under the structure. Diversion of natural drainage or site grading must be done carefully to avoid initiating or accelerating piping or erosion. Erosion can be reduced by lining canals and drainages with concrete, riprap, or gabions.

Figure 6. Erosion of unconsolidated sands and silts along La Sal Loop Road in Castle Valley. Depth of erosion is approximately 10 feet (3m).

Recommendations for Site Development

For development in areas subject to piping and erosion, construction design should avoid concentrating runoff. Concentrating runoff increases the potential for piping and erosion to occur. Examples of areas where damage can occur are around existing drainages, and where drainage from streets, gutters, and runoff from sprinkler systems collects. Irrigation ditches in susceptible areas should be lined and maintained. Landscape designs should distribute runoff away from structures and disperse flows.

OTHER HAZARDS

In Castle Valley there are three other hazards that could effect development: (1) radon, (2) the potential for contamination of culinary ground water by effluent from individual wastewater disposal systems, and (3) earthquakes. These hazards have not been mapped or documented in Castle Valley, but geologic conditions are favorable for their presence.

Indoor Radon

Radon is a naturally occurring radioactive gas emitted by certain geologic materials. When inhaled, radon decay products are a significant cause of lung cancer. Radon in sufficient indoor concentrations to represent a health hazard has been found in parts of Utah. The U.S. Environmental Protection Agency (EPA) estimates that between 8,000 and 40,000 Americans will die each year from lung cancer caused by long-term radon inhalation (Schmidt and others, 1990).

Radon is an odorless, tasteless, and colorless radioactive gas which forms as a product in the radioactive decay of uranium. Radon has a half-life of about four days (Sprinkel and Solomon, 1990). Radon concentration is measured in picocuries per liter of air (pCi/L); a picocurie is the decay of about 2 radon atoms per minute (Sprinkel and Solomon, 1990). Most buildings in the United States contain small amounts of radon, however, these concentrations are usually less than 3 Pci/L. The average indoor-radon concentration is usually about 1 Pci/L (Sprinkel and Solomon, 1990). Long-term exposure to these levels is considered a low health risk to the general population; higher concentrations pose greater risk (figure 7).

Uranium, and thus radon, is found in almost all rock and soil in minute concentrations. Because radon is an inert gas, it is very mobile. It can move with air or can be dissolved in water and travel through any opening in soil and rock. Uranium-enriched rocks such as granite, metamorphic rocks, black shales, and some volcanic rocks are the most common sources for radon gas (Sprinkel and Solomon, 1990). When found at the surface or beneath well-drained, porous, and permeable soil, these rocks can transmit radon gas into overlying structures. Other sources of radon are uranium mines and tailings from uranium mills. These latter two sources are referred to as point sources, and are more localized and have a much higher radon concentration.

The radon hazard in Castle Valley is presently undetermined. However, the sediments there are such that there could be a localized potential for radon. The granodiorite porphyry in the La Sal Mountains, the Moenkopi

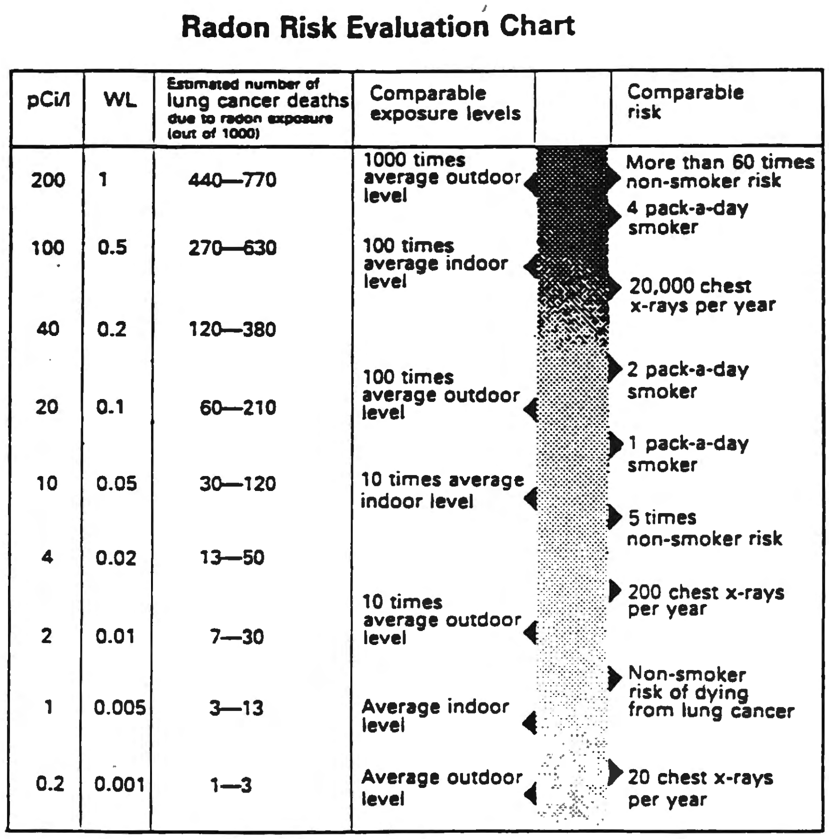

Figure 7. Radon risk evaluation chart. From EPA (1986).

Formation, and the Cutler Formation are a potential radon sources (B.D. Black, verbal communication, July 1, 1992). Igneous crystalline rocks are typically enriched in uranium, the major source of radon. Streams draining the La Sal Mountains, in particular Castle and Placer Creeks, transport gravel and sand derived from this porphyry into Castle Valley. Much of the valley floor is covered by these alluvial sediments. Campbell and others (1982) indicate that areas of the Moenkopi and Cutler Formations are enriched in uranium, making them potential sources for radon gas.

In general, most of the alluvium from Castle and Placer Creeks is coarse grained (fine sand to gravel, cobbles, and boulders). Radon moves readily upward to the surface in such permeable deposits. Shallow ground water can reduce the potential for elevated indoor radon levels by transporting radon with ground water rather than with soil gas. Thus less radon is available to enter overlying structures. The depth to ground water in Castle Valley is variable, and in areas with ground water deeper than 30 feet (10 m), the potential for radon movement to the ground surface is high. Faults also act as pathways for the movement of radon gas. The northeastern and southwestern margins of Castle Valley are bounded by faults formed during collapse of overlying sediments due to dissolution of the salt diapir beneath the valley. Along these faults higher concentrations of radon may be present.

The method of construction and type of structure also affects indoor radon concentrations. With the trend toward more energy efficient construction, buildings have much less air circulation and may trap radon gas entering the structure. Older structures are often not as well constructed and air circulation is better, allowing indoor radon to exit, however, foundation cracks and poorly sealed basements may act as paths for radon to continually enter the structure. The greatest radon concentrations are commonly in basements or crawl spaces where radon can enter the structure from the ground surface. Cracks in foundations, leaky seals around pipes which pass through foundation slabs, floor drains, and the water supply are the most common pathways for radon to enter a home. Radon can be concentrated in ground water that fills air spaces between soil particles. If radon contaminated aquifers are used for culinary water, radon can enter the home when faucets and showers are used.

Hazard-Reduction Measures

Individuals can acquire short term (20-30 days) radon test kits from most hardware stores for around $25. For the most accurate assessment of long-term radon exposure, a year-long test should be conducted. One-year test kits are not readily available, however, a list of vendors certified to sell them can be obtained from the Utah Department of Environmental Quality in Salt Lake City (appendix). These test kits are placed in the home for a period of one month to a year. The longer test periods are the most diagnostic of the long-term indoor-radon exposure level because changes in atmospheric pressure, temperature, and moisture can affect radon concentrations.

High indoor-radon levels can be reduced by a variety of methods. Short-term actions with minimum expense include discouraging smoking in your home (radioactive isotopes formed from radon decay attach to smoke particles which are then inhaled), and spending less time in areas with high radon concentrations such as basements. Increasing ventilation by opening windows or turning on fans may also reduce radon concentrations.

Determining the proper long-term radon-reduction methods requires identification of radon entry paths and driving forces, and testing to select the most effective radon-reduction measure. Longer-term radon-reduction measures include sealing openings in the foundation to prevent radon entry and soil ventilation to remove radon-contaminated soil gas and vent it outdoors. Soil ventilation methods include subslab suction, where pipes are inserted through the floor slab into a layer of crushed rock between the foundation and soil. A fan removes radon-contaminated soil gas from beneath the slab into the pipes, which pass through the house to the roof and release it into the outdoor air (U.S. Environmental Protection Agency, 1986). Air cleaning (with air filtration systems) will remove the radon decay products, which are solid particles, from the air after the entry of radon gas into the house (Sprinkle and Solomon, 1990).

New homes can incorporate design to prevent the buildup of radon gas. Most designs are similar to methods used to retrofit existing homes. They include: (1) preventing radon from entering structures by sealing around pipes penetrating basement floor and walls, sealing cracks in walls and floor, and (2) diverting the radon from entering the house by using sub-slab ventilation (Osborne, 1988). Using these methods in new homes can add from $1,300 to $2,000 to the cost of construction (U.S. Environmental Protection Agency, 1986). Detailed descriptions of these construction methods are available from the U. S. Environmental Protection Agency.

Recommendations for Site Development

The radon hazard in Castle Valley is unknown. Extensive indoor testing of existing homes is needed to determine if a hazard is present. For new homes, the potential for radon may be assessed through site investigations to characterize the local geology, depth to ground water, and permeability of the deposits. The hazard potential is greatest in areas of deep ground water, permeable soils, and either shale or gravel containing clasts of La Sal Mountain porphyry. If a high radon potential is found, radon-resistant construction is recommended.

Ground-Water Contamination

As Castle Valley has no municipal sewer system, each home has an individual wastewater disposal system. Currently, much of the culinary water in Castle Valley is obtained from domestic wells in shallow, unconfined alluvial aquifers. Records from the Utah Division of Water Rights indicate that many of these wells are less than 100-feet deep. State regulations require that there be a 1500-foot protection zone around such shallow wells, within which wastewater disposal systems cannot be installed. An exception to this regulation is made if a clay layer isolating the water source from the soils above is present. The clay is thought to act as a confining layer and prevents effluent from contaminating the well.

The basin-fill sediments in Castle Valley are generally sand and silt with some discontinuous clay and gravel lenses. Although these clay lenses are present in some wells, they do not form a continous confining layer. As development increases in Castle Valley, the potential for contamination of shallow culinary wells by wastewater effluent will also increase. As more homes are built, the number of individual disposal systems increase, concentrating effluent and increasing the potential for aquifer contamination. The current practice of platting five-acre lots should reduce, but not eliminate, the potential for aquifer contamination. More information on the hydrology of the unconfined aquifers which supply culinary water in Castle Valley is needed to assess the extent of the potential problem. The Utah Division of Water Rights (appendix B) is currently in the process of sampling wells in Castle Valley to determine water quality and quantity. This project will set the groundwork for a more detailed study by the U.S. Geological Survey to be conducted in the next few years. Potential aquifer contamination problems can be reduced by developing culinary water sources upgradient from wastewater disposal systems, or by collecting and treating wastewater, or by installing a community-wide culinary water system.

Earthquake Hazards

The region is one of low historical earthquake activity. Wong and Humphery (1989) studied the seismicity in the Castle Valley-Moab region and determined that, in general, earthquakes in the Colorado Plateau are small to moderate magnitude, and occur infrequently. The strongest recorded earthquake in the area occurred on February 1, 1967 (magnitude 3.8) near Upheaval Dome in west-central Grand County.

The closest major fault with a possible tectonic component, capable of causing strong ground shaking, is the Moab fault, located approximately 12 miles (19 km) to the southwest. Movement during Quaternary time (last 1.6 million years) is suspected on this fault. Although a tectonic component has been suggested, salt dissolution beneath Moab and Spanish Valleys is the major source of movement on the fault (Hecker, in preparation). Other faults with possible Quaternary displacement are found bounding valleys in the area, including Castle Valley, but all are thought to result from dissolution of underlying salt and are probably not capable of causing large earthquakes with strong ground motion (Hecker, in preparation).

Ground Shaking

The potential for strong ground shaking due to earthquakes is low, with peak ground acceleration on rock with a 10 percent probability of being exceeded in 50 years of less than .05 g (Algermissen and others, 1990). The 1991 Uniform Building Code (UBC; International Conference of Building Officials, 1991) designates this area as seismic zone 1, the zone of least earthquake hazard in Utah.

Other Earthquake and Related Hazards

The surface-fault-rupture hazard is low because no active faults with evidence for Holocene or late Pleistocene activity are present in Castle Valley. However, in the southeastern part of Castle Valley there is a fault of suspected Quaternary age (plate 3). This fault could have a tectonic origin, but is most likely related to salt dissolution beneath Castle Valley. Because of these uncertainties, we do not know if surface rupture is instantaneous, as in a earthquake, or gradual. The likely amount of rupture and width of zone of deformation are also unknown. Although improbable during 50-100-year time frames, surface rupture is possible on this fault.

In addition, a sinkhole at the northwest end of the fault (plate 3) indicates dissolution or piping is occurring along the fault zone. Other such sinkholes may develop elsewhere along the fault in the future, particularly if water is introduced into the zone.

Liquefaction potential is low because of low earthquake activity, and deep ground water. Rock falls may be triggered by earthquakes of magnitude 4.0 or greater (Keefer, 1984) but even earthquakes of this small magnitude are rare in this area.

USES OF MAPS IN LAND-USE PLANNING

Plates 1-4 can be used in a variety of ways by residents, developers, and local governments in Castle Valley. One use is for general information to show where hazards most likely exist and what may be expected should a hazards-event occur. In this way, homeowners and residents can individually assess their exposure to hazards and take whatever action they deem appropriate. Maps may also be used in real-estate disclosure, where sellers of homes in hazard areas would disclose to buyers the possible existence of hazards.

Maps which depict non-life threatening hazards (plates 1 and 4) may be used to alert landowners and home builders to potential problems where it is in their best interest to perform studies prior to construction to define hazards and design structures and landscapes appropriately. Maps depicting life-threatening hazards (plates 2 and 3) may be used for emergency response planning, or more comprehensive land-use planning to protect life safety. This more comprehensive level of planning may include adoption of any or all of the maps in local government ordinances to show areas where site-specific investigations addressing hazards prior to development are required. Those site-specific studies should, in addition to evaluating the hazards, recommend hazard-reduction measures. To be effective, such ordinances must stipulate that the studies be prepared by qualified professionals (engineering geologists, geotechnical engineers, hydrologists), and be reviewed by qualified professionals acting on behalf of government, prior to planning commission approval for all construction in the hazard area.

Because of the relatively small scale of the maps, the possibility exists that some small hazard areas are not shown; complete hazard studies are therefore recommended for critical facilities (essential, hazardous, and special occupancy facilities as defined in the Uniform Building Code, 1991 edition, Table 23-K, p. 185; for example, hospitals, schools, water tanks, fire stations), even outside the mapped hazard areas.

Acknowledgments

Don Mabey of the Castle Valley Planning Commission has been a valuable source of information and suggestions. G.E. Christenson and W.R. Lund of UGS provided technical assistance and critically reviewed the text. Mike Lowe of UGS provided his text concerning geologic hazards in Davis County, Utah, which served as the model for this study. P.A. Pearthree of the Arizona Geological Survey provided information concerning hazards mapping on alluvial fans.

GLOSSARY

Alluvium - a general term for clay, sand, gravel, or similar unconsolidated sedimentary material deposited by a stream.

Alluvial fan - a low, outspread, relatively flat to gently sloping mass of loose rock material, shaped like an open fan or segment of a cone, and made by a stream where it runs out onto a level plain or meets a slower stream.

Bedding - the arrangement of a sedimentary rock in beds or layers of varying thickness and character.

Collapsible soil (hydrocompaction) - loose, dry, low-density soil that decreases in volume or collapses when saturated for the first time since deposition.

Colluvium - a general term applied to any loose, unconsolidated mass of soil material, usually at the foot of a slope or cliff, and brought there chiefly by gravity.

Colorado Plateau physiographic province - area of southeastern Utah and adjacent states consisting of generally flat-laying sedimentary rocks, characterized by plateaus, mesas, and deep canyons.

Conglomerate - a coarse-grained sedimentary rock, composed of rounded to subangular larger fragments set in a matrix of sand or silt.

Debris flow - relatively rapid, viscous flow of mixtures of water and predominantly coarse-grained surficial material.

Diapir - a dome or anticlinal fold which pierces overlying rocks which have been ruptured by the squeezing upward of a plastic core material, typically salt.

Dip - the angle that a bedding plane makes with the horizontal.

Fault - a break in the earth along which movement occurs.

Flood plain - an area adjoining a body of water or natural stream that has been or may be covered by flood water.

Formation (geologic) - a rock unit consisting of distinctive features/rock types separate from units above and below.

Ground shaking - the shaking or vibration of the ground during an earthquake.

Gypsum - a mineral composed of hydrated calcium sulfate. A common mineral of evaporites.

Igneous - a rock or mineral that solidified from molten or partly molten material, i.e., from magma. Igneous rocks are one of the three main classes into which all rocks are divided (igneous, metamorphic, sedimentary).

Joints - a fracture or parting in a rock without displacement.

Montmorillonite - a clay characterized by expansion upon wetting and shrinking upon drying.

Permeability - the capacity of a porous rock or soil to transmit a fluid.

Picocurie - unit of measurement of radioactivity. Picocuries per liter is a common unit of measurement of the concentration of radon in air.

Piping - a weak incoherent layer in unconsolidated deposits that acts as a channel directing the movement of water. As the layer becomes saturated it conducts water to a free face (cliff or stream bank) that intersects the layer, and material exits out a "pipe" formed in the free face.

Radon - the only radioactive element which is a gas.

Soil ventilation (radon) - a method to prevent the movement of radon from soil into a house. Soil gas is drawn or blown away from the house before it can enter.

Solution - geologic the conversion of rock from solid to liquid state by its combination with a liquid, usually water.

Talus - rock fragments of any size or shape (usually coarse and angular) derived from and lying at the base of a cliff or very steep, rocky slope.

Weathering - a group of processes, such as the chemical action of air, rain water, and plants and the mechanical action of temperature changes which cause rock to decay and crumble into soil.

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APPENDIX

APPENDIX A

GEOLOGIC TIME SCALE

Subdivisions of Geologic Time			Apparent Ages (millions of years before present)
Eras	Periods	Epochs	
CENOZOIC	Quaternary	(Recent) Holocene	.01
		Pleistocene	1.6
	Tertiary	Pliocene	5.3
		Miocene	23.7
		Oligocene	36.6
		Eocene	57.8
		Paleocene	66.4
MESOZOIC	Cretaceous		144
	Jurassic		208
	Triassic		245
PALEOZOIC	Permian		286
	Pennsylvanian (Upper Carboniferous)		320
	Mississippian (Lower Carboniferous)		360
	Devonian		408
	Silurian		438
	Ordovician		505
	Cambrian		570
PRECAMBRIAN			

APPENDIX B

AGENCIES PROVIDING GEOLOGIC/HAZARD INFORMATION

Utah Geological Survey
2363 South Foothill Drive
Salt Lake City, Utah 84109
(801) 467-7970

Geologic information concerning engineering geology, geologic mapping, and economic geology. Applied geology section conducts local and regional engineering geology studies.

Utah Division of Water Rights
1636 North Temple
Salt Lake City, Utah 84116
(801) 538-7240

Technical publications concerning local and regional water resources. Publications contain information on water source, amounts, and quality, more locally oriented than U.S. Geological Survey Water Resources publications.

Grand County Planning Commission
County Building Inspector
121 East Center Street
Moab, Utah 84532
(801) 259-7839

Information on current county development and building regulations.

Southeastern Utah District Health Department
471 South Main Street
Moab, Utah 84532
Sanitarian
(801) 259-5602

Information on current Health Department reg- ulations concerning wastewater disposal systems.

Department of Environmental Quality
Utah Division of Radiation Control
288 North 1460 West
Salt Lake City, Utah 84114-4850
(801) 538-6734

Radon test kits and radon remediation information.

Utah Division of Comprehensive Emergency Management
1110 State Office Building
Salt Lake City, Utah 84114
(801) 538-3400

Provides information concerning hazards preparedness, mitigation, and regulations.

ASCS Aerial Photography Field Office
2222 West 2300 South
Salt Lake City, Utah 84119
(801) 524-5856

Agency sells air photos covering much of Utah and much of the western U.S.

U.S. Soil Conservation Service (SCS)
Price Field Office
350 North 400 East
Price, Utah 84501
(801) 637-0041

District Conservationist Regional and local soil surveys. Surveys contain information on soil type, description, engineering properties, and agricultural uses.

U.S. Bureau of Land Management
Moab District Office
82 Dogwood Avenue
Moab, Utah 84532
(801) 259-6111

Ownership and management of federal lands, knowledge of geology, water resources, and vegetation on lands under their jurisdiction.

U.S. Geological Survey
Earth Science Information Center
125 South State
Salt Lake City, Utah 84138
(801) 524-5652

Topographic and geologic maps, and related publications.

U.S. Geological Survey Water Resources Division
Investigations Section
1745 West 1700 South
Salt Lake City, Utah 84104
(801) 524-5654

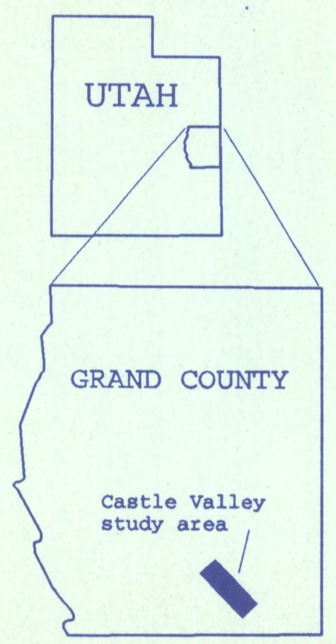
Technical publications on local and regional water resources such as source, availability, and quality of water for a given area (e.g., Moab-Spanish Valley, Grand County).

EXPANSIVE AND GYPSIFEROUS SOIL AND ROCK IN CASTLE VALLEY, GRAND COUNTY, UTAH

Utah Geological Survey
Open-File Report 238
Plate 1

by

William E. Mulvey



SCALE 1:24 000

CONTOUR INTERVAL 40 FEET

Base map from USGS 1:24,000 scale topographic maps of Big Bend, Warner Lake, Fisher Towers, and Rill Creek.

Explanation

Expansive and gypsiferous soil and rock.

Hazard map based on unpublished geologic mapping by M.L. Ross and H.H. Doelling.

DISCUSSION

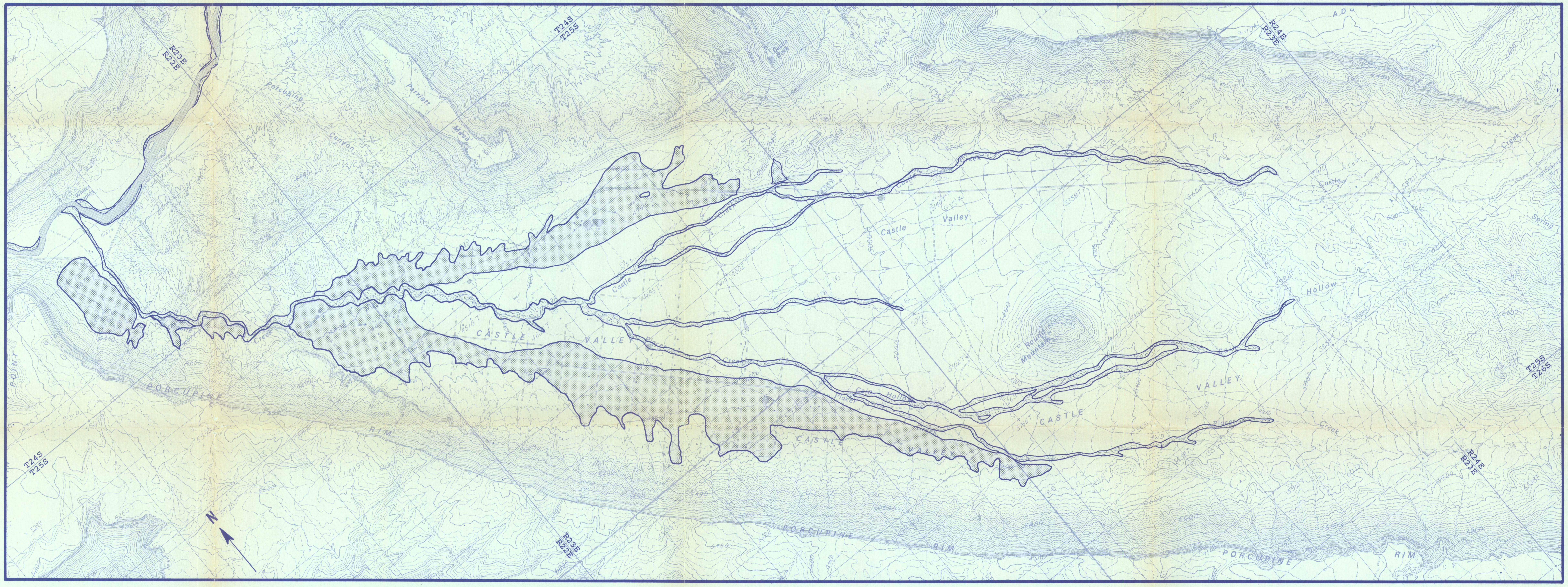
Expansive soil and rock in Castle Valley contains clay minerals capable of absorbing large quantities of water. The Triassic-age Moenkopi and Chinle Formations, and the soil derived from them, are the source of these expansive minerals. As moisture content changes, the clay minerals expand and contract, causing as much as a 10 percent change in volume. When clay minerals expand due to the addition of water, the expansion can be vertical and horizontal.

Problems commonly associated with expansive soil and rock are cracked foundations and severe structural damage; heaving and cracking of roads, sidewalks, and driveways; damage to pipelines; and plugging of wastewater disposal system drain fields. Single-family homes are particularly susceptible because foundation loads (1,500 to 2,500 lbs/ft^2 / 5858 to 12,205 kg/m^2) may be less than expansive pressures from clays (3,000 to 11,200 lbs/ft^2 / 14,646 to 54,678 kg/m^2), making structures subject to heave. Larger, heavier buildings are less susceptible.

Gypsiferous soil and rock are subject to subsidence and collapse due to the dissolution of gypsum, creating a loss of internal structure and volume within the deposit. Gypsum is present in localized beds in the Moenkopi Formation and soils in the immediate vicinity of the beds.

When water is introduced to gypsiferous soil or rock, such as by irrigation for crops and landscaping or wastewater disposal systems, gypsum soil grains may dissolve causing settlement. If thick gypsum beds are present, underground solution cavities may develop and collapse, causing sinkholes. Gypsum is also a weak material with low bearing strength, which can cause problems for heavy structures. In addition, when gypsum weathers it forms sulfuric acid and sulfate, which may react with certain types of cement and weaken foundations.

This map is designed to show potential hazard areas for planning purposes only. In mapped hazard areas site-specific studies are needed to evaluate the hazard and, if necessary, recommend hazard-reduction measures. The studies must be prepared by qualified professionals (engineering geologists, geotechnical engineers, hydrologists). Because of the relatively small scale of the maps (1:24,000), the possibility exists that some small hazard areas are not shown; studies are therefore recommended for critical facilities even outside the hazard areas.

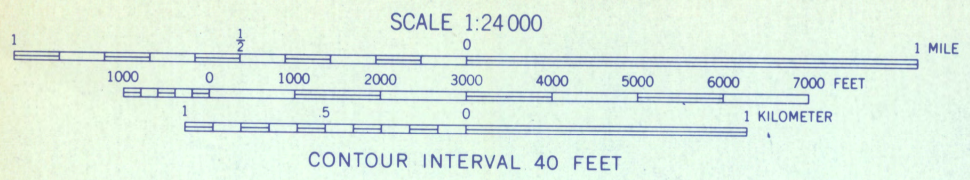


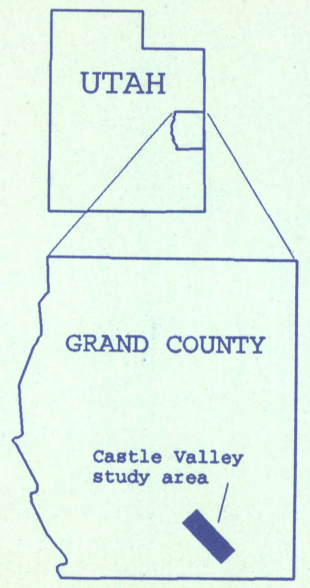
ALLUVIAL-FAN FLOODING, STREAM FLOODING, DEBRIS-FLOW HAZARDS, AND COLLAPSIBLE SOIL IN CASTLE VALLEY, GRAND COUNTY, UTAH

Utah Geological Survey
Open-File Report 238
Plate 2

By

William E. Mulvey





Explanation

Alluvial-fan/debris-flow-flood-hazard areas and collapsible soil.

Stream-flooding-hazard areas.

Hazard map based on unpublished geologic mapping by M.L. Ross and H.H. Doelling.

Base map from USGS 1:24,000 scale topographic maps of Big Bend, Warner Lake, Fisher Towers, and Rill Creek.

DISCUSSION

Flooding in Castle Valley results from cloudburst storms and spring snowmelt. Localized, high-intensity, convective-type thunderstorms centered over tributary areas are most effective in generating alluvial-fan flooding, stream flooding, and debris flows in areas like Castle Valley. Such storms, which last from a few minutes to several hours, generally occur between mid-April and September. Cloudburst thunderstorms are generally characterized by high peaks, high velocity, short duration, and small volume of runoff. The flooding potential of cloudburst rainstorms is dependent upon many factors including: 1) the intensity or amount of rainfall per unit time, 2) the duration or length of time of rainfall, 3) the distribution of rainfall and direction of storm movement over a drainage basin, 4) soil characteristics, 5) antecedent soil-moisture conditions, 6) vegetation conditions, 7) topography, and 8) drainage pattern. Because many of these conditions are generally not known until rain is actually falling on critical areas, the magnitude of flooding from a given cloudburst storm is difficult to predict. Snowmelt floods are characterized by large volume runoff, moderately high peak flows, and marked diurnal fluctuation in flow. They are somewhat predictable because flood levels depend primarily on the volumes of snow in the mountains and temperature. Whether generated by cloudburst storms or snowmelt, three types of flooding may result: (1) alluvial-fan flooding, (2) stream flooding, and (3) debris flows.

Alluvial-fan flooding occurs with little advance warning and can be quite severe and damaging with unpredictable flow paths. Cloudburst storms cause most alluvial-fan flooding, generating high velocity flows that may occupy several different channels on the fan surface at once. These floods can erode some channels and deposit large volumes of sediment in others. Flood waters on alluvial fans can contain large amounts of sediment as suspended and bed loads, including boulders and cobbles.

As with alluvial-fan flooding, stream flooding in Castle and Placer Creeks is caused by cloudbursts as well as seasonal snow- melt. However, the primary cause is rapidly melting snow, usually from late April to early July. Snowmelt floods are characterized by large volume runoff, moderately high peak flows, and marked diurnal fluctuation in flow. They are somewhat predictable because flood levels depend primarily on the volumes of snow in the mountains and temperature. Flood waters are generally contained within the channels of Placer and Castle Creeks, which are incised to depths of 10 to 30 feet (3 to 10 meters).

Debris flows are mixtures of water, rock, soil, and organic material (70-90 percent solids by weight; Costa, 1984) that form a muddy slurry much like wet concrete, and flow downslope due to gravity, commonly in surges or pulses. They generally remain confined to perennial or ephemeral stream channels in mountainous areas, but may reach and deposit debris over large areas on alluvial fans at and beyond canyon or drainage mouths.

Debris flows can form in at least two different ways: (1) heavy precipitation during cloudburst storms, and (2) directly from debris slides. In the La Sal Mountains and Castle Valley, cloudburst rainstorms are common. Runoff from these storms can scour materials from the ground surface and stream channels, increasing the proportion of soil materials to water until the mixture becomes a debris flow. The size and frequency of debris-flow events generated by rainfall depend on several factors including the amount of loose material available for transport, the magnitude and frequency of the storms, the density and type of vegetative cover, and the moisture content of the soil.

Debris flows also mobilize from debris slides. A debris slide is a type of landslide involving predominantly coarse-grained debris, chiefly colluvium. A debris flow may be generated when the debris slide reaches a stream, or when the water content is increased by some other means until sufficient to flow. Rapid melting of snow during the spring can also increase water content in soils enough to cause debris slides and flows.

Collapsible soils are subject to volume reductions that can damage overlying structures. They are chiefly debris-flow, loess, and alluvial-fan deposits. When wetted for the first time following deposition, collapsible soils lose the internal bonds holding them together, causing the ground surface to subside or collapse. Alluvial fans on the southwestern side of Castle Valley, that are subject to and mapped as debris-flow and alluvial-fan-flood-hazard areas can also be an environment favorable for collapsible soils. Collapsible soils are common in Utah, particularly in alluvial fans with shale in their source areas. The Moenkopi and Chinle Formations contain shale, and contribute sediments to alluvial fans in southwestern Castle Valley.

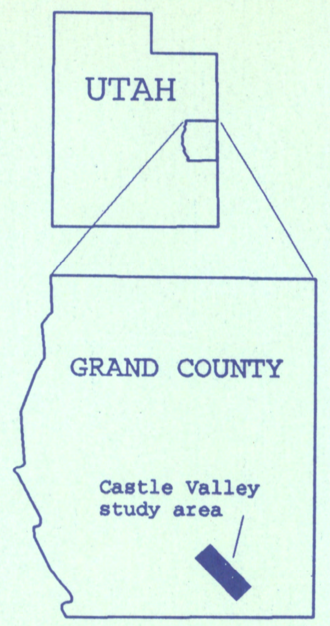
This hazard map shows areas where alluvial-fan-flooding, stream-flooding, and debris-flow hazards and collapsible soils may occur. The map is designed to show potential hazard areas for planning purposes only. In mapped hazard areas, site-specific studies are needed to evaluate hazards and, if necessary, recommend hazard-reduction measures. The studies must be prepared by qualified professionals (engineering geologists, geotechnical engineers, hydrologists). Because of the relatively small scale of the maps (1:24,000), the possibility exists that some small hazard areas are not shown; studies are therefore recommended for critical facilities even outside the hazard areas.

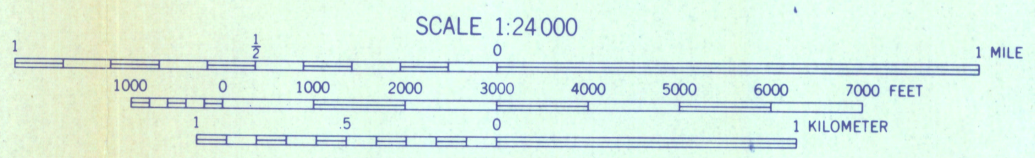
ROCK-FALL AND SURFACE-FAULT-RUPTURE HAZARDS IN CASTLE VALLEY, GRAND COUNTY, UTAH

Utah Geological Survey
Open-File Report 238
Plate 3

By

William E. Mulvey





CONTOUR INTERVAL 40 FEET

Hazard map based on unpublished geologic mapping by M.L. Ross and H.H. Doelling.

Base map from USGS 1:24,000-scale topographic maps of Big Bend, Werner Lake, Fisher Towers, and Rill Creek.

Explanation

Rock-fall-hazard areas.

Area of possible surface fault rupture (bar and ball on downthrown side of fault) and sinkhole formation.

Sinkhole.

DISCUSSION

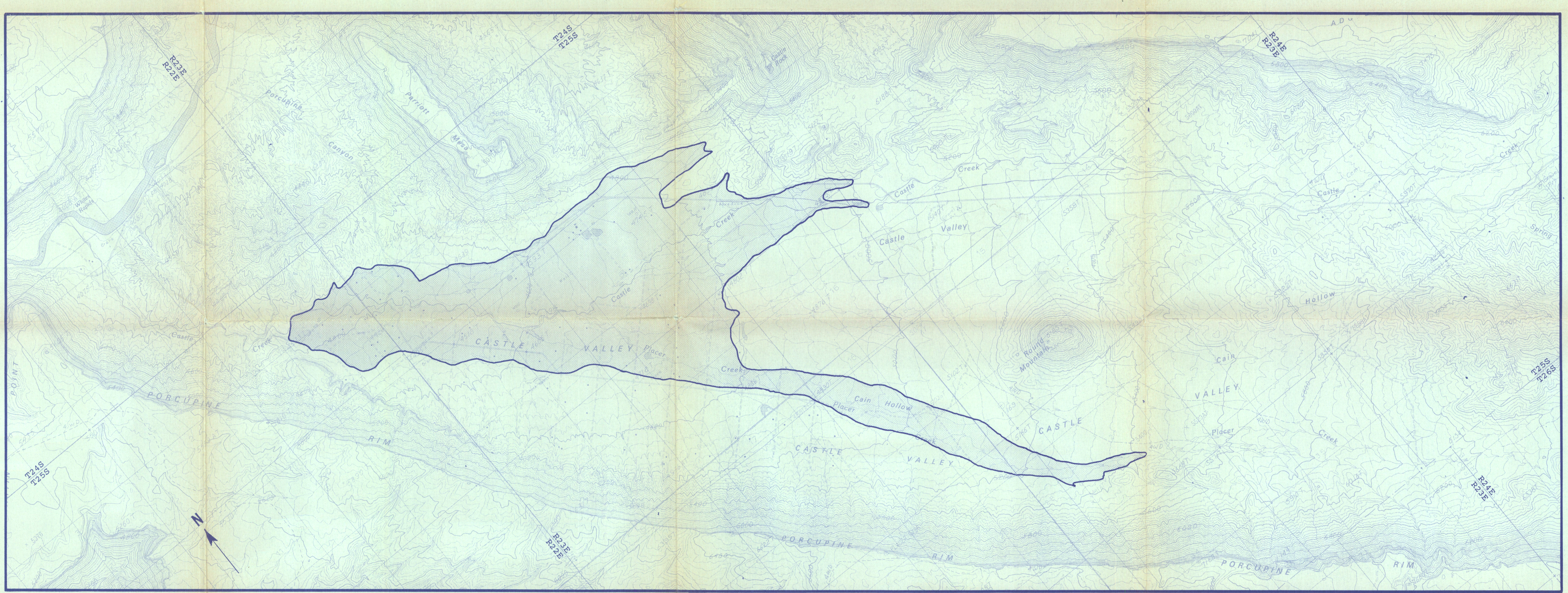
Rock falls originate when erosion and gravity dislodge rocks from cliffs or slopes. In Castle Valley, cliffs of Triassic-age Wingate Sandstone are the most common rock-fall source. The most susceptible cliffs are those with outcrops broken by bedding surfaces, joints, or other discontinuities that break rock into loose fragments, clasts, or slabs. Rocks in talus and cliffs may dislodge, fall onto steep slopes, and travel great distances by rolling, bouncing, and sliding.

Weathering and freeze-thaw in outcrop discontinuities is responsible for triggering most rock falls. In addition, rock falls can be initiated by earthquakes of magnitude 4.0 or larger.

The region is one of low historical earthquake activity. In general, earthquakes in the Colorado Plateau are small to moderate magnitude, and occur infrequently. The strongest recorded earthquake in the area occurred on February 1, 1967 (magnitude 3.8) near Upheaval Dome in northern Canyonlands National Park.

The surface-fault-rupture hazard is low because no active faults with evidence for Holocene or late Pleistocene activity are present in Castle Valley. However, in the southeastern part of Castle Valley there is a fault of suspected Quaternary age. This fault could have a tectonic origin, but is most likely related to salt dissolution beneath Castle Valley. Although improbable during 50-100 year time frames, surface rupture is possible on this fault. In addition, the sinkhole at the northwest end of the fault indicates dissolution or piping along the fault zone. Such sinkholes may develop elsewhere along the fault in the future, particularly if water is introduced into the zone.

This hazard map shows areas where site-specific studies concerning rock-fall hazards are recommended prior to development. The map is designed to show potential hazard areas for planning purposes only. Site-specific studies should evaluate hazards and, if necessary, recommend hazard-reduction measures. The studies must be prepared by qualified professionals (engineering geologists, geotechnical engineers). Because of the relatively small scale of the maps (1:24,000), the possibility exists that some small hazard areas are not shown; studies are therefore recommended for critical facilities even outside the hazard areas.

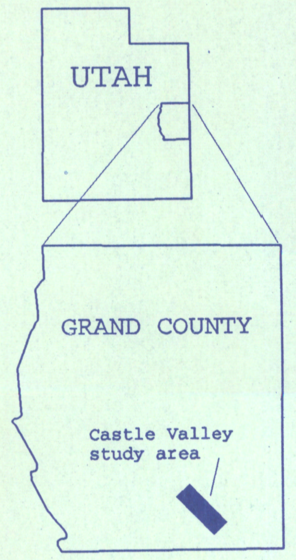


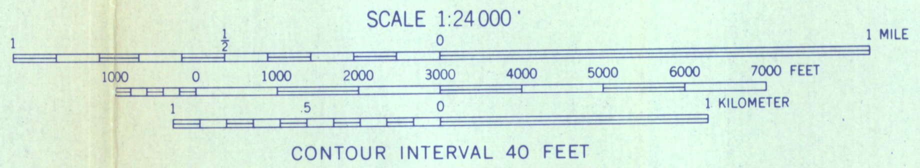
SOIL SUSCEPTIBLE TO PIPING AND EROSION IN CASTLE VALLEY, GRAND COUNTY, UTAH

Utah Geological Survey
Open-File Report 238
Plate 4

By

William E. Mulvey





Hazard map based on unpublished geologic mapping by M.L. Ross and H.H. Doelling.

Base map from USGS 1:24,000-scale topographic maps of Big Bend, Werner Lake, Fisher Towers, and Rill Creek.

Explanation

Soil susceptible to piping and erosion.

DISCUSSION

Piping is subsurface erosion by ground water that moves along permeable, noncohesive layers in unconsolidated materials and exits at a cliff face that intersects the layer. Removal of fine-grained particles (silt and clay) by this process creates voids within the material that act as minute channels which direct the movement of water. As channels enlarge, water moving through the voids increases velocity and removes more material forming a "pipe". The pipe becomes a preferred avenue for ground-water drainage and enlarges as more water is intercepted. Increasing the size of the pipe removes support from the walls and roof, causing eventual collapse. Collapse features form on the surface above the pipes, directing even more surface water into the pipes. Eventually, total collapse forms a gully that concentrates erosion along the line of collapse features.

Piping is common in arid climates where fine-grained, uncemented Holocene-age (10,000 years ago to present) alluvium is incised by stream drainages. When enough water is introduced, water soaks into the subsurface until it reaches layers that can conduct the water to a free face. Types of material susceptible to piping that are found in Castle Valley are fine-grained alluvium (sand, silt, and clay) and fine-grained rock (siltstone, mudstone, and claystone).

The characteristics that make soil susceptible to piping also make them subject to rapid erosion. Erosion is the removal of material, particularly unconsolidated deposits by running water. In Castle Valley sheetwash erosion during cloudburst storms is common, as is vertical and lateral cutting of stream channels. During cloudbursts, sheetwash can affect talus slopes and alluvial fans.

Piping and erosion can damage roads, bridges, culverts, and structures. In Castle Valley, roads are most susceptible because they parallel and cross-cut incised drainages. Roads can contribute to piping and erosion by altering natural runoff and channeling water. Channelized water can increase infiltration and potential for pipes to develop, as well as erosion. Earthfill structures such as dams may also be susceptible to piping.

This hazard map shows areas where soil susceptible to piping and erosion may be found. The map is designed to show potential hazard areas for planning purposes only, and site-specific studies are needed to evaluate hazards and, if necessary, recommend hazard-reduction measures. The studies must be prepared by qualified professionals (engineering geologists, geotechnical engineers, hydrologists). Because of the relatively small scale of the maps (1:24,000), the possibility exists that some small hazard areas are not shown; studies are therefore recommended for critical facilities even outside the hazard areas.