THE BALANCED ROCK HILLS LANDSLIDE, SPRINGDALE, WASHINGTON COUNTY, UTAH

BILL D. BLACK[1]

ABSTRACT

On September 2, 1992, a Richter magnitude (M_L) 5.9 earthquake occurred southeast of St. George, Utah. The most damaging geologic effect of the earthquake was the Balanced Rock Hills landslide in the town of Springdale. The landslide formed on bluffs north of Blacks Canyon and destroyed three homes and forced the temporary evacuation of condominiums and businesses around the periphery of the slide. The basal slide plane is likely in the Petrified Forest Member of the Chinle Formation, which is responsible for a large number of deep-seated landslides in Utah. The probable cause of the landslide was a combination of earthquake ground shaking and marginal stability caused by increased precipitation or water from other sources and unstable geologic materials. The landslide is being monitored to evaluate additional movement and response of the landslide to rainfall and future earthquakes.

INTRODUCTION

At 4:26 a.m. (MDT) on September 2, 1992, a Richter magnitude (M_L) 5.9 earthquake occurred 5 miles southeast of St. George (Arabasz and others, 1992), which triggered two slope failures in the town of Springdale, Utah, in sections 28 and 29, T. 41 S., R. 10 W., Salt Lake Base Line and Meridian (figure 1). The Balanced Rock Hills landslide is at the site of an older slide which has been moving since the late 1960s (Jim Fraley, Springdale Waterworks Superintendent, verbal communication, September 15, 1992). Although the landslide was probably triggered by earthquake ground shaking, previous studies have noted instability problems in the area and a correlation between movement and precipitation on the older slide (Kaliser, 1975; Hamilton, 1992). The landslide destroyed two water tanks (one of which was abandoned), several storage buildings, and three homes in the Balanced Rock Hills subdivision. The landslide also ruptured buried and above-ground utilities in the subdivision and along SR 9, and temporarily blocked SR 9 leading to Zion National Park. Earthquake ground shaking also triggered the small slope failure west of the Balanced Rock Hills landslide (Paradise Road landslide, figure 1). However, this failure caused no damage.

[1]Utah Geological Survey, 2363 South Foothill Drive, Salt Lake City, Utah

GEOLOGY

Three geologic units are mapped in the bluffs north of Springdale (Cook, 1960): (1) the Jurassic-age Kayenta Formation, consisting of light-gray to light-brown siltstone, pale reddish-brown silty mudstone, and mottled dark reddish-brown mudstone (Averitt, 1962); (2) the Triassic-age Moenave Formation, which consists of an upper massive reddish-brown sandstone that weathers into prominent ledges (Springdale Sandstone Member) and a lower reddish-orange lenticular sandstone (Dinosaur Canyon Member) (Harshbarger and others, 1957); and (3) the Triassic-age Chinle Formation (Petrified Forest Member), a structureless claystone, clayey siltstone, and cross-bedded clayey sandstone ranging from light greenish-gray to grayish purple (Stewart and others, 1972).

The Balanced Rock Hills landslide involved the lower Dinosaur Canyon Member of the Moenave Formation and the Petrified Forest Member of the Chinle Formation, and included colluvium containing rock-fall boulders derived from the Kayenta Formation and Springdale Sandstone Member of the Moenave Formation. Although the Moenave Formation is not known to be susceptible to landsliding, the underlying Petrified Forest Member of the Chinle Formation contains abundant clay and is susceptible; a significant number of deep-seated landslides occur in the Petrified Forest Member in Utah (Harty, 1991). The basal slide plane is likely within the Petrified Forest Member, and older landslides in this unit are present in the Springdale area (Harty, 1990). A geologic reconnaissance for the Southern Utah Bicentennial Amphitheater (Kaliser, 1975), in Black's Canyon west of

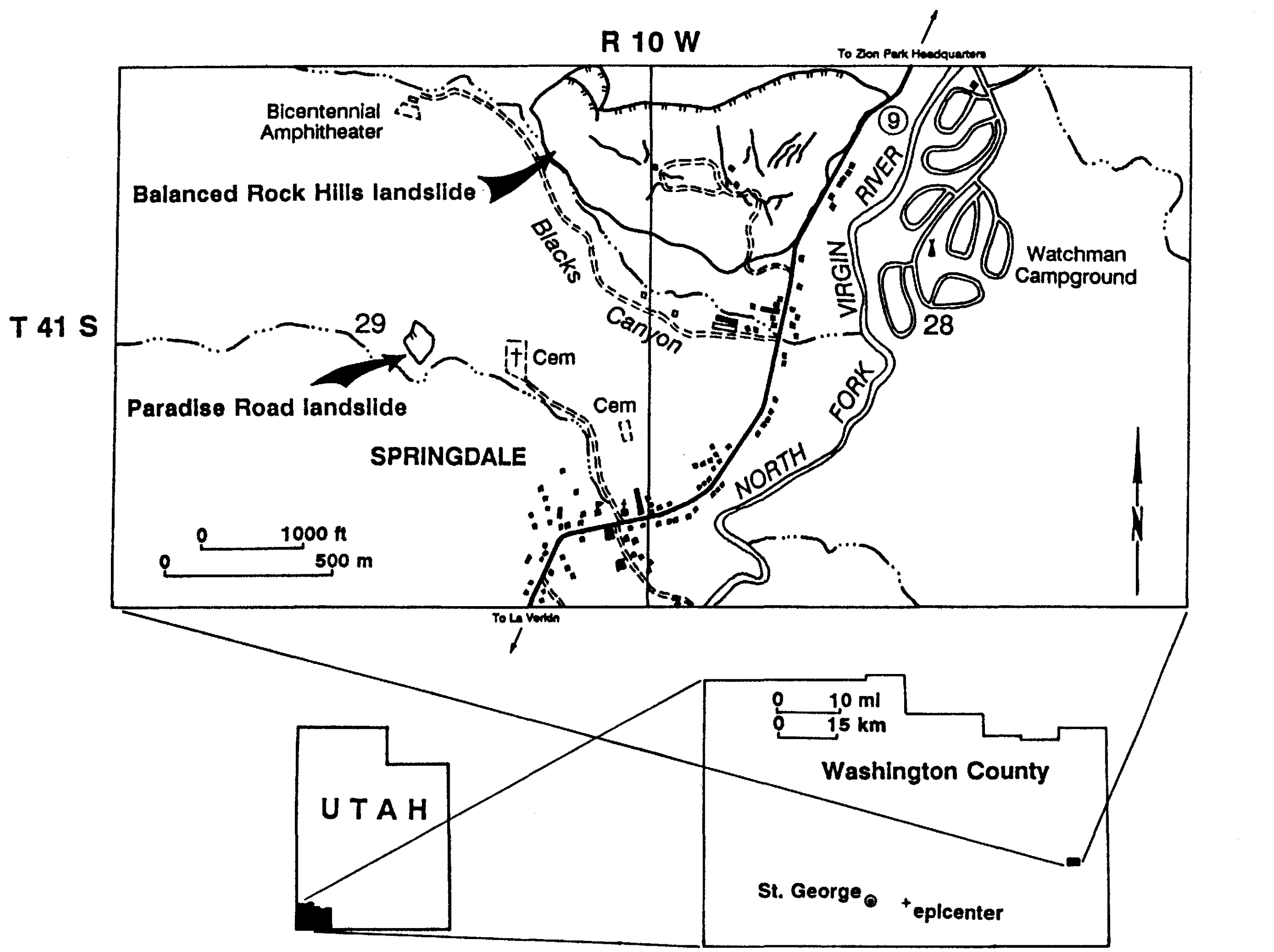

Figure 1. Location of the Balanced Rock Hills and Paradise Road landslides and epicenter of the 1992 St. George earthquake.

the Balanced Rock Hills landslide (figure 1), also noted potential slope instability hazards in this unit.

LANDSLIDE DESCRIPTION

The Balanced Rock Hills landslide is a complex coherent landslide likely involving both rotational and translational elements. The landslide has a clearly defined main scarp as high as 80 feet (24 m) in places, fissures up to 20 feet (6 m) deep, and minor scarps up to 10 feet (3 m) high that form a broken irregular topography on the surface of the slide mass (figure 2). The orientation of these scarps and fissures indicates that the landslide likely moved in several coherent blocks. Smaller discrete landslides have also formed on the oversteepened toe.

The landslide is roughly 1,625 feet (495 m) from the main scarp to the toe, with a width of about 3,595 feet (1,096 m). The slide plane does not appear to daylight in drainages which dissect the landslide. Using a calculated surface area of 4.4 million square feet (400,000 m^2) and an estimated average depth to the projected slide plane of 110 feet (34 m), the total volume of the landslide is about 18 million cubic yards (14 million m^3). The average gradient of the slope prior to the slide was 30 percent.

LANDSLIDE CAUSES

Previous landslide studies in the Springdale area have noted a correlation between precipitation and slope failures. Kaliser (1975) cites a verbal communication with Wayne Hamilton, a geologist with Zion National Park, who indicated that the hill on which the (now abandoned) Springdale water tank rests in the Balanced Rock Hills

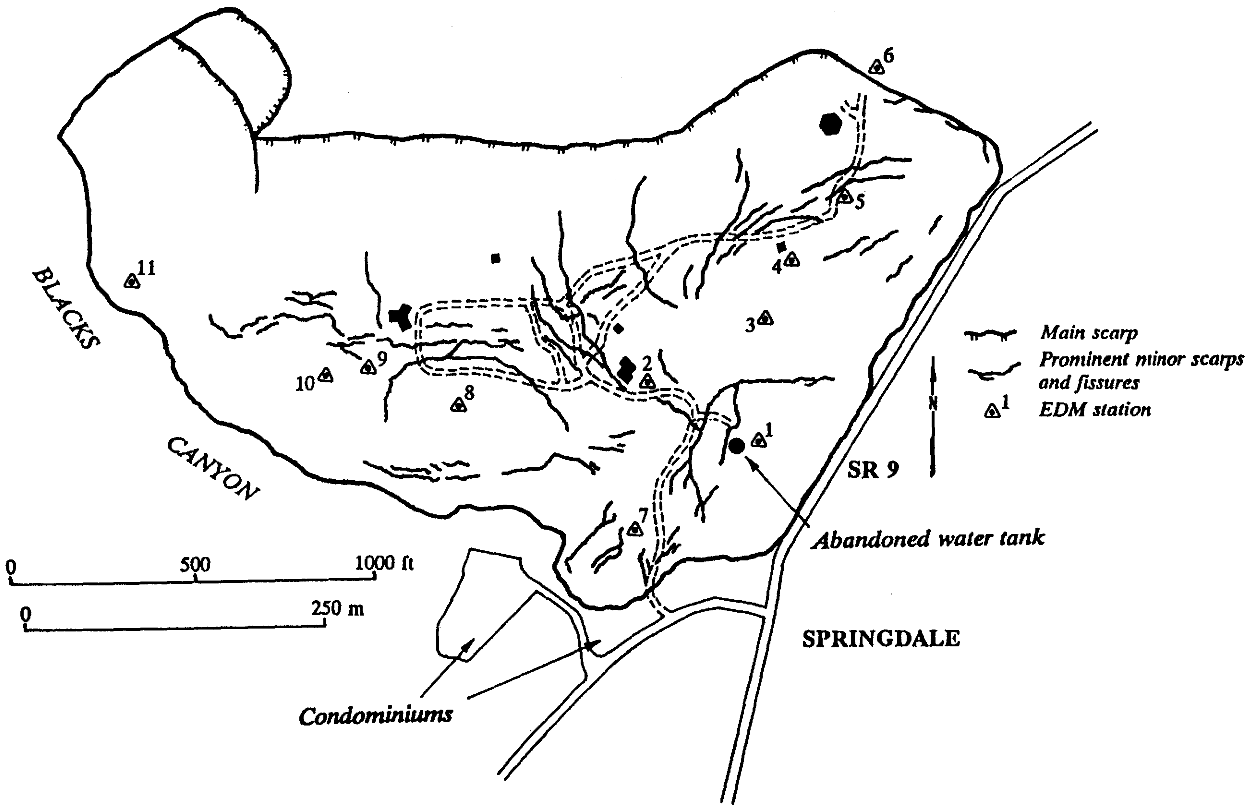

Figure 2. Main scarp, prominent minor scarps and fissures, and location of EDM stations on the Balanced Rock Hills landslide.

subdivision was differentially moving on the order of two to three inches (5-8 cm) per year. Hamilton (1992) noted a correlation between movement of the landslide and precipitation during a study period between August 1974 to June 1975. Ten inches (25 cm) of precipitation and 1.3 inches (3.3 cm) of landslide movement were noted during this period (Hamilton, 1992). Another landslide in Springdale in May, 1988, was also attributed in part to increased precipitation (Harty, 1990). This landslide occurred following a total of 4.33 inches (11 cm) of precipitation in a 10-day period in April of that year (Harty, 1990).

A combination of long-term marginal stability and earthquake ground shaking is the most likely cause of the landslide. The failure is roughly 28 miles (45 km) from the epicenter of the St. George earthquake (figure 1); Keefer (1984) predicts a maximum distance of approximately 20 miles (32 km) for coherent landslides to occur from the epicenter of a M_L 5.9 earthquake. However, if failure of a slope is imminent before an earthquake, a landslide could be initiated even by weak ground shaking (Keefer, 1984). Increased precipitation, which is about 120 percent of normal for the current water year in the Dixie region (Utah Climate Center, 1992), may have contributed to instability of the slide. Weather records from Zion National Park, the closest weather station to Springdale, show only 0.67 inches (1.7 cm) of precipitation between August 15th, 1992, and September 1st, 1992. However, Al Warneke (verbal communication to Gary E. Christenson, September 8, 1992) reported 0.9 inches (2.3 cm) of precipitation in Springdale in 20 minutes on August 25, 1992, which caused local flooding along SR 9 near the landslide. Other possible sources of water include effluent from septic systems or leaking water lines or tanks in the Balanced Rock Hills subdivision. However, no water (or evidence of any) was observed issuing from the slide. The role of water from these sources is unclear, particularly in light of the Paradise Road landslide (figure 1) in an undeveloped area lacking any of these potential sources.

HAZARD POTENTIAL AND MONITORING

A potential hazard exists for further movement of the landslide or portions of the slide, and for smaller slope failures on the oversteepened toe. Precipitation or water from other sources entering the numerous cracks and fissures on the landslide and infiltrating to the slide plane could reactivate the landslide or cause smaller slope failures. The potential also exists for another large earthquake in the region to trigger further movement of the landslide. The landslide appears to be broken into several separate blocks and, based on mapping of minor scarps and fissures, EDM reflector stations were placed on each block where possible (figure 2). These will be periodically resurveyed by Alpha Engineering, contracted by Springdale to serve as city engineer, with results sent to the Utah Geological Survey, to evaluate landslide movement and response of the landslide to rainfall and future earthquakes. At this time, there are no plans to stabilize the landslide.

In addition to the potential for further movement, other hazards now exist around the periphery of the landslide from debris flows or floods off the now-disrupted landslide surface during cloudburst storms. On the landslide, additional hazards include continuing settlement, erosion in disrupted drainages, piping, and collapse and widening of open fissures.

REFERENCES CITED

Arabasz, W.J., Pechmann, J.C., and Nava, S.J., 1992, The St. George (Washington County), Utah, earthquake of September 2, 1992: Salt Lake City, University of Utah Seismograph Stations Preliminary Earthquake Report, 6 p.

Averitt, Paul, 1962, Geology and coal resources of the Cedar Mountain quadrangle, Iron County, Utah: U.S. Geological Survey Professional Paper 389, 72 p.

Cook, E.F., 1960, Geologic atlas of Utah - Washington County: Utah Geological and Mineralogical Survey Bulletin 70, 124 p., scale 1:125,000.

Hamilton, W.L., 1992, The sculpturing of Zion: Zion National Park, Utah, Zion Natural History Association, 132 p.

Harshbarger, J.W., Repenning, C.A., and Irwin, J.H., 1957, Stratigraphy of the uppermost Triassic and the Jurassic rocks of the Navajo Country: U.S. Geological Survey Professional Paper 291, 74 p.

Harty, K.M., 1990, Geologic investigation of a landslide in Springdale, Washington County, Utah, in Black, B.D., compiler, Technical reports for 1988-1989, Applied Geology Program: Utah Geological and Mineral Survey Report of Investigation 220, p. 94-96.

-----1991, Landslide map of Utah: Utah Geological and Mineral Survey Map 133, 28 p., scale 1:500,000.

Kaliser, B.N., 1975, Geologic reconnaissance of the Southern Utah Bicentennial Amphitheater, Springdale, Utah: Utah Geological and Mineral Survey Report of Investigation 103, 4 p.

Keefer, D.K., 1984, Landslides caused by earthquakes: Geological Society of America Bulletin, v. 95, p. 406-421.

Stewart, J.H., Poole, F.G., and Wilson, R.F., 1972, Stratigraphy and origin of the Chinle Formation and related Upper Triassic strata in the Colorado Plateau region: U.S. Geological Survey Professional Paper 690, 336 p.

Utah Climate Center, 1992, Utah climate update: Logan, Utah State University, Utah Climate Center, v. 3, no. 37, 2 p.