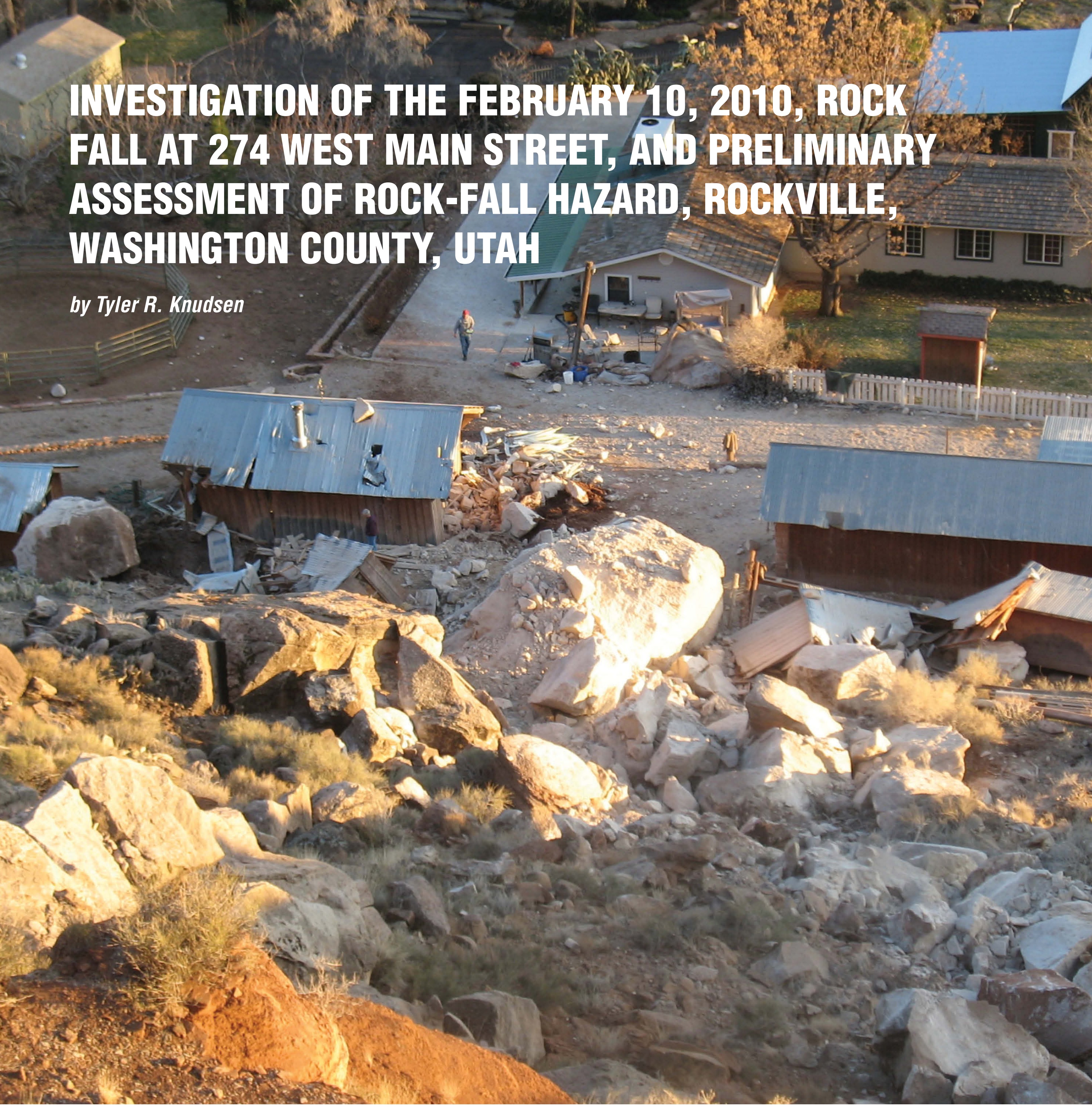
INVESTIGATION OF THE FEBRUARY 10, 2010, ROCK FALL AT 274 WEST MAIN STREET, AND PRELIMINARY ASSESSMENT OF ROCK-FALL HAZARD, ROCKVILLE, WASHINGTON COUNTY, UTAH

by Tyler R. Knudsen



UTAH DNR GEOLOGICAL SURVEY

REPORT OF INVESTIGATION 270
UTAH GEOLOGICAL SURVEY
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Cover photo: *View downslope toward the property damaged by debris from a large rock fall on February 10, 2010, in Rockville, Utah. Had the previously fallen boulder (large boulder covered with pulverized rock in photo center) not been present to break up the rock-fall boulder, this property and nearby properties may have incurred more severe damage.*

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INVESTIGATION OF THE FEBRUARY 10, 2010, ROCK FALL AT 274 WEST MAIN STREET, AND PRELIMINARY ASSESSMENT OF ROCK-FALL HAZARD, ROCKVILLE, WASHINGTON COUNTY, UTAH

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ABSTRACT

On February 10, 2010, a large rock released from near the top of Rockville Bench on the north side of Rockville, Washington County, Utah. The rock rolled downslope and collided with a large boulder already resting at the slope's base near the northern property boundary at 274 West Main Street. The collision broke the rolling rock into numerous smaller pieces that destroyed two sheds and damaged several other outbuildings, a house, and two vehicles; people in the house were not injured. The purpose of this investigation is to determine the geologic characteristics and cause of the rock fall, document the severity and extent of property damage, and make a preliminary evaluation of rock-fall hazard elsewhere in Rockville.

The rock fall consisted of a single remobilized talus boulder of the Shinarump Conglomerate Member of the Chinle Formation that detached more than 15 years ago from the Shinarump cliff that caps the Rockville Bench. The resistant Shinarump cliff overlies easily erodible shale, siltstone, and sandstone of the upper red member of the Moenkopi Formation. Initially, the boulder traveled a slope distance of about 40 feet and remained in a quasi-stable state high on the steep, south-facing Moenkopi slope below the Shinarump cliff. Rain-gage data from a nearby weather station documents a protracted storm over a four-day period prior to the rock fall that may have triggered the boulder's release. A second large talus boulder resting in a similar position on the Moenkopi slope continues to threaten the property at 274 West Main Street and other nearby structures. This remaining boulder and other talus high on Rockville Bench are a significant rock-fall source all along the north side of Rockville, as is the Shinarump sandstone cliff capping the bench.

Although many rock falls occur after storms, earthquakes, or periods of freeze-thaw, a review of historical Rockville rock falls showed a lack of obvious triggering mechanisms, emphasizing that rock falls have and may occur without warning anytime and anywhere along the southern slopes of the Rockville Bench. The Utah Geological Survey recommends a detailed rock-fall hazard assessment for Rockville that includes an evaluation of rock-fall sources and maximum runout distances. Residents, planners, and city officials can use this information to implement hazard-mitigation measures. Private homeowners should be informed if they are in a high rock-fall hazard area; if so, they may wish to retain a geological consultant to investigate their risk from rock falls and the feasibility of rock-fall risk-reduction measures for their property.

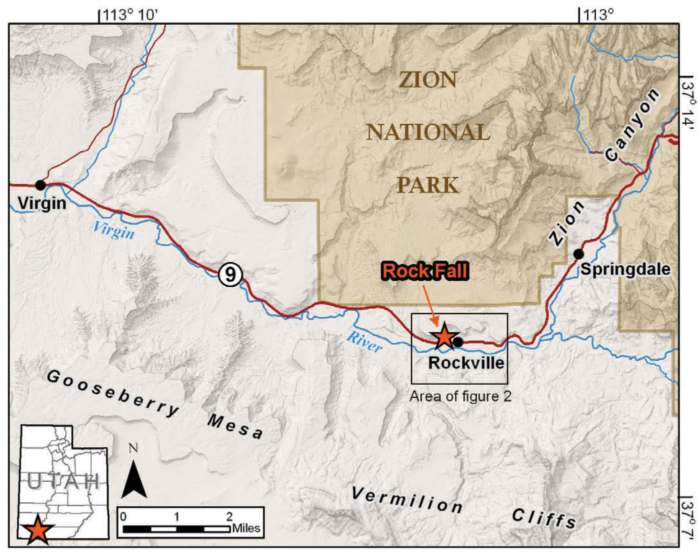

Figure 1. *Location of the February 10, 2010, rock fall in Rockville, Utah.*

INTRODUCTION

At approximately 7:40 a.m. on February 10, 2010, a large rock released from the upper south-facing slope of the Rockville Bench above Rockville, Utah (figures 1 and 2). Based on aerial-photo analysis, the size of the boulder's detachment surface, and amount of material observed at the bottom of the slope, I estimate the boulder was roughly rectangular with dimensions of about 21 x 17 x 17 feet and weighed an estimated 450 tons. The rock slid downslope for several feet until it fell over a 12-foot-high ledge and began to roll. The rock collided with a large previously fallen boulder at the base of the slope and shattered into numerous smaller fragments that destroyed two sheds and damaged several other outbuildings, a house, and two vehicles at 274 West Main Street (figures 3–6). Although the house was occupied at the time, no injuries occurred. Another large boulder, similar to the boulder that fell, remains on the upper slope.

On the afternoon of February 10, 2010, Rockville City Mayor Allen Brown requested that the Utah Geological Survey (UGS) investigate the rock fall. Tyler Knudsen and Robert Blackett, UGS, met with the mayor and the occupants of the home that evening and investigated the rock fall until dusk. Unpublished UGS Technical Report 10-1 (Knudsen, 2010), provided to Rockville City in March 2010, included my observations and initial conclusions and recommendations.

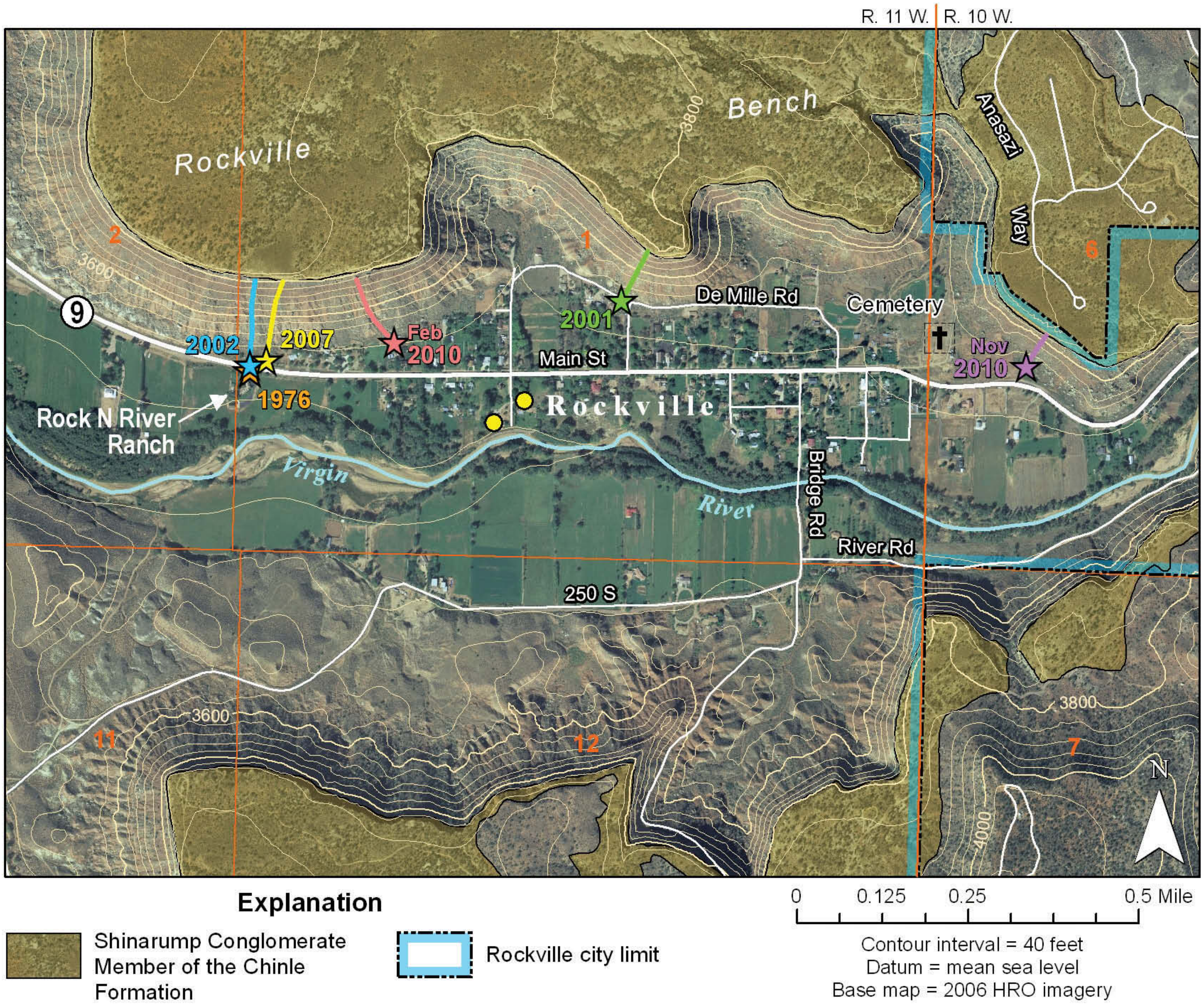

Figure 2. *Historical rock falls (stars) and their travel paths (bold colored lines). Yellow circles show locations of isolated boulders interpreted to be cliff-retreat deposits. Shinarump outcrop pattern from Willis and others (2002).*

Purpose and Scope

The purpose of this report is to provide supplemental information on the February 10, 2010, Rockville rock fall and make the investigation results more broadly available. This report summarizes my observations and conclusions, discusses future rock-fall hazard potential, and provides recommendations for homeowners, Rockville City, and other officials to consider in managing rock-fall risk. I focused on the rock-fall susceptibility of rock outcrops and talus above the site, the rock-fall travel paths to structures, and rock-fall runout distances. I also investigated other historical rock falls in Rockville.

The project scope is limited to the use and interpretation of existing data to characterize rock-fall hazard in a general manner. Except for a brief reconnaissance visit, no new fieldwork was conducted nor data collected as part of this investigation. Slope angles, distribution of large talus boulders, and many boulder size estimates were analyzed using geographic information systems (GIS) methods.

Sources of Information

In addition to a site reconnaissance, I reviewed relevant geologic maps, literature, and aerial photography including the UGS 1:24,000-scale (1 inch = 2000 feet) geologic map of the Springdale West quadrangle (Willis and others, 2002), rock-fall hazard maps for Zion National Park (Lund and others, 2010) and the St. George–Hurricane area (Lund and others, 2008), U.S. Geological Survey 1993 orthophotography at various scales (Utah Automated Geographic Reference Center, 2010a), 2003 color orthophotography viewed in Google Earth (no source provided) at various scales, 2006 high-resolution orthophotography (HRO; Utah Automated Geographic Reference Center, 2010b), 2009

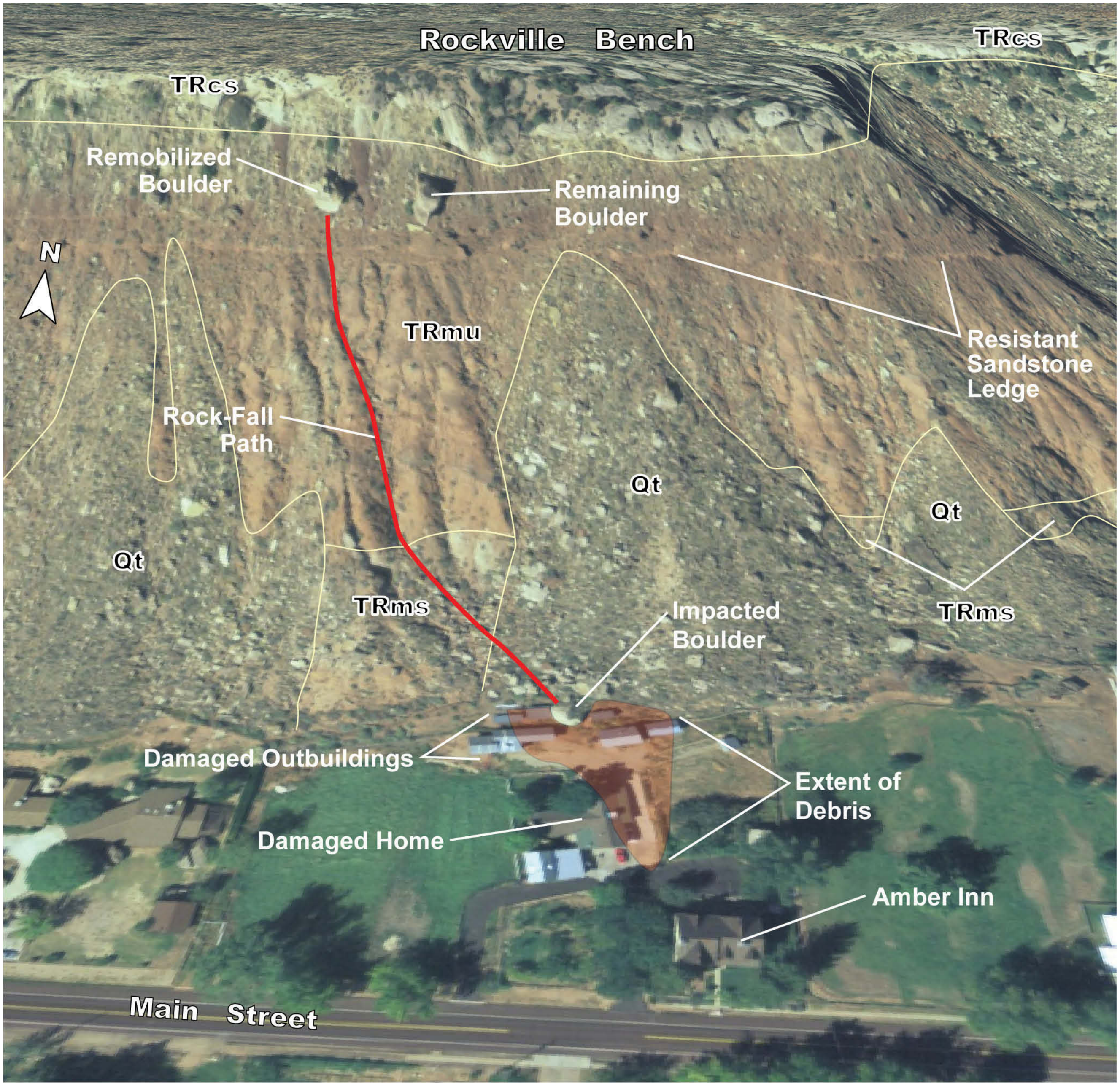

Figure 3. *Three-dimensional model of the February 2010 rock-fall site constructed by draping 2006 HRO imagery over a 10-meter-resolution digital elevation model. Rock-fall source area, path (red line), extent of post-impact debris, and damaged structures are shown. Rockville Bench geology modified from Willis and others (2002): TRcs = Shinarump Conglomerate Member of the Triassic Chinle Formation, TRmu = upper red member of the Triassic Moenkopi Formation, TRms = Shnabkaib Member of the Moenkopi Formation; Qt = Quaternary talus deposits.*

National Agriculture Imagery Program (NAIP) orthophotography at various scales (Utah Automated Geographic Reference Center, 2010c), and undated oblique aerial photos acquired by Pictometry International and viewed using Microsoft's Bing Maps software (http://www.bing.com/maps/). I used a 10-meter-resolution digital elevation model (Utah Automated Geographic Reference Center, 2010d) to construct a three-dimensional model of a portion of Rockville Bench and to calculate slope angles.

I also conducted interviews with the occupants and homeowner of the 274 West Main Street residence, current and past Rockville City mayors, and other residents that are knowledgeable of historical rock falls in Rockville.

Figure 4. *View to south of impact area and property damage at 274 West Main Street; photo taken on February 10, 2010. Red arrow indicates the path traveled by the rock-fall boulder to the area of impact with a previously fallen boulder. Yellow ellipses show locations of destroyed sheds. Red ellipses show the approximate locations of damaged vehicles before they were removed. Yellow dashed arrow shows travel path of a large fragment that damaged the house and a parked vehicle.*

THE FEBRUARY 10, 2010, ROCK-FALL EVENT

The rock fall consisted of a single remobilized sandstone talus boulder of the Shinarump Conglomerate Member of the Triassic Chinle Formation that had been resting on the steep south-facing slope just below the resistant Shinarump cliff that caps the Rockville Bench mesa (figure 3). The Shinarump outcrop is about 320 feet above the valley floor. The boulder had previously detached from the cliff, traveled a slope distance of about 40 feet, and came to rest on a 44° slope underlain by shale, siltstone, and sandstone of the upper red member of the Triassic Moenkopi Formation. A review of historical orthophotography showed that the boulder had been at that position, 290 vertical feet above the slope's base, since at least 1993 (figure 7). Well-developed desert varnish observed on the likely cliff detachment surface and local residents' accounts indicate that the talus boulder may have been resting at that position for several decades. Downslope-oriented grooves in the boulder's slope-detachment surface indicated that the boulder's initial movement was translational, parallel to the slope (figure 8). After sliding about 15 feet, the boulder fell over a resistant sandstone ledge that forms a 12-foot-high cliff and began rolling down a shallow talus-lined gully (figure 3). Near the bottom of the gully, the boulder deflected to the southeast, collided with a large boulder at the base of the slope, and shattered into numerous smaller fragments (figure 4). Most of the rock fragments traveled onto the property at 274 West Main Street by rolling, bouncing, or as airborne projectiles.

Debris from the impact destroyed two small sheds immediately adjacent to the impact area, and a larger wood-framed workshop was severely damaged and knocked off its foundation (figures 4 and 5). Three other outbuildings ranging from a small chicken coop to a more substantial wood and stone hay barn sustained moderate to light damage from falling and rolling debris. A 3.5 x 3 x 1.7-foot boulder weighing an estimated 1.3 tons rolled through the mudroom on the east side of the house, broke through a glass doorway, exited through an exterior wall, and struck and severely damaged a vehicle parked in the home's driveway (figures 4 and 6). A second vehicle parked near the workshop was also heavily damaged by debris. Both vehicles had been removed from the property by the time of my site visit.

The largest post-impact fragment came to rest about 50 feet from the impact site; it measured about 9 x 6 x 5 feet and weighed an

Figure 5. *Damaged outbuildings at 274 West Main Street; photos taken on February 10, 2010.* ***A., B.*** *Destroyed sheds adjacent to impact area.* ***C.*** *Damaged workshop knocked off its foundation.* ***D.*** *Largest (9 x 6 x 5 feet) post-impact boulder that damaged a workshop (right) and shed (left).*

estimated 20 tons (figures 4 and 5D). Most post-impact debris accumulated within a 75-foot radius of the impact site, but I found a few small (0.5- to 1-foot-diameter) fragments as much as 180 feet away.

The rock fall created a clear rock-fall path delineated by churned and crushed soil and vegetation, fresh rock deposition, rock gouge, and impact craters (figure 9). The 12-foot vertical drop and the average 38° slope along the gully bottom imparted a high initial velocity to the boulder. Several freshly broken smaller boulders in the rock-fall path likely include pieces broken from the falling/rolling boulder as well as talus crushed by the moving boulder. Near the bottom of the slope, the boulder deflected slightly eastward either off the western gully wall or perhaps off another talus boulder before striking a large, stationary boulder at the base of the slope. The rock-fall boulder traveled a total distance of 500 feet before striking the stationary boulder. If the rock-fall boulder had remained intact, the house may have sustained more damage, and the rock may have had enough momentum to reach the nearby Amber Inn on Main Street and/or other nearby structures.

Disturbed and freshly deposited debris remaining in the rock-fall path appeared stable at the time of my reconnaissance and presents little hazard to structures below. However, a second large boulder, approximately 30 x 15 x 14 feet and weighing an estimated 470 tons, lies about 80 feet east of where the February 10th rock fall originated and appears similar to the boulder that rolled down the slope. The remaining boulder is also Shinarump Conglomerate talus and rests on a 44° slope of the upper red member of the Moenkopi Formation (figure 10A). Inspection of the boulder's base revealed a 1- to 2-foot-wide undercut beneath the boulder's eastern edge where surface water has eroded underlying shale and siltstone (figure 10B). This boulder is also

Figure 6. Rock-fall damage to the house at 274 West Main Street; photos taken on February 10, 2010. ***A.*** *View downslope along path of the rock that damaged the house. Narrowly missing a barbeque grill, the rock rolled through the entryway and mudroom on the left (east) side of the house.* ***B.*** *Looking through the mudroom where the boulder broke through a glass door, which is still on its hinges, and exited through an exterior wall and window.* ***C****. After exiting the mudroom, the rock collided with a parked car and came to a rest. The rock, estimated to be 3.5 x 3 x 1.7 feet, was later moved up against the house when the damaged car was moved.*

visible in 1993 orthophotography (figure 7). The impacted house at 274 West Main Street, the Amber Inn (244 West Main Street), and other structures at the base of the slope may be damaged if this boulder also moves downslope. Additionally, the Shinarump Conglomerate cliff face from which the boulders were initially derived is also a potential source of future large, damaging rock falls.

HISTORICAL ROCK FALLS, RUNOUT DISTANCES, AND HAZARD CHARACTERIZATION

Historical Rockville Rock Falls

The well-indurated Shinarump Conglomerate, where it caps slopes of less-resistant Moenkopi Formation, is a well-known source of rock falls in southwestern Utah (Lund and others, 2008, 2010). In the Rockville area, the Shinarump Conglomerate ranges from 60 to 135 feet thick, dips 1° to 2° to the east, and contains widely spaced vertical joints (Willis and others, 2002). Weathering along joints combined with undercutting of the cliff by erosion of the softer underlying Moenkopi Formation weakens the Shinarump rock mass and creates opportunities for frost and root wedging, rainfall, or earthquakes to trigger rock falls. The orientation, spacing, and intersection of bedding planes and joints within the Shinarump typically produce large, equidimensional rock-fall blocks. Numerous fresh rock-fall scars on the Shinarump cliff face and widespread distribution of Shinarump-derived talus up to 45 feet in long dimension at the base of Rockville Bench (figure 11) attest to the frequency and widespread occurrence of rock falls in Rockville sourced from the Shinarump cliff.

The February 10, 2010, rock fall demonstrated that, in addition to rock falls detaching directly from the Shinarump cliff, talus below the cliff but high on the steep slope of Rockville Bench

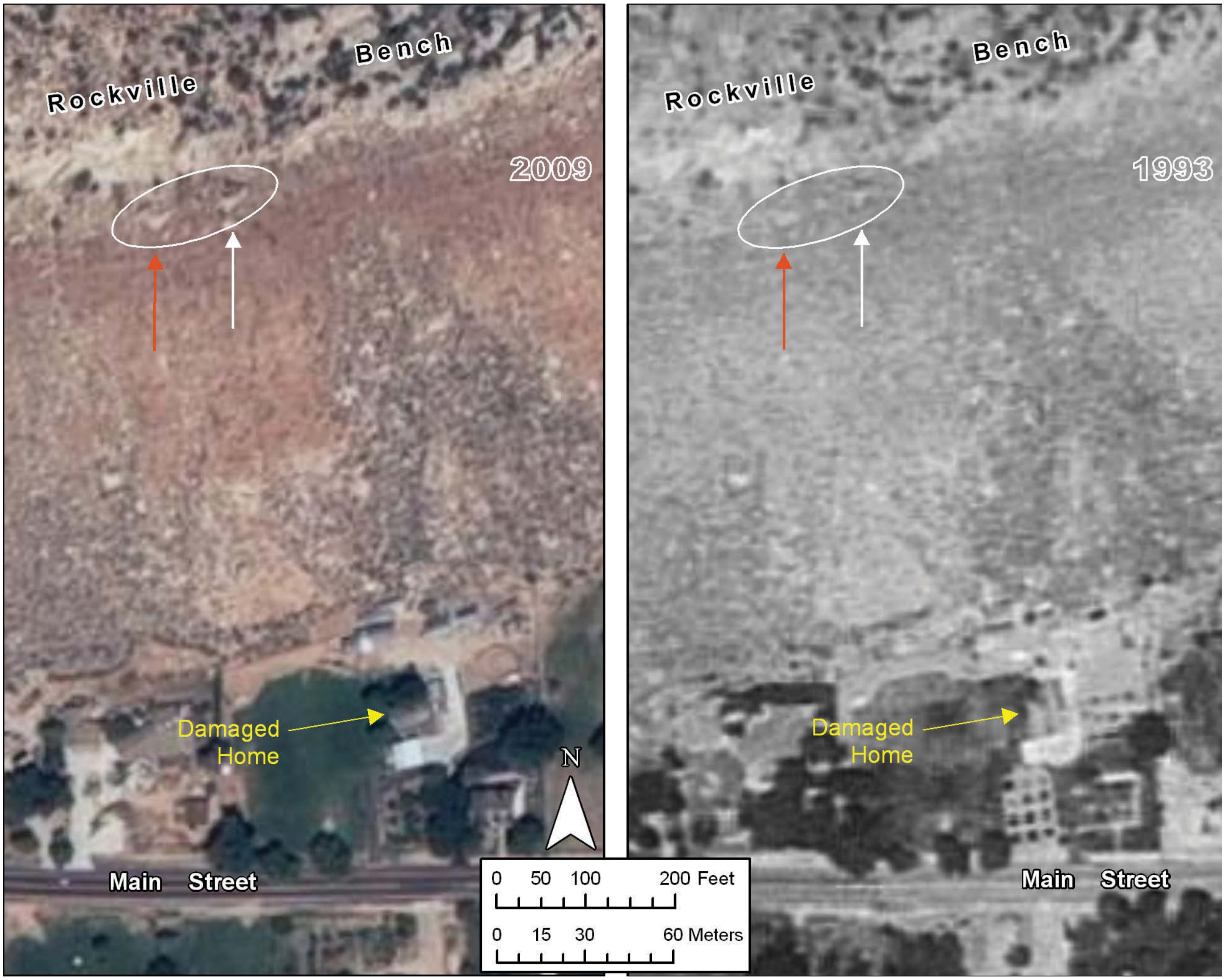

Figure 7. *Comparison of 2009 NAIP and 1993 U.S. Geological Survey orthophotos showing the source area and damaged home at 274 West Main Street. Both the February 2010 rock fall (red arrow) and the boulder remaining on the hillside (white arrow) are visible in the 2009 photo; although not as clear, the boulder pair also appears to be present in the 1993 photo.*

may also remobilize. Several precariously perched talus boulders are evident on the steep slope above Rockville (figure 12).

At least six relatively large rock falls sourced from the Shinarump cliff have occurred within the past 35 years in Rockville (figure 2), five of them within the past nine years. Undoubtedly, additional historical rock falls have occurred in the area but were poorly documented, and details such as timing, location, size, and damage are lacking. A discussion of documented rock falls in the area follows.

Long-time Rockville residents reported that the Shinarump boulder near the entrance to the Rock-N-River Ranch south of State Route 9 (SR-9; figures 2 and 13A) is a 1976 rock fall (Dan McGuire, former Rockville Mayor, verbal communication, 2010). No other details of the 1976 event are available. The tabular boulder is about 20 x 17 x 10 feet. During a reconnaissance visit, I noticed a second large Shinarump boulder (~18 x 10 x 10 feet) (figure 13B) about 50 feet to the west that may have been part of the same rock fall.

On October 18, 2001, a large boulder estimated to weigh about 300 tons released from the Shinarump cliff north of Rockville and impacted and severely damaged a home at the corner of Terry Lane and De Mille Road (200 North Center Street; figures 2 and 14; Lund, 2002). The homeowner, sleeping inside at the time, narrowly escaped injury. The boulder was part of a larger rock fall consisting of several Shinarump boulders, at least one of which was larger than the boulder that impacted the home.

One year later, on the evening of October 24, 2002, a tabular, car-sized boulder rolled down the south slope of Rockville Bench

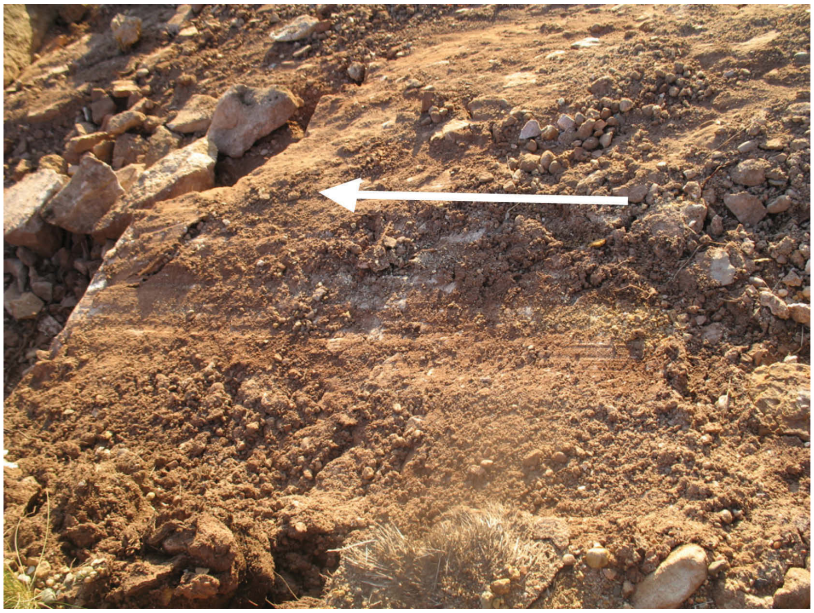

Figure 8. *Parallel grooves (~5 feet long) in the detachment area of the February 10, 2010, rock fall; photo taken on February 10, 2010; arrow indicates direction of travel.*

Figure 9. *View looking north to the February 2010 rock-fall source area (red arrow) showing fresh rock fragments in the rock-fall path (dashed red line); photo taken on February 10, 2010. Remaining talus boulder is shown with white arrow.*

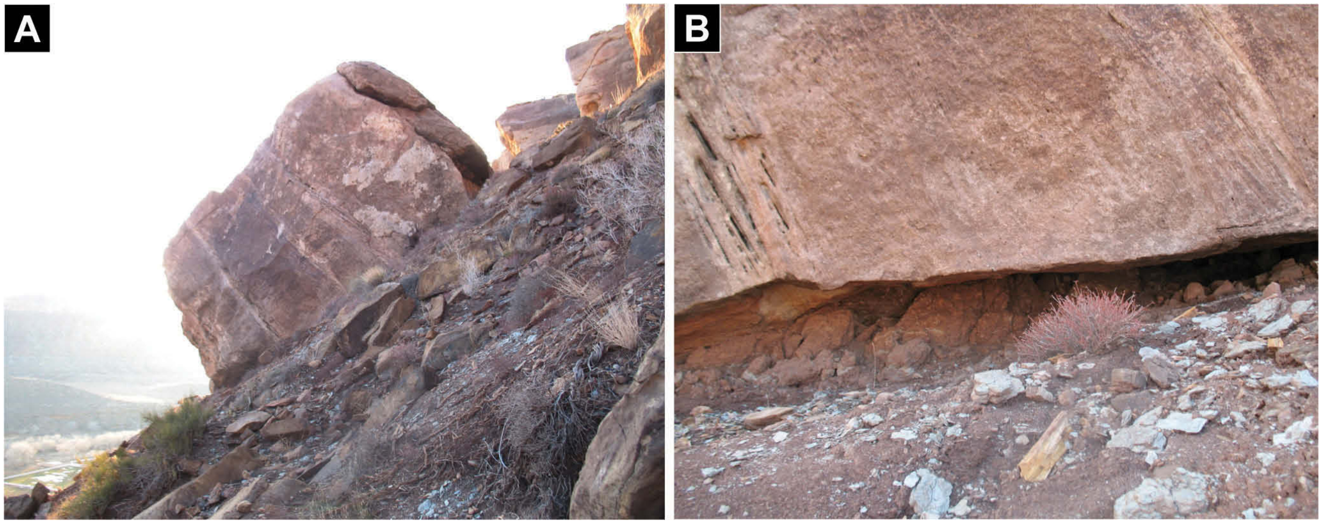

Figure 10. *Remaining boulder above the damaged house at 274 West Main Street; photos taken on February 10, 2010.* ***A.*** *Rock resting on steep slope of mudstone and siltstone of the upper red member of the Moenkopi Formation; the rock is about 30 feet wide (view to the west).* ***B.*** *Void space (~1 foot high) created by erosion extending 1 to 2 feet beneath the eastern edge of the boulder.*

Figure 11. *Large talus boulders litter the southern slope of Rockville Bench and adjacent residential area; photo taken on September 29, 2010.*

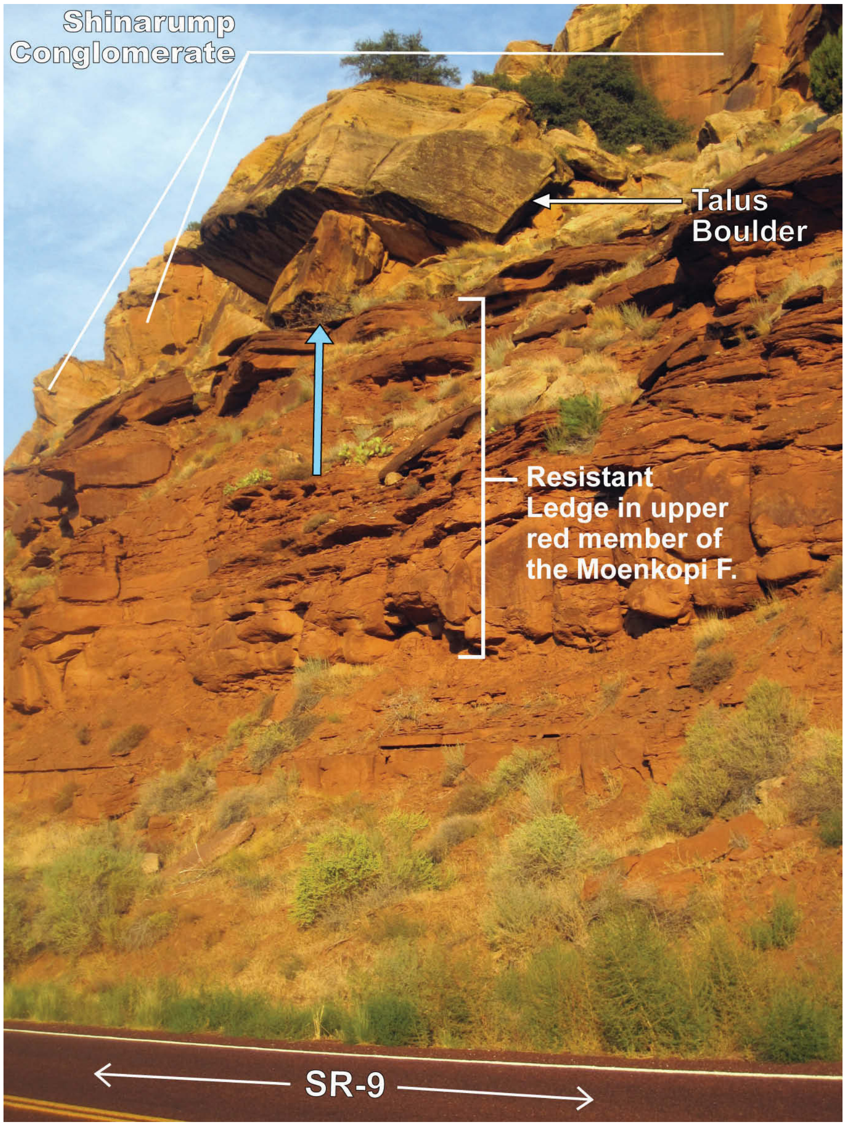

Figure 12. *Example of a large, precariously balanced talus boulder of Shinarump Conglomerate near the eastern end of Rockville; photo taken on September 29, 2010. Boulder measures approximately 32 x 20 x 20 feet and is tenuously held in place (about 95 vertical feet above SR-9) by a much smaller talus boulder (blue arrow).*

Figure 13. *Rock-fall boulders at the Rock-N-River Ranch. Both photos taken September 29, 2010; views are to the south.* ***A.*** *Approximately 20 x 17 x 10-foot boulder that reportedly rolled across SR-9 in 1976.* ***B.*** *Approximately 18 x 10 x 10-foot boulder lying about 50 feet to the west that may have fallen at the same time.*

Figure 14. *Rockville home at 200 North Center Street struck by an estimated 300-ton rock-fall boulder on October 18, 2001. Photo courtesy of Bill Lund.*

Figure 15. *October 24, 2002, rock fall in Rockville. Photos courtesy of Jim Harlan, ZionEventPhotos.com.* ***A.*** *Rock-fall debris on SR-9 centerline, view is toward the east.* ***B.*** *View to south of rock-fall debris and impact crater in highway shoulder.*

Figure 16. *2003 Google Earth image showing where the October 24, 2002, rock fall impacted SR-9. Note fresh rock fragments delineating the probable travel path.*

and came to rest on the centerline of SR-9 (Main Street) just north of the Rock-N-River Ranch (figures 2 and 15). Fortunately, the highway was clear of traffic and no injuries occurred. Traffic was blocked on Main Street for a few hours until the debris was removed. The only documentation of this event is photos taken by a local photographer. From the photos, I determined the exact location where the boulder came to rest, and that the boulder was composed of Shinarump Conglomerate. Rising dust in several of the photos indicates the boulder originated from near the top of the bench. A probable rock-fall path is discernable on 2003 aerial photography (figure 16), and also supports a source near the base of the Shinarump cliff, although it remains unclear if it originated from the cliff or as remobilized talus.

In late spring of 2007, a Shinarump boulder measuring approximately 9 x 9 x 8 feet fell from Rockville Bench and damaged a newly installed vinyl fence (figure 17) within 150 feet of the 1976 and 2002 rock falls (figure 2). Although the largest boulder stopped about 20 feet north of SR-9, local resident Jeff Ballard reported that a passing motorist collided with a smaller fragment that had reached the highway, causing substantial damage to the vehicle. Fresh-looking rock fragments, still visible in September 2010, indicate a source near the base of the Shinarump cliff (figure 17).

On the morning of November 2, 2010, a large mass of Shinarump Conglomerate detached from near the top of Rockville Bench east of the Rockville cemetery (figure 2). The rock mass broke apart into hundreds of smaller pieces that cascaded down the slope (figure 18A). At least 15 individual fragments measured approximately 4 x 4 x 5 feet or larger; the largest fragment measured 13 x 10 x 8 feet and weighed an estimated 78 tons (figure 18B). A single 13 x 8 x 6-inch rock shard came to rest within 20 feet of SR-9. No infrastructure was damaged by the rock fall.

Figure 17. *Rock-fall boulder deposited in late spring of 2007 that damaged a vinyl fence; photo taken on September 29, 2010. Fresh-looking rock fragments delineate the probable travel path.*

Rock-Fall Runout Distances and Hazard Characterization

The average angle of an imaginary line extending from the bottom of a rock-fall source to the rocks' resting place is termed the "shadow angle" (figure 19; Evans and Hungr, 1993; Wieczorek and others, 1998). Shadow angles vary based on rock type, boulder shape, slope steepness, slope composition, and rock source height. Minimum shadow angles measured from outlying boulders farthest from the source are used to estimate maximum rock-fall runout distances for rock-fall-hazard evaluations (figure 19).

I measured 24° and 23° shadow angles from the farthest outlying rock fragment found in the February and November 2010 rock-fall debris fields, respectively. Although a shadow angle was not measured at the site of the 2001 rock fall, using various maps and elevation data, I calculated an approximate shadow angle of 26° for that event. However, since the 2001 and both 2010 rock falls broke apart and impacted other boulders and/or structures, these

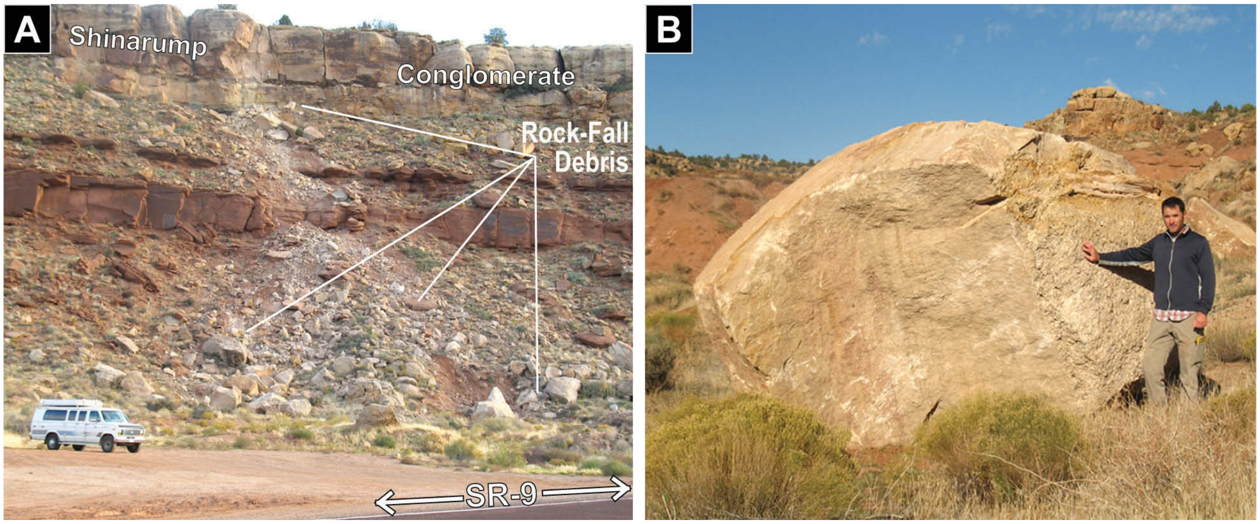

Figure 18. *Photos taken five days after the November 2, 2010, rock fall in east Rockville, near the Rockville cemetery.* ***A.*** *Fresh-looking rock fragments indicate the extent of the debris field.* ***B.*** *Largest rock-fall fragment measured 13 x 10 x 8 feet and weighed approximately 78 tons.*

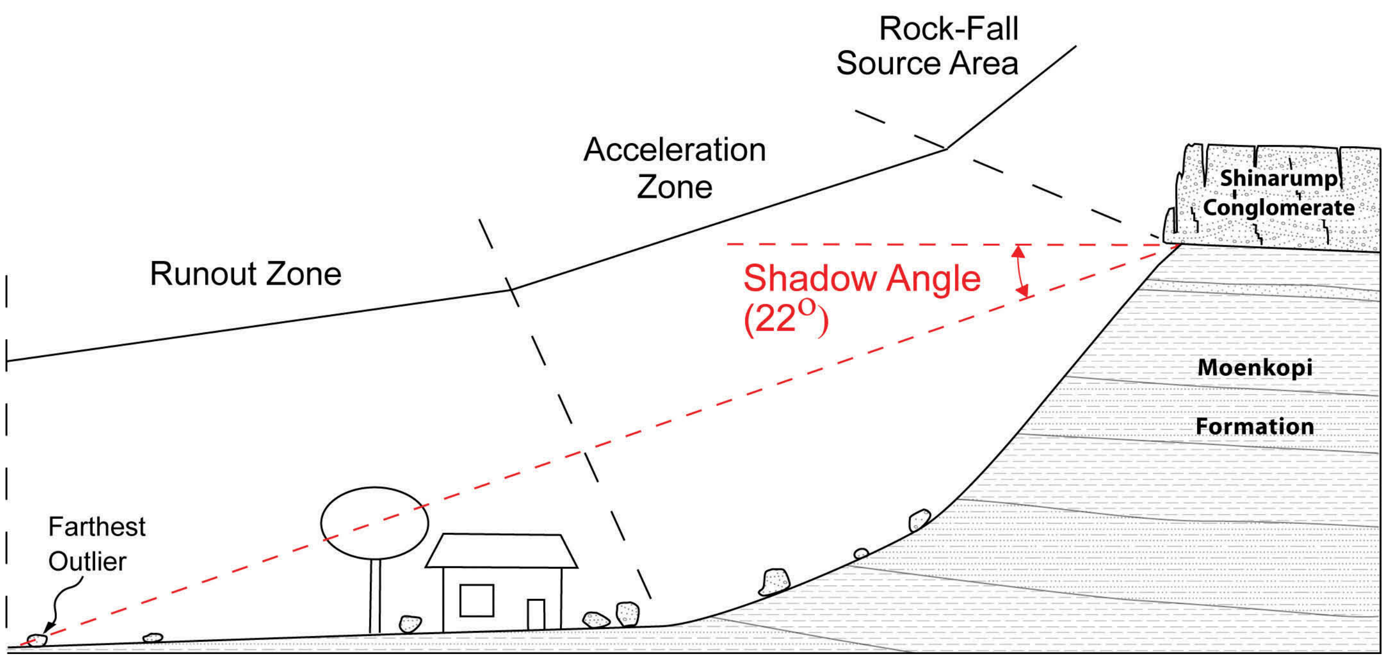

Figure 19. *Components of a characteristic path profile for rock falls sourced from Rockville Bench (modified from Lund and others, 2008). The 22° shadow angle shown is a reasonable value for estimating maximum runout distance in the Rockville area.*

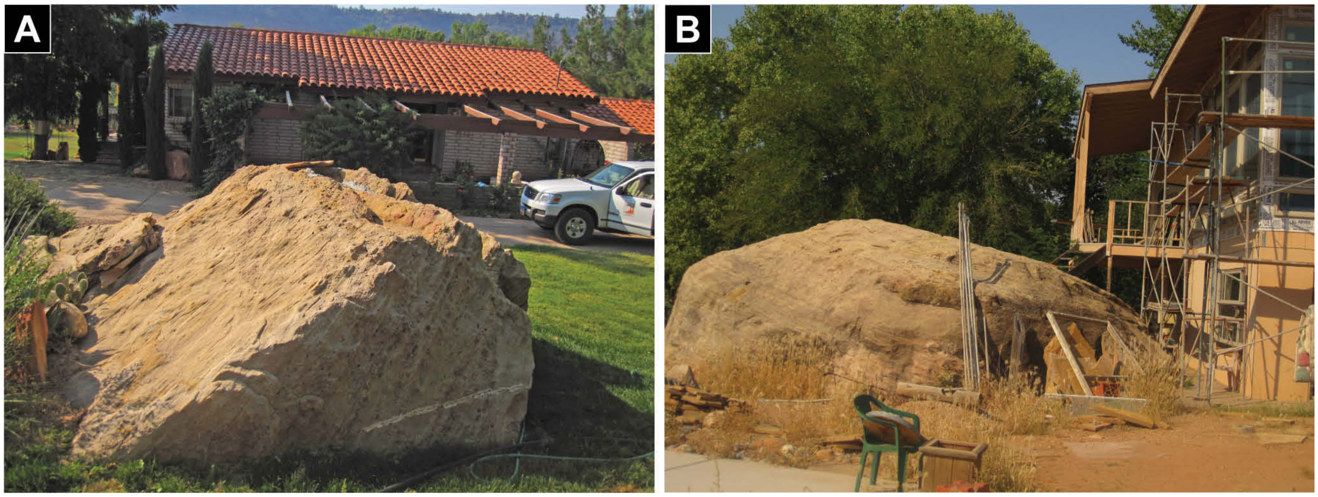

Figure 20. *Isolated boulders of Shinarump Conglomerate that are too far from the Rockville Bench to have been deposited as rock fall in recent times. They are most likely either cliff-retreat deposits or flood deposits that do not represent the extent of the present-day rock-fall hazard. Boulder locations are shown on figure 2.*

measurements should be considered maximum angles. Shadow angles for the 1976, 2002, and 2007 rock falls were not measured at the time of the events, but assuming they originated from the base of the Shinarump cliff, I estimated angles of 26°, 28°, and 30°, respectively, for those events.

Many outlying rock-fall boulders that would have represented the maximum runout distance below Rockville Bench have been removed to accommodate construction of buildings and roads and leveling farm and pasture land. My reconnaissance revealed two large boulders south of SR-9 near Rockville's west entrance that have an approximate shadow angle of 22°. The 22° angle is similar to minimum shadow angles measured in Zion Canyon (Lund and others, 2010), the St. George area (Lund and others, 2008), and elsewhere (Wieczorek and others, 1998). Until a detailed rock-fall inventory and study is completed for Rockville Bench, it is my opinion that a 22° shadow angle is a reasonable value for estimating maximum runout distance for rock falls originating from the Shinarump cliff capping the Rockville Bench.

There are several large boulders of Shinarump Conglomerate up to 30 feet in long dimension near the center of town about 0.25 mile from the nearest Shinarump outcrop on Rockville Bench (figures 2 and 20). The shadow angle measured for the boulders is less than 15°. Similar large isolated boulders found in lower Zion Canyon by Lund and others (2010) were thought to either be talus/cliff-retreat deposits left isolated by canyon widening or flood deposits. However, the possibility that the Zion Canyon boulders could be remnants of infrequent but catastrophic fin-collapse or rock-avalanche events sourced from the roughly 2000-foot-high vertical canyon walls could not be excluded. Thus, Lund and others (2010) classified the area surrounding the boulders with a "low probability, high hazard" designation. The anomalous Rockville boulders are most likely old cliff-retreat deposits that fell from Rockville Bench at a time when the bench was positioned much farther south, with a possibility that they are flood deposits that emanated from a small, unnamed drainage to the north. The relatively thin Shinarump Conglomerate overlying the easily erodible Moenkopi Formation and the comparatively low height of Rockville Bench are not conducive to anomalously large rock-fall runout distances; therefore, I conclude that the isolated boulders do not represent the limit of the current rock-fall-hazard area in Rockville. Biek and others (2004) reported additional cliff-retreat deposits consisting of Shinarump boulders on an abandoned terrace about 0.5 mile west of town.

The gentle bedrock dip combined with the Virgin River valley gradient cause the height of the Shinarump cliff capping Rockville Bench to gradually decrease from a maximum of 400 feet above the valley floor near Rockville's western border to less than 100 feet on the east side of town near Anasazi Way (figure 2). Therefore, rock-fall runout distances will decrease eastward along the base of the slope north of town.

A 22° shadow angle from the base of the Shinarump cliff places many homes, roads, and other facilities in the northern part of Rockville within a high rock-fall-hazard area. Several structures south of the Virgin River on River Road (figure 2) may also be at risk from falling rock originating from the Shinarump-capped mesa to the south.

PROBABLE ROCK-FALL CAUSES

Rock falls typically result from the cumulative effects of weathering and other geologic processes, but also may be initiated by discrete triggers such as earthquakes or meteorological events. For the February 2010 event, no earthquakes were recorded at the time of the rock fall; however, the rock fall did occur shortly after

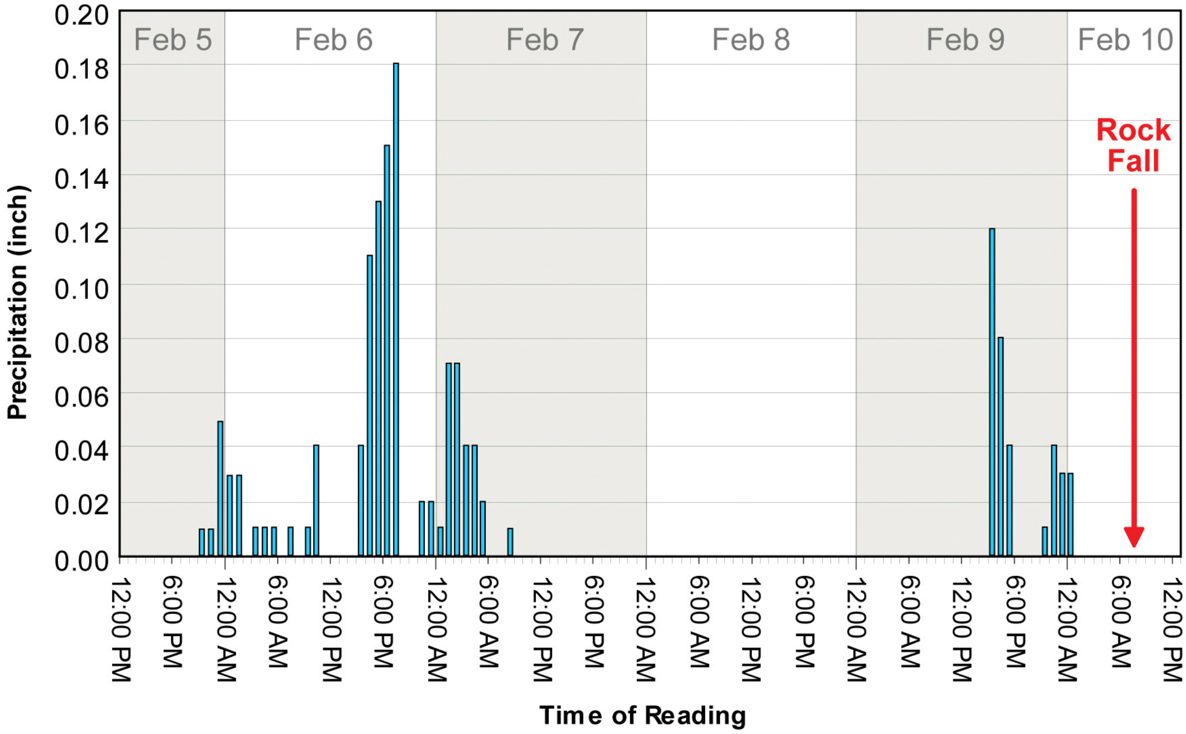

Figure 21. *February 5–10, 2010, hourly rain-gage data from Zion Canyon RAWS station (MesoWest, 2010).*

a prolonged period of rain during February 5–9 that produced 1.38 inches of precipitation at the Zion Canyon RAWS MesoNet station (MesoWest, 2010; figure 21) about 4.5 miles northeast of Rockville. Station records show that 0.35 inch of rain fell the evening before the rock fall. Although it was not raining at the time of the rock fall, soil and rock slopes near the source area were still saturated when I visited the site approximately nine hours after the rock fall occurred. Observation of the detachment area revealed a zone of saturation extending 1 to 2 feet inward from the outer perimeter of the boulder's footprint. Although saturation of the relatively weak siltstone and mudstone beneath the boulder likely affected the timing of the rock fall, the precise failure mechanism is unclear. Surface water may have eroded material from beneath the boulder causing instability, or increased pore water pressure within the silty and clayey material beneath and/or buttressing the boulder may have resulted in a reduction of cohesion and subsequent failure.

Although the precise timing and possible triggering mechanisms of the 1976 and 2007 rock falls are unknown, the 2001, 2002, and November 2010 rock falls were preceded by several weeks of relatively dry weather, and no earthquakes were recorded at the time of or prior to any of these events. Initiation of the 2001, 2002, and November 2010 events are attributed to the cumulative effects of gravity and erosion. Similar rock falls can be expected at anytime and anywhere along the south edge of the Rockville Bench without warning or obvious triggering mechanisms.

SUMMARY AND RECOMMENDATIONS

On February 10, 2010, a large talus boulder fell from the upper slope of Rockville Bench, rolled 500 feet downslope, impacted a large previously fallen boulder, and shattered into dozens of smaller fragments that destroyed two sheds and damaged several other outbuildings, a house, and two vehicles at 274 West Main Street in Rockville. The rock fall was closely associated in time with rainfall from a protracted storm during February 5–9, 2010. A rainfall triggering mechanism is likely but cannot be confirmed in the absence of detailed monitoring of the detachment area at the time of the rock fall. Another similarly sized boulder remains high on the hillside.

The Shinarump cliff capping Rockville Bench has produced numerous prehistoric and historical rock falls. The impacted property at 274 West Main Street is less than 2000 feet west of a home damaged in 2001 by a similarly large rock fall, and about 1000 feet east of a portion of Rockville Bench that has produced at least three large rock falls within the past 35 years. Erosion of the underlying Moenkopi slope will continue to destabilize the Shinarump cliff, and rock-fall initiation mechanisms will undoubtedly trigger future rock falls. The combination of rock size and shape, cliff height, slope steepness, and a lack of dense vegetation promotes high momentum for rock falls initiating from the Rockville Bench, resulting in long runout distances. The damaging 2001 and February 2010 rock falls, and the presence of numerous large boulders on the slopes above (and in some cases surrounding) homes at the base of the Rockville Bench, clearly indicate that many homes are in areas of high rock-fall hazard.

The timing of rock falls cannot be predicted, but they are most common during and following high-precipitation storms, periods of freeze-thaw, and during earthquakes. However, at least two of the four rock falls documented within the past nine years lacked obvious triggering mechanisms. Rockville rock falls are possible at any time and typically occur with no warning.

The UGS recommends further detailed investigation to evaluate the rock-fall hazard in Rockville; investigations should include a detailed assessment of potential sources (including bedrock and talus) and maximum runout distances (minimum shadow angle). Investigation results should include a map delineating areas susceptible to rock fall. Site-specific, rock-fall-hazard investigations should be performed by qualified geologic consultants for future development. Owners of existing homes within high rock-fall hazard areas should be informed of the hazard, and they may wish to retain a team of geologic and geotechnical consultants to investigate the risk from rock falls to their property and the feasibility of rock-fall risk-reduction measures.

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