Landslide25_36

A survey of large-scale landslide deposits in Nevada, USA

Daniel Sturmer** *(University of Cincinnati, Department of Geoscience)*, ***O. Ivanik *(University of Cincinnati, Department of Geoscience; Taras Shevchenko National University of Kyiv, Department of General and Historical Geology, Institute of Geology)*

SUMMARY

Tectonically and volcanically active areas commonly contain geologic conditions conducive to formation of large landslides. Areas that have been tectonically active over geologic time also may have landslide deposits preserved in the rock record. Though perhaps not as well studied as modern landslides and landslide hazards, it is important to evaluate and understand these older landslides to better understand both landslides and the geologic processes that lead to landslide occurrence.

Nevada, USA has been tectonically active for much of the past 350 Myr, including periods of contraction, extension, oblique deformation. Over 700 large-scale (with deposits covering >1 km2) landslide deposits have been identified across the state. These have a wide variety of sizes and failure styles linked in part to tectonic or volcanic environment. In this presentation, we will discuss the styles of large-scale landslides in Nevada, with four examples, three from the southern part of the state and one from the northwest. It is important to study and understand these ancient landslides as they provide a window into the role large-scale landslides play in landscape evolution and provide a range of possibilities for the ways slopes can fail.

Introduction

Nevada is one of the most tectonically active areas within the USA. The state covers more than 286,000 km^2 which is slightly smaller than Italy. Most of the state sits within the Basin and Range province, which is a ~1000 km wide area of extending crust that has been active for the past ~18-15 Ma. The extension has resulted in formation of dozens of alternating mountain ranges and basins across the state. Additionally, the western portion of the state sits within the Walker Lane, which is a zone of dextral shear that accommodates ~20% of the plate motion between the Pacific and North American plates, with the rest taken up on the San Andreas system in California (e.g., Dickinson, 2006). Tectonic and associated volcanic activity is nothing new in Nevada, which has been continuously tectonically active since at least Carboniferous time (Dickinson, 2006). This activity has resulted in hundreds of large-scale (herein defined as deposits that cover >1 km^2) landslide events, with a variety of failure styles and triggering mechanisms, that are recorded in the rock record. However, of the hundreds of large-scale landslide deposits across the state, very few (perhaps 10 or 20) have been studied in detail. In this presentation we discuss the geologic and landslide history of Nevada and describe 4 landslide deposits across the state which display the wide variety of landslides Nevada has experienced.

Study area and characterization of landslide deposits

Nevada has over 300 named mountain ranges, many of which trend north-south and are ~15 km wide and up to 125 km long. These ranges are separated by valleys with relief commonly between 1.5 and 2.2 km. This physiography is reflective of the present-day tectonics in Nevada, which includes Basin and Range extension affecting the entire state and dextral and oblique shear affecting the western portion. Steep relief has resulted in large landslides affecting many of the present-day ranges. Landslide deposits are also associated with older tectonic events, including Oligo-Miocene metamorphic core complexes and the Cretaceous-Paleocene Sevier orogeny. These landslides show a wide variety of failure styles, including rock avalanches, rotational failures, rock planar slides, and rock compound slides.

Several Cenozoic magmatic events resulted in formation of landslide deposits across the state (e.g., Dickinson, 2006). The Oligo-Miocene ignimbrite flareup consisted of dozens of caldera-forming eruptions, mainly in the central part of the state. Caldera collapse landslide breccias are some of the largest landslides present in the central part of Nevada. In southeastern Nevada, a thick stack of ash-flow tuffs that were erupted from the Oligo-Miocene calderas forms the core of several mountain ranges. Many of the large landslide deposits in that part of the state are sourced from the ash-flow tuffs. The northern tier of Nevada is dominated by Miocene basalt flows and plateau-forming basalts that are related to initiation and migration of the Yellowstone hot spot. Rock avalanches and slumps from the plateaus and along rivers that have incised the plateaus also contribute to the variety of landslides in the state.

Method and/or Theory

Nearly 700 known or suspected landslide deposits across Nevada were mapped by gathering data from published United States Geological Survey, Nevada Bureau of Mines and Geology maps in addition to field observations (Figure 1a; Sturmer and Micander, 2020). The source maps were at scales ranging between 1:24,000 to 1:250,000. Most of the state has not been mapped at 1:24,000 scale, and many landslide deposits that remain unmapped in detail. The landslide polygons were traced in Google Earth and several parameters including drop, runout, deposit length, width, and area, flow direction, lithology, age of lithology involved, age of capping lithology if present, and age of landslide if known were documented.

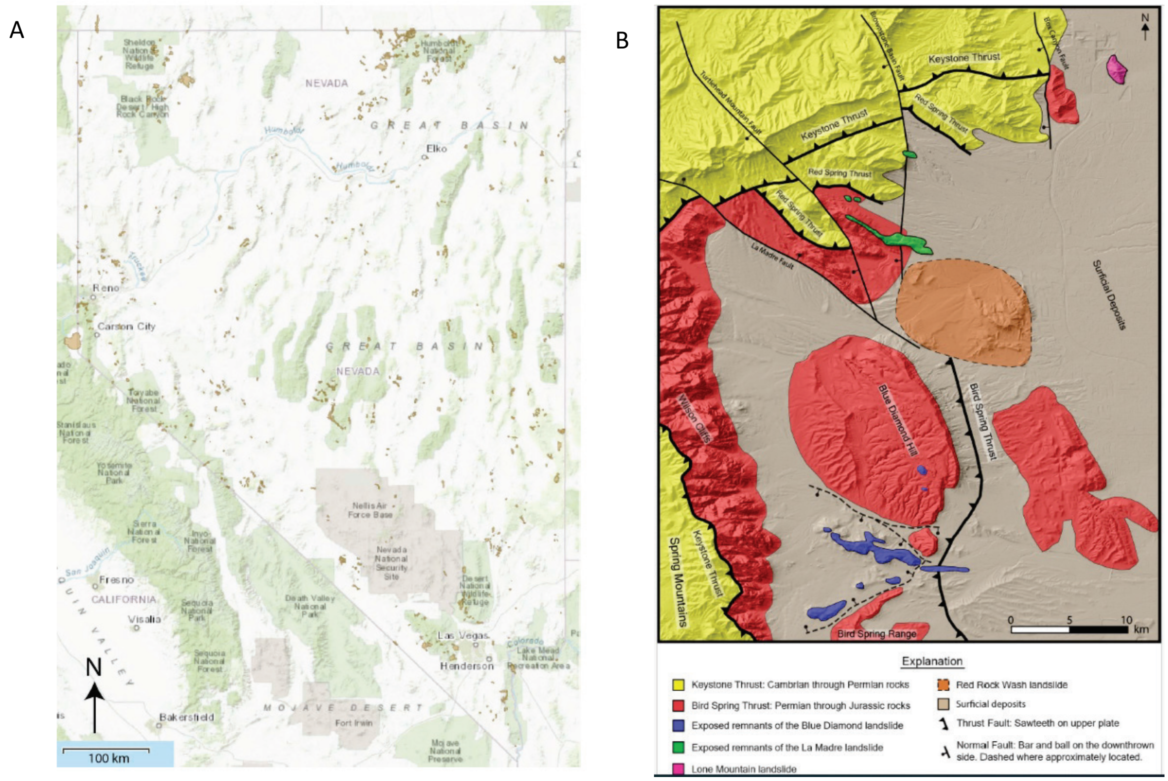

Figure 1 *A. Map of Nevada showing Geologic map showing ~700 landslide deposits (data from Sturmer and Micander, 2020). B. Map of landslides near Blue Diamond, NV, including the Blue Diamond (blue, south-central), La Madre (green, central), and Lone Mountain (pink, northeast) landslide deposits (from Ferry and Sturmer, 2022).*

Results

Here, we describe four landslides across Nevada to demonstrate the variety of landslide deposits. The first three of these are located within the same general area near Las Vegas in the southern part of the state (Figure 1b).

The Blue Diamond landslide deposit (Figure 2) is a rock avalanche deposit that is up to 20 m thick and caps hills and ridges over an area of ~25 km^2 near the town of Blue Diamond, NV (Page et al., 1998; Ferry et al., 2022). The deposit sits within the valley between the Wilson Cliffs and Blue Diamond Hill. The Wilson Cliffs is a ~1 km high escarpment that served as the source area for the Blue Diamond landslide. Deposit runout was nearly 10 km. The deposit is dominantly comprised of Paleozoic carbonate clasts with lesser Mesozoic sandstone and siltstone. The age of the deposit is poorly constrained, likely Miocene to Pleistocene, though it could be as old as Late Cretaceous (Ferry et al., 2022). One of the curious features of the landslide deposit is that there are two outcrops of the landslide deposit atop Blue Diamond Hill, which are ~100 to 250 m higher in elevation than the other deposit exposures. To explain these observations, Ferry et al. (2022) proposed a two-phase emplacement, where the initial rock avalanche was deposited onto Blue

Diamond Hill, followed by a secondary collapse southward as a compound landslide facilitated by thick and weak gypsum layers in the Permian Kaibab Formation (Figure 2d).

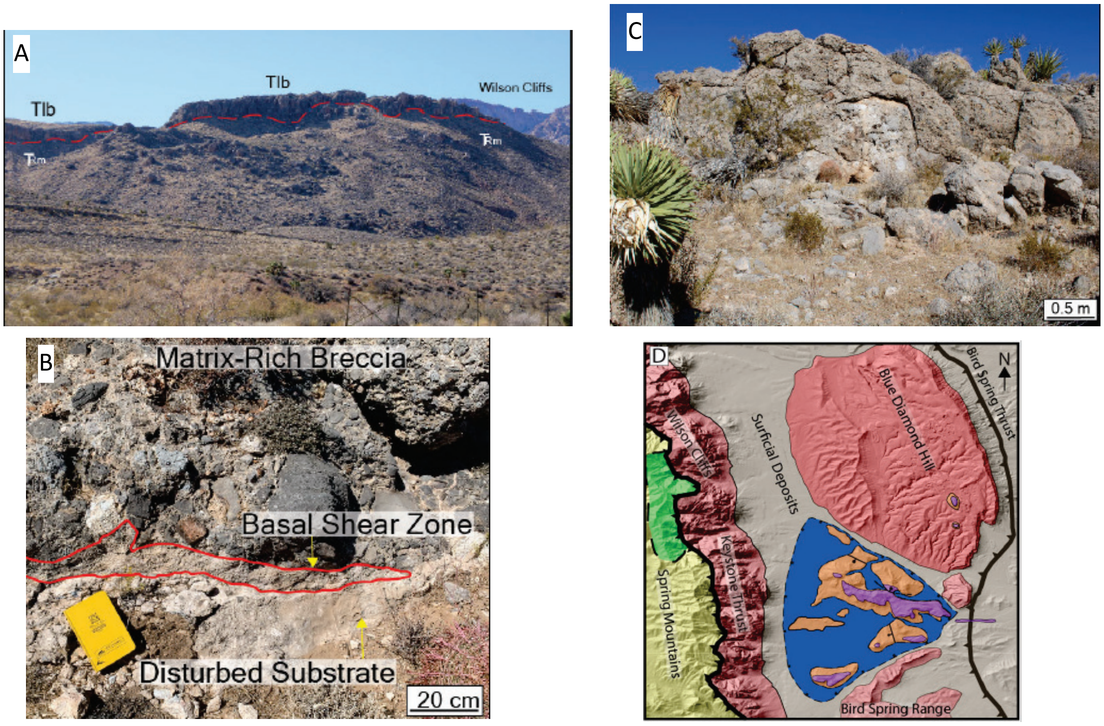

Figure 2. *Photos of the Blue Diamond landslide deposit. A. Landslide deposit (Tlb) capping Moenkopi Formation (TRm) along Blue Diamond ridge. B. Basal shear zone atop disturbed substrate. C. Outcrop of matrix-rich breccia. D. Deposit emplacement model with initial rock avalanche emplacement onto Blue Diamond Hill followed by detachment on gypsum-bearing substrate and compound landslide emplacement. Figures from Ferry et al. (2022) and Ferry and Sturmer (2022).*

The La Madre landslide deposit covers ~7 km^2 just north of the Blue Diamond landslide (Figure 3a,b; e.g., Axen, 1985; Ferry and Sturmer, 2022). The La Madre deposit is ~0.75 km wide and 4 km long, with an estimated 8 km runout. The deposit is dominantly brecciated Mississippian limestone and it sits atop Jurassic Aztec Sandstone and Triassic Moenkopi Formation. The long and narrow nature of the deposit suggests it was deposited in a channel with the topography subsequently inverted. The age of the deposit is not known, but it is likely Cenozoic as it covers the post-Cretaceous Brownstone Basin fault (Figure 3b; Axen, 1985).

Lone Mountain is a 1-km wide block of Paleozoic rocks located 2-2.5 km NE from the eastern flank of the Spring Mountains in western Las Vegas Valley (Figure 3c). Geophysical data indicate that the Paleozoic rocks are sitting atop low density sediments with low resistivity, which have been interpreted as either fully saturated Jurassic Aztec sandstone or Miocene-Quaternary unconsolidated basin fill (e.g., Page et al., 2005). These data lead to the interpretation that Lone Mountain is a block that slid out over Aztec Sandstone or basin fill during Miocene-Quaternary extension (Page et al., 2005; Ferry and Sturmer, 2022).

The Hays Canyon Range landslide (Figure 3d) is located in the northwest corner of Nevada. This landslide occurred as a rotational slump when weak unconsolidated tuff underlying Miocene basalt that caps the range failed, resulting in a ~5-km long slump.

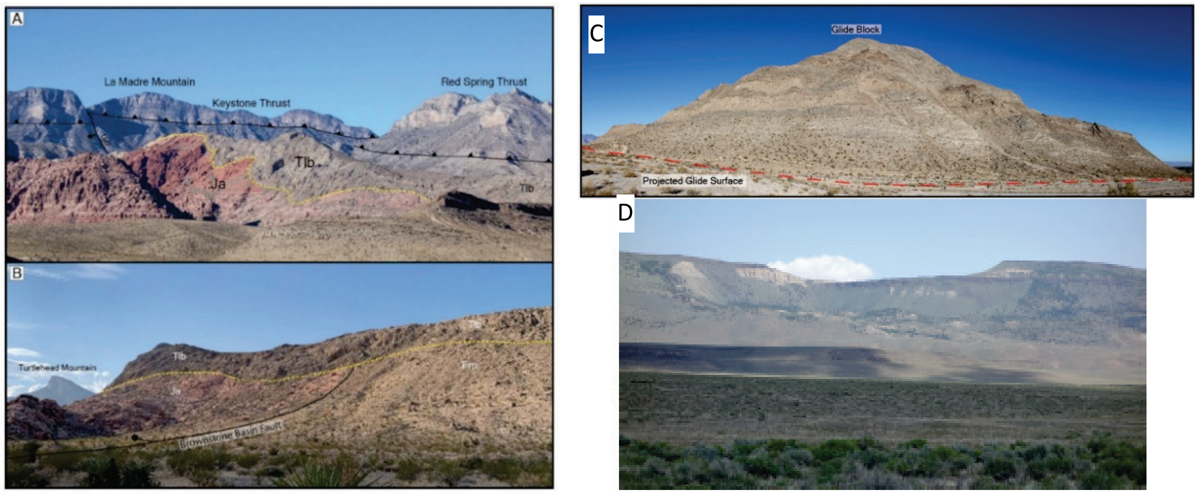

Figure 3. *Annotated photos of landslide deposits. A. La Madre landslide deposit (Tlb) atop the Jurassic Aztec Sandstone (Ja). B. La Madre landslide deposit where it is deposited atop the Cretaceous Brownstone Basin fault. TRm – Triassic Moenkopi Formation. C. View of the Lone Mountain slide block. D. Photo of the Hays Canyon Range slump. A-C from Ferry and Sturmer (2022)*

Conclusions

The tectonism that has occurred in Nevada has resulted in hundreds of large-scale landslides across the state. Most of these have not been studied in detail, but they should be studied to allow us to better understand the role these large landslides have played in the landscape evolution of Nevada.

Acknowledgments
Acknowledgement is made to the donors of the American Chemical Society Petroleum Research Fund for supporting this research (ACS PRF #58626-DN18).

References

Axen, G.J., 1985, Geologic map, and description of structure and stratigraphy, La Madre Mountains, Nevada: Geological Society of America Map and Chart Series MC-51, 17 p., scale 1:25,000.

Dickinson, W. R., 2006, Geotectonic evolution of the Great Basin: Geosphere, v. 2, p. 353-368.

Ferry, N., and Sturmer, D.M., 2022, Landslide deposits and mechanisms in the eastern Spring Mountains, Nevada, USA, in Jiang, G., and Dehler, C., eds, Field Excursions from Las Vegas, Nevada: Guides to the 2022 Cordilleran and Rocky Mountain Section Meeting: GSA Field Guide 63, p. 45-65.

Ferry, N., Sturmer, D., Ward, D., Taylor, W., and Brett, C., 2022, Origin and emplacement of the Blue Diamond landslide breccia, southern Nevada, USA: Journal of Sedimentary Research, v. 92, p. 659-675.

Page, W.R., Dixon, G.L., and Workman, J.B., 1998, The Blue Diamond landslide: a tertiary megabreccia deposit in the Las Vegas area, Clark County, Nevada: Geological Society of America Map and Chart Series MC-83, 11 p., scale 1:24,000.

Page, W.R., Lundstrom, S.C., Dixon, G.L., Rowley, P.D., Harris, A.G., Langenheim, V.E., Workman, J.B., Mahan, S.A., Paces, J.B., and Bell, J.W., 2005, Geology of the Las Vegas 30’ x 60’ Quadrangle, *in* Page, W.R., et al., eds., Geologic and geophysical maps of the Las Vegas 30’ x 60’ quadrangle, Clark and Nye Counties, Nevada, and Inyo County, California: USGS Sci. Inv. Map 2814, 55 p., 1:100,000.

Sturmer, D.M. and Micander, R.E., 2020, A new database of large-scale bedrock landslides in Nevada, USA: GSA Abstracts with Programs, v. 52, no. 6, doi: 10.1130/abs/2020AM-356734.