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A LiDAR-based landslide inventory and associated map portal (story map) for Grand Teton National Park

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Abstract Funding has enabled the design and implementation of a preliminary landslide inventory including roughly 500 deposits throughout GTNP. The three most common mass movement deposits were related to debris flows, translational earth slides and translational rock slides. More than 10% of the features were field-verified during campaigns mapping along the Teton Fault and in areas across varying lithology and relief including Steamboat Mountain, Paintbrush Canyon, Cascade Canyon, Two Ocean Lake, Open Canyon and lower Granite Canyon. Features were mapped according to protocols established by the Oregon Department of Geology and Mineral Industries (DOGAMI) and supported by the USGS. The Story Map remains under development, awaiting revised mapping and feedback from GTNP staff.

Introduction

Mass movements are most frequent in regions with high relief, recent deglaciation (Geertsema and Chiarle, 2013), seismic shaking (Jibson, 2013) and extreme precipitation (Dikau, 2013). This describes Grand Teton National Park (GTNP) and the Greater Yellowstone Ecosystem (GYE) quite well. As such, it is no surprise that mass movements are a known concern in GTNP (Bilderback, 2019) and have required recent management action (e.g. Germann, 2018). In an effort to support future decision-making and encourage further research into mass movements, we aim to produce a park-wide landslide inventory.

Landslide inventories are descriptive datasets that catalog the position and character of all mass movements within a given domain (Galli et al., 2008; Guzzetti et al., 2012). They span from highly local studies, such as a product generated for Yosemite Valley (Wieczorek et al., 1999), to expansive state-wide efforts to catalog all known features, such as the effort in the state of Wyoming (Larsen and Wittke, 2013). Landslide inventories serve as the foundational dataset for all future investigations into characterizing hazards and assessing the risks they pose to people and infrastructure. These sentiments are supported by National Park Service protocol documents focused on monitoring slope movements (Wieczorek and Snyder, 2009) and specific reports on addressing local hazard and risk (e.g. in Yosemite. Stock et al., 2014).

At the initiation of this project, no park-wide landslide inventory exists for GTNP. A previous investigation was limited to 5 canyons of GTNP and only utilized aerial photo mapping and field observation (Marston et al., 2011; Butler, 2013), techniques which have been demonstrated to be inferior to LiDAR-based analyses (Bunn et al., 2019). LiDAR-based landslide mapping enables sub-meter resolution of the bare ground topography, revealing the location of disturbed ground, headscarps and depositional lobes – even under dense tree cover (Wills and McCrink, 2002; McKean and Roering, 2004). Given the recent acquisition of LiDAR for the entire park (Woolpert, 2014) and the know concerns regarding mass movements, it is vital to add a landslide inventory to the park's management toolset while also enabling future research into hazards and risk.

Web-based map portals have become commonplace (e.g. Google Maps, Municipal Parcel Maps) and enable the public, agencies, industry and researchers broad access to imagery, topography, infrastructure and geospatial data (Tsou, 2004). These maps also enable public participation in the decision-making process by increasing access to geospatial information (Kingston, 2007). In recent years, these portals have become sophisticated enough to weave a narrative element into the presentation of that data. These 'Story Maps' (ESRI, 2019) merge video, photography, text and maps to convey complicated ideas to the public and to present data that can be independently explored by the viewer. A well-designed Story Map exists for GTNP (NPS, 2019). We aim to develop a similar educational portal focused on landslides within the park (e.g. City of Seattle, 2019; Geological Survey of Washington, 2019).

Methods

We mapped landslides initially using park-wide LiDAR data in ArcGIS Pro, following the protocols defined in Burns and Madin (2009). Preliminary designations, polygons and lines were revised by a second reviewer. Paper maps were generated for select areas and visited on foot to verify the extent and character of ∼10% of the failures. This field-validation seldom led to wholesale removal of features. Instead the typical outcome of field validation was either shape refinement or addition of previously undetected (often small) mass movements. The story map is still in development, awaiting the finalized map and guidance from GTNP.

Preliminary results

Roughly 500 large scale mass movement deposits were identified from the combination of LiDAR remote sensing and in-field observation. At present, there is still work to be done in refining the extent and character of these features. Consider these results preliminary.

Mapped features are typically greater than 10 meters in width, though field verification helped identify features that were down to 3-5 meters in width. The three most common mass movement deposits were related to debris flows, translational earth slides and translational rock slides. Mass movement initiation points (for debris flows), scarps, flow paths and scarp flanks were also added to the geodatabase.

In the high-relief, crystaline center of the Teton Range, mass movements were dominated by debris flows, rockfall and rock topples. Numerous rock glaciers were identified though not explicitly attributed as mass movements, though their form is similar to that of earthflow features.

In the lower relief range flanks where layers of either sedimentary or volcanic rock are found, the dominant mass movement types were translational slides of either rock or earth. These slides are typically down-dip and high volume. Smaller rockfalls and topples were found on anti-dip slopes, often creating debris flow deposits.

In the areas of glacial deposits (far northeastern end of the park), rotational slumps and earthflows were frequently observed. These features may be occurring in either glacial till or in volcanic rocks sculpted by glacial ice.

Conclusions

Lithology and relief appear to be the strongest controls on mass movement type and density. Mass movements do not appear to be of a uniform maturity (as a proxy for age), suggesting that they are not all the consequence of a single seismic event or post-glacial debutress-ing. Instead, it appears that feature initiation is well distributed in time and many features have been reactivated, many of which are active today.

Future work

We still need to complete a final revision of landslide attributes, polygons and lines which relies on meeting with the GTNP staff. This meeting will also help us define the scope of the proposed Story Map. At this time we are uncomfortable sharing preliminary landslide polygons as figures in this report until they are better vetted within our team and by NPS staff. A new graduate student has joined the ISU team, Joshua Lingbloom who will augment and finalize this project as part of his MS Geology thesis. This should be complete by the Summer of 2022.

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