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Landslide Hazards in Eastern Oklahoma Mountains

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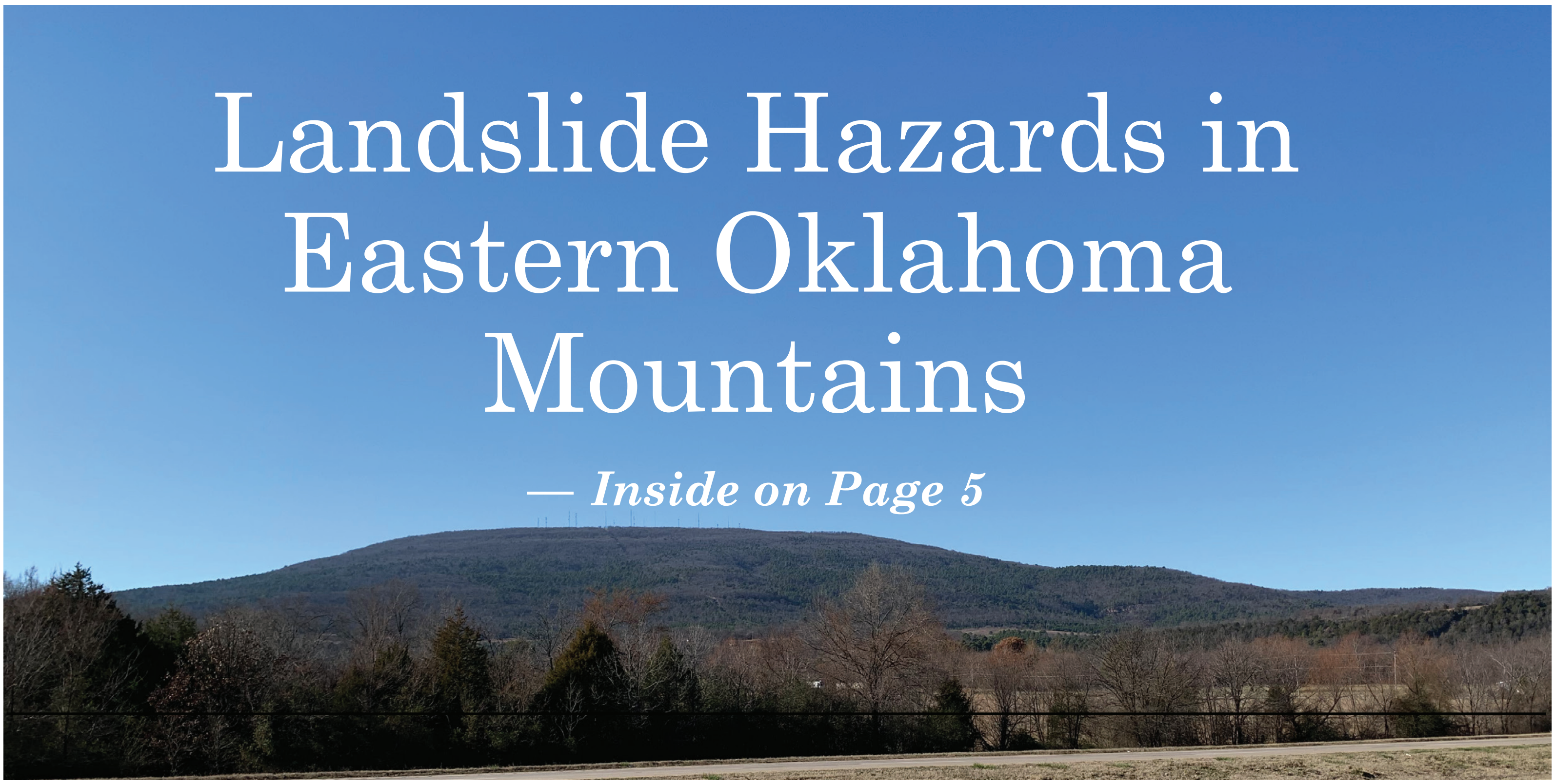

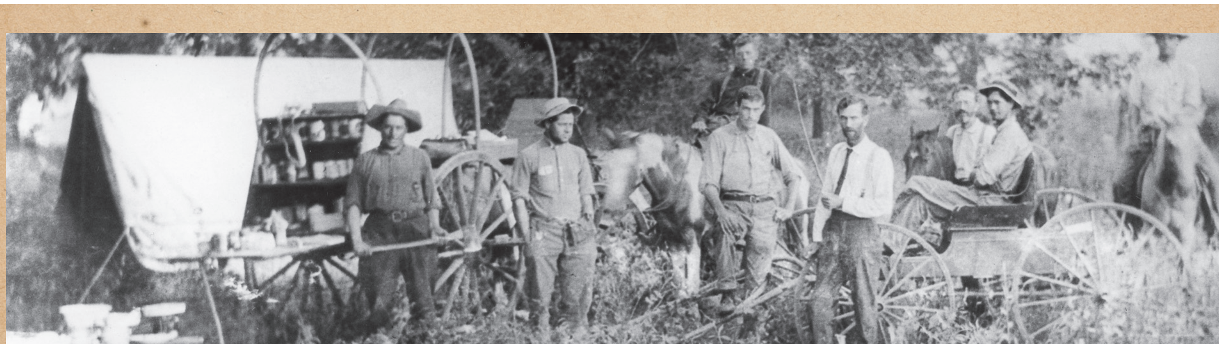

OGS History Part 4: Charles Gould's first era with the Survey

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OKLAHOMA GEOLOGICAL SURVEY

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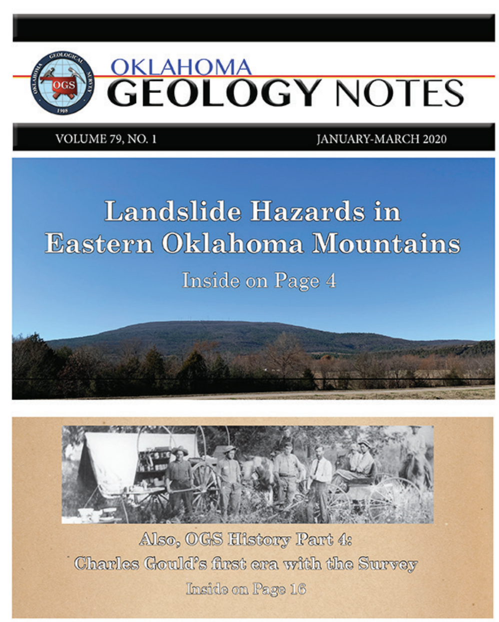


Cover design by Ted Satterfield.

Dear readers,

After a nearly yearlong search, the OGS has named a new director: Dr. Nicholas Hayman. He will start work July 1 of this year.

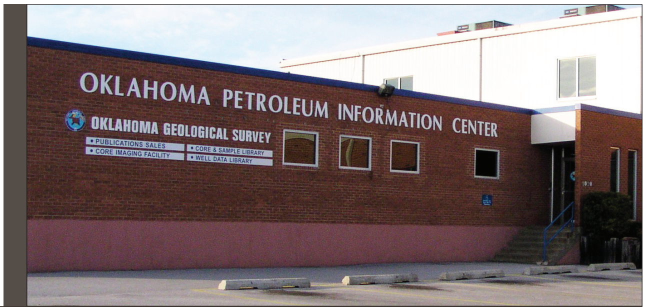
Dr. Hayman received his BS and MS from SUNY in Albany and received his doctorate in Geological Sciences at University of Washington. Most recently he served as Program Director, National Science Foundation, Marine Geology and Geophysics Program Ocean Sciences Division, as well as research scientist at the University of Texas-Austin's Institute for Geophysics.

An upcoming issue of the Oklahoma Geology Notes will dedicate a full article to introducing the incoming director to our readers.

Kind Regards,

Ted Satterfield
OGS Editor

OKLAHOMA PETROLEUM INFORMATION CENTER



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Also in the collection are 126,000 strip logs dating from the 1890s which have been recently digitized. In addition, the library maintains a hard copy of 1002A completion reports from 1904 to the 1990s; multiple sets of scout tickets; completion cards for Oklahoma wells; and hard copies of aerial photos dating from 1934-1986 that are filed by county, township and range.

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The OGS Publication Sales Office is also located at OPIC. There you can purchase any USGS 7.5 minute quadrangle map of the state, a variety of other USGS maps and all inprint maps and publications produced by the OGS, representing nearly a century's worth of research and mapping.

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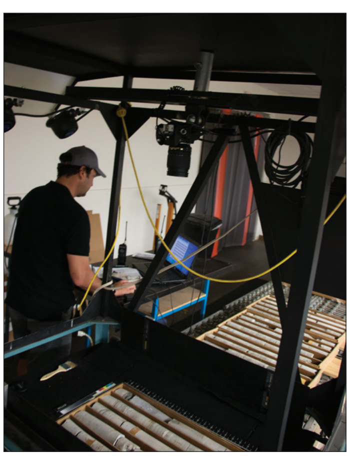

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Landslide Hazards in Eastern Oklahoma Mountains

By
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and
Jake Walter, OGS Geophysicist & State Seismologist

1.0 INTRODUCTION

Mass movement, including shallow and deep-seated landslides, is one of the major geologic hazards in Ouachita and Ozark Mountains of eastern Oklahoma. Factors that predispose landslides in this landscape are primarily deformed and weathered lithology, geological structure (i.e., fault, fold, joints and fractures), steep and rugged topography, intense precipitation, frequent seismicity and land use changes. We summarize results of a pilot study focused on understanding causes, mechanics and distribution of shallow landslides. These results and ongoing work will drive efforts towards modeling landslide susceptibility in Ouachita and Ozark Mountains, using remote sensing products, extensive field surveys, and mathematical and geospatial modeling.

The primary objective of the initial study was to characterize mass movement processes and hazards in Cavanal Hill and Sugarloaf Mountain in eastern Oklahoma. Specifically, we: (1) mapped shallow landslides, determined their geomorphic characteristics, and quantified the frequency, volume, and rate of sediment production; (2) evaluated the geomorphic characteristics of landslides and hillslopes; and (3) developed a technique of rapidly mapping hillslope susceptibility to shallow landslides using high resolution LiDAR topographic data.

Results showed that the frequency of shallow landslide in eastern Oklahoma has increased significantly since 2005. The observed rate of landslides since 2005 was obtained as ~10 landslides per year with landslide density of ~0.7 landslides per square kilometer and sediment production rate of ~1.5×10^5 m^3/yr (sediment yield rate: ~0.1 mm/yr). These landslides could have been triggered by increased regional seismic activity or intense tropical storms, amongst other potentially co-mingled factors. The study also showed that high resolution LiDAR topographic data mapped landslides with a model accuracy of 84%, and suggests that the tool is applicable in first-order characterization of landslides and landslide associated landforms.

2.0 STUDY AREA

2.1 Climate, geology and vegetation

The study area, a part of Ouachita Mountains

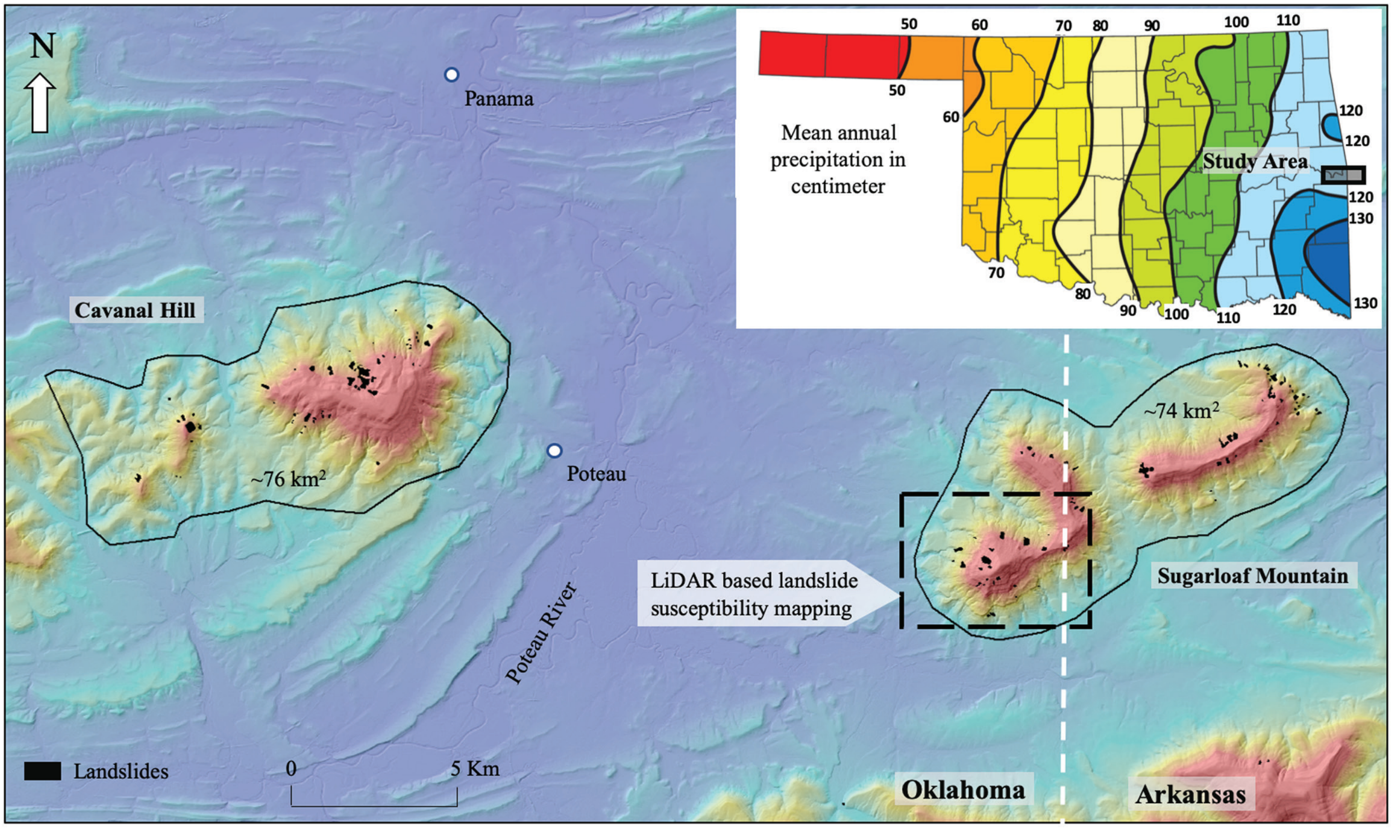


Figure 1. Location of the study area. The study area (~150 km^2) comprises upslope landscapes of Cavanal Hill (~76 km^2) and Sugarloaf Mountain (~74 km^2) of Ouachita Mountains. The map in the upper right corner shows the mean annual precipitation in Oklahoma based on 1971-2000 precipitation data (modified after Johnson and Luza, 2008).

(Figure 1), has humid subtropical climate, driven by the warm, moist air moving northward from the Gulf of Mexico (Oklahoma Climatological Survey, 2018). The area receives maximum precipitation during June, July and August, and minimum precipitation during December, January and February. The annual average precipitation is ~120-130 cm (47-51 in), and annual average temperature is ~ 16°C (61°F) (Johnson and Luza, 2008).

The study includes Cavanal Hill consisting of Pennsylvanian aged lithology of Boggy and Savana formations, and Sugarloaf Mountain consisting of the Savana Formation. Both formations comprise thin-bedded, deformed fine- to medium-grained sandstones, and thick, weathered and organic-rich fossiliferous shales as primary rock types, and limestone and coal as secondary lithology (Hemish and Suneson, 1997, Heran, et al., 2003). The hillslopes are dominantly soil-mantled underlain primarily by in-situ soil derived from shale and sandstone, and Quaternary colluvial and talus deposits. Lowlands around these mountains are underlain by sandstone and shale of the McAlester and Hartshorne formations and Quaternary terraces, alluvial and colluvial deposits. The area exhibits a few faults and a regional NE-SW trending synclinal structure known as the Cavanal syncline.

The vegetation in the area is primarily oak-pine forest in upland areas and post-oak blackjack forest in lowlands. Upland vegetation consists primarily of various Oak species and shortleaf pine, and associated vegetation includes trees and shrubs including flowering dogwood, highbush and lowbush blueberries, hophorn beam, redbud serviceberry, and sugar maple (Johnson and Luza, 2008).

2.2 Mass Movement

The Ouachita Mountains are steep and rugged, with significant relief. Triggers for past mass movements in the area include earthquakes and precipitation (He, et al., 2014, Oakes, 1952, Webb, 1960). For example, Oakes (1952) describes eyewitness reports of landslides along Cavanal Hill shortly after the April 9, 1952 El Reno earthquake, a M 5.5 earthquake that occurred ~300 km from Cavanal Hill. Those observations suggest a potential triggering of landslides in Ouachita Mountains by nearby and distant earthquakes. Similarly, a resident of Poteau, Oklahoma reported to the Oklahoma Geological Survey that a large landslide in northern hillslope of Sugarloaf Mountain was triggered by the rainstorm of September 2018. Recently, Oklahoma has experienced several moderate and damaging earthquakes including the November 2011 M_w 5.7 Prague earthquake (Keranen, et al., 2013), the September 2016 M_w 5.8 Pawnee earthquake (Walter, et al., 2017, Yeck, et al., 2017), and the November 2016 M_w 5.0 Cushing earthquake. Similarly, a number of precipitation events of intensity greater than that occurred during September of 2018 also have been recorded in the past (Oklahoma Climatological Survey, 2018). Although there are no studies that suggest these events triggered any landslides in the area, we consider that these events alone or in conjunction with other preexisting conditions, could have triggered many landslides in the area (Regmi and Walter, 2019).

3.0 METHODOLOGY

This study focuses on mapping landslides and associated geomorphic characteristics in Cavanal Hill and Sugarloaf Mountain by using remote sensing products, and detailed field surveys. The dataset includes aerial photographs acquired in different times since 1990, 10 m National Elevation Dataset (NED), 2 m LiDAR topographic data flown over Sugarloaf Mountain, and a geological map of 1: 24,000 scale. Locations and geomorphic characteristics of some of the landslides were verified in the field. In addition, hillslope characteristics including slope gradient, slope materials, and hydrology were confirmed in the field.

3.1 Landslide mapping

Shallow landslides, defined here as landslides with depth of slip surface less than an approximate tree root depth (< 10 m), were mapped from historical aerial photographs, and classified following Varnes (1978). The approximate ages (in five-year interval) of these landslides were determined based on their first appearance on aerial photographs acquired in different times since 1990. Landslide areas (A) were calculated in ArcGIS and the volumes (V) were estimated based on the equation (Equation 1) proposed for shallow landslides in North Fork Gunnison River Catchment of western Colorado (Regmi, et al., 2014). The Geologic environments of eastern Oklahoma and North Fork Gunnison River catchment is quite similar, both landscapes are dominated by sandstone, shale or mudstone and limestone.

$$V = 0.0254 \times A^{1.45} \qquad (1)$$

3.2 Hillslope characterization based on digital elevation data

NED 10 m digital elevation model (DEM) of the entire study area was used to compute slope gradient and curvature of landslides and slopes devoid of landslides. LiDAR DEM of Sugarloaf Mountain was used to test the effectiveness of LiDAR elevation data in mapping hillslope susceptibility to shallow landslides. LiDAR elevation data was smoothed out using 12 × 12 m roving window to remove the high frequency noises and DEM artifacts. The processed LiDAR DEM was then used to derive various derivative maps including hillshade image, slope, curvature and surface roughness. We observed in the field that landslide surfaces tend to have higher surface roughness relative to the roughness of slopes devoid of landslides. A simple mathematical algorithm that calculates roughness based on the standard deviation of slope within a 10 × 10 m moving windows was used to compute surface roughness following (Frankel and Dolan, 2007). We evaluated the effectiveness of the roughness map in mapping landslides or associated landforms, and a landslide susceptibility map was prepared from the surface roughness map.

4.0 RESULTS

4.1 Field and aerial photographic observation

Shallow mass movement features, including soil creep, soil slides, debris slides, debris flows, rock slides and rock falls were observed across the study area. Soil creep, soil slides and debris flows

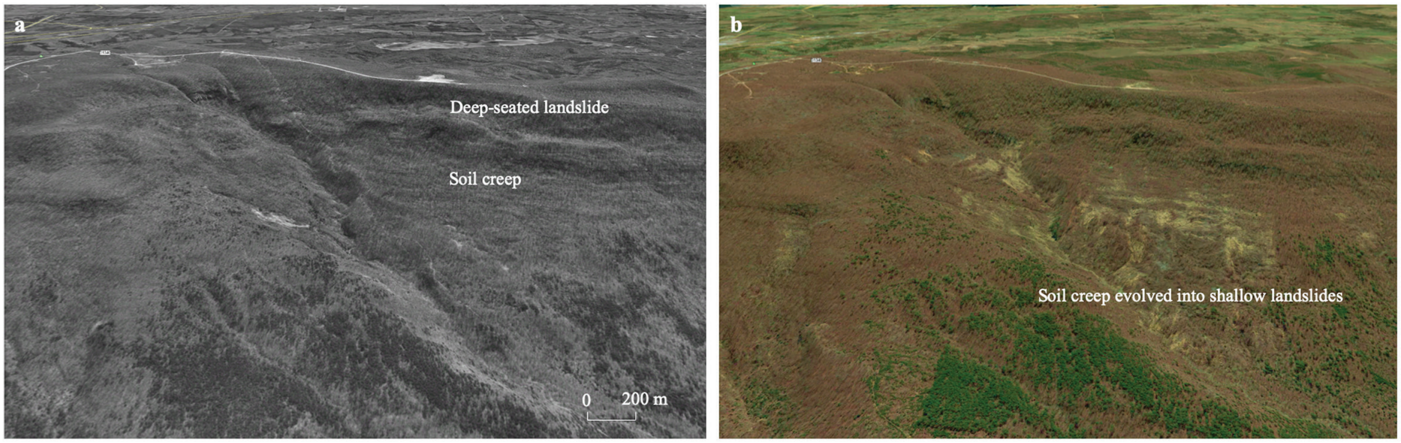


Figure 2. Aerial photographs showing a hillslope of Cavanal Hill in (a) 1995 and (b) 2016. The soil-mantle seems to be in creeping state in 1995, whereas observation of 2012 - 2016 aerial photographs suggested that the soil-creep evolved into shallow landslides during 2012-2016.

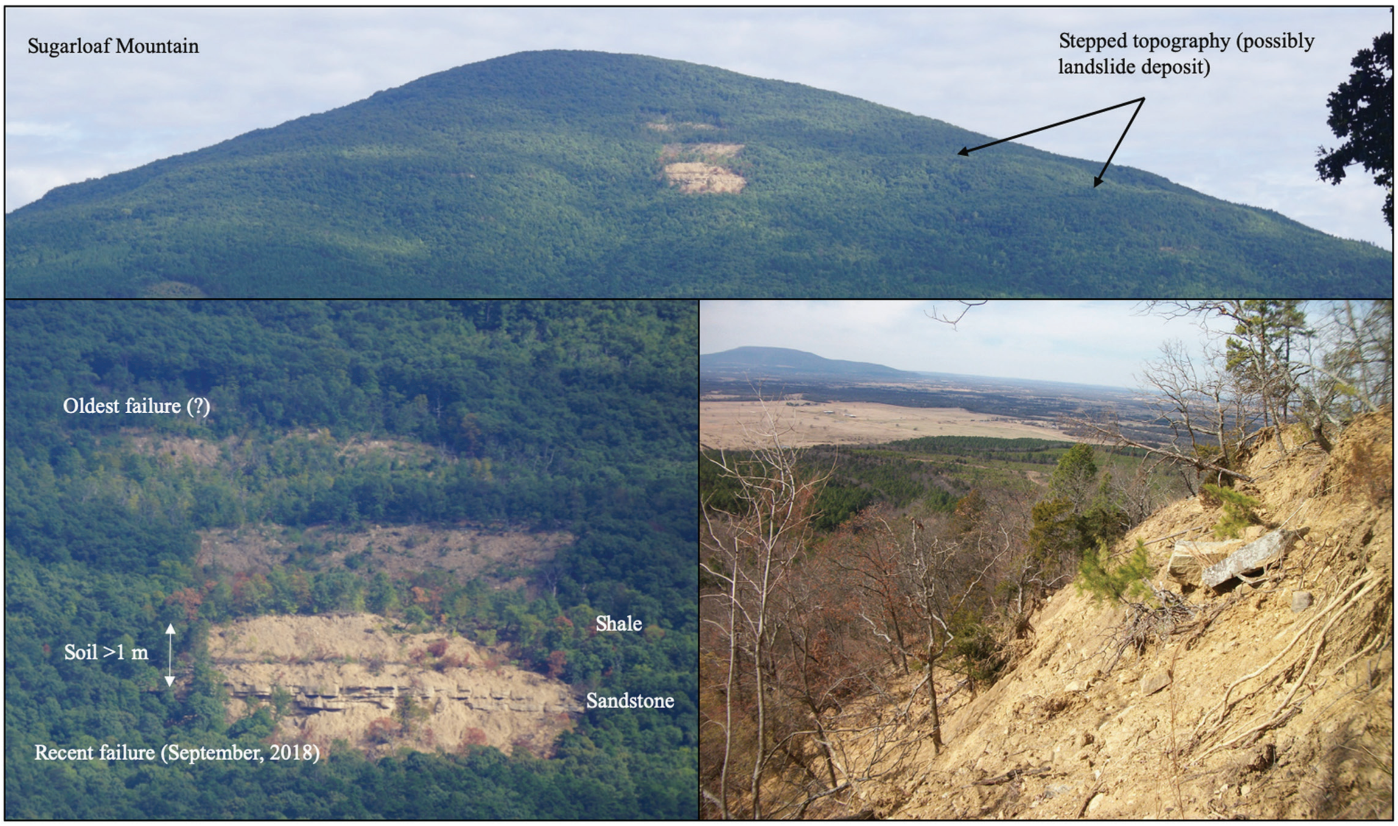
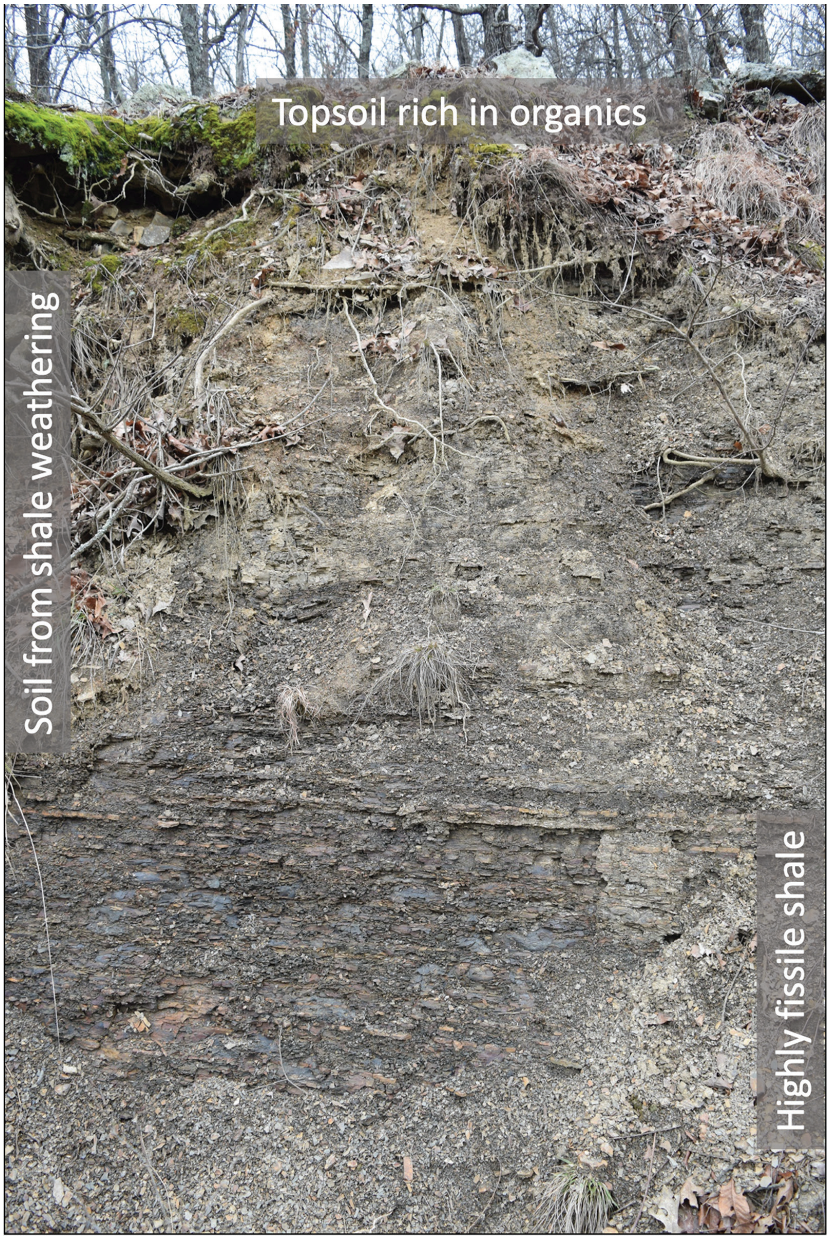


Figure 3. Photographs of a landslide in Sugarloaf Mountain (a) showing stepped topography formed by episodic movement, and (b) the close up view of the landslide scarp. Note the sandstone layer is thin and soil thickness is >1 m. Photographs taken in early September, 2018 by David Deaton and Steve Humphries.

are mostly located in thick shale deposits, debris slides are located in colluvial deposits, and rock slides and rock falls occur in sandstone exposure. Slopes underlain by shale are predominantly soil-mantled, concave in nature, and consist of soils developed primarily by the weathering of shale, and colluvium deposited by erosion and landslides. The average depth of the soil is observed as >1 m in most of the landscapes, particularly along the zones of topographic convergence (i.e., hillslope hollows or topographic depressions) (Figures 2 and 3). Shale is fissile, highly weathered, and the resulting soil is cohesive in nature, whereas colluvial deposits consist of rock fragments and boulders, thereby are relatively frictional. The sandstone is relatively thin, highly fractured and jointed, and exhibit relatively convex geometry. Both mountains of this study have similar soil and geomorphic characteristics, and exhibit colluvium, talus deposits and rock boulders at the base of the slopes (Figure 4).

ABOVE: Figure 4. Photographs showing (a) a large rock boulder deposited at the base of a slope in Sugarloaf Mountain, and (b) On-slope colluvial deposits at the base of sandstone and limestone exposure in Cavanal Hill. Note the deposit is under stressed condition as evidenced by the bended tree trunk. **BELOW: Figure 5.** Thick soil developed from weathered and fissile shale observed on a road cutslope of Cavanal Hill.



The degree of weathering decreases with depth. Observation of a road-cut section in Cavanal Hill (Figure 5) shows the top soil is about ~15 cm deep and comprises mostly vegetation matrix and organic materials. The depth of the soil above the bedrock is ~1.5 m thick, however the content of the organic materials appears to be decreasing with depth. The soil has some degree of moisture saturation and could be the result of a groundwater seepage that we observed in a nearby location. The upstream drainage area of the observed cut slope is small, however, the presence of seepage and moist soil suggest the effective infiltration of the soil is enough to maintain active sub-surface hydrological processes, which could be the subject of future study. We observed that the stream water in both mountains is milky in color, which could be the result of dissolution of carbonate rocks (Figure 6).

The majority of shallow landslides were observed primarily in three landscape positions including: 1) soil-mantled concave slopes underlain by shale; 2) colluvial deposits at the base of steep sandstone bedrock slopes; and 3) in close proximity to incised first and second order streams. Most of the

Figure 6. Stream water in (a) Sugarloaf Mountain and (b) Cavanal Hill. Note: the milky color of water is potentially the result of limestone dissolution.

observed landslides in soil-mantled hillslopes appear to be evolved from soil creep (Figures 7 and 8); and some landslides were observed in sandstone and shale transitions, probably caused by the difference in the shear strengths. Rockslides and rock falls, were observed mostly in steep sandstone bedrock slopes. On closer inspection, the area also exhibits hillslope sculpted by a few probably hundreds- to thousands-years-old large deep-seated landslides, incised first and higher order channels, and prominent gullies (Figure 2). Deep-seated landslides are large, and exhibit surface morphology similar to that of slump-block (Baum and Odum, 1996), and are plausibly related to structural failures of bedrock. Large deep-seated landslides, found on the edges of the upland plateau of Cavanal Hill, exhibit dense vegetation on the scarp and deposits, and smooth surfaces with well-evolved hydrological network, (Figure 2). These characteristics suggest these landslides are probably hundreds- to thousands-year-old and relatively stable now (LaHusen, et al., 2016). These landslides could have occurred in completely different climatic and tectonic conditions, and could be the result of completely different mechanisms than that of shallow landslides that are the main focus of this study.

4.2 Geomorphic characteristics and ages of shallow landslides

One hundred and eighty-five shallow landslides were mapped from aerial photographs. Most of these landslides are small to moderate in size. The landslide area ranges from 64 to 55,000 m^2, the runout ranges from 11 to 500 m, and the modeled volume ranges from 11 to 260,000 m^3 (Table 1). A few of the landslides observed in both Cavanal Hill and Sugarloaf Mountains are large. Average slope of the landslides was found as ~19±7°, significantly higher than the average slope of the entire area as ~11±7°.

Approximate ages of 137 landslides out of 185 were determined from aerial photographs acquired in different times from 1995 to 2016 (Table 1) and archived in Google Earth. Among 137 landslides, only 25 occurred prior to 2000, 4 occurred during 2000-2005, 46 occurred during 2005-2010, and 62 occurred during 2010-2016. The ages of rest of the landslides (48 landslides), however were difficult to determine because the size of landslides were nearly equivalent to the horizontal resolution of older aerial photographs or landslide surfaces were covered by dense vegetation. We only consider the inventory of landslides after 2005 to assess the rate of landslide occurrence and sediment yield. The frequency distribution of landslides over 2005-2016 indicates that ~10 landslides occur every year with landslide density of ~0.7 landslides per square kilometer. The sediment volume produced by landslides during that time period (2005-2016) was ~1.5×10^5 m^3/yr, and the sediment yield rate is ~ 0.10 mm/yr (Table 1).

4.3 Landslide susceptibility mapping using LiDAR topographic data

The surface roughness map (Figures 7 and

Approx. age	Freq.	Area (m^2)			Modeled volume (m^3)				Sed. yield (m^3/yr)	Sed. yield (mm/yr)
		min	mean	max	min	mean	max	Sum		
2010-2016	62	245	7394	46010	74	14854	146545	920963	153494	0.10
2005-2010	46	143	7880	55101	34	15916	190335	732122	146424	0.10
2000-2005	4	2008	3084	5092	1562	3046	6024	12184	2437	0.00
Prior to 2000	25	147	6761	68388	35	16979	260350	424466	NA	NA
Unknown	48	64	2500	29852	11	4267	78260	204798	NA	NA
Entire landslides	48	64	23381	29852	11	47803	78260	204798	NA	NA

Table 1. Observation of shallow landslide characteristics across the study area.

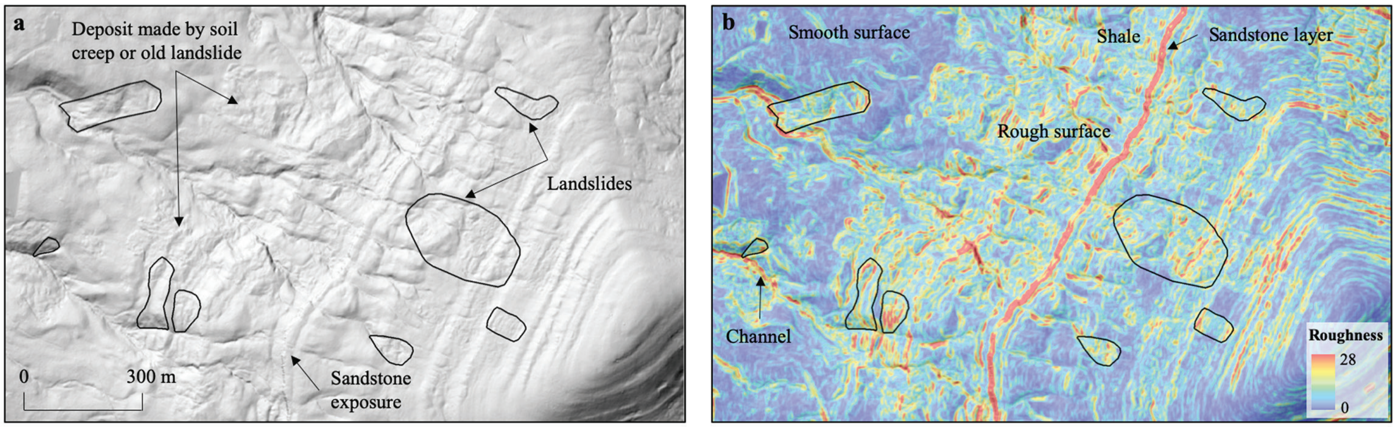


Figure 7. Two-meter LiDAR DEM-derived hillslope geometries, (a) Landslide polygons overlaid over hillshade image, b) surface roughness map computed as a standard deviation of slope at 10 × 10 m moving window.

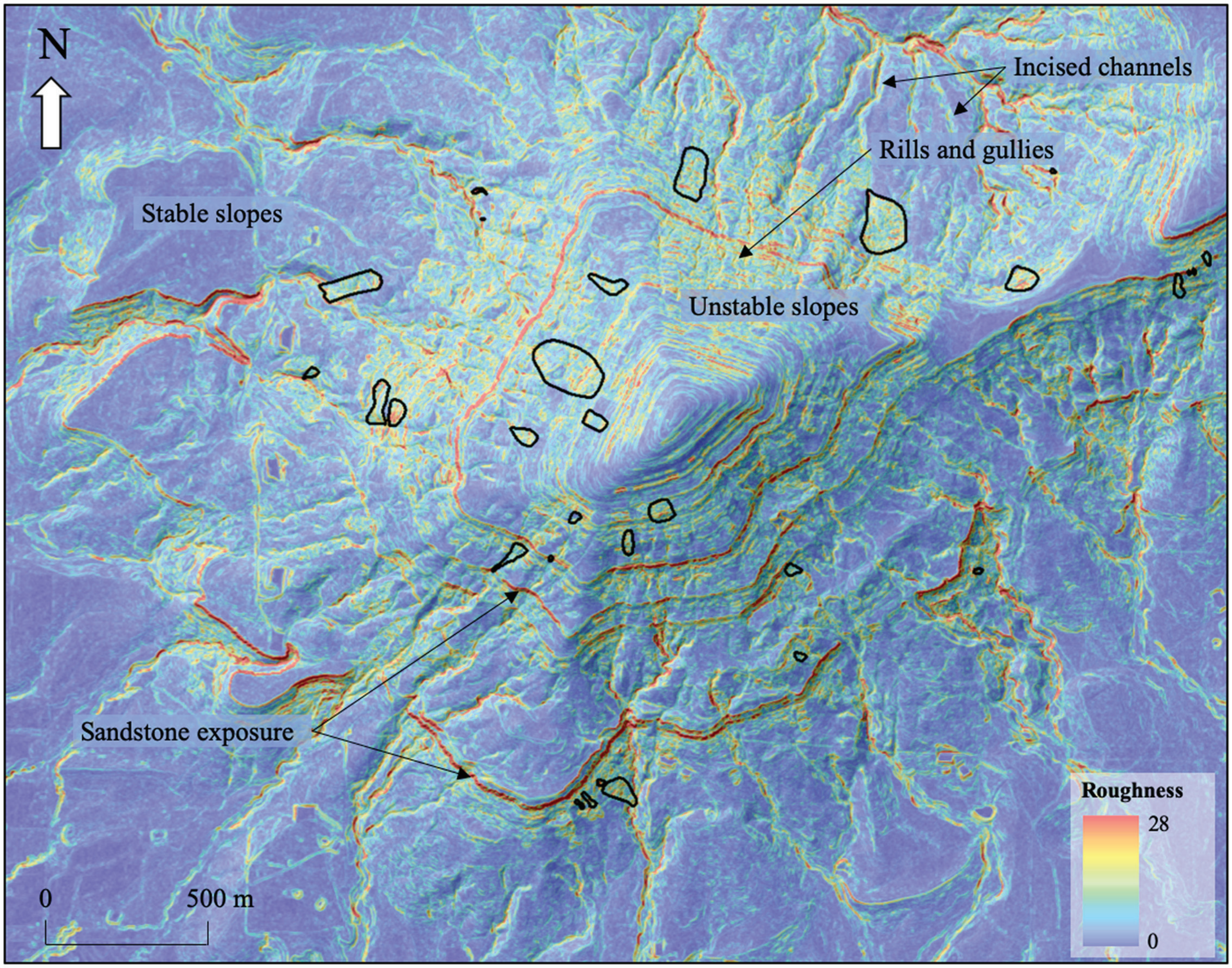
8), shows high roughness values in (1) landslide surfaces including scarps and deposits, and hummocky topography developed by soil creeps; (2) rills, gullies, incised first and higher order channels, ridges, and spurs; and (3) steep sandstone bedrock slopes (Figure 8). In addition, the roughness map also identified hummocky topography derived primarily by old landslide deposits, active surfaces of soil creeps, and sediments accumulated by rock falls and rockslides (Figure 7). Comparison of surface roughness map with observed map of landslides based on the Receiver Operating Characteristics (ROC) curve developed by plotting percentage of the study area from high to low surface roughness versus percentage of landslides shows that ~84% (AUC = 0.84) of the observed landslides are mapped by high surface roughness value (Figure 9). This illustrates that the surface roughness map can be used as a tool for the first-order characterization of unstable hillslopes for mapping hillslope susceptibility to shallow landslides and erosion.

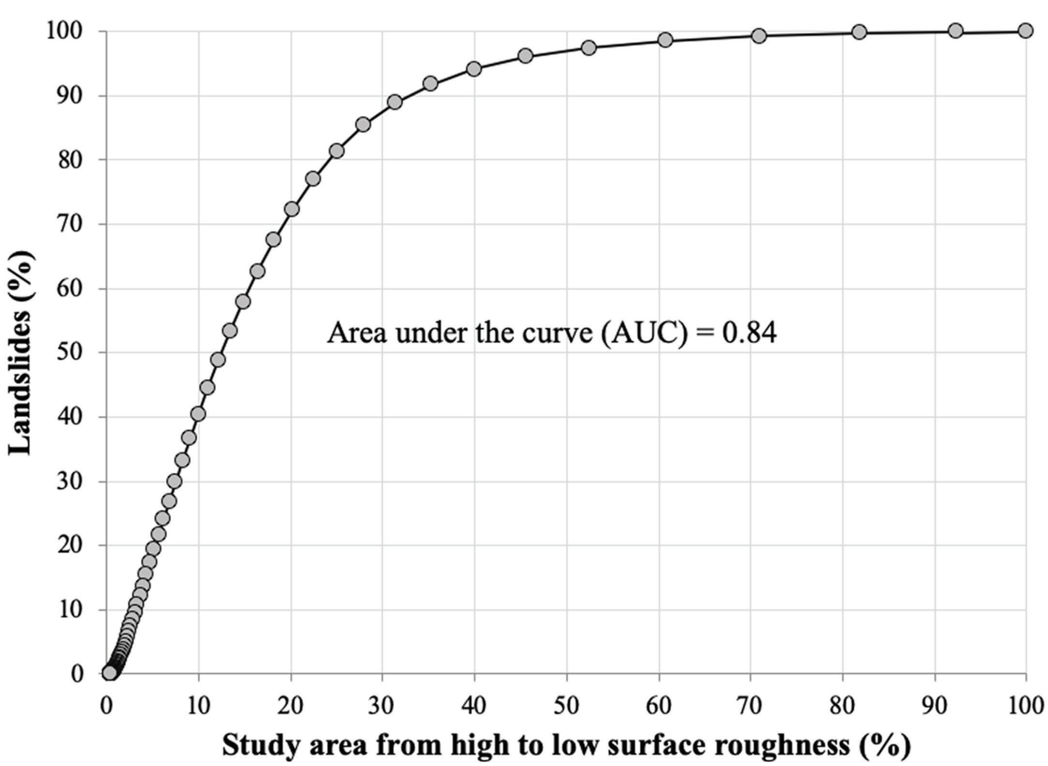
5.0 DISCUSSION

5.1 Landslide characteristics and sediment dynamics

This study represents a regional scale study of mass movement processes and hazards in part of the Ouachita Mountains, where climatic and seismic forces act together over deformed lithology and results in mass movement, erosion, and stream incision (Oakes, 1952, Webb, 1960).

This study shows increased frequency of shallow landslides during 2005-2016. Based on landslides that occurred during this period (Table 1), on average ~10 landslides with the spatial density of ~0.7/km^2 occur each year. These landslides alone produce ~0.10 mm/yr of sediments suggesting the hillslopes in the area are active and landslides are one of the major processes that yield and transport huge amount of sediments each year. We believe there exist some uncertainties in mapping landslide age, for example, the aerial photographs and other data are not sufficient to map all landslides prior





ABOVE: Figure 8. Landslide polygons overlaid over surface roughness map of hillslope in a part of the study area (See Fig. 1).

LEFT: Figure 9. A plot showing the shallow landslide prediction by surface roughness. Note percentage of landslides were plotted against percentage of the study area from high to low surface roughness. The area under the curve (AUC) characterize the overall prediction accuracy of the model.

to 2005 because of the coarser resolution of aerial photographs, and surfaces of landslides that could have smoothed out as feedback-response of hydrological, weathering, vegetation, and soil-biotic processes (Guthrie and Evans, 2007, LaHusen, et al., 2016). Nevertheless, the observed ages indicate that the landslide frequency has increased significantly since 2005 (Table 1), which in turn, highlights the requirement of landslide mapping in broader region to better understand the frequency and major causes of recent landslides. In this viewpoint, we are in the process of expanding the study to include broader areas including the Ouachita and Ozark Mountains both in Oklahoma and Arkansas.

We consider that precipitation, soil characteristics, and dynamic triggering by distant earthquakes could be the major factors that cause shallow landslides in the study area. The hilly landscape, consisting of alternating layers of sandstone and shale, exhibits a geomorphic dichotomy where thin sandstone layers maintain the slope, and thick shale undergoes relatively intense weathering, rapid soil development, erosion, channel incision, soil creeping, and episodic landsliding, thereby creating a concave slope profile. The majority of the slopes in the area are soil-mantled, underlain by soil derived from shale and sandstone. Deposits derived from sandstone are mostly frictional, whereas in situ soil developed by the weathering of shale has considerable cohesion because of the presence of clay and organics. Additionally, the area has dense vegetation which contributes to the development of thick soil profiles consisting of organic rich horizons that have relatively fine-grained texture and well-developed structure (Kay, 1998). In such environments, the subsurface also exhibits well-developed tree root associated flowpaths and drainage networks. In addition, the dissolution of the limestone also facilitates the development of subsurface flowpaths. The combined effect of these attributes results in higher infiltration, conductivity and moisture potential of soil (Easter, et al., 1991) which during storm events facilitates building up of pore-water pressure, and, thereby, landslides and erosion.

Very high precipitation, such as record precipitation highs recorded in 2015 (Oklahoma Climatological Survey, 2018), increased seismicity during the last decade, such as Pawnee, Prague, Cushing, and other recent Oklahoma earthquakes, and anthropogenic activities including urbanization in upslope areas, increased traffic load, and construction and maintenance of roads and other infrastructure, could have triggered many of the observed landslides, and could be responsible for the observed increased frequency of landslides. Considering these triggering factors of landslides, and soil deposit that is thick and has very high soil-water potential, the environment suggests that studied hillslopes are highly susceptible to shallow landslides.

5.2 Future work: Landslide susceptibility mapping

The surface roughness map indicates that mass movement features including shallow landslides, soil creeps, and sediments deposited by old landslides, and rock falls, are well captured by higher surface roughness values. The index also characterizes erosional features including rills, gullies, and incised channels as high surface roughness values. This illustrates that the index can be used as a mapping tool for the first-order identification of active and hazardous slopes. Similar kinds of indices have successfully been used in mapping landslides in different geologic, climatic and tectonic regions worldwide (Berti, et al., 2013, Booth, et al., 2009, Grohmann, et al., 2011, LaHusen, et al., 2016, McKean and Roering, 2004), and this study provides additional insights in the efficacy of the index in mapping shallow landslides. This study shows the index identified ~84% of the observed landslides, which is as good as the other studies that used a number of environmental covariates and robust statistical approaches in mapping landslide hazards and susceptibility worldwide (Dahal, et al., 2008a, Dahal, et al., 2008b, Lee and Choi, 2004, Lee, et al., 2002, Mathew, et al., 2007, Van Westen, et al., 2003).

CONCLUSIONS

Ouachita Mountain hillslopes have long been characterized as susceptible to landslides and erosion. This pilot study suggests upland slopes un-

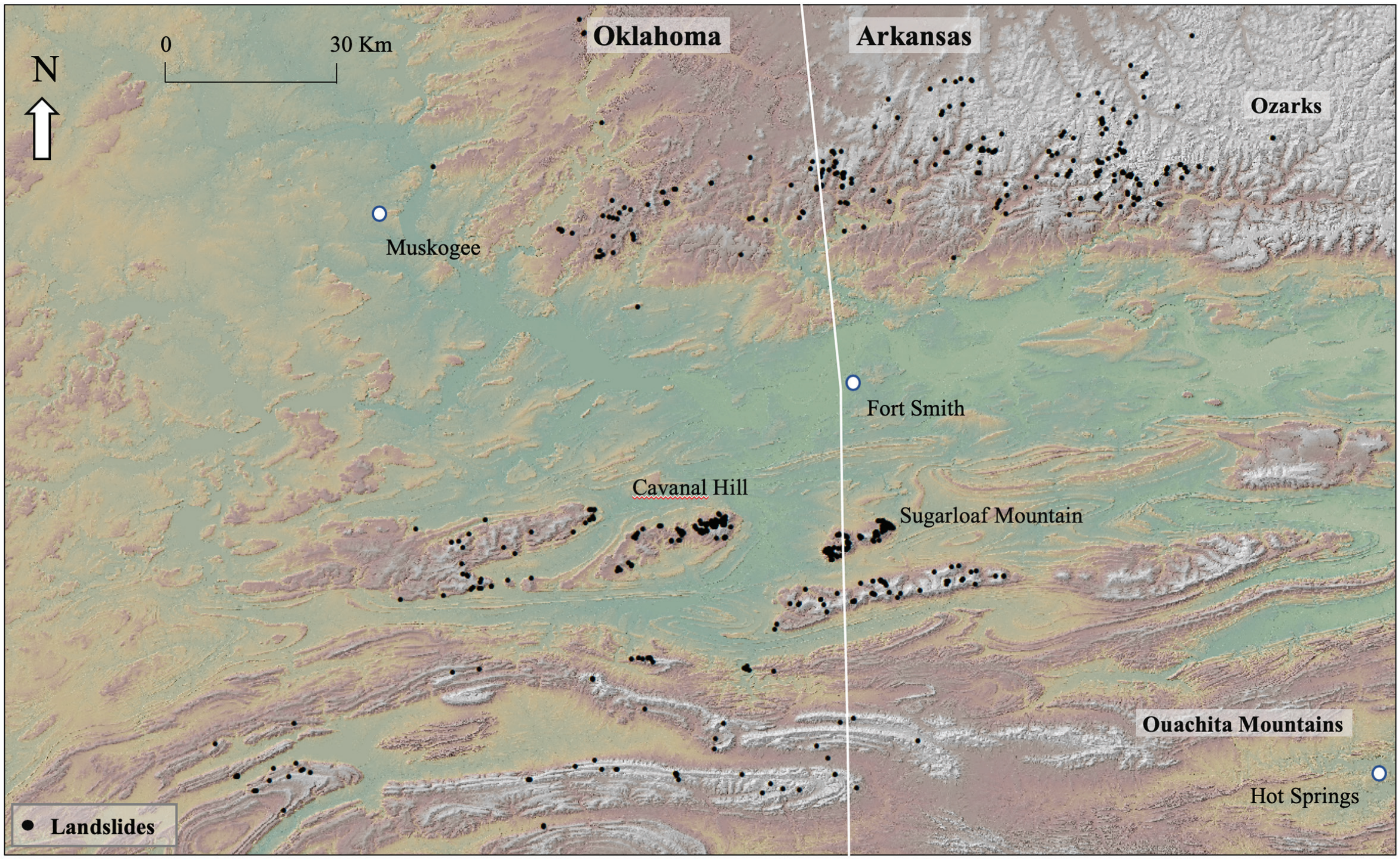


Figure 10. A preliminary landslide inventory mapped over the broader region that covers parts of Ouachita Mountains and Ozarks Mountains both in Oklahoma and Arkansas.

derlain by shale and sandstone in Cavanal Hill and Sugarloaf Mountain are highly dynamic and susceptible to landslides, soil creeps and erosion, and yield large amounts of sediments that could impact the downstream habitat and aquatic resources. This study highlights the importance of considering characteristics of shale and sandstone stratigraphy, which is the dominant lithology across the Ouachita Mountains, in decision making during mitigation planning for landslides and management of hillslopes.

This study also demonstrates that LiDAR elevation-derived map of surface roughness can characterize historical landslides and additional unstable landforms, such as hummocky topography developed by landslides, soil creep and colluvium, and steep slopes in close proximity to the first and higher order channels, which suggests that the tool is applicable in automatically mapping unstable hillslopes. Where LiDAR topographic data is available, the approach appears to be cost effective and time efficient in first order prediction of landslide surfaces, and seems applicable in automatically mapping unstable slopes for the purpose of making decisions in land, ecosystem and hillslope management. This study demonstrates the utility of LiDAR and those types of surveys should be expanded more uniformly across the state.

FUTURE DIRECTION

We have recently received financial support from the Federal Emergency Management Agency (FEMA) via the Oklahoma Department of Emergency Management and partly from the University of Oklahoma to study landslides in broader region. With this support, we have been mapping landslides in parts of Ouachita and Ozark Mountains (Figure 9). Our longer-term focus is to understand causes, mechanics and triggers of these landslides, and to prepare high resolution maps of landslide hazards. In addition, we plan to determine highly susceptible and relatively active slopes for further study, that may include frequent slope monitoring to understand how slopes respond during extreme precipitation and earthquakes. This sort of study will include field instrumentation to monitor soil moisture and groundwater level, seismic ground motion/amplification, and slope displacements and subsurface investigation using geophysical techniques; and periodic slope monitoring based on drone-based and terrestrial LiDAR mapping.

Acknowledgements

We are grateful to David Brown, Neil Suneson and Julie Chang of the Oklahoma Geological Survey for their valuable suggestions. We thank David Deaton and Steve Humphries for providing photographs of recent landslides in Sugarloaf Mountain. The research has been funded by FEMA, Oklahoma Department of Emergency Management, and the University of Oklahoma.

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OGS History Part 4: Charles Gould's first era with the Survey

By
Ted Satterfield
Editor, Oklahoma Geological Survey

Once Charles Gould was officially named director of the Oklahoma Geological Survey in July of 1908, work began immediately. Within an hour, he had arranged by phone his appointment of five geologists to begin field work immediately. The OGS put nine parties in the field during the summer of 1908 (Ham, 1983, p. 9). Gould appointed Lon. L. Hutchison assistant director of the Survey, who led a five-man party that investigated oil and gas fields in Tulsa, Creek, Okmulgee, Muskogee, and Wagoner Counties (Gould, 1932a, p. 155). Since all field parties relied on the work of both OU students, as well as a number of OU employees, field work had to stop in September with the start of school.

"Taking into account the untrained character of most of the men and conditions under which the field work was done, the results of the field season of 1908 more than justified the money spent," Gould wrote in "Geological work in Oklahoma," an unpublished manuscript Gould wrote on the history of geological work in the state where he devotes a chapter to the OGS, starting with the formation of the Territorial Survey.

Once Gould stepped into his role as director, he stepped back from his position at OU's Department of Geology. He technically retained his position on the faculty with the title "Professor of Oklahoma Geology" until he resigned from state work. Professor D. W. Ohern began overseeing the department after Gould. Ohern would do something similar in just a few years, as he would take over as OGS director after Gould resigned from the position.

Despite the impressive amount of field work accomplished, the Survey's first few years were rocky at best. The University of Oklahoma's administration building had burned down in December of 1906, which led to other buildings being crowded well beyond capacity. This left the Survey with no home at the point of its establishment, and prompted Gould to rent two buildings near his home on Apache Street to temporarily house the Survey. They remained working in this condition for the first year until new buildings were built on campus.

In addition to this, the climate on the OU campus was chaotic. The first and longtime university President David Ross Boyd was fired when Governor Charles Haskell took office shortly after statehood, and replaced him with President Arthur Grant Evans, a personal friend of the governor. This replacement appears to be entirely for political reasons, and President Evans struggled to oversee a university that had strongly supported President Boyd. Charles Gould speaks highly of President Evans in various texts addressing the university's early days, but notes that Evan's previous experience of being a missionary and school president of a denominational college in Indian Territory made him ill suited for the task of overseeing a university with exploding enrollment numbers, not to mention one caught in between warring political factions. Gould mentions in his book Covered Wagon Geologist that Evans had too much on his plate to interfere with the newly formed geological survey, and essentially left everything up to Gould.

Oklahoma citizens were excited to have a geological survey, and with an oil boom underway, as well as gold fever in the Wichita Mountains still lingering, the OGS was overwhelmed with requests for examinations of regions throughout Oklahoma. People were eager for development of mineral resources, and were begging researchers to come to their part of the state to analyze

The second OGS director, D. W. Ohern

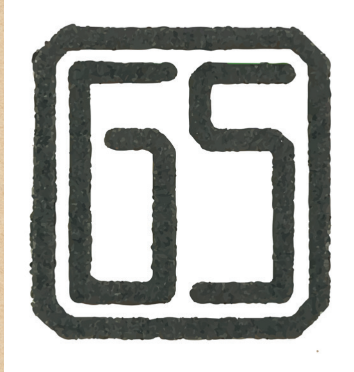
natural resources. The requests grew so numerous that Gould implemented a policy that the OGS wouldn't undertake an examination of a region unless a petition was signed by fifty taxpayers in the county requesting examination of a certain property in the region. Despite this policy, Gould says during his first three years as director of the survey more than 50 localities were examined and reports prepared on them. These reports were usually published in a local newspaper in the region of the state.

In his unpublished account, Gould reveals just how much he was involved in every aspect of the new survey. For example, in this account, he goes into great detail explaining his philosophy behind publications, viewing them as needing to be accessible to nonscientists as well as scientists. He even suggested that state surveys, in order to

D. W. Ohern's geological camp on the Verdigris River, 1909. D. W. Ohern, Charles N. Gould, Everett Carpenter, Arthur Reeds, Ben Bolt and Robert Wood.

survive, needed to "pander to popular demand." After requesting feedback from multiple state geological surveys as well as the US Geological Survey, he decided the OGS would predominantly publish bulletins and circulars. Bulletins being "more formal papers dealing with a strictly geological problem" and circulars being "shorter occasional papers, sometimes dealing with a subject not geological, sometimes popular in nature."

Gould also viewed the OGS logo to be very important, and first attempted to hire a well-known New York designer to accomplish the job. Gould wasn't happy with the results and wound up selecting a design that was "worked out in the office." The design consisted of the letter "O" in bold-face type with the letters "G" and "S" within.



This is the first logo of the Oklahoma Geological Survey.

Attention to so much details concerning the Survey no doubt contributed to him beginning to experience burnout after just a few years as director. In his book Covered Wagon Geologist, he addressed his reasons for leaving the Survey the first time and the top reason listed is he "had begun to realize that there is a limit to one's power of endurance," and this had led to a number of concerns about his overall health. He cites other reasons for his departure, including financial concerns, but he was also tired of the contentious political climate the Survey, as well as the university, was constantly forced to endure. When Oklahoma elected its second governor, Lee Cruce, he began imposing major changes at the university, starting with removing President Evans. But Gould mentions how much the budget of the survey was a constant political fight, too. Although he doesn't provide many details about what happened, he says a stenographer mistake during the state's second legislative session resulted in Governor Haskell vetoing a significant amount of the Survey's appropriations. Gould says this handicapped the survey's field work for two years.

After his resignation in October 1911, for the first time in more than a decade, Charles Gould moved away from Norman and the university community, pursuing a new career as an oil industry consultant. Professor Ohern replaced him as OGS director for the following two years, but, as mentioned in a previous installment, Charles Gould would eventually return for another stint as director at the Oklahoma Geological Survey.

We will discuss the Ohern and Shannon eras of the OGS in the next installment of this series.

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About the Author

Ted Satterfield became the OGS Editor in August 2015. A native Oklahoman, Ted has a diverse professional background. After receiving his master's in the Gaylord College at OU, he spent two years as a newspaper editor before switching to an academic career. For six years he was a mass communication faculty member at Northwestern Oklahoma State University, where he taught Intro to Mass communication, Photography, News Editing, and Media Convergence. He also acted as advisor to the student-media website. Ted is also an accomplished screenwriter and director, winning numerous awards, including the best short screenplay at the 2012 deadCENTER Film Festival. He and his wife, Melanie, co-wrote the stage play "Alcoholidays," which was produced in Oklahoma City in 2013, and ran through December 2015 at the Oklahoma City Civic Center. Ted is an active member of the Association of Earth Science Editors.

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OGS History Series Part 5: The Ohern and Shannon eras

The Ohern and Shannon eras of the Survey mark a time period of expansion for the OGS in every way. The era ends, however, in 1923, with an Oklahoma governor vetoing all appropriations, which resulted in the OGS having to close its doors for a year.