GROUNDWORK
Furthering the Influence of Earth Science

The Great Acceleration and the Disappearing Surficial Geologic Record

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The surficial geologic record is the relatively thin veneer of young (<~1 Ma) and mostly unconsolidated sediments that cover portions of Earth's terrestrial surface (Fig. 1). Once largely ignored as "overburden" by geologists, surficial deposits are now studied to address a wide range of issues related to the sustainability of human societies. Geologists use surficial deposits to determine the frequency and severity of past climatic changes, quantify natural and anthropogenic erosion rates, identify hazards, and calculate recurrence intervals associated with earthquakes, landslides, tsunamis, and volcanic eruptions. Increasingly, however, humans are eradicating the surficial geologic record in many key areas through progressive modification of Earth's surface.

Figure 1. Surficial geologic deposits (late Pleistocene wetland deposits) in Wadi Hasa, Jordan, being described and sampled. These deposits are being lost rapidly to agriculture and disturbance from animal husbandry and human dwellings.

IMPORTANCE OF THE SURFICIAL GEOLOGIC RECORD

Do we as a society really need to study high-resolution climate and environmental records that are preserved in the surficial geologic record? The short answer is a resounding "yes!" Most highly resolved records of past environmental change come from marine sediments and ice cores, or from specific localities on land, such as lake sediments, loess (dust deposits), speleothems (cave deposits), and recently, desert wetlands (springs in arid environments). These archives have provided detailed accounts of how Earth's systems responded to past changes in climate and help us understand how they may change in the future.

Planning for long-term sustainability also requires an understanding of potential geologic hazards. Surficial geologic records contain evidence of past geohazards, such as earthquakes and volcanic eruptions, which allow scientists to quantify the magnitude and locations of the most recent events for a given area. This information is a critical component of geologic hazard assessments, and the quality of such assessments is a direct reflection of the quality of the surficial record available for study.

THE GREAT ACCELERATION

The term *Great Acceleration* is used to describe a group of data that documents the increasing pressure that human society has had on Earth systems (Steffen et al., 2015). The original Great Acceleration graphs, developed by the International Geosphere-Biosphere Programme (IGBP), displayed changes in socio-economic data (population, gross domestic product [GDP], telecommunications) relative to changes in Earth systems (atmospheric gas concentrations, surface temperature, tropical forest loss, domesticated land, etc.) from 1750 until 2000 A.D. (Steffen et al., 2004). The increase ca. 1950 in most of the parameters has been attributed to the growing impact of human societies on Earth's systems, and has been used to demark the initiation of the Anthropocene (Zalasiewicz et al.,

GSA Today, v. 28, doi: 10.1130/GSATG341GW.1. Copyright 2017, The Geological Society of America.

2012). Although some aspects of the Great Acceleration are predicted to plateau (population), other factors such as primary energy use (energy consumption) show no sign of slowing down. In other words, even though global population is predicted to level off perhaps around 10 billion by the end of this century, increases in the extraction and utilization of Earth's resources are predicted to continue (Steffen et al., 2015).

Humans are now the dominant geomorphic agent on Earth, transporting more sediment with heavy equipment than the combined actions of water, wind, and ice (Hooke et al., 2012; Hooke, 1994). But it is not just bulldozers that are affecting the surficial geologic record. Topsoil and surficial sediments are being disturbed and eroded at unprecedented scales by conventional agriculture, increasing rates of erosion by orders of magnitude over background levels (Montgomery, 2007). Alteration of Earth's surface is also occurring at a rapid pace in urban and suburban areas, as well as coastal regions, in step with increases in global population, GDP, and primary energy use, leading to the widespread loss of the surficial geologic record.

IDENTIFYING AND STUDYING AT-RISK DEPOSITS

It is imperative that geoscientists identify areas containing surficial deposits that are most at risk. A new tool, the Timelapse feature in Google Earth Engine[1], vividly shows the remarkable impact that humans are having on the landscape. Combining multiple sources of satellite imagery, Timelapse allows users to track changes, determine or follow trends, and quantify differences in land use that have occurred during a 32-year period (1984–2016). It is an especially timely and effective tool for geologists that are interested in studying surficial deposits.

A particularly striking example of the visual power of this new tool is the Las Vegas Valley of southern Nevada. Since 1980, Clark County (Las Vegas metropolitan area) has experienced a nearly fivefold increase in population to over two million people. As the cities of Las Vegas, North Las Vegas, and Henderson burgeoned, fossil-rich deposits associated with springs and wetlands that once covered most of the valley were paved over or otherwise destroyed during the urban expansion (Fig. 2). Hundreds of square kilometers of the deposits were wiped out in just three decades. Fortunately, the last contiguous vestiges of the Las Vegas deposits, spanning nearly 23,000 acres, were protected in 2014 as Tule Springs Fossil Beds National Monument. Owing to their preservation and subsequent study, we now know that these deposits provide some of the most detailed records for understanding how desert wetland ecosystems responded to abrupt climate change during the late Quaternary (Springer et al., 2015). Had the monument not been established, such studies would not have been possible.

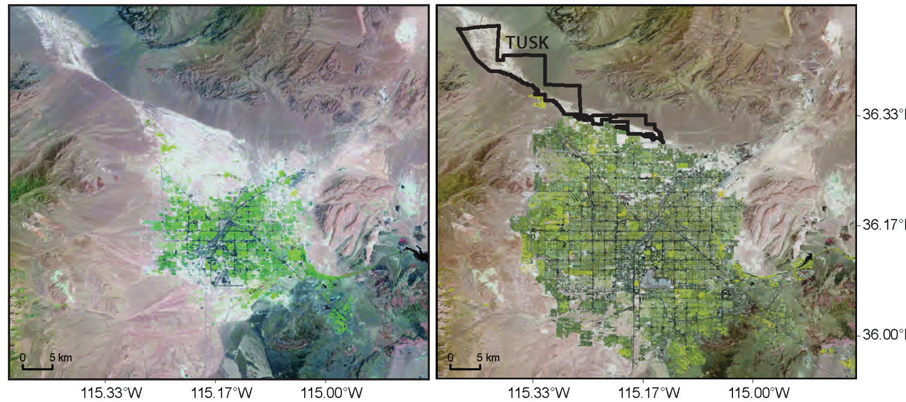

Figure 2. Landsat images of Las Vegas, Nevada, USA, in 1984 (left) and 2016 (right) showing the loss of light-colored Quaternary wetland deposits to urban expansion. The boundaries of Tule Springs Fossil Beds National Monument (TUSK), which preserve nearly 23,000 acres of the wetland deposits, are shown in the righthand image. Images are courtesy of the Earth Resources Observation and Science (EROS) Center.

The preservation of the Las Vegas deposits is an exception rather than the rule as the Great Acceleration marches on. Even in the most remote areas on Earth, from the high Arctic to the driest deserts, we are seeing massive alterations of the landscape due to the extraction of resources to meet human demands. We suggest that Google's Timelapse feature can be used in concert with surficial geologic maps to identify locations where deposits are threatened, allowing scientists to study them before it is too late.

A key concern and question is "How much time do we have?" The answer depends upon the prioritization of research questions, the availability of funding and resources, and the measures taken to preserve the deposits in select cases. Clearly, for those interested in studying the surficial geologic record, the time to do so is now. Now is also the time to focus on training the next generation of geologists because it can take years to hone the skills required to interpret and decipher these complex records.

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Manuscript received 31 March 2017
Revised manuscript received 15 July 2017
Manuscript accepted 24 July 2017

[1] The Timelapse feature can be accessed online at https://earthengine.google.com/timelapse/. (Note that any use of trade, firm, or product names is for descriptive purposes only and does not imply endorsement by the U.S. government.)