2015

Arizona Fissures: Unique and Possibly Dangerous?

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ABSTRACT

Fissures are cracks in the earth that form from stretching and pull-apart of geologic materials near earth's surface. They generally form in areas that experience frequent earthquake and volcanic activity; areas with active tectonics. Recently discovered fissures in Arizona are different, as they form from pumping of subsurface gas and water resources. In the UK, similar but also slightly different processes are happening. In this region, instability causes more rapid and more frequent fissure formation due to more active tectonic processes. Therefore, fissures in the UK are a more common occurrence than those in Arizona. Fissures in both locations are currently a nuisance, but may pose more serious threats to infrastructure in the near future. This discussion will focus on potential fissure threats and possible solutions for remediation.

INTRODUCTION

Fissures are cracks in the earth that form from stretching and pull-apart of geologic materials near earth's surface. Recently discovered fissures in Arizona are different, as they form from the lowering of the land surface as a result of pumping of subsurface gas and water resources. In the UK, similar but slightly different processes are happening. In this region, instability causes more rapid and more frequent fissure formation due to active tectonic processes. Not much is being done in the UK to resolve these issues, while here in the US, rapid steps are being taken to minimize damage to construction of roadways and nearby developments. Fissures in both locations are currently a nuisance, but may pose more serious threats to infrastructure in the near future. In this paper I will discuss how the Arizona fissures are unique, how fissures in the UK are different and similar in comparison to the Arizona fissures, explain the dangers associated with these fissures, and propose solutions for remediation.

Fissure Development and Hazards

Subsidence and earth fissures generally form from slow and gradual processes. Looking across an expanse of subsiding land, a person may not perceive any evidence of the settling land mass. Place man-made structures and projects on that expanse of land and subsidence is likely to take a toll. Damages that result from subsidence and fissures often are costly and disruptive. For example, subsidence can be costly to farmers in a number of ways. Irrigation ditches and canals can be compromised as land settles. Uneven and irregular subsidence can alter the slope of previously leveled fields, disrupting the flow of irrigation water. A developing fissure cutting across an irrigated field may cause sections of land to be taken out of production and abandoned. The crevice remains as a hazard to people, livestock and wildlife (Schumann & Genualdi 1986). Urban areas are especially vulnerable to the effects of subsidence. Many cities are densely populated, with clusters of buildings, transportation systems and varied projects and structures that make up the urban infrastructure. Movement of a land mass, even the gradual settlement of subsidence can cause significant damage, requiring repairs to streets and highways, and more frequent and costly maintenance. Any system that depends on gravity flow could be disrupted if differentiated subsidence shifts the gradient. Railroads, earthen dams, and canals also are vulnerable to damage from subsidence. Any structure built across the path of a fissure likely will suffer serious damage. Groundwater pollution also is concern. Earth fissures may be quite deep, possibly extending to the water table. Surface flow and its possible contaminants-chemicals, animal waste, etc., may therefore have a direct channel to the water table, without percolating through the unsaturated zone for filtration. That fissures often are used as convenient sites to dump trash and refuse compounds the potential threat to groundwater quality. Finally, it is worth emphasizing that land subsidence and the damage and destruction they cause should not be interpreted merely by their effects on humans, their activities and structures. Even if land subsidence were to occur in the remoteness of the desert, unnoticed and posing no threat to humans, it still is an ominous occurrence (Gelt 1992).

Fissure Development in Arizona

The earth fissures in Arizona are associated with basin subsidence that accompanies extensive ground water mining. Their physical appearance varies greatly, but they may be more than a mile in length, up to 15 feet wide, and hundreds of feet deep. They are typically long linear cracks at the land surface with little or no vertical offset. During torrential rains they erode rapidly,-presenting a substantial hazard to people and infrastructure. Moreover, these fissures provide a ready conduit to deliver runoff and contaminated waters to basin aquifers (AZGS 2011). There are several hypotheses for how these fissures are formed. The most widely accepted of which is differential compaction. As ground-water levels decline in unconsolidated alluvial basins, less compaction and subsidence occurs in the thinner alluvium near the margin of the basin than in the thicker alluvium near the deeper, central part of the basin. The tension that results from the differential compaction stretches the overlying sediment until it fails as a fissure, as shown in Figure 1 (Eaton & others 1972; Carpenter 1993). In a very early stage, fissures can appear as hairline cracks less than 0.02-inch wide interspersed with lines of sink-like depressions resembling rodent holes. When they first open, fissures are usually narrow vertical cracks less than about 1-inch wide and up to several hundred feet long. They can progressively lengthen to thousands of feet (Carpenter 2009).

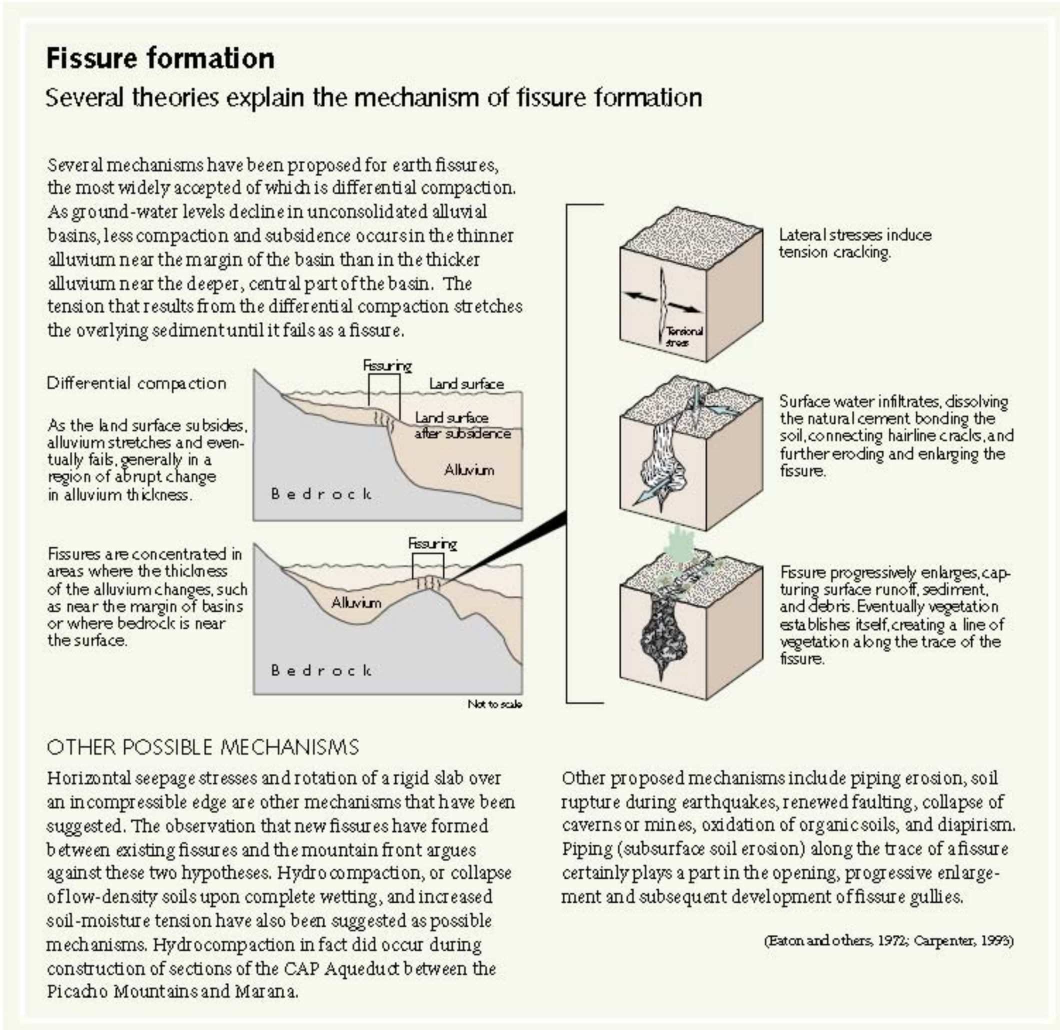

Figure 1: Potential mechanisms associated with fissure failure (Eaton and others, 1972; Carpenter, 1993).

Fissure Development and Hazards in the UK

Fissures in the UK are forming by slightly different processes. In certain regions of the country, these fissures are being created by mining in certain circumstances. The underground extraction of coal creates additional stresses and strains that can exacerbate the existing faults and breaks causing weaknesses within the rocks and sometimes large cracks, or fissures, to appear at the surface (Coal Mining Data 2014). These fissures occur as pronounced, distinct and often extensive morphological features of the South Wales Moorland plateau. (It is difficult to determine the age when these features were initiated and reactivated. There remains the possibility that some of these originated several thousands of years before present by processes associated with the deglaciation of the valleys under periglacial conditions (Donnelly 2005).) This may have caused the reactivation of faults and the dilation of high-angled joints in the 'Pennant' sandstones, facilitated by the weakening of the underlying mudstones and shales which form the sides of the valleys underlying the stronger sandstone cap rock (Donnelly 2008). Reactivation of the faults and renewed dilation of the fissures is likely to have occurred as a result of strains induced by coal mining subsidence associated mostly with longwall coal mining extraction methods. Fault reactivation changes the geometry of subsidence profiles and can affect the area of influence. Fault reactivation, in certain circumstances, may continue for weeks to several years after 'normal' subsidence has been completed but eventually ceases (Whittaker& Reddish 1989). Fault reactivation occurs throughout the coalfields of Britain. Reactivated faults which are unequivocally induced by mining subsidence alone rarely exceed 0.5m to 1m in height, but most are much less. The magnitude and extent of the fissures in South Wales differ markedly from those cases investigated in other UK coalfields as they are much more pronounced and distinct (Donnelly 2006).

Fissure hazards in the UK are similar to those in Arizona. Unlike Arizona however, there are not many areas of expansive land with no developments or roadways in the UK. This makes the hazards in the UK almost twice as dangerous, due to the fact that many farmers and developments within the area depend on their water systems and roadways for their day to day activities. Also, due to the older nature of some of the coal fissures, some areas might currently be an unknown hazard since the UK Geological Survey have yet to map all of the possibly affected sites (Coal Authority 2012).

Solutions for Fissure Remediation

In August 2005, torrential monsoon rains reactivated an earth fissure near Queen Creek, Pinal County, Arizona. Within days the fissure became a large open crevasse. In response to growing public outcry, the Arizona Legislature drafted legislation that Governor Napolitano signed in to law to address earth fissures in Arizona (AZGS 2011). To date, nine of 23 designated earth fissure study areas are mapped and published. Work continues in the Tator Hills and Signal Peak areas of Pinal County, and near Sulfur Springs in Cochise County. In basins torn by earth fissures, these maps are powerful tools for land-use planning (AZGS 2011). Although geologists are constantly working to map out new fissures to monitor them, more needs to be done to actually rehabilitate the land-Mitigating hazards of earth fissures requires diligent monitoring and the advent of new and effective models that incorporate historical and continuous observations in analytical techniques to foster new approaches to this problem. Equally important is the need for a complementary and groundbreaking effort to identify and test engineered structures that promote human health and safety (ALSG 2007). One possible solution is to limit the amount of water being pumped from one aquifer and instead pump small amounts from multiple sources. Another solution would be to direct subsurface water flows away from existing and new-forming fissures to decrease the chances of groundwater contamination. In the UK, monitoring is also being done, though not nearly as extensively as in Arizona. They have recently published an article on how to do a risk assessment of fissures in an area of interest for development (Coal Authority 2012). However, information on what could be done to rehabilitate the land from these coal mining induced fissures could not be located.

CONCLUSION

Arizona fissures are unique due to forming from excessive pumping of subsurface gas and water supplies. They can be hazardous for man-made structures, farms and their livestock, and subsurface piping. In the UK, fissures generally form due to extensive coal mining. Many of the same hazards from Arizona apply to the UK, and even more so due to a smaller surface area. Although both locations are currently monitoring and mapping these fissures, as well as keeping local communities and government informed, neither have really started resolving the issue. Arizona has however noticed that something needs to be done and currently is working on economic solutions.

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