Discovery of a large earth fissure in the Southern Picacho Basin, Pinal County, Arizona

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Fresh earth fissure exposed in southern Pinal County.

OPEN-FILE REPORT OFR-17-01

January 2017

Arizona Geological Survey

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Arizona Geological Survey

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Manuscript approved for publication in January 2017
Printed by the Arizona Geological Survey

For an electronic copy of this publication: www.repository.azgs.az.gov

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Recommended Citation: Cook, J.P., 2017, Discovery of a large earth fissure in the Southern Picacho Basin, Pinal County, Arizona. Arizona Geological Survey Open-File Report, OFR-17-01, 7 p., 1 appendix.

Introduction

Sometime between Mar. 2014 and Dec. 2014, a mile-long, north-south trending earth fissure opened near the Tator Hills, 13 miles south of Arizona City. The fissure extended an additional ¾ mile to the south sometime after March 2016. The sudden appearance of this deep, jagged fissure in an area of modest but continuous rate of land subsidence (up to 1 inch or 3 cm annually over the past decade), and otherwise without active fissure formation since the early 1990s, was surprising. Arizona Geological Survey (AZGS) geoscientists used this opportunity to couple repeat aerial photography, available via Google Earth, with drone technology to complement sub-meter field mapping in order to better understand the timing and geomorphological expression of the fissuring process.

The AZGS released the Earth Fissure Map of the Tator Hills Study area in June of 2009 (AZGS DM-EF-11, Figure 1). The Tator Hills are a series of small isolated bedrock peaks extending northward from the West Silverbell Mountains in southern Picacho Basin. Nearly 11 miles of earth fissures are represented on the map in multiple zones; along the base of both the east and west sides of the Tator Hills, within agricultural fields to the north, along the power line road to the southeast, and along the lower piedmont near Greene Wash several miles to the east.

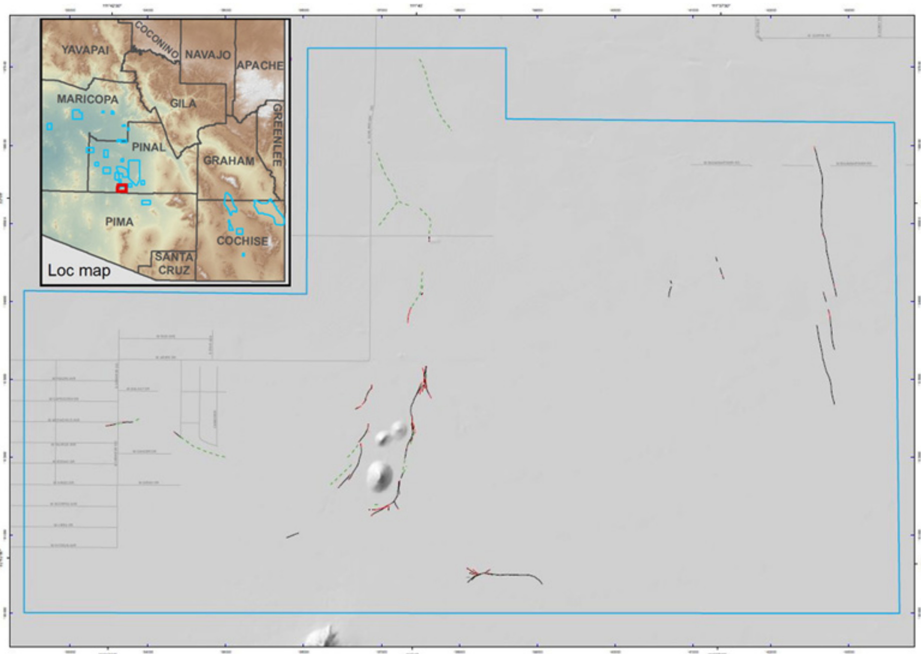

Figure 1. Excerpt of mapped area from AZGS DM-EF-11, Earth Fissure Map of the Tator Hills Study Area: Pinal County, Arizona

Land subsidence and earth fissures in Picacho Basin

Earth fissures are tension cracks that form in response to land subsidence (Galloway et al., 1999). In Arizona, land subsidence is largely attributed to groundwater withdrawal in excess of recharge (Slaff, 1993). Earth fissures are found in a number of basins in five counties (Cochise, Maricopa, La Paz, Pima, and Pinal) in southern and central Arizona where long-term agriculture and associated groundwater withdrawal coincide. Agricultural use of groundwater in Picacho Basin has been ongoing since the 1920s. Land subsidence and progressive formation of earth fissures associated with groundwater overdraft were first observed in the 1950s. Dramatic land subsidence of more than 15 feet from 1952 to 1985 has been documented in the area near Eloy, AZ (Slaff, 1993).

Availability of Central Arizona Project (CAP) water for agricultural use in the late 1980s reduced groundwater pumping which allowed partial recovery of groundwater levels, yet residual land subsidence continues today. Land subsidence near the Tator Hills in recent years is on the order of 1-3 cm/year (Figure 2; Arizona Department of Water Resources (ADWR), 2016). It is likely many fissures in AZ formed in response to land subsidence linked with pumping from decades prior. In the 26 designated earth fissure study areas, it is unknown how many more fissures may be present in the subsurface. Sustainable use of AZ groundwater is required to lessen or end land subsidence and associated earth fissure formation.

To date, approximately 69 miles of earth fissures have been mapped in the Picacho Basin. Earth fissures near the base of the Tator Hills appear on USGS topographic maps from 1981; these same fissures were present in 1977 aerial photos. Additional fissures were mapped by AZGS in 1994 (Harris, 1994). The earth fissure zone along the eastern edge of the study area near Greene Wash trends north-south and is located along the edge of a persistent subsidence bowl visible in ADWR InSAR data (Figure 2). This fissure zone is over two miles long and comprises several en echelon fissures. These fissures are not present on aerial imagery from mid-1983 but are evident in imagery from late 1990. Fissures in this zone do not appear on any maps until the 2009 AZGS DM-EF-11.

Mapping fresh Tator Hills earth fissure

In January 2017, I visited and mapped the new Tator Hills fissure. By this time the portion of the fissure visible in December 2014 Google Earth imagery was partially filled with sediment from sidewall collapse and incision along captured drainages. The surface trace of the fissure extended considerably south of the trace visible in Dec. 2014 imagery. In total, the length of the new fissure is 1.8 miles, nearly a mile longer than what is evident in aerial imagery. No trace of the southern portion of the fissure is evident in Google Earth imagery from March 2016 so the fissure extension must be more recent, most likely having occurred during the 2016 summer monsoon season.

The southern mile of the earth fissure appears very fresh with sharp vertical walls, large partially sunken blocks of earth along un-collapsed reaches, with piles of angular soil blocks along wider open sections. Surface expression of the new fissure ranges from a hairline, jagged surface crack less than 1 inch wide to open chasms 10 feet across tapering with depth to more than 25 feet deep (Figures 3 and 4). It is difficult to see the bottom of the open fissure in some locations due to the near-vertical to overhanging walls and unstable ground possible following heavy rain as collapse along the fissure continues. Extension and dramatic collapse along fissures with narrow surface cracks following rains has been observed along other fissures throughout the state.

Because this fissure lies in a remote area (Figure 5) it is more likely to impact livestock than people, however, off-road vehicles and hikers could encounter the fissure and potentially suffer injury. There is no fence, barrier, or warning sign anywhere along the fissure. Anyone recreating in the area should exercise extreme caution anywhere near the fissure including areas outside the visible surface crack as

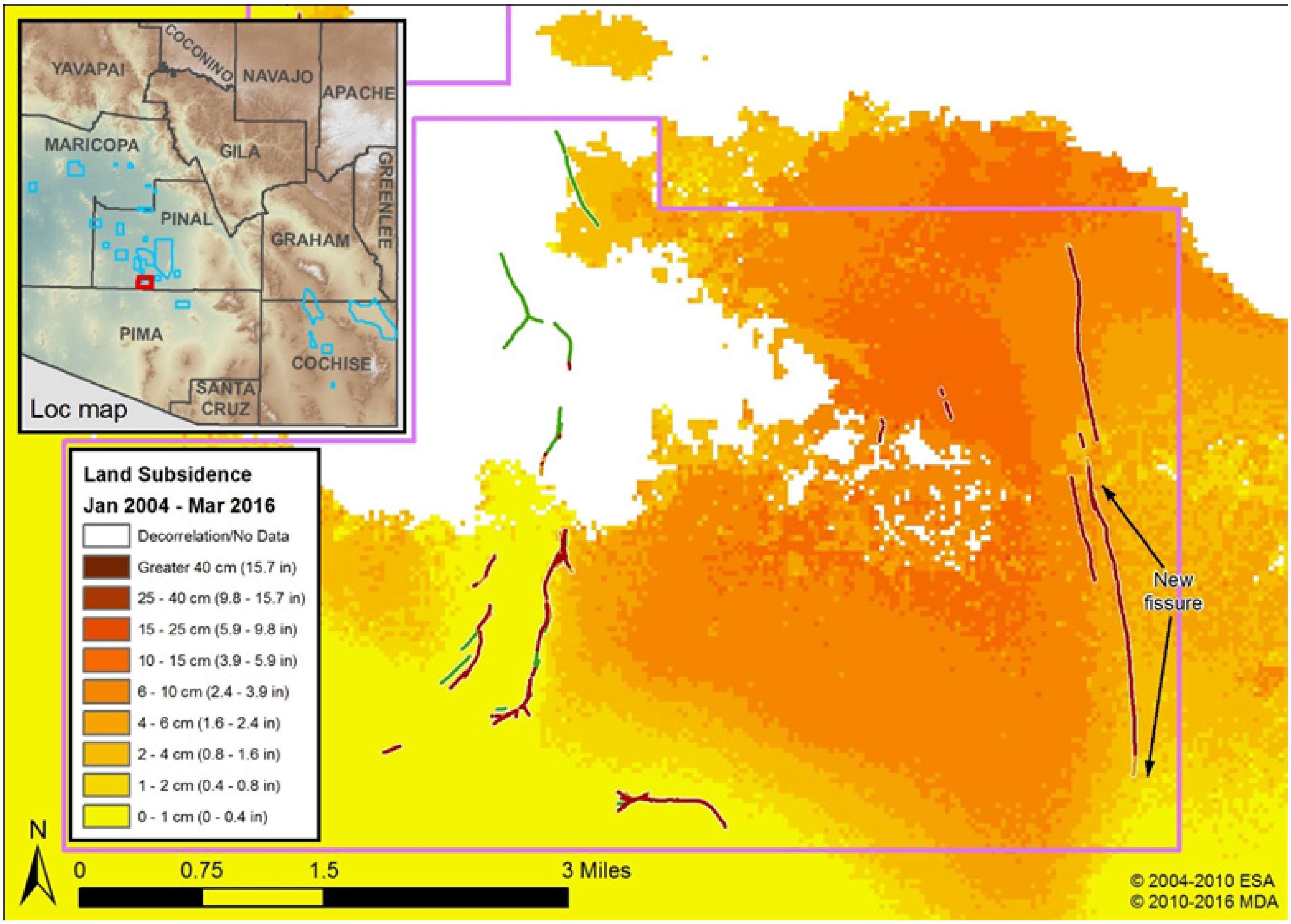

Figure 2. Location of Tator Hills fissures relative to land subsidence measured by InSAR. Earth fissures form in response to land subsidence, especially along the areas of the greatest change. Often, fissures form along a mountain front, above buried bedrock topography, or along the edge of subsidence features as seen here. Subsidence data represented here is a compilation of InSAR data supplied by Arizona Department of Water Resources Hydrology and Geophysics/Surveying Unit.

along the fissure at the surface. The total depth of the earth fissure is unknown but must be much greater than what is visible from the surface based on the volume of sediment that has been swallowed along its length.

The portions of the earth fissure which are currently a narrow surface crack are particularly hazardous because there may well be large voids immediately below the surface. It is likely the total length of the earth fissure is under-represented by the surface trace. Extension of the fissure to the south is rapid collapse is possible. Rescue of an individual from the fissure would be made difficult by the remote location and lack of reliable cell coverage.

In former agriculture lands undergoing development and urbanization, earth fissures can impact property values and could damage or disrupt infrastructure including roads, canals, homes, buildings, gas lines, and utilities. Examples of urban impacts of fissures are Chandler Heights, Apache Junction, Queen Creek, Scottsdale, and the west Phoenix Valley.

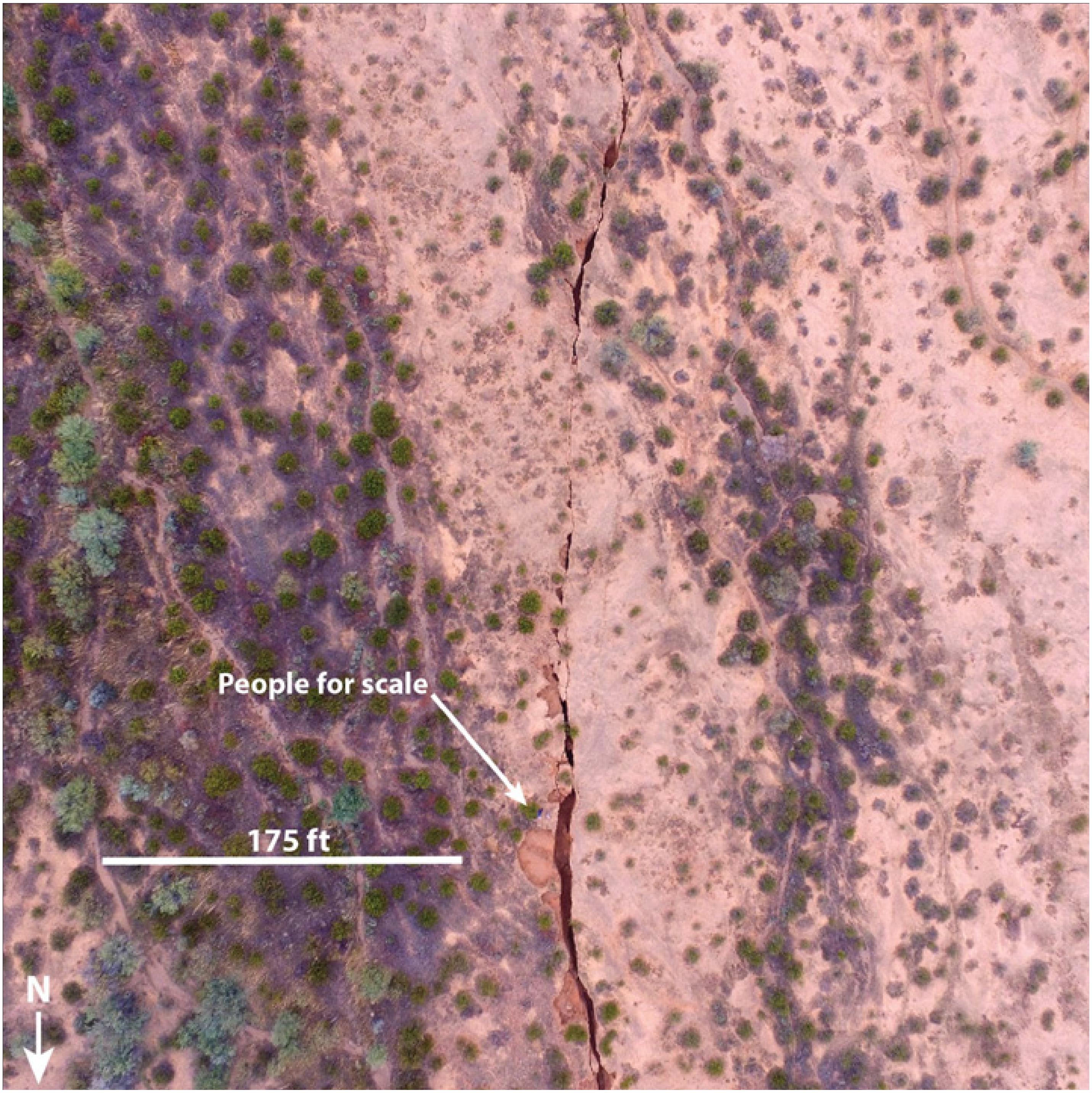

Figure 3. Drone aerial photograph of new Tator Hills fissure on January 19, 2017 captured by AZGS geologist Brian Gootee.

Coupling time-series aerial photography with drone technology to monitor and image in 3-D earth fissure activity

Generations of high-resolution aerial imagery allow us to conduct time-series analysis to detect subtle changes in the landscape; i.e., reactivation of existing earth fissures and formation of new fissures. Heavy rains in September and October of 2014 yielded new earth fissures in Pinal and Maricopa County. Affected AZGS Earth Fissure study areas include Luke, Chandler Heights, Apache Junction, Wintersburg, Picacho, Picacho Mountains SE, and Santa Rosa Wash. Updates to these fissure maps were released in early 2016 to represent the new fissure mapping. The new Tator Hills fissure is not present in Google Earth imagery from March 2013 (Figure 6a) and appears very fresh in the December 2014 imagery (Figure 6b). Based on the sharp surface crack morphology, and lack of vegetation along the new fissure in 2014 imagery it is likely this fissure formed during the fall of 2014 coincident with the same dissipating tropical storm rains that resulted in new fissures in other study areas.

AZGS geologists employed drone/UAV technology to provide a more comprehensive aerial view of the new Tator Hills fissure. These photos and video are the only aerial photo documentation of the new fissure that we are aware of at this time. Low altitude aerial photos captured in this manner provide a better sense of scale for the fissure in the landscape than possible with ground-based photos. Overlapping aerial photo frames and structure-from-motion software were used to generate a digital elevation model of the fissure and surrounding area. Extensive erosion through headcutting on the upstream side of channels cut by the fissure is commonly observed following fissure formation (Figure 6b). Repeat drone flights and data collection can be used to compare landscape changes and calculate the volume of sediment entering the fissure from captured drainages. Changes along the northern mile of the fissure are already apparent when comparing December 2014 and March 2016 Google Earth imagery. High resolution handheld GPS points were collected along the length of the fissure and can be referred to in future visits by AZGS geologists to determine how much extension, if any, has occurred.

Drone-collected video of the fissure is available online at the AZGS YouTube page:

Aerial overview: https://www.youtube.com/watch?v=9xdAnftBKvY
In-fissure view: https://www.youtube.com/watch?v=Rbd1sWPTxyk

Acknowledgements

Thanks to AZGS geologist Brian Gootee for the generous use of his expert piloting abilities and drone photography. You are probably the first person to fly a drone inside an earth fissure. Thanks to Brian Conway and the Arizona Department of Water Resources for access to their excellent InSAR land subsidence data. The subsidence maps produced by ADWR are vital to the AZGS Earth Fissure mapping program.

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Harris, R.C., 1994, A reconnaissance of earth fissures near Apache Junction, Chandler Heights, and southwestern Picacho Basin. Arizona Geological Survey Open File Report, OFR-94-11, 2 map sheets, map scale 1:24,000, 5 p.

Slaff, S., 1993, Land Subsidence and Earth Fissures in Arizona, Arizona Geological Survey Down-to-Earth Series 3, DTE-3, 24 p.

Figure 4. Low-altitude oblique aerial view of new Tator Hills fissure on January 19, 2017. View to the south with Silver Bell Mountains in the background. Photo captured by Brian Gootee via drone. AZGS and ADWR personnel for scale.

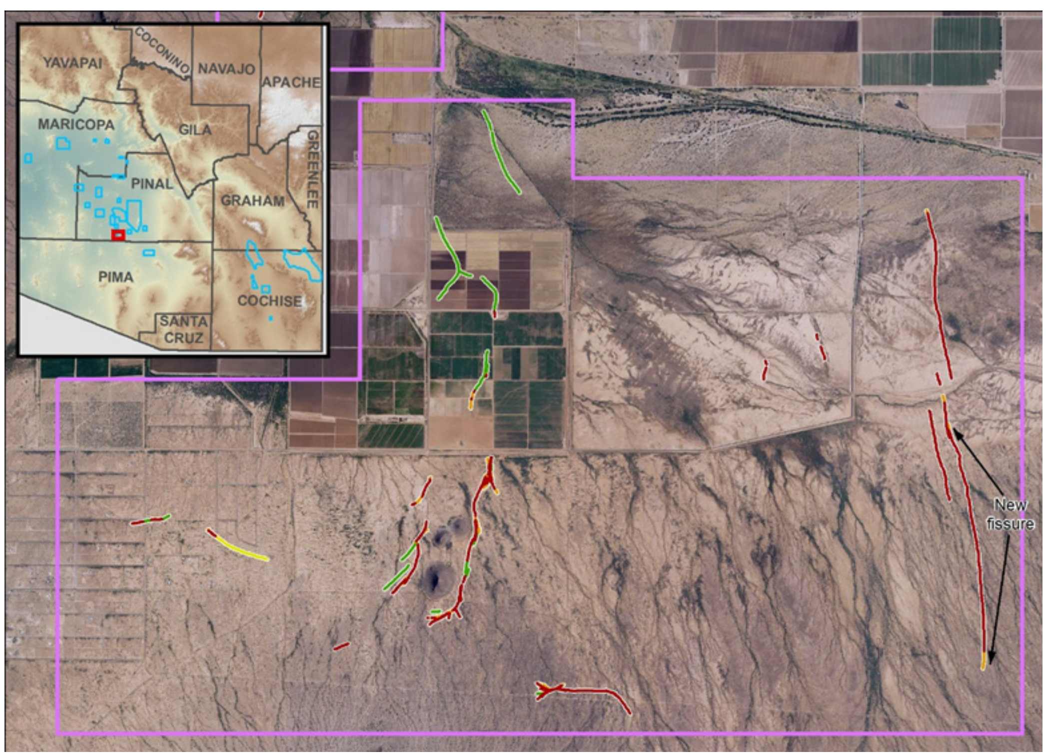
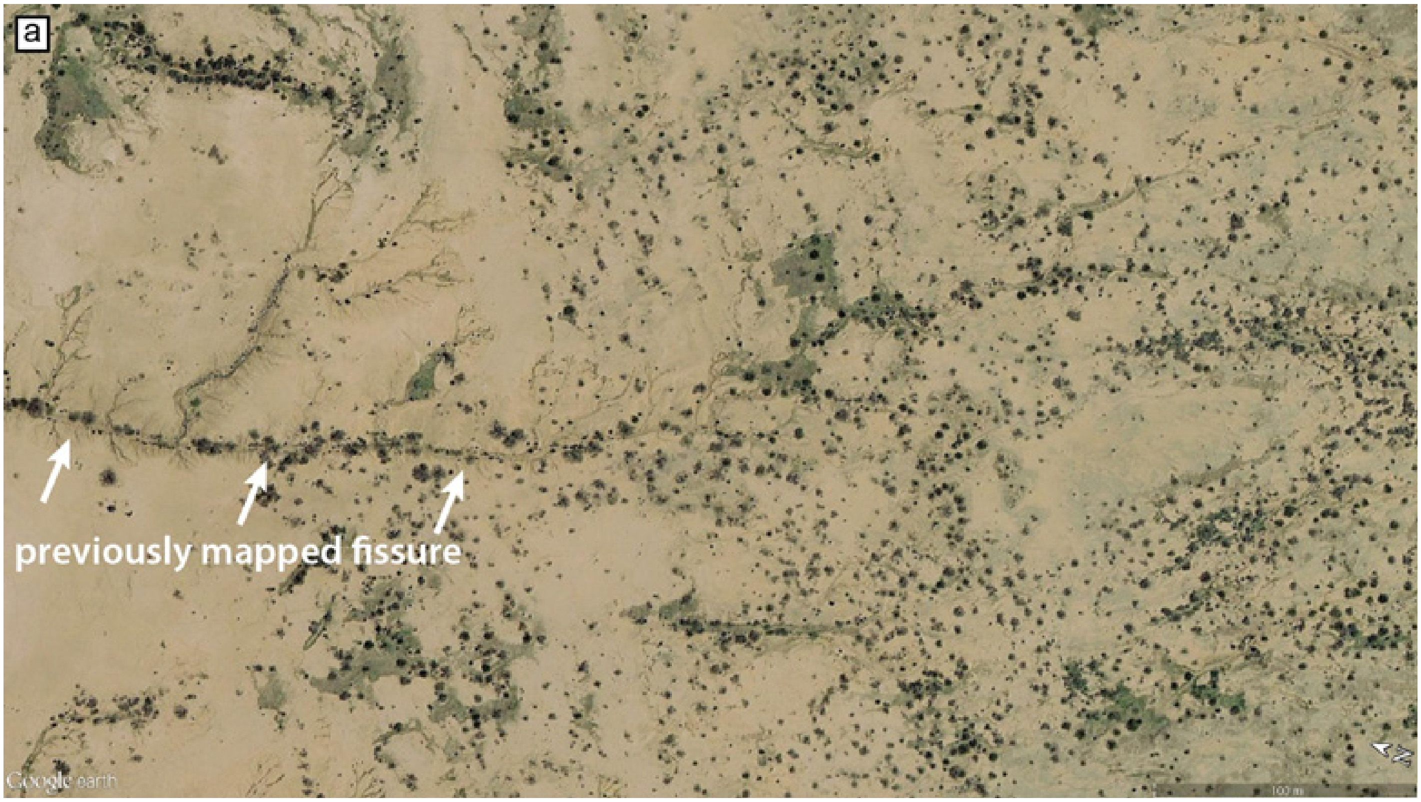


Figure 5. Location of new Tator Hills earth fissure near previously mapped fissures. Purple line demarcates the boundary of the Tator Hills Earth Fissure Study Area.



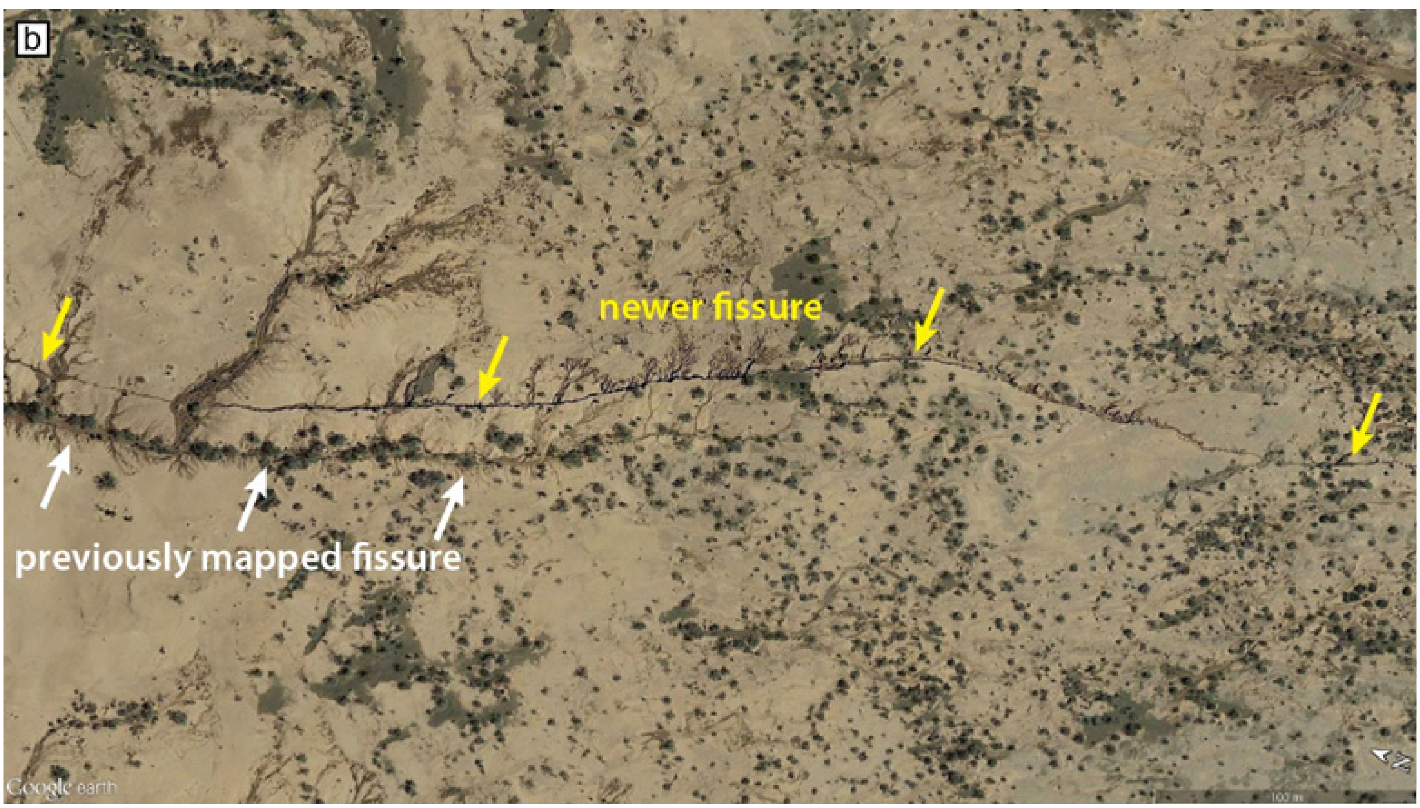


Figure 6. a) Appearance of Tator Hills fissures in March 2013 Google Earth imagery. The more heavily vegetated trace left of center is an older eroded earth fissure which was previously mapped in AZGS DM-EF-11. b) Appearance of Tator Hill fissures in December 2014 Google Earth imagery. The extent of this image is the same as Figure 6a. Note sharp, unvegetated appearance of new earth fissure compared to the old fissure. Evidence of recent rain includes muddy swales, sheetflow, and incision of channels captured by the new fissure.

Appendix I. Ground-based and drone photographs of the Tator Hills Earth Fissure.

Deeply incised fissure segments near the southern terminus; to the right, central down-dropped block. Photos by Joe Cook.

Drone images of the southern end of the earth fissure. Note people for scale in both photos. Left photo by Brian Conway, right photoby Brian Gootee.

Drone photo with Brian Conway of AZ Dept. of Water Resources. Ground photo showing fissure scar - photo by Joe Cook.