Fissure Planning Maps: The First Step in Managing a Geologic Hazard Risk

June 6, 2007

The AZGS' earth fissure planning maps are the first statewide compilation of these geologic hazards. Yet this is only the first step in a multi-year program to identify and map in detail all the fissures in Arizona. Making the fissure maps easily accessible will provide buyers and developers of real estate, and local government planners the information they need to make informed decisions. But our job as scientists can't stop with the public release of either the planning maps or the upcoming stream of high-resolution fissure maps. We have an obligation to educate those interested in how to read and interpret the maps and reports, and and assist with technical help them in their decision-making process.

Last fall, I appointed an Earth Fissure Advisory Group comprising members from state and local governments, professional organizations, and the real estate industry. The Group advises AZGS on our mapping program and the needs of the Arizona public. We discuss the societal impacts, legal issues, and educational needs that result from release of complex geologic data to the general public.

A second group, the Arizona Land Subsidence Group, an informal forum for geologists and engineers that meets monthly, serves as a technical advisory body for AZGS' fissure mapping program.

As we go around the state briefing agencies and organizations on the fissure maps, we note that while public disclosure of these hazards is an important step, we have limited information on the origin of fissures, little ability to predict precisely where or when new fissures will develop or existing fissures grow, and only general guidelines on mitigation strategies. For the latter, avoidance of building in fissure-prone areas is an obvious strategy but not always practical or realistic. Structures should be set back from fissures, but we have no technical basis at present to state how far the setbacks should be. It's also wise to divert overland water flow away from fissures. While fissures are typically only an inch or so wide with irregular larger voids, dramatic large gullies can form rapidly as water and runoff washes soils and surface sediments into fissure depths and along their extensive lengths. These "fissure gullies" can threaten buildings and infrastructure, including roads, pipelines, canals, and dams for example.

Cities and counties have to decide how to balance the rights of private property owners with the risks involved in building on or adjacent to earth fissures. While geologists still have more questions than answers, working closely and openly with stakeholder groups (local government, real estate agents, contractors, and the Arizona public) assures us the best possible chance of managing this burgeoning geologic hazard and reducing risks.

NEW FACES AT AZGS

New Hires

Dominique Villela, Web Designer
Diane Love, R.G., Hydrogeology
Ryan Clark, M.S., GIS Specialist
Jeri Young, Ph.D., Hydrogeology
Mimi Diaz, M.S., Chief, Phoenix Office
Michael Conway, Ph.D., Chief, Geologic Extension Service

Project Hires

Pam Wilkinson, Hydrogeology Research Associate
David Haddad, Quaternary Mapping,
Michael Cline, Quaternary Mapping
Jennifer Roper, Accounting
Sara Jenkins, Hazard Analysis

Volunteers

Denise Saenz

EXTENSION SERVICE

Shaping Arizona: The Geologists & Geoscientists Who Shaped Arizona Geology (http://shapingarizona.wikispaces.com/)

Our knowledge of Arizona's geology is the result of the work of hundreds of remarkable and memorable geologists from John Wesley Powell to Stanley Beus to Susan Kieffer. Some were exemplary field geologists, others excelled in the laboratory, while some were excellent teachers. This site is dedicated to acknowledging the contribution of the many individuals who shaped our understanding of the geologic landscape that makes up Arizona. Please log into our wiki site at http://shapingarizona.wikispaces.com/ and take a moment to include a note – and favorite picture—about a geologist whom you admire and who contributed to our collective

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416 West Congress, Suite 100
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Phone: (520) 770-3500 Fax: (520) 770-3505
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THE STATE AGENCY FOR GEOLOGIC INFORMATION

The Role of AZGS in Mapping Earth Fissures in Arizona

M. Lee Allison and Todd C. Shipman

Introduction

In August 2005, torrential monsoon rains reactivated an earth fissure near Queen Creek, Maricopa County, Arizona. Overnight, the fissure became an open crevasse 5 to 10 ft wide, and up to 25 ft deep crossing two residential lots (Figure 1). In response to growing public outcry, the Arizona Legislature drafted legislation to map earth fissures in Arizona. Effective 21 September 2006, House Bill 2639 charges the Arizona Geological Survey (AZGS) with 1) comprehensive mapping of earth fissures throughout Arizona, and 2) delivering earth fissure map data to the State Land Department for posting online with other GIS map layers so the public can make customized maps. A complementary statute, A.R.S. 33-422, requires disclosure of earth fissures in non-incorporated areas as part of real estate transactions. To meet the task of mapping all the state's earth fissures, AZGS received continuing funds for hiring three staff geologists and one-time only funds to purchase high-precision Global Positioning System receivers and field-based computers.

Figure 1: Earth fissure near Chandler Heights, Maricopa County, August 2005. Earth fissures range from insipient, where they are characterized by discontinuous, pock-marked ground and hairline fractures, to mature features miles in length and hundreds of feet deep, with associated gullies at the surface that are more than 10 feet wide and several tens of feet deep. (Photo by Ray Harris)

Stage 1: Earth Fissure Planning Maps

The first priority of the fissure mapping program was to compile all extant maps, published literature, and reports on earth fissures from throughout Arizona. Additionally, we acquired aerial photographs of areas in the Cochise, Maricopa, Pima, and Pinal counties known for hosting earth fissures. Wherever possible we acquired high-resolution aerial photographs directly from the county governments, otherwise we acquired older, low-resolution photographs from the U.S. Geological Survey. As part of our stage 1 efforts, we performed a cursory examination of the four counties to explore for previously unmapped and unreported earth fissures. At the same time, the AZGS mapping team was trained in recognizing earth fissures on both aerial photographs and on the ground.

Stage 1 culminated in the production and distribution of 1:250,000 scale earth fissure planning maps showing the distribution of all known or reported earth fissures in Cochise, Maricopa, Pima, and Pinal counties. Earth fissures from the four counties were than assigned to one of 22 discrete study areas. To facilitate communication between scientists, local governments, realtors, and the general public, we assigned local geographic names to each of the study areas. The 22 study areas were then ranked for priority, high resolution mapping

Mission

To inform and advise the public about the geologic character of Arizona in order to increase understanding and encourage prudent development of the State's land, water, mineral, and energy resources.

Activities

Public Information

Inform the public by answering inquiries, preparing and selling maps and reports, maintaining a library, databases, and a website, giving talks, and leading field-trips.

Geologic Mapping

Map and describe the origin and character of rock units and their weathering products.

Hazards and Limitations

Investigate geologic hazards and limitations such as earthquakes, land subsidence, flooding, and rock solution that may affect the health and welfare of the public or impact land and resource management.

Energy and Mineral Resources

Describe the origin, distribution, and character of metallic, non-metallic, and energy resources and identify areas that have potential for future discoveries.

Oil and Gas Conservation Commission

Assist in carrying out the rules, orders, and policies established by the Commission, which regulates the drilling for and production of oil, gas, helium, carbon dioxide, and geothermal resources.

TABLE 1. List of 22 priority areas for earth fissure mapping at 1:24,000 scale.

1) Chandler Heights / Queen Creek (Pinal & Maricopa)
2) Apache Junction (Pinal)
3) Luke (Maricopa)
4) Toltec Buttes (Pinal)
5) Picacho (Pinal)
6) Heaton (Pinal)
7) White Horse Pass (Pinal)
8) Signal Peak (Pinal)
9) Tator Hills (Pinal)
10) Greene Wash (Pinal)
11) Sacaton Butte (Pinal)
12) Scottsdale/NE Phoenix (Maricopa)
13) Pete's Corner (Pinal)
14) Santa Rosa Wash (Pinal)
15) Sulphur Springs North (Cochise)
16) Three Sisters Buttes (Cochise)
17) Bowie-San Simon (Cochise)
18) Dragoon Road (Cochise)
19) Wintersburg (Maricopa)
20) Marana (Pima)
21) Harquahala Plain (Maricopa)
22) Mesa (Maricopa)

on the basis of three criteria: 1) proximity to an area of rapid development; 2) the presence of multiple fractures; and 3) basins characterized by rapid subsidence. Table 1 lists the study areas in order of mapping priority. Most of the highest priority study areas are in Pinal County where the density of known fissures is greatest and where new construction rapidly encroaches on known earth fissures.

The 1:250,000 scale earth fissure planning maps are now available at the AZGS Bookstore in Tucson and at Department of Mines and Mineral Resources in Phoenix for $4.00 per map. Maps are accompanied by open-file report (OFR-01 2007), Earth Fissure Mapping Program: 2006 Progress Report. Both the maps and report are available free in pdf format at www.azgs.az.gov.

Stage 2: High Resolution Mapping

Stage 2 involves systematic, meter to sub-meter GPS mapping of earth fissures in priority study areas (Table 1). Given the large number of reported earth fissures, more than 250 in the four counties, and the likelihood of discovering new fissures, we anticipate it will take three to five years to complete detailed mapping. With input from members of the Arizona Land Subsidence Group and Dave Minkel with the US National Geodetic Survey, we established field protocols for using high-precision GPS receivers to map fissures and laboratory protocols for post-processing the GPS data.

Not all earth fissures have a through-going, well-defined surface expression. As a result, ground lineaments whose origin as earth fissures is questionable will be categorized as "possible fissures", to be shown as a dotted or dashed line on maps. After completing mapping of a study area, the processed GIS data will be handed off to the Arizona State Land Dept. (ASLD) for inclusion in an interactive, online GIS service with other 1:24,000 scale map layers so anyone can build customized maps at the ASLD website.

The earth fissure mapping team comprises AZGS geologists, Todd Shipman (research geologist & lead scientist), Mimi Diaz (Phoenix branch chief), and Michael Mahan (geologist). Additional AZGS staff are aiding with development of the digital database as needed.

Balloon Photography of Earth Fissures
Apache Junction
5 November, 2002
Mosaic image courtesy of Dr. Ramon Arrowsmith, ASU

Origin of earth fissures

The southern and western part of Arizona lies within the Basin and Range Province, which comprises deep sediment-filled basins separated by long narrow mountain ranges. These deep basins – comprising 6000 ft or more of sediment fill — hold large quantities of groundwater in storage. Pumping of groundwater in some basins may be hundreds of times faster than recharge. Where agriculture or municipalities rely extensively on groundwater, the groundwater tables have declined as much as 300 feet or more.

As groundwater tables lower, aquifer sediments undergo compaction leading to basin subsidence. In the Luke basin, immediately west of Phoenix, the land subsided about 18 feet by 1992. In the Picacho basin near Eloy, land subsided more than 15 feet between the 1920s and early 1980s. Earth fissures frequently develop around the margins of most Arizona basins where the land has subsided more than a few feet. Fissures propagate upward to the surface from the compacted aquifer sediments at or near the lowered water table depths. They preferentially form where there is a change in the mechanical or physical properties of the rocks, such as where the sediment layers intersect bedrock at basin margins, where buried bedrock highs poke up through the sediments, or where there are changes in the composition of sediment layers such as from clay/shale to sand/gravel.

Fissures may exist for months or years in the subsurface, extending their lengths for thousands of feet, before eventually breaking through to the surface. Thus, the absence of surface expression of earth fissures does not preclude their existence below ground.

AZGS Announcements

Geologic Extension Service

In April 2007, AZGS created the Geologic Extension Service (GES) as a bridge for showcasing AZGS products to the Arizona public. The GES comprises the AZGS Library, AZGS Website (www.azgs.az.gov), our science outreach program, and the AZGS Tucson Bookstore. The Service resides in the AZGS headquarters at 416 W. Congress, Tucson, AZ 85710; ph. 520.770.3500, e-mail—inquires@azgs.az.gov. Contact Section Chief, Michael Conway (michael.conway@azgs.az.gov) for information.

AZGS Opens Phoenix Branch Office

In April 2007, AZGS opened a branch office in Phoenix to address the needs of the state's largest metropolitan area. The focus of our Phoenix branch is on natural hazards, especially earth fissures, and groundwater resources. The office is housed at the Arizona Dept. of Mines and Mineral Resources, 1502 W. Washington Ave. Contact AZGS Branch Chief, Mimi Diaz, at mimi.diaz@azgs.az.gov or 602.708.8253, for information.

Oil & Gas Conservation Commission

New Commissioner Appointed!

Governor Janet Napolitano appointed Stephen Cooper to the Arizona Oil and Gas Conservation Commission to replace outgoing Commissioner Joe Lane. Mr. Cooper is a principal with Cooper & Reuter Law Office in Casa Grande. His appointment runs until January 2012.

OGCC's next meeting is scheduled for the State Land Department in Phoenix on July 13, 2007.

New AZGS Publications

Allison, M.L., and Shipman, T.C., 2007, Earth fissure mapping program: 2006 progress report. Open-File Report 07-01, 4 County Sheets 1:250,000, with 25 p. text.

Cook, J.P, Shipman, T.C., and Pearthree, P.A., 2007, Geologic map of the Hereford 7.5' Quadrangle and the northern part of the Stark 7.5' Quadrangle, Cochise County, Arizona: Arizona Geological Survey Digital Geologic Map 57, v. 1.0, layout scale 1:24,000, with 12 p. text.

Ferguson, C.A., and Johnson, B.J., 2006, Bedrock geologic map and cross sections of the Hereford 7.5' Quadrangle, Cochise County, Arizona: Arizona Geological Survey Digital Geologic Map DGM-58, v. 1.0, two scanned sheets, scale 1:12,000.

Leighty, R.S., 2007, Geologic map of the Black Canyon City and Squaw Creek Mesa area, central Arizona: Arizona Geological Survey Contributed Map CM-07-A, v. 1.0, scale 1:24,000, with 46 p. text.

Pearthree, P.A., 2007, Geologic map of the Needles NE 7.5' Quadrangle, Mohave County, Arizona: Arizona Geological Survey Digital Geologic Map DGM-53, layout scale 1:24,000, v. 1.0, with 14 p. text.

Shipman, T.C., Richard, S.M., and Spencer, J.E., 2007, Geologic map of the Fortuna 7.5' Quadrangle, Yuma County, Arizona: Arizona Geological Survey Digital Geologic Map DGM-55, v. 1.0, layout scale 1:24,000, with 11 p. text.

Youberg, A., Spencer, J.E., and Richard, S.M., 2007, Geologic map of the Galleta Flat East 7.5' Quadrangle, Cochise County, Arizona: Arizona Geological Survey Digital Geologic Map DGM-56, v. 1.0, layout scale 1:24,000, with 6 p. text.

Geoinformatics

AZGS is a Leader in Building a National Geoscience Information Network

In February 2007, the nation's geological surveys (all the state geological surveys and the USGS) agreed to the development of a national geoscience information network that is distributed, interoperable, uses open source standards and common protocols, respects and acknowledges data ownership, fosters communities of practice to grow, and develops new web services and clients. This agreement quickly transformed into a global effort with AZGS Geoinformatics Section Chief, Dr. Stephen Richard, as one of the leaders in developing the computer architecture, protocols, and mark-up language to be adopted globally (www.geoingormatics.info).

A national workshop of academic leaders in geoinformatics in March 2007 agreed to collaborate with the Survey plan for an information network, as did the 53 countries that signed an accord in Brighton England for "OneGeology," an international effort to build a 1:1,000,000 seamless geologic map of the world (www.onegeology.org).