OPEN FILE REPORT OFR 07-01

Arizona Geological Survey
416 W. Congress St. #100 Tucson, AZ 85701
www.azgs.az.gov

EARTH FISSURE MAPPING PROGRAM

2006 Progress Report

June, 2007

M. LEE ALLISON AND TODD C. SHIPMAN
ARIZONA GEOLOGICAL SURVEY

Earth Fissure Mapping Program

2006 Progress Report

Open-file Report 07- 01
June, 2007

M. Lee Allison, and Todd C. Shipman
Arizona Geological Survey

Arizona Geological Survey

Earth Fissure Mapping Program

2006 Progress Report

Earth fissure that re-opened overnight in the Chandler Heights area, Maricopa County, following heavy rains. August 25, 2005. Photograph by Ray Harris.

EXECUTIVE SUMMARY

The Arizona Geological Survey (AZGS) is tasked by statutes approved in House Bill 2639 of the 2006 legislative session to undertake comprehensive mapping of earth fissures and deliver earth fissure map data to the State Land Department (SLD) starting in 2007 and every five years subsequently (Appendix A). The legislation and funding for the AZGS became effective on September 21, 2006.

Earth fissures have developed around the margins of most Arizona basins where the land has subsided more than a few feet. The potential for risk and damage to property from earth fissures has increased due to urban development into fissure-prone areas, and due to continued basin subsidence which results in earth fissures forming at depths of hundreds of feet and propagating to the surface.

The first priority of the fissure mapping program is completing preliminary photograph-interpretation planning maps of fissures for Maricopa, Pinal, Pima, and Cochise counties, which are included in this report. Areas of known or reported earth fissures are designated by names but not by formal boundaries. Once detailed mapping in an area is complete, AZGS will provide the mapped data to SLD for processing onto their website to serve in GIS format with other supporting data layers for public access, at an anticipated scale of 1:24,000.

The earth fissure planning or study areas are currently scheduled to be mapped in the following order, based largely on likelihood of development in the shortest time frame:

1) Chandler Heights, including the Queen Creek area (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)

The Arizona Land Subsidence Group (ALSG) serves as a technical advisory resource to the AZGS earth fissure mapping program and discussion forum issues related to identifying, characterizing, and mapping earth fissures.

Under the authority of A.R.S. 27-151C3, the State Geologist appointed an earth fissure advisory group (EFAG) in late 2006 with representatives from state and local government, professional organizations, industry, and other organizations with concerns about earth fissures.

Significant progress has been achieved in developing standards and procedures for the earth fissure mapping program to ensure accuracy, coordinating among the designated agencies in the program, and working with affected stakeholders in preparing to deal with the maps when they are released.

Detailed mapping of earth fissures is underway. The mapping program is completing its start-up phase and moving quickly into production mode. .

INTRODUCTION

In 2006, in response to the re-opening of an old earth fissure in the Queen Creek area south of Phoenix, state legislation was passed mandating that all earth fissures in the state be mapped and those maps made available to the public. Earth fissures have been known in Arizona since 1927 and became increasingly common starting in the 1950s, but this recent legislation marks a turning point in how government agencies deal with the problem.

Statutory authority

The Arizona Geological Survey (AZGS) is tasked by statutes approved in House Bill 2639 of the 2006 legislative session to undertake comprehensive mapping of earth fissures and deliver fissure map data to the State Land Department (SLD) starting in 2007 and every five years subsequently (Appendix A).

An important aspect of this legislation is new funding for three staff positions to map earth fissures and one-time funding to acquire field computers and high-precision Global Positioning System instruments for detailed mapping.

Companion legislation passed in 2006 (A.R.S. 33-422) requires disclosure of earth fissures within non-incorporated areas, and the new fissure mapping program described in this report will create detailed maps of the hazards to help the public assess the risks.

The legislation and funding for the AZGS became effective on September 21, 2006.

History

The road leading to this legislation was a long one. Geologists warned about the potential hazards of earth fissures for more than 40 years, but with a few notable exceptions the warnings were viewed as mostly of academic interest. In the past, earth fissures were largely ignored because they mostly occurred in undeveloped areas around the edges of the basins where few people lived and where their impact was minimal. With new construction expanding into areas

where earth fissures exist, the potential for risk and damage to property has increased. The issue today is not so much new earth fissures forming where people have built houses, but that people are building on or adjacent to known earth fissures and in areas that may be vulnerable to fissuring as excessive groundwater withdrawal results in further subsidence. Until recently, specific disclosure of the presence of earth fissures on property being sold was not required by the state. Also, land subdivided into five or fewer parcels is not subject to locally required background geotechnical assessments. With the recent increased awareness of problem with earth fissures, however, Arizona is responding to the growing risk from this hazard.

Origins 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. Bedrock under the valleys is commonly 6,000 feet or more below the surface. These deep basins hold large quantities of groundwater in storage, but in some basins, this water has been pumped as much as 500 times faster than nature can recharge it. Where agriculture or municipalities rely extensively on groundwater, the groundwater tables have declined, in some places 300 feet or more.

As groundwater tables lower, aquifer sediments undergo compaction. If compaction is great enough, the ground surface sinks. In the Luke basin, immediately west of Phoenix, the land had subsided about 18 feet by 1992. In the Picacho basin near Eloy, land subsided more than 15 feet by the early 1980s. Earth fissures have developed around the margins of most Arizona basins where the land has subsided more than a few feet.

Fissures are believed to propagate upward to the surface from the compacted aquifer sediments at or near the lowered water table depths. Fissures may initiate 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 take 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, just waiting for conditions such as diversion of runoff into the area, continued subsidence, heavy rainfall to break through,.

Giant desiccation cracks

Giant desiccation cracks (GDCs) look similar to earth fissures at the surface and can present similar hazards, but they form under different circumstances.

Where earth fissures likely propagate from hundreds of feet down in the basins, giant desiccation cracks form as a result of drying and shrinkage of fine sediment fairly close to the surface. GDCs may be quite large and moderately deep, but they do not have large voids extending down into the subsurface hundreds of feet that facilitate erosion of materials from the surface by rains or runoff. Like

earth fissures, GDCs can open up suddenly and dramatically due to heavy rains, and in some areas in southeastern Arizona they have impacted public infrastructure. GDCs have formed recently in sediments above the water table, and thus their development is probably related to climate variations (drought) and not directly to groundwater withdrawal.

Discriminating between fissures and GDCs often requires mapping the features in enough detail to delineate polygonal patterns of exposure that are characteristic of GDCs. However, GDCs may look like fissures for months or seasons, so it may not be possible to differentiate fissures and GDCs until the system has matured.

AZGS will conduct at least reconnaissance-scale identification of GDCs because they may present hazards to property owners and local governments.

EARTH FISSURE MAPPING PROGRAM

Need for detailed mapping

The new fissure mapping legislation is timely. Most of the existing fissure maps were made before the GPS (global positioning satellites) system was available, are not digital, or were completed at scales that are inadequate for the detailed planning required by developers and local building officials. A number of known earth fissures have never been mapped at more than regional scale. In addition, continued groundwater pumping has produced new fissures or extended existing ones in some areas since the last mapping was done.

Preliminary planning maps designate fissure areas

The first priority of the fissure mapping program is completing preliminary photograph-interpretation planning maps of fissures for Maricopa, Pinal, Pima, and Cochise counties. Those planning maps are included in this report (Sheets 1 through 4).

The county planning maps identify general areas of known and reported but unmapped fissures, and assign a name to each area. These maps provide a preliminary assessment of which areas of southern and south-central Arizona are known to have fissures. They include an index – designated names of fissure study areas – to facilitate communication between scientists, local governments, real estate agents, and the general public.

The preliminary planning maps provide a means of assessing areas known to have fissures in terms of: (1) which areas have been mapped previously by AZGS or others; (2) which areas have never been mapped; and (3) how extensive the fissures are in mapped areas. The AZGS is using the preliminary planning to plan where to begin detailed mapping, what level of effort will be involved in various areas, and how long it will take to map fissures in an area. Once detailed mapping in an area is complete, AZGS will provide the mapped data to SLD for processing onto their website. This process will facilitate the prompt release of detailed fissure maps for public use.

Government and other organizations can use the earth fissure planning maps to broadly determine where earth fissures are for their planning and siting of

important infrastructure. County and city governments can also use the planning maps to identify areas where actions may be needed to more accurately identify and mitigate earth fissure impacts before the final detailed disclosure maps are completed by AZGS, a process that is expected to take several years.

As part of generating the planning maps, AZGS has completed much of the acquisition of materials and data needed for the detailed disclosure mapping. High-resolution, recent aerial photography has been obtained from Maricopa and Pinal Counties, and older, lower resolution photography for all known earth fissure areas was obtained from the U.S. Geological Survey through a web service hosted by the University of Arizona. AZGS purchased professional quality GPS equipment and data processing software to ensure that all disclosure mapping is done to exacting standards of accuracy and precision.

Mapping methods and protocols

In the process of generating fissure planning maps, the AZGS geological mapping team has been trained in recognizing what earth fissures look like on aerial photographs and on the ground. Developing the maps has provided an opportunity to prioritize areas for mapping, evaluate mapping at different scales and levels of detail, and develop consistent standards, protocols, and methodologies.

Preparation of preliminary planning maps of earth fissures also offered a means of obtaining feedback and review from outside experts. Several technical experts with many years experience studying and mapping fissures reviewed the preliminary planning maps, as did policy and legal experts. Their feedback and insights were invaluable.

Before detailed mapping begins in any area we first look at previous mapping and aerial photographs. When active and growing, typical earth fissures are 1 to 5 feet wide at the surface and 5 to 20 feet in apparent depth, although total depth is believed to be hundreds of feet. Earth fissures can be thousands of feet long. Earth fissures commonly intersect drainages and can sometimes hold water temporarily. Because of the extra water in fissures, vegetation along their trace is denser than that in the surrounding desert and stands out on aerial photographs and on the ground. The characteristic alignment of dense vegetation on aerial photographs is a valuable tool that aids in identifying and mapping fissures. Some fissures are large enough to be clearly visible on aerial photographs even without the vegetation alignment.

Some skill is required when examining aerial photographs to distinguish earth fissures from other linear features such cattle trains, old roads, or other, human-produced features. Most photographs contain linear traces that are not fissures. Because it is not always certain on photographs if a feature is a fissure, linear features identified as fissures must be examined on the ground.

In the field, geologists must interpret the features to determine whether they are fissures or not. Although earth fissures may seem to appear “overnight” following intense rainfall, the precursor fissure may have been forming for years or even decades at depth. In the earliest stages of development, a fissure may appear at

the surface as a series of small depressions, or hairline cracks only a fraction of an inch wide and tens of feet long. Heavy rain softens the surface material, allowing it to cave into the underlying fissure.

Once a fissure opens to the surface, water running into the fissure erodes the sides and washes the material deep down into the fissure system, often enlarging the original small crack into an impressive gully. Many fissures are spectacular open cracks that are immediately obvious even to the untrained eye. Others are old and eroded and look like washes, or have mostly filled with sediment. In these cases, other characteristics must be relied on to determine if the feature is a fissure versus a wash, an old irrigation ditch, or a drainage control berm, for example.

Discussion at a recent meeting of the Arizona Land Subsidence Group indicated that coincidence of some earth fissures and giant desiccation cracks may be causally related. Thus, in some areas it will be necessary to map both earth fissures and giant desiccation cracks.

Display of data

Features determined with certainty upon field checking as fissures will be displayed on maps as solid lines. Fissures that are inferred to exist but are not visible continuously at the surface, such as a known fissure on both sides of a road that is not visible crossing under the pavement, will be shown as a dashed line to indicate the fissure's approximate location. Fissures that are visible on photographs but have since been obscured by human activity or erosion are considered certain. Because their location cannot be mapped directly on the ground, their location must be based solely on older aerial photographs and these fissures will be shown as dashed lines. Locations of some features will remain uncertain even after field observation. AZGS is mapping only the surface expression of a fissure. In some cases, such as when a fissure has been filled in with stream sediment, the determination of which part of the feature is a wash and which part used to be a fissure cannot be made without either trenching or use of geophysical techniques. Under the new statute AZGS is directed to expand its resources only on surface mapping rather than to do such subsurface exploration, so some features will remain "possible fissures" and these will be shown as a dotted line or with some other designation to indicate the continued uncertainty in the identity of the features.

Study Areas

We have identified and named study areas in which earth fissures are present as part of the planning process both as a way to keep project areas manageable in size and also to help determine which areas have the highest priority for detailed mapping. Once mapping of a study area is completed, the maps will be turned over to the State Land Department (SLD) for online public distribution. A preliminary list of study areas has been established but this list is subject to change based on new information, and input from our advisory committees. Map plates 1 through 4 show the designated areas and names. The boundaries of the study areas are indefinite and are expected to develop and change as the AZGS carries out its mapping. They should not be viewed as construing any official or scientifically-based delineation. The names of the areas are strictly

informal and are not necessarily used outside AZGS. Listed below are the study areas, shown in order of mapping priority, with the county in parentheses:

1) Chandler Heights, including the Queen Creek area (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)

Study areas were ranked based on three criteria; 1) potential for rapid development of communities; 2) the presence of known or reported fissures; and 3) areas where rapid land subsidence has been reported. Most of the study areas are in Pinal County because this county has the greatest number of reported fissures and because new construction is rapidly encroaching on fissure zones in several places. For the most part, Maricopa County fissures are in areas that either are rural and unlikely to be developed in the near future, or are in places that were developed years ago, in which case it is too late for detailed mapping to be of use for guiding development. Figures located in the back of the report show maps of the study areas.

Dissemination of fissure disclosure maps and data

Following completion of detailed, GPS-based mapping of a designated fissure study area by AZGS geologists, the fissure map GIS layer will be transmitted to the SLD in digital format compatible with their standards. By statute, SLD has ninety days to prepare the final fissure map layer and incorporate it with the other map layers they maintain in an online web service format. Fissure maps will be served at a scale of 1:24,000, which is compatible with other data layers they maintain.

Maps and data on the AZGS website

AZGS currently serves (exhibits, displays, portrays?) four generalized maps online (http://www.azgs.az.gov/Earth%20Fissure%20Map.htm) showing locations of reconnaissance-scale fissure studies completed over the past two decades, as well as areas of fissures that have not been mapped at all (Figures 5 through 9). Fissure locations are displayed as stars to avoid possible misinterpretation by

users who might try to enlarge the location maps to project fissure locations at a larger scale. Such results may be highly misleading.

These previously published fissure maps and reports are for sale as printed reports from AZGS.

CONSULTATION AND INTERACTION WITH STATE AGENCIES

Arizona Department of Transportation

Beginning in October, 2004, AZGS Research Geologist Ray Harris began interacting with the Arizona Department of Transportation (ADOT) and that agency's contracted engineering consultants to study and design mitigation for an earth fissure in the path of the Loop 202 freeway under construction east of Phoenix. This fissure, immediately north of Apache Trail and west of N. Ellsworth Dr., in east Mesa, was first reported in the mid 1970s by the U.S. Geological Survey. The corridor for the freeway, planned by ADOT decades ago and before the fissure formed at the surface, passed over the fissure in a sub-grade section, where the freeway is about 25 feet below grade.

In October, 2004, Harris accompanied the engineer in charge of this section of the freeway project to the field site to confirm that a feature seen on all aerial photographs from 1985 to 2005 was an earth fissure. Because of the subgrade construction and uncertainty about whether the fissure was still active and capable of damaging the new freeway roadbed, ADOT and its engineering consultants took extraordinary mitigation measures. Their design consists of a 50-foot wide reinforced section of the highway that straddled the fissure below the roadbed.

During excavation of this sub-grade section the fissure was exposed in vertical cuts in the road. This excavation was likely the deepest exposure of an earth fissure ever seen in Arizona and a field trip for geological, geotechnical, and engineering professionals was quickly arranged to examine this unique exposure. Nearly 80 people attended. In November 2006 the fissure was again exposed during excavation of the trench hosting the reinforced section below the main road bed. Harris accompanied ADOT officials and engineers to the site to investigate the fissure at a depth of about 30 feet below the surface. In early December other sections of the fissure were exposed in the angle cuts along the shoulders of the freeway during final cutting of the slopes. Harris again accompanied ADOT and its engineers to the site to assess whether the new exposures necessitated change in ADOT's plans.

The cooperation of AZGS with ADOT and its consultants has led to a better appreciation of the issues involved when important engineered structures are built on or near fissures. ADOT is planning and building freeways in other areas of the state that host fissures and this experience with the Loop 202 fissure has been of great help in setting the standard for mitigation design.

On February 1, 2006, Ray Harris and AZGS Director Lee Allison accompanied Nick Priznar of ADOT to inspect troublesome cracks affecting a small ADOT facility in Benson. The site has been subject to branching cracks up to a foot wide and a few feet deep for the past several years. The large size and

polygonal nature of the cracks led AZGS to conclude that they were giant desiccation cracks rather than normal shrink-swell soil cracks or fissures from groundwater decline.

Arizona State Land Department

Shortly after the earth fissure mapping legislation was signed into law in 2006, the Arizona Geological Survey started coordinating implementation of the statutes with the two other affected agencies, the SLD and the Arizona Department of Real Estate (ADRE). As a consequence of initial discussions, it became clear that there were many technical issues and policy consequences to the fissure mapping program.

A key issue is the scale at which mapped fissures would be displayed via the SLD interactive online map server. Meetings with the State Cartographer and the Arizona Land Subsidence Group resulted in the conclusion that we should produce maps at 1:24,000 scales.

Arizona Department of Real Estate

AZGS Director Allison met with senior department officials, at the request of then-Commissioner Elaine Richardson, starting on January 23, 2006 and throughout the year to brief them on the nature of earth fissures and coordinate plans for implementation of the mapping program. On April 19, 2006, he gave a formal presentation on the origin and extent of fissuring to the department's extended management team. Discussions focused on distribution of the new fissure maps, possible setback requirements for new construction, and the need for training seminars for real estate professional and local government officials. ADRE is represented on the AZGS's Earth Fissure Advisory Group.

INTERACTION WITH COUNTY AGENCIES

AZGS briefed the Association of Arizona Counties (AACO) about its work on fissures and other hazards and discussed AZGS providing seminars on fissures to county officials. AZGS will prepare such programs in 2007 and plans further collaboration with AACO.

AZGS has contacted the Associations of Governments in each of the four counties with fissures as well as the League of Arizona Cities and Towns, County Supervisors Association of Arizona, and the Arizona Association of County Engineers to alert them to our fissure mapping, invite their inquiries, and offer to work with them in utilizing the maps and responding to their implications.

Pinal County

AZGS met with Pinal County officials in Florence, June 20, 2006. This meeting included members of several Pinal County departments, including Planning and Development, Building Safety, Flood Control, Public Works, and Development Services. Ray Harris presented a review of the occurrence of fissures in Pinal County and a summary of AZGS plans for comprehensive fissure mapping. Pinal County officials expressed support for an AZGS proposal to help the county review and comment on the geological and geotechnical aspects of development plans submitted by consultants for developers. The county does not have the technical resources to review these parts of the reports. A conclusion of the

meeting was that development plans should include documentation and discussions of whether fissures are present in an area and what mitigation measures are needed or proposed. Pinal County officials noted that many submitted plans are lacking such information.

The proposal for hazards response and mitigation assistance to local governments was included in Governor Janet Napolitano's FY08 budget request to the legislature, submitted in January 2007. The Joint Legislative Appropriations Subcommittee zeroed out the Governor's request. Supporters of the proposal are working to reinsert it in the full appropriation currently under consideration by the Legislature.

Cochise County

AZGS attended a meeting of Cochise County officials, state legislators, and staff from the County Supervisors Association of Arizona in Bisbee, December 7, 2006. Ray Harris provided an introduction and overview of earth fissures and giant desiccation cracks.

This meeting was held to discuss what options counties might have to respond to earth fissure and related features that create risk to public safety. The discussion was prompted by a giant sinkhole-like erosional feature that crossed a private road near a Cochise county road that the county feared could be dangerous. AZGS explained that mitigation efforts would have to occur along the entire length of a fissure to be effective. Water entering a fissure at any location could move along the entire fissure and cause collapse anywhere along its length. Changes in drainage on properties nearby but not directly crossed by fissures could result in water inadvertently being moved into a fissure. Thus, there are complex technical, societal, and legal issues in attempting to mitigate potential impacts from fissures that will take involved deliberations to resolve.

INTERACTION WITH FEDERAL AGENCIES

The U.S. Geological Survey started a hydrologic study of Willcox basin in Cochise County in 2006, under contract to the Arizona Department of Water Resources. As part of their field work, the USGS announced plans to also map earth fissures. In February 2006, AZGS geologists led USGS project staff on a reconnaissance of fissures in the greater Willcox area. It became evident that the number, length, and complexity of the fissures were greater than anticipated by the USGS, raising their concerns about their ability to complete this work within the primary hydrologic scope of work.

TECHNICAL ADVISORY GR0UP

AZGS had been participating for the past year in the Arizona Land Subsidence Group (ALSG) meetings. ALSG is an informal network of industry and government geologists and engineers that meets monthly to discuss technical and programmatic issues about subsidence, including earth fissures. ALSG accepted our request that they serve as a technical advisory resource to the AZGS fissure mapping program and discussion forum on issues related to identifying, characterizing, and mapping earth fissures.

EARTH FISSURE ADVISORY GROUP

Under the authority of A.R.S. 27-151C3, the State Geologist, Lee Allison, appointed an earth fissure advisory group (EFAG) in late 2006 with representatives from state and local government and other organizations with concerns about earth fissures.

The many issues that need attention from the advisory group include:

- ensuring compatibility among the digital fissure maps and the three state agencies computer systems and applicability to users
- implications of the fissure maps for state and local policies and possible recommendations to the Governor and Legislature
- review of the map products for clarity to users
- prioritization of areas to be mapped
- education of users (real estate agents, homebuilders, homebuyers, local officials) on interpretation and use of the maps and other information
- dealing with unanswered questions

A list of members and their affiliation is attached (Appendix B).

The group met twice in late 2006 in Phoenix. Subsequent discussions are being done largely by email and conference calls.

<u>Technical and policy issues</u>
The EFAG is a forum to raise issues and address questions brought forward from the members and others. Among the questions EFAG has addressed are:

Q: Do we need to establish a formal definition of “earth fissure?”
A: Probably not. The scientific literature is adequate. Other states rely on established usage for definitions of natural hazards.

Q: How precise is the GPS data that AZGS will collect?
A: Nominally, the fissures will be collected at two meters or greater accuracy after post-processing. David Minkel, a GPS expert with the National Geodetic Survey and housed at the State Land Department is advising AZGS on precision, accuracy, and operational aspects of data collection and processing.

Q: At what scale should the fissure maps be displayed by State Land?
A: ALSG recommended 1:24,000. EFAG supports scales between 1:10,000 and 1:24,000 as appropriate given the accuracy of existing base maps. This scale is compatible with other data layers provided by SLD. Disclaimers and restrictions on scale of representation may be needed to prevent misuse of the data.

Q: What other layers or data besides fissure locations should be in the interactive map service product hosted by State Land?
A: Basic layers like topography and roads. Legislative intent was to allow users to create their own maps online interactively from a menu of data available from SLD. We plan to ask stakeholders for other recommendations.

Q: Do agencies need to issue warnings for areas of concern? Local government may feel the need or want to delineate areas potentially “affected” by earth

fissures but there is no basis to determine how big an area should be. Who defines it? What are the implications?
A: This is not purely a technical decision at this time. AZGS does not have adequate scientific basis to define appropriate setbacks or recommend potential "buffer zones" around earth fissures. AZGS will work with local governments to interpret the results of fissure maps and advise on their efforts to respond to the information. This is expected to be an on-going topic of major discussion with EFAG and affected bodies.

Q: Will AZGS make publicly available precise GPS locations of earth fissures?
A: Yes. AZGS is designing a digital database for these data. EFAG will be asked to advise on how best to make them available and what guidelines or restrictions may be required to prevent misuse of the data. We anticipate that third parties will use the data along with real estate plats and other detailed maps to offer value-added services to builders, real estate agents, and home buyers. The question has been raised as to whether AZGS is required by law to charge for the commercial use of these data.

Q: How will uncertainty and variations in fissure characterization be shown?
A: Fissures vary from well-exposed, continuous openings in the ground, to discontinuous, obscure, ambiguous depressions. They will be shown on maps as solid, dashed, or dotted lines, depending on the certainty of their continuity and location.

Q: Is the disclosure legislated in 2006's HB2779 necessary? Concerns have been raised in the real estate community over possible misrepresentations by third parties of the reporting requirements. There is interest in amending the statute or repealing it.
A: The consensus of the EFAG is that there are adequate disclosure requirements elsewhere and the statute is not needed. Early in the 2007 legislative session, the statutes were successfully amended to address the concerns.

Q: HB2779 indicates the AZGS will provide maps of soils subject to earth fissures. Are they available yet?
A: Fissures can occur in any type of soil, so that making maps of soils will not help locate fissures. The language in statute appears to be a mistaken use of a related description on expansive soils but it is not applied correctly to earth fissures. AZGS recommended amending the language to eliminate the term "soils maps" in relation to earth fissures. The 2007 Legislature passed the changes with AZGS support.

FUTURE PLANS

<u>Online database of fissure locations</u>
The new fissure data that AZGS will collect will go into digital maps that SLD will serve online. AZGS, however, is planning to collect GPS data with an estimated horizontal accuracy of 6 feet or better. We intend to develop a database of these locations that will be available online, possibly for a fee. Users would be able to download the processed GPS locations to plot fissures themselves at larger

scales than what would be available via the SLD map service. The GPS data will be in a database format, not presented on a map.

Training seminars

AZGS is developing plans to offer seminars and briefings to potential users of the earth fissure maps, including real estate agents, developers/builders, and county and city officials. The seminars will be aimed at non-technical audiences and will cover the nature, history, and causes of fissures, where to find maps and other resources, how to read and interpret the fissure maps, and how other jurisdictions have dealt with them. These seminars should be 2-3 hours in length. We hope to hold these in cooperation with professional organizations who would advertise them to their members. At this time, we do not plan on charging fees to attend. The hosting professional groups may offer continuing education credits to their members for attendance.

Educational Materials

AZGS will develop educational materials describing earth fissures in lay terms that will be used for the training seminars as well as stand-alone flyers and brochures to be available to the public. These materials will be placed online for viewing and downloading.

SYMPOSIA AND PUBLIC TALKS

AZGS has given talks at numerous conferences, symposia, professional organizations and to the public. Talks given in 2006 include:

- Prescott Community College, Environmental Sciences class, Scottsdale, January 19, 2006. Speaker: Ray Harris
- Arizona Department of Environmental Quality, March 1, 2006. Speaker: Ray Harris
- Sunsites Gem and Mineral Club, Sunsites, March 13, 1006. Speaker: Ray
    - Harris
- 55th Annual Arizona Conference on Roads and Streets, La Paloma, Tucson AZ, panel discussion, “Subsidence and Earth Fissures: Their History and Impact on Transportation in Arizona,” April 13, 2006. Speaker: Lee Allison
- Southwest Desert Conference, Tucson, May 4, 2006. Speaker: Ray Harris
- Association of Engineering and Environmental Geologists, Tempe, May 11, 2006. Speaker: Lee Allison
- Arizona Society of Professional Engineers and Arizona Council of Engineering Companies, joint symposium on earth fissures, Scottsdale, August 18. Speakers: Ray Harris and Lee Allison
- Arizona Association of Civil Engineers, Tempe, September 13, 2006. Speaker: Ray Harris
- Arizona Floodplain Managers Association and Arizona Association of County Engineers, Joint Annual Meeting, Bisbee, Nov 2-3, 2006. Speaker: Ray Harris
- Cochise County Historical Society, Bisbee, Nov 5, 2006. Speaker: Ray Harris

- Wings Over Willcox symposium, Willcox Community Center, January 13, 2007. Speaker: Ray Harris

BRIEFINGS

AZGS staff gave briefings to numerous state, local, and professional groups during 2006:

Arizona Department of Real Estate, Commissioner Richardson and senior staff, Phoenix, January 23
Arizona Department of Real Estate, Management Team, Phoenix, April 19
Pinal County Public Works Department, Florence, June 20
Association of Arizona Counties, Phoenix, May 18
Arizona Association of County Supervisors/Cochise County Supervisors, Bisbee, December 7

FIELD TRIPS TO FISSURES

AZGS led numerous trips to visit earth fissures and giant desiccation cracks during the past year. These trips included:

- Prescott Community College Environmental Sciences class, January 19, 2006: Apache Junction. Leader: Ray Harris
- Arizona Department of Transportation, Benson facility and Kansas Settlement region, February 1, 2006. Leaders: Ray Harris and Lee Allison
- U.S. Geological Survey, February 23, 2006; Willcox and Kansas Settlement region. Leader: Ray Harris
- Arizona Department of Environmental Quality, March 1, 2006; Apache Junction. Leader: Ray Harris
- Delegation from Aguas Calientes, Mexico and Town of Queen Creek, May 2006; Queen Creek. Leaders: Sylvia Centoz (City of Queen Creek) and Ray Harris
- Arizona Department of Transportation and geotechnical professionals, Loop 202 freeway fissure in Mesa, June 29, 2006. About 80 people attended. Leaders: Naresh Samtani (NCS Consultants) and Ray Harris
- Analysts from the JLBC and Governor's OSPB, August 8, 2006; visited Loop 202 freeway fissure and Apache Junction fissures. Leaders: Ray Harris and Lee Allison.
- Richard Kamp, Wick Communications, October 9, 2006; San Simon. Leader: Ray Harris

NEWS MEDIA INTERVIEW AND BRIEFINGS

AZGS staff spoke with reporters dozens of times as part of at least 17 stories printed in local and statewide news media. Staff also provided extensive materials to KAET-TV for a documentary to be aired in Spring, 2007, and did on-camera presentations.

NEW PUBLICATIONS

During 2006 AZGS geologists published several articles about subsidence and earth fissures:

"Hazardous Cracks Running through Arizona," *Geotimes*, American Geological Institute, August 2006. Authors: Ray Harris and M. Lee Allison
"Earth Fissures in Arizona," *Our Real Estate Community* newsletter, September 2006: Author: Ray Harris.
"Earth Fissures in Arizona," *Arizona Department of Real Estate Newsletter*, November 2006: Author: Ray Harris.
"Earth Fissures in Arizona," *Arizona Journal of Real Estate and Business*, January 2007: Author: Ray Harris.

EARTH FISSURE PUBLICATIONS FROM THE AZGS

Down-to-Earth Series

DTE-3-Land Subsidence and Earth Fissures in Arizona, by S. Slaff, 1993, 24 p**.** $4.50

DTE-13-A Home Buyer's Guide to Geologic Hazards in Arizona, by Raymond C. Harris and Philip A. Pearthree, 1993, 24 p. $8.95

Maps

M-23-Land Subsidence, Earth Fissures, and Water-Level Change in Southern Arizona, by H.H. Schumann and R.B. Genualdi, 1986, scale 1:1,000,000. $4.00

Special Papers

SP-5-Geologic Diversity of Arizona and Its Margins; Excursions to Choice Areas, edited by G.H. Davis and E.M. VandenDolder, 1987, 422 p.[Field-Trip Guidebook for the 100th Annual Meeting of The Geological Society of America, Phoenix, Ariz., 1987]. $20.00

SP-2-Guidebook to the Geology of Central Arizona, by D.M. Burt and T.L. Péwé, 1978, 176 p. [Field-Trip Guidebook for the 74th Regional Meeting of the Cordilleran Section, The Geological Society of America, Tucson, Ariz., 1978]. $15.00

Open-File Reports

OFR-04-01-Giant Desiccation Cracks in Arizona, by R.C. Harris, 2004, 93 p. $22.00

OFR-03-07-Additional Giant Desiccation Cracks near Wintersburg, Maricopa County, Arizona, by R.C. Harris, 2003, 17 p. $5.50

OFR-01-10-A New Earth Fissure Near Wintersburg, Maricopa County, Arizona, by R. C. Harris, 2001, 22 p.$6.50

OFR-99-26-Field Guide to Earth Fissures and Other Land-Subsidence Features in Picacho Basin, Pinal County Arizona, by R.C. Harris, 1999, 55 p. $10.00

OFR-99-18-Geologic Map of the Picacho Mountains and Picacho Peak, Pinal County, Southern Arizona, by S.M. Richard, J.E. Spencer, C.A. Ferguson, and P.A. Pearthree 1999, 43 p., 2 sheets, scale 1:24,000. Text and sheets. $10.00

OFR-98-23-Geology and Geologic Hazards of the Casa Grande Area, Pinal County, Arizona, by J.E. Klawon, P.A. Pearthree, S.J. Skotnicki, and C.A. Ferguson, 1998, 26 p., scale 1:24,000, 6 sheets, [1-Stanfield; 2-Casa Grande West; 3-Casa Grande East; 4-Coolidge; 5-Double Peak; 6-Chuichu]. Complete set.$15.00

OFR-97-19-Earth Fissures in the Bowie-San Simon Area, Cochise County, Arizona, by R.C. Harris, 1997, 10 p., scale 1:24,000. Text and sheet**.** $7.00

OFR-96-23-Geologic Map of the Mesa 30' x 60' Quadrangle, East-Central Arizona, by J.E. Spencer, S.M. Richard, and P.A. Pearthree, 1996, scale 1:100,000. $3.00

OFR-95-11-Bibliography on Subsidence and Earth Fissures in the Metropolitan Phoenix Area, by R.A. Trapp and R. Frisch-Gleason, 1995, 6 p.$2.00

OFR-95-8-Bibliography of Subsidence and Earth Fissures Within Arizona, by R. Frisch- Gleason, Steven Slaff, and R.A. Trapp, 1995, 21 p. $4.50

OFR-95-6-A Reconnaissance of Earth Fissures Near Stanfield, Maricopa, and Casa Grande, Western Pinal County, Arizona, by R.C. Harris, 1995, 6 p., scale 1:24,000. Text and sheet. $5.00

OFR-94-11-A Reconnaissance of Earth Fissures Near Apache Junction, Chandler Heights, and Southwestern Picacho Basin, by R.C. Harris, 1994, 5 p., scales 1:24,000 and 1:27,000, 2 sheets. Text and sheets. $4.00

OFR-94-7-Surficial Geology of the Santan Mountains Piedmont Area, Northern Pinal and Eastern Maricopa County Area, Arizona, by Gary Huckleberry, 1994, 32 p., scale 1:24,000, 2 sheets. Text and sheets. $8.00

OFR-93-11-Earth Fissures and Related Subsidence Features Adjacent to the Tucson Aqueduct, Central Arizona Project, Pinal and Pima Counties, Arizona, by S. Slaff, 1993, 18 p., scale 1:24,000, 6 sheets. Text and sheets.$15.00

OFR-93-1b-Gravity and Magnetic Surveys at Brady Earth Fissure, Picacho Basin, Pinal County, Arizona: Raw Data, by Steven Slaff, 1993, 15 p. $2.50

OFR-93-1a-Gravity and Magnetic Surveys at Brady Earth Fissure, Picacho Basin, Pinal County, Arizona, by Steven Slaff, 1993, 29 p., scale 1:24,000. Text and sheets. $7.00

OFR-92-13-DRASTIC Analysis of the Potential for Groundwater Pollution in Pinal County, Arizona, by D.L. Moulton, with a fissures study by Steven Slaff, 1992, 67 p., scale 1:250,000, 11 sheets. Text and sheets. $25.00

OFR-91-1-Earth-Fissure Activity Near Brady and Picacho Pumping Plants, Tucson Aqueduct, Central Arizona Project, Pinal County, Arizona, by Steven Slaff, 1991, 43 p., scale 1:24,000, 2 sheets. Text and sheets. $10.50

OFR-90-7-Bibliography on Arizona Earth Fissures and Related Subsidence, With Selected References for Other Areas, by Steven Slaff, 1990, 28 p. $4.75

OFR-90-2-Surficial Geologic Maps of the Picacho Basin, by Garrett Jackson, 1990, 9 p., scale 1:24,000, 5 sheets [1-Picacho Reservoir; 2-Newman Peak; 3-Casa Grande Mts.; 4-Eloy North; 5-Eloy South]. Complete set. $11.50

OFR-89-10-Development of Earth Fissures in Picacho Basin, Pinal County, Arizona From 1959 to 1989, by Steven Slaff, G.W. Jackson, and P.A. Pearthree, 1989, 38 p., scale 1:24,000, 6 sheets [1-Red Rock NW (Newman Peak); 2-Picacho Reservoir; 3- Casa Grande Mts.; 4-Eloy NE (Eloy South); 5-Eloy North; 6-Valley Farms]. Text and sheets. $18.25

OFR-88-20-Potential Land Surface Subsidence at the Arizona Superconducting Super Collider (SSC) Site; Considering Past, Current and Possible Future Ground-Water Withdrawal, by S.J. Brooks, 1988, 28 p.$4.50

OFR-86-14-Land Subsidence, Earth Fissures, and Water-Level Change in Southern Arizona, by H.H. Schumann and R.B. Genualdi, 1986, scale 1:500,000 [also printed at 1:1,000,000 scale as Map 23]. $5.00

Appendix A

Statutory requirements

Arizona Revised Statutes:

27-152.01. Duties of Arizona geological survey
The Arizona geological survey shall:
3. Beginning on or before January 1, 2007 and every five years thereafter, submit to the state land department copies of all data files of known areas of earth fissures for the purposes of section 37-173, paragraph 11. On receipt of the earth fissure maps from the state land department that are based on data files submitted, the Arizona geological survey shall provide any map to any member of the public in printed or electronic format on request. The following notice shall be displayed below each map:

Notice
The state of Arizona has made a reasonable effort to ensure the accuracy of this map when it was produced, but errors may be present and the state of Arizona does not guarantee its accuracy. The map supplements, and is not a substitute for, a professional inspection of property for defects and conditions.

37-173. Duties [of the Department of State Land]
11. Within ninety days after receiving data files of known areas of earth fissures from the Arizona geological survey pursuant to section 27-152.01, paragraph 3, produce maps of those areas with overlays showing affected counties, cities, towns, highways and streets. The division shall transmit the maps in printed and electronic format to the Arizona geological survey and the state real estate department for purposes of providing public access to the earth fissure maps pursuant to sections 27-152.01 and 32-2117.

32-2117. Earth fissure maps; posting; immunity [Department of Real Estate]
A. On receipt of maps from the state land department, the department of real estate shall provide any earth fissure map to any member of the public in printed or electronic format on request and provide access on its web site to the earth fissure maps prepared by the state land department pursuant to section 37-173, paragraph 11. The following notice shall be displayed below each map:

Notice
The state of Arizona has made a reasonable effort to ensure the accuracy of this map when it was produced, but errors may be present and the state of Arizona does not guarantee its accuracy. The map supplements, and is not a substitute for, a professional inspection of property for defects and conditions.

B. Nothing in this section shall be construed as denying a person rights guaranteed by the Arizona Constitution, and notwithstanding any other

law, a subdivider, owner or licensee is not liable to any person or governmental entity for any act or failure to act in connection with:

1. The disclosure of real estate subject to earth fissures if the subdivider, owner or licensee provides a written disclosure or includes notice in a public report, issued pursuant to section 32-2183 or 32-2195.03, with respect to real estate subject to earth fissures, of the map and web site described in subsection A of this section. The written disclosure or notice in a public report, issued pursuant to section 32-2183 or 32-2195.03, of the map and web site does not create an independent cause of action.

2. Any disclosure that occurred before the date the map described in subsection A of this section is posted on the web site if the subdivider, owner or licensee had no actual knowledge that the land was subject to earth fissures before the map was posted.

33-422. Land divisions; recording; disclosure affidavit

F. The affidavit of disclosure shall meet the requirements of section 11-480 and follow substantially the following form:

When recorded mail to:

_____

_____

_____

_____

Affidavit of Disclosure

Pursuant to A.R.S. §33-422

I, _____ (seller(s))

being duly sworn, hereby make this affidavit of disclosure relating to the real property situated in the unincorporated area of:

_____, County, State of Arizona, located at:

_____

and legally described as:

(Legal description attached hereto as exhibit "A")

(property).

7. The property (is (is not subject to (fissures or (expansive soils. (unknown

Explain: _____

_____

_____

_____

Appendix B

Arizona Geological Survey
Earth Fissure Advisory Group membership

Association of Engineering and Environmental Geologists
Frances Ackerman
c/o Gannett Fleming, Inc.
4722 North 24th St., #250
Phoenix, AZ 85016
602.553.8817, x234
aackerman@gfnet.com

Arizona Department of Emergency Management
Mimi Diaz*, HMGP/FMA Program Manager
5636 E McDowell Rd, Bldg 505
Phoenix, AZ 85008
602.231.6349
mimi.diaz@azdema.gov

Arizona Association of Realtors
Tom Farley
VP Government Affairs
255 E. Osborn Rd. #200
Phoenix, AZ, 85012
602.248.7787 or 1.800.426.7274
TomFarley@AARonline.com

State Land Department
Gary Irish, GIS Section Chief
Eugene Trobia, State Cartographer (alternate)
1616 W. Adams St.
Phoenix, AZ 85007
602.542.2605 girish@land.az.gov
602.542.3190 gtrobia@land.az.gov

Arizona Department of Real Estate
Cindy Ferrin, Deputy Director of Subdivisions & Land Development
Ron Passarelli, Deputy Commissioner (alternate)
2910 N. 44th St.
Phoenix, AZ 85018
602.468.1414, x440 cferrin@azre.gov
602.468.1414, x115, rpassarelli@azre.gov

Arizona Land Subsidence Group
Raymond Sadowski
Sr. Environmental Engineer
Freeport-McMoRan
One North Central Avenue– 17th Floor

Phoenix, AZ 85004
602.366.8592
Raymond_Sadowski@fmi.com

Central Arizona Association of Governments
Robert Wilson
271 Main St.
Superior, AZ 85273
1.800.782.1445 (x25) or 520.689.5004 (x25)
rwilson@caagcentral.org

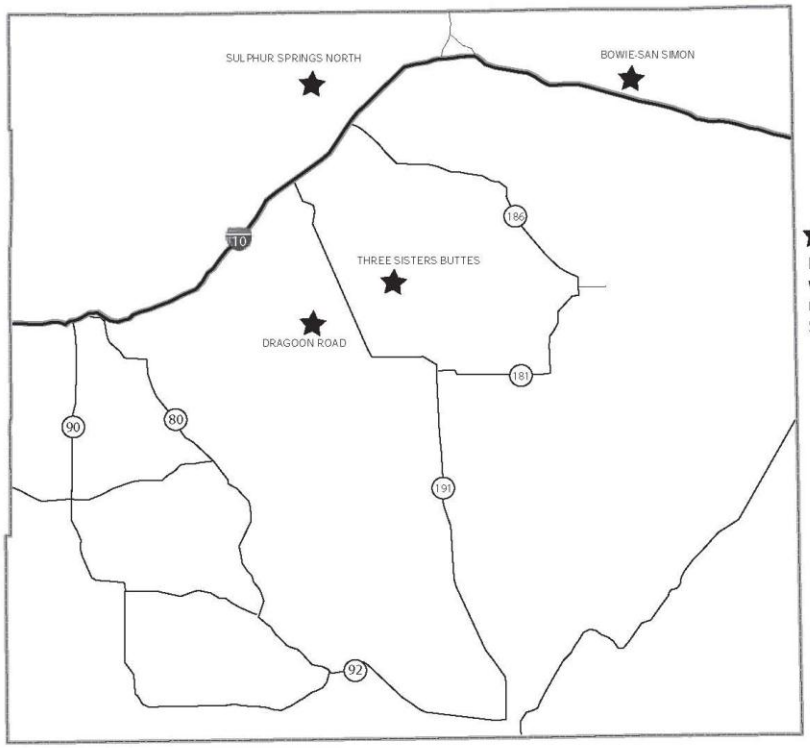
Office of the Attorney General
Laurie Woodall, Assistant Attorney General
1275 W. Washington St.
Phoenix, AZ 85007
602.542.7798
Laurie.woodall@azag.gov

County Supervisors Association of Arizona
Craig Sullivan, Executive Director
1905 W. Washington St. Suite 100
Phoenix, Arizona 85009
602.452.4500
craigs@countysupervisors.org

Arizona Geological Survey, Earth Fissure Program Staff
416 W. Congress, #100
Tucson, Arizona 85701
520-770-3500
Todd Shipman, todd.shipman@azgs.az.gov
Phil Pearthree, phil.pearthree@azgs.az.gov

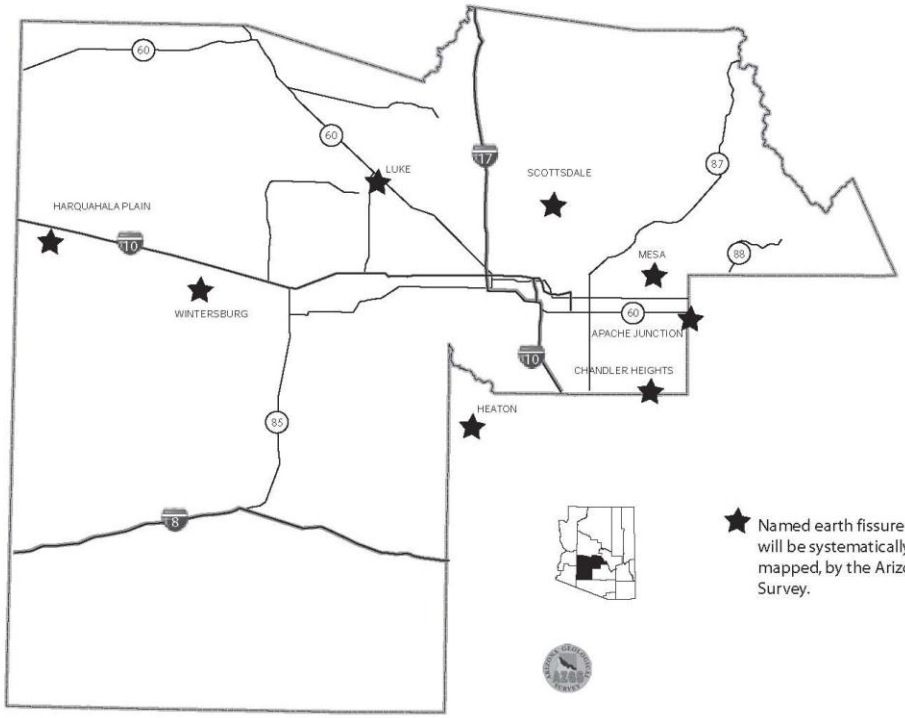
*Effective March 26, 2007, Mimi is with the Arizona Geological Survey

COCHISE COUNTY EARTH FISSURE PLANNING MAP



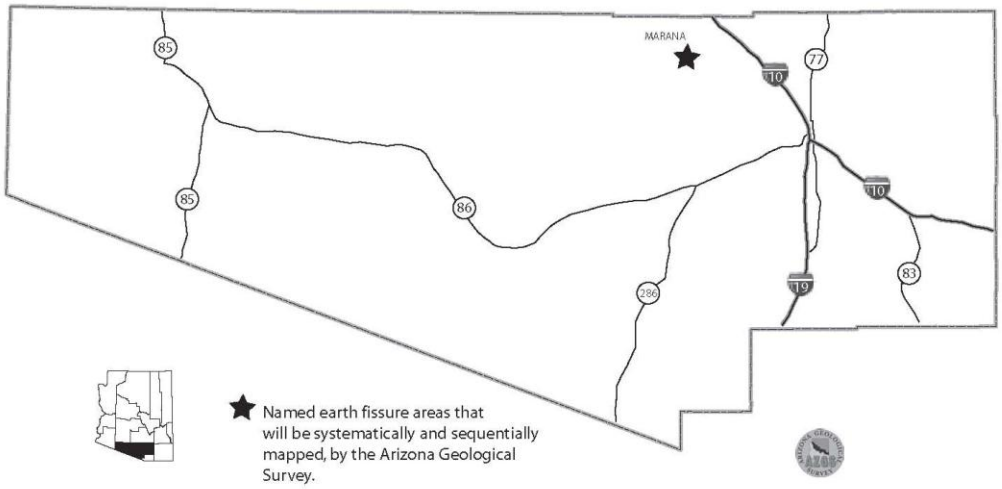
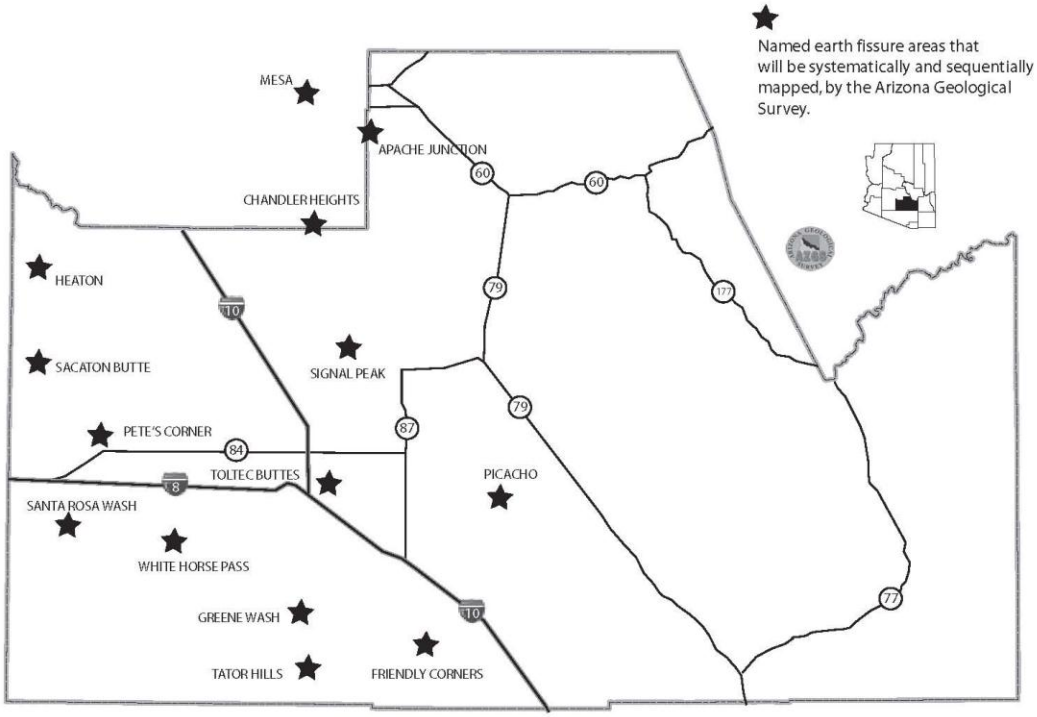
Named earth fissure areas that will be systematically and sequentially mapped, by the Arizona Geological Survey.

MARICOPA COUNTY EARTH FISSURE PLANNING MAP



Named earth fissure areas that will be systematically and sequentially mapped, by the Arizona Geological Survey.

PIMA COUNTY EARTH FISSURE PLANNING MAP



PINAL COUNTY EARTH FISSURE PLANNING MAP