A NEW EARTH FISSURE NEAR WINTERSBURG, MARICOPA COUNTY, ARIZONA

Arizona Geological Survey
Open-File Report 01-10

Raymond C. Harris
Arizona Geological Survey

November 2001

22 pages

ARIZONA'S NEWEST EARTH FISSURE

A new earth fissure has been reported southeast of Wintersburg, about 75 km (50 miles) WSW of Phoenix (Figure 1). The fissure was reported to AZGS in early September and was visited several times through early November. Field mapping was done with a hand-held GPS. This fissure appeared over the past summer, probably during a heavy rainstorm in July. The earth fissure and adjacent desiccation cracks are plotted on a topographic base (Figure 2) and an aerial photo base (Figure 3).

The fissure is nearly north-south and is 307 m (1007 ft) long (Figure 4). The fissure is very young, with narrow, steep sides and a highly irregular apparent depth ranging from <1 foot to >8 feet over short distances. In two locations the fissure is en echelon (Figure 5), with NW-SE steps. There is no discernable vertical offset across the fissure.

At the time of the first visit in mid September, little material had sloughed off into the fissure, only enough to open a narrow trench. Erosional downcutting of 4-12 inches has created miniature badlands up to 10 feet wide on the uphill (east) side of the crack (Figure 6). At the time of a follow-up visit in early November, the edges of fissure were noticeably rounded off from a small rainstorm the previous day. Much of the fissure had been partially filled in but there had not been enough runoff to enlarged it.

Both ends of the fissure are characterized by a gradual fading of the trench to miniature grabens and then to a hairline crack. The final 50 feet of both ends are slightly curved. Typical segments of the fissure are shown in Figures 7 and 8.

It is common for earth fissures to seemingly appear "overnight" following severe rainfall. Heavy rain softens the surficial material, allowing it to cave into the underlying fissure. The surface expression of the fissure probably formed in response to heavy rain associated with a monsoon storm in July. At depth, the precursor fissure may have been forming for years or even decades.

The location of the fissure, at the edge of the basin and somewhat in line with the trend of a small hill, suggests that a shallow buried bedrock ridge may extend south of the hill beneath the trace of the fissure. If this scenario is correct, the crack may represent fissuring due to compaction and subsidence on either or both sides of the buried ridge. This mechanism of differential subsidence due to buried topography has been proposed for earth fissure development in other areas of the state (Jachens and Holzer, 1982).

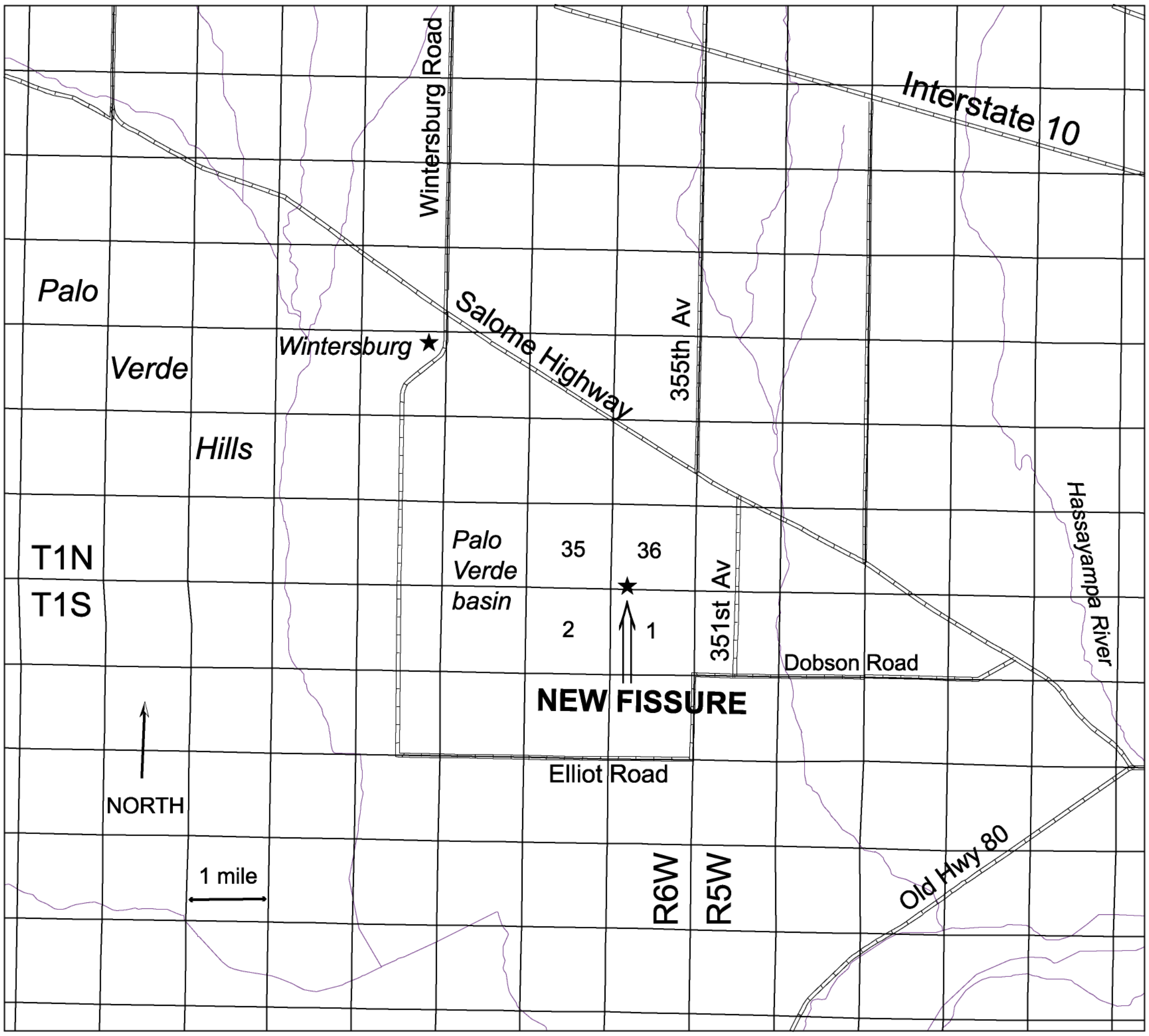


Figure 1. Location of new earth fissure near Wintersburg.

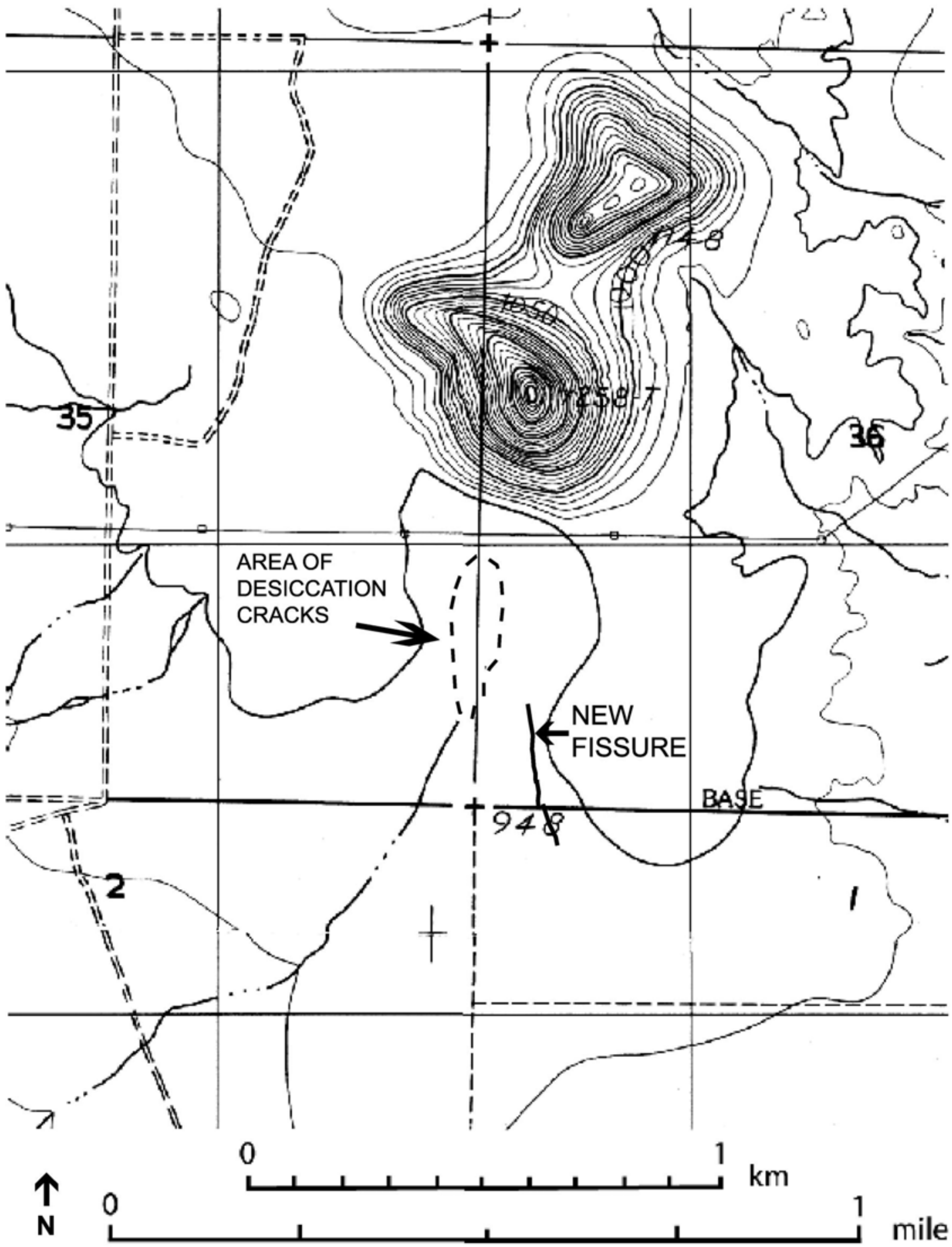


Figure 2. Topographic map showing location of new earth fissure and area of Desiccation cracks. Hill at top of map is 3 miles southeast of Wintersburg. (*Base from Wintersburg and Arlington 7.5-minute quadrangles*)

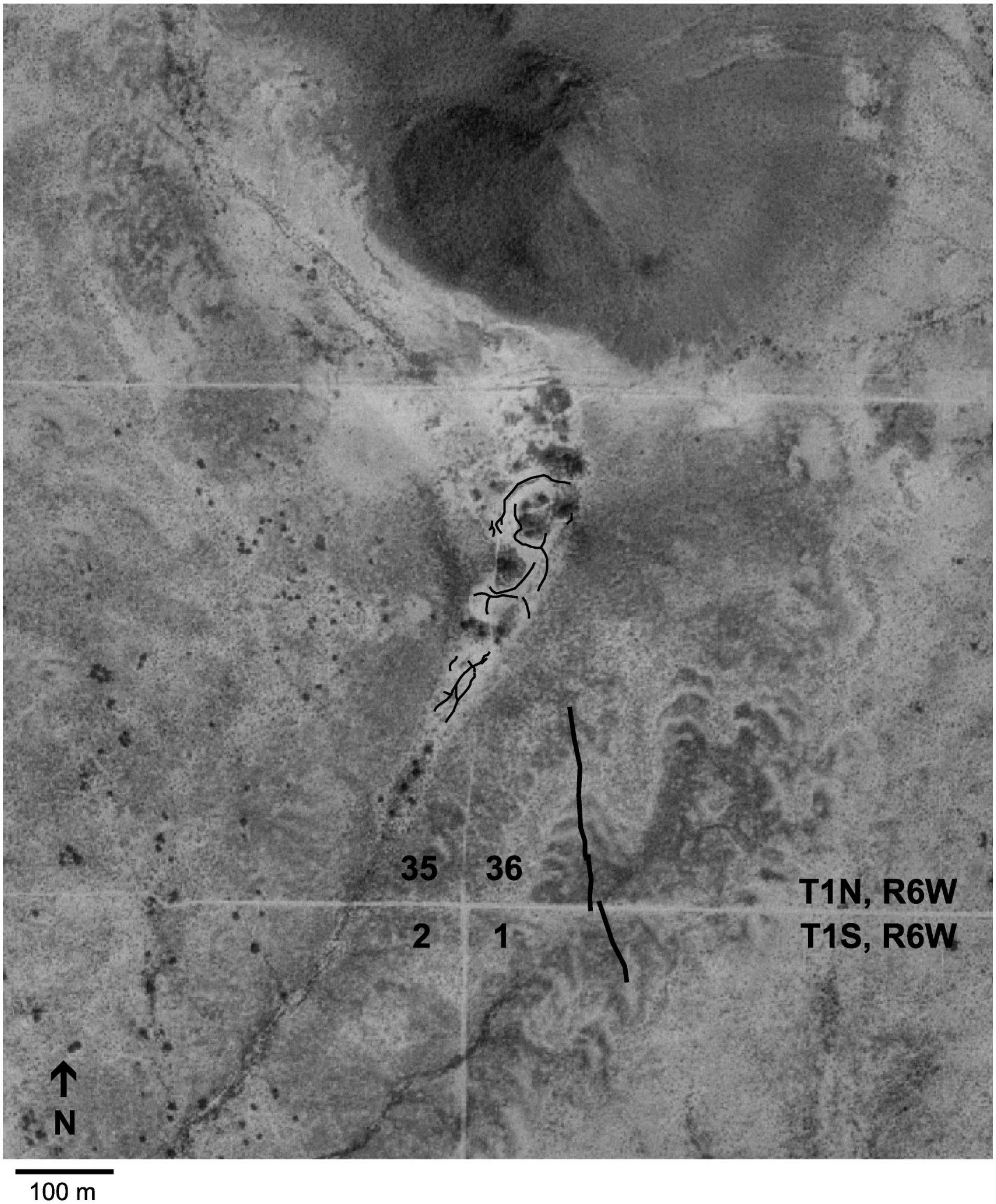


Figure 3. Aerial photo showing location of earth fissure and desiccation cracks.

Figure 4. Detailed aerial view of new earth fissure.

Figure 5. En echelon section of earth fissure crossing Baseline Road, looking NW. Fissure is 6-12 inches wide here. Second earth fissure crosses road at far left (arrow).

Figure 6. Section of earth fissure north of Baseline Road, showing erosion on uphill (east) side. Fissure is 12-18 inches wide, 1-6 feet deep in this section.

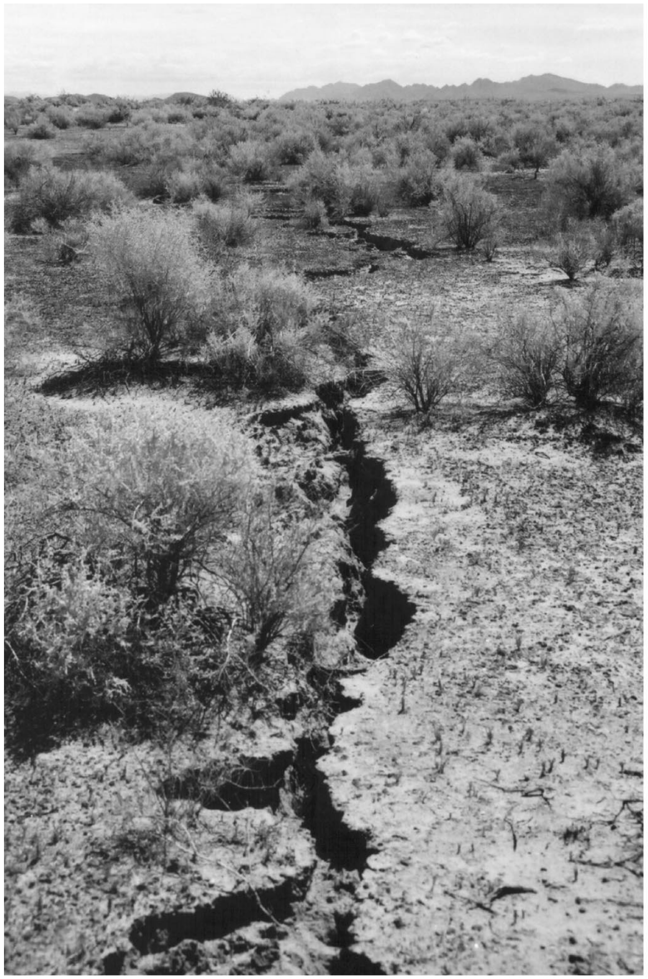


Figure 7. Typical section of earth fissure south of Baseline Road, looking south. Fissure here is 6-12 inches wide, with minor erosion on uphill (east) side.

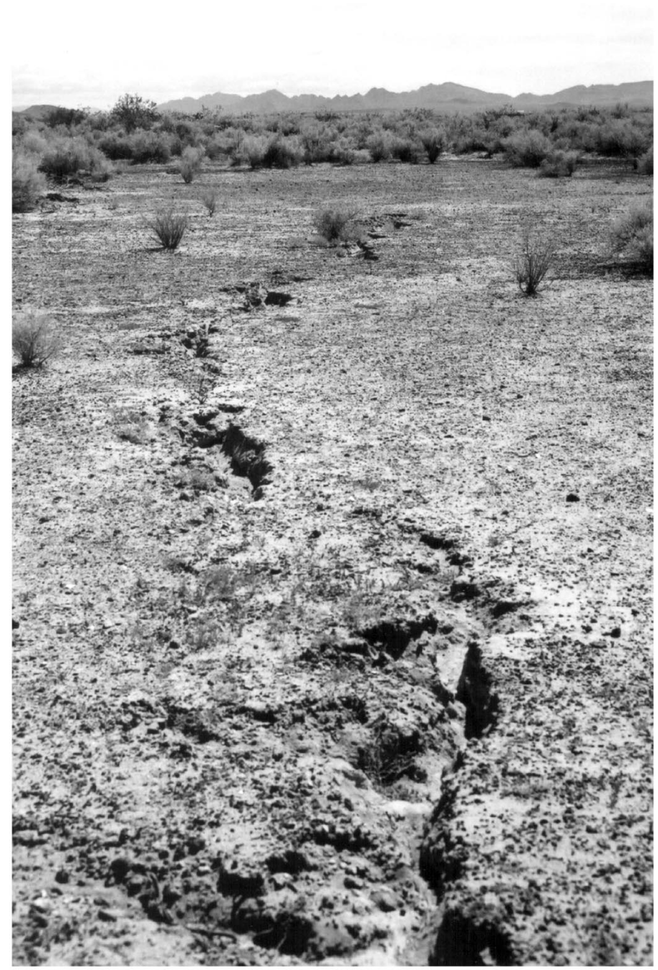


Figure 8. South end of earth fissure, looking south. Fissure decreases in size from 6-10 inches in foreground to hairline crack near far end of clearing.

GIANT DESICCATION CRACKS

Northwest of the new earth fissure is a small area of giant desiccation cracks, plotted in detail in Figure 9. The polygonal cracks are probably not related directly to the earth fissure, but do share the aspect of their opening at the surface in response to heavy rain. (In this report, the term *fissure* is reserved for earth fissures caused by subsidence from groundwater pumping. Ruptures resulting from desiccation are called *cracks*.) Similar polygonal desiccation cracks are found in several locations in southeastern Arizona, such as Willcox (Anderson, 1978; Holzer, 1980) and along Interstate 10 between Bowie and San Simon (Holzer, 1980; Harris, 1997). Photos in Figures 10-16 show typical features of these desiccation cracks.

As with other polygonal cracks in Arizona, the Palo Verde cracks formed by the drying out of sediments containing a large fraction of expansive clay, typically sodium-montmorillinite. Because these sediments are thick and buried, desiccation to the point of forming giant "mudcracks" probably takes many years or perhaps decades, and likely reflects natural long-term climate cycles. Such polygonal cracks appear on the earliest air photos of southeastern Arizona, taken in the mid 1930s, so conditions that caused these recent cracks to form have occurred in the past as well.

There appears to be at least two generations of desiccation cracks at this site. New cracks have opened as both extensions of older ones and as separate cracks. Traces of older cracks are marked by distinct alignments of thick vegetation within shallow, curvilinear depressions. New cracks, which appear to have opened during the past summer, were very fresh looking when visited in September 2001. Some had vertical sides showing no erosion. At the time of a follow-up visit to the site November 5, 2001, the day after a rainstorm, the edges of the cracks had been noticeably rounded off.

Most of the cracks are less than a foot deep and the depth is relatively uniform over much of their length. The deepest of the cracks are about three feet deep, somewhat shallower than other such desiccation cracks elsewhere in the state, and much shallower than earth fissures. Future heavy rains may open the cracks more. Eventually, the cracks fill with sediment transported during floods and the only record of the former crack is the line of vegetation that develops.

Desiccation cracks are distinguished from earth fissures by their pattern of branching that typically forms polygons tens of yards to one hundred yards across. Individual cracks may be hundreds of feet long and in some places, including here, are large enough to mimic earth fissures. Earth fissures tend to be longer, straighter, and much deeper. Fissures can branch or have en echelon segments, but do not form polygons.

Polygonal desiccation cracks of this size form at depth and work their way to the surface by stoping (Neal and others, 1968). Ironically, it takes both aridity and periodic wetness to produce polygonal cracks at the surface. Long dry periods create the underlying shrinkage crack but periodic flooding softens or liquefies shallower clays, which allow stoping to open the crack at the surface. It is probably no coincidence that these cracks are located in the axis of a small, low-gradient drainage where runoff is sluggish during heavy rains.

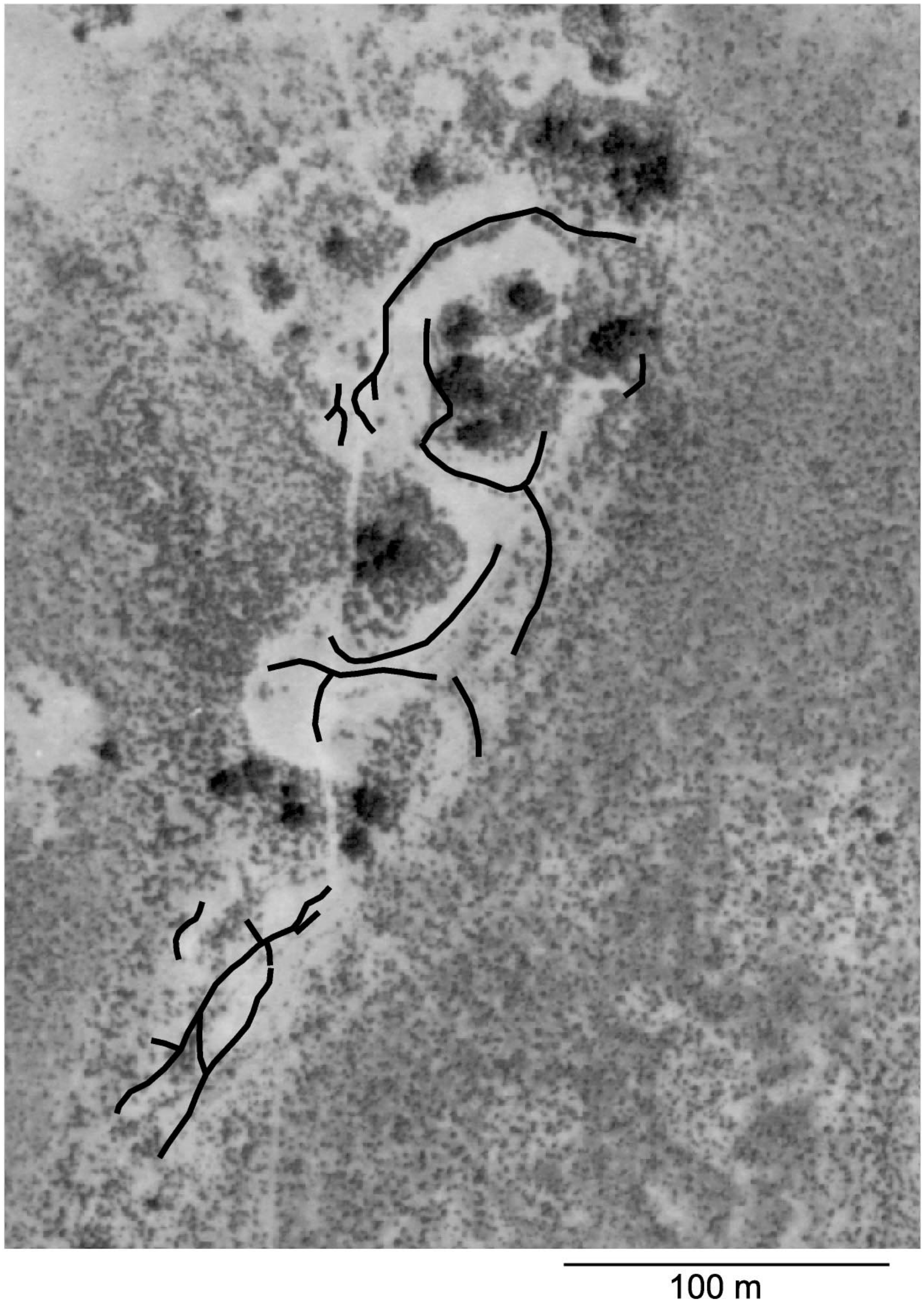


Figure 9. Area of giant polygonal desiccation cracks, northwest of new earth fissure. These cracks are similar in size and shape to other known desiccation cracks in southeastern Arizona.

Figure 10. New generation desiccation crack (center), with lack of vegetation. An older, reactivated crack is defined by the alignment of mature vegetation on the left side of the vehicle. A third crack (center right edge) joins the large crack at the center of the photo.

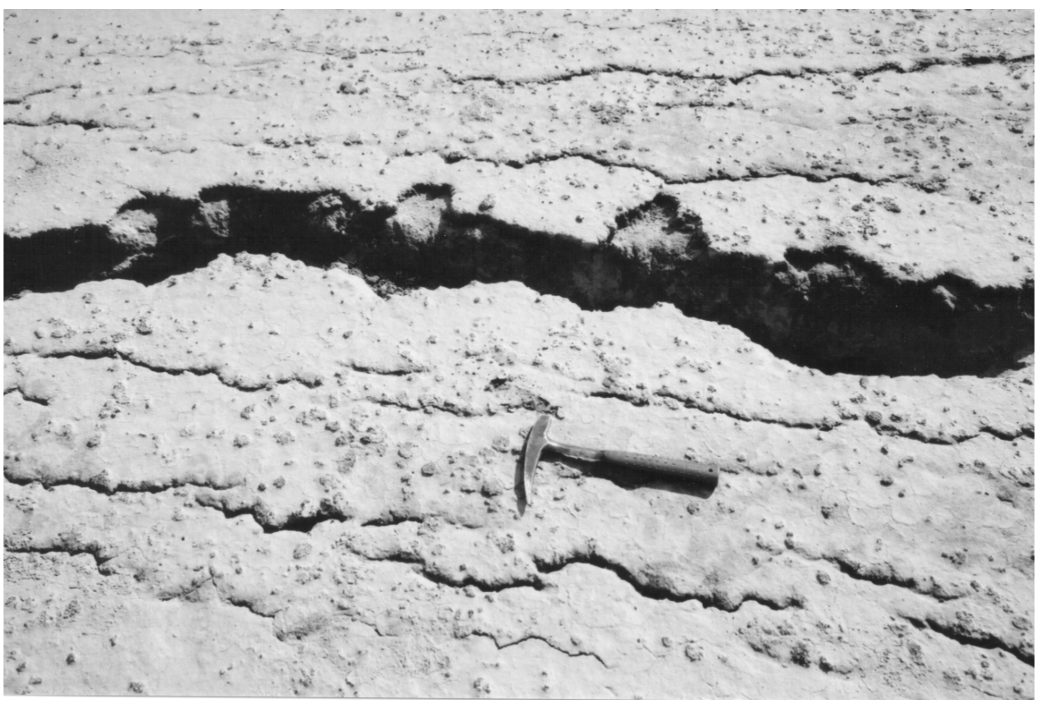


Figure 11. Close up of large, new crack shown in Figure 10, above. Parallel small cracks indicate further collapse and enlargement of the crack is likely in the event of another heavy rain.

Figure 12. New desiccation crack, with vertical sides, sharp angles, and lack of vegetation. Rock hammer for scale.

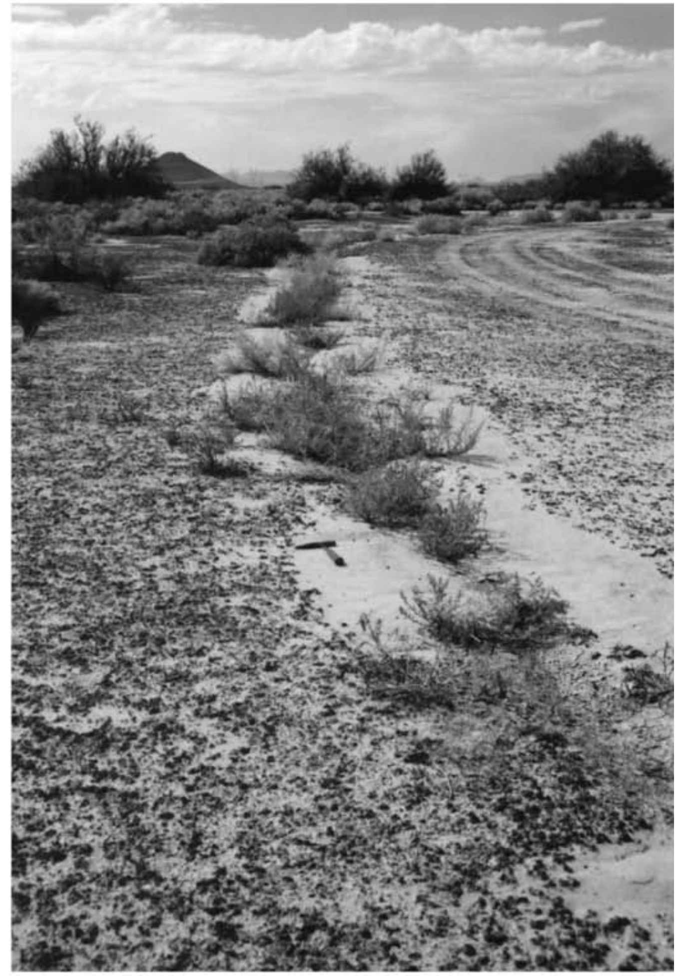


Figure 13. Older generation desiccation crack with well-developed vegetation alignment. Rock hammer for scale.

Figure 14. Junction of desiccation cracks by hammer at center of photo. Arrows point to three separate cracks. Note alignment of mature vegetation in the cracks, indicating that the cracks are old features, recently reactivated.

Figure 15. Junction of three cracks (arrows) at center of photo. Alignment of mature vegetation indicates this is at least the second cycle of cracking.

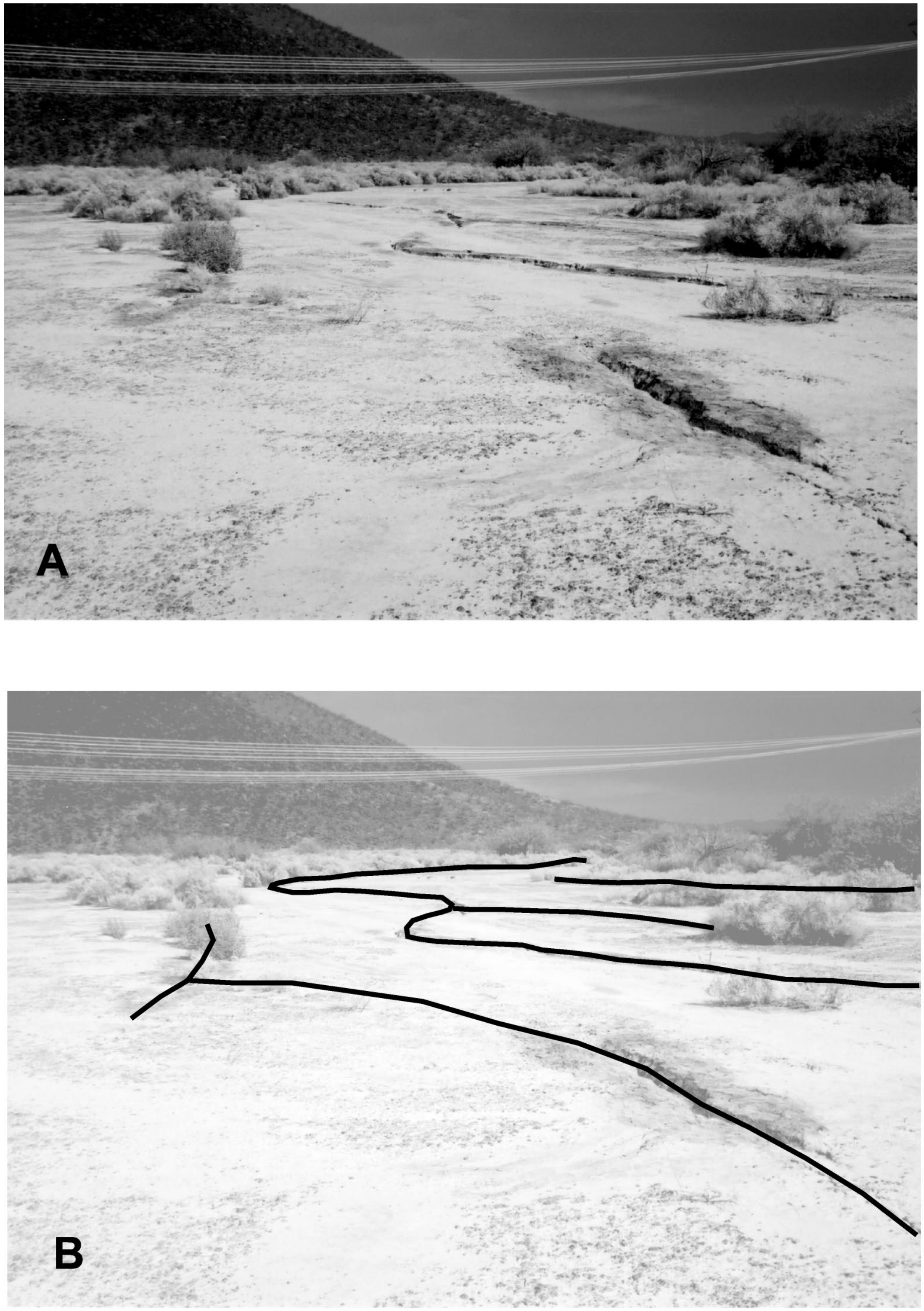


Figure 16. **(A)** View of northern-most group of desiccation cracks. **(B)** Trace of cracks plotted. Note new cracks in foreground lack vegetation, whereas older cracks in background are marked by very mature vegetation alignments.

GEOLOGIC SETTING

The site of the new fissure is immediately south of a small hill three miles southeast of Wintersburg. A ring of similar small hills defines the tiny Palo Verde basin, with the new fissure near its eastern margin. Figure 17 is a generalized geologic map of the Wintersburg area, based on the mapping of Demsey (1989) and Reynolds and Skotnicki (1993). Geologic units are described in Tables 1 and 2.

The oldest rocks in the area shown in Figure 2 are middle Tertiary basalts and basaltic andesites of the Palo Verde Hills. Age dates on these volcanic rocks range from 16.9 to 20.7 million years (Reynolds and others, 1986). Beginning 12-13 million years ago, Basin and Range faulting broke the crust into blocks that were tilted 15-23 degrees to the southwest in the region that became the Palo Verde Hills.

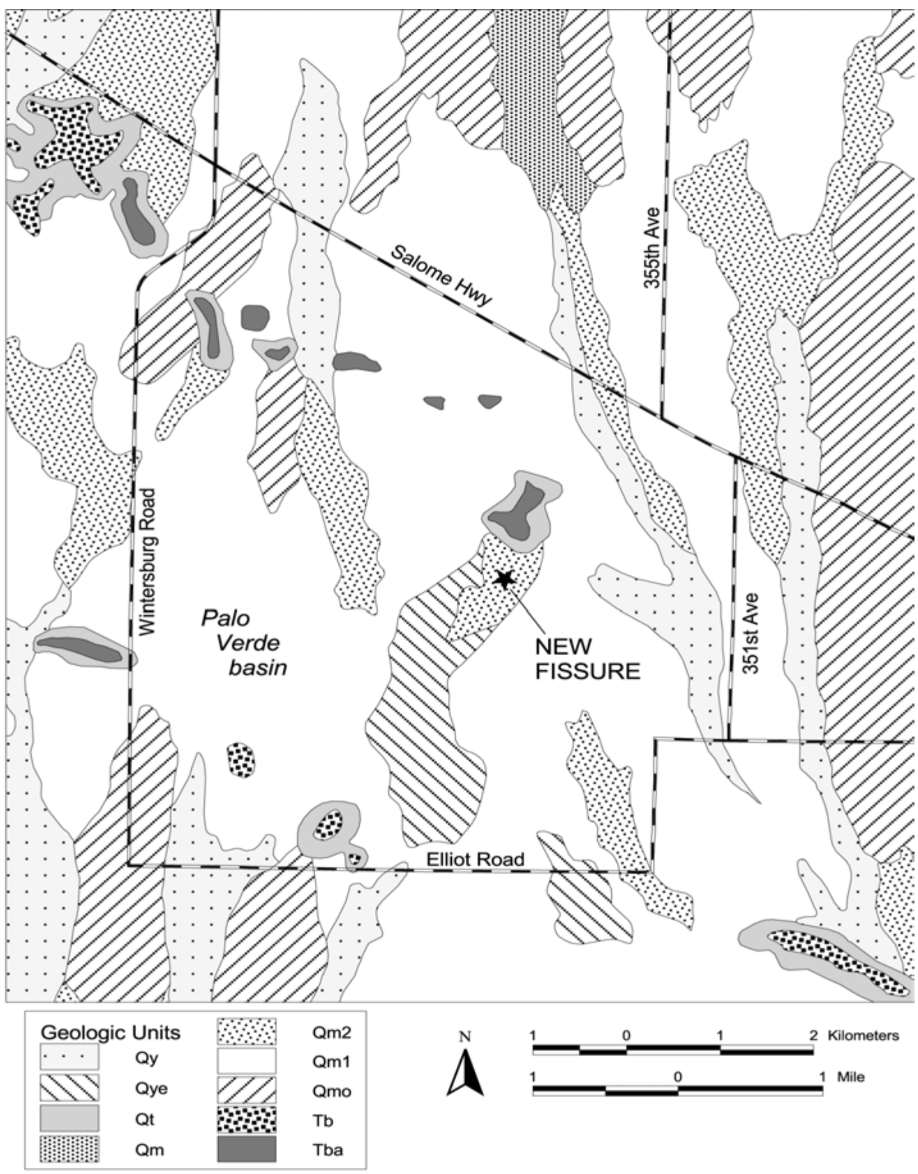


Figure 17. Geologic map of the Wintersburg area. Units described in Tables 1 and 2.

After faulting formed the tilted mountain blocks, sediments began filling the basins. Drainage was internal in much of the Basin and Range Province, including the region from Phoenix to Yuma. Sediments in the region of the Palo Verde Hills were deposited in intermittent lakes and later by streams as drainage became integrated. These basin-fill sediments were deposited mostly after cessation of Basin and Range faulting, about 6 million years ago, and so they have not been tilted. Cross sections based on numerous boreholes show that sedimentary layers in the Palo Verde basin and surrounding region are flat-lying (FUGRO, 1976).

A distinctive clay layer, called the Palo Verde Clay, was encountered in boreholes over an area extending from at least 5 miles to the northeast and southeast of the Palo Verde basin (FUGRO, 1976). The lacustrine clay was deposited in an internally drained basin that covered much of the lower Gila Trough. The unit is older than the 2.8 million year old Arlington basalt flow that overlies it. In the Palo Verde basin the clay averages 80-100 feet thick and its top is about 150 feet below the surface. In the basin the thickness of unconsolidated sediments capable of compaction is less than 480 feet (FUGRO, 1976).

TABLE 1. GEOLOGIC UNITS

Quaternary and Late Tertiary Surficial Deposits

Qy	Young alluvium (Holocene)
Qye	Eolian deposits (Holocene)
Qt	Talus (mostly Holocene)
Qm	Middle alluvium, undifferentiated (Late to Middle Pleistocene)
Qm2	Younger middle alluvium (Late to Middle Pleistocene)
Qm1	Older middle alluvium (Middle Pleistocene)
Qmo	Middle and older alluvium, undifferentiated (Middle to Early Pleistocene)

Tertiary Volcanic and Sedimentary Rocks

Tb	Basalt, undifferentiated (mostly Middle Tertiary)
Tba	Basalt, basaltic andesite, tuff, and clastic rocks (Middle Tertiary)

Units from Demsey 1989; Reynolds and Skotnicki, 1993

TABLE 2. DESCRIPTION OF SURFICIAL GEOLOGIC UNITS
Summarized from Demsey, 1989

Unit **Estimated age (years)**

Qy <1000
Deposits of inferred latest Quaternary age (Holocene; perhaps locally latest Pleistocene), including channels and low terraces of small drainages, young alluvial fans, and broad terraces of major drainages. Surfaces are primarily underlain by well-sorted sand and silt, with local occurrences of fine gravels. Surfaces are slightly (<0.5 m) but abundantly dissected by active gullies and washes. Minimal soil development has occurred in these deposits.

Qye 0 – 10,000
Deposits of eolian sand; designation limited to areas dominated by sand dunes. Eolian sand locally mantles surfaces of Qm1, Qm2, and Qy units.

Qt
Talus; composed of angular fragments of adjacent bedrock units.

Qm 10,000 – 790,000
Undifferentiated Qm2 and Qm1 units (discussed below).

Qm2 10,000 – 250,000
Alluvium of inferred middle to latest Pleistocene age. Deposits are composed of silt, sand, and fine gravel to cobbles; generally well-sorted. Surfaces are slightly to moderately dissected (~1-4 m above active channels). Remnants typically have smooth and fine-grained surfaces or a fine gravel lag. Mafic clasts on surfaces are moderately to darkly varnished; felsic clasts are lightly varnished.

Qm1 250,000 – 790,000
Alluvium of inferred early middle to middle Pleistocene age. Deposits include silt, sand, and fine gravel to large cobbles; in general, deposits are coarser and moderately sorted on the piedmonts, and finer grained (silt and sand) and well sorted in the basins. The surfaces are typically moderately dissected (~3-6 m above active channels). Mafic clasts on surfaces are darkly varnished; felsic clasts lightly to moderately varnished.

Qmo ~500,000 - ~1,000,000 (?)
Alluvium of inferred early middle Pleistocene to early (?) Pleistocene age. Deposits include silt, sand, and fine gravels to cobbles. These deposits are abundantly dissected (up to a depth of ~10 m) such that underlying deposits are also significantly exposed.

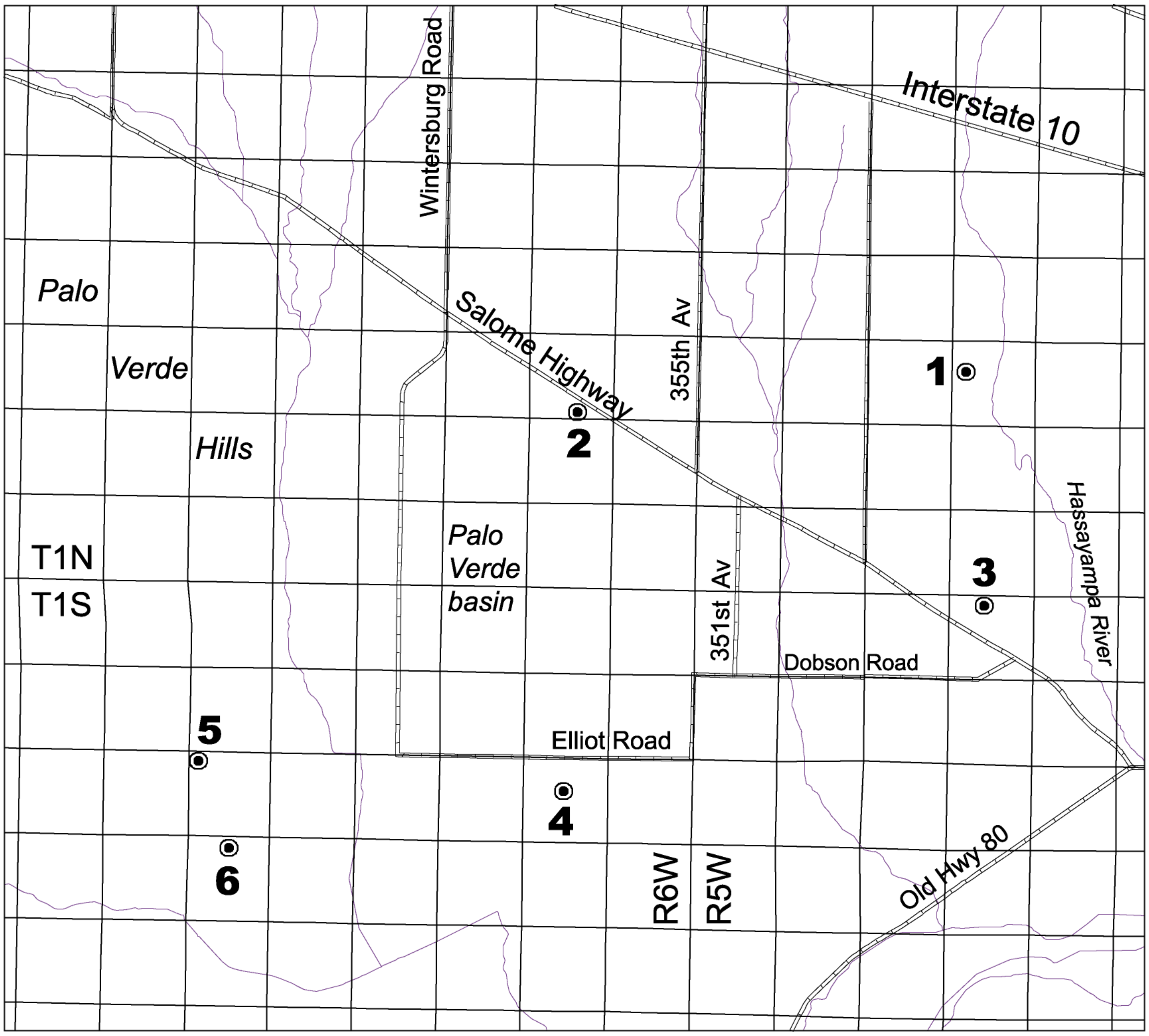
GROUNDWATER

Groundwater levels in the vicinity of the fissure have been measured for many years. Long-term records for six wells in the region were obtained from the Arizona Department of Water Resources. Well locations are plotted in Figure 18. Water levels seem to be fairly steady in the area immediately surrounding the fissure. Plots of water levels over several decades in three wells (Figure 19, a-c) north and east of the fissure show little sign of groundwater decline. Three wells (Figure 19, d-e) southwest of the Palo Verde Hills do record groundwater decline trends on the order of 100 feet (neglecting the lowest "outlier" points on the plots) from the 1950s to about 1980. Groundwater declines of similar magnitude have been responsible for subsidence and earth fissures in other Arizona basins. Since 1980, however, groundwater levels in these three wells have recovered to almost the 1950s levels.

Water pumping in the region is for agriculture and domestic use. Palo Verde Nuclear Generating Station (PVNGS), in the center of the Palo Verde basin, does not use groundwater for its industrial operations. Groundwater is pumped only for drinking and laboratory uses. Reclaimed effluent from Phoenix is used for cooling towers and all other industrial uses at the plant.

Calculations done for the PVNGS initial site assessment (FUGRO, 1976) predicted that groundwater levels would rise in the Palo Verde basin because groundwater was used for agriculture prior to the installation of the plant. The switch from agricultural pumping to limited non-industrial pumping was expected to greatly reduce groundwater use within the basin and allow a subsequent rebound of the regional water table under the plant.

In addition to the regional water table, a shallow perched aquifer in the Palo Verde basin was present in the 1970s under irrigated areas. This perched aquifer, at a depth of 50-70 feet, was interpreted (FUGRO, 1976) as the result of infiltration of irrigation water in the Palo Verde basin, which was occupied by farmland until construction of the power plant.



Well	Location	Depth (ft)
1	(B-01-05)27bbc	384
2	(B-01-06)23dcd	460
3	(C-01-05)3baa	170
4	(C-01-06)14dbb	1114
5	(C-01-06)18bbb	1333
6	(C-01-06)19abb	1045

Figure 18. Location of wells with long-term water level measurements.

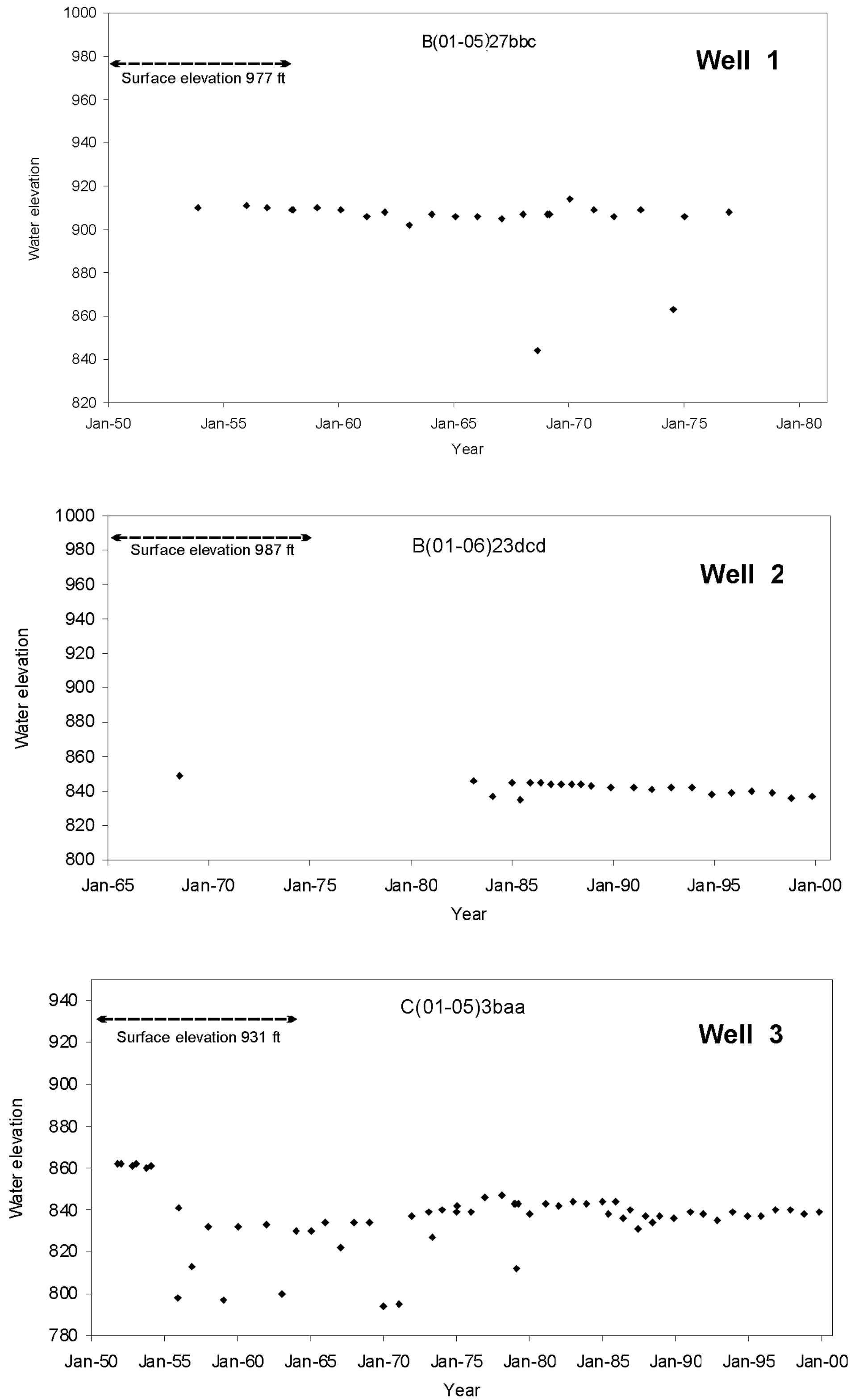
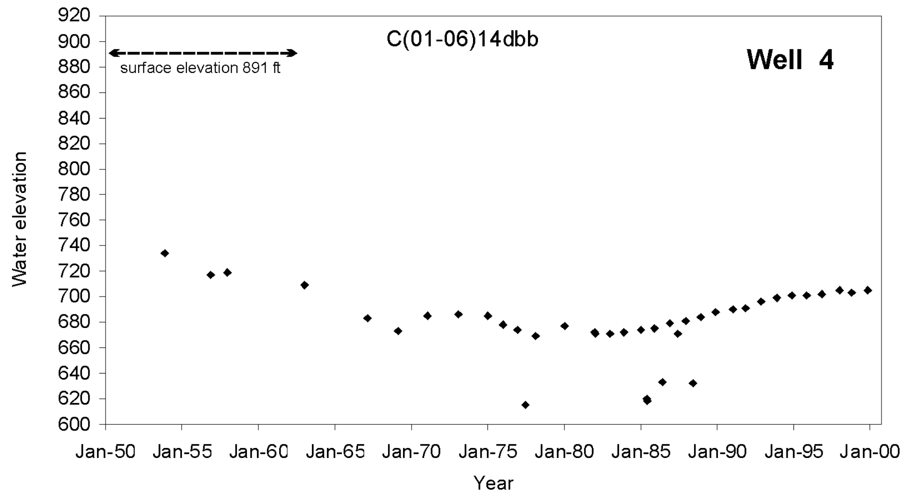
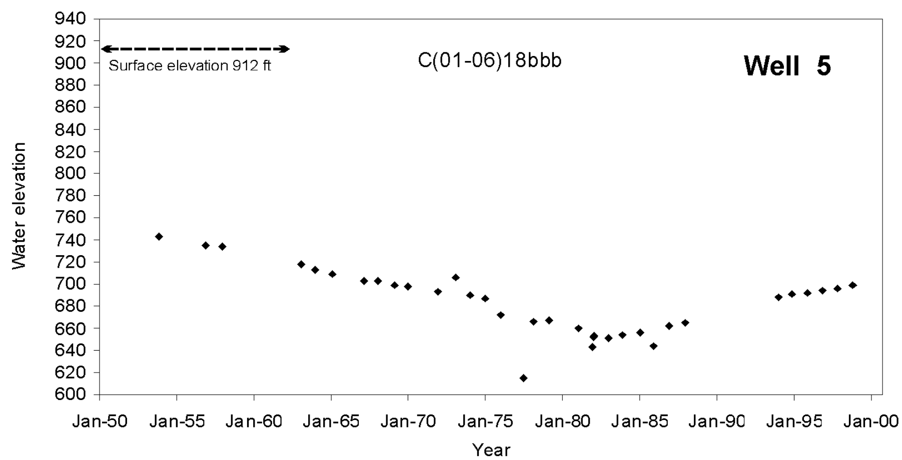


Figure 19. Water level measurements in selected wells near the Palo Verde basin.





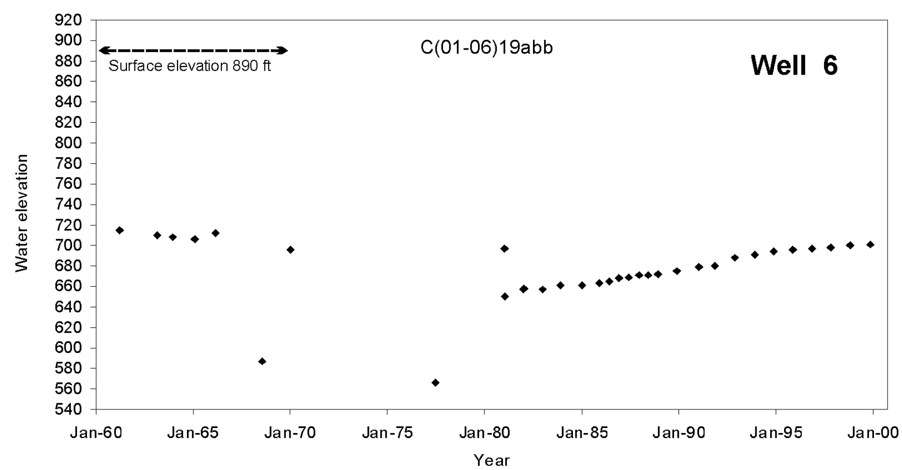


Figure 19 (continued). Water level measurements in selected wells near the Palo Verde basin.

DISCUSSION

Earth fissures have formed in many deep alluvial basins in Arizona because of differential compaction and land subsidence resulting from groundwater pumping, usually associated with agriculture. If the new earth fissure formed as a result of subsidence, the location and magnitude of the subsidence are as yet unknown. Groundwater declines have occurred in the region southwest of the new earth fissure from agricultural pumping, but the declines have reversed since about 1980. Water levels north and east of the fissure have not declined appreciably. Calculations done prior to construction of PVNGS predicted a rebound of the regional water table under the Palo Verde basin due to cessation of agricultural pumping (FUGRO, 1976), so no subsidence is expected there.

Some desiccation cracks northwest of the new earth fissure are older than the fissure (at least at the surface) because mature vegetation occurs in them. Other desiccation cracks, and the new fissure, are too young to have grown vegetation.

An interesting aspect of the development of the new earth fissure adjacent to the area of polygonal cracks is the role desiccation may play. Normally, an earth fissure forms only after differential subsidence has generated enough tension to rupture the sediments. In the Palo Verde area, there does not seem to be enough groundwater lowering to generate the amount of subsidence needed to form earth fissures.

One possibility is that desiccation in the area has provided some or much of the tension responsible for the fissure. If this is the case, the earth fissure developed under circumstances that would normally not allow an earth fissure to form if the only tensional stress were that from differential subsidence. In this respect, the new earth fissure may well owe its existence as much or more to desiccation than to subsidence.

In the Willcox and Bowie-San Simon areas, earth fissures and giant desiccation cracks commonly occur together. Earth fissures may trend into an area of polygonal cracks and in many cases it is impossible to tell where the fissure ends and the desiccation crack begins. But in all of these areas, the desiccation cracks are obvious on mid-1930s photos and so they are older than the earth fissures, which have formed because of pumping that began in the 1940s. It may be that earth fissures opportunistically capture the preexisting desiccation cracks or that that extra tension from desiccation helps earth fissures form.

Although the new fissure is within 1.5 miles of PVNGS, it poses no threat to the facility. If the fissure is caused by a regional lowering of groundwater from pumping to the southwest, it is likely that any subsidence in the Palo Verde basin is fairly uniform across the basin, with differential subsidence only at the margins.

Monitoring of groundwater levels and land subsidence in the region may offer clues as to the origin of the new earth fissure. Continued visitation of the fissure after heavy rains may help determine if it is a true earth fissure or is partly due to desiccation. If it is a true earth fissure, and there is continuing subsidence in the area, it should continue to enlarge during large rainstorms. Monitoring of the nearby polygonal cracks will help chronicle their typical life span.

REFERENCES

Anderson, S.R., 1978, Earth fissures in the Stewart area of the Willcox basin, Cochise County, Arizona: University of Arizona unpublished M.S. thesis [Hydrology Department), 72 p.

Demsey, K.A., 1989, Geologic map of Quaternary and Upper Tertiary alluvium in the Phoenix South 30' x 60' quadrangle, Arizona: Arizona Geological Survey Open-File Report 89-7, scale 1:100,000.

FUGRO, inc., 1976, Palo Verde Nuclear Generating Station Units 1, 2, &3, Preliminary Safety Analysis Report: Phoenix, Arizona Public Service Company, volumes 1-6.

Harris, R.C., 1997, Earth fissures in the Bowie-San Simon area, Cochise County, Arizona: Arizona Geological Survey Open-File Report 97-19, scale 1:24,000.

Holzer, T.L., 1980, Earth fissures and land subsidence, Bowie and Willcox areas, Arizona: U.S. Geological Survey Map MF-1156, 2 sheets, scale 1:24,000.

Jachens, R.C. and Holzer, 1982, Differential compaction mechanism for earth fissures near Casa Grande, Arizona: Geological Society of America Bulletin, v. 93, no. 10, p. 998-1012.

Neal, J.T., Langer, A.M., and Kerr, P.F., 1968, Giant desiccation polygons of Great Basin playas: Geological Society of America Bulletin, v. 79, p. 69-90.

Reynolds, S.J., Florence, F.P., Welty, J.W., Roddy, M.S., Currier, D.A., Anderson, A.V., and Keith, S.B., 1986, Compilation of radiometric age determinations in Arizona: Arizona Bureau of Geology and Mineral Technology Bulletin 197, 258 p.

Reynolds, S.J. and Skotnicki, S.J., 1993, Geologic map of the Phoenix South 30' x 60' quadrangle, central Arizona: Arizona Geological Survey Open-File Report 93-18, scale 1:100,000.