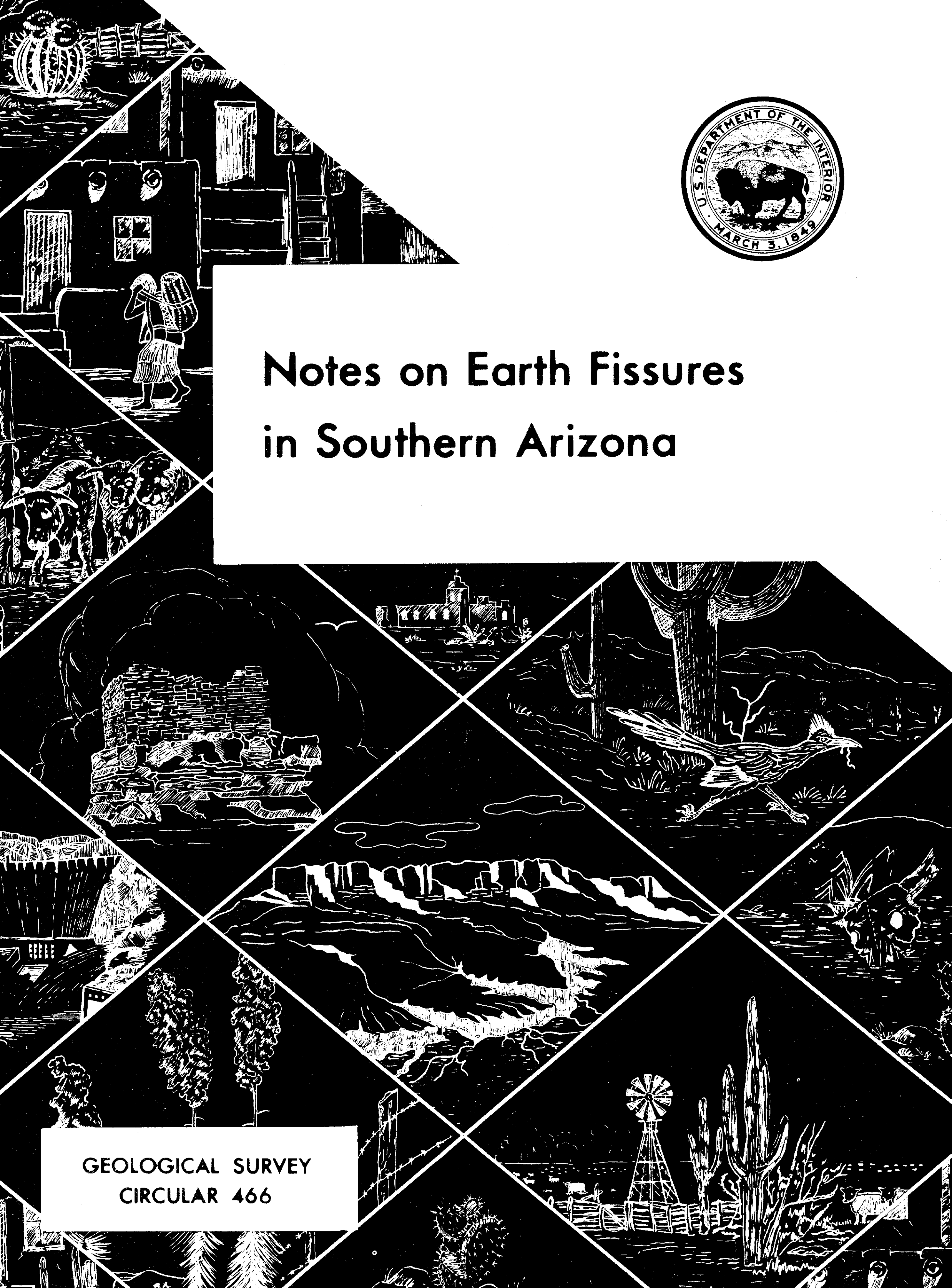
Notes on Earth Fissures in Southern Arizona



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By G. M. Robinson and D. E. Peterson

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ABSTRACT

This report describes earth fissures at six sites in southern Arizona. These notes are preliminary to a more extensive study and detailed analysis being prepared by hydrologists in the Water Resources Division. Earth fissures were first recorded in Arizona in 1927, and have been noticed with increasing frequency since 1949. Fissures at Black Canyon, Bowie, Chandler Heights, Luke Air Force Base, Picacho, and Sells are discussed and illustrated with photographs.

INTRODUCTION

A recent short paper by Pashley (1961) called attention to large cracks or fissures that have appeared from time to time in valley alluvium in southern Arizona. Pashley's discussion was confined, however, to a brief review of several earlier accounts of earth fissures in the Picacho area, to his own observations during 1958-60 on fissures near Casa Grande, and to his hypothesis for their origin. No comprehensive paper has yet appeared that discusses the occurrence and formation of fissures throughout the State.

Although certain local residents are well aware that earth fissures have been developing for many years in several areas in the southern part of the State, earth scientists may not have been generally aware of the specific areas in which these phenomena have been, and still are, forming. Data are being collected by hydrologists in the Water Resources Division but the collection, interpretation, and analysis are not yet complete. Nevertheless it seems timely to present these notes on earth-fissuring activity in six distinct local areas, so that patterns and orientation may be viewed regionally as well as in local reference to the exposed rock masses and the general geologic environment. Subsequent reports will present more data and the conclusions that may be drawn therefrom.

The first earth fissure recorded in Arizona was discovered in September 1927, about 3 miles southeast of Picacho (pl. 1), and was described in some detail by Leonard (1929). Similar cracks recurred in that area in 1935 and 1949. Since 1949 reports of earth fissuring have been made with increasing frequency from widely separated areas throughout the southern part of the State.

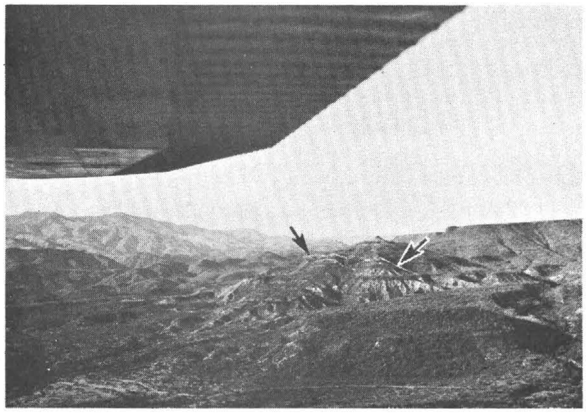
Of special interest is the fact that until February 1962 all reports concerned fissuring in valley alluvium. On February 1, 1962, however, local residents in the Black Canyon area north of Phoenix (pl. 1) reported new earth cracks or fissures; these occurred in a basalt and semiconsolidated sedimentary rock section exposed on a relatively steep dissected slope. Local investigation revealed that similar fissuring and slumping of the earth materials in this area had obviously taken place on previously unrecorded occasions.

Presented in the following paragraphs are a few details on earth fissuring in the selected areas, arranged in alphabetical order. Fissure locations, patterns, and orientation may be observed on plate 1 and in the photographs and subsidence profile included in figures 1 through 8.

BLACK CANYON

Earth fissures have formed in a volcanic rock area about 45 miles north of Phoenix on the east side of Arizona Highway 69, approximately 2 miles northeast of the junction of Squaw Creek with the Aqua Fria River. The fissures traverse a section of volcanic and semiconsolidated sedimentary rocks near the north edge of a small valley. Virtually no ground water is developed in the valley.

The sequence, in time, of the fissure development is not known. Aerial photographs of the general area, taken from an altitude of about 11,000 feet in 1936, clearly show the east-west traces of earlier fissures developed in conjunction with faulting. On February 1, 1962, however, Phoenix newspapers reported the discovery by local residents of new earth movement in the fissure area. The exact time of occurrence seems to have gone unnoticed but air and ground inspection confirmed that the movement was indeed new and that it had been substantial. A photograph (fig. 1A) taken on February 1, 1962, from a



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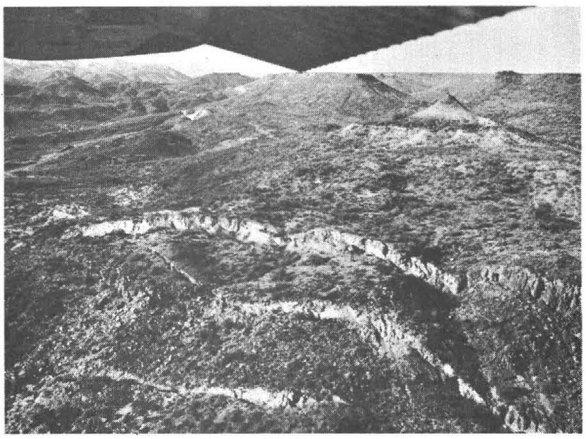

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Figure 1. —Aerial views looking north at fissures near Black Canyon; A, distant view; B, closer view. Light-colored areas indicate the recent exposures. Photographed on February 1, 1962, by H. T. Chapman and A. E. Robinson.

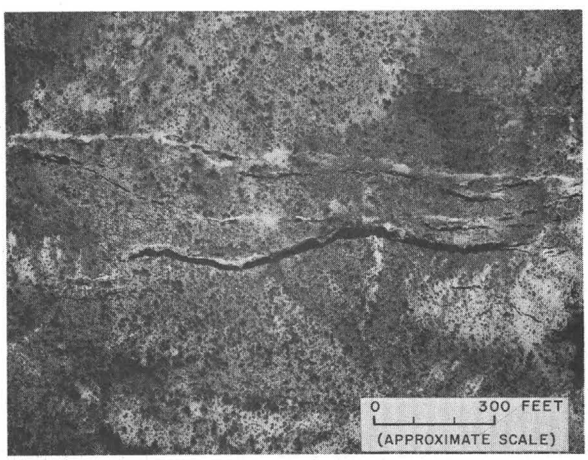
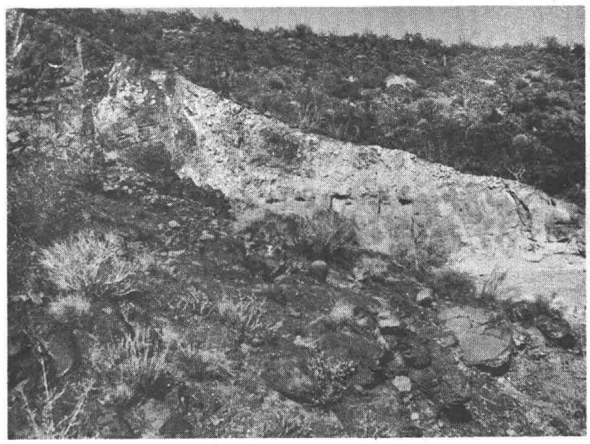


Figure 2. —Aerial photograph from altitude of 4, 000 feet showing principal fissures near Black Canyon. Photographed on March 26, 1962, by H. T. Chapman.



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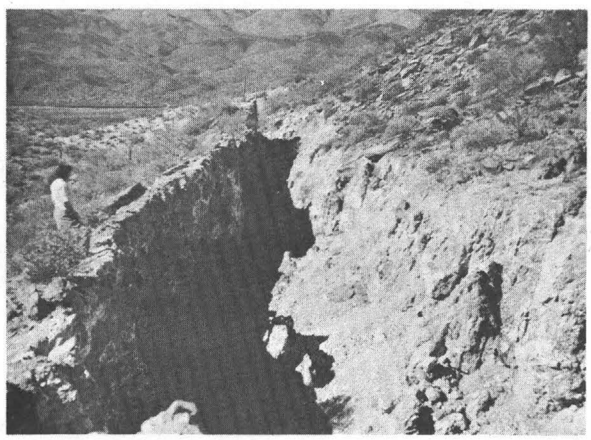

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Figure 3. —Ground views of uppermost and lowermost principal fissures near Black Canyon. A, View looking north at vertical displacement near east end of slippage fault produced by upper fissure. B, View looking west at size of opening near western end of lower fissure. Photographs taken on February 3, 1962, by H. T. Chapman.

low-flying light plane, shows (white trace between arrows) freshly exposed areas on the face of the uppermost fissure or fault in relation to the local relief. The vertical interval from the valley floor (approximate elevation 2,100 feet, mean sea level) to the small cone-shaped hill that rises to the distant skyline (right of center) is between 600 and 700 feet. A similar photograph (fig. 1B) on the same date gives a closer aerial view of this and adjoining major fissures. The cone-shaped hill is again a convenient reference marker. A vertical aerial photograph (fig. 2) taken from an altitude of about 4,000 feet (mean sea level) identifies the major fissure pattern. The fresher and lighter appearing areas, along the northernmost fissure in the photograph, identify the new exposures associated with the most recent earth movement. The duller and darker areas denote exposures dating back to earlier movements. These details, as well as the vertical movement (about 10 to 15 feet) at this particular fissure, show to advantage in figure 3A, as photographed on February 3, 1962. The black band (fig. 2) along the lower or southernmost principal fissure is the shadow that the sharply defined southern rim casts into the opening. The opening size can be judged from figure 3B, photographed on February 3, 1962, from a ground vantage point on the fissure rim at about the western quarter point with respect to its length as indicated in figure 2.

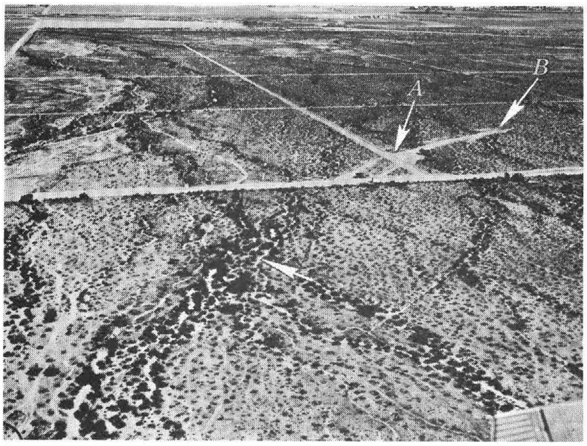
Figure 2 is one of a series of six overlapping aerial photographs which when viewed stereoscopically give dramatic evidence of the substantial earth movement. At each opening the earth or rock material appears to have failed in tension or to have been literally pulled apart. The photographs show no significant differential horizontal movement along the fissures. Elongate islands or blocks of material, created when fissures intersected one another, in some instances settled or slumped as grabens. Examples are found by carefully studying stereoscopically various pairs of fissures.

BOWIE

Approximately 6 miles east of Bowie on State Highway 86 an earth fissure crosses both the highway and the Southern Pacific Railroad. The fissure is in the center of a broad alluvial valley, north of the Dos Cabezas Mountains, and extends about 1 mile northward and about 1 mile south-southeastward from the highway (pl. 1). The use of ground water for irrigation has lowered water levels in the Bowie area more than 100 feet since 1950 (U.S. Geological Survey, 1940-61). The fissure site is near the common perimeter between two centers of heavy pumping, namely, the Bowie and San Simon areas. Compaction of the sediments in these two areas, accompanying the water-table decline, could gradually have built up tensile stresses in the peripheral area common to the two centers of pumping, leading to ultimate rupture of the earth material in the form of the observed fissure.

CHANDLER HEIGHTS

Close to the northernmost flank of Santan Mountain, approximately 30 miles southeast of Phoenix and 12 miles southeast of Chandler, local residents report that earth fissures have occurred on several occasions. The fissures are oriented roughly parallel to the nearest exposed segment of the mountain mass (pl. 1). The trace of a spectacular opening that formed in 1961 is marked on photographs (figs. 4A and B), which were taken from the air on February 10, 1962, to show the fissure site and part of the surrounding area. The lower left part of figure 4A is viewed closer up in figure 4B to show more clearly some details of the fissure trace. The circled saguaro cactus, about 30 feet tall, is also partly circled in the lower left corner of figure 4A. Irrigated land is visible to the north (fig. 4A) of the fissure site but the principal irrigated acreage and area of ground-water withdrawal lies to the northwest. The white scar bracketed by arrows A and B marks the interval in which the fissure terminated. The area was reworked by earth-moving equipment to fill the fissure. The magnitude of the fissure opening is graphically revealed in figure 5, as photographed on September 16, 1961, from a ground site near arrow A (fig. 4A). These photographs suggest that again the earth material has simply pulled apart. No differential horizontal movement can be seen along the fissure and no differential vertical movement is apparent. Where islands or blocks of material have been left standing in the larger openings some crumbling and slumping have occurred.



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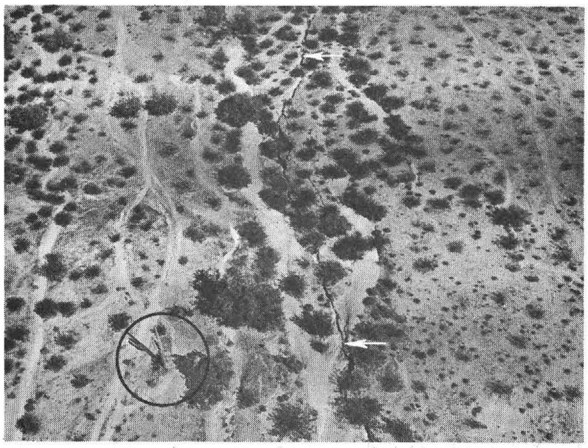

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Figure 4.—Aerial views looking north at fissure near Chandler Heights. A, General view of the area with arrows denoting fissure trace. B, Closer view of fissure trace with same saguaro cactus circled. Photographs taken on February 10, 1962, by H. T. Chapman and A. E. Robinson.

LUKE AIR FORCE BASE

Earth fissures were first observed in the fall of 1959 in a 300-acre well-field area 1¼ miles east of Luke Air Force Base which is about 15 miles northwest of Phoenix (pl. 1). The well field has yielded substantial quantities of water for irrigation since 1936, with annual pumpage ranging between 4,000 and 8,000 acre-feet. The well-field area itself, in which the fissures occur, has never been in cultivation. To shallow depths, at least, the soil consists of caliche. Surrounding the well field are cultivated fields and additional wells for irrigation. The longest fissure extends for a distance of about 1 mile in a northwest-southeast direction.

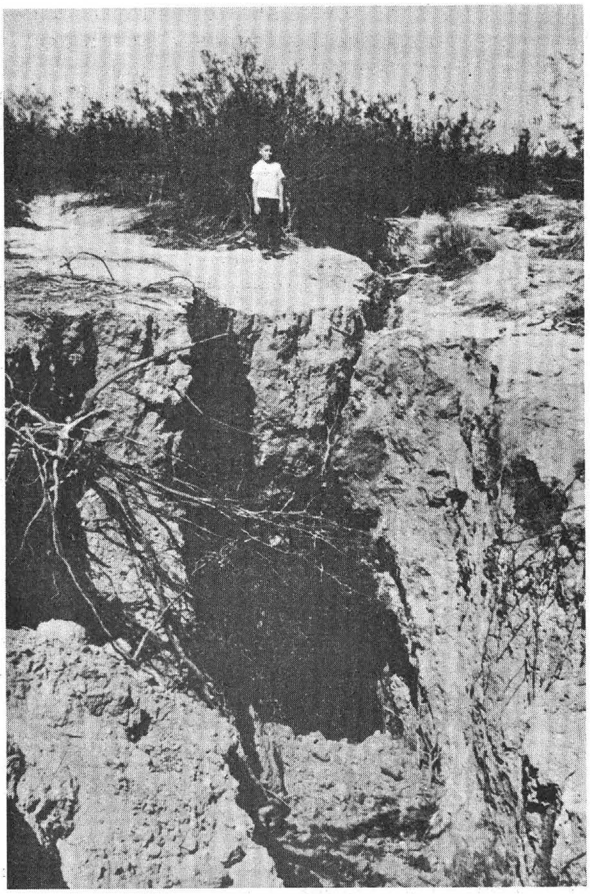


Figure 5.—Magnitude of fissure opening near Chandler Heights, viewed from site marked by arrow A in figure 4A. Photographed on September 16, 1961, by D. E. Peterson.

PICACHO

Heretofore the limited notes and observations on earth fissures in Arizona, published in technical journals, have focused attention principally on the Picacho portion of the general Picacho-Eloy-Casa Grande area (pl. 1). The valley or basin floor is characterized by a northwesterly sloping plane that ranges in elevation from 1,750 feet (mean sea-level datum) near Picacho Peak and the Picacho Mountains to 1,400 feet near the Casa Grande Mountains. These mountains rise abruptly from the basin floor, effectively bounding it on the east and west. Agricultural development in the basin has been extensive.

Ground-water production for irrigation began near Eloy in 1936 because of the favorable market for cotton. A steady increase in irrigated acreage continued until after the war, at which time a sharp rise was noted. The following data on ground-water pumpage furnish a partial index to the agricultural development:

Year	Pumpage (acre-feet)	Data source
1937---	64,000	Smith, 1940, p. 26.
1940---	172,000	U.S. Geol. Survey, 1940-61.
1948---	360,000	Do.
1952---	300,000	Do.
1960---	330,000	Do.

The ground-water production has been accompanied by a steady water-table decline throughout the area. Present water levels range from 100 to nearly 200 feet below an assumed static level for 1930. Until the late 1940's the center of the cone of depression in the water table remained slightly west of Eloy. Subsequently the cone center has migrated steadily eastward in consort with the development of new irrigated acreage and the consequent production from new irrigation wells.

First-order leveling and subsequent checks, by the U.S. Coast and Geodetic Survey, of bench marks along Arizona Highway 84 yield extremely valuable subsidence data. The surveys span the 55-year period from 1905 to 1960 and show (fig. 6) how markedly subsidence rates have increased in the valley alluvium, especially in the Eloy-Picacho region. Of particular interest is the fact that the data show some land-surface subsidence centered around Eloy over the period from 1905 to 1934, before extensive ground-water development. However, the process seems to have been greatly accelerated, probably beginning in 1936, by the effects of persistently increasing ground-water pumpage and application of the water to the steadily increased acreage placed under cultivation. The correlation between subsidence rate and ground-water development is strengthened by noting (fig. 6) how the point of maximum subsidence migrated southeastward with time. This roughly correlates with the similar shift in the deepest part of the cone of depression in the water table. Maximum subsidence along the profile is now approaching 4 feet.

Also shown in figure 6 are the points at which several observed earth fissures intersect the profile along Arizona Highway 84. As might be expected, the fissures are near the outer limits of the subsidence profiles where the earth material could have been subjected to tensile stresses.

The fissure shown at the extreme right in figure 6, at a point on Highway 84 about 3 miles southeast of Picacho, is the one described by Leonard (1929) as having first opened in September 1927. Subsequent filling and reopening of this and other fissures in the general area are described by Heindl and Feth (1955). Leonard's description mentions the fissure length as one-fourth mile; it is now at least 8 miles long. Part of the fissure appears in a photograph (fig. 7A) taken on August 6, 1961, looking northeast across

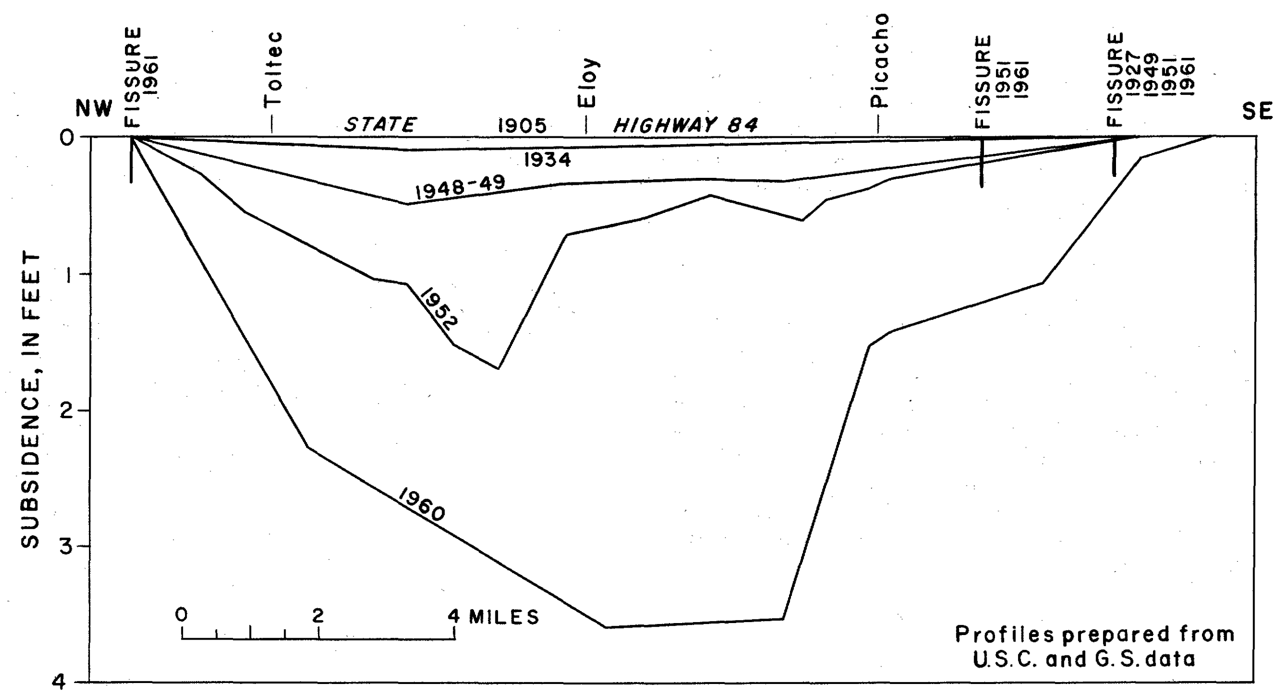
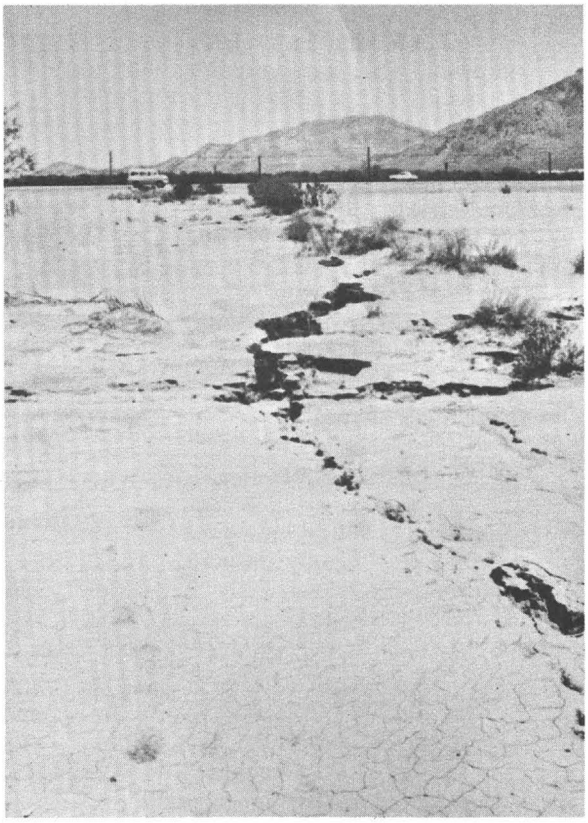


Figure 6.—Changes in land-surface elevation in the Eloy-Picacho area, Pinal County, Arizona.



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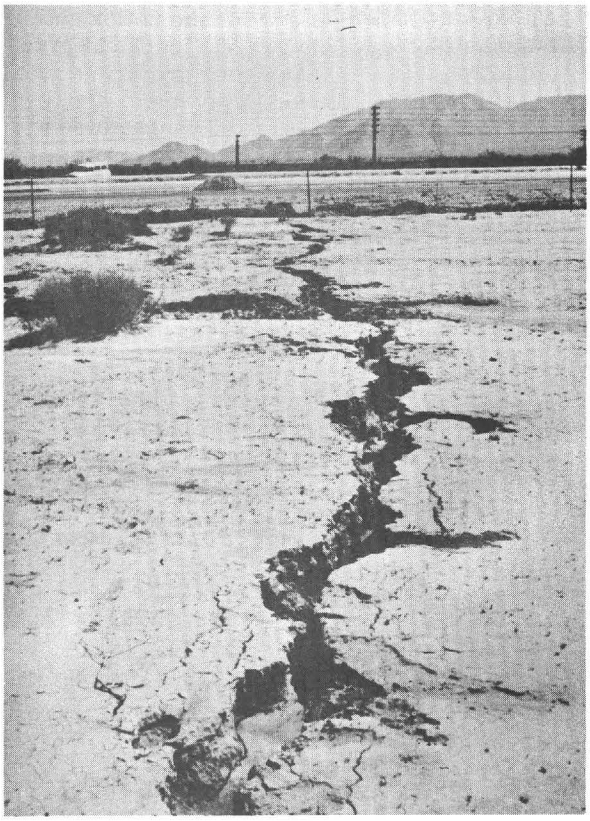

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Figure 7.—Views looking northeast at fissures crossing Arizona Highway 84 near Picacho Mountains. A, Fissure 3 miles southeast of town of Picacho; 2 days previous width appeared less than half an inch; torrential rain on previous day revealed this opening; note vegetal growth along fissure. B, Fissure 1 mile southeast of Picacho. Photographs taken on August 6, 1961, by D.E. Peterson.

Arizona Highway 84 at the distant Picacho Mountains. A second photograph (fig. 7B) shows a similar fissure about 1 mile southeast of Picacho. Again the view is northeastward across Highway 84 with the Picacho Mountains in the distance. Note the absence (figs. 7A and B) of differential vertical or horizontal movement along the two fissures. The openings are characterized by clean breaks and near-vertical walls.

Numerous other earth fissures have been observed from time to time in the general area of Picacho. Those examined as recently as 1961 are shown in the large circled area on plate 1. Some fissures intersect Picacho Reservoir (pl. 1) and in 1961 a retaining embankment overlying a fissure failed. Although the reservoir is only occasionally used to collect surplus water, the Bureau of Indian Affairs, responsible for its operation, is debating whether or not to discontinue its maintenance.

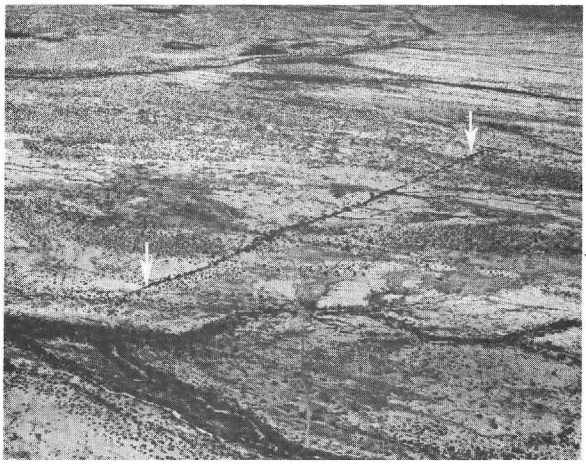

Figure 8.—Aerial view looking northeast at east-west trending fissure near Sells. Fissure intersects, nearly at right angles, a wash that is tributary to Chukut'Kuk Wash. Photographed on February 8, 1962, by H.T. Chapman and A.E. Robinson.

During the summer of 1961 the junior author surveyed the general area of Picacho by gravity meter and certain Bouguer gravity anomaly highs were observed. These are apparent highs but they can be related to the amount of rock mass present between the meter station and the mean sea level datum. Significantly, the location and trends of the earth fissures in the Picacho-Eloy basin are in general linear conformity with the gravity anomaly highs. This would appear to support the hypothesis advanced by Heindl and Feth (1955) that some fissures are tensional breaks that may result from differential settlement along the edge of a concealed (buried) pediment.

SELLS

An earth fissure 1/2 to 3/4 mile long was first observed in the early 1950's by personnel of the Bureau of Indian Affairs. The fissure is about 12 miles southwest of Sells near (east of) the Indian settlement of Chukut Kuk (pl. 1), in an area where irrigation farming, using ground water, has not been extensively practiced. A photograph (fig. 8) taken on February 8, 1962, from a low-flying light plane shows the straight east-west fissure trace intersecting at right angles with a wash tributary to Chukut Kuk Wash.

CONCLUSION

Observing the development, with respect to time, of earth fissures like those described in these brief notes affords an excellent opportunity to document the rates of certain geomorphic processes. In the Black Canyon area, for example, periodic detailed mapping of the local fissure area, using photogrammetric techniques, will reveal the rates and manner in which the landform changes and talus or debris accumulates. In valley-floor areas the occurrence of fissures in alluvial materials may present another useful key in the continuing search for improved understanding of the natural and man-induced mechanisms of sediment compaction and earth subsidence. Corollary thereto are changes in the landform, the surface drainage pattern, and the movement of sediment to streams.

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