SUBSIDENCE CRACKS IN ALLUVIUM NEAR CASA GRANDE, ARIZONA

By

E. F. Pashley, Jr.

U. S. Geological Survey, Tucson, Arizona

INTRODUCTION

Large cracks have appeared in the alluvium of the valleys of southern Arizona at various times but few have been located, described, or studied in detail. New occurrences of these cracks, popularly termed "earth cracks," are being reported continually. The purposes of this paper are (1) to review the few published accounts of these cracks, (2) to describe earth cracks observed by the writer near Casa Grande, Ariz., and (3) to suggest an explanation for the origin of these cracks by comparison to cracks formed under similar conditions in California (Inter-Agency Committee on Land Subsidence in the San Joaquin Valley, 1958).

REVIEW OF LITERATURE ON ARIZONA EARTH CRACKS

The first earth crack recorded in southern Arizona occurred at a point about 3 miles southeast of the town of Picacho. According to Leonard (1929, p. 765), the crack was discovered on the morning of September 12, 1927 after a severe rain and windstorm. In his discussion of the possible origin of the crack Leonard does not dismiss completely the possibility that the torrential rainstorm may have been a contributing factor; however, he prefers to attribute the cause of the crack to seismic vibrations presumably originating about 200 miles to the south at the same time as the crack appeared.

Fletcher and others (1954, p. 259-260), in a discussion of a tunnel-forming type of erosion known as piping, mention earth cracks at Picacho which appeared in 1949, 1951, and 1952. The appearance of all the cracks was preceded immediately by violent rain and windstorms, but seismic shocks were absent. They concluded that the cracks were erosional features called piping.

The Picacho earth cracks were examined independently by Heindl and Feth (1955, p. 343-345) who stated that the clean walls and sharp edges suggest tensional breaks. These may have been the result of differential settling along the edge of a concealed pediment marking a fault line or a buried fault-line scarp. They suggest that the heavy summer storms may have resulted in differential loading of sediments on either side of the possibly concealed pediment edge, or in the reduction of bearing strength of the surficial materials, or both.

The Casa Grande Dispatch (August 15, 1957) described a big crack that opened in the alluvium 3 miles north of Bon Station between Maricopa and Casa Grande. The break was reported to have occurred during a violent electrical storm on the morning of July 19, 1957.

DESCRIPTION OF SOME CASA GRANDE EARTH CRACKS

During 1958-60 the writer had the opportunity to observe the development of several earth cracks along the southeast edge of the Casa Grande Mountains about 3 miles southeast of the town of Casa Grande. The earth cracks were partly or completely filled by sediments when first observed in December 1958. Frequent visits to the area revealed no change until February 1960. In early February, heavy rains in the area had collected in two natural shallow basins, about 40 and 10 acres in extent. At this time, 5 or 6 new earth cracks had formed and some of the old, filled earth cracks had reopened. Some of the old cracks had been extended to several hundred feet in length. Many of the cracks paralleled the edge of one of the ponds near the foot of the mountains, much like a contour line on a topographic map (Fig. 1). The general trends of the pattern formed by the cracks and their apparent relationships to the edge of the bedrock are shown in Figure 2. Other cracks seemed to show no obvious relationship to the ponds or the bedrock outcrops. In all instances the cracks were confined to the alluvium and did not continue into the metamorphic and igneous bedrock complex of the Casa Grande Mountains.

The longest zone of cracks, consisting of several long cracks and a number of parallel short cracks, is continuous for slightly more than half a mile. The cracks range in depth from a few inches to as much as 8 feet, and in width from several inches to about 3 feet (Figs. 3 and 4). The depth seems to vary inversely with the width; the deepest cracks were usually the narrowest. Also, the depth of individual cracks varies greatly along their courses, and is roughly proportional to the amount of slumping. Widening of the cracks seems to have resulted from the slumping from the sides and the slumped material partly fills or bridges the deep parts of the cracks. No cracks showed evidence of horizontal movement.

Although the cracks appear to have received and acted as drains for large amounts of water, in most places the water did not flow laterally in the crack as it would in a graded arroyo; instead it either moved downward through outlets in the bottom of the cracks, possibly recharging the ground-water reservoir, or was absorbed by the dry permeable alluvium. None of the cracks is associated or connected with arroyos, as in piping, and in general the cracks show no relationship to the surface drainage of the area (Fig. 1). The outlets at the bottoms of some cracks apparently had become plugged and water was standing in them; other adjacent cracks were dry, indicating that the water in the cracks did not represent the level to which the underlying alluvium was saturated. In several places the cracks opened up into circular sinklike depressions as much as 4 feet in diameter (Figs. 5 and 6). These "sinkholes" occurred where lesser cracks joined a main crack and the lesser cracks may have been a contributing factor in the formation of the sinkholes.

At one place, a line of small depressions as much as a foot in diameter continued the trace of a crack after the crack itself had died out. The alined depressions suggest that the crack is present in the subsurface (Fig. 7).

A firsthand account of the formation of an earth crack was related to the writer by Mr. Ted Brown, an employee of Eloy Farms which controls the land immediately adjacent to, and partly including the area of this report. Brown had recently finished the construction of a new irrigation ditch across land which had never been farmed or irrigated. The new ditch crossed the faint trace of an old earth crack. On March 15, 1960, water was released into

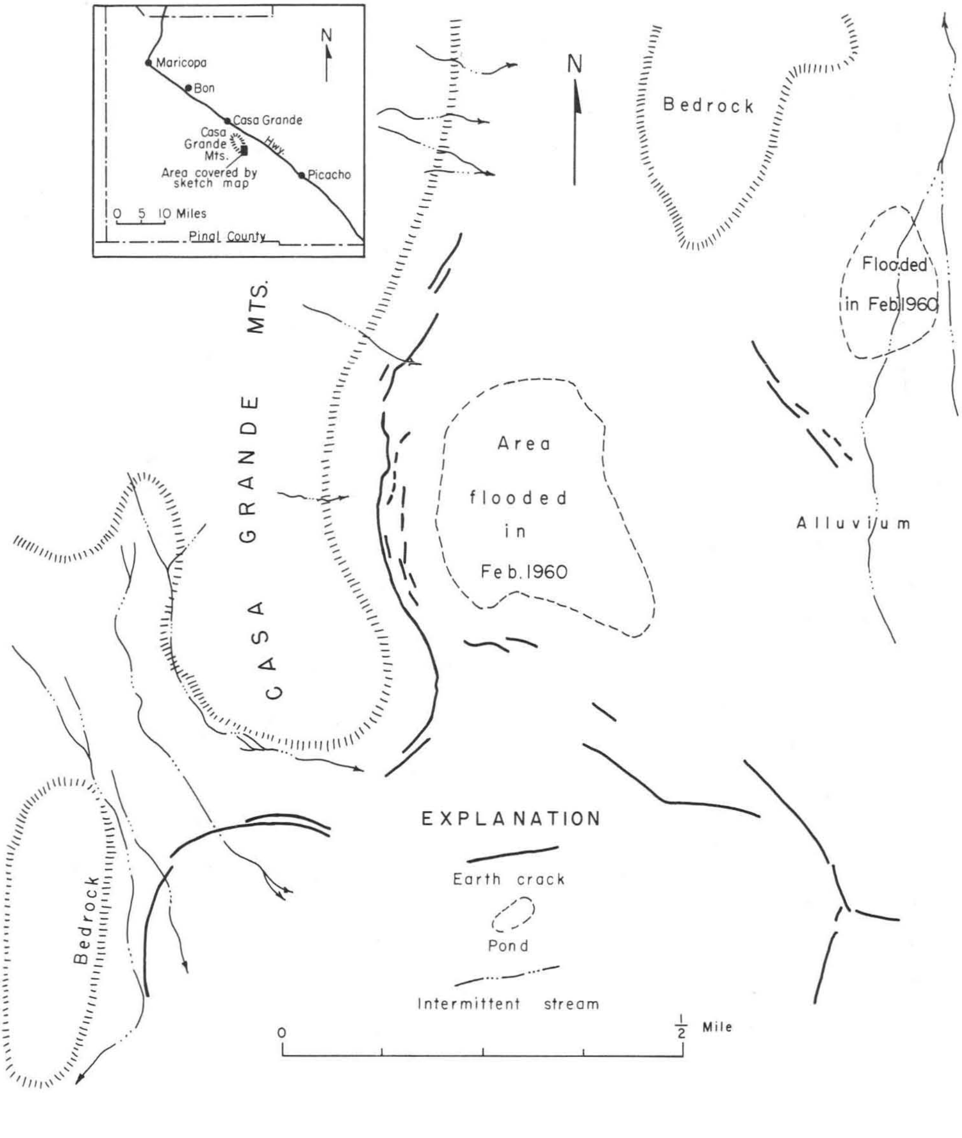

Figure 1. —Sketch map showing pattern of earth cracks at the southeast corner of the Casa Grande Mountains, February 1960.

the ditch for the first time to irrigate the new farmland. An estimated 300 gpm (gallons per minute) had been running through the ditch for about 3 hours, when suddenly the old crack opened up and diverted the entire flow of the ditch. This diversion continued for about 18 hours before the crack filled and began to overflow. In the meantime, several yards of dirt was pushed into the crack by a bulldozer without noticeably filling it. The crack was 6 inches wide when it first opened, but eventually widened to 14 inches by a process of spreading apart rather than by caving in of the walls. Brown stated that he was "unable to touch bottom of the crack with a 14-foot pole." Brown also described how subsidence in one of the adjacent fields had destroyed the grade of an irrigation ditch so that it had to be built up in order to get water through the sinking area.

SUBSIDENCE STUDIES IN CALIFORNIA

Some of the results of subsidence studies in California (Inter-Agency Committee on Land Subsidence in the San Joaquin Valley, 1958) will be reviewed here, because the work was done in an area geologically and geographically similar to southern Arizona. The investigation in California has led to recognition of two types of subsidence: (1) shallow subsidence of soil and near-surface deposits above the water table that occurs after initial application of irrigation water; and (2) deep subsidence that results from compaction of deposits below the water table, chiefly due to the withdrawal of ground water from confined deposits and the resulting decline in head. Earth cracks seem to be associated only with shallow subsidence and occur in deposits that compact appreciably on wetting. These deposits are restricted generally to the alluvial fans formed at the toe of small drainage areas with steep gradients. The deposits are composed of loose, loamy soils and sediments which have a large percentage of air-filled voids. Poor sorting and other features suggestive of mudflows also are characteristic of these deposits. Invariably the shallow subsidence occurs in the unsaturated deposits above the water table and is related closely to changes that take place in the deposits when wetting occurs. The rate and, undoubtedly the amount, of subsidence seem to be dependent on the quantity of water applied.

In California, compaction of the deposits above the water table occurred after the first application of irrigation water to the land surface, and, locally, has caused shallow subsidence of more than 10 feet. Extensive shrinkage and soil cracking commonly occurred along ditches or where water accumulated in ponds. Irregular, undulating surfaces developed in fields when irrigation was attempted. At one test plot, which was flooded in order to measure the rate of subsidence, the surface of the land settled more than 9 feet within about a year and concentric cracks encircled the plot to a radial distance of more than 150 feet. In one place a crack was reported to be 20 feet deep.

CONCLUSIONS

Wherever earth cracks have been described in southern Arizona, their sudden appearance has been associated closely with a heavy rainstorm or the sudden application of water to deposits that are normally dry. In California the earth cracks and shallow subsidence have occurred under similar conditions involving low-density, dry deposits soon after the initial application of irrigation water or ponding of rainwater.

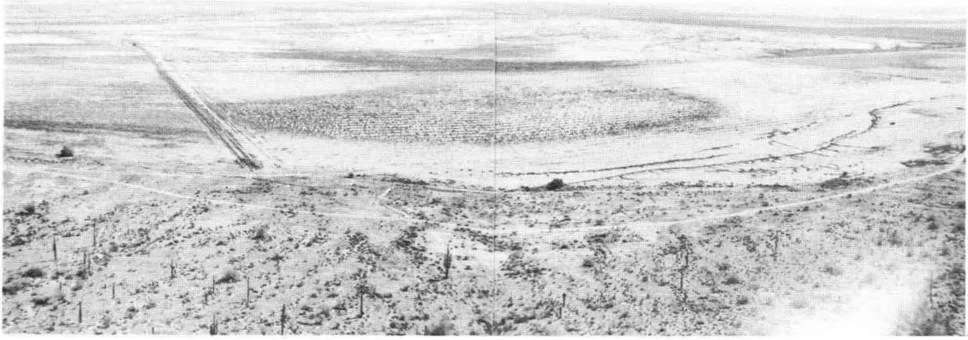

Figure 2. --View looking southeast from the Casa Grande Mountains across large pond in center of Figure 1, showing ponded rainwater in center of furrowed field and earth cracks bordering the pond.

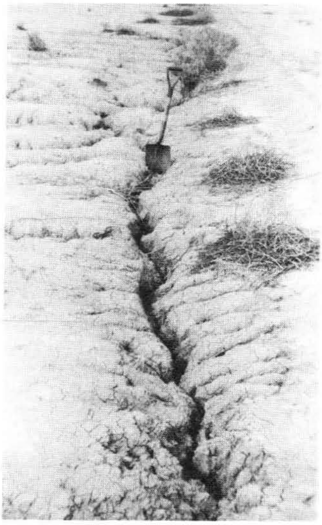

Figure 3. --Typical earth crack, showing some modification by erosion but little slumping of sides.

Figure 4. --Earth crack which has become wider and shallower by slumping of the sides.

Figure 5. --Sinklike depression along an earth crack.

Figure 6. --Sinklike depression where three earth cracks meet.

Figure 7. --Circular depressions which continue the trace of an earth crack.

In the area adjacent to the Casa Grande Mountains the trend of the cracks parallel to the edges of the ponds and the edge of the mountains supports the idea that the earth cracks are the result of shallow subsidence caused by the ponding of rainwater. Also, the ponds themselves probably occupy subsidence depressions.

No information is available regarding possible ponding of water in the Picacho and Bon areas, but the cracks formed during or following heavy rainstorms during which ponding may have occurred. Although the sudden application of water may not be the sole cause of the cracks at Picacho and Bon, the evidence suggests that it at least played a part in triggering their formation.

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