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Seismotectonic Investigation

for Stewart Mountain Dam Salt River Project, Arizona

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SEISMOTECTONIC INVESTIGATION
STEWART MOUNTAIN DAM
SALT RIVER PROJECT
ARIZONA

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Seismotectonic Report No. 86-2

Seismotectonic Section
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Engineering and Research Center
Denver, Colorado

August 1986

3.3.2 Sugarloaf Fault

The Sugarloaf fault is a slightly arcuate, northwest-southeast trending fault located near the junction of Mesquite Wash and Sycamore Creek. The fault was identified by Fugro (1981), which considered the fault in its MCE analysis for Stewart Mountain Dam because of the evidence for possible Quaternary activity along the structure.

Subsequent work by Menges and Pearthree (1983) and Pearthree and Scarborough (1984) identified evidence of possibly latest Pleistocene or even Holocene displacement on the fault. Because the Sugarloaf fault is only 15 km from Stewart Mountain Dam, and because the fault is the only structure within about 50 km of the dam with strong evidence of Quaternary activity, a detailed program of geologic mapping, scarp profiling, and soil profile analysis was conducted. The goal of these studies was to determine the total length of the fault zone, the age of most recent displacement, the length and amount of surface displacement associated with the most recent event, and to identify any evidence for recurrent Quaternary surface faulting.

A generalized geologic map of the Sugarloaf fault area is shown on plate 2. The rocks exposed in this area consist primarily of Precambrian granitic rocks. Overlying the Precambrian rocks are Tertiary basalt flows and Tertiary basin-fill deposits (arkosic pebbly conglomerate and sandstone). Relatively minor deposits of Quaternary alluvium are present along the major drainages.

The Tertiary basalt and basin-fill deposits dip to the southwest, west, and northwest (pl. 2). The distribution of these basin-fill deposits roughly delineates what is being called here the Mesquite basin. The basin has a total length of approximately 10 km based on the distribution of the basin-fill deposits and general physiographic expression. The basalt flows and basin-fill deposits lap onto the gently sloping surface of granitic basement on the east side of the Mesquite basin. In contrast, the west side of the basin is marked by a steep slope and a linear 4-km-long contact between the basin-fill deposits and the granitic rocks (pl. 2).

A fault is exposed in a roadcut on the west side of Highway 87 (pl. 2). At this location, Tertiary basin-fill deposits are faulted against basalt along a N 60° W striking shear zone that dips 70° to the northeast. The basalt appears to be a small flow remnant lying on the granitic basement. The basin-fill deposits dip about 30° to the southwest, into the fault.

Geologic mapping was conducted both north and south of the highway exposure to ascertain the relationship between the basin-fill deposits and the granite, as well as search for areas with evidence of late Quaternary faulting. The basin-fill deposits appear to be in fault contact with the granite for a total distance of about 4 km. The contact is generally marked by a subtle to abrupt break-in-slope that appears to represent a Quaternary fault scarp. Also, several scarps are present within the basin-fill material (including apparent grabens) in close proximity to the granite-basin-fill contact (pl. 2). It must be pointed out that the basin-fill deposits are moderately to highly dissected and some judgment was used in mapping what are identified as fault scarps.

A profile was made at one location where the granite-basin-fill contact is particularly well expressed by an abrupt, 8-m-high scarp. The general methods of Wallace (1977) and Bucknam and Anderson (1979) were used even though the scarp is in consolidated basin fill deposits and granitic bedrock.

The scarp has a maximum slope angle of over 21° (fig. 9). Both the granitic bedrock and the basin-fill deposits have pediment-like surfaces that slope 3 to 6° to the east. The pediment developed on the granite is about 100 to 150 m in length (perpendicular to the scarp) to where it joins the main mountain front which slopes at 20 to 30°. Assuming that the surfaces of the granitic pediment and the basin-fill deposits are time-equivalent, the vertical displacement represented by the scarp totals approximately 7 m. Because the scarp is in bedrock material, no estimate of the age of the scarp can be made. However, the scarp height strongly suggests recurrent displacement on the fault and the relative morphology of the feature suggests the scarp is mostly a Quaternary feature.

Just south of Sycamore Creek, a small alluvial fan is present adjacent to the bedrock scarp (Qaf, pl. 2). The alluvial fan is probably of early to mid-Holocene age, based on the characteristics of the soil developed on it. The soil has only minimal A-C development (Appendix C, soil profile SF 1). Trending at a right angle across the fan (N 30° W) is a 50-m-long, 0.9-m-high break-in-slope. This break-in-slope has been interpreted to be a fault scarp by Pearthree and Scarborough (1984), and we agree with their interpretation. The scarp is essentially parallel to and on strike with the bedrock-basin-fill contact and the scarp is at right angles to the local drainage. A nonfaulting origin for the scarp appears unlikely.

A scarp profile was made using the general methodology of Wallace (1977) and Bucknam and Anderson (1979). The profile indicates that the maximum scarp angle is 21° and the scarp height is 0.9 m, which corresponds to a maximum vertical displacement of 0.7 m (fig. 10). Although there are no well dated fault scarps in Arizona, the comparison of the Sugarloaf fault scarp data with that from Utah (Bucknam and Anderson, 1979; Hanks and others, 1984) and New Mexico (Machette and Colman, 1983), suggests that the scarp is quite young, in all probability Holocene in age, and represents a single event.

The one location at Sycamore Creek is the only place found where the Sugarloaf fault obviously displaces a Quaternary deposit. The low terrace deposits along Sycamore Creek must be younger than the faulted alluvial fan because no scarp is present in them (soil profile development is not sufficient to differentiate the ages of the fan and the terrace deposits). In other areas along the fault trace, alluvial and colluvial deposits (Qa; pl. 2) either do not cross the fault trace, or they appear to be extremely young (latest Holocene).

The length of fault rupture associated with the most recent surface faulting event on the Sugarloaf fault is not clear because of the lack of scarps in Quaternary deposits. However, an approximation for the length of surface

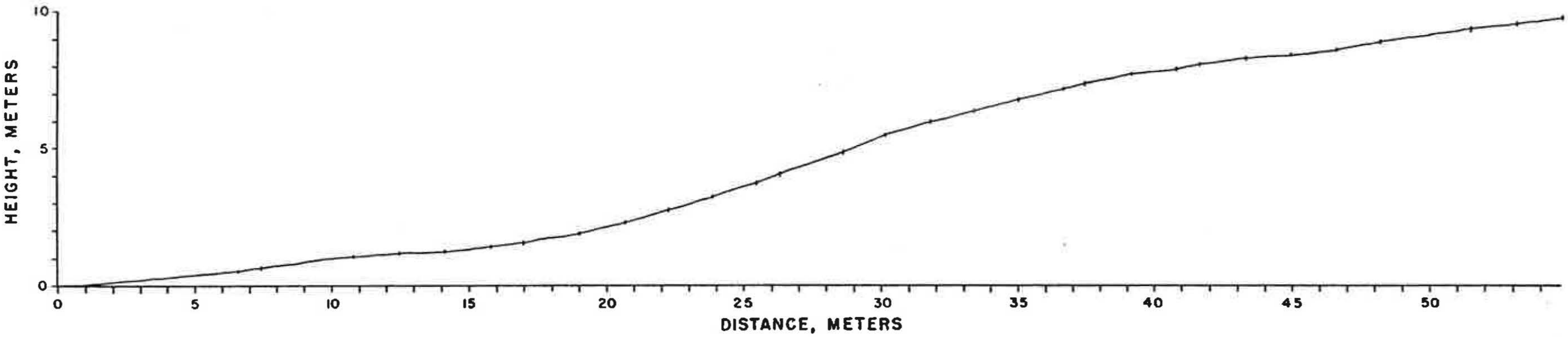

Figure 9. Scarp profile I, Sugarloaf fault
(for location, see plate 2)

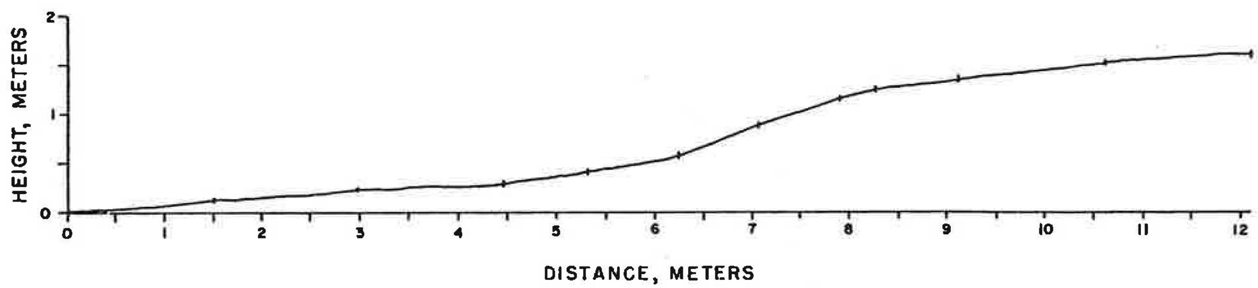

Figure 10. Scarp profile 2, Sugarloaf fault.
(for location, see plate 2)

rupture may be indicated by the length of the bedrock-basin fill contact, which is about 4 km. It appears that this northern end of the basin has been more active as evidenced by the presence of the basin-fill deposits, the basin width, and the fact that the basin-fill deposits are faulted. No evidence indicative of late Quaternary faulting was found south of about "hill 2340", a large granite hill east of the main valley margin (pl. 2). Also, a debris flow (Qdf; pl. 2) with what appears to be a very well developed soil (strong argillic horizon), crosses the valley margin southeast of "hill 2340". No obvious scarps were identified in this Quaternary deposit, suggesting a lack of surface displacement on this part of the Sugarloaf fault in at least 50 to 100 ka.

In summary, the Mesquite basin is a 10-km-long late Cenozoic basin, bounded on the west and southwest by the Sugarloaf fault. The fault displays evidence of recurrent Quaternary activity with the most recent surface faulting event occurring during the Holocene. This most recent event produced by about 0.7 m of apparent vertical displacement with a maximum surface rupture length of approximately 4 km.

3.4 Maximum Credible Earthquake

3.4.1 Sugarloaf Fault

Based upon the results of this and previous studies, the only potential seismic source considered significant to Stewart Mountain Dam is the Sugarloaf fault. Other possible Quaternary faults in the region such as those to the northwest near Horseshoe Reservoir (~ 50 km) and in the Verde Valley to the north (> 80 km) are either at a sufficiently great distance, or are not considered capable of generating earthquakes significantly larger than that postulated for the Sugarloaf fault. The area of The Rolls, 5 to 10 km north of Stewart Mountain Dam, is not considered a potential source because of the evidence for no mid to late Quaternary faulting.

Several factors can be analyzed to estimate the MCE for the Sugarloaf fault. These factors include the vertical displacement associated with the most recent faulting event (0.7 m), length of the scarp associated with this event (4 km), length of the fault bounded basin not associated with the most recent surface faulting event (6 km), and total length of fault bounded Mesquite basin (10 km).

Using the various equations of Slemmons (1982) and Bonilla and others (1984) that relate earthquake magnitude to rupture length and amount of displacement yield a wide range of magnitude estimates. Concentrating on two factors in particular (fault length not associated with the most recent surface faulting event and the amount of displacement associated with the most recent surface faulting event), suggests earthquakes of about M_s 6-1/2. The 6 km fault length suggests magnitudes in the M_s 6 range (Slemmons, 1982), whereas the amount of displacement (0.7 m) implies higher magnitudes, M_s 6.6 (Bonilla and others, 1984), and M_s 6.7 to 7.5 (Slemmons, 1982) depending on the data set used.

Because of the short fault length involved (6 km), we believe that the most likely earthquake event that could be associated with the Sugarloaf fault is an event in the M_s 6-1/2 to 6-3/4 range (upper range for events based on fault length; lower range for events based on displacement). Therefore, we believe that M_s 6-3/4 is appropriate for the MCE for the Sugarloaf fault. The closest approach to Stewart Mountain Dam for the epicenter of this event is 15 km, at a focal depth of approximately 10 km.

3.4.2 Random Earthquake

Fugro (1981) included in their analysis for Stewart Mountain Dam a so-called "random" earthquake. They considered this to be a M 5.5 event with a hypocentral distance as close as 5 km to the damsite. Fugro did not address the recurrence or likelihood of such an earthquake event. The random earthquake was included in their MCE analysis to account for the observation (Fugro, 1981; Arabasz and Smith, 1981; sec. 3.2) that moderate magnitude earthquakes have occurred in Arizona and elsewhere in the western United States with no apparent correlation to Quaternary faults. Because these events do not produce surface faulting, the maximum magnitude for such events is usually considered to be less than the magnitude of earthquakes associated with surface faulting in the Basin and Range and adjacent provinces (sec. 3.5).

In an attempt to assess in more detail the potential significance of the random earthquake for Stewart Mountain Dam, we employed a probabilistic treatment of the historic seismicity and the recurrence estimates obtained above (sec. 3.2). As previously noted, the low rates of historic activity in the region make recurrence estimates highly uncertain. Thus, the confidence in this analysis must be considered low. In fact, in this study the probabilistic assessment of the random earthquake is only being considered because of the minimal agreement between recurrence rates estimated from geologic data and seismicity data. It is stressed here that geology and seismicity based recurrence rates are compared here only to provide guidelines to review decisions based on judgment.

Estimates were made of the size of area within which no earthquake will occur in one year for a given magnitude range at some specified level of probability by assuming that earthquakes occur over time as a Poisson process (see Gilbert and others, 1983, Appendix J). These areas were interpreted in terms of epicentral distances calculated for whole magnitude intervals, and are presented in Table 4 for annual probabilities varying from 0.01 to 0.00002.