Surficial and Environmental Geology of the Sierra Vista Area, Cochise County, Arizona

by

Karen A. Demsey and Philip A. Pearthree

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INTRODUCTION

This map depicts the surficial geology of the eastern piedmont of the Huachuca Mountains in southeastern Arizona, from Sierra Vista south to the U.S. - Mexico border. Areas within the Ft. Huachuca Military Reservation were not mapped. The map data and interpretations presented here provide a basis for interpreting the Quaternary geologic history of the piedmont. The map and report also provide substantial information on potential geologic hazards in this area, including the general character and distribution of flood hazards, debris flows, soil conditions, and seismic hazard. This information may be used as a general guide in assessing possible geologic impacts on existing and future development in the Sierra Vista area.

Mapping consisted of description and delineation of surficial geologic units deposited by streams or washes on the eastern Huachuca piedmont, the gently sloping plain extending from the Huachuca Mountains to the San Pedro River. Alluvial deposits are differentiated by age based on their relative topographic positions, surface characteristics, dissection, and soil-profile development. Primary mapping was done using aerial photographs provided by the U.S. Forest Service and Cochise County, with extensive field checking. Unpublished Soil Conservation Service mapping of this area (provided by Lloyd Law, Douglas Field Office, SCS) was used to help characterize soil-profile development associated with the map units. Map units range from areas of very recent (active) deposition to very old relict alluvial-fan deposits that may be more than 1,000,000 years old.

This report also includes descriptions of various geologic hazards and surficial geologic conditions in the Sierra Vista area. The surficial geologic map itself provides a substantial amount of information about the areal distribution of various geologic hazards in this area, because some hazards correlate with surfaces of different ages. For example, significant flooding during the past few thousand areas has occurred in areas covered by young deposits; areas covered by older deposits have not been subject to flooding for a very long time. Soil characteristics that may impact human structures, including clay content, carbonate accumulation, and potential for compaction, vary with surface age. In addition, we delineate areas that may be subject to debris flows (sediment-charged slurries that can be quite destructive) based on historical debris-flow activity and the existence of physical evidence of past debris flows. Finally, we assess the earthquake hazards related to a fault zone in this area that has been active during the late Quaternary.

GEOLOGIC AND GEOGRAPHIC SETTING

The Sierra Vista area is built on the eastern piedmont of the Huachuca Mountains. The Huachuca Mountains are an approximately 30 km (20 mile) long range that trends northwest from the Arizona-Mexico border in southeastern Arizona. They form part of the western margin of the

San Pedro Valley. The mountain range is composed primarily of Precambrian granite, Paleozoic sedimentary rocks, Mesozoic volcanic rocks, and Mesozoic sedimentary rocks (Hayes and Raup, 1968). The Huachuca Mountains vary in altitude from about 1550 m (5000 ft) to 3000 m (9500 ft). Streams draining the eastern side of the range have deposited alluvial fans and terraces on the piedmont extending from the mountain front to the San Pedro River, which is the axial drainage and local base level of the valley. This piedmont ranges in altitude from about 1250 m (4000 ft) along the San Pedro River to 1550 m (5000 ft) at the mountain front.

The Sierra Vista area lies within the Mexican Highland subprovince of the southern Basin and Range province. Widespread extensional deformation, including normal faulting on the range-bounding faults along which the Huachuca Mountains were uplifted, ceased or greatly diminished in this region by about 5 Ma (million years ago; Menges and McFadden, 1981; Morrison, 1985; Menges and Pearthree, 1989). After the end of major tectonism, the San Pedro basin continued be filled by sediment shed from the bordering mountain ranges. The primary post-tectonic basin-fill sediments in this area are the Pliocene-early Pleistocene St. David Formation. These sediments have been interpreted by Lindsay and others (1990) to record: (1) a period of fine-grained deposition in an arid, closed-basin setting in the early Pliocene (~5.5 to 3.4 Ma); (2) integration of the upper San Pedro drainage system and a transition to a less arid regime of perennial streams and marshes in the middle Pliocene (3.4 to 3.0 Ma); (3) diminished sedimentation and landscape stability in the latest Pliocene (~2 Ma); (4) the beginning of widespread progradation of coarse-grained alluvial fans in the early Pleistocene (~1.6 Ma); and (5) basin-wide incision initiated by downcutting of the San Pedro River in the middle Pleistocene (0.6 Ma).

The Huachuca Mountains have continued to shed alluvium onto the adjacent eastern piedmont during the Quaternary. Major depositional pulses may have probably been triggered by regional climatic changes that affected critical drainage basin factors such as vegetation density, in turn affecting hillslope stability (Bull, 1979). Suites of deposits similar to those of this study have been described for other piedmonts in southeastern Arizona (e.g., the Santa Rita Mountains piedmont; Pearthree and Calvo, 1987). The Huachuca piedmont is currently characterized by discontinuous, ephemeral washes and relatively small areas of active alluvial fans. Most of the piedmont is covered by alluvium that was deposited 10's to 100's of thousands of years ago.

CHARACTERISTICS OF SURFICIAL GEOLOGIC UNITS

Alluvial surfaces may become isolated from active deposition due to lateral shifts in loci of deposition or to vertical incision by active channels. The age of an alluvial deposit is considered to be the age of abandonment of its upper depositional surface. The criteria used to differentiate and map alluvial surfaces also serve as the basis for estimating the time since the end of significant deposition.

Relative topographic height, surface morphology, drainage network characteristics, and soil development are geomorphic indicators of surface ages. Active depositional surfaces are generally characterized by unweathered deposits and minimal incision or entrenchment by active channels. Surfaces that become isolated from deposition are usually entrenched to some degree and (on piedmonts characterized by base-level lowering) typically become progressively more deeply entrenched with time, as deposition shifts to lower areas. The entrenched deposits commonly become more dissected as tributary drainage networks consisting of gullies and channels heading on the fan become established.

Soil profiles develop gradually once active flow and deposition has ceased. Soils in this environment develop by a combination of input of material (clay, silt, and calcium carbonate) from atmospheric sources and in situ weathering of mineral constituents of the soil. Soils near the mountains are dominated by zones of clay accumulation and reddening (argillic horizons). Calcium-carbonate accumulations associated with upper piedmont and canyon bottom soils are minimal to modest; evidently, these areas receive sufficient rainfall to leach most calcium carbonate through the soil profile. With increasing distance from the mountains, rainfall is less and older soil profiles exhibit pronounced zones of carbonate accumulation (caliche).

The Quaternary piedmont units are divided into broad age categories of "Young" (Y), "Middle" (M2 and M1), and "Old" (O). Subdivisions of these age categories were mapped where feasible (see map explanation). No independent data for evaluating the numerical ages of these map units were obtained in this study. Most of the estimates of the ages of the deposits of the Sierra Vista area are based on comparisons of soil-profile development in these units to soils associated with well-dated units in an area of similar physical and climatic setting in southern New Mexico (the piedmont-slope soil chronosequence of the Desert Project; Gile and others, 1981; Machette, 1985). Ages for the youngest (Y1 and M2b) and oldest units (O, Ogr, and TQbf) of this area are based in part on correlations with depositional units described in previous studies in the San Pedro Valley (Haynes, 1987; Waters and Haynes, 1987; Lindsay and others, 1990).

QUATERNARY ALLUVIAL HISTORY

The distribution and characteristics of the various alluvial deposits record the Quaternary history of deposition and erosion on the eastern Huachuca piedmont. The apparent pattern over the course of the Quaternary is one of decreasing caliber of bed load and transport capacity of streams, as well as progressive channel incision and dissection of the piedmont as the result of long-term downcutting by the San Pedro River.

The early Pleistocene was a period of widespread progradation of coarse-grained alluvial fans in the San Pedro basin. Material deposited during this period forms much of the upper St.

David Formation in the Benson - St. David area (Lindsay and others, 1990). The coarse gravelly fan remnants of unit O in the upper portions of the eastern Huachuca piedmont may well correspond to this early Pleistocene period of alluvial fan progradation. Inferred early Pleistocene fan remnants with similar morphologic and sedimentologic characteristics exist in basins throughout southeastern Arizona (e.g., Menges and McFadden, 1981; Morrison, 1985; Pearthree and Calvo, 1987). These units may have been deposited as a result of the onset of regional climatic conditions or fluctuations favoring removal of coarse sediment from mountains and deposition of this sediment on adjacent piedmonts. The highest preserved levels of unit Ogr may represent the early Pleistocene period of aggradation in the middle and lower piedmont. The occurrence of these relatively coarse gravels on distal portions of the piedmont suggests deposition in a similar environment dominated by high capacity of sediment transport in braided channels. If our correlation of Ogr and O is correct, then dissection began in the upper San Pedro Valley during the early Pleistocene after deposition of Ogr, while sediment continued to accumulate farther north in the San Pedro basin near Benson and St. David.

Since the early Pleistocene, the upper and lower parts of the piedmont have evolved somewhat differently. The upper piedmont has experienced several major pulses of aggradation that resulted in the deposition of extensive alluvial fans. The evolution of the lower piedmont has been dominated by entrenchment of channels and landscape dissection due to base-level lowering of the San Pedro River. Coarse middle Pleistocene (M1) alluvial fan remnants are extensive in the upper and middle piedmont, indicating a major period of aggradation. Like Unit O gravels, M1 sediments were probably deposited in an environment of alluvial fans and/or braided stream channels with greater transport capacities than currently active channels. Middle Pleistocene deposits are inset into basin-fill deposits (QTbf) and early to middle Pleistocene fan surfaces (Ogr) in the lower piedmont. M1 surfaces in the lower piedmont generally are of limited extent, indicating that the this area was substantially dissected by the middle Pleistocene. Further evidence of progressive incision by the San Pedro River is the occurrence of middle Pleistocene terrace gravels (unit M1t) along the river, which record former positions of the San Pedro channel as much as about 30 m above the modern channel.

An extended period of net erosion evidently followed the deposition of M1 fans. The next major period of net aggradation is represented by the late to latest Pleistocene alluvial-fan and valley-fill deposits of unit M2 (including units M2a and M2b). These units form widespread gravelly fans over much of the upper piedmont near the mountain front, and finer grained deposits covering much of the middle portion of the piedmont. M2 alluvial fans represent significant depositional events in the late Pleistocene. The finer grain sizes of M2 deposits compared with M1 deposits suggests that fluvial systems were being supplied with finer sediment from the hillsides or were less able to transport coarse bedload away from the mountains. M2 deposits in the lower piedmont typically are inset terrace or valley-fill deposits. These deposits evidently represented periods of aggradation superimposed on the long-term downcutting of the lower piedmont.

The extent of Holocene channel, terrace, and alluvial-fan deposits (units Y, Y1, and Y2) on the piedmont is relatively limited. They are generally restricted to narrow belts along active channels and small alluvial fans emanating from small drainage basins at the base of the mountains. A few larger areas of young deposition exist in the middle and upper piedmont; these areas have experienced distributary flow and alluvial-fan deposition during the Holocene. Detailed studies of the stratigraphy of Y1 deposits in Curry Draw reveal several episodes of aggradation and arroyo cutting (Waters and Haynes, 1987; Lindsay and others, 1990). The early Holocene (11 to 8 ka) was characterized by aggradation. A major arroyo developed after 8 ka, which was subsequently filled between 6.5 and 4.3 ka. One or two more episodes of arroyo development and filling occurred after 4.3 ka. Filling of the youngest prehistoric arroyo began about 500 years ago. The modern arroyo that exists in Curry Draw began to form early in this century. Headcuts associated with the modern arroyo are actively migrating upstream at this time. This latest episode of erosion and arroyo formation may have been enhanced or accelerated by floodplain misuse during the late 19th and early 20th centuries (Waters and Haynes, 1987).

GEOLOGIC HAZARDS

A variety of potential geologic hazards exist in the Sierra Vista area. The primary geologic hazards that are likely to affect this area are flooding and soil problems; debris flows and rockfalls present localized hazards in and near the Huachuca Mountains. In addition, a fault zone on the upper piedmont of the Huachuca Mountains has been active at least once during the late Quaternary. The general character of these hazards and the areas that may be affected by them and considered below.

Flood Hazards

Surficial geologic mapping provides important information about the extent of flood-prone areas on this and other piedmonts. Floods leave behind physical evidence of their occurrence in the form of deposits. Therefore, the extent of young deposits on piedmonts is a good indicator of areas that have been flooded in the past few thousand years. Alluvial surfaces that have recently experienced flood flow or deposition are generally likely to experience future flooding and deposition. Alluvial surfaces that have been isolated from significant deposition for a long time are generally unlikely to experience flooding in the forseeable future.

On the Huachuca piedmont, young alluvial surfaces that may be flood prone include active channels, adjacent low terraces, and active alluvial fans (map units Y2, Y1, and Y). Active channels and low terraces included in unit Y2 have the highest degree of flood hazard. These very young surfaces are flooded frequently (channels) to occasionally (terraces). Y1 surfaces include slightly higher terraces and young alluvial fans. These areas may be subject to occasional to rare flooding. Because they are topographically or spatially separated from areas of most frequent flow, flooding probably occurs only during moderately large to very large flood events. The young map units also include historical floodplains that have been isolated by the development of several-meter-deep arroyos. In these situations, which are common on the lower and middle piedmont, very young alluvial surfaces flanking the arroyos probably are no longer subject to flood inundation. Alluvial surfaces in the "Middle" and "Old" age categories (M2b, M2a, M2, M1, M1t, Ogr, O, and TQbf) have been removed from fluvial activity for 10,000 years or more. These surfaces generally do not receive significant flow or deposition from active channels. "Middle" surfaces that are immediately adjacent to young surfaces and which are not much or any higher than the young surfaces may be flood prone, however. Situations such as this typically are found in the middle piedmont, where some M2 surfaces are adjacent to and nearly at the same topographic level as young alluvial fans (extensive Y units).

The areal extent of young alluvial surfaces on the Huachuca piedmont is rather limited, implying that the extent of flood-prone areas on the piedmont is limited as well. Geologic evidence indicates that most flooding is restricted to well-defined channels and low areas immediately adjacent to them. A few extensive areas of young deposition on the middle and upper piedmont may be subject to alluvial-fan flooding, which is characterized by both channelized flow and sheet flooding; the potential exists for shifts in channel positions during floods in these areas.

Another important flood-related hazard in the Sierra Vista area is lateral bank erosion during large flow events. Virtually all of the piedmont stream banks as well as the banks of the San Pedro River are composed of erodible alluvium or basin-fill deposits. Substantial bank erosion occurred historically along the San Pedro River after arroyo incision began in the late 1800's (Hereford, 1993). Bank erosion is also likely to be a significant problem along any of the steep-sided arroyos that have developed along piedmont drainages. Until these arroyos widen substantially, bank collapse and lateral erosion may proceed at fairly rapid rates.

The potential for bank erosion along channels may be assessed based the size of the drainage and the nature of the bank materials. Larger drainages have larger and more frequent flow events, and thus have more potential to erode their banks than do smaller drainages. The character of the bank materials is also of critical importance. Young deposits in the map area typically have little cohesion, and commonly are finer-grained, than older deposits. Historically, the arroyo development and bank widening along the San Pedro River has occurred within Holocene deposits (inferred from Hereford, 1993; this map). Virtually all of the Holocene arroyos that have developed in Curry Draw have been eroded into Holocene or late Pleistocene deposits (Haynes, 1987). The potential for bank erosion generally is much higher for young deposits (units Y1, Y, and M2) than for older units.

Debris Flows

Debris flows are another flood-related hazard in the canyons of the Huachuca Mountains and some upper piedmont areas. Debris flows are slurries of poorly sorted rock and soil mixed with water. They have much greater strength and viscosity than water floods and are responsible for substantial erosion and deposition in the mountains of southern Arizona. Typically, they begin as mass movements (landslides) on very steep hillsides and then move some distance down channel systems. Debris flows may travel at fairly high velocities and are capable of conveying much larger particles (boulders) than water floods; thus, they may cause significant damage to structures in their path.

The existence of steep mountain slopes, the potential for forest fires, and the intense rainfall associated with summer thunderstorms in this region combine to make debris flows a serious hazard in and near the Huachuca Mountains. Numerous debris flows occurred in the southern Huachuca Mountains during the summer rainy season in 1988, following a large, human-caused forest fire in June, 1988. Most of the debris flows occurred in steep, uninhabitated mountain drainages, but one of the debris flows damaged a cluster of houses on a young alluvial fan near Ash Canyon. The summer thunderstorm season apparently was not especially intense, based on weather data from reporting stations around the Huachuca Mountains. Debris flows also occurred following another major forest in the central Huachuca Mountains in 1977 (summarized from Wohl and Pearthree, 1990; 1991). The recent historical record implies that debris flow occurrence is linked to fires in this area, and that debris flows should be anticipated in steep drainages that have experienced recent fires. Older debris-flow deposits are common where steep tributary drainages enter the larger mountain canyons of the Huachuca Mountains, indicating that they are an important process in conveying sediment from hillslopes down to the major drainages.

Historical debris-flow activity and abundant evidence of older debris flows indicate that debris flows are an important hazard in the steep drainage basins of the Huachuca Mountains. The potential for debris flows evidently increases significantly shortly after forest fires. The areas that might be affected by debris flows are shown by the light stipple pattern on the map that accompanies this report. Debris-flow occurrence is restricted to mountain areas and a few young alluvial fans in the uppermost piedmont. Debris-flow hazards can be minimized by avoiding building in channels and near the mouths of steep mountain drainages.

Problem Soils

Several types of soil/substrate problems may be encountered in the Sierra Vista area. Soil collapse or compaction upon wetting or loading (hydrocompaction) may be an important geologic hazard in portions of the mapped area. Hydrocompaction is a reduction in soil volume that occurs when susceptible deposits are wetted for the first time after burial. Deposits that are susceptible to hydrocompaction are typically relatively fine-grained, young sediments that are deposited in a moisture-deficient environment. Deposits on the Huachuca piedmont that are candidates for hydrocompaction are the fine-grained alluvial fans of units Y1 and Y2 on the middle and lower piedmont. Silty sands of the late Holocene San Pedro River terrace in the northeastern part of the mapped area may also have the potential to compact upon loading.

Clay-rich soils associated with middle and early Pleistocene deposits may have some potential for shrinking and swelling during dry and wet periods, respectively. Particularly in the middle and upper piedmont, units M1 and O have very clay-rich soil horizons (argillic horizons) very near the surface. Clay mineralogy was not assessed in this study, but if montmorillonitic clay is an important constituent, then shrinking and swelling may be associated with these units. In addition, very clayey soils result in low near-surface infiltration capacities. Beneath the clay-rich soil horizons, infiltration capacities typically are much higher.

Soil horizons indurated with calcium carbonate (petrocalcic horizons or caliche) may affect ease-of-excavation and near-surface infiltration rates in some portions of the Sierra Vista area. Significant calcium-carbonate accumulations associated with the older surficial geologic units (M1 and Ogr) on the middle and lower piedmont probably result in low infiltration rates. Our reconnaissance field investigations and the unpublished soil survey information for this area, however, do not indicate the presence of extensive, strongly cemented petrocalcic horizons associated with any piedmont units.

Quaternary Faulting and Seismic Hazard

A series of north-trending fault scarps cutting alluvial deposits on the Huachuca piedmont are evidence that one or more large earthquakes occurred during the Quaternary on the system of faults bounding the east side of the Huachuca Mountains (the Huachuca fault zone). The fault scarps form a discontinuous band from the U.S.-Mexico border north to Arizona Highway 90, a distance of about 25 km (15 miles). Alluvial surfaces on the piedmont have been vertically displaced vertically less than 2 m across these fault scarps, with the basinward (east) side being downdropped relative to the mountains. Basic surficial geologic mapping provides substantial information about the length of Quaternary fault rupture(s), the history of fault movement, and the size of paleoearthquakes on the Huachuca fault zone. Total displacement of alluvial deposits and morphology of the fault scarps provide further evidence of timing and recurrence of fault ruptures, and are thus useful in evaluating the potential for future large earthquakes.

The timing of movement on the Huachuca fault zone during the Quaternary can be evaluated based on surface age and displacement relationships on the piedmont. Ages of faulted deposits and unfaulted deposits that cross the rupture zone bracket the age of youngest fault rupture. Surficial geologic mapping indicates that middle Pleistocene (M1, 125 to 700 ka) and early Pleistocene (Ogr and O, 500 to 2 Ma) deposits are faulted; M2a and younger units (< 125 ka) are not faulted, and thus were deposited after the most recent faulting event. The uncertainties in the surface-age estimates limit the precision of the estimate of the age of youngest fault movement, but a late middle Pleistocene age (~100 to 200 ka) for the youngest fault movement is consistent with surface-age constraints. There is no clear evidence of more than one rupture during this late middle Pleistocene interval, but neither can the possibility of several smaller ruptures be ruled out without excavating trenches across the fault zone.

At least one paleoearthquake evidently occurred on the Huachuca fault zone during the early Quaternary as well. Along the main strand of late Quaternary fault scarps discussed above, early to middle Pleistocene alluvial surfaces (unit Ogr) are not clearly displaced more than middle Pleistocene surfaces (unit M1), which suggests that all Quaternary fault movement has occurred since the middle Pleistocene. However, early Pleistocene surfaces are faulted and middle Pleistocene surfaces are <u>not</u> faulted along two subsidiary fault strands in the southern portion of the map area (downslope from Ash Canyon and in the Montezuma Canyon area). These latter relationships imply that fault movement occurred in the early Pleistocene along portions of the fault zone, although the extent and character of surface rupture may have been significantly different from the youngest surface rupture.

Analysis of fault-scarp morphology provides further evidence regarding the timing of youngest fault movement. Fault scarps are initially very steep after surface rupturing earthquakes, but fairly quickly degrade to the angle of repose (about 35° for coarse alluvial gravels). After they reach the angle of repose, scarps gradually become more rounded and the maximum slope of the scarp decreases. Because of this gradual degradation process, the current morphology of a fault scarp can be used to estimate the time that has elapsed since it formed (from Wallace, 1977). Several quantitative methods have been proposed that relate scarp form, scarp size, and scarp age (for example, Bucknam and Anderson, 1979; Nash, 1984). We surveyed and analysed 11 topographic profiles of fault scarps from various locations along the fault zone. Scarp heights range from about 1 to 3 m, with maximum slopes of 7° or less. It is clear from the degraded morphology of these scarps that they are quite old. Based on comparison with other scarps studied in the Basin and Range province, an age estimate of about 100 ka for the Huachuca fault scarps is reasonable (see figure 1).

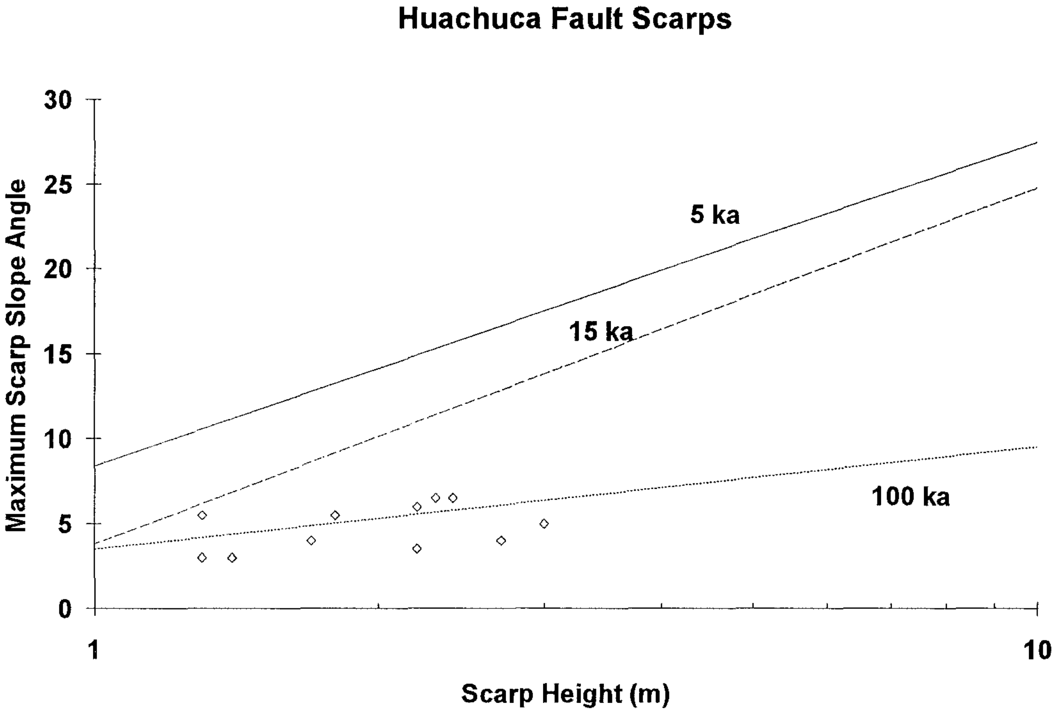

Figure 1. Maximum scarp slope vs. scarp height relationships for the Huachuca fault scarps (shown as diamonds). Lines on the graph are linear regressions derived from morphologic data from several dated scarps in the Basin and Range province. The Huachuca fault scarps are morphologically older than scarps dated at 5 ka from New Mexico (Machette and others, 1986) and 15 ka from central Utah (Bucknam and Anderson, 1979). The Huachuca fault scarps are morphologically similar to fault scarps studied along the Santa Rita fault zone south of Tucson, Arizona, which are estimated to be about 60 to 100 ka (Pearthree and Calvo, 1987).

The length of surface rupture along the Huachuca fault zone and the amount of surface displacement across the fault zone can be used to estimate the size of the paleoearthquake that likely generated the fault scarps. We estimated the earthquake magnitude associated with rupture on the Huachuca fault zone assuming that the fault scarps along the main strand of the fault zone formed during one late Quaternary faulting event. Using recently developed relationships between (1) surface rupture length and magnitude; (2) maximum surface displacement and magnitude; and (3) average surface displacement and magnitude (Wells and Coppersmith, 1993?), the estimated paleoearthquake magnitude ranges from 6.7 to 6.8 (see table 1). Using seismic moment - magnitude relationships developed by Hanks and Kanamori (1979) and varying the parameters of average displacement and fault-plane width, we obtained magnitude estimates ranging from 6.6 to 7.0 (see table 2).

Parameter	**Equation**	**Moment Magnitude**
surface rupture length	5.09 + 1.15*log **25** (km)	6.7
maximum surface displacement	6.63 + 0.64*log **2** (m)	6.8
average surface displacement	6.78 + 0.65*log **1.2** (m)	6.8

Table 1. Moment magnitude estimates for late Quaternary paleoearthquake on the Huachuca fault zone using empirical regression equations based on historical earthquakes. Estimates are obtained using surface-rupture parameters (in **bold**) and regression equations developed for historical normal faulting events by Wells and Coppersmith (1993).

Rupture Length (km)	**Average Displacement (m)**	**Depth of Faulting (km)**	**Fault Plane Dip**	**Seismic Moment (dyne cm)**	**Moment Magnitude**
25	1	10	60	9.53E+25	6.6
25	2	15	45	3.50E+26	7.0

Table 2. Magnitude estimates for late Quaternary paleoearthquake on the Huachuca fault zone based on moment - magnitude relationships (Hanks and Kanamori, 1979). Estimates are obtained using various reasonable fault-plane and displacement characteristics.

The Huachuca fault zone evidently has generated large earthquakes very infrequently during the Quaternary. Evidence for a large (M~6.6 to 7) late Quaternary earthquake is fairly clear, and more subtle evidence suggests that at least one large earthquake occurred in this area during the early Quaternary. Given the length of time since the latest faulting event and the small amount of total displacement during the Quaternary, it is clear that recurrence intervals between large earthquakes on the Huachuca fault zone are very long. This fault behavior is consistent with other Quaternary faults that have been studied in southeastern Arizona and adjacent New Mexico and Sonora, Mexico (Machette and others, 1986; Pearthree, 1986; Pearthree and Calvo, 1987; Bull and Pearthree, 1988; Menges and Pearthree, 1989). This region is subject to large earthquakes, but they occur infrequently.

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