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QUATERNARY FAULT SYSTEM IN THE TULAROSA AND HUECO BASINS, SOUTHERN NEW MEXICO AND WEST TEXAS

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INTRODUCTION

Many geologists in West Texas and New Mexico are aware of the nearly continuous fault scarps of Quaternary age that border the eastern edge of the Sierra Juarez–Franklin–Organ–San Andres Uplift and western Tularosa and Hueco Basins. Less well-known is the system of comparatively minor faults breaking the surface of the two basins (figs. 1 and 2). These minor faults, which block out a somewhat jumbled array of horsts, grabens and tilted blocks in basin-fill deposits, constitute a swath about 5 to 25 km wide sub-parallel to the boundary fault of the adjacent uplifts. A major conclusion of this paper is that these faults formed when basin fill warped down in response to localized extension—a pull-apart—beneath the western side of the basins. Although many of the minor faults may be comparatively shallow features, some are not; all have potential for growth as long as movement on the range-boundary fault of the Franklin–Organ–San Andres Uplift continues.

Some of the scarps were recognized years ago. Sayre and Livingston (1945) identified several scarps and depressions in northeastern El Paso and along the Carlsbad highway (U.S. 62-180) as faults, and showed them on their map. Knowles and Kennedy (1958) subsequently acknowledged the presence of scarps in the Hueco Bolson, agreeing with Sayre and Livingston that they were a product of faulting. Only recently has the extent of the fault swarm...
become apparent (Woodward and others, 1978). The present
study has revealed a still more remarkable array of fault blocks
that provide considerable topographic variety to the floors of the
western Tularosa and Hueco Basins—bolson floors usually thought
of as “flat.”

**DESCRIPTION OF THE FAULTS**

In general, the floors of the Tularosa and Hueco Basins slope
westward, about 2.3 and 3.2 m/km respectively, to closed depres-
sions near the base of the Franklin and Organ Mountains. Modifying
this slope, however, are the fault scarps mapped on Figure 2,
which extend from highway 70, south of Lake Lucero, southward
to the Rio Grande valley below El Paso. Although the scarps prob-
ably continue farther in both directions, they are masked by depo-
sitional and erosional effects of Lake Lucero and the Rio Grande.
Most of the fault system parallels the frontal fault zone of the
Franklin–Organ Uplift with remarkable fidelity. Where the frontal
fault is embayed or bulges outward, the basin faults duplicate the
trend; this seems to indicate a genetic linkage of the two fault
systems. Only 3 to 5 km wide in the western Tularosa Basin, the
system widens southward to embrace the entire width of the
Hueco Bolson east of El Paso. Many pairs of faults outline narrow
horsts and grabens, especially in the Tularosa Basin; these are
expressed on the ground as linear hills or depressions bounded by
relatively gentle slopes mantled with sand. Most scarps in the
Hueco Basin east of El Paso face east, and these as well as other
east-facing scarps in the system are antithetic to the general
westward slope of the basin floors. Longest faults in the system
can be traced on topographic maps or aerial photos for at least 30
km, and less certainly for nearly 40 km. However, many appear to
be short, 5 to 7 km or less. All are curving or somewhat angular in
trend, and a few divide into multiple faults along their length.
There is little continuity in structural relief along strike; horsts may
pass into grabens, or west-facing scarps may be replaced with east-
facing ones. Heights of scarps range from 3 to 7 m to as much as
28 m. Scarp-slope angles are generally less than 15 degrees,
mostly because the material composing them is relatively uncon-
solidated sand, silt, clay and minor gravel of the Camp Rice Forma-
tion. Caliche, which represents soil on the bolson floor, caps most
of the fault blocks but provides only modest resistance to erosion.
Consequently, the faults are not striking features of the landscape;
instead they form low, rounded scarps or rounded, elongated hills
or shallow depressions marked by alluvial flats or small playas.
Some scarps also have distinct linear vegetation breaks across
them, presumably due to mounding of groundwater behind the
faults (C. Henry, personal communication, 1980). These are best
seen on aerial photos, but the fault blocks themselves are most
clearly revealed on topographic maps such as Newman, Newman
SW, or Fort Bliss SE 7½ minute quadrangles.

**AGE OF THE FAULTS**

Regrettably, the time of latest movement on any faults in the
system within the two basins has not been established with any
precision. About all that can be said is that the faults are younger
than about 0.5 m.y., based on offset of both uppermost beds of
the Camp Rice Formation and the soil developed on it. The faulted
deposits contain land mammals as well as local volcanic ash
layers, the former identified by Strain (1966; 1969a,b) as middle
Pleistocene in age, the latter as about 0.7 m.y. old by Hawley
(1978). The Camp Rice is no younger than the 0.2 to 0.25 m.y. old
dates obtained on basalt flows above the Camp Rice Formation
west of the Mesilla Valley (Hoffer, 1971; Hawley and others, 1976).

More recent unpublished dates from the basalts indicate the
Camp Rice Formation may be no younger than 0.5 m.y.

Due to the efforts of L. Gile and M. Machette, the time of most
recent movement on the Franklin–Organ frontal fault is well
established. Their studies near White Sands Missile Range head-
quarters indicate movement within the last 4,000 to 5,000 years.
By comparing soil development on the youngest faulted fan and
on the oldest unfaulted fan, Gile arrived at the mid–Holocene date
corroborated Gile’s conclusion by investigating scarp-slope angle
and scarp height relationships (after Bucknam and Anderson,
1979).

The most recent scarp, up to 9 m high, extends for at least 35 km
along the mountain front. Successively higher scarps displace suc-
cessively older generations of fans; oldest fans, thought to be of
late Pliocene or early Pleistocene age, exhibit scarps about 90 m
high. Clearly, the older scarps are composite, the result of
repeated movement on the frontal fault for the last 2 to 3 m.y.
Similar relationships are likely to exist elsewhere along the
Franklin–Organ–San Andres frontal fault, as well as evidence for
Holocene movement.

**ORIGIN OF FAULTS**

A brief account of the known or inferred geometry of the Hueco
and Tularosa Basins would be a useful preface to discussion of the
origin of the fault system that displaces the basin surface. Semi-
diagrammatic cross-sections through each basin illustrate the
essential features (fig. 3). Both basins are asymmetric, west-tilted
grabens, deepest along their western margin according to avail-
able gravity, aeromagnetic and drill hole data (Mattick, 1967; Bath,
1977; Healey and others, 1978). Mattick’s (1967) gravity model pre-
dicts as much as 2750 m of bolson fill in the western Hueco bolson
drift holes confirm at least half of that near El Paso and at

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Figure 3. Cross-sections of the Tularosa and Hueco Basins con-
structed using available gravity, aeromagnetic, drill-hole and
geologic data (see text for data sources and Figure 2 for location of
sections). Dotted pattern indicates late Cenozoic basin fill. Down-
bending of basin fill is thought to be a result of localized pull-apart
beneath the western part of the basins. The width of the flexed
zone, indicated by the width of the fracture system (figs. 2 and 4),
suggests that the pull-apart zone is wider beneath the Hueco Basin
than beneath the Tularosa Basin.
Newman (King, 1935). Near White Sands Missile Range headquarters about 2400 to 2750 m of bolson fill is consistent with gravity data of Seager and Brown (1978) and Healey and others (1978); drilling has proven at least 1800 m (Doty and Cooper, 1970).

By comparison with their western counterpart, the eastern boundary faults of both grabens have much less displacement as indicated by geologic, drill-hole, and especially gravity data. Nevertheless, the eastern boundary fault of the Tularosa Basin, west and southwest of the Jarilla Mountains, is clearly revealed by gravity and aeromagnetic surveys (Bath, 1977; Healey and others, 1978). Judging from the lack of scars this fault is inactive. In the case of the Hueco Basin, an eastern boundary fault, or a series of stepped fault blocks, is indicated along the irregular western edge of the Hueco Mountains by drill-hole data between the main mountain mass and bedrock outliers. Elevation differences of various Permian formations between the escarpment and outlying hills also suggests down-to-the west faulting, and west-facing scarps are discontinuously present just west of the westemmost bedrock hills (C. Henry, personal communication, 1980). Figure 2 shows the location of all known or inferred faults along the eastern side of the grabens.

Clearly, subsidence has been greatest and most rapid beneath the western part of both basins, in areas adjacent to the Organ–Franklin boundary fault. The westward inclination of the surface of the basins indicates that asymmetry is continuing to develop as a result of Quaternary faulting along the range front (King, 1935; Sayre and Livingston, 1945). It is worth repeating here that the system of minor faults in the Tularosa Basin is comparatively narrow, lies just east of the depressions along the western edge of the basin, and comprises a rather disorderly but closely spaced array of horsts, grabens and tilted blocks. In contrast, the fault system in Hueco Bolson extends across the entire width of the basin, but individual faults are comparatively widely-spaced, and nearly all are antithetic to the westward tilt of the basin. With this setting in mind, we turn to a possible explanation for the faults.

The clay model experiments of E. Cloos (1968) reveal structures strikingly similar to those observed in the Tularosa and Hueco Basins (figs. 4A and 4B). Most obvious is the swarm of tension fractures, antithetic faults, and shallow horsts and grabens created by extension where the clay cake bent down into the “master fault” of the model; these may be analogous to the faults in the western Tularosa Basin, which may have formed by similar downbending of the bolson fill of the Tularosa Basin. Notice that in the model, as well as in the Tularosa Basin, unfaulted topographic as well as structural depressions lie between the “master” fault at the edge of the graben and the zone of minor antithetic rifts. The wider zone of more uniformly spaced antithetic faults in the Hueco Basin may indicate a much broader zone of downbending than is apparent either in the model or in the western Tularosa Basin.

The closely spaced, low-angle, antithetic faults in the lower half of the clay model apparently reflect a less-brittle response to extension relative to upper parts of the model. (Initially steep fractures, these faults subsequently rotated into low-angle attitudes as downbending of the clay progressed.) Such faults may be expected at depth within both basins (and are shown diagrammatically on Figure 3). However, judging from their length, many of the faults that break the basin surfaces may also extend deep into the upper crust.

Whereas the extension indicated by the fault system appears to be caused by downbending of the basin fill, the origin of the downbending itself poses a more significant problem. An analogy can readily be drawn again between Cloos’ models and the Tularosa and Hueco grabens. In Cloos’ models the clay bent down to fill the gap created when the clay slab was pulled apart at its base. An analogous zone of active horizontal extension can be inferred beneath the topographically lowest and structurally deepest part of the Hueco and southern Tularosa basins—that is, along their western margin (fig. 3). Downbending of the basin fill into this “pull-apart” zone resulted, and stretching of the basin fill across the downwarp created the fault system shown in Figures 1 and 2.

Considerable geophysical evidence suggests that a widespread zone of ductile horizontal extension does underlie the Basin and Range Province and Rio Grande rift in the middle to upper crust.
The general lack of earthquake foci below about 8 to 10 km beneath the Basin and Range (with few deeper than about 15 km) suggests that a transition from brittle to ductile crust takes place within that depth range (Thompson, 1959, 1966; Stewart, 1971; Smith and Sbar, 1974). In fact, Shurbet (1960), Mueller and LANDINGMAN (1966), Braile and others (1974) and Smith and others (1975) postulated the existence of low-seismic velocity (reduced rigidity) upper crust material between 6 and 15 km depth, and Shurbet and Cebull (1971) suggested that it is within this zone that horizontal ductile extension takes place beneath the Basin and Range Province. Earthquake foci disappear at similar depths beneath the Rio Grande rift (King, 1935; Handin, 1966; Moore, J. G., 1960, Curvature of normal faults in the Basin and Range province, in Seismic studies of the earth's crust in the western United States, U.S. Air Force Cambridge Research Laboratories Report 66-848).

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