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EVIDENCE FOR ACTIVE WESTWARD TILTING OF FORTYMILE WASH, NYE COUNTY, NEVADA

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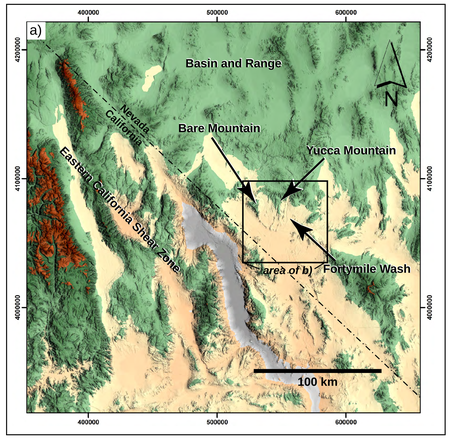
BACKGROUND

Fortymile Wash is located east and south of the potential high-level nuclear waste repository at Yucca Mountain, Nevada (Figure 1). The region lies in a transition zone between the Eastern California Shear Zone to the west and southwest, and the Basin and Range to the north and east. Because of this location and national interest in the area, a number of tectonic models have been suggested. Clarification of the tectonic environment will lead to a better assessment of the natural hazards in the Yucca Mountain region. Carr (1990) based the eastern boundary of his proposed Kawich-Greenwater rift on local gravity data (Inferred Gravity fault of Winograd and Thordardson, 1974), regional gravity, and geology (i.e., eastern boundary of Miocene calderas to the north of Yucca Mountain). Carr (1990) and later Young et al. (1992) were early proponents of such a boundary. Young et al. (1992), based upon results from geologic cross-section balancing and restoration, interpreted the occurrence of a N-S oriented fault to explain the east- dipping Miocene tuffs on the west side of Fortymile Wash and older Miocene tuffs and lavas in the Calico Hills on the east side of the wash. Later other authors, (e.g., Ferrill et al., 1996; Fridrich, 1999; Wernicke et al., 2004) proposed eastern boundaries for their tectonic models in the vicinity of Fortymile Wash. All recognized there is not sufficient field evidence or conclusive geophysical data to clearly define a significant boundary.



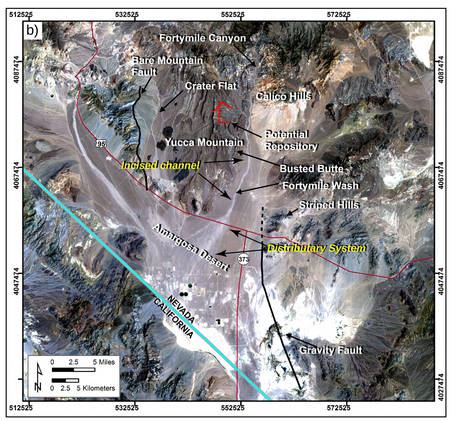
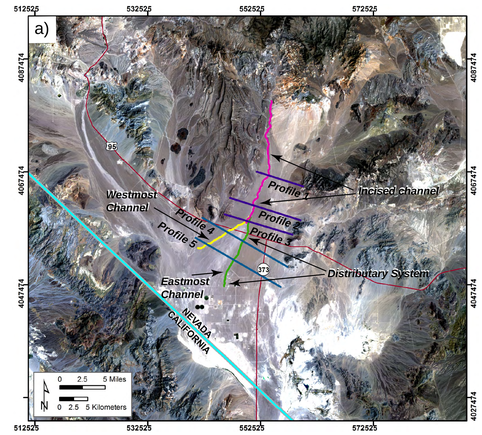


Figure 1: a) Digital shaded relief image showing regional context of Bare Mountain, Yucca Mountain, and Fortymile Wash. Yucca Mountain lies in a transition zone between the Eastern California Shear Zone to the west and southwest and the Basin and Range to the north and east. Approximate location of b) shown in outline. Coordinates are UTM NAD83, meters. b) Landsat TM image showing Bare Mountain, Yucca Mountain, and Fortymile Wash, including incised and distributary sections of the wash. The Bare Mountain and Gravity Fault locations are generalized as heavy black lines. Coordinates are UTM NAD83, meters.



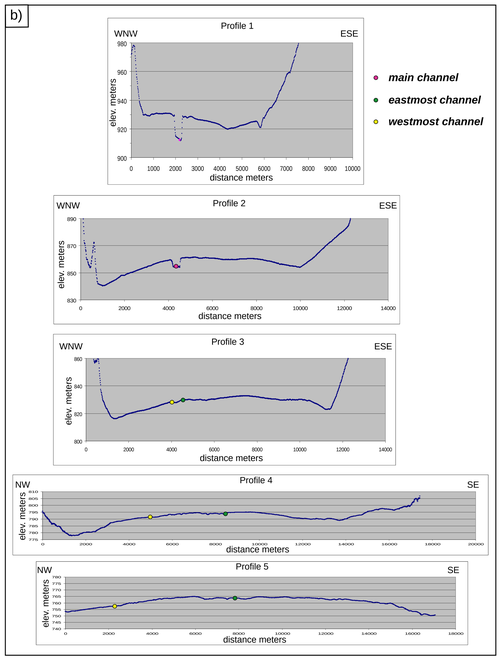


Figure 2: a) Location of channel segments and profiles shown in b) Topographic profiles across Fortymile Wash showing evidence of increasing westward tilt. Viewed in profiles oriented normal to the incised channel and across the Fortymile Wash distributary system, topographic elevation decreases westward, resulting in the elevation of the western margin of Fortymile Basin being lower than the channel system on the eastern fan margin. Elevations are sampled from USGS 10 m Digital Elevation Model (DEM). Northwest is to readers left. Vertical scale is meters elevation above MSL and horizontal scale is distance along profile in meters. Vertically exaggerated. Vertical and horizontal scales are approximately uniform between profiles.

Several lines of evidence suggest that southern Fortymile Wash may be an area of active westward tilting associated with the continued development of Crater Flat basin and slip on the Bare Mountain normal fault. These lines of evidence are considered below.

Fortymile Wash Drainage System

Huber (1988) suggested that the Fortymile drainage system has been in existence for about 11 million years and, although it has had a long and complex history, it has been in its present location over that time span. The system consists of an upper catchment area that drains through Fortymile Canyon and into Fortymile Wash (Figure 2). In the incised upper portion of the wash the deposits in the channel walls show an interbedding of fan and gravelly fluvial deposits (Ressler et al., 2000).

Southward, the incised main channel grades to a divergent distributary channel system that shows evidence of westward tilt (Figure 2b). Viewed in profiles oriented normal to the incised channel and across the Fortymile Wash distributary system, topographic elevation decreases westward, resulting in the elevation of the western margin of Fortymile Basin being as much as 18 m [59 ft] lower than the channel system on the eastern fan margin. Mapping of the surficial deposits within the distributary channel system (Pelletier et al., 2005) may be interpreted to show a westward shift (downslope) of the locus of erosional activity toward the topographically lower western fan margin (Figure 3). Most of the older alluvium (Qa3 {86±40-16 ka}) has been eroded from the eastern portion, while incipient incision into the older alluvium is occurring on the western side of the distributary channel system. Deposits within the eastward distributary channels are interpreted to be younger than the older alluvium.

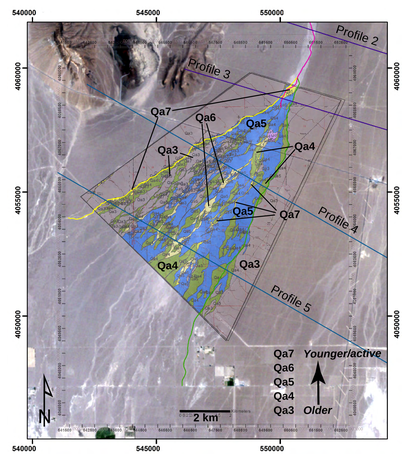
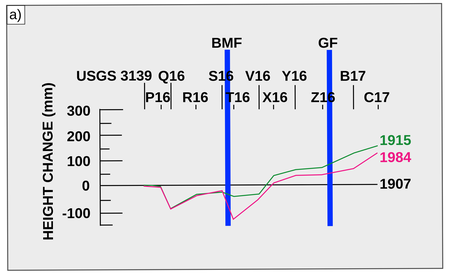


Figure 3: Detailed view of distributary system of Fortymile Wash (Landsat TM) with transparent overlay of alluvial deposits as mapped by Pelletier et al. (2005). Mapping of the surficial deposits within the distributary channel system (Pelletier, et al., 2005) may be interpreted to show a westward shift (downslope) of the locus of erosional activity toward the topographically lower western fan margin. Most of the older alluvium (Qa3 {86±40-16 ka}) has been eroded from the eastern portion, while incipient incision into the older alluvium is occurring on the western side of the distributary channel system.

Level line data

Gilmore (1992) and Castle et al. (2005) have reprocessed and reinterpreted level lines surveyed in 1907, 1915, and 1984 between Beatty and Las Vegas, Nevada. Figure 4 (4a modified from Gilmore 1992, figure 4) shows the height changes between bench marks P16 and C17 by comparing the 1915 and 1984 level line surveys with the 1907 survey. Castle et al., 2005 maintained the surveys were not contaminated by significant measurement errors, and recognized "… relatively large magnitude vertical displacements..." of an episodic nature. Gilmore (1992) refers to this area as the Crater Flat/Yucca Mountain structural depression. From near X16 to Z16 and eastward both surveys show a systematic increase in height when compared with the 1907 survey, with the 1915 line showing slightly greater increases. West of X16 both lines show systematic subsidence relative to the 1907 line, the 1984 survey showing the larger amount. The combination of relative uplift eastward and subsidence westward of X16 results in an overall westward tilt from Z16 to T16. This is consistent with the features in Fortymile Wash described above. In addition the 1984 survey in the area of T16 and V16 indicates that westward tilting increased by a factor of three compared with the earlier (1915) survey.



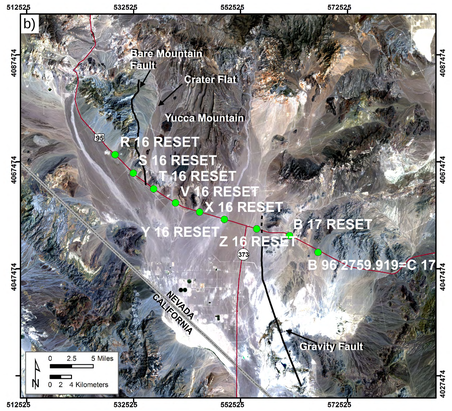


Figure 4: a) Level lines from 1915 and 1984 first-order surveys plotted against 1907 third-order survey as baseline reference (after Gilmore, 1992, Figure 4). 1907 survey is x axis, 1915 survey shown as green line, 1984 survey as magenta line. Relative benchmark locations are indicated and labelled along the top of the plot. Locations of the Bare Mountain Fault (BMF) and Gravity Fault (GF) are shown as blue vertical bars.
b) Location of benchmarks used in a) plotted as green-filled circles. Note position of Bare Mountain and Gravity faults relative to survey markers.

Close comparison between the 1915 and 1984 surveys plotted in Figure 4b indicates difference in the pattern of height change during the sixty-nine years between 1915 and 1984. In this case the 1915 line serves as a baseline. Westward height decrease is pronounced from V16 to T16 (~100mm). A sharp westward increase in height is indicated where the line crosses the Bare Mountain Fault Zone between T16 and S16 (~120mm). A systematic slight decrease in height (~40-60mm) is indicated eastward of V16, including the portion of the lines crossing Fortymile Wash (Figure 4a).

Height changes westward of V16 as indicated by both the 1907 and 1915 relative baselines are consistent with the interpretation of hanging wall rollover (Figure 5a) into the Bare Mountain Fault. In the case of the 1907 baseline, height decrease is systematic westward from the Gravity Fault to the Bare Mountain Fault indicating westward tilting of the land surface. Though less obvious, eastward tilting indicated by the 1915 baseline could also result from faulting antithetic to the Bare Mountain Fault, as evidenced by the prevalent eastward dip of rock layers at Yucca Mountain. An alternative interpretation for the eastward tilt is hangingwall rollover into the Gravity Fault (Figure 5b).

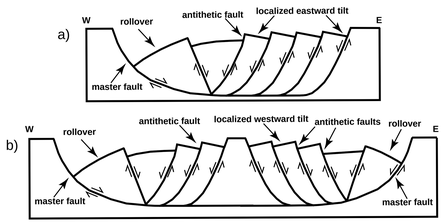


Figure 5: Diaschematic conceptograms of fault geometries developed over a) single and b) opposing master faults accommodating both eastward and westward tilting. a) Rollover into master fault produces westward tilting. Displacement of antithetic faulted blocks results in localized eastward tilting. b) System of symmetric master faults with rollover into both the west master fault and east master fault. Localized tilting of antithetic blocks in the hanging wall away from the master fault. In the case of both a) and b), active extension increases dilation and slip tendencies on fault surfaces oriented perpendicular to the extension direction.

Discussion and Summary

Preliminary examination of the southern Fortymile Wash area reveals geomorphic features that may be indicative of neotectonism. Viewed separately, the indicators may be interpreted as normal variability in the evolution of surface morphology and morphometry. Taken together geomorphic features may be indicative of processes associated with particular classes of tectonic models, or even particular tectonic models. Further, these processes may affect a variety of geologic processes or interpretations, including:

- Seismicity: Fault zone dilation is also associated with high slip tendency (Ferrill and Morris, 2003). Fault surfaces with high slip tendencies are most likely to be active.
- Volcanism: Areas of active extension and large fault dilation tendencies may serve as preferential pathways for ascending magma (Connor et al., 2000).
- Groundwater flow rates and flow paths: High flow rates have been observed in Nye County EWDP well 24PB. Which is near and possibly intersects the Paintbrush Canyon Fault, a west-dipping fault located in the hanging wall of and antithetic to the Bare Mountain Fault . High dilation tendency faults may affect fast flow paths in the alluvium (Ferrill and Morris, 2003).

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