Chapter 14

Summary of the Temporal and Spatial Relations of Quaternary Faulting During the Past 100 k.y. at Yucca Mountain: Evidence for Distributive Surface Ruptures on Multiple Faults

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Contents

Abstract

We have used the estimated ages of displacements on eight Quaternary faults at Yucca Mountain to correlate the timing of surface ruptures on the various faults and to examine the evidence for distributive surface ruptures on multiple faults within the past 100 k.y. Trenching showed that fissures along three different faults on the west side of Yucca Mountain contain basaltic ash correlated with the eruption of the nearby Lathrop Wells volcanic center at 77±6 ka; thus, coeval surface ruptures on these faults were probably contemporaneous with that eruption. Though less certain, age data indicate additional cases where two or more faults may have been active simultaneously, including one faulting event with a narrowly defined date near 3 ka and three other faulting events at about 50, 30–20, and 13 ka, in all of which distributive surface ruptures may have occurred on multiple faults that are close to one another and, possibly, linked at depth.

Introduction

The purpose of this chapter is to evaluate paleoseismic data from all of the main trench sites at Yucca Mountain (fig. 2) for evidence of distributive surface ruptures on the major Quaternary faults. In particular, we address the following questions: (1) did distributive surface ruptures occur simultaneously on multiple faults, and (2) if so, what are the spatial relations of the affected faults? Our answers are based on a summary of the data on faulting events within only the past 100 k.y., as presented in the preceding chapters, because the age constraints on earlier faulting events are generally too broad or poorly defined for adequate temporal correlations. The Bare Mountain and Rock Valley Faults, which are outside the immediate area of Yucca Mountain, are not included in this summary.

The timing of an individual faulting event commonly is based on age determinations for the youngest deposit or soil horizon displaced by the event, relative to the maximum age of the oldest overlying deposit that postdates the event. Thus, resolution of the estimated date for the event itself critically depends on the time interval spanned by dated units that stratigraphically bracket the event horizon. This interval may vary widely; for example, in many places the youngest faulted and oldest unfaulted deposits or soils simply underlie and overlie an event horizon within the overall stratigraphic sequence exposed in a given trench. In other places, however, more precise age constraints on the event may be provided by a datable deposit or feature directly associated with the event itself (for example, fissure fills, scarp-derived colluvial wedges, and fracture or fault coatings terminated at the event horizon). Another source of uncertainty in time intervals is the reported analytical errors for each age determination itself.

The estimated dates for individual faulting events within the past 100 k.y. identified in the various trenches (fig. 2) excavated across each of the eight Quaternary faults at Yucca Mountain are plotted in figure 59 and listed in table 43. Many of these dates range widely (some as much as 50 k.y. or more) because of the inherent uncertainties in age assignments; thus, determining a date within narrow limits is generally impossible for many paleoearthquakes. To reduce the uncertainty, many investigators selected either a preferred date or a more restricted interval within the estimated age range, on the basis of expert judgment that considered the stratigraphic position of an event horizon relative to dated units or assessments of the relative strengths and weaknesses of the available age control (table 43). Preferred estimated ages, where available, are plotted in figure 59 as heavier dots or lines within the estimated dates.

Temporal and Spatial Distribution of Quaternary Faulting Events

The available age data (table 43) indicate several possible distributive surface ruptures on two or more faults (fig. 59). The strongest case for coeval displacements on multiple faults is informally termed the “ash event.” This event has been identified in trenches on three faults on the west side of

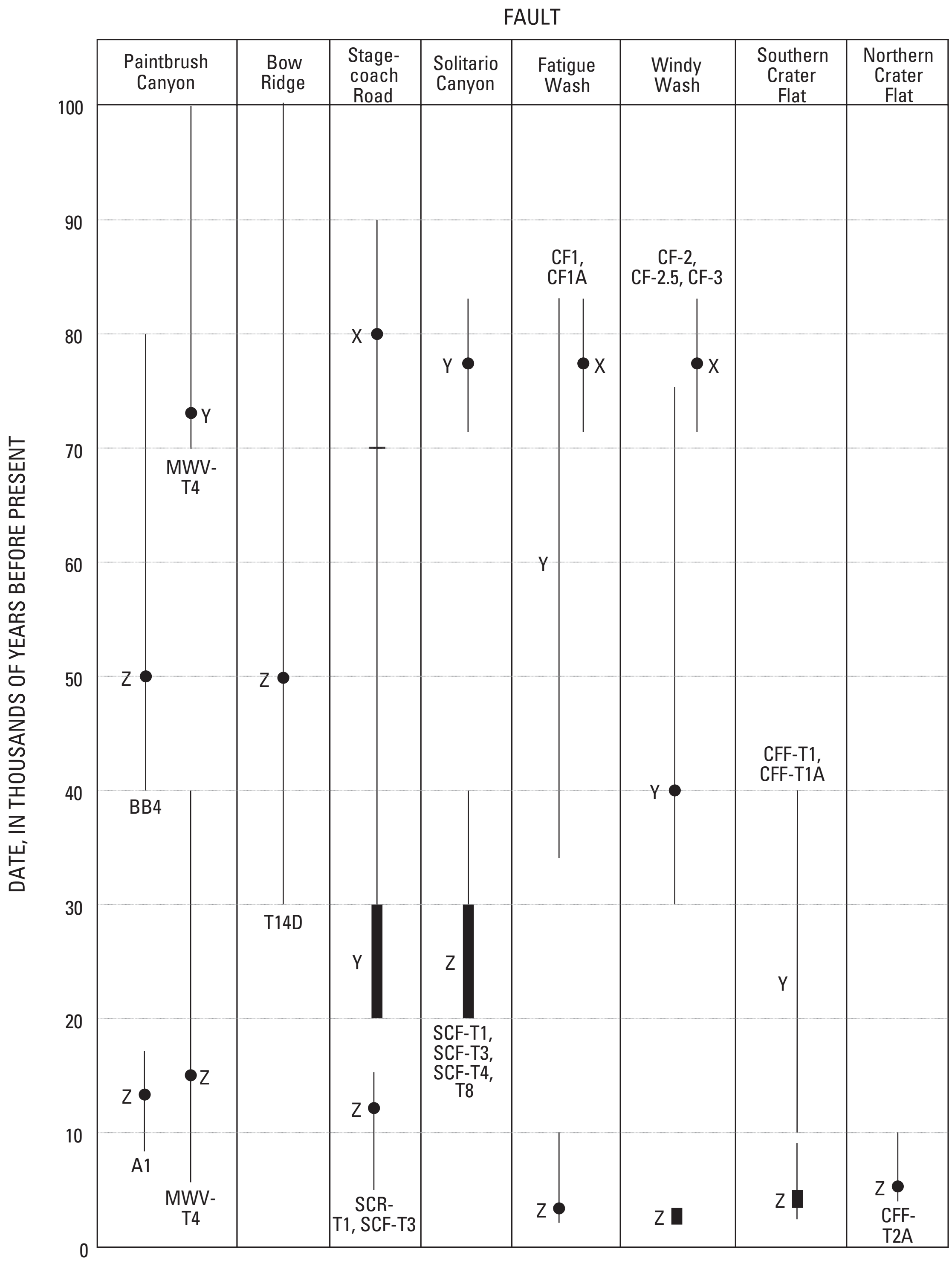

Figure 59. Ranges in estimated dates of Quaternary faulting events identified in trenches excavated in the Yucca Mountain area, southwestern Nevada (figs. 1, 2; table 43). Dots, preferred date (if one was selected); bold lines, preferred-date range. Letters X–Z refer to event-labeling scheme used in designated trench(es) (letter-number combinations).

Table 43. Estimated dates of faulting events during the past 100 k.y. in the Yucca Mountain area, southwestern Nevada

[See figures 1 and 2 for locations. Data from chapters 5 through 11. Faulting events are labeled according to scheme used in designated trench(es)]

Fault (fig. 2)	Trench (fig. 2)	Event	Date (ka) Min	Pref	Max
Paintbrush Canyon------	A1	Z	9	13	17
	BB 4	Z	40	50	80
		Y	80	– –	150
	MWV–T4	Z	6	15	40
		Y	70	73	100
Bow Ridge ---------------	T14D	Z	30	50	130
Stagecoach Road--------	SCR–T1, SCR–T3	Z	5	12	15
		Y	20	30–20	70
		X	70	80	90
Solitario Canyon --------	SCF–T1, SCF–T3, SCF–T4, T8	Z	20	30–20	40
		Y	71	77	83
Fatigue Wash ------------	CF1, CF1A	Z	2	3	10
		Y	34	– –	83
		X	71	77	83
Windy Wash -------------	CF2, CF2.5, CF3	Z	2	3–2	3
		Y	30	40	75
		X	71	77	83
Southern Crater Flat ----	CFF–T1, CFF–T1A	Z	2	4–3	9
		Y	10	– –	40
Northern Crater Flat ----	CFF–T2A	Z	4	5	10

Yucca Mountain—event Y on the Solitario Canyon Fault, and event X on the Fatigue Wash and Windy Wash Faults (figs. 1, 2, 59)—on the basis of conspicuous fissures that contain geochemically correlated basaltic ash from an eruption of the nearby Lathrop Wells volcanic center (fig. 1) at 77±6 ka (Heizler and others, 1999). A reasonable interpretation is that the fissures formed simultaneously on these three faults during a single event temporally associated with that eruption (see chaps. 7–9). The affected faults lie within a 3- to 7-km-wide zone of interconnected and splayed faults aligned southward toward the Lathrop Wells basaltic cone (see chap. 3; figs. 1, 2).

The other five Quaternary faults at Yucca Mountain show no clear evidence of being affected by the ash event. Basaltic ash from the Lathrop Wells eruption is present in a fracture at the top of trench 14 on the Bow Ridge Fault. However, this fracture does not represent a specific faulting event, and similar ash is absent within the deposits recording the main rupture sequence exposed in trench T14D (fig. 2). The estimated date for event Y in trench MWV–T4 on the Paintbrush Canyon Fault is compatible with the date of the Lathrop Wells eruption; however, no basaltic ash was identified at that trench site. A basaltic ash was identified only in the lower part of trench A1 on the northern section of the Paintbrush Canyon Fault, but this ash differs geochemically from the Lathrop Wells ash and is correlated more closely with an older basaltic eruption at the Sleeping Butte cone, which lies 40 km to the northwest (see chap. 5). Although basaltic ash correlated with the Lathrop Wells eruption was identified in Quaternary deposits at the Busted Butte wall 4 locality on the Paintbrush Canyon Fault, in trenches SCR–T1 and SCR–T3 on the Stagecoach Road Fault, and in trenches CFF–T1 and SCF–T1A on the Southern Crater Flat Fault, in none of these sites was the presence of the ash identified with a dated faulting event. No basaltic ash was recognized within trench CFF–T2A on the Northern Crater Flat Fault. In summary, basaltic ash from the Lathrop Wells eruption either was not identified or was dispersed in deposits between event horizons on the Paintbrush Canyon, Stagecoach Road, and, probably, Bow Ridge, Southern Crater Flat, and Northern Crater Flat Faults.

A second probable distributive surface rupture, with an estimated date within a narrow time interval, is represented by event Z on the Fatigue Wash, Windy Wash, and Southern Crater Flat Faults (fig. 2). The preferred dates of this event on these three faults of 3, 3–2, and 4–3 ka, respectively (fig. 59; table 43), provide the only evidence for Holocene faulting activity observed at any of the trench sites in the Yucca Mountain area. The surface traces of the three faults lie close to one another, and they may be interconnected in a complex splay pattern (fig. 4). During the Holocene faulting event (~3 ka), measurable displacements ranging from 10 to 20 cm occurred on the Windy Wash and Southern Crater Flat Faults; the event on the Fatigue Wash Fault is represented only by fracturing with no detected offset. In trenches on all three faults, however, the vesicular A (Av) soil horizon was affected. Concurrent movement may also have occurred on the nearby Northern Crater Flat Fault, but a closely constrained minimum date for event Z on that fault is 4 ka, as discussed in chapter 11.

Comparison of the dates of faulting events indicates three other possible distributive surface ruptures in the Yucca Mountain area during the past 100 k.y. However, correlations are less reliable than for the two faulting events just described, owing to the broader ranges in the estimated ages for the bracketing stratigraphic units (fig. 59).

1. Event Z on the Paintbrush Canyon Fault, as identified in trenches A1 and MWV–T4 (fig. 2), is dated as ranging from 17 to 9 ka and from 40 to 6 ka, respectively, (preferred values, 13 and 15 ka, fig. 59; table 43). These trench sites are 5 km apart on the northern segment of the fault (fig. 2); thus, simultaneous surface rupture is strongly possible. Event Z is dated at 15–5 ka (preferred value, 12 ka) from evidence observed in trenches SCR–T1 and SCR–T3 on the Stagecoach Road Fault. As indicated in chapter 3, a subsurface connection may exist between this fault and the southern segment of the Paintbrush Canyon fault a few kilometers southwest of Busted Butte; thus, structure and trench data support an interpretation of a simultaneous surface rupture at about 13 ka along the Stagecoach Road Fault and the northern section of the Paintbrush Canyon Fault. However, at the Busted Butte wall 4 site, the most recent faulting event (Z) identified on the Paintbrush Canyon Fault is dated at no later than 40 ka (fig. 59; table 43). Therefore, if simultaneous surface ruptures did occur at about 13 ka on the Paintbrush Canyon Fault north of Busted Butte and on the Stagecoach Road Fault south of Busted Butte, this faulting event was not reflected (or recognized) on the Paintbrush Canyon Fault in the intervening area.
2. Event Z on segments of the Solitario Canyon Fault system and event Y on the Stagecoach Road Fault occurred at preferred ages between 30 and 20 ka, indicating possible contemporaneous displacements. A surface-rupturing paleoearthquake may also have occurred on the Southern Crater Flat Fault during this same time interval; event Y on that fault is dated at 40 –10 ka, but no preferred date was assigned (table 43; see chap. 10).
3. The most recent event (Z) identified in trench T14D on the Bow Ridge Fault and at Busted Butte wall 4 on the southern section of the Paintbrush Canyon Fault (fig. 2) have both been assigned a preferred date of 50 ka (fig. 59), indicating possible simultaneous surface ruptures. The estimated dates are reasonably well constrained; minimum dates are derived from the ages of deposits or features that formed relatively soon after the event (that is, a colluvial wedge in trench T14D and an eolian mantle across a carbonate-filled fracture at Busted Butte wall 4). The Bow Ridge Fault is inferred to continue southward and southeastward in the subsurface to merge with the southern section of the Paintbrush Canyon Fault (see chap. 3), and so distributive surface ruptures could be expected. However, because such an event has not been recognized in trench MWV–T4 or A1 (fig. 59), both of which are farther north on the Paintbrush Canyon Fault (fig. 2), the relations, if interpreted correctly, would indicate that distributive surface ruptures occurred on the Bow Ridge Fault and on a segment of the Paintbrush Canyon Fault south of its inferred intersection with the Bow Ridge Fault.

Conclusions

Interpretations of temporal and spatial relations among the eight Quaternary faults at Yucca Mountain indicate, with varying degrees of confidence, that distributive surface ruptures may have occurred on various combinations of closely spaced and (or) possibly interconnected faults during paleoearthquakes within the past 100 k.y. The best examples of probable distributive surface ruptures on multiple faults are provided by (1) the presence of geochemically correlated basaltic ash dated at approximately 77 ka within the fissure fills of three faults on the west side of Yucca Mountain; and (2) a Holocene event, dated at about 3 ka, on three closely spaced faults on the west side of Yucca Mountain. Greater uncertainties exist in the dating of other distributive surface ruptures because the estimated ages of the bracketing stratigraphic units cannot be as narrowly defined as in these two examples. However, the accumulated data indicate possibly three additional faulting events at about 50, 30–20, and 13 ka, each involving two or three faults.

The occurrence of distributive surface ruptures has profound implications for seismic-hazard evaluations at Yucca Mountain. Distributive surface ruptures on multiple faults increase the estimated lengths and (or) surface displacements for a given faulting event, which in turn increases the maximum estimated magnitudes for the associated paleoearthquakes. Linking events on multiple faults into a single distributive surface rupture also bears directly on composite recurrence estimates for the Yucca Mountain fault system as a whole. All these input parameters are critical for seismic-source characterization of the proposed repository site for the storage of high-level radioactive wastes.