STRUCTURE AND LATE QUATERNARY ACTIVITY OF THE NORTHERN OWENS VALLEY FAULT ZONE, OWENS VALLEY, CALIFORNIA

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ABSTRACT


The Fish Springs fault is a primary strand in the northern end of the Owens Valley fault zone (OVFZ). The Fish Springs fault is the northwest strand in a km-wide left echelon step of the OVFZ which bounds the Poverty Hills bedrock high. The Fish Springs fault strikes approximately north-south, dips steeply to the east, and is marked by a prominent east-facing scarp. No other faults in the OVFZ have prominent east-facing scarps at the latitude of Fish Springs, which indicates that the Fish Springs fault has accommodated virtually all of the local late Quaternary vertical displacement on the OVFZ.

The Fish Springs fault exhibits normal dip slip with no measurable lateral slip. Vertical displacements of a Late Pleistocene (0.314 ± 0.036 Ma, 2σ) cinder cone and of an overlying Tahoe-age (0.065-0.195 m.y.) alluvial fan are 76 ± 8 m and 31 ± 3 m, respectively. The maximum vertical displacement of ancient stream channels in a Tioga-age (0.011 to 0.026 Ma) alluvial fan averages 3.3 m. Two nearly equal vertical displacements of the active stream channel in the Tioga-age fan total 2.2 m. Vertical displacement of a stream terrace incised into the cinder cone is 1.2 ± 0.3 m. The minute amount of incision into that terrace indicates that uplift of the terrace probably occurred during the 1872 Owens Valley earthquake.

Three displacements of 1.1 ± 0.2 m each apparently have occurred at the Tioga-age fan since the midpoint of the Tioga interval, allowing an average recurrence interval of 3500 to 9000 years. Based on the age and displacement of the cinder cone, the average late Quaternary vertical displacement rate is 0.24 ± 0.04 mm/yr (2σ). At this rate, and assuming an average vertical displacement of 1.1 ± 0.2 m per event, the average recurrence interval would be 4600 ± 1100 years (2σ). The recurrence interval for the Fish Springs fault is similar to that for a strand in the southern part of the OVFZ which also ruptured in 1872.

Right-lateral, normal oblique slip characterizes the OVFZ. The location of the Poverty Hills bedrock high at a left step in the north-northwest-striking fault zone is consistent with the style of slip of the zone. The pure normal slip on the north-striking Fish Springs fault and the alignment of local cinder cones along north-striking normal faults indicate that the late Quaternary maximum horizontal compression has been oriented north-south at the north end of the OVFZ. Data from southern Owens Valley indicate a similar stress regime there. Late Quaternary slip on the OVFZ is consistent with north-south maximum horizontal compression.

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INTRODUCTION

The Owens Valley fault zone of east-central California (Fig. 1) generated one of California's greatest historical earthquakes (Townley and Allen, 1939; Richter, 1958) and thus poses a significant seismic hazard. However, the structure and behavior of the fault zone have received relatively little attention. The purpose of this study is to augment our understanding of the Owens Valley fault zone by a detailed investigation of the structure and late Quaternary activity near its northern end.

The Owens Valley fault zone was first mapped by Knopf (1918). It has been mapped more recently by Bateman (1965), Ross (1965), Nelson (1966), and D.B. Slemmons (Hill, 1972). The displacement along the fault zone and its structure were studied by geophysical means by Pakiser et al. (1964).

Most of the geologic studies on the fault zone have focused on effects of the

Fig. 1. Index map of the Owens Valley fault zone.
great Owens Valley earthquake of 1872. The earliest studies were by Gilbert (1884), Whitney (1888) and W.D. Johnson (Hobbs, 1910). More recent work on 1872 displacement includes that of Bateman (1961) and Bonilla (1968). The prehistoric behavior of the fault zone has been investigated by Carver (1970), Richardson (1970), Slemmons (Oakeshott et al., 1972) and Lubetkin (1980). Except for Whitney, these workers concentrated on the southern Owens Valley.

Along the little-studied northern end of the fault zone, where the oldest exposed Quaternary features are offset, the Quaternary displacement history can be analyzed in detail. The strand of the fault zone examined herein is referred to as the Fish Springs fault. The Fish Springs study area, centered around a prominent basaltic cinder cone, is about 11 km south of Big Pine, California.

STRUCTURAL GEOLOGY OF WESTERN OWENS VALLEY

Owens Valley is a complexly faulted block down-dropped between the Sierra Nevada and the White-Inyo Mountains (Knopf, 1918; Pakiser et al., 1964). The three major structures of western Owens Valley are the Owens Valley and Sierra Nevada fault zones, and the Coyote Warp (Fig. 2). The Owens Valley fault zone branches to the east off the Sierra Nevada fault zone about 3 km south of the Alabama Hills. Both fault zones are well defined between the latitudes of Lone Pine and Big Pine. The Coyote Warp, a large flexure, is between Big Pine and Bishop, and lacks major through-going faults (Bateman, 1965). The Warp is bounded on the southeast by the Owens Valley fault zone and on the northwest by the Round Valley fault.

The Owens Valley fault zone

The Owens Valley fault zone is approximately 120 km long and extends from the west side of Owens Lake to a few kilometers north of Big Pine. The maximum width of the fault zone is approximately 3 km. The zone has an overall strike of N17°W and typically dips 60° to 70° to the east (Tocher et al., 1963). West-side-up, dip-slip displacement along the fault zone is indicated by historical accounts, by east-facing scarps in Quaternary alluvium and lavas, and by displacement of pre-Cenozoic bedrock. From gravity and seismic data, Pakiser et al. (1964) infer vertical displacements of basement of 2400 ± 600 m at Lone Pine, 300 m at Independence, and 1800 ± 450 m at Big Pine. Assuming that vertical displacement rate at Big Pine and Lone Pine would be approximately the data of Giovanetti (1979) and Bacon et al. (1982), the average late Cenozoic vertical displacement rate of Big Pine and Lone Pine would be approximately 0.3 mm/yr and 0.4 mm/yr, respectively.

Although left-lateral displacement might have occurred locally during the 1872 earthquake (Whitney, 1888; Gianella, 1959; Pakiser et al., 1964), the evidence for overall right-lateral slip across the fault zone is compelling. The only published photographs of 1872 strike-slip offset show right-lateral offset (Bateman, 1961) as do the only maps (Bateman, 1961; Lubetkin, 1980). Geodetic
surveys across southern Owens Valley have indicated right-lateral deformation at rates of $3.6 \pm 1.2$ mm/yr (Savage et al., 1975) and $2.4 \pm 0.9$ mm/yr (Savage and Lisowski, 1980); the uncertainties are one standard deviation. Finally, right-lateral solutions have been obtained for microearthquakes in northern Owens Valley on northwest-trending faults (Pitt and Steeples, 1975).
Structure of the northern end of the Owens Valley fault zone

North of the Fish Springs fault, a series of conspicuous scarps in Crater Mountain clearly marks the main trace of the Owens Valley fault zone. This northernmost section of the zone strikes N19°W. However, no fault traces of that orientation are obvious between Poverty Hills and Crater Mountain.

On the basis of gravity data, Pakiser et al. (1964) interpreted the fault zone as extending beneath Poverty Hills on a linear N19°W trend (Fig.3). They
contended that Poverty Hills represents a gravity slide mass, derived from the Sierra Nevada, that overlies the Owens Valley fault zone. However, this interpretation seems incompatible with the geology of Poverty Hills. If Poverty Hills were a gravity slide mass, it would have to predate the 1.0 Ma rhyolite dome (Moore and Dodge, 1980) between Poverty Hills and the Sierra Nevada. Given over one million years, a "buried" Owens Valley fault zone should have had sufficient time to rupture the Poverty Hills mass, yet no through-going faults have been mapped in Poverty Hills (Bateman, 1965).

Only if the trace of the fault zone lies east of Poverty Hills could west-side-up displacement on the fault zone bring plutonic rock to the surface (Fig.3). Three short scarp just east of Red Mountain (Fig.3) indicate that the trace indeed does deflect to the east side of the hills. This interpretation is compatible with the geophysical data of Pakiser et al. (1964), the geology of Poverty Hills, and the character of displacement on the Owens Valley fault zone.

If the trace of the Owens Valley fault zone lies east of the Poverty Hills, then a geometric discontinuity in the fault zone must occur north of Poverty Hills, for no fault trace links the northeast corner of the hills with the fault zone trace on Crater Mountain. The Fish Springs fault is the only west-side-up fault with a prominent scarp in the alluvium between Poverty Hills and Crater Mountain, and it is most likely the primary element in the Owens Valley fault zone between those two topographic highs. The depth to which the discontinuity in the fault zone extends is unknown. Below some depth the fault zone might be a continuous structure. The decrease of 2100 m in bedrock displacement across the fault zone between Lone Pine and Independence might be due to the discontinuity in the fault zone at Poverty Hills. Under this interpretation the Poverty Hills bedrock high is at a left step in a right-lateral, normal oblique shear system. The Coyote Warp is at an analogous, but much larger left step between the Owens Valley fault zone and the Round Valley fault. Theoretical work (Segall and Pollard, 1980) and field studies elsewhere (Clayton, 1966; Sharp and Clark, 1972) demonstrate that areas between left-stepping echelon fault strands in right-lateral shear systems are likely sites for uplift.

LATE QUATERNARY DISPLACEMENT ON THE FISH SPRINGS FAULT

Five major geomorphic features of late Quaternary age dominate the Fish Springs study area (Fig.4). These are: (1) the compound east-facing scarp; (2) the Fish Springs cinder cone; (3) an alluvial fan exposed west of the fault, hereafter referred to as the west fan; (4) an alluvial fan east of the fault and north of the cinder cone, hereafter referred to as the north fan; (5) an alluvial fan east of the fault and south of the cinder cone, hereafter referred to as the south fan. These features were mapped at scales of 1:2000 and 1:500 by plane table and at a scale of about 1:2000 on aerial photographs.

The cinder cone is the oldest feature. The fault trace splits the cone asymmetrically, the east segment being larger than the west segment. The
The Fish Springs fault scarp

This scarp is tallest in the west segment of the cinder cone. The alluvial scarp is tallest immediately north and south of the cinder cone. The height of the alluvial scarp decreases from the cinder cone towards the apices of the north and south fans. The scarp height increases north of the north fan, but decreases south of the south fan. The scarp height variation north of the cinder cone primarily reflects the burial of the scarp by the north fan. The decrease in scarp height south of the cinder cone probably is due to a combination of increasing burial by the south fan and decreasing displacement near the south end of the fault.
The fault trace was located on the alluvial scarp at the contact between abundant in-place boulders upslope of the trace and abundant translocated cobbles downslope of the trace (Fig.5). The contact apparently marks the top of a debris slope at the base of the scarp and should coincide with the fault trace (Fig.6). The slope above the boulder/cobble contact is generally a few degrees steeper than the slope below it. Wallace (1977) noted similar effects at the top of debris slopes on fault scarps in Nevada. At several places south of the cinder

Fig.5. View to west of fault trace at the cobble/boulder contact. Field assistant is standing on the contact.

Fig.6. Profile of an idealized compound fault scarp showing the location of the fault trace.
cone the boulder/cobble contact corresponds with the base of a band of shrubs. At several places on the scarp north of the cinder cone, the soil is redder below the boulder/cobble contact than above it. The bases of fresh scarps on the compound scarp also coincide with the top of the debris slope.

Across the fault trace the cinder cone is obscured. A scarp across the west segment of the cinder cone (Fig.7) probably is not a fault scarp, but rather a landslide scarp, formed as the slope was oversteepened by faulting. If that scarp marked the fault trace, then, based on the solution of a three-point problem, the fault dips 59° to the east. This is the minimum dip for the fault, for the cinders

![EXPLANATION](image)

Fig.7. Topographic map of a section of the Fish Spring fault scarp showing the locations of the cross-sections of Fig.8.
west of this scarp show no evidence of being faulted. However, as shown in Fig. 8a, if the fault dip is $59^\circ$, the amount of cinder talus immediately east of the fault would be roughly five times the amount available from the source area west of the fault. If the fault is vertical, the amount of cinder talus nearly equals the amount available from the source area. Thus, the fault dips between $59^\circ$ and $90^\circ$ and is probably close to vertical.

The Fish Springs cinder cone

The cinder cone records the greatest displacement on the fault. A cross-section perpendicular to the fault (Fig. 7) indicates that the fault has vertically separated the cinder cone by $82 \pm 2$ m (Fig. 8a). The uncertainty represents the range of possible separation values and should be interpreted as approximately two standard deviations. The minimum vertical displacement is $68$ m (assuming a $59^\circ$ fault dip), and the maximum vertical displacement is $84$ m (assuming a $90^\circ$ fault dip). The vertical displacement of the cinder cone is thus $76 \pm 8$ m.

In order to estimate the lateral offset of the cinder cone, the position of the
contact between the cinder cone and west fan was compared to the theoretical contact for a cone offset vertically but not laterally. The contact between the cinder cone and the overlying fan is exposed in the fault scarp. Where well-exposed, the contact marks a sharp transition from abundant cinders, covered by sparse granitic boulders, to abundant granitic boulders. In some places, however, gravels sloughed off the west fan have obscured the contact. In these places, the contact was mapped at the highest position on the slope of orange-brown vesicular cinders, but the position of the contact could lie slightly higher. The theoretical contact was found by displacing a model of the original surface of the cinder cone to yield a vertical separation of 82 ± 2 m, and then intersecting that surface with the mapped topography. The model of the original shape of the west half of the cinder cone was made by extrapolating the western surface of the east segment of the cinder cone. Theoretical contacts were constructed for fault dips of 59°, 70°, and 90°. The sections of the theoretical contacts that are the most important for assessing the amount of lateral slip, the northernmost and southernmost sections, were identical for the three different dips.

The mapped and theoretical contacts between the cinder cone and overlying gravels are compared in Fig.9. The location of the southern part of the theoretical contact relative to the mapped contact indicates that no right-lateral offset has occurred, but does not preclude a small amount of left-lateral offset. Similarly, the northern portions of the cone/fan contact indicate that no left-lateral offset has occurred, although a small amount of right-lateral displacement cannot be ruled out.

The simplest explanation is that no lateral offset has occurred, although a few meters of offset might go undetected. Imperfections in the fit of the modeled contact to the mapped contact are attributed to the difficulties in mapping the exact location of the cone/fan contact, to differences in shape between the model and the actual cinder cone, and to variations in vertical displacement along the strike of the fault.

The west fan

The west fan is characterized by a weathered surface that slopes gently to the east. The surface displays reddish brown soils, moderately- to highly-weathered granitic boulders, and is armored by platy oxidized metamorphic pebbles and cobbles.

The west fan is either exposed or buried very shallowly east of the tallest parts of the alluvial scarp. South of the cinder cone is a flat, slightly dissected surface (Qwaft(?)) on Fig.4 that might be a downdropped remnant of the west fan. This surface is characterized by patches of oxidized metamorphic pebbles, a dark tan soil, and partly weathered boulders, as is the west fan. This surface is distinctly different from the light-colored sandy surface of the adjacent south fan. The flat surface does not resemble a small alluvial fan constructed at the base of the scarp because it lacks the convex-up cross profile of fans and its clasts do not decrease in size downslope. Immediately north of the cinder cone
is the southern margin of the north fan. As is discussed below, the north fan probably is less than 26,000 years old. The west fan probably is buried shallowly by the distal margin of such a young fan.

Displacement of the west fan surface can be estimated from profiles across the tallest part of the alluvial scarp because the west fan is exposed west of the scarp and is at or near the surface to the east of the scarp. The vertical
separation of the west fan south of the cone is 28 m (Fig.8b). North of the cone
the separation is slightly more than 30 m (Fig.8c). Assuming that the west fan
lies no more than 2 m below the southern margin of the north fan, the vertical
separation of the west fan surface is estimated as 30 ± 2 m and the correspond-
ing vertical displacement as 31 ± 3 m.

The small terrace in the west segment of the cinder cone

A small uplifted stream terrace occurs in the northern half of the west
segment of the cinder cone. The scarp bounding the terrace consists of cinders,
has a slope that locally exceeds 80°, and is not faceted. The lack of facets
indicates that the terrace probably was offset during a single event. The
vertical separation and displacement on the terrace are 1.2 ± 0.3 m (Fig.8d).
Post-uplift incision of the terrace by a 1- to 2-m-wide intermittent stream has
resulted in the knickpoint in the stream profile migrating only 5 m upstream
from the fault. This erosion conceivably could have occurred in a single intense
storm, and the possibility that the terrace uplift is older than 1872 seems very
remote. As no significant earthquakes have occurred in the Fish Springs area
since 1872, the terrace displacement most likely occurred during the 1872 earth-
quake.

The north fan

The complex interaction among deposition, stream migration and downcutt-
ing, and faulting has resulted in the formation of two lobes on the north fan
(Fig.4). The younger, southern lobe lies almost entirely east of the fault. It is
characterized by bouldery ridges 1–4 m tall and numerous sandy distributary
channels. The intermittent main stream of the southern lobe has been eroding
the north slope of the cinder cone. The apex of this lobe is where the main
stream crosses the fault. The older, abandoned northern lobe exhibits a
distinct convex-up cross profile and covers about twice the area of the
southern lobe. The apex of the northern lobe is on the upthrown block, 200 to
300 m west of the fault. The northern lobe is characterized by a subdued
topography punctuated by a few partly buried bouldery ridges. The light
colored, sandy surface of the north lobe contrasts sharply with the darker
surfaces of the west fan. The maximum height of the fault scarp in the
northern lobe is approximately 3.5 m.

Three prominent terraces on the upthrown block border the main stream
through the north fan. They record previous locations of the stream. The
terraces are successively higher to the north. These surfaces show that the
main stream of the north fan migrated to the south during deposition of the
north fan. These terraces are not offset laterally by the fault.

The north fan is interpreted to have formed in the following manner. The
apex of the north lobe was initially at the fault scarp (Fig.10). Eventually,
deposition on the downthrown block reached the top of the scarp, allowing the
stream channel on the upthrown block to be backfilled. This accounts for the
Fig. 10. Inferred development of the north fan.

The presence of north lobe sediments west of the fault. Deposition on the upthrown block eventually filled the stream channel to near the level of the west fan surface. Then, either avulsion of the stream channel or stream piracy by a fault scarp gully resulted in abandonment of the apical stream channel and the start of southward channel migration. Development of the terraces was in part due to lowering of the local base level as the stream migrated towards its present position and encountered lower points on the surface of the north lobe.

The scarp of the north fan probably reflects three major displacements on the Fish Springs fault. Evidence of these displacements comes from: (1) desert varnish rings on a fault scarp boulder a few meters south of the main stream channel through the north fan; (2) knickpoints in the profile of the stream channel; and (3) displacements on sandy surfaces of the north fan.

Two distinct desert varnish rings on the fault scarp boulder (Fig. 11) suggest that the north fan has been displaced at least twice. This boulder is immediately upslope from the fault trace. Desert varnish rings on fault scarp boulders coincide with the levels of stable ancient ground surfaces (e.g., Lubetkin, 1980). Seismic displacements can lower the ground level around fault scarp
boulders, allowing varnish rings to record displacements. As measured on the
downslope side of the boulder, the lower desert varnish ring is approximately
1 m above the present ground surface, suggesting that the most recent
displacement of the ground surface at the boulder was about 1 m. This
displacement is consistent with the 1.2 ± 0.3 m displacement of the cinder
cone’s stream terrace. The higher varnish ring is approximately 0.5 m above
the lower ring, suggesting that the total displacement at the boulder in the last
two events has been about 1.5 m. However, this displacement is substantially
less than the maximum displacement of the north fan, indicating that the
maximum fan displacement represents more than two events.

Knickpoints in the present main channel of the north fan suggest that the
channel has been displaced twice. A profile along the channel shows two
distinct knickpoints upstream of the fault trace (Fig. 8e). The downstream
knickpoint is at the top of the fault scarp. The displacement at this scarp is
1.2 m, an amount consistent with the displacement on the cinder cone terrace
and at the fault scarp boulder. The upper knickpoint suggests a previous
displacement of 1.0 m. The total displacement of 2.2 m is still less than the
maximum displacement of the northern lobe, suggesting that the northern lobe
has been displaced more than twice.

The vertical displacement of the northern lobe can be inferred from profiles
F–F' through L–L' (Fig. 8). On most of the profiles, the slope of the surface east
of the fault parallels the slope west of the fault, whereas on a few profiles
(G–G', and H–H') the east slope is steeper than the west slope. However, any
slope angle differences are small, and the displacement can be estimated to
within 15%.

The profiles reveal two sets of displacements. Displacement of the terrace
located immediately north of the modern channel is approximately 2.5 m, similar to the channel displacement of 2.2 m. The mean displacement of sandy terraces further north (profiles G–G', H–H', I–I, J–J', and K–K', Fig. 8) is 3.3 m, 1½ times the channel displacement. As the modern channel apparently has been displaced twice, three displacements are indicated for the oldest parts of the north fan.

The vertical displacement during each of the last three ruptures of the north fan apparently was $1.1 \pm 0.2$ m. The most recent displacement most likely occurred in 1872. This suggests that 1872 displacement might be representative of displacements on the Fish Springs fault.

The south fan

The south fan has been deposited by Birch Creek. It is characterized by a light colored sandy surface with concentrations of unweathered gravel along its distributaries. The surface of the south fan appears to be unbroken by the fault. If the south fan surface was offset recently, as seems likely, then the record of offset may have been erased either by Birch Creek or by the recent land development at the head of the south fan.

Ages of offset features

The cinder cone has been dated radiometrically at $0.314 \pm 0.036$ m.y. ($2\sigma$) by Martel et al. (1987). The west and north fans are considered to be of Tahoe- and Tioga-age, respectively, based on a comparison (Martel, 1984) of their weathering characteristics with other Owens Valley gravels that have been dated (Lubetkin, 1980; Gillespie, 1982). The age of the Tahoe glaciation is controversial and is conservatively estimated as between 0.065 and 0.195 Ma (Martel et al., 1987). The age of the Tioga glaciation is 0.011–0.026 Ma (Birkeland et al., 1971; Smith, 1979; Atwater et al., 1986; Mezger and Burbank, 1986). The three displacements of the north fan apparently occurred after the northern lobe was abandoned, and as the northern lobe forms at least two-thirds of the north fan, the displacements probably occurred during the latter half of the Tioga interval.

DISCUSSION

Sense of movement during the late Quaternary Period

The Fish Springs fault exhibits west-side-up normal slip with no discernible strike-slip displacement. The lack of measurable lateral offset for the oldest feature of the study area, the cinder cone, and some of its youngest features, the north fan stream channels, suggests that the style of displacement has been consistent throughout the latter part of the Quaternary Period.
Average recurrence interval

Three 1872-type displacements apparently have occurred since the latter part of the Tioga glaciation (10,600–18,000 B.P.), suggesting an average recurrence interval of 3500 to 6000 years. However, from this data, the maximum recurrence interval would be estimated more conservatively at 9000 years (had the recurrence interval been calculated in 1871 only two events would have occurred in the prior 10,500 to 17,900 years). Based on the 76±8 m vertical displacement of the 0.314±0.036 Ma cinder cone, the average late Quaternary displacement rate is 0.24±0.04 mm/yr, similar to the late Cenozoic displacement rate across the Owens Valley fault zone at Big Pine. Assuming that the last three displacements of 1.1±0.2 m are average displacements, the long-term average recurrence interval for the Fish Springs fault would be 4600±1100 years (2σ).

Implications of 1872 rupture of the Fish Springs fault

Discontinuities along fault zones in some cases act as either barriers or nuclei for fault ruptures (Aki, 1979; Lindh and Boore, 1981). The discontinuity in the fault zone at Poverty Hills apparently was too small to prevent rupture through the Fish Springs area in 1872. If 1872 displacement had terminated at the Poverty Hills discontinuity, the Fish Springs fault could have become "loaded" and posed a near-future seismic hazard. However, in light of evidence for 1872 rupture of the fault and its long average recurrence interval, the fault probably is "unloaded" and a small seismic hazard in the near future. Rupture of the Fish Springs fault may have loaded the area to the northwest though, for the Coyote Warp is the site of several of the largest Owens Valley earthquakes since 1872 (Martel, 1984).

Relationship of the Fish Springs fault to the Owens Valley fault zone

The displacement behaviors of the Fish Springs fault and the Lone Pine fault, which are near opposite ends of the Owens Valley fault zone, are similar in some interesting aspects. The Lone Pine fault ruptured three times within the last 10,000 to 20,000 years (Lubetkin, 1980) and has a 5000–7000-year recurrence interval (L.K.C. Lubetkin, written commun., 1981). The Fish Springs fault apparently has ruptured three times in the last 10,600 to 18,000 years and has a long-term average recurrence interval of 4600±1100 years. Perhaps ruptures of the Fish Springs fault are associated with ruptures of the entire Owens Valley fault zone.

The structure and displacement on the Fish Springs fault may provide some insight into the regional stresses acting on the Owens Valley fault zone. The pure normal slip on the north-striking fault suggests that the maximum horizontal compression may be oriented north–south. A different orientation could cause lateral slip on the fault. Additionally, both the Fish Springs cinder cone and Red Mountain (another cinder cone) are linked to Crater Mountain.
by north-striking normal faults. Such alignments of cinder cones tend to parallel the maximum horizontal compression (Nakamura et al., 1977). Carver (1970) concluded that the late Quaternary maximum horizontal compressive stress at the south end of Owens Valley has been oriented approximately north–south based on the north–south orientation of faults with pure dip-slip displacement and on the north–south orientation of desiccation cracks on the Owens Lake playa. A north–south orientation of the maximum horizontal stress is significantly different from the N33°E orientation inferred by Zoback and Zoback (1980). Although right-lateral, normal oblique slip on the Owens Valley fault zone is consistent with both stress regimes, a N33°E maximum horizontal stress orientation is consistent with neither the observations at Fish Springs nor those in southern Owens Valley by Carver. Because the maximum horizontal compressive stress in California west of the Sierra Nevada is approximately north–south (Zoback and Zoback, 1980), perhaps Owens Valley is also in that stress regime.

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