Geologic Reconnaissance of the Granite Range Fault Zone and Adjacent Areas, Washoe County, Nevada

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INTRODUCTION

The Granite Range is a large northwest-trending horst block separating the Black Rock and Smoke Creek Deserts and associated basins in northwest Nevada. The southwest flank of the Granite Range is bounded by a major southwest-dipping normal-dextral fault zone that accommodates several kilometers of displacement. This fault zone is here referred to as the Granite Range fault zone. South of this fault zone lies the northern part of the Smoke Creek desert, which is a large composite basin consisting of numerous fault blocks and half grabens. Previous work in this area has been limited to regional reconnaissance (Bonham and Papke, 1969) and preliminary studies of several geothermal fields (e.g., Keller and Grose, 1978).

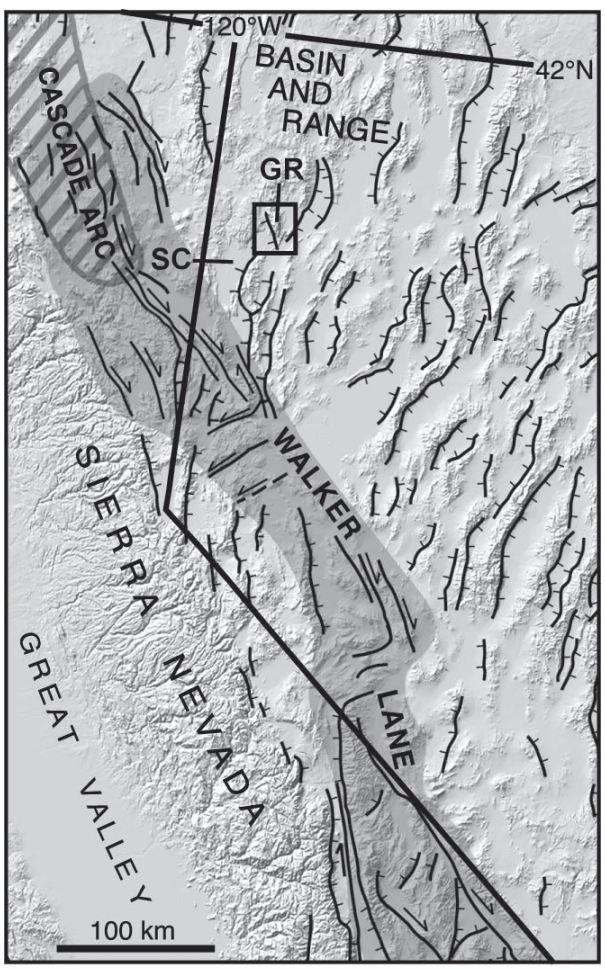

Figure 1. Regional map showing Granite Range (GR) and Smoke Creek Desert (SC) relative to the Walker Lane and major faults. Box surrounds map area.

The Granite Range-Smoke Creek Desert area lies directly north of the northern part of the Walker Lane (e.g., Stewart, 1988), which is a system of right-lateral strike-slip faults that accommodate ~10–25% of the Pacific – North American plate motion (Bennett and others, 2003; Hammond and Thatcher, 2004). The system of right-lateral strike-slip faults within the Walker Lane loses displacement to the northwest in western Nevada and northeastern California (Faulds and others, 2003; 2005). Much of this displacement diffuses into systems of northerly striking normal faults within the Great Basin, including those that bound large basins in both the Smoke Creek and Black Rock Desert regions. This transfer of strain may be driving much of the ongoing extension and geothermal activity within the northern Great Basin (fig. 1; Faulds and others, 2004). In this report, we briefly describe the stratigraphic and structural setting of the southwest flank of the Granite Range and northernmost part of the Smoke Creek Desert and discuss constraints on the timing of deformation.

GEOLOGIC SETTING

Stratigraphic Framework

The stratigraphy of the Granite Range-northern Smoke Creek Desert area consists of middle to late Tertiary volcanic and sedimentary rocks that rest directly on Mesozoic granitic and Permian-Triassic metamorphic basement (plate 1). Roughly in ascending order, the Tertiary section includes sequences of 1) interbedded tuffaceous siltstone (Tts on plate 1), sandstone, conglomerate (Tc), and sparse ash-flow tuff; 2) dacite lavas (Td); 3) rhyolite lavas and domes (Tr); and 4) olivine basalt to basaltic andesite flows (Tb). Most of these units interfinger with one another, generating locally complex stratigraphic relationships. Several tephras (i.e., ash-fall deposits) are intercalated within the tuffaceous siltstone. In addition, granitic detritus is locally common within the sandstone and conglomerate. Some of the sandstone, for example, in the northern part of Bloody Point Ridge is composed almost entirely of grussy granitic material (fig. 2).

Figure 2. Abundant granitic detritus in Tts unit.

On the basis of similarities with sections described elsewhere in western Nevada (e.g., Stewart and Perkins, 1999; Trexler and others, 2000; Henry and Perkins, 2001; Faulds and others, 2002, 2003; Faulds and Garside, 2003), most of the Tertiary rocks in this area are probably middle to late Miocene in age. However, some of the basalts in the western part of the map area (Squaw Valley area) may be younger (late Pliocene?), as evidenced by several relatively well preserved volcanic centers in the nearby Buffalo Hills.

The Tertiary rocks are overlain by Quaternary alluvial fans, lacustrine deposits associated with late Pleistocene Lake Lahontan, and eolian deposits. Alluvial fans comprise most of the Granite Range piedmont. Along the southern part of the range, fan deposits consist primarily of granitic detritus, with clasts up to boulder size in a grussy matrix. Northwestward, fan deposits have a generally increasing component of Tertiary volcanic clasts. Lacustrine deposits crop out only along the northern fringe of the Smoke Creek Desert and associated playa. These include silts and fine-grained sands, beach gravel, and reworked fan deposits. Eolian deposits occur throughout the area but are most common along fan toes and the margin of the basin floor (Qpm and adjoining areas, plate 1).

Structural Framework

The structural framework of the area is dominated by the north- to northwest-striking, moderately to steeply west- to southwest-dipping Granite Range fault zone (plate 1). The Granite Range is a large gently northeast-tilted horst block bounded by the Granite Range fault zone on the southwest and major north-northeast to north-northwest-striking normal fault zones on the east and northeast. Several gently (<25°) to locally moderately (~40°) tilted, small fault blocks (e.g., Bloody Point Ridge) are found within the hanging wall of the Granite Range fault zone. Most of the fault blocks in the central part of the map area are tilted to the east or northeast (cross sections A–A′ and B–B′), whereas blocks within the northern and southern parts of the area are tilted southwest (plate 1).

Although its main strand clearly bounds the abrupt southwest front of the Granite Range (fig. 3), the Granite Range fault zone includes an ~3 km wide zone of en echelon faults that cut Tertiary volcanic rocks and Quaternary piedmont deposits in both the Squaw Valley area and

Figure 3. Looking north at the steep front of the Granite Range. About 1,500 m of relief separate the basin in the foreground from the high peaks. The frontal facets are some of the highest found in the Great Basin.

northernmost part of the Smoke Creek Desert (plate 1). Several relatively minor northeast-dipping antithetic faults occur within this broad fault zone. A more significant east-dipping normal fault zone bounds Squaw Valley on the west but appears to terminate northward against the Granite Range fault zone. The gently east-tilted Bloody Point fault block is bounded on the west by a major west-dipping, northerly strike normal fault zone, which also appears to merge northward with the Granite Range fault zone.

Exposures of actual fault surfaces are sparse within the map area. Only three possible surfaces were observed; two along the main strand of the Granite Range fault zone and one on a subsidiary fault (fig. 4). In the southern part of the map area, late Quaternary faults that extend along the flank of the Granite Range have been obscured by the effects of Lake Lahontan shoreline processes and eolian deposition. Because of the limited exposures of fault surfaces, inferences on fault geometry and kinematics must be largely deduced from map patterns.

The main strand of the Granite Range fault zone contains at least three distinct right steps consisting of relatively short northerly striking segments that link longer northwest-striking segments (figs. 5 and 6; plate 1). Some of the right steps are associated with major north to north-northeast-striking down-to-the-west normal faults that continue into the footwall and penetrate the interior of the Granite Range, where they mark discrete down-to-the-west topographic steps (fig. 5). The westernmost step is the most profound and marks the westernmost exposure of granitic-metamorphic basement, which essentially corresponds to the western edge of the Granite Range.

This pattern of faulting suggests that the Granite Range fault zone accommodates a component of dextral slip, with each right step generating a small pull-apart (fig. 6). Alternatively, the north-striking segments may postdate and offset the northwest-striking strands, implying an earlier episode of NE-SW extension and a later interval of E–W extension. However, the north-striking segments do not appear to project into the hanging wall of the Granite Range fault zone; thus, this interpretation seems unlikely. In any case, the apparent lack of deep basins within the inferred pull-apart zones suggests that the amount of dextral displacement is not particularly large. Normal slip has presumably dominated the Granite Range fault zone and exceeded 1,500 m in the central part of the map area (fig. 3), as evidenced by comparing elevations of the highest exposed granite in the footwall with that of the Tertiary-Cretaceous nonconformity in the Bloody Point fault block. The magnitude of dextral displacement is more difficult to estimate. One possibility is that the west-dipping normal fault bounding the Bloody Point block on the west was once continuous with the similarly oriented fault associated with the large right step in the range front just to the north (plate 1; fig. 6). If correct, the present locations of these faults implies ~1 km of right-lateral displacement.

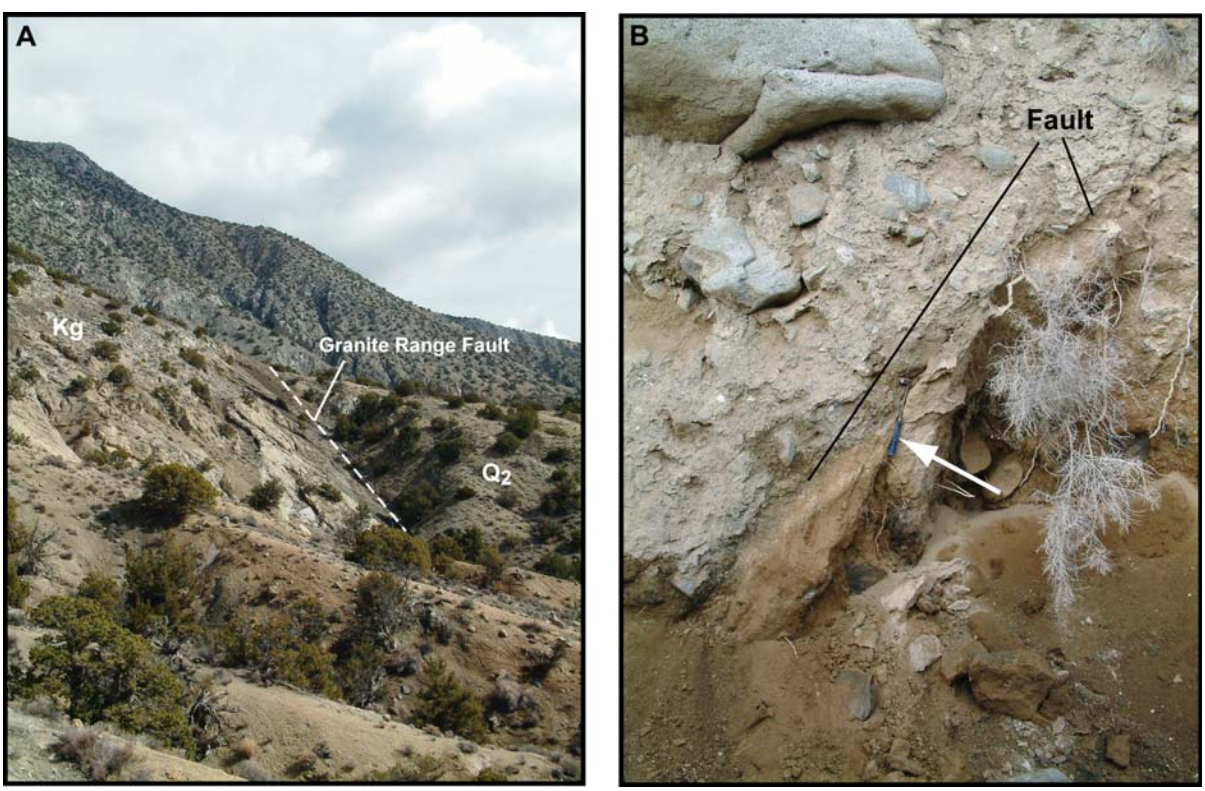

Figure 4. Exposed fault surfaces in map area. A. Main strand of Granite Range fault zone dipping ~58° southwest. Kg, granitic basement; Q_2, Quaternary alluvial fan. B. Minor fault cutting alluvial fan deposits in Granite Range piedmont. Note hammer for scale (white arrow).

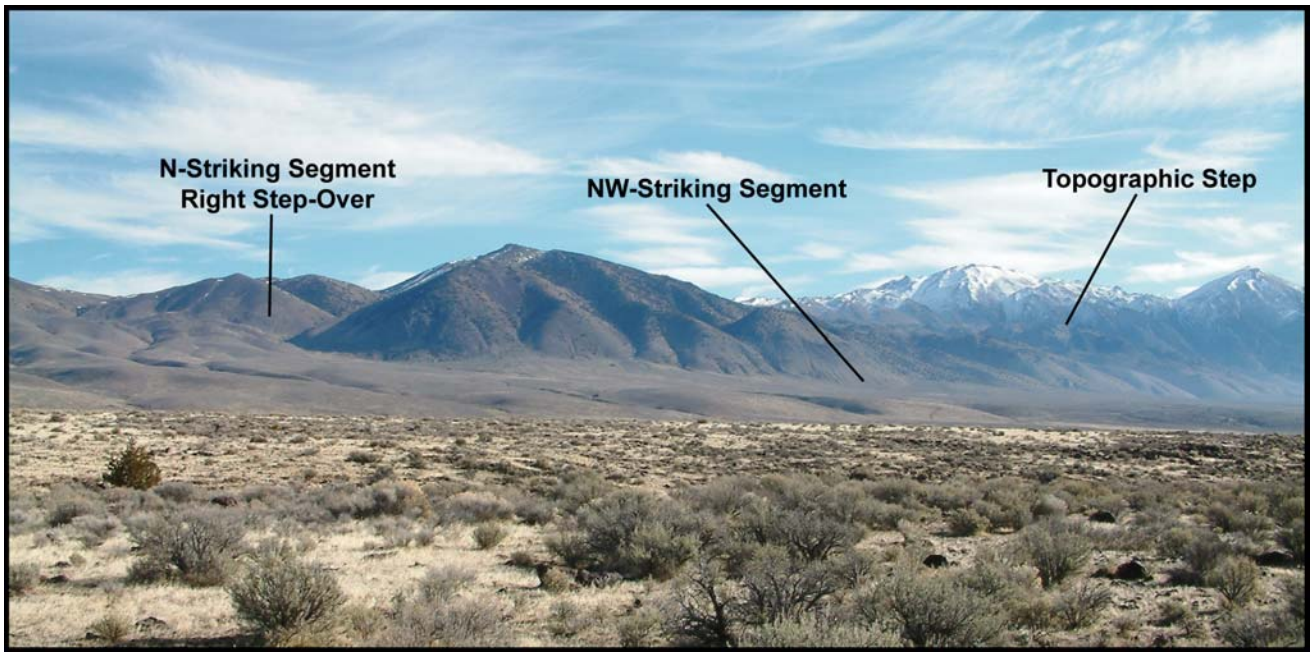

Figure 5. View looking east at Granite Range showing right-stepping, segmented nature of fault zone and topographic steps in range associated with northerly striking, west-dipping normal faults.

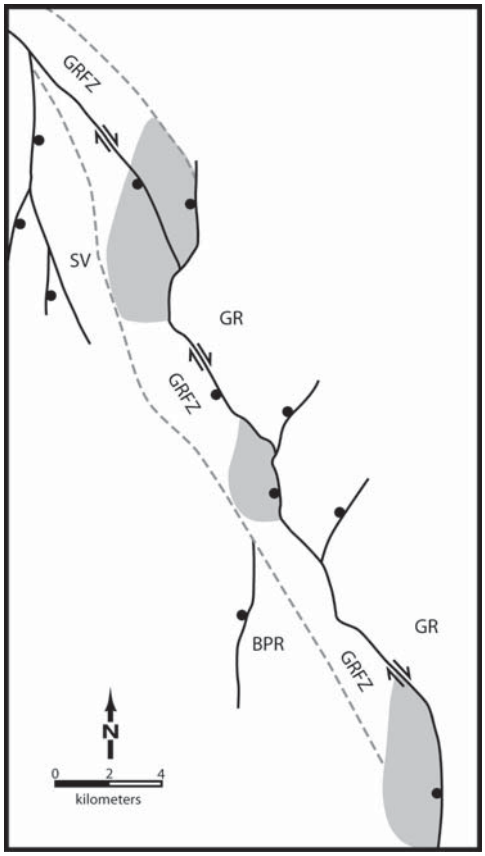

Figure 6. Generalized geometry of Granite Range fault zone showing northerly striking right steps that link northwest-striking segments. Shaded areas depict small pull-aparts developed at right steps. BPR, Bloody Point ridge; GR, Granite Range; GRFZ, Granite Range fault zone bounded by dashed gray line; SV, Squaw Valley.

Geomorphology and Quaternary Deposits

The geomorphology of the Granite Range and surrounding area is largely related to an abrupt relatively youthful range-front fault zone and the influence of pluvial Lake Lahontan. In an analysis of the relations between range-front facets and fault activity, dePolo (1998) interpreted the western front of the Granite Range (fig. 3) to have the highest frontal facet of his entire data set, and thus inferred that the fault has a relatively high slip rate (see discussion below).

Late Pleistocene Lake Lahontan reached its most recent highstand about 13,000 years ago. The lake receded quickly and dried up completely within 2000 years. Due to isostatic rebound, highstand elevations vary around the Lahontan basin and are highest (~1340 m) in the central part of the basin (Adams and others, 1999). In the Granite Range area, wavecut shorelines and lacustrine deposits extend up to about 1333 m. At its peak, the lake extended into the footwall of the fault zone in the southern part of the range (plate 1). During periods of desiccation, the lake floor in the Smoke Creek Desert provided a source of abundant eolian material.

Timing of Deformation

Several features within the Miocene strata indicate synextensional deformation. These include: 1) a decrease in tilt up-section (i.e., tilt fanning), as best expressed in the northern part of the Bloody Point block (cross section B–B′); 2) an angular unconformity between younger basalts and older tuffaceous rocks exposed in the easternmost fault block of Tertiary rocks within the map area (fig. 7); and 3) abundant granitic detritus within parts of the section, including the section in the Bloody Point block displaying tilt fanning (fig. 2). Although no radiometric ages or

geochemical correlations of tephras (e.g., Perkins and Nash, 2002) have been determined in the map area, the timing of deformation in nearby parts of western Nevada (e.g., Trexler and others, 2000; Henry and Perkins, 2001; Colgan and others, 2004) suggests that extension in the Granite Range area is younger than 12 Ma. Considering the inferred timing of major strike-slip faulting in the region (e.g., Cashman and Fontaine, 2000; Faulds and others, 2005; Henry and others, 2006), much of the deformation in the Granite Range area may have begun since 9 to 3 Ma. Radiometric dating and/or geochemical correlations of tephras are clearly needed to place tight age constraints on the onset of deformation in the area. Multiple fault scarps within the piedmont, including significant offset of late Pleistocene deposits, clearly indicate, however, that deformation has continued into the Quaternary.

The Granite Range fault zone cuts late Pleistocene deposits in several locations, but nowhere does it clearly accommodate offset of deposits younger than the 13-ka Lake Lahontan highstand. Based on our reconnaissance study, we conclude that the most recent surface-rupturing event on the fault predates the 13-ka highstand. Without more detailed study, it is difficult to preclude small displacements (<0.5 m) that postdate the highstand, but we are fairly confident that the fault has not ruptured with displacements of 1 m or more during the Holocene. The fault appears to cut all deposits that predate the highstand, so we loosely estimate that the most recent large seismic event, associated with surface rupturing, occurred 13 to 20 thousand years ago.

The USGS Faults and Fold Database of the United States includes the following report for the Western Granite Range fault (referred to as the Granite Range fault zone in this report)

http://qfaults.cr.usgs.gov/faults/FMPro?-db=us%20web%20fault%20database.fp5&-format=record3%5fdetail.htm&-lay=scientist%20input&-recid=34491&-find=.

The compilers of that report (Adams and Sawyer) estimated the slip rate of the fault between 0.2 and 1.0 mm/yr, and they included the following statement:

> *Comments:* No detailed data exist to determine slip rates for this fault. dePolo (1998 #2845) assigned a reconnaissance vertical slip rate of 1.503 mm/yr based on an empirical relationship between his preferred maximum basal facet height and vertical slip rate. The size of the facets (tens to hundreds of meters, as measured from topographic maps) indicates they are the result of many seismic cycles, and thus the derived slip rate reflects a long-term average. However, the late Quaternary characteristics of this fault (overall geomorphic expression, continuity of scarps, age of faulted deposits, etc.) suggest that the slip rate during this period is of a lesser magnitude. Accordingly, the 0.2–1.0 mm/yr slip-rate category has been assigned to this fault.

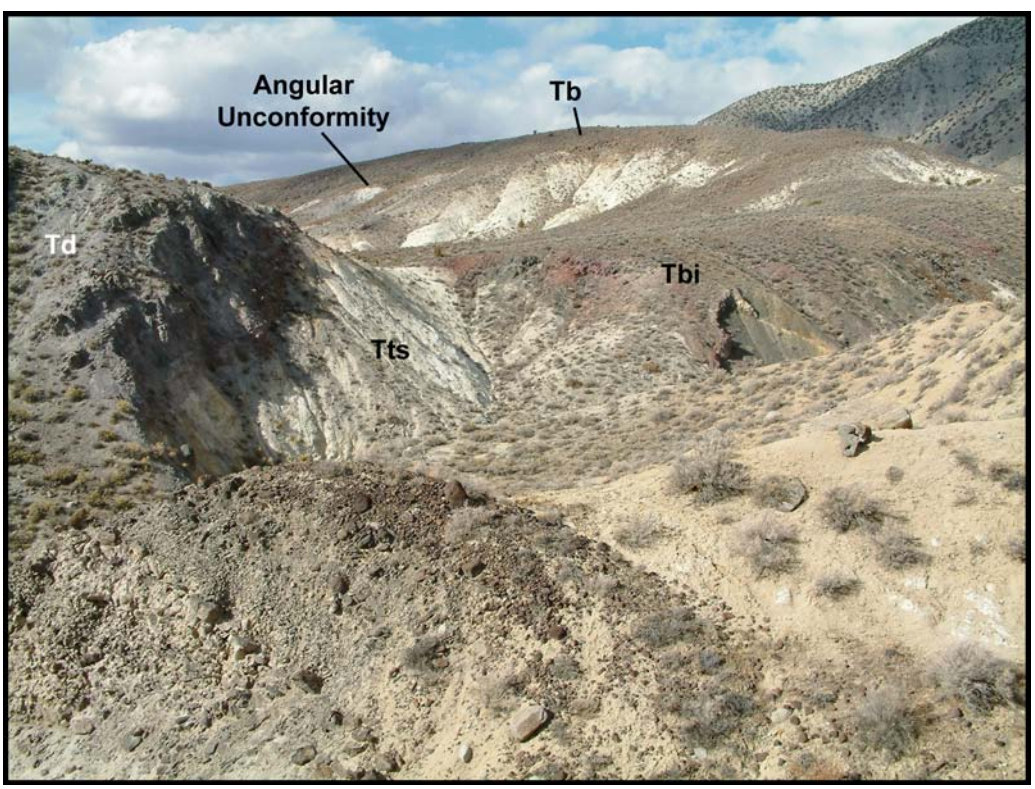

Figure 7. Angular unconformity developed between capping basalt lavas (Tb) that are dipping ~20° to the southwest and underlying tuffaceous sedimentary rocks (Tts) dipping ~40°. This exposure lies in the easternmost block of Tertiary volcanic rocks within the map area (view looking northwest). Td, dacite lavas; Tbi, basalt intrusion.

Based on the apparent lack of a significant post-13-ka event, we estimate the recent slip rate of the fault over the latest Pleistocene to Holocene to be near the lower end of this range, possibly closer to 0.1 mm/yr. The height and steepness of the range front (fig. 3) support a higher long-term rate, so this fault may be an example of non-uniform activity.

ACKNOWLEDGMENTS

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