Text and references for Nevada Bureau of Mines and Geology Map 140

GEOLOGIC MAP OF THE GOVERNMENT WASH QUADRANGLE

CLARK COUNTY, NEVADA

by

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INTRODUCTION

The Government Wash 7.5' Quadrangle is located north of the western part of Lake Mead in southern Nevada. The Lake Mead area, between the Grand Wash Cliffs and Las Vegas, Nevada, at about the latitude of 36° N, lies in the central Basin and Range province (terminology of Wernicke, 1992) between (and south of) the Sevier orogenic belt and the Colorado Plateau. A marked change in the style of Basin and Range extension occurs in the Lake Mead area. To the south, the metamorphic core complexes of the Colorado River extensional corridor expose ductilely deformed rocks in the lower plates of regional detachment faults (Davis and others, 1980; 1982; 1986; Howard and John, 1987; many others) and major strike-slip transfer zones (classification of Faulds and Varga, 1998) appear to be rare. For 250 km to the north, exposures of ductilely deformed lower-plate rocks are rare and strike-slip transfer zones are common (Duebendorfer and Black, 1992). The Lake Mead area contains core complex-type detachment systems, the Saddle Island and Lakeside Mine (Gold Butte block) faults, and two of the largest strike-slip transfer faults in the Basin and Range province. These faults, the Lake Mead fault system and the Las Vegas Valley shear zone, mark the northern terminus of the northern Colorado River extensional corridor (Howard and John, 1987; Faulds and others, 1990, 1992).

The Government Wash Quadrangle can be divided into two physiographic and structural domains. North of the right-slip Las Vegas Valley shear zone, the Gale Hills average about 900 m in elevation and consist of a thick section of Miocene sedimentary rocks that overlie Mesozoic rocks deposited in the foreland of the Sevier thrust belt (farther north, in the Muddy Mountains, these same Miocene rocks overlie Paleozoic rocks of the Muddy Mountains thrust allochthon). South of the Las Vegas Valley shear zone is a topographically low (300–500 m) and relatively featureless terrain developed on the Boulder basin (Longwell, 1936). With the exception of areally limited exposures in the upper and lower plates of the Saddle Island detachment fault (fig. 1), pre-Tertiary rocks are not exposed south of the Las Vegas Valley shear zone in Boulder basin. Because pre-Tertiary rocks are not exposed here, and because it is possible that the Saddle Island detachment may underlie much of Boulder basin (Duebendorfer and Wallin, 1991), the sub-Tertiary geology of the southern half of the Government Wash Quadrangle is not known. Possibilities include: (1) the entire Paleozoic and Mesozoic section, exposed at Frenchman Mountain about 15 km west of the quadrangle, is present, (2) highly dismembered, fault-bounded blocks of Paleozoic and Mesozoic rock may occur at depth, and (3) the Tertiary section could be juxtaposed against Proterozoic crystalline rocks along the Saddle Island detachment, which projects northward in the subsurface toward the Government Wash Quadrangle, due to complete tectonic removal of the Paleozoic and Mesozoic sections.

TERTIARY STRATIGRAPHY

Tertiary rocks in the Government Wash Quadrangle comprise three unconformity-bounded sequences (Bohannon, 1983, 1984). These are the Horse Spring Formation (26–13 Ma), the informally named red sandstone unit of Bohannon (1984) (12.1–8.5 Ma), and the Muddy Creek Formation (8.5–5.8 Ma; Lucchitta, 1979; Feuerbach and others, 1991).

Horse Spring Formation

The Horse Spring Formation is divided into four lithologically distinct members (Bohannon, 1984). The lowest member, the Rainbow Gardens (26–18 Ma; Bohannon, 1984; Beard, 1996), records no evidence for active faulting during its deposition and is considered to predate extension (Bohannon, 1984; Beard, 1996). The

Rainbow Gardens Member is not present in the Government Wash Quadrangle, but is exposed in the Callville Quadrangle to the east (Anderson, 2003). The Rainbow Gardens Member consists of a thin basal conglomerate overlain by gypsum and limestone. Regionally, the Rainbow Gardens Member is interpreted as a shallow basin deposit (Bohannon, 1984; Rice, 1987) that accumulated on a low-relief surface at the southern margin of extensive volcanism in the Caliente, Nevada, area (Beard, 1996).

The Thumb Member (17–13.5 Ma; Bohannon, 1984) of the Horse Spring Formation comprises a complex sequence of sandstone, siltstone, gypsiferous mudstone, conglomerate, and megabreccia that was deposited in a variety of terrigenous environments including distal alluvial fan, fluvial channel and floodplain, playa, and lacustrine. The Thumb sections north and south of the Las Vegas Valley shear zone differ markedly. North of the Las Vegas Valley shear zone, the Thumb Member is dominated by boulder-cobble conglomerate, sandstone, and siltstone with a few prominent green tuff beds within the sandstone-shale sequence. Some of the thickest sections of conglomerate are mapped separately (Thtc, Thumb conglomerate), but appreciable thicknesses of conglomerate also occur within the unit mapped as Tht. Conglomeratic layers within the sandstone-dominated parts of the Thumb typically grade laterally and abruptly into sandstone and siltstone. No megabreccia deposits of Proterozoic crystalline rocks are present north of the Las Vegas Valley shear zone, but large landslide blocks of Mississippian Monte Cristo Limestone and the Pennsylvanian Bird Spring Formation are present in the Government Wash and Callville Quadrangles. South of the Las Vegas Valley shear zone, the Thumb Member is dominated by red gypsiferous siltstone; sandstone is present only locally and conglomerate is absent. West and north of Black Mesa, the

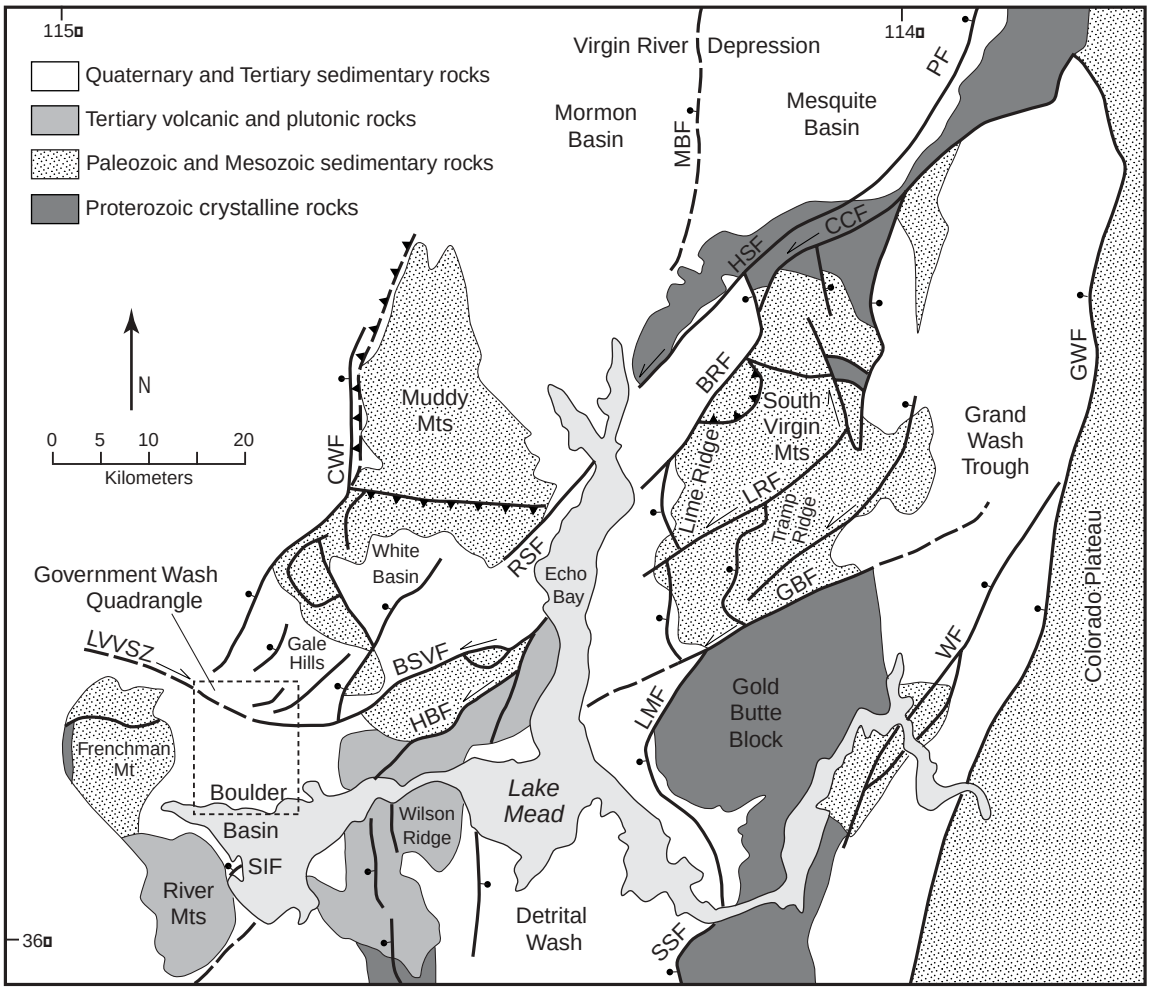

Figure 1. Generalized geologic map of the Lake Mead area showing major faults and location of the Government Wash Quadrangle. Bar and ball indicates downthrown side of normal faults, sawteeth on upper plate of thrust faults, arrows show movement sense along strike-slip faults. Unadorned faults indicate complex oblique-slip or unknown movement sense. BRF=Bitter Ridge fault, BSVF=Bitter Spring Valley fault, CCF=Cabin Canyon fault, CWF=California Wash fault, GBF=Gold Butte fault, GWF=Grand Wash fault, HBF=Hamblin Bay fault, HSF=Hen Spring fault, LMF=Lakeside Mine fault, LRF=Lime Ridge fault, LVVSZ=Las Vegas Valley shear zone, MBF=Mormon Basin fault, PF=Piedmont fault, RSF=Rogers Spring fault, SIF=Saddle Island fault, SSF=Salt Spring fault; WF=Wheeler Ridge fault.

Thumb Member contains megabreccia blocks of Proterozoic crystalline rocks up to several tens of meters in size. These megabreccias are interpreted as proximal large rock avalanche deposits and record early development of extension-related topographic relief in the Lake Mead region. The source of the megabreccias was probably the Gold Butte block, about 50 km to the east (Longwell, 1974; Parolini, 1986; Rowland and others, 1990). The megabreccia deposits were transported to their present location by movement along normal and strike-slip faults (e.g., Duebendorfer and others, 1998)

The Bitter Ridge Limestone Member (13.5–13.0 Ma) of the Horse Spring Formation consists of uniform crystalline limestone with minor calcareous sandstone and siltstone. It is confined to the area north of the Las Vegas Valley shear zone. The unit was deposited in a large lake that formed north of the Las Vegas Valley and Lake Mead fault systems (Bohannon, 1984).

The Lovell Wash Member (13.4–13.0 Ma; Bohannon, 1984; Harlan and others, 1998), consists principally of limestone and dolostone with interbedded air-fall tuffs and tuffaceous sandstones. Although the Lovell Wash Member is largely restricted to the area south of the Las Vegas Valley shear zone in the Government Wash Quadrangle, it crops out over a large area north of the shear zone in the Callville Bay Quadrangle directly to the east. An olivine phyric basalt flow interbedded with tuffaceous and calcareous sandstone and siltstone in the upper part of the of the Lovell Wash Member of the Horse Spring Formation yielded a whole-rock $^{40}Ar/^{39}Ar$ plateau date of 13.17±0.10 Ma (Harlan and others, 1998). An aphanitic basalt within the unit yielded a whole-rock $^{40}Ar/^{39}Ar$ isochron date of 13.28±0.09 Ma. These mafic volcanic rocks occur only south of the Las Vegas Valley shear zone despite the fact that the thickest Lovell Wash section lies north of the shear zone in the Callville Bay Quadrangle.

Red Sandstone Unit of Boulder Basin

The Horse Spring Formation is overlain by the informally named red sandstone unit of Bohannon (1984), a heterogeneous unit of conglomerate, sandstone, siltstone, claystone, air-fall tuff and tuffaceous sandstone. Within the Government Wash Quadrangle, the red sandstone unit is overlain by, and locally interbedded with, the volcanic rocks of Callville Mesa. The largest exposures of red sandstone unit are present south of the Las Vegas Valley shear zone; however, scattered exposures are present directly north of the shear zone in the northwest part of the quadrangle. A conglomeratic facies directly adjacent to the Las Vegas Valley shear zone contains clasts of Bitter Ridge Limestone Member, indicating a source to the north. In the central part of the map area, the unit is a light brown to tan medium-grained sandstone. Near Black Mesa, the unit is dominated by fine-grained sandstone and gypsiferous siltstone. South of Black Mesa, the red sandstone unit contains megabreccia deposits that contain clasts of Proterozoic quartzofeldspathic orthogneiss and amphibolite, and blocks of hornblende-biotite dacite dated at 12.93±0.10 Ma (Harlan and others, 1998). The clast composition in the red sandstone megabreccia deposits differs strikingly from those of the Thumb Member, which are dominated by 1.4 Ga megacrystic granites and migmatitic pelitic gneiss. In addition, the red sandstone megabreccia deposits contain abundant fracture networks that are coated with riebeckite and edenite of probable hydrothermal origin. Similar vein networks are present within the Wilson Ridge pluton at the northern end of the Black Mountains (Feuerbach, 1986). These observations suggest different source areas for the two megabreccia deposits—Gold Butte for the Thumb megabreccias and the northern Black Mountains for the red sandstone unit.

In the central part of the map area, the red sandstone unit overlies the Lovell Wash Member with no apparent angular discordance. Elsewhere, the unit lies with variable angular discordance on older rocks including the Thumb Member. In places, the red sandstone unit is strongly (50° upright to 85° overturned) tilted to the south and east. Dip magnitudes in the unit locally decrease systematically up section and there appears to be an intraformational unconformity about 2 km west of the northern part of Black Mesa. The unit is cut by many faults that do not cut the overlying Muddy Creek Formation.

Volcanic rocks of Callville Mesa overlie and are interbedded with the uppermost parts of the red sandstone unit. This unit consists of basaltic andesite flows, breccias, and rare plugs and is restricted to the Boulder basin (the area south of the Las Vegas Valley shear zone, east of Frenchman Mountain, and west of Hamblin Mountain). Dates on the unit range from 11.41±0.14 ($^{40}Ar/^{39}Ar$ whole rock, Harlan and others, 1998) to 8.49±0.20 (K/Ar plagioclase, Feuerbach and others, 1991).

The above observations indicate that the period between 12 and about 10 Ma was characterized by basin development and disruption, volcanism, normal faulting, and stratal tilting and was the most tectonically active period in the western Lake Mead area. Duebendorfer and Wallin (1991) suggested that the red sandstone basin was formed as an extensional basin in the upper plate of the Saddle Island detachment during that time interval.

Muddy Creek Formation

The late Miocene Muddy Creek Formation (8.5–5.8 Ma, Damon and others, 1978; Feuerbach and others, 1991) contains coarse boulder-cobble conglomerate, sandstone, siltstone, and gypsum. Exposures south of the Las Vegas Valley shear zone probably represent continued filling of the red sandstone basin that formed between 12 and 10 Ma. The Muddy Creek Formation is separated into a lower unit composed of claystone, siltstone, gypsiferous siltstone and minor sandstone and conglomerate, a middle unit that consists of gypsum and gypsiferous mudstone, and an upper unit dominated by boulder-cobble conglomerate with minor sandstone and siltstone. The Muddy Creek Formation is interpreted as late extensional basin fill.

STRUCTURE

The Government Wash Quadrangle can be divided into two principal structural and lithological domains, separated by the Las Vegas Valley shear zone. North of the shear zone, the Gale Hills are characterized by highly faulted and folded Tertiary and Mesozoic rocks. Mesozoic rocks are exposed in a west-narrowing, fault-bounded and uplifted block that is fundamentally anticlinal (note opposing dips in Thumb Member strata on opposite sides of the uplifted block of Mesozoic rocks; cross section A–A´). Highly sheared Paleozoic and Triassic rocks are exposed in a narrow band interpreted as marking the trace of the Las Vegas Valley shear zone. Fault orientations are highly variable, but northeast to east-northeast strikes dominate, with the exception of strands of the Las Vegas Valley shear zone, where strikes are west-northwest. The traces of fold axial surfaces range from northeast to east-northeast in the extreme northern part of the quadrangle to east-west and west-northwest just north of the Las Vegas Valley shear zone.

Paleozoic and Mesozoic rocks are not exposed south of the Las Vegas Valley shear zone where late Tertiary and Quaternary strata, known to either postdate or bracket only the latest part of the deformational history, dominate. Structural trends south of the Las Vegas Valley shear zone are highly variable. The most conspicuous structure south of the shear zone is an east-trending band of uplifted and internally deformed strata of the Thumb and Lovell Wash members of the Horse Spring Formation and the red sandstone unit. This band of uplifted strata extends east from the western boundary of the quadrangle to Black Mesa and west for at least 3 km into the adjacent Frenchman Mountain Quadrangle (Castor and others, 2000). The trend of this structure changes abruptly to a north-south orientation near Black Mesa. Coincident with this change in orientation is a north-trending anticline that is overturned to the east.

Las Vegas Valley shear zone

The principal structure in the Government Wash Quadrangle is the Las Vegas Valley shear zone, which has well documented right slip of 48±7 km based on stratigraphic correlations and offset of Mesozoic thrust faults (Longwell, 1960; 1974; Burchfiel, 1965; Fleck, 1970; Wernicke and others, 1988). Most or all activity on the Las Vegas Valley shear zone appears to be younger than 15 Ma (Fleck, 1970). Duebendorfer and Wallin (1991) suggested that significant movement may postdate 12 Ma. Paleomagnetic data from north of the Las Vegas Valley shear zone (Sonder and others, 1989, 1994; Jones and others, 1991) show that rocks as young as 14 Ma are strongly rotated in a clockwise sense.

In the eastern and central parts of the quadrangle, the shear zone consists of a series of highly brecciated fault slices that contain Permian and Triassic rocks. The principal displacement zone is interpreted to coincide with fault contacts (displaced by later left-slip faults) that separate the Thumb Member from the narrow band of intensely brecciated Permian and Triassic rocks. The presence of structurally deep-level rocks at the surface requires a substantial component of uplift within the shear zone. Dips of individual fault strands range from subvertical near the west end of the band of Permian and Triassic rocks to less than 50° north in eastern part of the map area. Local down-dip fault striae that overprint larger subhorizontal grooves and mullions suggest that the shear zone may have been reactivated as a reverse fault associated with post-red sandstone, north-south shortening (discussed below).

The extension of the Las Vegas Valley shear zone to the northwest is uncertain due to either burial beneath alluvium or the lack of discrete faults. The lack of faults in the Thumb Member and the red sandstone unit in the northwest part of the quadrangle may be a function of lithology. Both units in this area consist largely of strongly tilted and folded and weakly to non-indurated gypsiferous siltstone. It is possible that deformation associated with movement on the shear zone is penetrative throughout these rheologically weak units.

Duebendorfer and Black (1992) interpreted the Las Vegas Valley shear zone as an extensional transfer fault between differentially extended blocks following the early suggestions of Davis and Burchfiel (1973) and Wernicke and others (1984). Displacement along the Las Vegas Valley shear zone appears to decrease to zero near Hamblin Mountain and increase systematically to the west as suggested by Duebendorfer and Black (1992) and corroborated by the paleomagnetic studies of Sonder and others (1994).

Other faults

Steeply dipping, west-northwest-striking faults generally accommodated normal or dextral movement, whereas moderately dipping, west-striking faults are principally reverse faults (Duebendorfer and Simpson, 1994). Right slip faults are restricted to a narrow zone directly adjacent to the Las Vegas Valley shear zone. West-northwest-striking faults of all types are cut by northeast-striking faults.

Northeast-striking faults are the most abundant within the quadrangle and range in dip from subvertical to moderately east- and west-dipping. Steeply dipping faults have subhorizontal striae with left-slip kinematic indicators and moderately dipping faults have normal slip displacement (Duebendorfer and Simpson, 1994). Regionally, northeast-striking faults, north of the Government Wash Quadrangle (Bohannon, 1983) become oriented more easterly toward the Las Vegas Valley shear zone, probably due to clockwise vertical axis rotations associated with the shear zone (Sonder and others, 1994). These faults cut the Las Vegas Valley shear zone, have subhorizontal striae, and exhibit left separation, indicating that they are left-slip faults.

In the central part of the quadrangle, a zone of west- to west-northwest-striking faults separates subvertical panels of internally folded and faulted rocks of the Thumb and Lovell Wash Members and red sandstone unit to the south from the Muddy Creek Formation to the north. The internal structure of this fault zone and its structurally high position are similar to that of the uplifted Permian and Triassic rocks that mark the inferred trace of the Las Vegas Valley shear zone 3–4 km to the north. A west-northwest-striking, hypabyssal hornblende-plagioclase "diabase" dike (unit Ti on map) occurs within this fault zone. The fault zone exhibits north-side-down separation but no fault striae were observed.

Folds

Most folds in the Government Wash Quadrangle plunge 20–40°east. Tight to nearly isoclinal folds are best developed within 500 m north of the Las Vegas Valley shear zone. East-trending folds with a more open profile are present both north and south of the shear zone. Rocks as young as the Muddy Creek Formation are involved in folding and folds are spatially associated with reverse faults that also cut the Muddy Creek Formation. Crosscutting relations suggest that the folds and reverse faults are contemporaneous with one another but predated, or were in part synchronous with, the northeast-striking left-slip faults.

An enigmatic, map-scale, steeply plunging fold is present northwest of Black Mesa. Here, rocks of the Lovell Wash and Thumb Members are rotated 90° from nearly east striking and subvertical to north striking and overturned to the east. The origin of this fold is unknown.

Structural Chronology

All structures described above deform rocks as young as the 12- to 10-Ma red sandstone unit. Because the timing of initiation of these structures cannot be determined, some may have been active contemporaneously. Unambiguous crosscutting relationships exist, however, that permit development of the following structural chronology (from oldest to youngest) based on the *most recent phase* of movement of each set: (1) north- to northeast-striking normal faults, (2) right-slip faults associated with and including the Las Vegas Valley shear zone, (3) east-striking reverse faults and east-trending folds, including reactivation of the Las Vegas valley shear zone as a reverse fault, and (4) northeast-striking left-slip faults. The latter two events may, in part, be contemporaneous.

Evidence for early normal faulting is indirect, but is inferred based on the following observations: (1) Regionally, normal faults are rotated clockwise near the Las Vegas Valley shear zone suggesting that these structures partly predate displacement along the shear zone. (2) Young east-trending folds plunge consistently east. One way to accomplish this systematic plunge is to fold strata with a pre-existing, regional eastward tilt developed by slip on west-dipping normal faults. (3) Development of the Boulder basin (Duebendorfer and Wallin, 1991) at 12–10 Ma (red sandstone time) suggests active normal faulting at that time. Normal faults that accommodated extension in Boulder basin may be concealed beneath the Muddy Creek Formation and younger deposits.

The Las Vegas Valley shear zone and associated right-slip faults were clearly active at the time of deposition of the red sandstone unit because they control the distribution of facies within the unit (coarse cobble conglomerate adjacent to the shear zone, fining to the south). The shear zone cuts the red sandstone unit but is locally onlapped by the Muddy Creek Formation indicating activity between 11.9 and 8.5 Ma. The inception of movement is indirectly constrained to have postdated 13.5 Ma, the age of the youngest rocks with the large clockwise rotation (upper part of Thumb Member) (Sonder and others, 1994).

East-striking reverse faults in the Las Vegas Valley shear zone and associated tight folds clearly deform rocks of the red sandstone unit, and locally, the Muddy Creek Formation. This relation requires that north-south shortening postdated formation of the Boulder basin. The Las Vegas Valley shear zone may have been reoriented during shortening to a dip of 40–60° north, an unusually low angle for a major strike-slip fault. South of the Las Vegas Valley shear zone, several small reverse faults place Triassic strata or the red sandstone unit over the Muddy Creek Formation. Slip dies out up section within the Muddy Creek Formation suggesting that reverse faulting was waning during Muddy Creek time.

Northeast- to east-northeast-striking left-slip faults cut folds and fault sets in the area including the Las Vegas Valley shear zone. These faults also cut rocks of the Muddy Creek Formation and therefore were active, at least in part, after 8.5 Ma. Timing of inception of left-slip faulting in the western Lake Mead area is unknown and it is possible that left-slip faulting may have, in part, been contemporaneous with north-south shortening.

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