Nevada Bureau of Mines and Geology Open-File Report 13-12

Evidence for High Contemporary Slip Rates along the Eglington Fault, Clark County, Nevada

by

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2013

The Nevada Bureau of Mines and Geology concludes that well-documented published evidence indicates a higher fault slip rate for the Eglington fault in Las Vegas Valley than the 0.1 mm/yr currently used in the 2008 National Seismic Hazard Map. The importance of this consideration was demonstrated recently by Lamichhane and others (2013), who conducted sensitivity studies that included higher slip rates along the Eglington fault, resulting in significant increases in estimated peak ground acceleration in the north-central parts of Las Vegas Valley.

The supporting evidence for a higher slip rate are radiocarbon dates that constrain the age of a deposit known as "Unit D" and the vertical offset of the upper part of Unit D. The slip rate is relatively high for a short-length intrabasinal fault.

The Eglington fault is unusual in that it is largely marked at the surface by a flexure rather than a discrete scarp (figures 1 and 2). Further, despite the high contemporary strain rate, it is not marked by a range front and is not bounded by an upland area. The flexure may represent a fault-propagation fold indicative of relatively immature fault. The lack of a range front further suggests that the fault has become more active since the late Pleistocene. These relations reflect the episodic nature of strain accommodation in southern Nevada. Although further studies are needed to better constrain the history and origin of the Eglington fault, the documented vertical offset and contemporary slip rates, together with its presence within a major population center, warrant modification of its slip rate in the National Seismic Hazards Map.

It is important to note that information comparable to that on the Eglington fault is not yet available for other Quaternary faults in Las Vegas Valley (figure 1), although late Quaternary earthquakes have occurred along some of these faults (e.g., dePolo and others, 2006). Considering the major potential consequences of an earthquake within the Las Vegas Valley, detailed analyses should be undertaken in the near future to characterize the activity on the other Quaternary faults.

EGLINGTON FAULT

The 11-km-long northeast-striking Eglington fault dissects the northern part of Las Vegas Valley (figures 1, 2, and 3). This fault was originally named and described as the Eglington Scarp by Haynes in 1967. Latest Quaternary movement along this fault has formed a faulted warp in the fine-grained deposits of Tule Springs at the surface (Bell, 1979 and 1981; Ramelli and others, 2012). Ramelli and others (2012) showed an inferred fault trace along the base of the Eglington scarp (figure 3) and estimated an approximate 10 m average vertical offset across the scarp. Older fine-grained deposits (Units A and B combined) crop out in the footwall of the scarp, overlain by Units D and E, respectively (Ramelli and others, 2012). The hanging wall is mostly buried by Unit E deposits and younger alluvium, with a few a small patches of Unit D (Ramelli and others, 2012). A large surface or "Flat" was formed on top of Units D and E, and was subsequently offset by movement along the Eglington fault. These are called the Gilcrease Flat in the footwall and the Stewart Flat in the hanging wall. Thus, contemporary movement along the Eglington fault has offset the upper part of Unit D and Unit E.

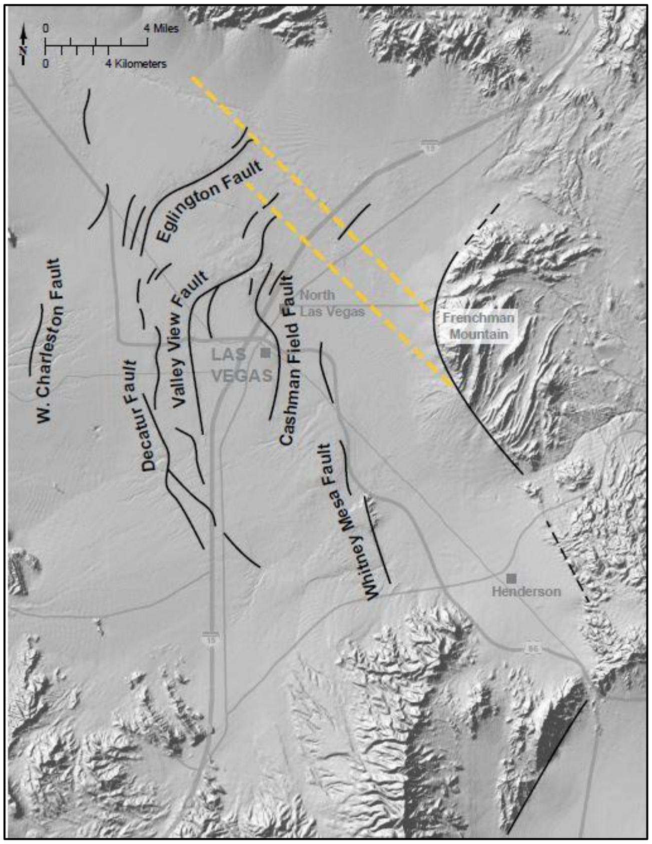

Figure 1. Schematic map of the Las Vegas Valley fault system.

Figure 2. Pre-development photograph of the Eglington scarp. View towards the north-northeast. The warped and faulted fine-grained deposits are visible in the lower half of the photo. *Photograph by John Bell, Nevada Bureau of Mines and Geology*

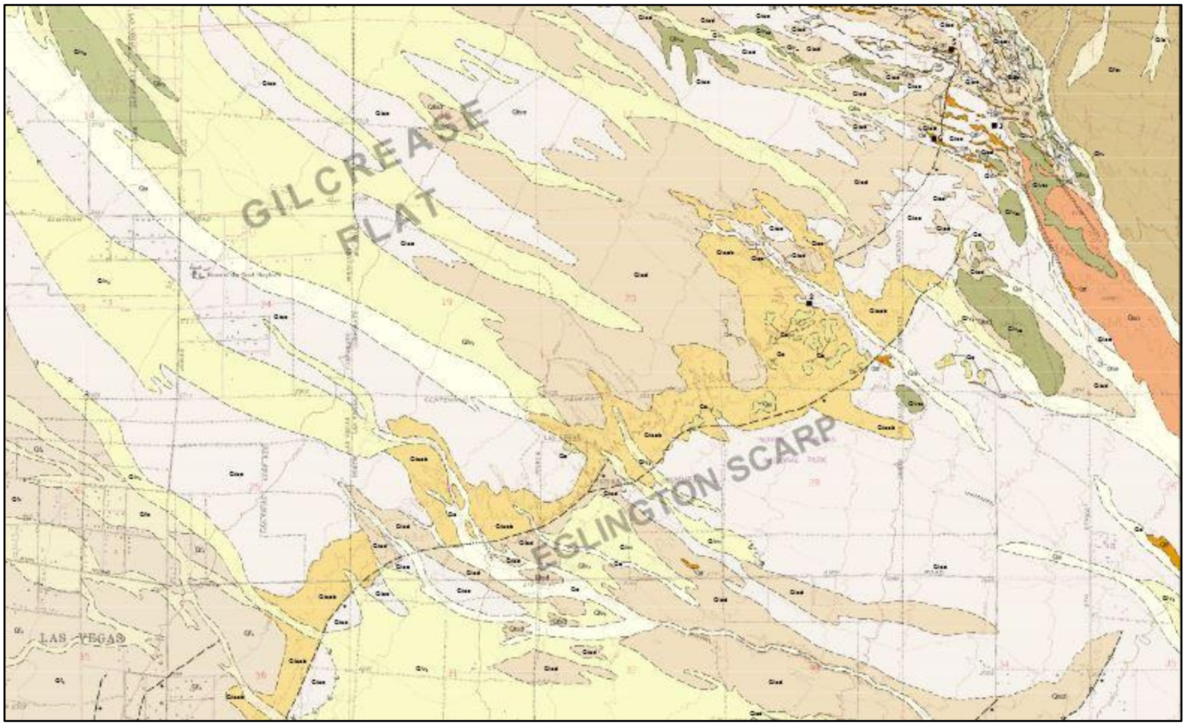

Figure 3. Part of the Geologic Map of the Gass Peak SW Quadrangle by Ramelli and others (2012) showing the Eglington scarp.

AGE OF UNIT D OF THE FINE GRAINED ALLUVIUM OF TULE SPRINGS

The age of Unit D ranges from 35–40 k cal BP to 21 k cal BP based on 14 radiocarbon dates (table 1). The oldest dates are from Haynes (1967) and were collected during a study of the local megafossil assemblage. These dates were from shells, and Haynes (1967) concluded that they may be 1000 radiocarbon years too old based on other shell-wood dating pairs. Other dates were associated with geologic mapping by the Nevada Bureau of Mines and Geology for the Tule Springs Park, the Corn Creek Springs, and most recently the Gass Peak SW quadrangles (Bell and others, 1998, 1999; Ramelli and others, 2012, respectively). All but one of the dates from Tule Springs Park and the Corn Creek Springs quadrangles were from shells; one was from carbonized wood. The dates from the Gass Peak SW quadrangle were from organic sediments, black mats, and charcoal. The dates have been calendar corrected using Calib 6.0 (Stuiver and Reimer, 1993) using the INTCAL09 data set option. The calibrated dates are reported in two-sigma-error ranges.

Table 2 lists some important dates from deposits that are younger than Unit D. The oldest date from Unit E (20,332–21,140 cal BP) from Ramelli and others (2012) and an unpublished date (21,500–23,181 cal BP) from a sample collected in a 1991 pipeline exposure by John Bell (NBMG) additionally constrain the younger age limit of Unit D. Bell's date additionally post-dates the onset of the recent activity that produced the Eglington scarp, as it is from a deposit that accumulated over a small fault offset in a graben near the top of the escarpment. The younger date (2,159–2,336 cal BP) in table 2 is an unpublished date from a sample collected by Wanda Taylor (UNLV) that is close to, but post-dates a young event on the Eglington fault. All three of these dates are from charcoal (table 2).

In their discussion of Unit D, Ramelli and others (2012) summarized, "radiocarbon ages range from about 18 to 30 ^{14}C ka (Haynes, 1967; Bell and others, 1998, 1999; Quade and others, 2003), indicating correlation with marine isotope stage 2." Considering the two-sigma-error range of calendar-corrected dates in table 1 and 2, the age of Unit D ranges from 35–40 ka in the oldest parts to possibly as young as 18–23 ka in the youngest part. The fault scarp post-dates the deposition of the upper part of Unit D, which is the datum for the offset measurement. Thus, the oldest possible age of the offset along the Eglington fault that produced the scarp is 40 ka and the youngest is 18 ka. Because the offset measurement is made on the surface formed on Unit D, the preferred age is closer to the youngest value. Bell's date from a charcoal sample collected in 1991 indicates that the activity generating the scarp was underway by 21,560 to 23,181 cal BP. Assuming activity began just before this date, a reasonable approximation of the age of recent activity is the rounded midpoint of this range, ~22 ka. In summary the age of the displacement across the Eglington scarp is ~22 ka, with a minimum age of 18 ka and a maximum age of 40 ka.

Table 1. Radiocarbon Dates from Unit D in Northern Las Vegas Valley

Radiocarbon Date	Calendar Corrected	Reference	Sample #
22,600 ±550 ^{14}C ybp	25,791–28,517 cal BP	Haynes (1967)	UCLA-536
31,300 ±2,500 ^{14}C ybp	31,193–41,104 cal BP	Haynes (1967)	UCLA-462
Gass Peak quadrangle – Ramelli and others (2012)			
20,310 ±120 ^{14}C ybp	23,851–24,531 cal BP	Ramelli + (2012)	Beta252833
25,950 ±170 ^{14}C ybp	30,380–31,049 cal BP	Ramelli + (2012)	Beta268971
27,850 ±180 ^{14}C ybp	31,473–32,659 cal BP	Ramelli + (2012)	Beta268972
31,100 ±240 ^{14}C ybp	35,022–36,339 cal BP	Ramelli + (2012)	Beta264964
Tule Springs Park quadrangle – Bell and others (1998)			
29,560 ±390 ^{14}C ybp	33,230–34,867 cal BP	Bell + (1998)	GX-23075
20,110 ±2,050 ^{14}C ybp	19,395–28,887 cal BP	Bell + (1998)	GX-23076
20,390 ±160 ^{14}C ybp	23,881–24,838 cal BP	Bell + (1998)	GX-23077
Corn Creek Springs quadrangle – Bell and others (1999)			
24,830 ±4,690 ^{14}C ybp	18,576–39,153 cal BP	Bell + (1999)	GX-23084
28,707 ±290 ^{14}C ybp	32,175–34,431 cal BP	Bell + (1999)	GX-23992
19,290 ±2,350 ^{14}C ybp	17,771–28,671 cal BP	Bell + (1999)	GX-24249
32,840 ±820 ^{14}C ybp	35,350–39,437 cal BP	Bell + (1999)	GX-24251
34,370 ±420 ^{14}C ybp	38,507–40,626 cal BP	Bell + (1999)	GX-24481

Table 2. Radiocarbon Dates from Alluvium or Colluvium Overlying Unit D

Radiocarbon Date	Calendar Corrected	Reference	Sample #
17,370 ±60 ^{14}C ybp	20,332–21,140 cal BP	Ramelli + (2012)	Beta282792
18,690 ±170 ^{14}C ybp	21,560–23,181 cal BP	Bell (1991 unpub)	GS-2958
2,245 ±15 ^{14}C ybp	2,159–2,336 cal BP	Taylor (2006 unpub)	EF-ECG-1-05

VERTICAL OFFSET OF UNIT D ACROSS THE EGLINGTON SCARP

The vertical offset of the upper part of Unit D across the Eglington scarp is 10 to 14 m. Haynes (1967) estimated a 25 m vertical displacement of the carbonate deposits in the upper part of Unit D across the fault. Nitchman and others (1991, unpub.) visited the Eglington scarp in 1991, prior to development, and measured a 14 m vertical offset in the western half of Section 29, T19S R61E (Gass Peak SW quadrangle). Ramelli and others (2012) estimated the approximate average vertical offset of Unit D across the Eglington Scarp to be 10 m. dePolo and Taylor (in prep) constructed a longer topographic section just to the northeast of that carried out by Nitchman and others

(1991, unpub) and reproduced the 14 m vertical offset of the top of Unit D (figure 4). Potential uncertainty in this offset estimate is ±3 m to account for potential erosion, burial, and possible errors in projection.

Thus, the offset of the upper part of Unit D is 10 to 14 m, with a possible maximum of 17 m. It is presumed that the higher estimate of 25 m by Haynes (1967) was based on scarp height rather than projected offset of individual units.

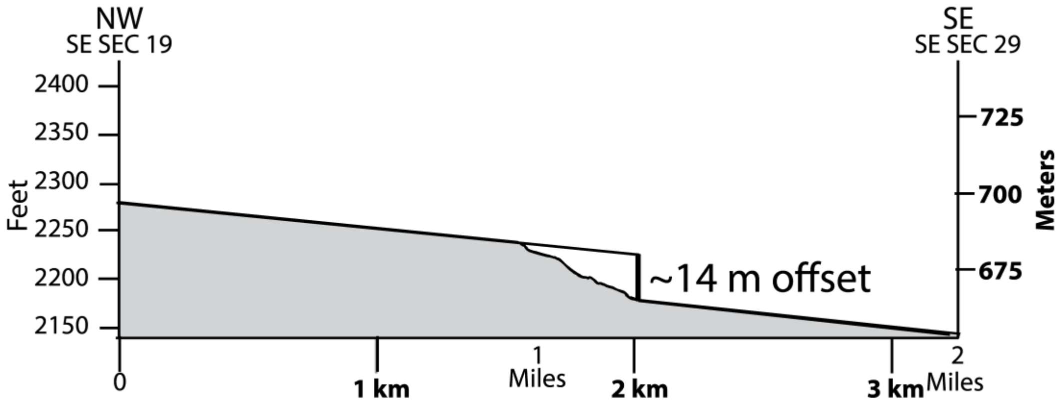

Figure 4. Topographic profile across the Eglington fault showing a vertical offset of 14 m on top of unit D (from dePolo and Taylor, in prep.).

VERTICAL SLIP RATE OF THE EGLINGTON FAULT

The estimated vertical offset of the Eglington fault is 10 to 17 m, with a preferred value of 14 m. The age of this offset is estimated to be 18 to 40 ka, with a preferred value of 22 ka. Using these values the preferred slip rate of the Eglington fault is 0.6 mm/yr, with a range of 0.25 to 0.9 mm/yr.

This is a relatively high fault slip rate for the Basin and Range province, and faults with similar slip rates are commonly range-bounding faults (c.f., dePolo and Anderson, 2000). Thus, some additional investigation of how an intrabasinal fault has such a high contemporary slip rate is useful. The Eglington fault is a major fault in the Las Vegas basin and apparently bounds a small part of the deeper part of the basin. The Las Vegas basin is a composite basin, with deeper portions that began forming in the Tertiary. Thus, the Eglington fault is apparently a long-lived fault, active since the Tertiary in an internal subbasin-bounding position.

The contemporary high rate of activity along the Eglington fault may be part of an apparent recent increase in tectonic activity of several faults in southern Nevada. Northeast of Las Vegas, the California Wash fault had a cluster of three earthquakes since about 16 ka (Zaragoza and others, 2005). South of Las Vegas, UNLV geoscientists have found evidence for 4 to 5 paleo-earthquakes since about 25 ka along the Black Hills fault (Fossett, 2005). Within Las Vegas Valley, two paleoevents occurred along the northern part of the Valley View fault since about 17 ka (dePolo and others, 2006) and a possible latest Quaternary event along the Frenchman Mountain fault (Anderson and O'Connell, 1993). To the west of Las Vegas, UNLV geoscientists have also discovered evidence for four or five paleo-earthquakes along the Pahrump Valley fault zone, three of which have occurred in the last ~3,300 cal BP (Carter, 2012; Carter and others, in prep). Southern Nevada is commonly considered to have less tectonic activity than the northern Basin and Range province, but these examples of latest Pleistocene and Holocene paleo-earthquakes indicate that we need to critically review assumptions about fault activity and be mindful that temporally clustered earthquake activity along faults or groups of faults is common.

With such a significant slip rate, the Eglington fault would be expected to have ruptured in young events. The youngest documented event along the Eglington fault was discovered by Wanda Taylor (UNLV) in a fault trench. This trench exposed a fault, which appears to be a splay of the Eglington fault, and a small colluvial wedge. A charcoal sample collected from the colluvial wedge yielded a date of ~2,200 cal BP. Whether or not this is the youngest event on the Eglington fault is not known, but this is consistent with the notion of having relatively frequent earthquakes along the Eglington fault. Although the contemporary slip rate of the Eglington fault may seem relatively fast, it is certainly plausible in the context of episodic strain partitioning across the southern Nevada region.

TECTONIC VERSUS HYDRO-COMPACTION ORIGIN TO THE EGLINGTON SCARP

Maxey and Jameson (1948) proposed a hydro-compaction origin for the fault scarps in Las Vegas Valley, and this hypothesis has become entrenched over the past 50 years. More recent studies have suggested that these fault scarps are tectonic and were formed by paleo-earthquakes (c.f., Bell, 1981; Bell and dePolo, 1998; dePolo and others, 2006). A detailed discussion of this topic is beyond the scope of this report, but the evidence for a tectonic origin to the Eglington fault includes: (1) basement offsets below most of the faults, as shown by Langenheim and others (2001) and Snelson and others (2004), indicating that these faults had a role in basin formation and are more than just compaction faults confined to a basin, (2) evidence that paleo-earthquakes occurred along faults in Las Vegas Valley (surface offsets with colluvial wedges), (3) faults appear to have smaller offsets in upper, younger deposits than deeper units, indicating progressive growth faulting (e.g., Eglington fault), and (4) Las Vegas Valley has background earthquake activity (c.f., dePolo and dePolo, 2012), which is consistent with tectonic activity. Arguments against a hydro-compaction process for the origin of these scarps have been laid out by Bell (1981) and Bell and dePolo (1998) and include 1) a lack of plausibility of the water level drops required to produce enough compaction to induce the displacement along the scarps, and 2) a lack of contrasts in sediment grain size across faults like the Eglington fault to generate the required differential compaction effect.

DISCUSSION

A challenging consequence of a relatively high slip rate along the Eglington fault is that its short length correlates to a small earthquake size and small displacement events. This, in turn, would be modeled to occur every several hundred years. In the Basin and Range province, this is inconsistent with even the fastest faults, which have major earthquakes every 1000–3000 thousand years. Several scenarios may account for this dilemma. For example, a rupture model that episodically includes the Decatur fault would have larger offsets that could correlate with recurrence intervals in thousands of years. The Decatur fault is aligned with the Eglington fault and is structurally connected at depth (Donovan, 1996). This would increase the total length of the fault rupture from 11 km to 28 km. Using a magnitude-versus-fault-area relationship instead of a magnitude-versus-fault-length relationship may also help better represent the potential earthquakes along the Eglington fault.

HAZUS modeling indicates that the consequences of even a moderate earthquake in Las Vegas Valley are substantial. A magnitude 6 could cause several billions of dollars of losses (Price and others, 2009). Thus, it is imperative that we develop a better understanding and characterization of the faults in the Las Vegas Valley. Of critical importance is dating of offset Quaternary sediments to support better slip rate calculations and paleoseismic studies to determine the ages of recent events. Recent mapping by Ramelli and others (2012) illustrates the potential problems in our understanding of the ages of surficial sediments offset by the faults. The Las Vegas NW quadrangle was mapped by Matti and others (1987) and is directly south of the Gass Peak SW quadrangle. In the northwest part of the Las Vegas NW quadrangle, a fan deposit interpreted as late Pleistocene in age by Matti and others (1987) has been reinterpreted as an early Holocene deposit by Ramelli and others (2012) in the adjacent quadrangle. Similarly, a fine-grained deposit with a petrocalcic unit interpreted as Plio-Pleistocene by Matti and others (1987) has been remapped as latest Pleistocene age Unit D by Ramelli and others (2012). How extensive such changes will be based on modern mapping and dating methods is unknown, but this clearly demonstrates that recent studies indicate younger fault activity than previously envisioned for Las Vegas Valley.

We do not have a good understanding of the displacement per event for the Eglington fault. The only measurement of offset thus far is 38 cm normal dip-slip for the youngest event (~2.2 ka) made by Dr. Taylor of UNLV, but this was on a secondary fault within the faulted flexure. The event that generated this secondary offset must have had a larger displacement. The 11 km length of the Eglington fault has been modeled by the National Seismic Hazard Map as correlating with a magnitude M 6.29. Using an average displacement versus magnitude relationship for faults (Wells and Coppersmith, 1994), M 6.29 correlates with a 0.35 m average displacement, and using the maximum displacement relationship yields 0.5 m. Table 1 shows potential average earthquake recurrence intervals given some of the estimated parameters of the Eglington fault. Vertical offsets of 0.5 m and 1 m per event are used as representative of the vertical deformation along the Eglington fault during hypothetical events.

Table 1. Hypothetical earthquake recurrence intervals given the displacement per event, fault offset, and a time of initiation of activity.

Displacement per event	0.5 m /event	0.5 m /event	1 m /event	1 m /event
Fault Offset	10 m	14 m	10 m	14 m
40 ka	**2 kyr**	**1.4 kyr**	**4 kyr**	**2.9 kyr**
22 ka	**1.1 kyr**	**0.79 kyr**	**2.2 kyr**	**1.6 kyr**
18 ka	**0.90 kyr**	**0.64 kyr**	**1.8 kyr**	**1.3 kyr**

The constraints used in Table 1 are a post-Unit-D offset of 10 to 14 m and the initiation of activity at 18–40 ka, with a preferred value of 22 ka. The offset was divided by the displacement per event giving the total number of events. The time of initiation was divided by the total number of events to estimate the associated average recurrence intervals. Although the 40 ka age of the bottom of Unit D is used, this is an end-member value that is unreasonable given the offset is measured from the top of the unit; it is shown for perspective.

The current representation of the Eglington fault in the National Seismic Hazard Map is a M 6.29 every 14,000 years. Strictly interpreting this recurrence interval, only two M 6.29 events could be responsible for creating the Eglington escarpment. This illustrates the fundamental problem with the current values. A M 6.29 earthquake is near the threshold of generating surface rupture, and considering only two of these produced the offset is unreasonable. More events must have been involved.

For adopting a provincial recurrence interval of the faster faults, we would advocate a range of recurrence intervals of 1.3 kyr to 3 kyr. The 1.3 kyr would be similar to the average recurrence interval of the Weber segment of the Wasatch fault zone (DuRoss and others, 2011). A 3 kyr recurrence interval would be similar to the Pyramid Lake fault zone (Briggs and Wesnousky, 2004). The average of these two values is 2.15 kyr, or about 2000 years.

CONCLUSIONS

Substantive evidence suggests that the Eglington fault has a higher contemporary fault slip rate than currently used in the National Seismic Hazard Map. Although further studies are needed on the Eglington fault, we advocate that the USGS increase the slip rate of this fault in their earthquake source modeling, especially considering its location within a major population center. Published and unpublished data support a slip rate of 0.25 to 0.9 mm/yr., with a preferred value of 0.6 mm/yr.

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Suggested citation:

dePolo, C.M., Taylor, W.J., and Faulds, J.E., 2013, Evidence for high contemporary slip rates along the Eglington fault, Clark County, Nevada: Nevada Bureau of Mines and Geology Open-File Report 13-12, 8 p.