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Latest Quaternary Fault Movement along the Las Vegas Valley Fault System, Clark County, Nevada

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ABSTRACT

Several faults exposed in a 4- to 8-m-deep excavation in North Las Vegas exhibit evidence for two surface-faulting earthquakes that offset latest Pleistocene deposits and paleo-land surfaces about 2 to 3 m per event. These faults are secondary to a major trace of the Las Vegas Valley fault system. The rupture events, defined here as the most recent and penultimate events in the excavation, are expressed as fault displacements within, and buried by, a latest Pleistocene and Holocene stack of intercalated silt-rich and clay-rich deposits. Rapid, brittle faulting offset soft sediments that had the potential to deform plastically and formed a fault scarp 2 to 3 m high in weakly to moderately consolidated materials. A radiocarbon date from organic-rich soil at the surface offset by the most recent event indicates it occurred after about 14,500 ^{14}C years before present. The penultimate event likely was a few hundred to a few thousand years before this date, based on our estimate of the time required for intervening sedimentation and lack of soils. Local earthquakes along the Las Vegas Valley fault system likely caused the sudden fault offsets because these are typical features created by earthquakes (e.g., brittle faulting, fault scarps, tectonic colluvium), and the faults are in line with and adjacent to a distinct main fault. The faults are encountered at 2- to 3-m depths, and the events are evident below this. Therefore, exploratory trenches in young sediments within Las Vegas Valley should be deeper than 3 m if the existence of latest Quaternary faulting is to be detected.

INTRODUCTION

With a population of over 1.3 million people, Las Vegas Valley is the largest metropolitan area in Nevada and one of the fastest growing metropolitan areas in the United States. Las Vegas Valley is a faulted half graben, underlain by a pull-apart basin, with a major normal fault (the Frenchman Mountain fault) along its eastern side (Langenheim et al., 2001). The Las Vegas Valley fault system (LVVFS) occupies the central part of this valley, and fault scarps, hanging walls, and footwalls have been heavily modified and urbanized. A non-tectonic, hydrocompaction hypothesis for the origin of this fault system and fault scarps has dominated professional opinion in Las Vegas since the 1950s, so few studies have been undertaken to investigate local faults for earthquake potential. Nevertheless, current codes discourage building occupied structures across faults, regardless of their origin.

To date, there is little direct, documented evidence of Quaternary faulting along the LVVFS. This is partly due to a general poor surficial expression of faults, including warping. A 4- to 8-m-deep building excavation revealed evidence for late Quaternary fault activity along a strand of the LVVFS. The approximately 76- by 200-m excavation exposed at least seven late Quaternary secondary faults of the LVVFS that were quickly recognized as among

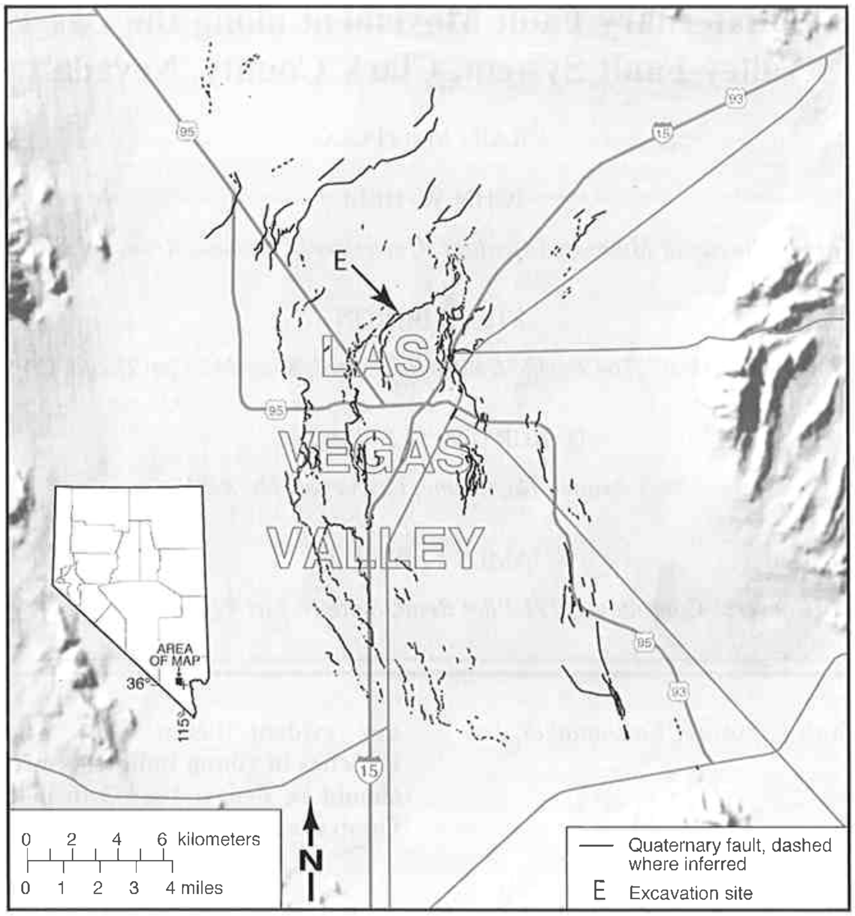

Figure 1. Late Quaternary faults of the Las Vegas Valley fault system. Location of excavation indicated with an "E."

the most impressive young fault offsets ever encountered in Las Vegas Valley. Although observations were limited because of safety and time constraints, a combination of available field observations, photographs, digital images, and a radiocarbon date has produced the most specific information yet regarding paleo-displacements along the LVVFS.

LAS VEGAS VALLEY FAULT SYSTEM

The LVVFS is a complex series of faults that lies within Las Vegas Valley and is about 30 km long (Figure 1). The system is wide, with a cross-strike distance of up to 11 km, and consists of several subparallel and intersecting faults (Slemmons et al., 2001). The system has been mapped at a scale of 1:24,000 (e.g., Matti et al., 1987) and compiled at a scale of 1:62,500 (Bell and Price, 1991).

Quaternary fault scarps that range from a few meters to 30 m high are along the main faults of the LVVFS. The scarps result from faulting and/or warping of surficial deposits. Most scarps are located at faults and appear to have late Quaternary activity, but some may be fault-line scarps. Subsurface information indicates that several of the faults correspond to displacements in the basement/sediment contact and that the LVVFS developed initially during the formation of the Las Vegas Valley basin in the Miocene (Langenheim et al., 2001).

Hypotheses for the origin of the Quaternary fault scarps include tectonic or earthquake generated (cf. Bell, 1981; Bell and dePolo, 1998) and differential hydro-compaction (cf. Mifflin, 1998). Other hypotheses include lacustrine strandlines (Price, 1966), erosional scarps (Mifflin, 1998), and dissolution scarps (Mifflin, 1998). Currently these faults are not included as potential earthquake sources in the National Earthquake Hazard Reduction Program seismic hazard maps.

EXPOSURES OF SECONDARY FAULTS

The seven faults exposed in the excavation collectively displace latest Pleistocene alluvium 4 to 6 m. Observations were made during brief field visits by the authors, who made some limited measurements, collected radiocarbon samples, and took many photographs and digital images of the excavation faces. Safety considerations of the temporary steep walls precluded detailed field studies of these faults. Nevertheless, despite these restrictions, we made several important observations regarding these faults and displacements. This section describes the exposed deposits, their fault offsets, and the history of offsets.

Deposits Exposed

The excavation was in latest Pleistocene basin-fill deposits consisting of 8 m of alternating layers of sands, silts, and clays. The deposits tilt gently to the west, and although there are some lateral variations in character, the beds are remarkably continuous for over 200 m (the approximate excavation length). Individual packages of alluvium are commonly about 0.5 to 1.5 m thick, and some units thicken slightly to the west. The silty and sandy deposits commonly consist of different colored layers that serve as marker horizons with which to gauge deformation. The beds are light brown, brown, or gray green. Clay-rich packages have undergone shrinking and swelling and have columnar and blocky structure with moderately to poorly preserved internal sedimentary structure. Clayey deposits are several hues and values of brown along with reddish browns and gray greens where deposits are oxidized or reduced, respectively. The deposits formed from a combination of alluvial and eolian processes and are part of a regional group of sediments in Las Vegas Valley, named Unit E by Haynes (1967). Unit E deposits are latest Pleistocene to Holocene, ranging in age from about 16,000 ^{14}C ybp to as young as 8,000 ^{14}C ybp (Haynes, 1967; Quade et al., 1995; and Bell et al., 1998).

Units 1 through 8 are designated for the distinct packages of sediments exposed in the excavation, with Unit 1 being the youngest. All these units are local subdivisions of the regional Unit E of Haynes (1967); Table 1 lists distinguishing characteristics of the excavation units. In addition to these deposits, there are younger alluvial channels that cross at high angles to the excavation and minor colluvium shed from a fault scarp (Unit 2d).

Unit 2 is important to understanding fault activity and is subdivided in the southern part of the exposure into three subunits, 2a, 2b, and 2c. Unit 2c is in the lowest part of Unit 2 and consists of three distinctive layers of light-brown, dark-brown, and light-brown silty deposits, overlying a dark-brown, structured clayey deposit (Unit 3). Unit 2c is 40–60 cm thick, and thickens to about 80 cm in a hanging-wall depression adjacent to Fault F1. Unit 2b is a relatively massive green silt capped by discontinuous, blackish, organic-rich pods that appear to be a relict vegetated surface. A radiocarbon age of 14,690 ± 570 ^{14}C ybp was obtained from one of these organic-rich soil pods using conventional radiocarbon methods. Surface faulting from the most recent event was followed by deposition of Unit 2a, a light brown silt that infilled and smoothed out the irregular, postevent topography of the surface on top of Unit 2b.

Table 1. *Characteristics of deposits in the excavation.*

Name	Description
Unit 1	Light brown to brown silty deposits; weak cambic soil on top; likely Holocene
Unit 2	Green silty deposits; this unit has discontinuous organic pods locally, one of which was radiocarbon dated 14,690 ± 570 ^{14}C ybp; divided into three subunits: 2a, 2b, and 2c
Unit 3	Dark brown clayey deposits with columnar structure
Unit 4	Light brown silty deposits
Unit 5	Dark brown clayey deposits with columnar structure
Unit 6	Light brown silty deposits
Unit 7	Dark brown clayey deposits
Unit 8	Brown banded sandy silt deposits

Structures Exposed

We identified seven faults in the excavation, designated F1 through F7 (Figure 2). Some of these faults are likely exposures of the same fault projected across the excavation. The faults generally strike northeast and dip to the southeast and the northwest. The exposed faults splay to the northeast from a bend in a major strand of the LVVFS (Figure 1) and are secondary extensions of that fault. The main fault trends ~N65°E and forms a broad scarp about 16 m high. The faults in the excavation are in the upper part of this fault scarp and in the upper surface immediately above the scarp. A north–south face oriented about 50° from the strike of the faults exposes Faults F1 and F2, and excavation faces oriented about 40° from the strike of the faults expose Faults F3 through F7. Fault F3 was near a corner of the excavation and could be more easily be viewed perpendicular to its strike. The faults are dominantly normal dip slip, although one of the faults has slickenlines indicating about a 20 percent right-lateral component. A few of the faults show evidence of progressively greater displacements in older deposits. Fault displacements and dips are corrected to true displacements and angles unless otherwise noted.

Fault F1 is the southeasternmost of a zone of three faults exposed in the southern part of the excavation (Figure 2). Fault F1 (Figure 3) is a normal fault with a northeast strike and a 45–50° SE dip. Slickensides along the fault plane have a 90° rake. The fault is narrow in its lower part but splays upward through the more ductile clays of Unit 3.

Two fault displacement events occurred along Fault F1, the most recent and penultimate events. These events are best illustrated by a series of time/retro-deformation