Text and references accompanying Nevada Bureau of Mines and Geology Map 176

Geologic Map of the Jean Quadrangle, Clark County, Nevada

by

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INTRODUCTION

The Jean quadrangle is located about 40 km southwest of Las Vegas. It is named for the small community of Jean, located along U.S. Highway I-15 which bisects the quadrangle. The principal geographic features of the quadrangle include Sheep Mountain, the Jean Lake playa, northern Ivanpah Valley, and the southern end of the Bird Spring Range.

The first geologic mapping in the Jean quadrangle was conducted in the 1920s by D.F. Hewett of the U.S. Geological Survey. That mapping was not published until 1956 as part of a 1:250,000-scale geologic map of the Ivanpah 1°x1° quadrangle (Hewett, 1956). This geologic mapping was later compiled at the same scale for the Clark County geologic map (Longwell et al., 1965). Hewett (1956) reported that his mapping in the quadrangle averaged 7 square miles per field day as this mapping was done before the advent of modern aerial photography. Mapping by Paul Barton was done in the early 1950s for a Ph.D dissertation at Columbia University. That work, covering the bedrock of the northern part of the quadrangle at an approximate scale of 1:68,000, was published in essentially the same format as the dissertation (Paul Barton, oral communication, 2009) by the U.S. Atomic Energy Commission (Barton and Behre, 1954). The Barton and Behre (1954) map does not have a base other than the railroad and adjacent highway, and the contacts are apparently somewhat distorted with respect to the base elements. Kohl (1978) mapped the low hills north of Sheep Mountain (informally referred to herein as The Jean Hills) at an approximate scale of 1:50,000 as part of a M.S. thesis. Geologic mapping in the McCullough Range to the east of the quadrangle was summarized by Smith et al. (2010), and Carr and Pinkston (1987) mapped the Goodsprings mining district to the west.

Mapping of surficial units in the area was done to support the development of a series of relative flood hazard maps of the Ivanpah Valley area (see House et al., 2010). Current bedrock mapping to provide a complete geologic map of this and adjacent quadrangles was begun in 2007, supported in part by the U.S. Bureau of Land Management.

Modern bedrock field mapping was recorded on Mylar® overlays of prints of scanned 1:24,400-scale U.S. Geological Survey color aerial photographs flown in 1986. This mapping was digitally compiled in ESRI ArcGIS using the 1:24,000-scale topographic base map, and digital orthoimages of satellite (QuickBird®) and aerial imagery (NAIP – National Agriculture Imagery Program). Data locations were established with handheld GPS. Geologic mapping by S.M. Rowland in the Sheep Mountain area and by B.C. Burchfiel in the Bird Spring Range (northwestern map area), both from the 1980s, was compiled from paper maps of several scales, predominantly ~1:15,000. Contacts from this mapping were drawn on a desktop computer by a combination of manual "heads-up" compilation and digital tracing of georeferenced map images. Geologic unit thicknesses were estimated from map widths and bedding attitudes, supplemented with published thickness data from nearby areas.

Geologic data for surficial units were initially compiled using a combination of field reconnaissance and interpretation of various types of remotely sensed imagery including aerial photographs; digital orthophoto images; Quickbird® satellite imagery; and digital, orthorectified color aerial photographs. The methods of map compilation for surficial-unit contacts were described in detail by House et al. (2010).

DESCRIPTION OF MAP UNITS

Anthropogenic Features and Deposits

Qx Disturbed and modified areas Areas of extensive anthropogenic disturbance and modification, including commercial development (hotel casinos, apartments, homes, shopping malls, parking lots, power plants, and similar features mainly in the vicinity of Jean), mining operations (quarry and aggregate) and borrow pits, and major transportation corridors (Interstate Highway 15, Union Pacific Railroad).

Playa and Related Deposits

Surface drainage in the area is entirely internal. All runoff drains to one of two dry lakes (playas): Roach Lake (just south of quadrangle) and Jean Lake.

Qp Playa deposits (latest Holocene to late Pleistocene (?)) Flat-lying deposits of light-gray to light-brown silt, clay, and minor sand that comprise the playa surface of Jean Lake. Interfingered with and locally overlain by pebble to cobble gravel and sand along marginal interface with active alluvial surfaces. Morphology is very flat to broadly undulate. Mud-cracked surfaces and large desiccation cracks present locally. Unit includes some eolian features (dunes) on the playas.

The soils on these active playa surfaces are characterized by A-Bw-Bk horizons dominated by clay loam textures, and stage I or II carbonate morphology. These areas are active sites of deposition and are inundated frequently with shallow, standing water.

Qpf Playa fringe deposits (Holocene to late Pleistocene) Deposits of silt, sand, and pebble to cobble gravel along the perimeter of playa surfaces. Includes undivided mixture of eolian, fluvial, and playa sediments which vary in relative proportion depending on local conditions. Eolian and fluvial sediments are the dominant constituents. Locally, unit grades into Qea, Qe, or Qay and its related subunits. Unit is interpreted to represent a playa-bajada interface with a locally significant eolian component along the perimeter of Jean Lake.

Soils on Qpf surfaces are generally characterized by thin (4- to 15-cm-thick) A horizons composed of loamy sand or sandy loam, that usually overly a C horizon or a series of horizons belonging to a buried soil. Rarely, a Btk (15-cm-thick) horizon containing stage I carbonate morphology can occur beneath the surficial A horizon.

Eolian Deposits

Unconsolidated deposits of windblown sand in the form of dunes, ramps, and sand sheets contain a mixture of sand and alluvial gravel. Distribution of eolian units in the region defines a north-northeast trend that coincides with the distribution of playas and suggests a corridor of eolian transport extending from Ivanpah Lake (south of the mapped area) to the steep bedrock slopes along the eastern margin of Hidden Valley (east of the mapped area). Eolian deposits in the Jean quadrangle are, thus, consistent with that trend with the most extensive deposits on the west-facing slopes of Sheep Mountain and along the margins of Jean Lake. The playas and distal parts of alluvial fans are the presumed principal sources of sand.

Qe Eolian sand (Holocene to late Pleistocene) Deposits of windblown sand and minor silt. Light-tan to light-yellow color. Unit generally corresponds to areas with mantles of sand that are at least 1 m thick and may locally exceed 10 m. Morphology and types include flat-lying to broadly undulate sheets of sand on inactive alluvial fan surfaces, sand ramps on steep bedrock slopes (best expressed in the Sheep Mountain) and small areas of dunes. Soils on Qe surfaces are commonly characterized by A or C horizons overlying buried B or weak Bk horizons of variable thickness. With increased depth, Bk horizons may contain stage I filaments and, in places, stage II nodules.

Qea Mixed eolian sand and alluvium (early Holocene to late Pleistocene) Sand sheet deposits up to approximately 1.0 m thick overlying inactive alluvial fan surfaces (likely Qay_1 and Qai surfaces). Vegetation density distinctly higher than on Qe surfaces, but spotty. Thin (~single-grain) veneer of subangular fluvial gravel commonly at surface and separated from underlying alluvial gravel by sand with sparse pebbles. Gravel lag is generally loose and dispersed but grades upslope into moderately to well-developed gravel pavements in some areas. Loose gravel lag may be inflationary veneer or thin alluvial veneer, or both. Landscape position of this unit suggests that it represents burial of Qay_1 and Qai surfaces by significant episode(s) of eolian deposition, possibly in the early Holocene. Unit is more extensive than mapped. It is only mapped in areas where eolian sand component is strongly evident in imagery and where field examination indicates thickness of eolian mantle in excess of ~75 cm. Soils on Qea surfaces are weakly developed and generally similar to those associated with Qe surfaces.

Hillslope Deposits

Weakly to strongly consolidated deposits of angular and subangular gravel on steep bedrock hillslopes. Locally may include disaggregated mantles of weathered bedrock, but more commonly associated with gravity-driven accumulations of coarse gravelly talus below steep bedrock cliffs and gravel deposits forming small, steeply sloping debris fans. In many cases, the latter type exhibits morphology and sorting consistent with debris-flow processes.

Qc Colluvium (Holocene to Pleistocene) Coarse, poorly sorted deposits of angular to subangular gravel on steep bedrock slopes. Common in small mountain front embayments and below steep bedrock cliffs. May include irregular mantles of weathered and disaggregated rock on steep bedrock slopes, small debris cones and alluvial fans in small drainages, and areas of thick accumulations of angular gravel (talus) below steep bedrock cliffs. Unit mapped sparingly and with emphasis on the most extensive deposits and those easiest to discern on aerial imagery. Thickness varies considerably but rarely exceeds 5 m; 1–2 m is most common. Surface clasts vary from weakly to very strongly varnished, pavements rarely present, soil calcic horizon development varies from minimal (none to stage I) to very strongly developed (stage V–VI).

Qcf Colluvium and debris fans (Holocene to Pleistocene) Mixed coarse gravel deposits of debris-flow fans, irregular lobes, levees, block fields, and sieve deposits (e.g., Hooke, 1967) on steep bedrock slopes. Deposits composed of angular to subangular boulders and cobbles. This unit is particularly common on steep bedrock slopes formed on sedimentary rocks in the northwest part of the study area. Unit contains areas of Qc, but has more pervasive array of debris-flow features, Thickness varies considerably, and may locally exceed 5 m in some areas. Surface clasts are weakly to very strongly varnished, pavements are rare, and soil calcic horizon development varies from minimal (none to stage I) to very strongly developed (stage V–VI).

Alluvial Deposits

Deposits of ephemeral washes, alluvial fans, and fan remnants. Washes include alluvial fan feeder channels, well-defined axial streams, and channels in stable distributary flow networks; alluvial fans include extensive areas of downstream branching, unstable distributary flow networks, broad areas that convey relatively shallow swaths of unconfined flows, and areas of intricately braided washes. In most cases, active washes and fans are closely interrelated or mutually gradational, so no effort has been made to divide them at this scale.

The broad range of soil development observed on alluvial deposits in the map area and the diverse assemblage of related alluvial landforms indicates a complex history of alluvial fan formation, episodic activity, and abandonment spanning approximately the last 5–6 million years. Alluvial deposits form the bulk of the piedmont areas below mountains and hills in the study area. Correspondingly, their clast compositions reflect the primary source lithologies in the Bird Spring Range (predominantly Mesozoic and Paleozoic carbonate and siliciclastic rocks with minor volcanic rocks and Tertiary gravels), the Sheep Mountain area (Paleozoic carbonate and siliciclastic rocks), and the Jean hills—an informal name for an area northeast of Sheep Mountain (Tertiary volcanic rocks and gravel).

Alluvial deposits are composed predominantly of massive to moderately sorted, moderately to well-stratified sand and gravel ranging from pebbles to boulders. Clast diameter generally increases with proximity to highland source areas. Notably boulder-rich deposits are present near and within the interior parts of the major mountain ranges in the study area and are also common on alluvial fans fed by source areas with extensive outcrops of volcanic rocks. Older alluvial units are generally coarser than younger ones, but this may largely reflect the fact that the upper and middle parts of the older alluvial fans remnants are preserved. In all deposits, the constituent clasts are subangular and moderately sorted, and they are crudely to moderately stratified. Degree of consolidation increases markedly with deposit age and ranges from very weak to very strong.

Alluvial fans of different ages in the mapped area are divided on the basis of a suite of surficial and morphologic characteristics, including the following: topographic position, degree of dissection and nature of extant drainage pattern (e.g., tributary or distributary), alteration of original depositional morphology evident as progressive smoothing of surface morphology over time, development of gravel pavement, degree of chemical and physical weathering of surface clasts, and soil horizon development and carbonate morphology (e.g., Christenson and Purcell, 1985; Machette, 1985; Bull, 1991; Birkeland, 1999). Age designations reported for the alluvial units are based on correlation of observed surficial and morphological characteristics of deposits in the Ivanpah Valley area with similar features elsewhere in the Mohave Desert region with numerical age controls (Sowers et al., 1988; Reheis et al., 1992; Bell et al., 1998; Ludwig and Paces, 2002; McDonald et al., 2003; Page et al., 2005).

Qay Young alluvium, undivided (Holocene to late Pleistocene) Coarse-grained alluvial fan and wash deposits from principal drainages in the Bird Spring Range and various local sources. Composed of subangular sandy pebble- to cobble-gravel with lesser amounts of sand and silty sand (relative proportions vary with nature of and proximity to source area). Deposits are generally crudely to moderately stratified. Bouldery gravels are common in upslope parts of Qay deposits in high-relief mountain interior and mountain front areas. Unit includes debris-flow deposits. Surface and soil characteristics of Qay deposits depend strongly on relative age and frequency of fluvial activity. Surface morphology ranges from high-relief, fresh bar-and-channel forms reflecting original depositional morphology to progressively more subdued bar-and-swale forms to planar surfaces. Surface clasts exhibit slight to moderate coatings of varnish, and carbonate clast etching ranges from none to slight. Well-developed gravel pavements present only in oldest subunit surfaces (Qay_1). Relatively weak, loose pavements may be present in swales on surfaces of younger subunits.

Associated soil development ranges from non-existent to weak Bw and Bk horizons up to stage II Bk in Qay_1.

Qay_3 Young active alluvium (late Holocene) Active wash and alluvial fan deposits of poorly to moderately sorted gravel, sand, and minor silt. Fresh bar-and-channel morphology and relatively low density of vegetation. Alluvial fan surfaces include obvious and complex distributary flow patterns, and broad, sheet-like gravelly areas with few well-defined channels. Active washes are well defined and range from single channels with low flanking terraces, to braided channels interspersed with gravel bars. Exposed thickness of unit is typically 1–3 m. Deposits characterized by weak to no soil development. If present, soil development may be characterized by C or Av horizons overlying Bw/Bk or buried Bk horizons. Vesicular A horizons vary from 1 to 8 cm thick and overlie either Bw (8–23 cm thick) or Bk (10–95 cm thick) horizons containing very slight carbonate coats on clast bottoms. Unit is thin overall and commonly overlies buried soil horizons. Surface clasts are minimally weathered and unvarnished. Carbonate-coated clasts reworked from older deposits may be present.

Qay_2 Young active alluvium and recently abandoned active alluvial surfaces (Holocene) Intermittently active surfaces that flank and grade into Qay_3 surfaces as well as somewhat older abandoned surfaces that are interpreted as chronologically intermediate between Qay_1 and Qay_3. Surface morphology shows some modification of original depositional topography and ranges from bar-and-swale to subdued bar-and-swale, often interspersed with semistable distributary channel networks. Surface clast weathering ranges from slight to moderate varnish and minor carbonate clast etching. Gravel pavements relatively sparse, but may be weakly to moderately developed in some swales. Distributary flow pattern clear on high-resolution satellite imagery and aerial photos, but tone can vary from bright-white to dark-gray depending on source lithology, vegetation density, and presence of cryptobiotic crust which is locally common. Exposed thickness of unit is typically 1–4 m.

Soil development is characterized by Bk horizons with weak to strong stage I carbonate morphology; A (1–9 cm thick) horizons commonly occur in granitic parent materials near Lucy Gray and McCullough Mountains. Elsewhere Av (4–5 cm thick) horizons overlie either Bw (4–10 cm) or Bk (2–111 cm) horizons. Unit is largely unconsolidated. However, somewhat more consolidated buried soils are common at depth.

McDonald et al. (2003) reported a late to middle-late Holocene age range (4–6 ka) for surfaces and soils in the eastern Mohave Desert that are generally correlative to the Ivanpah Valley Qay, unit date in the range of latest to middle-late Holocene.

Qay_1 Young inactive alluvium (early Holocene to late Pleistocene) Young. inactive alluvial surfaces characterized by smooth morphology, moderately to strongly developed gravel pavement, and medium to dark rock varnish. Minor etching of carbonate clasts is common. In aerial photographs, deposit surface commonly has a distinctive pattern characterized by “trellis” or “alligator skin” appearance expressed as lighter-toned roughly rectangular areas with gravel pavement separated by roughly rectilinear pattern of vegetation bands and active, incised channels. Exposed thickness of unit ranges from 1 to ~4 m. Soil development is characterized by stage II carbonate morphology, and, in granitic parent materials, argillic horizons. A/Av/Avk horizons (1–7 cm thick) overlie Bw (8–10 cm thick), Btk (occurs in granitic alluvium only, 77 cm thick), Bk (20–89 cm thick), and/or Bkm (20–197 cm thick) horizons. Bk horizons may contain strong stage I carbonate morphology, but more commonly display stage II carbonate morphology. Argillic horizons contain clay cutans on sand grains. Deposits with correlative surface and soil characteristics have been described at several locations in the vicinity of Ivanpah Valley (Bell et al., 1998; McDonald et al., 2003; Page et al., 2005). Radiometric and mineral luminescence ages of the deposits reported in those studies range from early Holocene to late Pleistocene (approximately 9–22 ka).

Qai Intermediate alluvium, undivided (late to middle Pleistocene) Deposits and surfaces of inactive alluvial fans. Undivided unit includes up to three subunits that are locally divisible on the basis of slight differences in soil carbonate horizon development and topographic position (when adjacent to one another), but overall surface characteristics are very similar and consistent division is difficult. Surface is distinctly planar with strongly developed, tightly packed gravel pavement and dark to very dark varnish on surface clasts of siliceous composition. Many surface clasts are strongly weathered. Deeply etched and pitted carbonate clasts; and split, shattered, and disaggregated clasts of crystalline rocks, where present, are common. Surface drainage has tributary pattern and depth of channel incision generally ranges from 2 to 4 m. Exposed thickness of unit rarely exceeds 5 m. Qai deposits are moderately to strongly consolidated. Typical soil development is characterized by stage III to incipient stage IV petrocalcic carbonate morphology. A/Av/Avk horizons (1-7 cm thick) overlie Bw (8–10 cm thick), Btk (occurs in granitic alluvium only, 77 cm thick), Bk (20–89 cm thick), and/or Bkm (20–197 cm thick) horizons. Carbonate morphology increases with depth. Bk horizons display strong stage I to stage II carbonate morphology and overlie stage III Bkm petrocalcic horizons.

Youngest subunit within Qai is possibly as young as late Pleistocene (25–50 ka; Page et al., 2005); the older and more widespread subunit(s) possibly date to late-middle Pleistocene (>50 to 350 ka; Sowers et al., 1988; Page et al., 2005).

Qao Old alluvium (middle to early Pleistocene) Deposits and surfaces of old alluvial fans. Typically characterized by concordant, weakly to moderately crowned surface remnants separated by deeply (3–6 m) dissected tributary drainage networks. Surface clasts include moderately to deeply weathered fluvial pebble and cobble and sparse boulder gravels; abundant angular clasts of indurated soil carbonate; exposed mantle of eolian silt locally common. Abundant surface carbonate litter results in somewhat lighter to much lighter surface tone than typical of Qai and Qay_1 surfaces. Exposed thickness of Qao ranges from 5 to ~15 m.

Soils characterized by strongly developed, thick, stage IV petrocalcic horizons. A/Av/Avk (1–8 cm thick) overlies either Btk (9–39 cm thick) or Bk (16–38 cm thick) horizons that display stage I–II carbonate morphology. Btk horizons occur in granitic parent materials in the southeast part of the study area and contain well developed clay coats and clay bridges between sand grains. The underlying strongly indurated Bkm horizon (50+ cm thick) is characterized by a laminar cap <1 cm thick.

Ivanpah Valley Qao soil and surface characteristics generally correspond regionally to deposits that are ~700 ka (McFadden et al., 1986; McFadden, 1988; Sowers et al., 1988; Peterson et al., 1995).

Ancient Surficial Deposits, Early Pleistocene (?) to Late Miocene

Parts of the mapped area are characterized by surficial deposits and landforms with geomorphic positions and degrees of soil development that indicate ancient ages. A suite of alluvial fan remnants restricted largely to upper piedmont areas in the Bird Spring Range contains extremely strongly developed petrocalcic soil horizons. There is also an array of very strongly developed petrocalcic soil remnants formed in eolian sediment and colluvial rubble on weathered bedrock surfaces in some isolated locations in the Jean hills (northeast of Sheep Mountain). These features occur on local bedrock highs along the general trend of the eolian corridor delimited by the distribution of late Quaternary eolian deposits.

Note that a recent change in the geologic time scale has extended the lower boundary of the Pleistocene by 800 ky, thus placing it at 2.588 Ma (Gradstein et al., 2004). This significant change has required that the unit designated as Tay by House et al. (2006) now be designated as QTa.

The extremely thick (2–5 m) and strongly developed petrocalcic soils typical of the following units, their stratigraphic and geomorphic positions, and their inset stratigraphic relations strongly suggest that they may be millions of years old. Miocene age is plausible in the case of unit Tek, but has not been directly determined in the map area. Comparably strong soils in the general region have been reported only from the Mormon Mesa (Gardner, 1972; Bachman and Machette, 1977; Williams, 1996; Brock, 2008; Brock and Buck, 2009) and lower Colorado River areas (House et al., 2005), where reported age controls and stratigraphic relations support Pliocene to Miocene ages.

QTa Ancient alluvium (early Pleistocene to late Miocene) Ancient alluvial fan deposits characterized by massive, thick, often multiple, petrocalcic soil horizons. Commonly but not exclusively occurs as alluvial veneer on irregular erosion surfaces formed on sedimentary rocks. Deposits consist predominantly of subangular to subrounded gravel. Associated soil is characterized by strongly developed stage VI petrocalcic horizons developed in coarse alluvium. Commonly, the overlying soil horizons are eroded, leaving a surficial rubble layer of broken petrocalcic fragments and exposing the petrocalcic horizon at the surface. In some locations, multiple petrocalcic soil horizons are present and crop out as ledges on ridge slopes in deeply dissected areas. The petrocalcic horizons are characterized by multiple cross-cutting laminae up to 15 cm thick, multiple pisoliths, and ooids (often concentrated in 1- to 3-mm-thick zones within laminar layers). Where overlying horizons are present, one or more of the following may be present: C (recent eolian sediment), Av, and/or Bk (containing stage I or II) horizons of variable thickness. Where fully exposed, Tay petrocalcic horizons range between approximately 3 and 5 m in thickness. Overall thickness of this alluvial unit is quite variable, and ranges between 5 and ~15 m depending on local conditions.

Tek Ancient petrocalcic soil remnants (Pliocene to late Miocene) Unit composed of relatively flat-lying, possibly multiple, massively indurated 2- to 5-m-thick petrocalcic horizons (Bkm) with strong stage VI morphology. These petrocalcic horizons are formed in eolian silt and sand; and coarse, broken rubble of the underlying 13.1–14.1 Ma basalt (Smith et al., 2010), which suggests that eolian deposition and soil development were initiated shortly after cessation of volcanism. The great degree of induration of these petrocalcic horizons, coupled with continued episodic eolian deposition, has led to their preservation despite multiple episodes of partial erosion and re-cementation (e.g. Brock and Buck, 2009). This unit was first recognized in the map area by Kohl (1978). Its distribution is limited mainly to zones of persistent flux of eolian sediment in the Jean hills area northeast of Jean. These massive, brecciated stage VI petrocalcic horizons are characterized by intervals of multiple cross-cutting laminae that can be up to 12 cm thick, pisoliths (often vertically elongated), and ooids. Where present, one or more of the following horizons may overlie the stage VI petrocalcic horizon: C (recent eolian sediment of variable thickness); Av (4+ cm thick); and Bk (31+ cm thick) containing stage I, II, or incipient III carbonate morphology. In best exposures (e.g., the Jean hills area), thickness of Tek ranges from 2 to 5 m.

Pliocene to Miocene Rocks

Tcsu Younger sedimentary rocks (Pliocene or Miocene) Well-bedded, locally cross-bedded, volcanic sandstone, pebbly sandstone, and conglomerate. Quartzofeldspathic sandstone derived from underlying ash-flow tuffs is common. Conglomerate pebbles and cobbles consist of carbonate rock, olivine basalt, Tb, Tmd, felsic granitic rock, diorite, and gneiss. Rare clasts of chert-pebble conglomerate, and smooth, rounded, percussion-marked quartzite are observed. Locally the upper part of the unit contains a monolithologic unit, probably a debris flow, consisting of clasts of light-brown-weathering, white, aphyric, rhyolitic, vapor-phase-altered pumice. Included very locally are dark-gray clasts of devitrified aphyric vitrophyre; a very few of these are flow-banded. Tcsu crops out above Tmd in a north-striking wash about 4 km northeast of Jean. It lies on Tmd and may be, on average, tilted slightly less than the underlying Trg, Tb, and Tmd. Basalt clasts suggest it is younger than Tba, but olivine basalt also underlies the ash-flow tuffs northeast of the quadrangle. Maximum thickness less than 10 m.

Tba Basalt (Miocene) Dark-gray, weathering dark-brown, vesicular to massive olivine basalt. Olivine (~4%, 1–2 mm) converted to iddingsite; less 1–2 mm green clinopyroxene. Cinders observed locally. Maximum thickness less than 50 m.

Tmd Tuff of Mount Davis (middle Miocene, 15.0 Ma) (Faulds et al., 2002a, b) Grayish-pink, weathering pale-brown, moderately welded, rhyolitic ash-flow tuff, containing ~15% phenocrysts of sanidine, with significantly lesser amounts of plagioclase, biotite, and clinopyroxene. Lithic fragments (~2%), predominantly of intermediate-composition volcanic rock. Sphene is very rare; only observed in one hand sample. Distinguished from Tb by virtual absence of sphene, somewhat more phenocrysts, and somewhat larger sanidine. Thickness 0–15 m.

Tb Tuff of Bridge Spring (middle Miocene, 15.2 Ma) (Faulds et al., 2002a, b) Purplish-gray to light-gray, weathering pale-brown, moderately to densely welded rhyolitic ash-flow tuff containing 10–15% anhedral to subhedral phenocrysts of sanidine and significantly lesser amounts of biotite, clinopyroxene, plagioclase, hornblende, and distinctive, honey-yellow sphene. Lithic fragments (~1%, <5 mm) of reddish and dark-gray intermediate-composition volcanic rock and lesser granitic rock. Basal dark-gray vitrophyre commonly found at base. Weathers to rounded boulders. Distinguished from Tmd by presence of ubiquitous sphene and somewhat smaller sanidine phenocrysts. Appears to have accumulated in a northeast-striking topographic low defined by the underlying Trg. Thickness 0–25 m.

Trg Roundstone gravels (Miocene) Variably consolidated deposits of gravel conglomerate and minor sandstone and mudstone (House et al. 2006). It correlates in part to the "early alluvium" of Hewett (1931). Conglomerate is the most widely exposed facies and contains subrounded to rounded fluvial pebbles, cobbles, and boulders. The predominant clast types are carbonate rocks and chert-carbonate rock. Locally, the unit contains clasts of late Paleozoic (?) white to light-orange sandstone. In outcrops just northeast of the northeast corner of the quadrangle, clasts include abundant subrounded to well-rounded, percussion-marked quartzite, carbonate rocks, and granitic and metamorphic rocks. The observed degree of clast rounding and the presence of quartzite are uncommon in all younger alluvial deposits in the area and indicate a very different type of depositional system. Gravels are generally clast-supported, moderately sorted to well-sorted, and tilted 12°–15° east. Trg deposits are commonly associated with well-developed, high-standing ballena landforms characterized by highly degraded, possibly multiple, massive petrocalcic soil horizons. A series of Trg ballenas north of Jean define a distinctly linear, north-striking trend (House, Ramelli, and Buck, 2006). Trg gravel deposits rest unconformably on Ph and are overlain by Tb, a relationship first noted in the Jean area by Kohl (1978). The outcrop pattern of Trg suggests a broad, east-west-oriented channel. Herrington (2000) described east and northeast paleoflow directions (based on clast imbrication) for similar rocks (the McCullough Spring conglomerate) in the McCullough Range about 25 km to the east of the quadrangle. The channels there were interpreted to be part of a regional, middle Tertiary, northeast-trending drainage system (Herrington, 2000). However, Kohl (1978, p. 18) reported that vague cross-bedding and clast imbrication indicate that currents flowed from the south and east. It is possible that gravel of several different ages is found in and near the quadrangle, and certain gravel clasts may have been recycled one or more times. Easterly flowing streams in the Late Cretaceous or Paleogene may have deposited gravels that were derived from the Sevier orogenic belt to the west and north, or the somewhat later Laramide Kingman uplift (see Faulds et al., 2001) to the south and southeast (Goldstrand, 1992; Herrington, 2000;). Neogene streams may have flowed to the west, based on Kohl's paleoflow data (1978).

The unit is apparently younger than two ~25 Ma detrital zircons found within it (Hanson, 2008) in the northeast part of the quadrangle, and older than the overlying 15.2 Ma Tb. Based on the position of the possibly correlative McCullough Spring conglomerate of Herrington (2000) below the Peach Spring Tuff in the McCullough Range (see Smith et al., 2010), the unit may be older than 18.5 Ma. Thickness 0–40 m.

Cretaceous to Triassic Rocks

JKc Conglomerate (Cretaceous or Jurassic) Light-gray and brownish-gray, clast-supported, pebble conglomerate, containing subrounded to rounded clasts (commonly <0.5–5 cm) of light-gray carbonate rock, considerably less (~10%) light- and dark-gray chert, and rare quartzite in a matrix of calcite-cemented, rounded quartz sand. Sparse cross-bedding suggests derivation from the east. Exposed as small outcrops below the Bird Spring thrust in the northwest map area. The Jurassic Aztec Sandstone is the probable source of the sand. Equivalent to unit JKc of Burchfiel et al. (1997) exposed in the eastern Spring Mountains about 30 km to the north. Possibly equivalent to the carbonate-clast facies of the 99 Ma (Fleck and Carr, 1990) Lavinia Wash sequence (Carr, 1980; Carr and Pinkston, 1987) of the Goodsprings district, about 10 km to the west. Age uncertain; older than the Bird Spring thrust (pre-Tertiary?) and younger than Early Jurassic (Aztec Sandstone). Thickness less than 20 m.

Moenkopi Formation (Triassic)

Ŧmu Upper red member Grayish-pink, light-brown-weathering, ripple-marked sandstone; reddish, shaly weathering, fine-grained sandstone; and lesser maroon, platy-weathering siltstone. Local gypsum, most common near the base. A partial section has an estimated thickness of 50–75 m. The unit has a maximum thickness of 150 m in the Blue Diamond SE quadrangle about 15 km to the north (Carr et al., 2000).

Ŧmv Virgin Limestone Member Cream-yellow to nearly white, bioclastic and locally micritic limestone. A partial section is only approximately 10 m thick. The unit has a maximum thickness of 130 m in the Blue Diamond SE quadrangle about 15 km to the north (Carr et al., 2000).

Permian to Cambrian Rocks

Kaibab Formation (Permian)

Pkf Fossil Mountain Member Medium-gray-weathering, light-gray, fetid, thick-bedded, massive, cherty limestone, and cherty dolomitic limestone. Locally stromatolitic. A partial section is only approximately 65 m thick. The unit has a maximum thickness of 100 m in the Blue Diamond SE quadrangle about 15 km to the north (Carr et al., 2000).

Toroweap Formation (Permian)

Ptw Woods Ranch Member Fine- to medium-grained, reddish and yellowish calcareous sandstone and siltstone. Slope-forming. Thickness approximately 25 m.

Ptb Brady Canyon Member Pinkish-gray-weathering, brownish-gray, laminated, fetid, massive, cliff-forming dolomitic limestone. Contains bedding-parallel chert bodies. Thickness about 50 m.

Pts Seligman Member Buff to red, slope-forming, interbedded siltstone and very fine grained sandstone. Thickness approximately 50 m.

Pc Coconino Sandstone (Permian) Very light gray- to white-weathering to light-brownish and light-yellowish-gray, prominently cross-bedded, fine- to medium-grained quartz sandstone with variable amounts of calcite cement. It may be distinguished from the underlying pale-reddish-brown Hermit Formation by thicker cross-bed sets and generally lighter color. Thickness approximately 50 m.

Ph Hermit Formation (Permian) Pale-reddish-brown, fine- to medium-grained, thick-bedded, prominently cross-bedded sandstone. Minor amounts of reddish-brown siltstone. Thickness of a partial section is less than 50 m; the unit has a maximum thickness of 305 m in the Blue Diamond SE quadrangle 15 km to the north (Carr et al., 2000).

PMb Bird Spring Formation (Early Permian to Late Mississippian) Light-brownish-gray and yellowish-gray, thin- to thick-bedded, pelletoidal, bioclastic, and sandy limestone and dolomite. Local nodules of dark-brown- and orangish-gray-weathering chert. Also includes light-gray, calcareous, cross-bedded sandstone. Macrofossils include solitary corals. Estimated thickness of a partial section is less than 150 m, but about 760 m are exposed west of the quadrangle (Hewett, 1931).

Monte Cristo Group (Late to Early Mississippian)

Mmy Yellowpine Limestone Medium-dark-gray to light-olive-gray, medium-crystalline, thin- to thick-bedded limestone; contains sparse nodules of gray to brown chert, particularly near the contact with underlying Mmb. Commonly contains abundant rugose corals. Thickness approximately 50 m.

Mmb Bullion Limestone Light-gray limestone, commonly recrystallized to medium- to very light gray, coarse-grained dolomite. Chert is uncommon, in contrast to the underlying Mma. Estimated thickness 100–150 m.

Mma Anchor Limestone Alternating thin-bedded limestone and orange-weathering, light-gray, commonly nodular and layered chert. Limestone is medium-gray to light-olive-gray, partly burrowed, and fine- to medium-crystalline. Thickness approximately 25–75 m.

Mmd Dawn Limestone Dark-gray and brownish-gray, thin-bedded to massive, bioclastic limestone. Local nodules of brown chert, but the unit is relatively chert-free in contrast to overlying Mma. Thickness approximately 50–100 m.

MDcp Crystal Pass Limestone (Early Mississippian to Late Devonian) Very light gray, very fine-grained, ledgy, medium- to thin-bedded, aphanitic limestone. Fine laminations commonly visible on weathered surfaces. Distinctive light-gray bench between darker-gray Sultan Limestone below and Dawn Limestone above. Rarely contains 10% quartz sand grains. Typically not secondarily dolomitized. Formerly a member of the Sultan Limestone. Thickness approximately 75 m.

Sultan Limestone (Middle and Early Devonian)

Ds Sultan Limestone Undivided on Sheep Mountain. Medium-gray, coarse-grained dolomite, weathering brownish-gray. Forms a distinctive, dark-gray cliff on flanks of Sheep Mountain. A distinct 1- to 2-m-thick chert bed commonly caps the unit, and stromatoporoids are found in basal beds above DЄnm. Thickness approximately 175–200 m.

Dsv Valentine Member Alternating units of bedded dark-gray and medium-gray, secondarily dolomitized limestone; locally contains stromatoporoids. Thickness approximately 100 m.

Dsi Ironside Member Dominantly beds of dark-gray to black limestone and dolomite with some beds of light-bluish-gray, massive and platy limestone and light-gray dolomite. Contains abundant stromatoporoids. Thickness approximately 25 m.

DЄnm Mountain Springs Formation, Nopah Formation, and Dunderberg Shale, undivided (Middle Devonian, Ordovician, and Furongian, formerly Late Cambrian) Sheep Mountain. Fine-grained, greenish-gray, platy-weathering limestone and yellowish-gray dolarenite and dololutite. One sample contains ~3% very fine sand- and silt-sized quartz grains. Thickness approximately 5 m.

DOms Mountain Springs Formation (Middle Devonian, Late Ordovician, and Early Ordovician) Dark- to medium-gray, burrow-mottled, finely to coarsely crystalline, bioclastic, thin- to thick-bedded dolomite interbedded with rare orange- and green-weathering sandy limestone. Local chert nodules and stromatolites. Thickness approximately 75 m.

Єn Nopah Formation (Furongian, formerly Late Cambrian) Dark-to light-gray, mottled, medium to coarsely crystalline, thin-to thick-bedded, cliff-forming dolomite. Thickness approximately 75 m.

Єd Dunderberg Shale (Furongian, formerly Late Cambrian) Slope-forming, orange-weathering, silty dolomite, gray limestone, and rare green and tan shale. Formerly a lower member of Єn. Thickness less than 50 m.

Єf Frenchman Mountain Dolomite (Cambrian Series 3, formerly Middle Cambrian) Sheep Mountain. Thick-bedded, light- to medium-gray, burrowed and pelletoidal, locally banded, medium- to coarse-grained dolomite. Commonly recrystallized. Glauconite observed locally. Thickness of a partial section is approximately 120 m.

Єbk Bonanza King Formation (Furongian and Cambrian Series 3, formerly Late and Middle Cambrian) Light- to dark-gray, fine- to medium-crystalline dolomite and limestone; alternating light- to dark-gray beds give a distinctive banded appearance. Commonly mottled; local chert nodules and discontinuous layers. Thickness of an exposed partial section is approximately 250 m. Probably 600–800 m thick in total in the region (Burchfiel et al., 1997).

Єba Bright Angel Shale (Cambrian Series 2 and 3, formerly Early (in part) and Middle Cambrian) Platy-weathering, grayish-yellow-green, micaceous shale with interbeds (commonly 0.3–4 cm; rarely 10 cm) of brown, fine-grained, glauconitic quartz sandstone. Load casts and drag marks are found in the sandstone beds. Less than 10 m of the unit are exposed at a single small outcrop in alluvium 2.5 km southeast of Jean. Nearby outcrops of rocks considerably higher in the stratigraphic section suggest that faults of significant displacement are concealed by alluvium in this area. Hewett (1956) reported 73 m of the unit south of the Jean quadrangle.

Єt Tapeats Sandstone (Cambrian Series 2, formerly Early Cambrian) Highly indurated, brown, thick-bedded, locally cross-bedded, fine-grained quartz sandstone. Similar to quartz sandstone interbeds in the overlying Єba. About 1 m exposed below Єba in a wash about 2.5 km southeast of Jean. Hewett (1956) reported nearly 40 m of the unit south of the Jean quadrangle.

STRUCTURAL GEOLOGY

Sevier Fold and Thrust Belt

In the northwestern part of the Jean quadrangle, Paleozoic rocks crop out in the eastern part of the Bird Spring Range and along a north-south ridge to the east. Within the valley separating them, the softer red beds with gypsum of the upper Moenkopi Formation crop out. The Paleozoic rocks in the Bird Spring Range form two ridges in the south that merge northward into the main part of the Bird Spring Range. The eastern ridge contains large outcrop areas of Bonanza King Formation in the south that have a general gentle north dip, so that rocks become younger to the north where the Bird Spring and Monte Cristo Formations form the high part of the range. The western ridge, separated from the eastern ridge by a large, down-to-the-west, normal fault, is underlain by mainly middle Paleozoic rocks except along the west side where Cambrian Bonanza King Formation crops out.

The Paleozoic rocks in the eastern ridge have been thrust eastward above the Triassic Moenkopi Formation along the subhorizontal to gently west-dipping Bird Spring thrust fault, a fault that has been strongly modified (see below). The thrust fault carries progressively older rocks southward in its hanging wall; Mississippian-Devonian Crystal Pass Limestone in the north and Cambrian Bonanza King Formation in the south. Along the eastern part of the hanging wall are eastward-verging folds with overturned limbs that indicate the eastward displacement of the thrust fault. The footwall rocks are the Triassic red beds of the Moenkopi Formation that are overlain in two localities by coarse cobble conglomerate of uncertain age— probably Cretaceous, but possibly as old as Jurassic.

The thrust fault along most of its trace has been strongly modified by normal faults that dip east at a moderate to low angle, forming several blocks that have moved down to the east. These blocks carry both hanging wall and footwall rocks of the thrust fault, but appear to bottom in the red beds of the Moenkopi Formation. They are interpreted to have formed because gypsum-bearing beds in the Moenkopi underlie a steep slope above, held up by the resistant Paleozoic carbonate rocks that became unstable. The steep slope facilitated downward-to-the-east movement of the Paleozoic rocks on the underlying gypsum-bearing beds of the Moenkopi Formation. The fault contacts of these blocks are commonly marked by abundant breccia, suggesting surficial formation. Within the blocks are numerous small faults that move higher parts of the Paleozoic section down to the east against lower parts of the section. Most of the formational and member contacts of units within the blocks are also strongly brecciated, and the units are commonly thinned, demonstrating the surficial nature of the movements.

The hanging-wall rocks, even though cut by abundant, young, north-striking steeply dipping faults, have a gentle west dip indicating that this part of the Bird Spring thrust fault is subhorizontal (cross section A–A'). The western ridge of the Bird Spring Range in the south has been dropped down, so that in the south, upper Paleozoic rocks are adjacent to lower Paleozoic rocks, but the offset becomes less to the north. The gentle dip of the rocks in the western ridge continues with the subhorizontal thrust fault at depth to the west (cross section A–A'). A few kilometers to the west, the upper Paleozoic rocks dip consistently at a moderate angle to the west and define the ramp portion of the Bird Spring thrust fault that continues into the adjacent Goodsprings area (Carr and Pinkston, 1987).

Displacement on the Bird Spring thrust fault is at least 6 km, based on the position of the ramp west of the Jean quadrangle and its present day frontal trace along the east side of the Bird Spring Range. This is a minimum displacement because the eastern part of the thrust has been eroded. Regionally, the Bird Spring thrust fault loses displacement to the north. The hanging-wall rocks become progressively younger to the north as well (see Page et al., 2005).

The footwall rocks below the Bird Spring thrust are approximately subhorizontal (cross section A–A”). They are offset along a north-striking fault that is concealed by alluvium in the valley between the Bird Spring Range and the ridge to the east containing the upper Paleozoic rocks of the footwall. This fault is marked by the abrupt change from upper Paleozoic strata on the east to the Moenkopi Formation on the west. In the southeastern part of the Bird Spring Range there is an isolated outcrop of Bird Spring Formation that lies below the Bonanza King Formation, in the hanging wall of the Bird Spring thrust fault. This outcrop suggests that a pre-thrust fault, west side up, eliminated the Moenkopi Formation from the footwall of the thrust in the south (steep fault to the east of the Bird Spring outcrop on cross section A–A").

The Bird Spring thrust fault is the easternmost thrust fault of the Sevier thrust belt of the Cordilleran orogen at this latitude; however, the age of the Bird Spring thrust fault cannot be constrained within the Jean quadrangle. Based on regional geology presented by Burchfiel et al. (1997) and Carr and Pinkston (1987), the Bird Spring thrust fault is older than the Keystone thrust fault to the west—a thrust that is post ~99 Ma and probably late Cretaceous. A lower age limit is poorly constrained, but the thrust is younger than the Jurassic Aztec Sandstone.

Cenozoic Faults

All the Paleozoic rocks in the Bird Spring Range and the range to its east are cut by numerous generally north-south-striking faults. None of these faults displace the Quaternary rocks adjacent to or within the range, and they only rarely cut Cenozoic rocks in the southeastern part of the Jean quadrangle. The faults are considered to be Cenozoic, because north of the Jean quadrangle, similar striking faults cut Cenozoic rocks. For example, the

Cottonwood fault, a major northwest-striking high-angle fault originally thought to be associated with Sevier tectonism, continues from its namesake area, Cottonwood Valley, in the northern Bird Spring Range, curves to strike south, and splays into several faults into the northwest corner of the Jean quadrangle. The fault has north-side-up separation (Burchfiel et al., 1997, p. 845) consistent with the separation observed in the north-northwest-striking complex set of faults in the northwestern part of the Jean quadrangle. Burchfiel et al. (1997) presented evidence that movement on the fault in the north is entirely post-Keystone thrust age, and may be entirely Cenozoic. Unpublished mapping by Burchfiel (2003) indicates that the Cottonwood fault north of the Jean quadrangle cuts Cenozoic conglomerate, supporting its Cenozoic age.

Most of the north-striking faults in the Jean quadrangle have steep dips (50–70°). All displacements on these faults are separations, as there are no piercing points that determine their net-slip. They are presumed to be mostly normal faults, but strike-slip components cannot be ruled out.

Several concealed normal faults are shown on the map. In particular, we interpret down-to-the-west offset for the northern part of Ivanpah Valley west of Sheep Mountain, and the presumed fault responsible is continued north, to the west of the low hills northeast of Jean. Similarly, a mostly concealed fault is shown with down-to-the-west offset, cutting a ridge southeast of Jean at the Sheep Mountain front. To the east of that fault, an east-side-down concealed fault is required to explain the small outcrops of Ꞓba and Ꞓt. At the north end of Sheep Mountain, a mostly concealed fault separates Mississippian and Tertiary rocks. The main evidence for this fault is the steep dip of beds of MDcp immediately adjacent to the fault; however, the fault is not well exposed, and the contact could be depositional. Where concealed, the exact locations of these faults are somewhat speculative.

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REFERENCES

Bachman, G.O., and Machette, M.N., 1977, Calcic soils and calcretes in the southwestern United States: U.S. Geological Survey Open-File Report 77–794, 163 p.

Barton, P.B., Jr., and Behre, C.H., Jr., 1954, Interpretation and evaluation of the uranium occurrences near Goodsprings, Nevada: U.S. Atomic Energy Commission RME-3119, 108 p.

Bell, J.W., Ramelli, A.R., and Caskey, S.J., 1998, Geologic map of the Tule Springs Park quadrangle, Nevada: Nevada Bureau of Mines and Geology Map 113, scale 1:24,000.

Birkeland, P.W., 1999, Soils and geomorphology (3rd ed.): New York, Oxford University Press, 430 p.

Brock, A.L., 2007, Characterization of stage VI petrocalcic horizons—S. Nevada and N.W. Arizona, University of Nevada, Las Vegas, Ph.D. dissertation, 148 p.

Brock, A.L., and Buck, B.J., 2009, Polygenetic development of the Mormon Mesa, NV petrocalcic horizons—geomorphic and paleoenvironmental interpretations: Catena, v. 77, no. 1, p. 65–75.

Bull, W.B., 1991, Geomorphic responses to climatic change: New York, Oxford University Press, 352 p.

Burchfiel, B.C., and Davis, G.A., 1988, Mesozoic thrust faults and Cenozoic low-angle normal faults, eastern Spring Mountains, Nevada, and Clark Mountains thrust complex, California, *in* Weide, D.L., and Faber, M.L., editors, This extended land—geological journeys in the southern Basin and Range: Geological Society of America Cordilleran Section Field Trip Guidebook, University of Nevada, Las Vegas Geoscience Department Special Publication no. 2, p. 87–106.

Burchfiel, B.C., Cameron, C.S., and Royden, L.H., 1997, Geology of the Wilson Cliffs–Potosi Mountain area, southern Nevada: International Geology Review, v. 39, no. 9, p. 830–854.

Carr, M.D., 1980, Upper Jurassic to Lower Cretaceous (?) synorogenic sedimentary rocks in the southern Spring Mountains, Nevada: Geology, v. 8, no. 8, p. 385–389.

Carr, M.D., McDonnell-Canan, C., and Weide, D.L., 2000, Geologic map of the Blue Diamond SE quadrangle, Nevada: Nevada Bureau of Mines and Geology Map 123, scale 1:24,000.

Carr, M.D., and Pinkston, J.C., 1987, Geologic map of the Goodsprings district, southern Spring Mountains, Clark County, Nevada: U.S. Geological Survey Miscellaneous Field Studies Map MF-1514, scale 1:24,000.

Christenson, G.E., and Purcell, C., 1985, Correlation and age of Quaternary alluvial-fan sequences, Basin and Range province, southwestern United States, *in* Weide, D.L., editor, Soils and Quaternary geology of the southwestern United States: Geological Society of America Special Paper 203, p. 115–122.

Faulds, J.E., Feuerbach, D.L., Miller, C.F., and Smith, E.I., 2001, Cenozoic evolution of the northern Colorado River extensional corridor, southern Nevada and northwest Arizona: Utah Geological Association Publication 30, p. 239–272.

Faulds, J.E., Bell, J.W., and Olson, E.L., 2002a, Geologic map of the Nelson SW quadrangle, Clark County, Nevada: Nevada Bureau of Mines and Geology Map 134, scale 1:24,000, 15 p.

Faulds, J.E., Olson, E.L., Harlan, S.S., and McIntosh, W.C., 2002b, Miocene extension and fault-related folding in the

Highland Range, southern Nevada—a three-dimensional perspective: Journal of Structural Geology, v. 24, p. 861–886.

Fleck, R.J., and Carr, M.D., 1990, The age of the Keystone thrust—laser-fusion $^{40}Ar/^{39}Ar$ dating of foreland basin deposits, southern Spring Mountains, Nevada: Tectonics, v. 9, no. 3, p. 467–476.

Gardner, L. R., 1972, Origin of the Mormon Mesa caliche, Clark County, Nevada: Geological Society of America Bulletin, v. 83, p. 143–156

Goldstrand, P. M., 1992, Evolution of Late Cretaceous and early Tertiary basins of southwest Utah based on clastic petrology: Journal of Sedimentary Research, v. 62, no. 3, p. 495–507.

Gradstein, F.M., Ogg, J.G., and Smith, A.G., editors, 2004, A geologic time scale 2004. Cambridge University Press, 610 p.

Hanson, A.D., 2008, Detrital zircon constraints on the Jean conglomerate and Sevier unroofing near Las Vegas (abs.): Geological Society of America, Abstracts with Programs, v. 40, no. 1, p. 56, Cordilleran and Rocky Mountain Sections Joint Annual Meeting, March 2008.

Herrington, J.M., 2000, Evolution of the Kingman Arch, southern Nevada: University of Nevada Las Vegas, M.S. thesis, 83 p.

Hewett, D.F., 1931, Geology and ore deposits of the Goodsprings quadrangle, Nevada: U.S. Geological Survey Professional Paper 162, 172 p., scale 1:62,500.

Hewett, D.F., 1956, Geology and mineral resources of the Ivanpah quadrangle, California and Nevada: U.S. Geological Survey Professional Paper 275, 172 p., scale 1:125,000.

Hooke, R.LeB., 1967, Processes on arid-region alluvial fans: Journal of Geology, v. 75, 438–460.

House, P.K., Buck, B.J., and Ramelli, A.R., 2006, Preliminary surficial geologic map of the Ivanpah Valley part of the Jean and Bird Spring 7.5' quadrangles, Clark County, Nevada: Nevada: Nevada Bureau of Mines and Geology Open-File Report 06-11C, scale 1:24,000.

House, P.K., Buck, B.J., and Ramelli, A.R., 2010, Geologic assessment of piedmont and playa flood hazards in the Ivanpah Valley area, Clark County, Nevada: Nevada Bureau of Mines and Geology Report 53 [online version].

House, P.K., Ramelli, A.R., and Buck, B.J., 2006, Surficial geologic map of the Ivanpah Valley area, Clark County, Nevada: Nevada Bureau of Mines and Geology Map 156, scale 1:50,000.

House, P.K., Pearthree, P.A., Howard, K.A., Bell, J.W., Perkins, M.E., Faulds, J.E., and Brock, A.L., 2005, Birth of the lower Colorado River—stratigraphic and geomorphic evidence for its inception near the conjunction of Nevada, Arizona, and California, *in* Pederson, J., and Dehler, C.M., editors, Interior western United States: Boulder, Colorado, Geological Society of America Field Guide 6, p. 357–387.

Kohl, M.S., 1978, Tertiary volcanic rocks of the Jean-Sloan area, Clark County, Nevada, and their possible relationship to carnotite occurrences in caliches: University of California, Los Angeles, M.S. thesis, 116 p.

Longwell, C.R., Pampeyan, E.H., Bowyer, B., and Roberts, R.J., 1965, Geology and mineral deposits of Clark County, Nevada: Nevada Bureau of Mines and Geology Bulletin 62, 230 p., scale 1:250,000.

Ludwig, K.R., and Paces, J.B., 2002, Uranium-series dating of pedogenic silica and carbonate, Crater Flat, Nevada: Geochimica et Cosmochimica Acta, v. 66, no. 3, p. 487–506.

Machette, M.N., 1985, Calcic soils of the southwestern United States, *in* Weide, D.L., editor, Soils and Quaternary geology of the southwestern United States: Geological Society of America Special Paper 203, p. 1–21.

McDonald, E.V., McFadden, L.D., and Wells, S.G., 2003, Regional response of alluvial fans to the Pleistocene-Holocene climatic transition, Mojave Desert, California, *in* Enzel, Y., Wells, S.G., and Lancaster, N., editors, Paleoenvironments and paleohydrology of the Mojave and southern Great Basin deserts: Boulder, Colorado, Geological Society of America Special Paper 368, p. 189–205.

McFadden, L.D., 1988, Climatic influences on rates and processes of soil development in Quaternary deposits of southern California, *in* Reinhardt, J., and Siglio, W.R., editors, Paleosols and weathering through geologic time—principles and applications: Geological Society of America Special Paper 216, p. 153–177.

McFadden, L.D., Wells, S.G., and Dohrenwend, J.C., 1986, Influences of Quaternary climatic changes on processes of soil development on desert loess deposits of the Cima volcanic field, California: Catena, v. 13, p. 361–389.

Page, W.R., Lundstrom, S.C., Harris, A.G., Langenheim, V.E., Workman, J.B., Mahan, S.A., Paces, J.B., Dixon, G.L., Rowley, P.D., Burchfiel, B.C., Bell, J.W., and Smith, E.I., 2005, Geologic and geophysical maps of the Las Vegas 30′ × 60′ quadrangle, Clark and Nye counties, Nevada, and Inyo County, California: U.S. Geological Survey Scientific Investigations Map 2814, scale 1:100,000, 58 p.

Peterson, F.F., Bell, J.W., Dorn, R.I., Ramelli, R.A., Ku, T., 1995, Late Quaternary geomorphology and soils in Crater Flat, Yucca Mountain area, southern Nevada: Geological Society of America Bulletin, v. 107, p. 379–395.

Reheis, M.C., Sowers, J.M., Taylor, E.M., McFadden, L.D., Harden, J.W., 1992, Morphology and genesis of carbonate soils on the Kyle Canyon fan, Nevada, U.S.A.: Geoderma, v. 52, no. 3–4, p. 303–342.

Smith, E., Honn, D., and Johnsen, R., 2010, Volcanoes of the McCullough Range, southern Nevada, *in* Umhoefer, P.J., Beard, L.S., and Lamb, M.A., editors, Miocene tectonics of the Lake Mead region, central Basin and Range: Geological Society of America Special Paper 463, p. 203–219.

Sowers, J.M., Harden, J.W., Robinson, S.W., McFadden, L.D., Amundson, R.G., Jull, A.J.T., Reheis, M.C., Taylor, E.M., Szabo, B.J., Chadwick, O.A., Ku, T.L., 1988, Geomorphology and pedology on the Kyle Canyon alluvial fan, southern Nevada, *in* Weide, D.L. and Faber, M.L., editors, This extended land—geological journeys in the southern Basin and Range: Geological Society of America Cordilleran Section, Field Trip Guidebook, p. 137–157.

Williams, V.S., 1996, Preliminary geologic map of the Mesquite quadrangle, Clark and Lincoln counties, Nevada and Mojave County Arizona: U.S. Geological Survey Open-File Report 96-676, 1:24,000, 12 p.

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