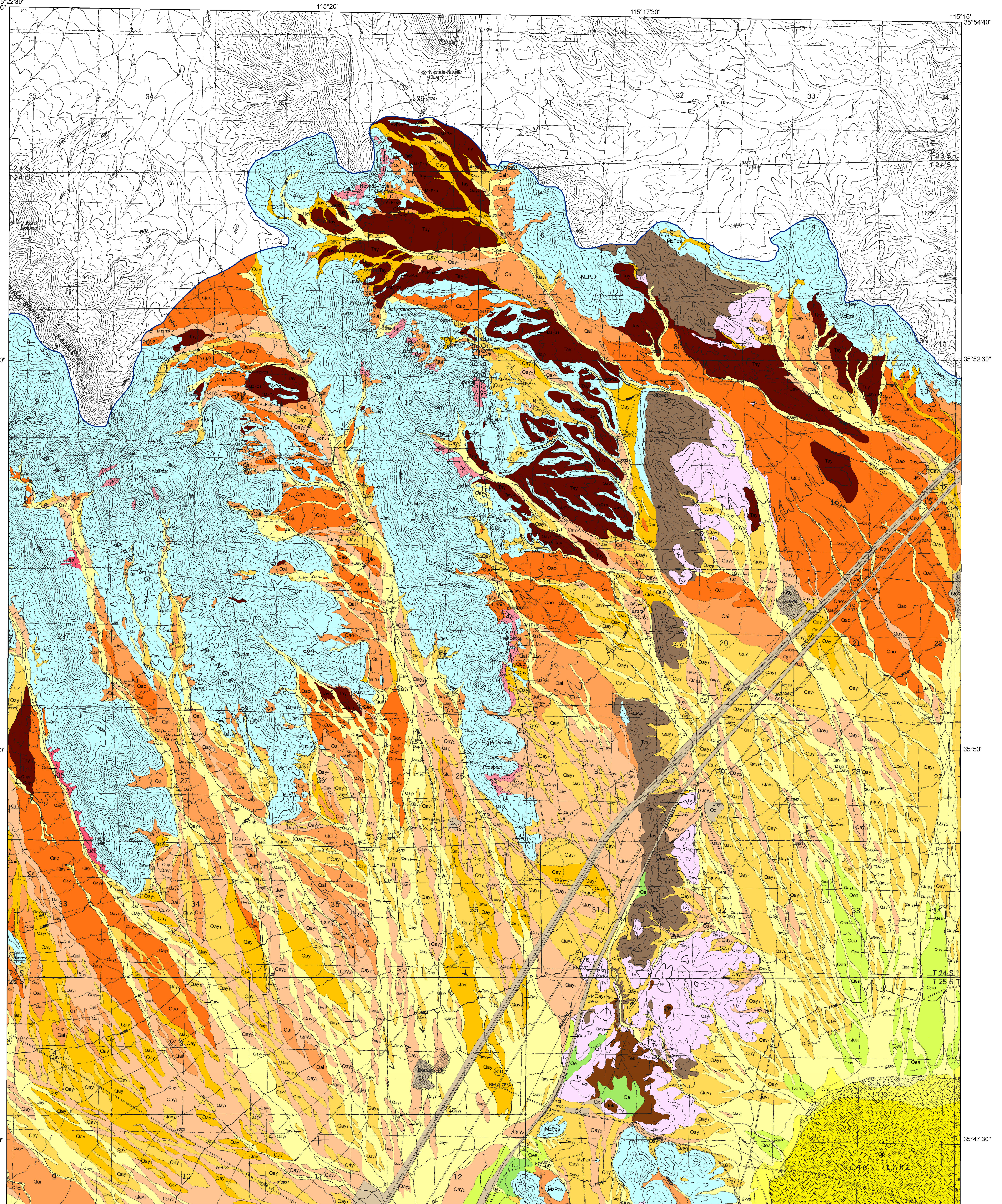

PRELIMINARY SURFICIAL GEOLOGIC MAP OF THE IVANPAH VALLEY PART OF THE JEAN AND BIRD SPRING 7.5' QUADRANGLES, CLARK COUNTY, NEVADA

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2006

SCALE 1:24,000

0 0.5 1 Kilometer

0 0.5 1 Mile

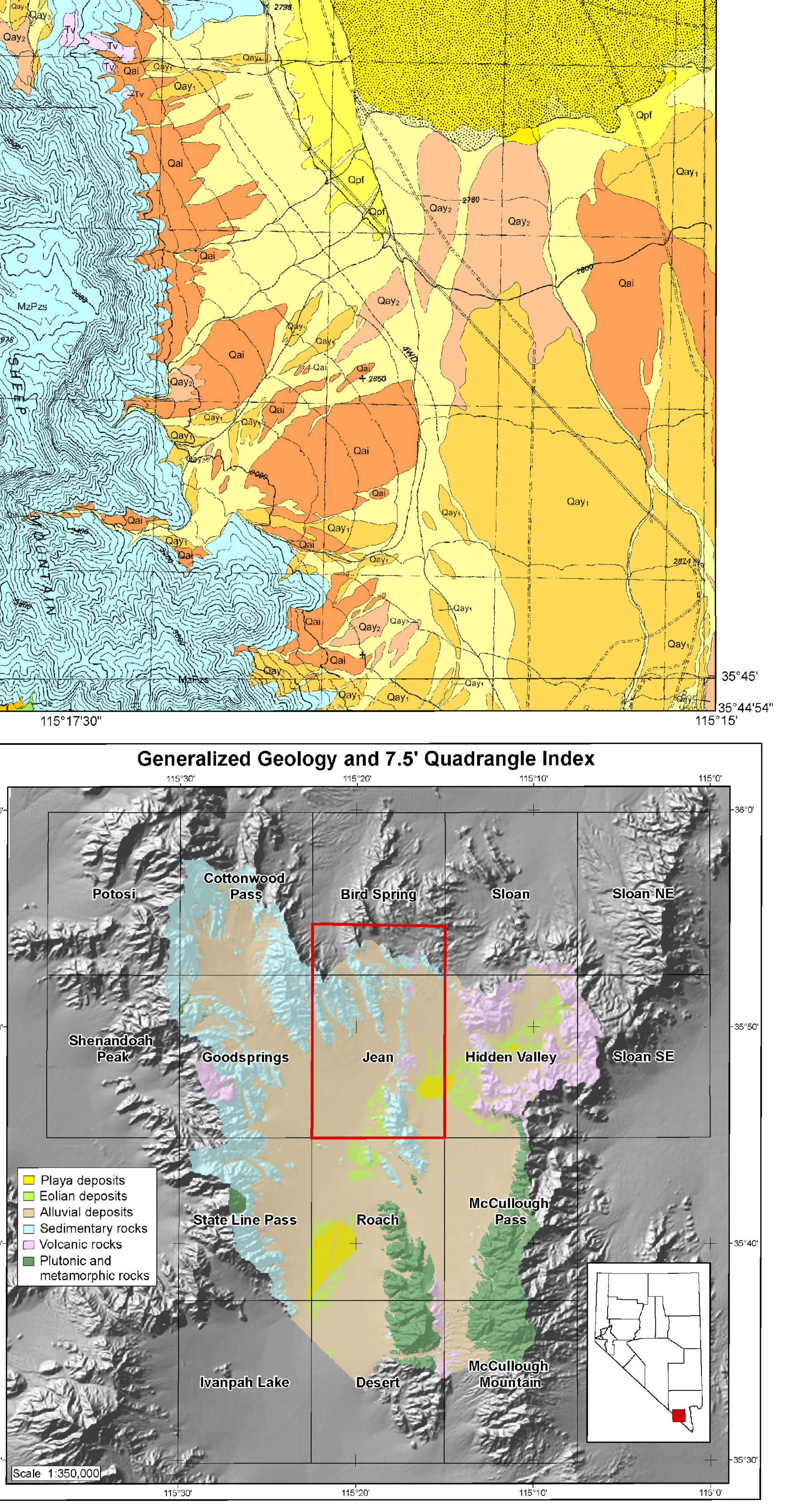
0 1,000 2,000 3,000 4,000 5,000 Feet

Base map: U.S. Geological Survey, Jean, NV, 7.5' Quadrangle, 1989
CONTOUR INTERVAL 40 FEET
Supplementary contour interval 20 feet
and U.S. Geological Survey, Bird Spring, NV 7.5' Quadrangle, 1989
CONTOUR INTERVAL 40 FEET
Projection: Universal Transverse Mercator, zone 11
1927 North American Datum

Contact Dashed where approximately located.

Watershed Boundary

Generalized Geology and 7.5' Quadrangle Index



SURFICIAL DEPOSITS, HOLOCENE TO MIOCENE

Descriptions modified slightly from House and others (2006)

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 vicinities of Jean, Primm, and Goodsprings); 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 mapped area is entirely internal. All runoff drains to one of two dry lakes (playas): Roach Lake 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 on the playas.

The soils on these active playa surfaces are characterized by A-Bw-Bk horizons composed of clay loam, 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 dominant constituents. Locally, unit grades into Qea, Qe, or Qay, and may include some Qay_1. Unit is interpreted to represent a playa-bajada interface with a locally significant eolian component, particularly along the east and northeast boundaries of playa surfaces.

Soils on Qpf surfaces are generally characterized by thin (4–15 cm) 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 containing a mixture of sand and alluvial gravel. Distribution of all 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). The playas and distal parts of alluvial fans are the presumed principal source of sand. Thickest accumulations occur along and upslope of the north and northeast margins of playas.

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 ranges from flat-lying to broadly undulate sheets of sand on inactive alluvial fan surfaces, sand ramps and falling dunes on steep bedrock slopes (best expressed in the Sheep Mountain and Hidden Valley areas), 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 moderate 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, but is divided 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 is 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, and block fields and sieve deposits on steep bedrock slopes. Deposits composed of angular to subangular boulders and cobbles. This unit is particularly common on steep bedrock slopes formed on volcanic bedrock in the northeast 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 and alluvial fans. 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, occupation, 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 (see inset). 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, minor Proterozoic granite and gneiss), and the Jean hills (informal name; Tertiary volcanic rocks and gravel).

Alluvial deposits are composed predominantly of massive to moderately sorted, moderately to well stratified sands and gravels 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 grained than younger ones, but this may largely reflect the fact that the upper and middle parts of the associated alluvial fans are best 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: 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 and others, 1988; Reheis and others, 1992; Bell and others, 1998; Ludwig and Paces, 2002; McDonald and others, 2003; Page and others, 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-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. In many of these cases there is strong evidence of debris flow processes.

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 clast weathering ranges from nil to moderate varnish and carbonate clast etching. 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 nil 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 have 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 semi-stable 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 and others (2003) reported a late to middle-late Holocene age range (4 to 6 ka) for surfaces and soils in the eastern Mohave Desert that are generally correlative to the Ivanpah Valley Qay_2 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 strongly planar morphology, moderate to strongly developed gravel pavement, and moderate to dark rock varnish. Minor etching of carbonate clasts is common. Deposit surface commonly has a distinctive aerial photograph 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 or Av horizons (2–8 cm thick) overlie Bw (8–31 cm thick), Bt (8–18 cm thick), and/or Bk (10–61 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 and others, 1998; McDonald and others, 2003; Page and others, 2005). Radiometric and mineral luminescence ages of the deposits reported in those studies range from the early Holocene to the late Pleistocene (approximately 9 to 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 at 1:50,000 scale. 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 to 50 ka; Page and others, 2005), the older and more widespread subunit(s) possibly date to late-middle Pleistocene (>50 to 350 ka; Sowers and others, 1988; Page and others, 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 Qay1 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.

Qao soil and surface characteristics generally correspond to deposits in parts of Las Vegas Valley that are older than 730 ka (Sowers and others, 1988).

Ancient Surficial Deposits, Pliocene 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, pre-Quaternary 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 comparably well developed to more strongly developed petrocalcic soil remnants formed in eolian sediment and colluvial rubble on weathered bedrock surfaces in some isolated locations in the Jean hills. These features occur on local bedrock highs along the general trend of the eolian corridor delimited by the distribution of late Quaternary eolian deposits.

The extremely strongly developed petrocalcic soils typical of the following units, their geomorphic position, and their inset stratigraphic relations suggest that they may be millions of years old. Comparably strong soils in the general region have only been reported from the Mormon Mesa (Gardner, 1972; Bachman and Machette, 1977; Williams, 1996) and lower Colorado River areas (House and others, 2005) where reported age controls and stratigraphic relations support Pliocene to Miocene ages.

Tay **Ancient alluvium (Pliocene 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 outcrop as ledges on ridge slopes in deeply dissected areas. The petrocalcic horizons are characterized by multiple crosscutting 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 soil carbonate horizons (Bkm) with strong Stage VI morphology formed in silt, sand, and coarse gravelly rubble on bedrock surfaces. First mapped by Kohl (1978). Distribution in the mapped area is limited mainly to zones of persistent flux of eolian sediment in the Jean hills area northeast of Jean, Nevada. These massive, Stage VI petrocalcic horizons are characterized by intervals of multiple crosscutting 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 between 2 and 5 m.

BEDROCK UNITS, MIOCENE TO PALEOZOIC

Descriptions modified slightly from House and others (2006)

This map shows three principal bedrock units divided on the basis of major lithologic characteristics, including: middle Miocene to Oligocene siliciclastic sedimentary rocks (conglomerate, sandstone, and minor mudstone); Mesozoic and Paleozoic sedimentary rocks (carbonate and siliciclastic, undivided); and Miocene volcanic rocks (undivided rhyolite, andesite, and basalt). No structure or individual formations are indicated on the map.

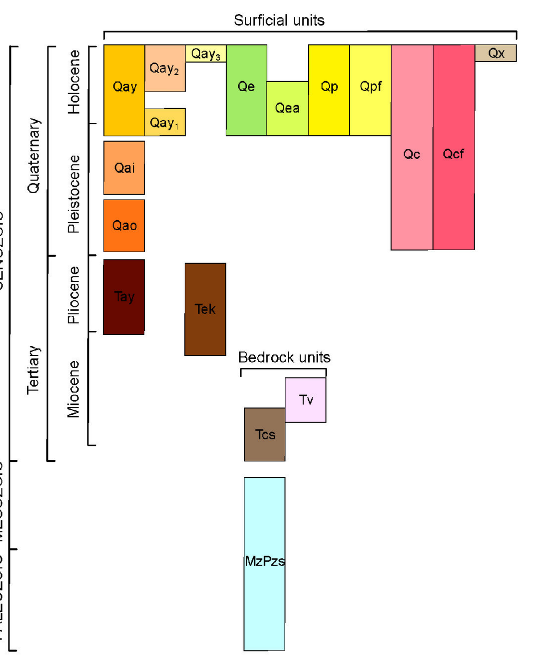
Tcs **Young sedimentary rocks, undivided (Miocene to Oligocene?)** Variably consolidated deposits of gravel conglomerate and minor sandstone and mudstone. Correlative in part to the 'early gravels' of Hewett (1931). Conglomerate is most widely exposed facies and contains subrounded to rounded fluvial pebbles, cobbles, and boulders. In many outcrops, clast composition includes abundant subrounded to well-rounded quartzite clasts. Observed degrees of clast rounding and the presence of quartzite are uncommon in all younger alluvial deposits in the study area and indicate a very different type of depositional system. Gravels are generally clast-supported, moderately sorted to well sorted, well bedded, and commonly tilted and faulted. Tcs deposits are commonly associated with well-developed, high-standing ballena landforms characterized by highly degraded, possibly multiple, massive petrocalcic soil horizons. A series of Tcs ballenas north of Jean define a distinctly linear, north-striking trend that may be fault-controlled.

Tcs gravel deposits rest unconformably on Mesozoic and Paleozoic sedimentary rocks (MzPzs) and are overlain by Miocene volcanic rocks (Tv). This relation was first noted in the Jean area by Kohl (1978). Other than this key stratigraphic constraint, the age of Tcs is not known with certainty. We interpret the age of this unit as Miocene based on the stratigraphic relation with the overlying volcanic rocks and suggest that the deposits may be correlative to the lower part of the 26–14 Ma Horse Spring Formation (Bohannon, 1984; Beard, 1996). In a deep wash cut through the hills northeast of Jean (the 'Jean hills'), a sequence of lithic sandstone, pebble conglomerate, and minor mudstone are included in Tcs. The pebble conglomerate contains clasts of vesicular basalt that may be Miocene in age. Also in this area there is a thin volcanic unit containing pebble- to cobble-size clasts of pumice and obsidian in an apparent but unresolved interbedded relationship with fine-grained Tcs sediments.

Tv **Young volcanic rocks, undivided (late? to middle Miocene)** Includes numerous volcanic rock units ranging in composition from basalt to rhyolite (Hewett, 1931, 1956; Bingler and Bonham, 1972; Kohl, 1978; Bridwell, 1991). Extensive exposures occur in the Jean hills and smaller outcrops overlie Tcs in the Bird Spring Range.

MzPzs **Old sedimentary rocks, undivided (Cretaceous to Cambrian)** Includes numerous carbonate (limestone and dolomite) and siliciclastic (sandstone, mudstone, and conglomerate) rock units spanning the Paleozoic and Mesozoic. This undivided unit contains numerous unconformities and is crossed by a series of major thrust faults (Hewett, 1931, 1956; Longwell and others, 1965; Burchfiel and others, 1974; Carr and Pinkston, 1987). These rocks form the bulk of the Bird Spring Range and Sheep Mountain.

A shapefile of the geology polygons is available at
www.nbmg.unr.edu/dox/Map156_Ivanpah_geo_polygons.zip



REFERENCES

Bachman, G.O., and Machette, M.W., 1977, Calcic soils and calcretes in the southwestern U.S.: U.S. Geological Society Open-File Report 77-794, 163 p.
Beard, L.S., 1996, Paleogeography of the Horse Spring Formation (Lake Mead Fault System), *in* Beratan, K.K., ed., Reconstructing the History of Basin and Range Extension Using Sedimentology and Stratigraphy: Geological Society of America Special Paper 303, p. 27–60.
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, 1:24,000.
Birkeland, P.W., 1999, Soils and Geomorphology (3rd ed.): Oxford University Press, New York, 430 p.
Bridwell, H.L., 1991, The Sloan Sag: A mid-Miocene volcanotectonic depression, north-central McCullough Mountains, southern Nevada [MS thesis]: University of Nevada, Las Vegas, 147 p.
Bohannon, R.G., 1984, Nonmarine sedimentary rocks of Tertiary age in the Lake Mead region, southeastern Nevada and northwestern Arizona: U.S. Geological Survey Professional Paper 1259, 72 p.
Bull, W.B., 1991, Geomorphic Response to Climate Change: Oxford University Press, New York, 326 p.
Burchfiel, B.C., Fleck, R.J., Secor, D.T., Vincelette, R.R., and Davis, G.A., 1974, Geology of the Spring Mountains, Nevada: Geological Society of America Bulletin, v. 85, p. 1013–1022.
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, 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., ed., Soils and Quaternary geology of the southwestern United States: Geological Society of America Special Paper 203, p. 115–122.
Gardner, L. R., 1972, Origin of the Mormon Mesa caliche, Clark County, Nevada: Geological Society of America Bulletin, v. 83, p. 143–156.
Hewett, D.F., 1931, Geology and ore deposits of the Goodsprings Quadrangle, Nevada: U.S. Geological Survey Professional Paper 162, 172 p.
Hewett, D.F., 1956, Geology and mineral resources of the Ivanpah Quadrangle, California and Nevada: U.S. Geological Survey Professional Paper 275, 172 p.
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, 1:50,000.
House, P.K., Pearthree, P.A., Howard, K.A., Bell, J.W., Perkins, M.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., eds., Interior Western United States: 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 [M.S. thesis]: University of California, Los Angeles, 116 p.
Longwell, C.R., Pampeyan, E.H., Bower, B., and Roberts, R.J., 1965, Geology and mineral deposits of Clark County, Nevada: Nevada Bureau of Mines and Geology Bulletin 62, 230 p.
Ludwig, K.R. and Paces, J.B., 2002, Uranium-series dating of pedogenic silica and carbonate, Crater Flat, Nevada: Geochemica et Cosmochemica Acta, v. 66, p. 487–506.
Machette, M.N., 1985, Calcic soils of the southwestern United States, *in* Weide, D.L., ed., 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, Mohave Desert, California: *in* Enzel, Y., Wells, S.G., and Lancaster, N., eds., Paleoenvironments and Paleohydrology of the Mohave and Southern Great Basin Deserts: Geological Society of America Special Paper 368, p. 189–205.
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' x 60' Quadrangle, Clark and Nye Counties, Nevada, and Inyo County, California: U. S. Geological Survey Scientific Investigations Map 2814, 1:100,000.
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, p. 303–342.
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., eds., This Extended Land, Geological Journeys in the Southern Basin and Range, Geological Society of America Cordilleran Section, Field Trip Guidebook, pp. 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 96-0678, 1:24,000, 12 p.

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This map is extracted directly from the House and others (2006) 1:50,000 scale geologic map. The data have not been explicitly reviewed at 1:24,000 scale

Preliminary geologic map.
Has not undergone office or field review.
Has not been edited.
Will be revised before publication.

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