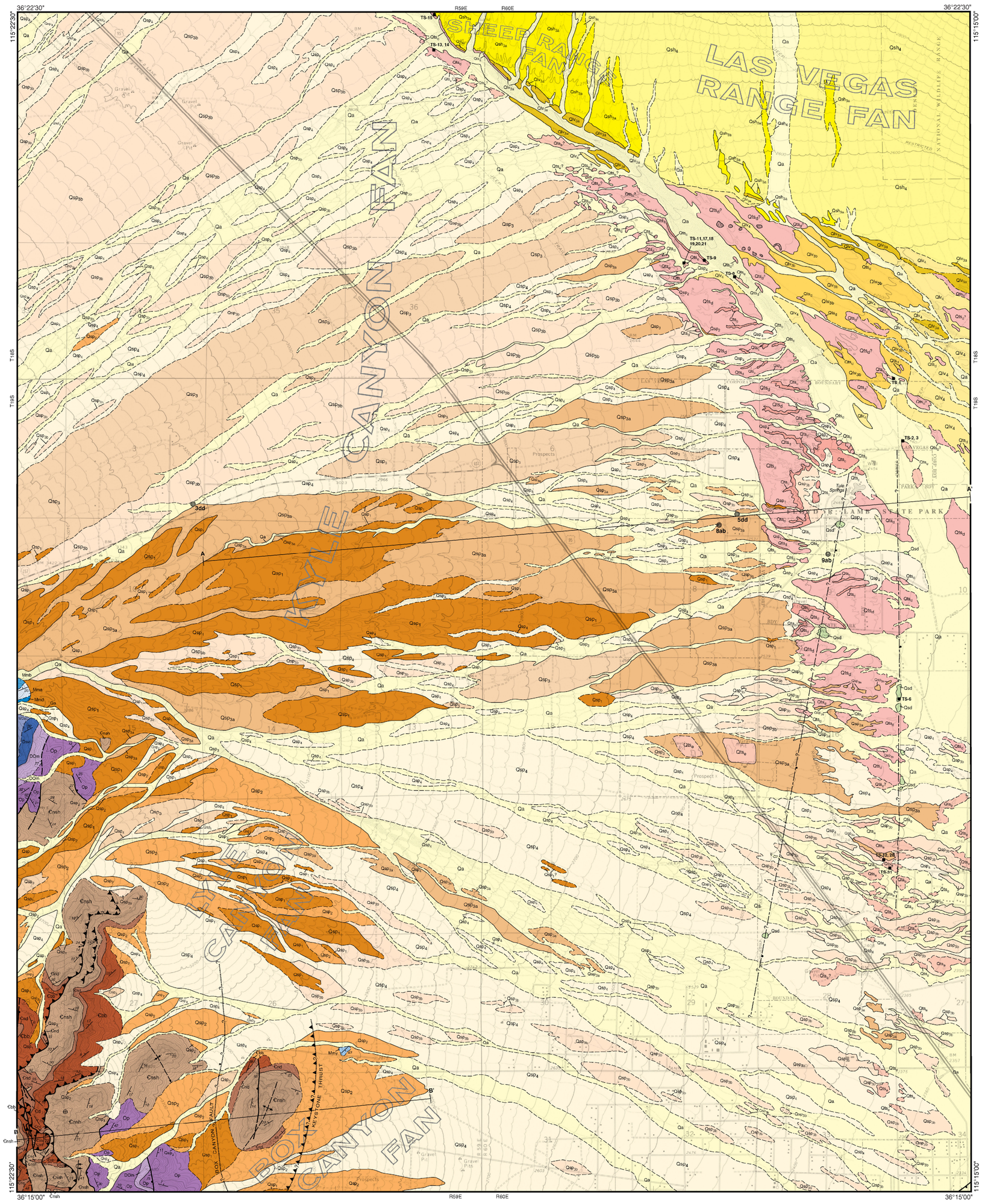


Scale 1:24,000

0 0.5 1 kilometer

0 0.5 1 mile

0 1000 2000 3000 4000 5000 feet

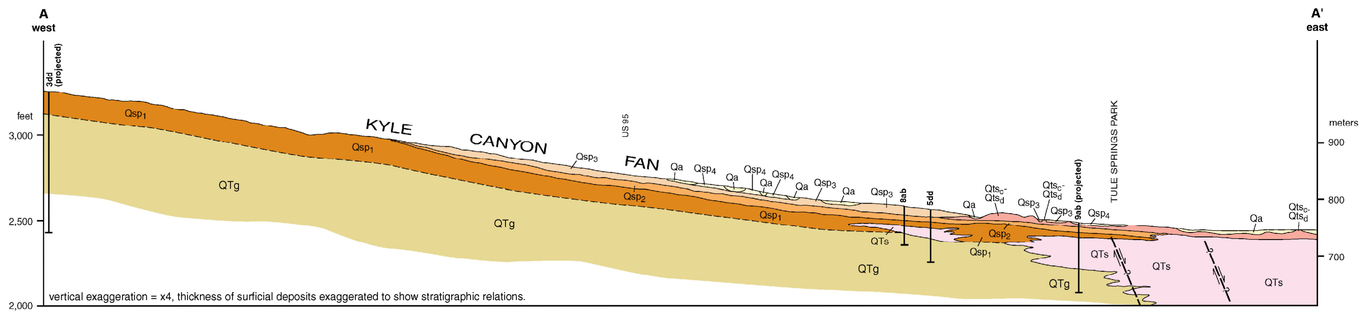
CONTOUR INTERVAL 20 FEET

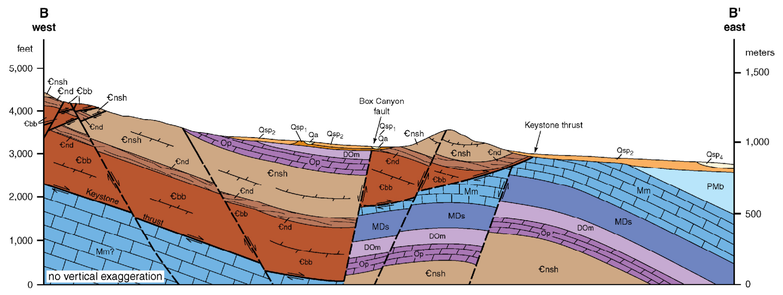
Base map: U.S. Geological Survey Tule Springs Park 7.5' Quadrangle, 1983

GEOLOGIC MAP OF THE TULE SPRINGS PARK QUADRANGLE, NEVADA

John W. Bell, Alan R. Ramelli, and S. John Caskey

1998





Field work 1997.

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Table 1. Radiocarbon ages from Tule Springs Park Quadrangle (this study)

Sample no.	Unit	Material dated	^{14}C age (yr BP)	Lab no.	Calibrated age (yr ±1σ)
TS-1	Qts_e	Organic mud	13,180±480	GX-23064	15,714 $^{+665}_{-777}$
TS-2	Qts_e	Carbonized wood, organic mud	12,230±560	GX-23065	14,278 $^{+632}_{-678}$
TS-3	Qts_e	Large snail	15,710±120	GX-23066*	18,604 $^{+142}_{-140}$
TS-6	Qsd	Peat, organic mud	1,665±70	GX-23068	1,541 $^{+143}_{-54}$
TS-8	Qts_e	Disseminated charcoal, carbonized wood	14,290±440	GX-23070	17,132 $^{+501}_{-530}$
TS-9	Qts_c	Small snails, gastropods, clams, organic mud	29,460±390	GX-23071*	**
TS-11	Qts_e	Disseminated charcoal, carbonized wood	11,900±350	GX-23073	13,872 $^{+452}_{-406}$
TS-12	Qts_e	Disseminated peat, organic mud	11,530±350	GX-23074	13,449 $^{+414}_{-364}$
TS-13	Qts_d	Small snails, clams	20,560±300	GX-23075*	**
TS-14	Qts_d	Large snails	20,110±2,050	GX-23076	**
TS-15	Qts_d	Small snails, gastropods, clams	20,390±160	GX-23077*	**
TS-17	Qts_e	Disseminated carbonized wood, organic mud	10,680±150	GX-23079	12,611 $^{+156}_{-171}$
TS-18	Qts_e	Organic mud	11,590±310	GX-23080	13,516 $^{+373}_{-333}$
TS-19	Qts_e	Detrital charcoal, carbonized wood	11,810±350	GX-23081	13,766 $^{+441}_{-398}$
TS-20	Qts_e	Disseminated charcoal, carbonized wood	10,790±180	GX-23082	12,718 $^{+179}_{-188}$
TS-21	Qts_e	Organic mud	10,100±170	GX-23083	11,678 $^{+444}_{-670}$
TS-28	Qts_e	Disseminated peat, organic mud	11,470±450	GX-23089	13,384 $^{+524}_{-451}$
TS-31	Qts_e	Organic mud	12,680±430	GX-23987	14,921 $^{+697}_{-691}$

* AMS date.
** Beyond maximum calibration range.

Contact Dashed where approximately located.

Spring lineament Possible concealed fault; ball on downthrown side.

Normal fault Arrow shows trend of striae, tic shows dip direction, numbers indicate dip angle; dashed where approximately located, dotted where concealed, queried where uncertain; ball on downthrown side. On cross section, arrows show sense of displacement.

Thrust fault Dashed where approximately located, dotted where concealed, queried where uncertain. Teeth on upper plate. On cross section, arrows show sense of displacement.

Syncline Showing plunge of fold and trace of axial surface, dashed where approximately located.

Overturned syncline Showing trace of axial surface and direction of dip of limbs.

Strike and dip of bedding
Inclined Horizontal Vertical

Well location
From Plume (1984) and D. Donovan (unpublished data).
TS-2

^{14}C sample location for this study

Surficial Deposits

Qsd **Spring mound deposits** Light- to medium-gray loose silt and hard mud; light-brown eolian sand occurring in mounds and caldrons. Contains dark-gray peat beds (black mats) as much as 30 cm thick. Locally contains 15- to 30-cm-thick spring tufa layers composed of carbonate-cemented mud and silt nodules. Ranges from late Pleistocene to modern in age. A ^{14}C age of 1,665±70 yr BP was obtained from the upper part of a spring mound at TS-6 (table 1), and ^{14}C ages of latest Holocene (1,000 yr BP) and Qts_a and younger age were reported by Haynes and others (1966), Haynes (1967), and de Narvaez (1995). Haynes (1967) suggested linear alignment of spring mounds was controlled by concealed faults.

Alluvial-Fan Deposits

Qa **Alluvium of active washes** Dominantly pebble-cobble sandy gravel with layers and lenses of reworked silt deposits. Anastomosing bar-and-channel network; poorly to very poorly sorted; poorly to moderately stratified; nonindurated. No soil development. Subject to intermittent flooding. Exposed thicknesses less than 3 m.

Alluvial-Fan Deposits of the Spring Mountains (Qsp)

Coarse-grained alluvial-fan deposits originating from principal drainages along the eastern side of the Spring Mountains. In this quadrangle, includes poorly to moderately sorted, rounded to subangular, sandy pebble-cobble gravels of the Kyle Canyon, Lyle Canyon, and Box Canyons fans. Derived from Paleozoic rock provenances to the west; Kyle Canyon fan dominated by Bird Spring Formation; Lyle and Box Canyon fans contain Cambrian to Mississippian assemblages. Clast compositions are more than 90% carbonate rocks with the remainder consisting of reddish to yellowish calcareous siltstones and sandstones and rare white quartzites. The deposits range from Pliocene(?) through Holocene in age. The fan unit nomenclature follows that of Sowers (1985, 1996); and Sowers and others (1988).

Qsp_4 Fan-terrace remnants characterized by subdued to nearly fully smoothed bar-and-channel surface morphology, incipient to moderately packed desert pavement, weak to moderate rock varnish, and slight etching of surface carbonate clasts. At fan heads and at distal end of Kyle Canyon fan, unit inset 1 to 2 m below adjacent older surfaces, but has minimal topographic separation in mid-fan areas. Soils are typically A-C profiles with a 5 cm Av and a 35 cm Bk horizon exhibiting stage I carbonate development (1-mm-thick clast coatings).

Qsp_3 **Qsp_{3a}** **Qsp_{3b}** Interfluvial and fan-terrace remnants overlying and inset into Qts_c deposits. Characterized by well-developed, tightly packed desert pavement; dark rock varnish; and moderately to strongly etched surface carbonate clasts. At fan heads, typically inset 0.5-1 m below adjacent older surfaces, in mid-fan areas have minimal topographic separation from younger or older surfaces; and at distal end of Kyle Canyon fan consists of multiple topographically inset levels. Two map subunits are distinguished based on soil differences; they are undifferentiated in cross section. Unit Qsp_{3b} consists of the oldest and topographically highest fan remnants overlying Qts_e. Unit typically contains a soil exhibiting a 5 cm Av horizon, 20 to 30 cm prominently reddened (7.5 YR 5/6 to 7.5 YR 6/4) Bw to Bt horizon, and 30+ cm Bk horizon (stage II to II+ with 2- to 10-mm-thick clast rinds). Unit Qsp_{3b} is inset 1 to 5 m below Qsp_{3a} at the distal end of the Kyle Canyon fan. Desert pavement may be less tightly packed and surface carbonate clasts may exhibit less etching than adjacent Qsp_{3a} surfaces. Unit typically contains a soil exhibiting a 5 cm Av horizon, 10 to 20 cm Bwk with localized reddening (10 YR 6/4 to 7.5 YR 6/6), and 20+ cm Bk horizon (stage I) with incipient pendants. Qsp_{3b} overlies Qts_e dated at 11,000 to 12,000 yr BP (TS-12, -28, -31; table 1). These ages are similar to 10,000 to 15,000 yr ^{14}C ages on soil carbonate west of quadrangle, but much younger than 47,000 to 76,000 yr uranium-series ages reported for this unit (Sowers and others, 1988).

Qsp_2 Fan-terrace remnants characterized by well-developed, tightly packed desert pavement, dark rock varnish, and very strongly etched surface carbonate clasts. Forms extensive dissected remnants on Lyle Canyon and Box Canyon fans and a few small remnants on that part of the Kyle Canyon fan in the map area. Lighter in tone than Qsp_3 on aerial photographs due to more abundant calcrete clast litter on surface. Unit typically contains a soil exhibiting a 5 cm Av horizon, 20 to 40 cm prominently reddened (7.5 YR 6/4 to 7.5 YR 6/6) and well structured Bt horizon, and 100 to 150 cm Bkm horizon (stage III with a few thin laminae). In upper parts of Lyle Canyon and Box Canyon fans, equivalent soil is formed on multiple inset surfaces and on erosionally rounded remnants. Upper soil horizons erosionally stripped in some areas. Uranium-series dating of soil carbonate west of quadrangle yielded an age of 129,000±6,000 yr (Sowers and others, 1988).

Qsp_1 Fan-terrace remnants characterized by deep dissection and discordant rounded remnants (ballenas); well-developed, tightly packed pavement dominated by whitish calcrete clast litter; and deeply etched surface carbonate clasts. Outcrops of massively cemented calcretes common; whitish tone on aerial photographs due to abundant calcrete clasts. Forms extensive remnants on southern part of Kyle Canyon fan complex. Unit typically contains a soil exhibiting a 3- to 5-m-thick, massively cemented calcrete (stage V), with upper soil horizons erosionally stripped. Unit is commonly carbonate cemented to depths of several meters. Sowers (1985) estimated the unit to be >730,000 yr based on paleomagnetic data.

QTg **Older alluvial-fan deposits, undivided** (in cross section only). Pebble to boulder gravel deposits and cemented fanglomerates. Unit underlies Qsp_1 and is coarse-grained facies of QTs; includes units A and B of Sowers (1985). More than 150 m thick based on well 3dd.

Alluvial-Fan Deposits of the Las Vegas and Sheep Ranges (Qsh)

Coarse-grained alluvial-fan deposits originating from principal drainages in the Las Vegas and Sheep Ranges. In this quadrangle, includes poorly sorted, subangular to subrounded, sandy pebble-cobble gravels. Derived from Paleozoic rock provenances to the east and northeast. Clast lithologies of the Sheep Range fan are similar to Qsp with more than 90% carbonate rocks and the remainder consisting of reddish to yellowish calcareous siltstones and sandstones and, here, commonly white quartzites. Lithologies of the Las Vegas Range fan are distinctly different, consisting of 60% carbonate rocks and 40% brownish to yellowish calcareous siltstones and sandstones, dark-red quartzites, and locally scattered aplitic and granitic rocks.

Qsh_4 Fan-terrace remnants characterized by subdued bar-and-channel surface morphology, incipient desert pavement, weak rock varnish, and slight etching of surface carbonate clasts. Equivalent to Qsp_4. Soils are typically A-C profiles with a 5 cm Av and a 35 cm Bk horizon exhibiting stage I carbonate development (1-mm-thick clast coatings).

Qsh_{3a} Fan remnants overlying and inset into Qts_d deposits; equivalent to Qsp_{3a}. Characterized by well-developed, tightly packed desert pavement; dark rock varnish; and moderately to strongly etched surface carbonate clasts. Soil contains 5 cm Av horizon, 20 to 30 cm prominently reddened (7.5 YR 5/6 to 7.5 YR 6/6) Bw horizon, and 30+ cm Bk horizon (stage II with 2- to 3-mm-thick clast rinds).

Mainstream Alluvium of Las Vegas Wash (Qlv)

Fluvial stream terrace remnants composed of reworked alluvial-fan gravels from the Spring Mountains and Las Vegas and Sheep Ranges. Subangular to subrounded pebble-cobble sandy gravel; moderately well sorted; locally well stratified and crossbedded. Generally 1 to 3 m thick. Erosionally inset into fine-grained deposits of Qts_d and Qts_e. In part includes the unit F_2 gravels of Haynes (1967). East of Tule Springs, deposits are part of broad distributary channel network across eroded Qts_d and Qts_e deposits. Clast lithologies are a mixture of carbonate, calcareous siltstone, sandstone, and quartzite rocks dependent upon proximity to alluvial fan sources.

Qlv_4 Broad anastomosing network of stream terrace and distributary channel remnants standing slightly (1 to 2 m) above active washes. Exhibits bar-and-channel morphology, incipient desert pavement and weak rock varnish. Soils are A-C profiles. Boundaries to Qlv_{3a} and Qlv_{3b} are gradational.

Qlv_{3b} Broad, flat stream terrace remnants inset 1 to 2 m below Qlv_{3a} deposits. Characterized by well-developed desert pavement, dark rock varnish, and moderate to strong etching of carbonate clasts. Reddened (7.5 YR 6/6) Bw and stage I to II Bk soil horizons.

Qlv_{3a} Linear stream terrace remnants forming prominent high-level surfaces inset slightly (<1 m) below Qsh_{3a} and Qsp_{3a}. In the narrows between the Kyle Canyon and Sheep Range fans at the northern edge of the quadrangle, prominent remnants overlying Qts_d on both sides of the present wash mark paleochannels of Las Vegas Wash. Well-developed desert pavement, dark rock varnish, and moderate to strong etching of carbonate clasts. Contains strongly reddened (7.5 YR 5/6) Bw horizon and a stage II Bk horizon.

Fine-Grained Deposits

Fine-Grained Alluvium of Tule Springs (Qts)

Spring and paludal deposits comprising extensive fine-grained valley-bottom fill in upper Las Vegas Valley; related to extensive groundwater discharge during glacial/pluvial periods (Quade, 1983, 1986; Quade and others, 1995). Originally believed to be largely lacustrine in origin (Longwell and others, 1965; Haynes, 1967) and mapped as the Las Vegas Formation by Longwell and others (1965); named the Tule Springs alloformation by Donovan (1996). Divided here into three members (units C, D, and E) after Haynes (1967).

Qts_e **Unit E** Light-brown to yellowish-brown silt, fine sandy silt, and light-gray to gray organic mud; locally light-green clay. Typically 1-3 m thick, consisting of channel fills and bedded layers erosionally inset into Qts_c and Qts_d. Thin-bedded (15 to 30 cm) to massive. In southeastern part of quadrangle, unit occurs as 1- to 2-m-thick layer of brown, loose fine sandy silt containing thin (10 to 15 cm) peat and charcoal layers (unit E_1 of Haynes, 1967); beneath Qsp_{3a} alluvial-fan gravels (unit E_2 of Haynes, 1967). No diagnostic soil distinguished, although unit may be locally capped by 15-cm-thick nodular carbonate layer. Contains numerous gray to dark-gray peat, charcoal, and organic-rich horizons (black mats) 10- to 15-cm-thick; 1-m-thick organic mud zones with aquatic and terrestrial fossils, including small (1 to 3 mm) clams, gastropods, and snails and locally large (2 cm) snails. Large vertebrate fossils include bison, mammoth, horse, deer, and camel (Mawby, 1967); commonly found as broken and scattered fragments on outcrop surfaces. Late Wisconsin to early Holocene age. ^{14}C dated at 10,000 to 16,000 yr BP (table 1); dated east and north of quadrangle at 7,000 to 14,000 yr BP (Haynes and others, 1966; Haynes, 1967; de Narvaez, 1995; Quade and others, 1995).

Qts_d **Unit D** Typically light-gray to gray organic mud, but also includes very light-gray, light-brown, light-yellowish-brown, and light-green mud, silt, fine sandy silt; fine sand, and locally clay. Interbeds and lenses of well-sorted pebble-cobble gravel (stippled on map) are common in Qts_d deposits along Las Vegas Wash where exhumed gravels form darkly varnished layers armoring surface outcrops. Exposed thickness is typically 3 to 4 m with a maximum of 8 m in deep wash cuts. Generally consists of uniformly massive to thick-bedded, flat-lying beds of hard mud dipping gently toward axis of valley; where consisting predominantly of silts and fine sands, the unit is thinly laminated and locally fissile. Unit is characterized by a prominent 30- to 50-cm-thick layer of massive, cemented calcium carbonate (calcrete). Morphologic variations in the calcrete horizon include layers of 2- to 3-cm-thick calcrete nodules, tubes, cicada burrows, and plates which form a lag deposit armoring the surface. Calcrete horizon occurs near, but not at the top of the unit and forms a resistant, exhumed platform-like cap on most large outcrops at and north of Tule Springs. Dark-gray mud layers contain 5- to 15-cm-thick layers of peat, disseminated charcoal, large mammal bones, and clams, gastropods, and snails similar to those in Qts_e. Distinguished from Qts_e deposits by presence of calcrete horizon. Late Wisconsin age. ^{14}C dated at 20,000 to 29,000 yr BP (table 1); dated east and north of the quadrangle at 14,000 to >30,000 yr BP (Haynes, 1967; Quade and others, 1995). A date of 25,300±2,500 yr BP was obtained by Haynes (1967) from Qts_d south of Tule Springs.

Qts_c **Unit C** Typically light-brown to brown mud; locally reddish- to yellowish-brown mud and clay. Exposed thickness is 3 to 5 m. Massive to thick (30 to 60 cm) bedded. Very hard in exposed outcrop. Fossil-poor. As mapped by Haynes (1967) unit underlies most outcrops of Qts_d in Tule Springs area with the contact marked by a disconformity locally exhibiting a weakly developed carbonate (Bk) soil with occasional carbonate nodules. The contact between the two units is prominent in outcrops immediately west and north of Tule Springs where distinctive light-gray Qts_d muds lie disconformably on brown Qts_c muds. But mapping indicates the two units are interbedded facies; a ^{14}C date on shells in Qts_c yielded an age of 29,460±390 yr BP (TS-9; table 1).

QTs **Older fine-grained sediments, undivided** (in cross section only). Light-colored silt, fine sandy silt, mud, pebbly sand, and interstratified pebble-cobble gravel. Moderately to well cemented; contains multiple layers and lenses of strongly cemented calcrete. Upper part includes the Tule Springs units A and B of Haynes (1967). Forms a basin-fill sequence in upper Las Vegas Valley more than 250 m thick based on well log data in SE1/4 section 16 south of Tule Springs. Grades abruptly to the west into Qsp and QTg alluvial-fan deposits, possibly along an east-dipping set of north-trending faults. Unit thins to less than 30 m in thickness 0.8 km west of Tule Springs.

Sedimentary Rocks

PMb **Bird Spring Formation** (Inferred in cross section only; description modified from Axen, 1985). Consists of variably alternating beds of tan to gray, thin- to medium-bedded limestone and dolostone, orange-weathering silty limestone and dolostone, and orange-weathering siltstone; chert layers and nodules up to 1 m in thickness or diameter are common; cross bedding and other sedimentary features are common; fossils are common throughout the unit and include corals (*Chaetetes* is diagnostic), spirifer brachiopods, gastropods, crinoids, and abundant fusilinids which are characteristic of the unit; basal Indian Springs Member (Indian Springs Formation of Webster and Lane, 1967) is 5 to 10 m thick and consists of orange-weathering, limy sandstone, siltstone and conglomerate; in the lower plate of the Keystone thrust in the La Madre Mountain area (Axen, 1985), the base of the formation is marked by a distinctive red-weathering limestone with abundant calcite vugs about 5 cm in thickness; total unit thickness below Keystone thrust in the adjacent La Madre Mountain area (Axen, 1985) is a minimum of 1 km.

Mn **Monte Cristo Limestone (undifferentiated)** (in cross section only). Composed of light- to dark-gray, commonly bioclastic limestone; generally forms steep cliffs, solitary rugose and tabulate colonial corals are common and are characteristic. Following the nomenclature of Axen (1985), the formation consists of five members (from youngest to oldest): the Yellowpine, Arrowhead, Bullion, Anchor, and Dawn Members. Total thickness of the formation in the adjacent La Madre Mountain area is about 300 m (Axen, 1985).

Mmy **Yellowpine and Arrowhead Members (undifferentiated)** Medium- to dark-gray, thickly bedded to massive limestone; commonly medium to coarsely bioclastic (crinoid detritus the most recognizable clasts); commonly contains prominent large solitary rugose corals up to 8 cm wide and 30 cm long which are spectacularly exposed on bedding planes; common small silicified corals (?) about 1 cm in diameter and nodular chert ranging from 1 to 2 cm in diameter to large masses up to 30 cm in diameter; contact with the Bullion Member below is not exposed in the quadrangle, but is reported to be sharp (Axen, 1985). Total exposed thickness of unit beneath and east of the inferred trace of the Keystone thrust is about 50 m.

Mmb **Bullion Member** Light- to medium-gray, thickly bedded to massive, locally coarsely grained bioclastic crinoidal limestone; bioclasts up to 1 cm in diameter, although the unit is typically nonfossiliferous (Axen, 1985); distinguished from Anchor Member below by a general lack of secondary chert; base of Bullion member is marked by the rapid upward disappearance of secondary chert in the Anchor Member. Exposed thickness of unit in the quadrangle is about 20 m.

Mma **Anchor Member** Light- to medium-gray, medium to thinly bedded, commonly medium- to coarse-grained bioclastic limestone containing abundant orange-weathering black chert beds, lenses, and nodules; abundant secondary chert is characteristic and generally comprises 10 to 15% of the unit, but may be as much as 90%. Discontinuous beds of secondary dolostone about 1 m thick are locally present; contact with the Dawn Member below is sharp and is marked by the lowest beds containing abundant secondary chert. Thickness of unit in the quadrangle is about 120 m.

Mmd **Dawn Member** Medium- to dark-gray, medium to thinly bedded, medium to coarsely crystalline, locally bioclastic dolostone although reportedly mostly limestone in adjacent areas (Axen, 1985); bioclasts consist of crinoid, gastropod, and brachiopod detritus; common distinct planar cross-bedding and planar laminations; rare chert nodules. Distinguished from Anchor Member above by lack of prominent secondary chert. Contact with Sultan Limestone below is not exposed in the map area, but is abrupt where exposed just west of the map area. Thickness of unit in the quadrangle is about 37 m.

MDs **Sultan Limestone (undifferentiated)** (in cross section only). Consists of three members (from youngest to oldest): the Crystal Pass, Valentine, and Ironside Members (Hewett, 1931). The formation generally forms steep cliffs and ledges above the slope-forming Mountain Springs Formation. Secondary dolomitization overprints nearly all of the Valentine and Ironside Members which are undifferentiated for this quadrangle. Total thickness of the Sultan Limestone in the adjacent La Madre Mountain area is about 175 to 200 m (Axen, 1985).

MDsc **Crystal Pass Member** Light- to medium-gray and bluish-gray, thinly bedded, pure, micritic limestone; locally weathers out to thin plates; contains silicified algal mounds up to 10 cm in diameter in lower part of the unit; the pure micritic nature of most of the unit and bluish-gray color are characteristic of the unit. Base of the unit is gradational with underlying dolostones and limestones of the Valentine Member and is marked above the last dolostone horizon. Total thickness of unit in adjacent areas to the west is about 80 m. (W.R. Page, USGS, personal commun., 1997).

Dsvi **Valentine and Ironside Members (undifferentiated)** Medium- to dark-gray, thickly bedded to massive, medium to coarsely crystalline dolostone. Base of unit consists of abundant conspicuous dark-brown silicified stromotoporoids generally ranging in diameter from 5 to 20 cm which weather as resistant mounds on outcrops; stromotoporoids become less common upsection, but are present throughout and are characteristic of the unit. Small (1 cm in diameter) silicified solitary rugose corals are also common locally. Limestone is present in the uppermost part of the unit; dolomitization front is locally abrupt at interface between limestone and dolostone and is also locally characterized by zones of intraformational breccias. Base of the unit is in sharp contact with dolostone of the underlying Mountain Springs Formation (Axen, 1985) and is marked by the first dark-brownish-gray stromotoporoid-bearing dolostone. Estimated unit thickness in the quadrangle is about 70 to 100 m.

DOm **Mountain Springs Formation** (Includes both **Om** and **DO** map units of the Mountain Springs Formation of Axen, 1985). Light- to medium-gray and tan to yellowish-orange weathering, thinly to medium-bedded, fine- to medium-crystalline dolostone and silty dolostone. Slope forming. Unit is distinguished from Pogonip Group strata below by its generally more yellow- orange-weathering lithologies. Base of unit is marked by a distinct carbonate and chert pebble conglomerate up to 5 m thick; conglomerate is locally both clast and matrix supported; clasts are well rounded, light- and medium-gray and yellowish-gray dolostone (95%) and rounded to subangular black chert (5%) generally ranging from 1 to 2 cm in diameter; carbonate clasts are locally as large as 10 cm. Basal conglomerate is in sharp and presumably disconformable contact with underlying Pogonip Group (Axen, 1985). Unit thickness in the adjacent La Madre Mountain area is about 105 m (Axen, 1985).

Op **Pogonip Group** Light- to medium-gray and orange-weathering, thinly to medium bedded, fine- to medium-crystalline dolostone and silty dolostone. Slope forming. Locally contains prominent black and bluish chert nodules and lenses up to several centimeters in diameter or in thickness and brown silicified algal mounds 10 to 15 cm in diameter. Unit is distinguished from the blocky and broken cliff forming Nopah Formation by its slope forming and orange-weathering silty lithologies. Lower contact is not exposed but is apparently sharp and marked by a change from slope-forming strata of the Pogonip Group to the cliff- and ledge-forming Nopah Formation below (Axen, 1985). Total unit thickness in the adjacent La Madre Mountain area is about 100 m (Axen, 1985).

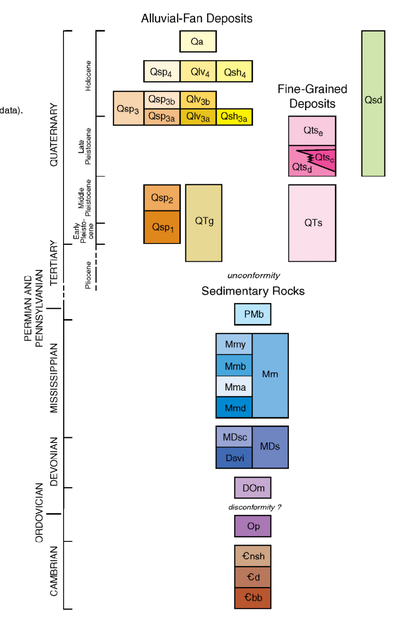
Nopah Formation Consists of three members (from youngest to oldest): the Smoky, Halfpint, and Dunderborg Shale Members. Total formation thickness is about 350 m.

€nsh **Smoky and Halfpint Members (undifferentiated)** Light- to medium-gray and white, thickly bedded to massive, medium crystalline dolostone. Forms blocky, broken cliffs and steep ledges. Lower parts of the unit are commonly medium-grained and bioclastic with recognizable trilobite detritus; weathered surfaces show distinct sugary granular texture which is characteristic of the unit; bedding and other sedimentary features are commonly poorly expressed in outcrop. Light-gray to yellowish-gray algal dolostone is common near the base of the unit; unit is locally similar to upper parts of the Bonanza King Formation, but can be distinguished by the lack of nodular chert characteristic of the upper Banded Mountain Member. Base of unit contains a 10- to 20-m-thick section with lithologies transitional and gradational with underlying Dunderberg Shale Member. Thickness of the unit in the La Madre Mountain area is about 300 m (Axen, 1985).

€nd **Dunderberg Shale Member** Light- to medium-brown and orange-brown, thinly bedded, fine- to medium-crystalline silty dolostone and medium- to dark-brownish-gray silty limestone, and green shale; silty dolostone and limestone are planar laminated and locally cross laminated, bioclastic with recognizable trilobite detritus, and locally contains distinct rip-up clasts of brown silty dolostone. Green shale intervals appear to be less than 0.5 m thick and are very poorly exposed; locally abundant and prominent burrow marks on bedding surfaces. Unit is distinguished by the unique shale lithologies and as a thin, orange-brown, slope-forming interval between overlying and underlying bioclastic dolostone of the Nopah and Bonanza King Formations; base of the unit is in sharp contact with the underlying Bonanza King Formation. Thickness in the quadrangle is about 50 m.

Bonanza King Formation Consists of two members (from youngest to oldest): the Banded Mountain and Papoose Lake Members. Only the Banded Mountain Member is exposed in the quadrangle.

€bb **Banded Mountain Member** Light-, medium-, and dark-gray and tannish-gray, thickly bedded to massive, fine- to medium-crystalline dolostone; locally thinly bedded and laminated. Contains nodular chert masses ranging from 1 to 10 cm in diameter; locally appears highly bioturbated where coarse white dolomite crystals formed along irregular thin beds and laminations; exhibits bands of alternating light- and dark-gray and tannish-gray lithologies which form steep ledges and slopes below the cliff-forming light-gray to white Nopah Formation and the slope-forming orange-brown Dunderberg Shale Member of the Nopah Formation. Upper parts of unit form small cliffs and exhibit sugary weathering texture similar to the Nopah Formation, but can be distinguished by the presence of nodular chert; base of unit is not exposed. Minimum thickness of this unit in the adjacent La Madre Mountain area is about 450 m (Gans, 1974).



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