Text to accompany Nevada Bureau of Mines and Geology Map 175

Geologic Map of the Gass Peak SW Quadrangle, Clark County, Nevada

by

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INTRODUCTION AND GEOLOGY

The Gass Peak SW quadrangle is located in northwestern Las Vegas Valley, Clark County, Nevada. The quadrangle covers portions of the cities of Las Vegas and North Las Vegas. U.S. Highway 95 passes through the southwestern corner of the quadrangle. The principal geographic features of the quadrangle include the southern end of the Las Vegas Range, upper Las Vegas Wash, and Gilcrease Flat.

The first geologic mapping in the Gass Peak SW quadrangle was conducted by C.R. Longwell and was included in the 1:250,000-scale geologic map of Clark County (Longwell et al., 1965). The quadrangle was later mapped by W.R. Page and S.C. Lundstrom of the U.S. Geological Survey for compilation of the 1:100,000 Las Vegas geologic map (Page et al., 2005).

Structural Geology

Paleozoic rocks in the northern Gass Peak SW quadrangle form the southernmost part of the Las Vegas Range. These rocks were deformed by two major contrasting structural episodes. Compressional structures, such as thrust faults and folds, formed during Late Cretaceous time, and are part of the Sevier orogenic belt that strikes northeastward in southern Nevada (Armstrong, 1968). The age of thrusting in the Gass Peak SW quadrangle is unknown, but in the Muddy Mountains, about 30 km to the east, Bohannon (1983) determined that Sevier-age thrust faulting occurred in late Albian and Cenomanian(?) time on the basis of Upper Cretaceous thick foreland clastic units that were deposited synchronous with thrust deformation. Fleck and Carr (1990) also concluded that Sevier thrusting occurred during Albian and Cenomanian time in the southern Nevada region of the Sevier orogenic belt. Mesozoic compressional structures are overprinted by Tertiary extensional structures such as oblique-slip faults (Las Vegas Valley shear zone) and high-angle normal faults that formed during late Miocene time when this part of Nevada experienced regional extensional deformation (Guth, 1980, 1990; Guth et al., 1988).

Sevier Orogeny

Structures in the Gass Peak SW quadrangle that formed during the Sevier orogeny include the north- to northeast-striking Valley thrust fault and associated folds (Lundstrom et al., 1998; Page et al., 2005). Although the Valley thrust fault is not exposed in the quadrangle, the trace of the fault projects southwestward into the quadrangle from exposures in the adjacent Valley quadrangle (cross section B–B′). Along the northeast edge of the quadrangle, the trace of the fault separates lower-plate, overturned beds of the Bird Spring Formation on the southeast, from upper-plate, south-dipping Mississippian-Devonian beds to the northwest. Several folds that are subparallel to the thrust are exposed in upper-plate rocks and deform mainly Mississippian rocks.

The Valley thrust fault is well exposed in the adjacent Valley quadrangle (Lundstrom et al., 1998), where a ramp-anticline composed of Mississippian rocks in the upper plate is faulted above an overturned syncline consisting of Pennsylvanian and Permian rocks in the lower plate; stratigraphic throw on the thrust is estimated at about 700 m (Lundstrom et al., 1998). The thrust fault principally strikes about N65E, and dips from 40 to 45° northwest. A duplex zone exposed along strike of the thrust contains overturned beds of the Mississippian Indian Springs Formation and the lower part of the latest Mississippian to Permian Bird Spring Formation. The Valley thrust most likely ramped along lithologically weak units; in this case, the Indian Springs Formation which contains shaly intervals and is widely exposed in the duplex zone. The Valley thrust fault has been correlated with the Lee Canyon and Macks Canyon thrusts in the northern Spring Mountains (Lundstrom et al., 1998; Page et al., 2005).

The Valley thrust and other major northeast-striking folds in the quadrangle are subparallel, footwall structures to the Gass Peak thrust fault, a first-order Sevier-age thrust fault located less than 10 km to the northwest in the

adjacent Gass Peak 7.5-minute quadrangle. In this area, the Gass Peak thrust has late Proterozoic to Early Cambrian rocks in the upper plate that ramp over Early Permian (Leonardian) rocks of the Bird Spring Formation in the lower plate (Guth, 1990; Maldonado and Schmidt, 1993; Ebanks, 1965). Guth (1980) reported the Gass Peak thrust to have as much as 5900 m of stratigraphic displacement and horizontal displacement greater than 30 km (Guth, 1980).

Tertiary Extensional Structures

The Las Vegas Valley shear zone (LVVSZ) is the major Tertiary extensional structure in the Gass Peak SW quadrangle, and in the region (Page et al., 2005). The LVVSZ is concealed by thick Tertiary and Quaternary basin-fill deposits, and its geometry and location are based mostly on geophysical studies (Langenheim et al., 1997; Page et al., 2005). The major effects of the LVVSZ include oroflexural bending of north-trending mountain ranges, including the Las Vegas Range, and offset of major Mesozoic thrust faults across Las Vegas Valley. Offset of thrust faults across Las Vegas Valley indicate about 48 km of right-lateral separation on the LVVSZ (Wernicke et al., 1988), and geologic, paleomagnetic, and structural data bracket the principal period of movement between 14 and 8.5 Ma (Duebendorfer and Black, 1992).

A steep WNW-trending gravity gradient projects just south of mapped exposures of Paleozoic rocks in the southernmost Las Vegas Range in the Gass Peak SW quadrangle; this gradient marks the northern margin of the basin beneath Las Vegas Valley, and probably coincides with the position of one of the main strands of the LVVSZ (Page et al., 2005). A three-dimensional inversion of the gravity data shows that the Cenozoic basin fill reaches thicknesses of about 2 km south of the basin edge in the quadrangle (Langenheim et al., 1997; Page et al., 2005). Modeling of a detailed gravity profile in the Gass Peak SW quadrangle indicates that the basin edge dips steeply to the south (Page et al., 2005), and may be defined by several down-stepping strands of the LVVSZ.

Quaternary Structures

The most prominent Quaternary structure in the Gass Peak SW quadrangle is the Eglington fault, which offsets Qtsd deposits by approximately 10 m. The Eglington fault is one of several north- to northeast-striking, dominantly down-to-the-southeast faults that displace the fine-grained basin-fill deposits in Las Vegas Valley by as much as 30 m (Anderson, 1999). Several additional Quaternary faults extend into the southern part of the quadrangle, and a fault that displaces Qtsd deposits was recognized during this study in the west-central part of the quadrangle.

Subsidence caused by groundwater extraction has caused ground fissuring along several faults in Las Vegas Valley, including the Eglington fault (Bell and Helm, 1998; Hernandez-Marin and Burbey, 2012).

Alteration Zones and Mineral Resources

Paleozoic rocks in the Gass Peak SW quadrangle are part of the Gass Peak mining district, a district containing several lead-zinc mines and occurrences in the southernmost Las Vegas Range. Production in the district was recorded in 1916–1917 from the June Bug Mine (Longwell et al., 1965), located in the north central part of the quadrangle in the Las Vegas Range. Zinc was the major commodity although lesser amounts of lead, silver, and gold were also extracted from the mine.

The ore deposits in the district are interpreted as low-temperature hydrothermal deposits, and are associated with stratabound carbonate (dolomite and calcite) alteration zones. These alteration zones are common to other lead-zinc deposits such as in the Mississippi Valley or Tri-State district of the mid-continent.

The alteration zones associated with the ore deposits are chiefly but not limited to the Bullion Dolomite and consist mainly of yellow-, white-, and tan-colored, coarsely crystalline calcite, dolomite, and "zebra rock" that fills pore space between breccia fragments of country rock. The ore is usually associated with dolomitized limestone in the district, and is likely tectonic in origin because it is localized along faults and fractures within the alteration zones (Longwell et al., 1965). The age of the deposits is unknown, although the alteration zones appear to be offset by probable late Tertiary high-angle normal faults, and inconclusive evidence suggests some of the deposits may predate or be contemporaneous with Sevier orogenic structures.

Fine-Grained Deposits of Tule Springs

The fine-grained deposits in northern Las Vegas Valley are groundwater discharge deposits similar to those found in many locations throughout the southern Great Basin. These deposits reflect the wetter conditions present during pluvial periods of the Pleistocene. Originally recognized by Longwell (1965) as the Las Vegas Formation, the first detailed study of the fine-grained deposits of Tule Springs was conducted by Haynes (1967), who defined several stratigraphic units (Units A to G). Haynes' nomenclature has been adopted by most subsequent workers. In this study, we adopted the use of Units A to E, but gave numbered designations to the younger units (F and G) for consistency with mapping of the adjacent piedmont areas. Quade et al. (2003) provide a good summary of paleoclimate and hydrologic changes over the late Quaternary.

SURFICIAL DEPOSITS

Qe Eolian deposits Well sorted eolian sand, typically forming stabilized, vegetated dunes (coppice dunes) up to 5 m high. Minimal to no soil development. Middle to late Holocene age.

Qtf Tufa deposits Dark-brown, massive calcareous tufa forming linear or curvilinear alignments resulting from spring discharge (Haynes, 1967). Tufa is interbedded within Qtse (units E2, E1, and E0), often in association with black mats. Commonly occurs as low-relief surficial lag deposit resting on resistant surface of Unit D of Haynes in the vicinity of Gilcrease Flat and Eglington fault scarp; locally armors remnants of host fine-grained spring deposits along upper Las Vegas Wash. External morphologies and spatial distribution are consistent with the braided fluvial model described by Pedley (1990) and Ford and Pedley (1996). Morphologies include stromatolites, cyanoliths (oncoids), phytoclasts, phytoherm crusts, and fissure-type resurgence features, Springer and Manker (2010); Manker and Springer (2010).

Alluvial-Fan Deposits

Coarse-grained alluvial-fan gravels derived from the Las Vegas Range in the northern part of the quadrangle and the Spring Mountains to the west of the quadrangle. Generally poorly to moderately sorted, subangular to subrounded, sandy pebble-cobble gravels dominated by Paleozoic carbonate lithologies. Fan-unit nomenclature follows that of Sowers (1985, 1986); Sowers et al. (1988), and Bell et al. (1998, 1999).

Qfa Alluvium in recently active fan washes Dominantly sandy pebble-cobble gravels and pebbly sand; locally bouldery near fan heads. Poorly to moderately sorted. No soil development. Inset only slightly into older surfaces over most of the map area, but generally confined to entrenched washes near fan heads.

Qf4 Late to middle Holocene fan deposits Fan remnants characterized by subdued to nearly fully smoothed surfaces, incipient to moderately packed desert pavement, weak to moderate rock varnish, and slight etching of surface carbonate clasts. Only slightly separated from Qfa surfaces over most of the map area, but typically 0.5 to 1 m higher than Qfa near fan heads. Soils are typically A–C profiles with an eolian cap (vesicular A horizon) up to 5 cm thick, and stage I $CaCO_3$ development (clast coatings less than 1 mm thick).

Qf3 Early Holocene to latest Pleistocene fan deposits Fan remnants characterized by fully smoothed surfaces, tightly packed desert pavement, dark rock varnish, and moderate etching of surface carbonate clasts. Generally separated only slightly from younger surfaces, except near fan heads where separation varies from less than 1 m to 10 m or more. Dominates the piedmont flanking the Las Vegas Range, but more recent flow has occurred over much of the piedmont surface in broad, anastamosing channel networks and much of the area shown as Qf3 includes undifferentiated Qfa and Qf4 deposits.

> **Qf3b Early Holocene to latest Pleistocene fan deposits** Fully smoothed surfaces with carbonate-clast etching of up to a few mm. Soils typically include an eolian cap (vesicular A horizon) up to 5 cm thick, moderately reddened Bw horizon, and stage I $CaCO_3$ development.
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> **Qf3a Latest Pleistocene fan deposits** Fully smoothed surfaces generally indistinguishable from Qf3b, although locally having carbonate-clast etching of several mm. Soils typically include an eolian cap (vesicular A horizon) 5 cm or more thick, prominently reddened Bw to Btj horizon, and stage I to II $CaCO_3$ development.

Qf2 Late to Middle Pleistocene fan deposits Fan remnants characterized by fully smoothed surfaces with erosionally rounded margins, tightly packed desert pavement, dark rock varnish, and strong etching (up to several cm) of surface carbonate clasts. Appears lighter-toned than Qf3 surfaces due to abundant carbonate litter. Separation from younger surfaces increases toward fan heads. Soils typically include an eolian cap more than 5 cm thick, a prominently reddened and well-structured Bt horizon, and a 0.5- to 2-m-thick Bkqm horizon. Upper soil horizons are locally stripped.

Qf1 Middle to early Pleistocene fan deposits Fan deposits exposed only as small remnants near the front of the Las Vegas Range and as highly dissected terrace deposits preserved on the sides of steep canyon walls in the lower reaches of canyons in the Las Vegas Range; typically separated from active washes by several tens of meters. Fan surfaces are whitish from abundant carbonate litter; terrace remnants in canyons of the Las Vegas Range are typically mantled by thin deposits of younger colluvium. Soils typically include massively cemented Bkqm horizons 3 m or more thick; upper soil horizons are generally stripped.

Alluvial Deposits of Las Vegas Wash

Fine- to coarse-grained alluvium reworked from alluvial-fan gravels, fine-grained deposits of Tule Springs, and eolian material. Subangular to subrounded; poorly to well sorted; locally well stratified and cross-bedded. Generally less than 3 m thick. Inset into fine-grained deposits along upper Las Vegas Wash and forming a broad anastomosing channel network across Gilcrease Flat.

Qa Alluvium in recently active washes Pebble to cobble gravel and sand in wash bottoms. No soil development. In part correlative to Unit G of Haynes (1967).

Qlv4 Late to middle Holocene alluvium Pebble to cobble gravel and sand. Characterized by subdued to nearly fully smoothed surfaces, incipient to moderately packed desert pavement, weak to moderate rock varnish, and slight etching of surface carbonate clasts. Along upper Las Vegas Wash, forms gravel-dominated stream-terrace remnants typically 0.5 to 1 m higher than recently active wash channels; across Gilcrease Flat, dominantly fine-grained deposits forming broad anastomosing channel networks. Generally correlative with Unit F of Haynes (1967).

Qlv3 Early Holocene to latest Pleistocene alluvium Pebble to cobble gravel. Characterized by fully smoothed surfaces, tightly packed desert pavement, dark rock varnish, and moderate etching of surface carbonate clasts. Soils similar to Qf3.

> **Qlv3b Early Holocene to latest Pleistocene alluvium** Surface characteristics and soils similar to Qf3b. Inset relations vary by several meters, ranging from being only slightly inset below Qlv3a to about 1 m higher than Qlv4, indicating deposition during a period of rapid dissection of upper Las Vegas Wash.
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> **Qlv3a Latest Pleistocene alluvium** Surface characteristics and soils similar to Qf3a, although Qf3a locally stronger indicating a broader age range. Commonly forms a sinuous capping deposit on Qtse.

Fine-Grained Deposits of Tule Springs

Basin fill comprised of fine sand, silt and clay forming broad flats in upper Las Vegas Valley. Paleospring, paludal, and fluvial deposits related to groundwater discharge during late Pleistocene pluvial periods. Originally recognized by Longwell et al. (1965) as the Las Vegas Formation. Generally poorly exposed except along upper Las Vegas Wash and in the dissected upthrown side of the Eglington fault scarp. Nomenclature follows that of Haynes (1967) and Bell et al. (1998, 1999). The Tule Springs Site (Wormington and Ellis, 1967), which includes most of Haynes' (1967) type localities, is located in the central part of the quadrangle. Pedogenic carbonate stages follow Gile et al. (1966).

Qtse Unit E of Haynes, 1967 Whitish to light-brown silt and fine sand, with minor light-gray or greenish clay; generally well sorted; thinly bedded to massive. Contains abundant tufa. Divided into three subunits: (E1 and E2 by Haynes, 1967; and E0 in this study). At map scale, represented as undifferentiated Qtse.

E2 Typically a few centimeters to 2 m thick; locally up to 4 m. Base of unit consists of green clay, silt, and fine sand, although not commonly exposed. Middle portion of unit is comprised of reddish-tan silt and sand, which fills depressions and dissected surfaces of older units (primarily D, E0, and E1); commonly contains black mats up to 10 cm thick and abundant tufa. Along Eglington fault scarp and Gilcrease Flat, overlies Unit D as a veneer several centimeters to 1.5 m thick; contains angular carbonate clasts reworked from Unit D; grades upward to tan silt and sand. Upper portion of unit is locally armored by gravelly alluvium (Qlv3a) forming characteristic sinuous inverse channel topography described by Haynes (1967). Numerous radiocarbon ages range between 7 and 11.5 ^{14}C ka BP (Haynes, 1967; Quade, 1989; Quade et al., 2003; Bell et al., 1998, 1999).

E1 Typically whitish to light-gray silt and fine sand, with minor light-gray or greenish clay. 1 to 3 m thick; locally up to 5 m thick where filling paleospring cauldrons or channels cut into older units. Base of unit, especially the bottom of filled channels, commonly contains abundant rounded to subrounded carbonate nodules reworked from older units (primarily Qtsd). Weak soil development generally limited to a 20- to 30-cm-thick horizon with weak structure and forming a slightly resistant cap; locally armored by a thin layer of light-gray platy carbonate, probably deposited by localized groundwater discharge. Commonly contains gray to dark-gray organic horizons (black mats) a few to several cm thick. Subunit contains abundant mollusk shells and large vertebrate bones (including bison, mammoth, horse, and camel). Numerous radiocarbon ages cluster between 11.5 and 14.5 ^{14}C ka (Haynes, 1967; Quade, 1989; Quade et al., 2003; Bell et al., 1998, 1999).

E0 Light-green silt and sand grading upward into gray silt and sand. Upper portion of unit typically consists of yellowish-tan silt. Commonly contains light- to dark-gray, thin platy carbonate associated with localized groundwater discharge. Represents the first generation of fluvial tufa formation, following the collapse of full glacial marshes of Unit D. Generally well sorted; thinly bedded with fine-scale cross-beds to massive. Typically 3 m thick; locally up to 5 m thick where spring-fed channels cut into older units (primarily Unit D). Base of unit, especially the bottom of filled channels, locally contains abundant rounded to sub-rounded carbonate nodules reworked from older units. Weak soil development generally limited to a 10- to 20-cm-thick horizon with weak structure and forming a slightly resistant cap. Locally mantles Unit D along upper Las Vegas Wash in the eastern half of the quad. Contains abundant mollusk shells and large vertebrate bones (including bison, mammoth,

horse, and camel). Radiocarbon ages range between 14.7 ^{14}C and 17.3 ^{14}C ka BP (table 1 on map).

Qtsd Unit D of Haynes, 1967 Yellowish-tan to whitish silt and fine sand, and light-green silt and clay with localized rounded to sub-rounded carbonate nodules reworked from older units. Commonly capped by a prominent 30- to 50-cm-thick, massively cemented petrocalcic horizon and characterized by surface rubble consisting of carbonate nodules and cemented cicada burrows. Locally contains gray to dark-gray organic horizons (black mats) a few to several cm thick. Facies include: phreatophyte flat–yellowish-tan silt and sand; wet meadow–whitish silt and fine sand; and marsh deposits–light-green silt and clay as described by Quade (1989). Radiocarbon ages range from about 18 to 30 ^{14}C ka (Haynes, 1967; Bell et al., 1998, 1999; Quade et al., 2003), indicating correlation with marine isotope stage 2. Similar to Qtse, contains abundant mollusk shells and large vertebrate bones. Qtsd dominates the broad area of Gilcrease Flat, albeit commonly mantled by younger fluvial deposits (mainly Qlv4) and thin deposits of Qtse; relatively minor, unmapped remnants of Qtsc also outcrop on the flat.

Qtsc Unit C of Haynes, 1967 Light-brown to brown silt and fine sand. Typically well sorted and massive to thickly bedded; 2 to 3 m thick; locally up to 5 m thick. Commonly inset into older units (primarily Unit B) along upper Las Vegas Wash. Sparsely fossiliferous, and likely reflecting drier conditions than during deposition of Qtsd and Qtsb. May be interbedded with Unit D. In the adjacent Tule Springs Park quadrangle, Bell et al. (1998) reported a radiocarbon date of 29 ka BP, and Page et al. (2005) reported a thermoluminescence date of 24–36 ka BP.

Qtsb Unit B of Haynes, 1967 Light-brown silt and fine sand, and pale-green clay. Commonly contains gravel lenses near base of unit. Page et al. (2005) reported a thermoluminescence date of 89-144 ka BP. Divided into three subunits by Haynes (1967): basal unit (B1), middle unit (B2), and upper unit (B3). These subunits are undivided at the map scale.

B3 Typically consists of light-brown to light-green silt and fine sand; well sorted and massive to thickly bedded. Locally contains cross-bedded sands where filling channels inset into older units (primarily units B1 and B2). Typically 1 to 3 m thick; locally up to 5 m thick. Along upper Las Vegas Wash, locally retains buried soil remnant S3 of Haynes (1967). Soil profile typically consists of moderately structured Bw horizon 10 to 30 cm thick (although not commonly preserved), and Bk horizon with stage I+ to II+ $CaCO_3$ development.

B2 Typically consists of pale-green sand, silt, and clay inset into unit B1. Locally contains gravel lenses at base of filled channels and depressions. Thick to massive bedded; up to 5 m thick. At the Tule Springs Site, commonly contains gray to dark-gray organic horizons (black mats) a few to several cm thick, abundant mollusk shells and large vertebrate bones (including bison, mammoth, horse, and camel). Previous excavation (Haynes, 1967) revealed sub-vertical conduits filled with very fine, well-sorted sand, representing groundwater discharge points.

B1 Typically consists of light-brown silt and fine sand with interbedded gravel. Well sorted and massive to thick bedded. Locally contains cross-bedded sands along channel axes. Forms characteristic resistant cliffs along wash walls up to 7 m thick. Commonly overlies and fills older dissected, resistant topography of Unit A. Along upper Las Vegas Wash and Eglington fault scarp area, locally retains buried soil remnant S2 of Haynes (1967). Soil profile typically consists of moderately structured Bw horizon 10 to 30 cm thick (although not commonly preserved), and Bk horizon with stage I to II $CaCO_3$ development.

Qtsa Unit A of Haynes, 1967 Light-brown to reddish-brown, hard, calcareous silt and clay; strong blocky to prismatic structure. Commonly has a mottled appearance from redox and irregular deposition of light-gray to whitish secondary carbonate. At the Tule Springs Site, exposed only in a few locations at the bottom of wash cuts; typically 1 to 3 m thick. Additional exposures identified during this study are located approximately two km to the east in the south wall of upper Las Vegas Wash, where the unit is up to 6 m thick. Unit contains several buried soils and intervening subunits. Uppermost subunit typically contains prominent 10- to 40-cm-thick massively cemented petrocalcic horizon similar to that of Unit D; forms resistant older topography over which younger units are draped (primarily unit B1). Subunits locally contain inset green clay, silt and fine sand exhibiting morphologies similar to unit B2, probably resulting from several episodes of past groundwater discharge. Page et al. (2005) obtained a thermoluminescence date of 131–225 ka.

Qtsab Undivided fine-grained alluvium Fine-grained deposits spanning a broad age range exposed in the dissected footwall of the Eglington fault scarp. Generally corresponds to areas mapped as Unit A by Haynes (1967). Page et al. (2005) recognized the presence of younger deposits and mapped these as Qab. In this study, we found that the few remaining exposures of these deposits are predominantly Units A and B, but they include remnants of all of the units defined by Haynes (1967). Locally includes minor exposures of older, massively cemented, fine-grained deposits (described as pre-Unit A by Haynes, 1967); these poorly exposed deposits are significantly older than Unit A.

Qso Old fine-grained spring deposits of Page et al., 2005 Light-toned, reddish-tan clay, silt, and sand, interbedded with silty gypsiferous beds (30 to 60 cm thick with medium to strong blocky structure), and variably cemented white calcareous layers. Unit restricted to the southeastern part of the quadrangle. Occurs as raised topographic inlier with rounded margins; forms subdued badland topography. Typically 6 to 7 m thick; locally mantled by Qlv3a gravel. Page et al. (2005) reported a thermoluminescence date of 226 to 399 ka from 3 m below top of a section in similarly mapped deposits to the east (SW ¼ of sec. 29, T. 19 S., R. 62 E.).

PALEOZOIC ROCKS

PMb Bird Spring Formation, undivided (Leonardian to Chesterian, Lower Permian to Upper Mississippian) Mostly limestone, dolostone, and minor quartzite and variegated shale. Limestone is medium-gray, light-gray, and yellowish-gray, silty, bioclastic, and thin- to thick-bedded. Dolostone is medium-gray, yellowish-gray, and light-gray, silty, and thin- to thick-bedded. Abundant layers and nodules of dark-gray and dusky-yellowish-brown chert; some parts of member contain more than 50 percent chert. Contains *Syringopora* corals, solitary rugose corals, *Chaetetes* corals, brachiopods, bryozoans, and pelmatozoan stems. Basal part of formation is Upper Mississippian (late Chesterian) in region (Webster, 1969). Contact with underlying Indian Springs Formation is conformable and gradational. Forms stair-step ledges; only lower 300 to 500 m of formation exposed in quadrangle and probably includes mostly Pennsylvanian-age units equivalent to member PMb1 of the Bird Spring Formation as mapped by Lundstrom et al. (1998) in the adjacent Valley quadrangle. Maximum thickness of the Bird Spring Formation in this part of the Las Vegas Range is estimated at 2500 m (Lundstrom et al.; 1998, Page et al., 2005).

Mis Indian Springs Formation (Upper Mississippian) In order of decreasing abundance, consists of limestone, shale, and quartzite. Limestone is medium-gray, grayish-red, and medium-yellowish-brown to grayish-brown, fine to coarsely crystalline, and mostly thin-bedded. Shale is dusky-red, grayish-red-purple, grayish-orange, and grayish-black, and is mostly in the lower part of the formation. Quartzite is olive-gray, light-gray, and medium-brown; composed of fine, subrounded, and moderately sorted quartz grains. Beds range from 0.5 to 1.0 m thick and show planar laminations. Fossils include *Rhipidomella nevadensis*, spiriferid and productid brachiopods, solitary rugose corals, pelmatozoan stems, and bryozoans; *Stigmaria* compressions present at the base of the formation. Formation is late Chesterian in age (Webster, 1969). Formation forms slope. About 60 m thick.

Mbw Battleship Wash Formation (Upper Mississippian) Consists of limestone and minor quartzite. Limestone is arenaceous and bioclastic, medium-dark-gray to light-olive-gray, mostly coarsely crystalline, and thin-bedded. Basal 1.5 m of formation consists of quartzite and sandy limestone. Quartzite is calcareous, medium-light-gray, and thin-bedded. Fossils in formation include solitary rugose corals, pelmatozoan stems, and spiriferid brachiopods. Conodonts collected in the adjacent Gass Peak NE quadrangle indicate that the formation is no older than late Meramecian and no younger than early Chesterian (Harris et al., 2005). The upper contact of the formation is usually covered, but where exposed, shale or quartzite units of the Indian Springs Formation overlie bioclastic limestone units of the Battleship Wash Formation; Webster (1969) interpreted the contact as disconformable on the basis of conspicuous lithologic and faunal changes between the two formations. Forms ledgy cliffs; about 20 to 40 m thick.

Monte Cristo Group (Upper and Lower Mississippian) From top to base, subdivided into Yellowpine Limestone, Bullion Limestone, Anchor Limestone, and Dawn Limestone; series and stage designations are mostly from Harris et al. (2005). Thickness of group is as much as 510 m.

Mmy Yellowpine Limestone (lower Meramecian and upper Osagean) Medium-dark-gray to light-olive-gray, medium-crystalline, and mostly thick-bedded limestone; contains sparse nodules of medium-dark-gray and dusky-yellowish-brown chert. Formation distinct from other units of the Monte Cristo Group because it contains unusually large solitary rugose corals (as much as 25 cm long). Also contains pelmatozoan stems, S*yringopora*, and *Lithostrotionella* biostrome at top of unit; also contains middle to late Osagean conodont *Eotaphrus burlingtonensis* near base of unit in adjacent Valley quadrangle (Harris et al., 2005). Yellowpine forms massive cliffs; about 80 m thick.

Mmb Bullion Dolomite (lower Meramecian to middle Osagean) Medium-dark-gray to medium-light-gray encrinitic limestone; finely to medium crystalline, and thick-bedded; contains discontinuous layers of dusky-yellowish-brown chert in beds 7 to 10 cm thick that have planar laminations and small-scale trough cross-beds. Fossils include abundant pelmatozoan stems, sparse brachiopods, and solitary corals. Conodonts collected in the adjacent Valley quadrangle are representative of the *anchoralislatus* Zone, indicating much of the formation is middle Osagean (Harris et al., 2005). The contact between Bullion and Yellowpine Limestones is arbitrary, but it was mapped following Langenheim et al. (1962) in the Arrow Canyon area. They placed the contact at the base of an interval of limestone beds that are

darker-gray, thinner-bedded, and contain more solitary rugose corals as compared to underlying limestone beds of the Bullion. Bullion forms massive cliffs; about 100 to 180 m thick.

Mma Anchor Limestone (Osagean) Alternating beds of thin-bedded limestone and chert. Limestone is medium-dark-gray to light-olive-gray and finely crystalline. Chert is medium-gray to dark-gray and dusky-yellowish-brown. Unit contains brachiopods, solitary and syringoporid corals, and pelmatozoan stems. Conodonts collected from formation in adjacent Valley quadrangle (Harris et al., 2005) include elements from *G. typicus* Zone through *S. anchoralis–D. latus* Zone (early through middle Osagean). Formation forms ledgy slope; about 140 to 180 m thick.

Mmd Dawn Limestone (lower Osagean and Kinderhookian) Limestone and some chert; limestone is dark-gray to light-olive-gray, and aphanitic to finely crystalline, and oolitic; chert is medium-brown to dusky-yellowish-brown and forms discontinuous layers and nodules. Abundant macrofossils consist of solitary rugose corals, *Lithostrotionella* corals, gastropods, brachiopods, bryozoans, and pelmatozoan stems. Conodonts collected in the adjacent Valley quadrangle indicate the formation is Kinderhookian to Osagean in age (Harris et al., 2005). Formation is disconformable with underlying unit. Forms ledgy cliffs; about 70 m thick.

MDu Mississippian to Devonian rocks, undivided (Lower Mississippian and Upper Devonian) Mostly medium-dark-gray, finely crystalline limestone; thin- to thick-bedded. Limestone beds are sandy and some contain abundant ooids and gastropod fragments. Upper part locally contains thin beds of brown-weathering sandy limestone, and yellowish-gray to grayish-brown, burrowed, sandy dolostone. Conodonts collected in adjacent Valley quadrangle from the upper 40 m of unit are very Late Devonian (Famennian) in age (Harris et al., 2005). Unit equivalent with Mississippian-Devonian Crystal Pass Limestone and upper part of Devonian Guilmette Formation. Although the upper part of unit occupies the stratigraphic position of Crystal Pass Limestone (which occurs below the Dawn Limestone and above the Guilmette Formation in the region), lithologic characteristics are atypical for the Crystal Pass, suggesting that (1) Crystal Pass Limestone is absent and the Dawn Limestone rests directly on the Guilmette Formation, or (2) Crystal Pass equivalent rocks are present and represent different facies (Page et al., 2005). Unit forms massive cliffs; about 160 to 180 m thick.

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