U. S. DEPARTMENT OF THE INTERIOR
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PRELIMINARY GEOLOGIC MAP OF THE VALLEY QUADRANGLE, CLARK COUNTY, NEVADA

by

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Description of map units

[Descriptive colors for map units are from the Rock-Color Chart Committee (1951)

Qayy **Youngest fan alluvium (Holocene)--**Noncemented alluvial-fan gravel, with interbedded sands; poorly to moderately well sorted; massive to well bedded; clast-supported to matrix-supported. Gravel is angular to subrounded, ranging in size from granules to boulders, and composed predominantly of carbonate lithologies derived from erosion of the Paleozoic section. Includes deposits of abundant modern channels that are too narrow (less than 30 m) to map separately, as well as Holocene deposits between modern channels. Etching on surficial limestone clasts ranges from absent on deposits of modern channels to incipient and sparse on deposits between modern channels. Bar-and-swale depositional morphology ranges from prominent in modern channels, to variably modified and muted by addition of eolian sediment in areas between modern channels. Desert pavement ranges from absent on deposits of modern channels, to loosely packed and weakly developed on deposits between active channels. Rock varnish, which does not form on many common limestone clasts, is generally very weakly developed to absent on more siliceous lithologies (including siliceous carbonates) except for relict rock varnish not abraded during transport. Typical non-cemented and weak soil development is characterized by the presence of stage I-II secondary carbonate morphology (mostly thin coats on clast undersides), and by a gradual increase of sand toward the surface through the upper 10 to 30 cm of the unit. The surficial sand component is considered to be a pedogenically mixed and infiltrated eolian sediment deposited after fluvial deposition of fan gravel. Minimum thickness is 1 – 2 m; base of unit is generally not exposed.

Qay **Young fan alluvium (Holocene and latest Pleistocene)--**Noncemented alluvial-fan gravel, with interbedded sands; poorly to moderately well sorted; massive to well bedded; clast-supported to matrix-supported. Gravel is angular to subrounded, ranging in size from granules to boulders, and composed predominantly of carbonate lithologies derived from erosion of the Paleozoic section. Includes deposits in common modern channels that are too narrow (less than 30 m) to map separately, as well as Holocene and locally latest Pleistocene (younger than about 15 ka) deposits between modern channels. Etching on surficial limestone clasts ranges from absent on deposits of modern channels to incipient and sparse to moderately developed and common on deposits between modern channels. Bar-and-swale depositional morphology ranges from prominent in modern channels, to variably modified and muted by addition of eolian sediment in areas between modern channels. Even in the most muted cases, cobbles and boulders protrude from eolian sand cover, and relict depositional microrelief is evident on aerial photographs. Desert pavement ranges from absent on deposits in modern channels, to loosely packed and weakly developed (especially in areas of relatively low dust-flux, as on the upper part of the fan) to moderately well packed in areas of higher dust flux, such as the lower southern ends of the fans which are more proximal to fine grained eolian source areas of the Las Vegas Valley. Rock varnish, which does not form on many common limestone clasts, is generally weakly developed to absent on more siliceous lithologies (including siliceous carbonates) except for relict rock varnish not abraded during transport. Typical non-cemented and weak soil development is characterized by a cambic Bw horizon, by the presence of stage I-II secondary carbonate morphology (mostly thin coats on clast undersides), and by a gradual increase of sand toward the surface through the top 0.5 m of the deposit. The surficial sand component is considered to be a pedogenically mixed and infiltrated eolian sediment deposited after fluvial deposition of fan gravel. Age control indicates that **Qay** is predominantly Holocene. At site LV-2 , southwest ¼ of S12, T19, S R61 E, a thermoluminescence date of 16 ka (Table 1) on a fine sand-rich eolian bed at 1m depth within this unit provides a maximum on the age of the overlying gravel (and not necessarily a close maximum). In the adjoining quadrangles to the west (Gass Peak SW, Tule Springs Park), correlative alluvium with similar characteristics to **Qay** either overlies or is inset within fine grained deposits with abundant radiocarbon dates ranging from about 12 to 8 ky B.P. (Haynes, 1967: Quade, 1986; Quade and others, 1995; Bell and others, 1998), so it is likely that most alluvium at the surface of **Qay** is Holocene. On both flanks of the Sheep Range to the north of this quadrangle, Spaulding and Quade (1986) report radiocarbon dates of about 1070 to 3300 yr B.P. on logs that provide maximum ages on alluvium that is correlative to **Qay** , and in which the logs occur. The above results thus indicate the likelihood of both early and late Holocene components of **Qay** in this quadrangle. **Qay** includes deposits correlative to youngest fan alluvium (**Qayy**) and deposits older than **Qayy**; **Qayy,** described above, is delineated separately only where there is a markedly greater proportion of modern channels and interchannel areas with minimal development of surface etching, varnish, pavement and soil. Minimum thickness of **Qay** ranges from less than 1m to at least 3 m, as exposed in borrow pits; base of unit is generally not exposed.

Qai **Intermediate fan alluvium (late and middle? Pleistocene)**--Cemented alluvial-fan gravel, with interbedded sand; poorly to moderately well sorted; massive to well bedded; clast-supported to matrix-supported. Gravel is angular to sub-rounded, ranging in size from granules to boulders, and composed predominantly of carbonate lithologies derived from erosion of the Paleozoic section. Includes modern channels too narrow to map separately. Surface between modern channels is somewhat erosionally rounded where it is more than about a meter above grade of adjoining channels. Surface between modern channels is characterized by a moderately to tightly packed desert pavement and smooth surface, which generally lacks bar and swale depositional morphology. Though nonsiliceous limestone clasts do not have rock varnish, more siliceous clasts possess dark varnish, which impart a darker tone to this unit on airphotos. This surface morphology is associated with a soil that typically includes a reddish-brown argillic (Bt) horizon and cemented stage II-IV carbonate morphology. Within the soil profile, the upward decrease in proportion of gravel is due to the addition of eolian material concurrent with pedogenesis. Within and beneath the zone of maximum pedogenic carbonate development, limestone gravel generally is distinctly more cemented than in younger Holocene alluvium. Depositional microrelief is minimal relative to other alluvial units; bar-and-swale morphology is generally absent, and surfaces are smooth between limited areas of erosional dissection. At site LV-13 (NW ¼, S19, T18S, R62 E; 600 m north of north boundary of quadrangle, and about 150 m east of Range line), the eolian part of a buried soil at about 2 m depth within unit Qai yielded a thermoluminescence date of about 100-120 ka (Table 1). At Yucca Mountain, thermoluminescence and U-series data constrain the deposition of correlative alluvium to **Qai** (Lundstrom and others, 1994) to have occurred between about 130 ka and 50 ka (the early part of the late Pleistocene, during the last interglacial) Exposed minimum thickness of **Qai** ranges from less than 1m to at least 5 m; base of unit not exposed.

Qau **Undivided young and intermediate alluvium (late Pleistocene and Holocene)**--Cemented and noncemented alluvial fan gravel, with interbedded sand; poorly to moderately well sorted; massive to well bedded; clast-supported to matrix-supported. Gravel is angular to subrounded, ranging in size from granules to boulders, and composed predominantly of carbonate lithologies derived from erosion of the Paleozoic section. **Qau** represents areas in which young fan alluvium (**Qay**), including common intermittent active channels, occurs as discontinuous but common (30-50 percent of **Qau**), thin (<1m), veneers over intermediate fan alluvium (**Qai**) in patches that are too narrow to map separately.

Qao **Old alluvium (middle and early? Pleistocene)**--Well-cemented, sandy gravel of alluvial fans, with interbedded sands; poorly to moderately well sorted; massive to well bedded; clast-supported to matrix-supported. Gravel is angular to subrounded, ranging in size from granules to boulders. The erosional upper surface consists of broadly rounded, accordant ridges--ballenas of Peterson (1981)--that are gradational to broader surfaces. Depositional microrelief is absent. Generally well-packed surface pavement includes variable but often darkly varnished clasts, and abundant clasts of pedogenic calcite and calcite-cemented gravel; these clasts impart a lighter surface tone to this unit than to adjoining surfaces of younger map units. Soil typically includes a laminar (stage IV, Gile and others, 1966) but partially eroded K horizon at least 0.5 m thick; an overlying argillic horizon of variable thickness and expression is commonly present. The surface characteristics indicate that the original upper depositional surface of **Qao** has been substantially eroded, so that its original depositional thickness is unknown. **Qao** is mapped in the northeast part of the quadrangle where it adjoins intermediate fan alluvium (**Qai**); in this area, the upper part of **Qao** is clearly at a higher grade and more eroded than **Qai.** Minimum exposed thickness of **Qao** is at least 4 m; base of unit is generally not exposed.

Qaoi **Undivided Pleistocene alluvium (Pleistocene)**--Cemented sandy gravel and interbedded sands of alluvial fans; consists of numerous inset to superposed veneers of intermediate fan alluvium (**Qai**) on old alluvium (**Qao**), such that surfaces of both units are interpersed at a scale too small to map separately.

QTa **Basin-fill alluvium (Pleistocene to late Miocene?)**--Well-cemented, sandy alluvial gravel; poorly to moderately well sorted; massive to well bedded; clast-supported to matrix-supported. Gravel is angular to subrounded, ranging in size from granules to boulders. Erosional upper surface consists of non-accordant rounded ridges--ballenas of Peterson (1981). **QTa** is distinguished from old alluvium (**Qao**) where **Qao** is clearly inset within and less deeply dissected than **QTa**. At an exposure of **QTa** in the northeast part of quadrangle, bedding has an eastward dip (15 degrees) that is significantly higher than the subparallel fan slope and bedding (3 degrees) of younger units. Surface characteristics are otherwise similar to **Qao**. The above characteristics apply only to the extremely limited surface exposure of **QTa** in the northeast part of the quadrangle. The unit in the subsurface is considered here to include basin-fill that probably include parts of the Muddy Creek and Horse Springs formations, which are not exposed in this quadrangle, but are exposed and described in nearby areas (Bohannon, 1984; Maldonado and Schmidt, 1990). Geophysically-based estimates (Langenheim and others, 1997; V.E. Langenheim, written communication, 1998) on the maximum thickness of basin fill which occurs at the southern end of the Valley Quadrangle range from 3.5 –6 km.

Qs **Fine-grained spring deposits (Pleistocene)**--Light-toned, variably cemented fine sand, mud and marl, generally associated with areas of past ground-water discharge. Generally calcareous, with different degree of cementation between beds, ranging from weakly to strongly cemented. Subvertical tubules within densely cemented layers may be plant casts. In the south-central part of the quadrangle, where **Qs** is crossed by I-15, white calcareous layers are interbedded with reddish-brown, silty, gypsiferous beds about 30 - 60 cm thick with medium to strong blocky structure, and which may represent buried soils. Two or three of these beds are exposed in eroded buttes south of highway I-15, where they are interbedded with strongly cemented carbonate rich layers. At site LV-1 (SW ¼ of S29, T19S, R62E), a thermoluminescence date (LV-1) of about 150 to 250 ka (Table 1) was obtained on the upper one of these reddish-brown beds at about 3 m below the carbonate cemented exposed top of the unit. **Qs** is geomorphically expressed as rounded poorly exposed badlands and less common resistant buttes mantled by thin colluvium, sheetwash, and eolian sand. **Qs** in the south central part of the quadrangle may correlate to unit Qx of Haynes (1967). In the southwest corner of the quadrangle (S23 and S26, T19S, R61E), fine grained deposits that are mapped as Qs are poorly exposed but are continuous with a good exposure in the adjoining Gass Peak SW quadrangle. At this exposure, about 4m of carbonate-rich massive mud includes 3 buried soils, expressed as more clay-enriched beds with strong blocky structure sharply truncated by overlying massive mud. Haynes (1967, Pl. 10, fig.4) refers to these beds as part of his unit Qb - their stratigraphic relationship with the main part of **Qs** described above to the east is not clear, but he considers his unit Qx to be older than his unit Qb. Minimum exposed thickness of unit is 5 m; base is generally not exposed

Qcf **Hillslope colluvium and alluvium (Holocene to early Pleistocene?)**--Interbedded colluvial and debris-flow diamicton beds that grade into and are interbedded with alluvium of a wide age range. Unit generally occurs on lower, concave-upward footslopes (Peterson, 1981), which are typically partially dissected. Consists of angular and subangular gravel ranging in size from granules to boulders, generally supported by a matrix with variable proportions of sand, silt, and clay; matrix material inferred to be at least partly of eolian origin. Includes boulder levees that adjoin and are parallel to modern gullies, and and that were formed by debris flows. Map unit is massive to finely bedded, and includes multiple buried soils indicating Pleistocene episodes of pedogenesis and eolian deposition. Thickness ranges from 0.5 m to more than 3 m, generally enough to obscure underlying bedrock. The contact with adjoining alluvium is well defined only where unit **Qcf** is truncated by younger alluvium. Exposed thickness ranges from 1-4 m

QTls **Gravity-slide blocks and landslide debris (Pleistocene and Pliocene?)**—Chaotic masses of unsorted debris that consist chiefly of highly brecciated Paleozoic rocks and mixed landslide debris. Exposed only as a single mass in the northeastern part of the mapped area, where it overlies bedrock. Maximum thickness estimated at about 20-30 m.

QTu **Undifferentiated fan alluvium and basin-fill deposits (Quaternary, Pliocene, and Miocene?)**—Shown only in cross section. Includes alluvial fan gravels and interbedded sands of units **Qay** and **Qai** at surface, and probably units **Qao** and **QTa** at unknown depth

Bird Spring Formation (Lower Permian, Pennsylvanian, and Upper Mississippian)--Subdivided into the following informal members (in descending order) as defined in the Arrow Canyon area (Page, 1992, in press), about 35 km northeast of quadrangle: upper limestone member, red slope-forming member, massive limestone member, dolomitic member, Tungsten Gap member, and basal limestone member. Series designations are based on conodonts analyzed by Anita Harris (U.S. Geological Survey, written commun., 1997), and on correlation with Cassity and Langenheim (1967) in the Arrow Canyon area. Maximum preserved cumulative thickness about 1945 m; top not exposed in quadrangle

Pb6 **Upper limestone member (Lower Leonardian)**--Bioclastic limestone and silty limestone, medium dark gray (fresh) and light olive gray (weathered), and thin-to-thick-bedded. Fossils consist mostly of pelmatozoan columnals, fusulinids, bryozoans, brachiopods, and colonial corals. Member also contains nodules and beds of dusky yellowish brown weathering chert. Contact with underlying red slope-forming member is transitional and was mapped at the top of the stratigraphically highest silty mudstone bed characteristic of the red slope-forming member. Maximum exposed thickness about 350 m

Pb5 **Red slope-forming member (uppermost Wolfcampian)**--Consists mainly of alternating, thinly laminated to laminated beds of limestone and mudstone, silty mudstone, calcareous siltstone, and chert. Limestone and mudstone is dark gray (fresh), and yellowish gray, dusky yellowish gray, pale red, light brown, and moderate brown (weathered), and commonly contains disseminated pyrite and organic matter. Some zones in member consist of greater than 60 percent chert beds; chert is olive gray to olive black (fresh) and moderate brown to dusky yellowish brown (weathered). These rocks generally lack macrofossils, although petrographic examination of some samples showed abundant sponge monaxons and poorly preserved radiolarians. Rocks show convolute bedding. Phosphatic concretions 0.5-4 cm in diameter are present at the base of member in the eastern part of the quadrangle; concretions are commonly cored by fish bone fragments. Member contains submarine debris-flow conglomerates in channels and sheets; clasts within the channel deposits average about 10 cm in diameter and show normal grading. Clasts within the debris-flow sheet deposits are as great as 2 m in diameter and float in a yellowish-gray weathering, silty bioclastic matrix. Most clasts in the debris-flow conglomerate deposits are biolcastic and contain fusulinids, pelmatozoan columnals, and transported colonial coral heads. Member also contains medium-gray bioclastic and turbiditic grainstone to packstone beds; transported bioclasts include fossils mentioned above, and are normally-graded. Entire member forms pinkish-reddish-brown ledgy slope. Contact with underlying massive gray limestone member is sharp and represents a transgressional sequence boundary (Page, 1993; in press). Member thickens from east to west across quadrangle from about 370 m thick in the northeastern part to as much as 600 m in the northwestern part

PPMbu **Bird Spring Formation undivided**--Includes all or part of massive gray limestone member, dolomitic member, Tungsten Gap member, and lower limestone member, in the northwestern part of the quadrangle where contacts between these members are difficult to define due to alteration and facies changes from east to west across the quadrangle

Pb4 Massive gray limestone member (Wolfcampian)--Rocks are cyclic and consist of alternating layers of resistant, medium-gray massive limestone, less resistant moderate-brown to yellowish-orange silty limestone, and discontinuous layers and nodules of dusky-yellowish-brown-weathering chert. Massive limestone is finely to coarsely crystalline, and thick to very thick bedded. Silty limestone is aphanic to finely crystalline, and thin bedded to laminated. Member contains abundant fossils including colonial and solitary corals, *Syringapora* corals, pelmatozoan columnals, fusulinids, bryozoans, brachiopods, and planispiral gastropods. About 120 m thick

PPb3 Dolomitic member (Desmoinesian to Wolfcampian)--Cyclic beds of medium-dark-gray and olive-gray to light-olive-gray (fresh), and medium-gray, yellowish-gray, light-olive-gray, moderate-yellowish-brown, and dusky-yellowish-brown (weathered), finely crystalline (less commonly medium to coarsely crystalline), thin to thick bedded limestone and dolomitic limestone. Fossils include pelmatozoan stems, colonial and solitary rugose corals, *Syringapora,* fusulinids, brachiopods, and bryozoans. Light-gray and yellowish-gray weathering dolomitic rocks characterize the upper half of member. Member forms step-like ledges and is about 360 m thick

Pb2 Tungsten Gap member (Desmoinesian)--Medium-gray (fresh) and dusky-yellowish-brown to moderate-brown, yellowish-gray, and grayish-orange (weathered), finely crystalline, thin bedded silty dolomitic limestone. Fossils include brachiopods and pelmatozoan stems. Member is distinctive because of a conspicuous desert varnish on weathered surfaces, and it is a prominent marker bed within the Bird Spring Formation in the region. Member probably equivalent to the Tungsten Gap Chert defined in the Arrow Canyon area (Castle, 1967; Langenheim and Webster, 1979). Shown only on cross section C-C'. Forms resistant, rounded cliff about 15 m thick

PMb1 Basal limestone member (Chesterian to Desmoinesian)--Mostly limestone, and minor amounts of dolomite, quartzite, and variegated shale. Limestone is medium gray, medium dark gray, and olive gray (fresh), and light gray, yellowish gray, light olive gray, and grayish orange to moderate yellowish brown (weathered). Commonly arenaceous and bioclastic. Includes abundant layers and nodules of dark-gray (fresh) and dusky-yellowish-brown (weathered) chert; some parts of member contain more than 50 percent chert. Several dolomite beds are in the middle part of unit; dolomite is medium gray (fresh) and yellowish gray to light gray (weathered). Member contains *Syringapora* corals, solitary rugose corals, chaetetes corals, brachiopods, bryozoans, and pelmatozoan stems. Basal 14 m of member is reportedly Upper Mississippian (late Chesterian) in age on the basis of brachiopods, conodonts, and calcareous foraminifers in the Arrow Canyon area (Webster, 1969; Brenckle, 1973; Lane and others, 1983). Contact with underlying Indian Springs Formation is conformable and gradational. Shown only in cross section C-C'. Member forms step-like ledges and is estimated to be about 500 m thick

Mis Indian Springs Formation (Chesterian)--In order of decreasing abundance, consists of interbedded limestone, shale, and quartzite. Limestone is medium gray, grayish red, and moderate yellowish brown to grayish brown, fine to coarsely crystalline, and mostly thin bedded. Shale is grayish green, dusky red, grayish red purple, grayish orange, and grayish black, and is mostly in the lower part of the formation. Quartzite, most abundant near the top of the formation, is olive gray to light gray (fresh) and moderate brown and moderate yellowish brown to dusky yellowish brown (weathered); composed of fine, subrounded, and moderately sorted quartz grains. Beds range from 0.5 to 1.0 m thick and show planar laminations. Fossils are abundant in limestone beds and include *Rhipidomella nevadensis*, spiriferid and productid brachiopods, solitary rugose corals, pelmatozoan columnals, and bryozoans; *Stigmaria* compressions are present near the base of the formation. Formation is reportedly late Chesterian in age (Webster, 1969; Brenckle, 1973; Lane and others, 1983). Formation forms slope. About 50 to 60 m thick

Mbw **Battleship Wash Formation (Chesterian and Meramecian)**--Consists of limestone and minor calcareous quartzite. Limestone is arenaceous and bioclastic, medium dark gray (fresh) and light olive gray (weathered), medium crystalline and thin to thick bedded. Basal 2 m of formation includes several thin calcareous quartzite beds that weather grayish orange to dusky yellowish brown. Fossils in formation include solitary rugose corals, pelmatozoan columnals, and spiriferid brachiopods. Formation is latest Meramecian and early Chesterian in age (Brenckle, 1973; Lane and others, 1983; Poole and Sandberg, 1991; Stevens and others, 1996). Although the contact with the overlying Indian Springs Formation is usually covered, Webster (1969) interpreted the contact as disconformable on the basis of conspicuous lithologic and faunal changes between the two formations. The lower contact with the Yellowpine Limestone may be disconformable as well (Langenheim and Webster, 1979). Forms ledgy cliffs in the northwestern part of the quadrangle and is about 20 to 42 m thick

Monte Cristo Group (Upper and lower Mississippian)-Exposed in western part of the quadrangle. From base to top, subdivided into the Yellowpine Limestone, Bullion Limestone, Anchor Limestone, and Dawn Limestone. The series designations are from Stevens and others, 1996. Thickness of group is as much as 510 m

Mmu **Monte Cristo Group undivided (Kinderhookian to Meramecian)**--Mapped in northwest part of the quadrangle where individual members of the Monte Cristo Group lack lateral continuity due to extreme alteration and brecciation in the upper plate of the Valley thrust fault. About 440 to 500 m thick

Mmy **Yellowpine Limestone (Meramecian and Osagean)**--Medium-dark-gray to dark-gray (fresh) and medium-light-gray to light-olive-gray (weathered), medium to coarsely crystalline, and thin to thick-bedded limestone. Contains sparse nodules of medium-dark-gray (fresh) and dusky-yellowish-brown (weathered) chert. Formation contains large solitary rugose corals as great as 25 cm in length, pelmatozoan stems, and a regionally persistent *Lithostrotionella* colonial coral biostrome is present near the top. Forms massive cliffs. About 80 m thick

Mmb **Bullion Limestone (Osagean)**--Encrinitic limestone, medium-dark-gray (fresh) and light-gray to light-olive-gray (weathered), finely to coarsely crystalline, and thick-bedded. Also contains some discontinuous layers of dusky-yellowish-brown chert. Fossils include abundant pelmatozoan stems, sparse brachiopods, and solitary corals. The contact between Bullion and Yellowpine limestones is arbitrary, but it was mapped following Langenheim and others (1962) in the Arrow Canyon area. They placed the contact at the base of an sequence of limestone beds that are darker gray, thinner bedded, and more rich in solitary rugose corals as compared to underlying encrinitic limestone beds of the Bullion. Bullion forms massive cliffs. About 170-180 m thick

Mma **Anchor Limestone (Osagean)**--Alternating beds of thin-bedded to laminated chert and thin- to thick-bedded limestone. Chert is medium gray to dark gray (fresh) and moderate yellowish brown to dusky yellowish brown (weathered). Limestone is medium dark gray (fresh) and medium gray to light olive gray (weathered) and finely crystalline. Contains several beds of medium gray encrinitic limestone in upper 40 m of unit. Unit contains brachiopods, pelmatozoan columnals, and rare colonial corals. Upper half of unit forms ledgy cliffs, due to a higher frequency of thick-bedded limestone interbeds, in contrast to the lower half of the unit, which forms ledgy slopes due to more abundant laminated to thin-bedded chert interbeds. About 140-180 m thick

Mmd **Dawn Limestone (Kinderhookian and Osagean)**--Thin bedded, medium-dark-gray (fresh) and medium-gray, medium-light-gray, and light-olive-gray (weathered), aphanic to finely crystalline limestone. Commonly contains elongate nodules and discontinuous layers of moderate-brown- to dusky-yellowish-brown-weathering chert. Abundant fossils consist of solitary rugose corals, *Lithostrotionella* corals, brachiopods, and pelmatozoan stems. Contact with underlying unit is sharp and disconformable. Forms ledgy cliffs. About 70 m thick

M?Du **Mississippian? and Devonian rocks undivided (Lower Mississippian and Upper Devonian)**--Medium-light-gray to medium-gray limestone, mostly aphanic but locally finely to coarsely crystalline, and thin to thick bedded. Limestone beds are sandy and commonly crossbedded, and some contain abundant ooids and gastropod fragments. Upper part locally contains interbedded pale-yellowish-brown quartzite, grayish-brown weathering massive-bedded sandy dolomite, yellowish-gray weathering laminated aphanic dolomite, and medium-gray thin-bedded dolomite with abundant medium-light-gray burrows. Sandy dolomite and limestone beds contain tabular planar crossbeds as great as 0.5 m thick. Unit may be equivalent in part with the Mississippian-Devonian Crystal Pass Limestone, the Mississippian-Devonian Narrow Canyon Formation (exposed further to the west in the Sheep Range), and/or the upper part of the Devonian Guilmette Formation; a more precise correlation for the unit is pending on results of conodont analyses of samples collected in the quadrangle. Forms massive cliffs and is from 160 to 180 m thick

STRUCTURAL GEOLOGY

Introduction

Paleozoic rocks in the northern Valley quadrangle form the southernmost portion of the Las Vegas Range. These rocks are subdivided into northwestern (west of Gass Peak road) and northeastern parts (east of Gass Peak road). Rocks in both parts were highly deformed by two major contrasting structural events. Most compressional structures, such as thrust faults and folds, formed during Late Cretaceous time, and are part of the Sevier orogenic belt that trends northeastward through southern Nevada (Armstrong, 1968; Fleck, 1970). The exact age of deformation in this part of the Sevier orogenic belt is unknown, although in the Muddy Mountains, about 30 km east of the quadrangle, 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 synchronously with thrust deformation. Mesozoic compressional structures are overprinted by Neogene extensional structures such as oblique-slip faults (Las Vegas Valley shear zone) and high-angle normal faults that formed when this part of Nevada experienced regional extensional deformation (Guth, 1981, 1990; Guth and others, 1988).

Mesozoic Structures

In the northwestern part of the quadrangle a thrust fault, here named the Valley thrust, is exposed where a ramp-anticline composed of Mississippian rocks in the upper plate was thrust above an overturned syncline consisting of Pennsylvanian and Permian rocks in the lower plate (cross sections A-A' and B-B'); stratigraphic throw on the thrust is about 700 m. The thrust fault principally strikes northeast and dips from 40 to 45^{o} northwest. A duplex zone exposed along strike of the thrust contains overturned beds of the Mississippian Battleship Wash and Indian Springs Formations, and the lower part of the latest Mississippian to Permian Bird Spring Formation (cross section B-B'). As common in many other thrust fault models, 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, is the weak unit. The thrust and other major northeast-striking folds in the quadrangle are subparallel lower plate 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 and Gass Peak NE 7.5-minute quadrangles. In this area, the Gass Peak thrust has late Proterozoic to early Cambrian rocks in the upper plate that ramped over early Permian (Leonardian) rocks of the Bird Spring Formation in the lower plate (Guth, 1990; Maldonado and Schmidt, 1991; Ebanks, 1965). Guth (1981) reported the Gass Peak thrust to have as much as 5900 m of stratigraphic displacement and horizontal displacement greater than 30 km.

Different members of the Bird Spring Formation are exposed in several structural blocks that form the lower plate of the Valley thrust. The structural block nearest to Gass Peak road consists of the Lower Permian (latest Wolfcampian) red slope-forming member. Just west of it, the thrust ramps over Pennsylvanian and Permian members of the Bird Spring. Because the thrust maintains relative lateral continuity along strike, except for minor offset by high-angle normal faults, we suggest that these different structural blocks were juxtaposed to one another along a pre-thrust high-angle normal fault of unknown age. This fault is mostly concealed by alluvium but generally strikes northwest and is down to the northeast, and we believe it is truncated by the Valley thrust 1.7 km south and 2.1 km east of the northwest corner of the quadrangle.

The Valley thrust is exposed about 1.5 km to the north of the quadrangle in the Gass Peak NE 7.5-minute quadrangle, where Longwell and others (1965) mapped it as an incipient thrust. At this location, rocks of the Monte Cristo Group in the upper plate ramp above overturned strata of the the Bird Spring Formation in the lower plate, just as in the Valley quadrangle. The Valley thrust rapidly loses throw northward, and we believe it dies out into a tight, overturned anticline about 3 km north of its exposure in the Gass Peak NE quadrangle. Overturned northwest-dipping beds of the Bird Spring Formation that form the lower plate rocks of the Valley thrust and the southeast limb of this overturned anticline, also form the northwest limb of a paired, overturned syncline. Rocks of the Bird Spring Formation in the northeastern part of the Valley quadrangle form the southeastern upright limb of this major syncline, in which compressional sub-structures consist mainly of broad, open, northeast-striking folds (see cross section C-C'). Fold axes of the anticline-syncline pair along the central part of cross section C-C' are discontinous along strike, but the axis of the broad anticline along the eastern part of C-C' is continouous for at least 5 km and is viewed from Las Vegas Valley. The western 2-km-long segment of the fold axis bends from a northeast trend to a northwesterly trend at its terminus. This apparent bending is most likely a deformational relict related to regional oroclinal bending of the southern Las Vegas Range along the Las Vegas Valley shear zone during late Tertiary time (see next section below).

Mesozoic thrust faults in the Las Vegas Range and southern Sheep Range correlate with thrusts in the northern Spring Mountains. These thrust faults were offset right-laterally along the northwest-striking Las Vegas Valley shear zone (Fig. 1) during the Miocene and serve as piercing points across the shear zone (Wernicke and others, 1988). The Gass Peak thrust, in the southern Sheep Range, correlates with the Wheeler Pass thrust in the northwestern Spring Mountains (Guth, 1981; Wernicke and others, 1988). We correlate the Valley thrust in the Las Vegas Range with the Lee Canyon-Macks Canyon thrust (Burchfiel and others, 1974) in the northwest Spring Mountains. The Macks Canyon thrust is a subsidiary splay of the Lee Canyon thrust (Burchfiel and others, 1974), and thus the two thrusts are considered here as one thrust system. Wernicke and others (1988) correlated the Lee Canyon-Macks Canyon thrust with the Dry Lake thrust, which is exposed in in the Dry Lake Range northeast of Las Vegas. However, marked similarities between the Valley and Lee Canyon-Macks Canyon thrusts are suggestive of a more accurate correlation. For example, both thrusts have ramp anticlines composed of members of the Monte Cristo Group in the upper plate and folded strata of the Bird Spring Formation in the lower plate, and both thrusts utilized the shaly Indian Springs Formation as a glide plane. In addition, measured distances from the Gass Peak thrust to the Valley thrust (8 to 9 km) are more compatible with distances from the Wheeler Pass thrust to the Lee Canyon-Macks Canyon thrust (9 to 10 km), than the distance from the Gass Peak thrust to the Dry Lake thrust (22 km). We correlate the Dry Lake thrust with the Deer Creek thrust (Burchfiel and others, 1974), which is exposed in the northern Spring Mountains at a distance of 18 to 19 km east of the Wheeler Pass thrust. Both the Dry Lake and Deer Creek thrusts have Lower Paleozoic rocks (Cambrian and Ordovician) in their upper plates, and contain Paleozoic rocks younger than the Bird Spring Formation (Permian redbeds and Kaibab-Toroweap Formations) in their lower plates. The Keystone thrust in the eastern Spring Mountains correlates with the Glendale-Muddy Mountain thrust, located northeast of Las Vegas in the Muddy Mountains area (Wernicke and others, 1988).

Neogene Structures

Las Vegas Valley Shear Zone

The Las Vegas Valley shear zone (LVVSZ) is a structure that has offset right-laterally and bent the predominantly north-south-trending mountain ranges of southern Nevada (Stewart and others, 1968). Geologic, paleomagnetic, and structural data suggest that the movement along the LVVSZ took place between 14 and 8.5 Ma (Duebendorfer and Black, 1992; Longwell, 1974). The location of the shear zone is somewhat ambiguous; however, gravity data indicate a steep, west-northwest-trending gradient marking the northern margin of the basin underlying Las

Vegas Valley. The basin margin, in fact, probably coincides with the position of one of the main strands of the LVVSZ (Campagna and Aydin, 1994; Langenheim and others, 1997).

The steep WNW-trending gravity gradient cuts across the central part of the Valley quadrangle, 2-3 km south of the exposed Paleozoic rocks of the southernmost Las Vegas Range. A three-dimensional inversion of the gravity data shows that the Cenozoic basin fill reaches thicknesses of 2 km south of the basin edge in the Valley quadrangle (Langenheim and others, 1997). Modeling of a detailed gravity profile about 10 km west of the western margin of the Valley quadrangle indicates that the basin edge dips steeply to the south and that the basin edge is buried less than 700 m (Langenheim and others, 1997). Thus, we can use the horizontal gravity gradient method to locate the edge of the basin and to infer the location of the LVVSZ. The horizontal gravity gradient is maximized directly over vertical or near-vertical contacts that separate rocks of contrasting densities. The location of the LVVSZ is based on maxima in the horizontal gravity gradient that were calculated using a computer algorithm (Blakely and Simpson, 1986). Because the horizontal displacement of a gradient maximum is always less than or equal to the depth to the top of the source edge (Grauch and Cordell, 1987), the maximum error in the inferred location of the basin margin is 700 m. Another geophysically-inferred fault that is based on a subtle gravity gradient crosses the southwestern part of the Valley Quadrangle; this inferred fault may bound a narrow, deep sub-basin.

The geophysically-determined location of the basin margin does not have an obvious geologic or geomorphic expression. However, 3-4 km southwest of the inferred basin margin, and mainly in the adjoining Gass Peak SW quadrangle along the base of the alluvial-fan slope, young alluvial-fan gravel has a markedly linear northwest-striking contact with older fine-grained deposits formed during late Pleistocene ground-water discharge (Haynes, 1967). The generally linear margin of past ground-water discharge may have been localized by a buried strand of the LVVSZ that formed a barrier to ground-water flow. We have extended this inferred buried fault into the Valley Quadrangle, where it occurs near the northward limit of three areas of fine-grained deposits that are associated with past ground-water discharge (unit **Qs**). This discharge may have occurred on the order of about 200-400 ka, which is about an order of magnitude older than the deposits of late Pleistocene discharge to the east noted above (Haynes, 1967). The much greater difference in age between the young fan gravels (**Qay**) and the spring deposits (**Qs**) in the Valley Quadrangle may account for the more embayed disconformable contact between these units in this quadrangle than occurs in the adjoining Gass Peak SW Quadrangle.

Oblique-slip fault in Las Vegas Range related to the Las VegasValley shear zone

A structural block in the northwestern part of the quadrangle bordering Las Vegas Valley appears "out of place" compared to adjacent blocks. We believe that the east-northeast striking fault that bounds the north side of this block may be a right-lateral oblique-slip fault related to the LVVSZ. The fault is curvilinear, but attitudes of the fault plane indicate it is a relatively steep fault, dipping on an average of 75° south. The fault juxtaposes rocks of the upper limestone member of the Bird Spring Formation against the lowermost part of the red-slope forming member, and parts of the massive gray limestone and dolomitic members of the Bird Spring. Contrasting structural styles exist between the two different blocks. In the structural block north of the fault, overturned beds dip north and strike almost east-west, and they represent a portion of the overturned limb of the Valley thrust footwall syncline. The rocks in the southern block generally strike northwest and dip southwest, but more importantly, are upright as opposed to overturned. These structural discontinuities indicate that the southern block does not restore along a simple dip-slip high-angle normal fault. Thus we propose that the southern block restores eastward of its current position along a right-lateral oblique-slip fault, to an area where the upright limb of the Valley thrust footwall syncline is exposed at the surface.

Miscellaneous High-angle Normal Faults

High-angle normal faults in the Paleozoic rocks have varied orientations, but most cut and offset Mesozoic compressional structures and are interpreted to have formed mostly during the Miocene, when this area experienced regional extensional deformation. In the northwestern part of the quadrangle, normal faults offset the Valley thrust fault.

High-angle normal faults in the northeastern part of the quadrangle display a more complex pattern than in the northwestern part. This pattern is characterized by kilometer-size blocks bounded by major faults that are internally broken up into smaller blocks by minor faults. In addition, at the southeastern margin of the range, successively younger blocks of Paleozoic rocks are downdropped basinward along south-stepping high-angle normal faults.

Quaternary stratigraphic, climatic, and structural controls on hydrology

The distribution and characteristics of Quaternary units significantly affect modern hydrologic processes. Moreover, the mapped Quaternary geology provides a paleohydrologic record of the area. In the northeastern corner of the quadrangle, the valley floors are dominated by older, cemented, and eroded Pleistocene alluvial units with relatively low infiltration capacity and high potential for runoff generation. In contrast, in the central part of the quadrangle, the piedmont south of the Las Vegas Range is mainly a single large alluvial fan flanked by a smaller fan on the east, both predominantly covered by noncemented, permeable, mostly Holocene alluvium. During and after deposition of fan gravels, these extensive highly permeable deposits provided likely areas of ground-water recharge into washes during runoff events. Recharge into the fan during recent runoff events is consistent with the southward convexity of the contours on the water table that are similar to altitude contours on the fan surface, and which contrast with the regional southwestward hydraulic gradient of this area. (Loeltz, 1963; Morgan and Dettinger, 1996) . Intersection of downfan surface flows by the newly constructed flood-control structure built across the fan will likely decrease recharge into this fan.

The lower southern end of the large fan adjoins and is inset against eroded fine-grained deposits associated with past ground-water discharge (unit **Qs**). A thermoluminescence date (LV-1) on an eolian silt-rich bed within unit **Qs** of about 200-430 ka indicates that ground-water discharge at this location may have occurred before the time of the highest lake stand in Death Valley over the past 200 k.y. (Lowenstein, 1997). The age estimate here contrasts with the timing of younger episodes of late Pleistocene ground-water discharge to the west in the Tule Springs and Corn Creek areas (Haynes, 1967; Quade, 1986). The area of past ground-water discharge in this quadrangle is along the general trend of the Las Vegas Valley shear zone, which may have provided a control on the location of past spring discharge, as well as influencing the juxtaposition of young alluvial fan gravels with older spring deposits along generally northwest- and northeast-trending contacts. Whatever the cause of the juxtaposition, the contacts were probably fluvially trimmed during deposition of the younger fan gravels which lack apparent fault scarps. A northeast-striking fault scarp in unit Qs just crosses the central part of the southern map boundary from its more prominent expression in the Las Vegas NE quadrangle (Matti and others, 1993). This scarp is similar to other prominent scarps within the northern Las Vegas Valley (Matti and others, 1987: Bell, 1981, Plume, 1989) in its association with fine grained deposits and in its northeast strike which appears to terminate against the Las Vegas Valley Shear zone. The origin of these scarps is equivocal and controversial, but a tectonic component to their origin is difficult to dismiss (Bell, 1981; 1996).

Alteration Zones and Mineral Resources

Rocks in the Valley quadrangle are in the Gass Peak mining district, a district containing several lead-zinc deposits in the southernmost Las Vegas Range. Production in the district was recorded in 1916-1917 from the June Bug Mine located in the adjacent Gass Peak SW quadrangle (Longwell and others, 1965). Zinc was the major commodity, although lesser amounts of lead, silver, and gold were also extracted from the mine. The Sampson claim is in the Valley quadrangle, 2.4 km east and 0.1 km south of the northwestern corner of the quadrangle. No record of production is known, although Longwell and others (1965) included a brief description and map of the claim workings.

The ore deposits in the district are low-temperature hydrothermal deposits that are associated with stratabound carbonate alteration zones. Most alteration zones, such as those in the far northwestern corner of the quadrangle that are laterally continuous with those in the June Bug Mine area, average from 20 to 30 m thick, and chiefly occur within middle and upper parts of the Bullion Limestone; they consist mainly of pinkish-gray to pale-yellowish-brown and tan coarsely crystalline dolomite, and dolomite "zebra rock". Other alteration zones, such as those in Mississippian rocks directly above the Valley thrust fault, are composed predominantly of pinkish gray to white sparry calcite that fills pore spaces between breccia clasts of country rock. Most ore in the district is associated with the dolomite alteration zones, and it is probably tectonic in origin because it is localized along faults and fractures within the alteration zones (Longwell and others, 1965). The age of the ore deposits is unknown, although the alteration zones appear to be offset by, and thus pre-date, probable Miocene high-angle normal faults.

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Table 1 - Thermoluminescence data

sample	depth (cm)	stratigraphic position	modal size	% moisture		dose rate (grays/ky)		T at peak (C)	ED (1) (grays)	age (ka)	
				field	saturated	field	saturated			minimum	maximum
LV-1	300	in Qs	silt	4	74	2.3	1.2	300	519	226	433
LV-2	120	pre-Qay	fine sand	0.2	27	2.7	1.9	300	44.2	16	23
LV-13	200	in Qai	fine sand	3	21	3.85	3.18	300	382	99	120

note: (1) ED is equivalent dose at peak temperature T of glow curves