U.S. DEPARTMENT OF THE INTERIOR

U.S. GEOLOGICAL SURVEY

PRELIMINARY GEOLOGIC MAP OF THE MOAPA WEST QUADRANGLE, CLARK COUNTY, NEVADA

by

Dwight L. Schmidt, William R. Page, and Jeremiah B. Workman[1]

Open-File Report 96-521

Prepared in cooperation with the Southern Nevada Water Authority

This report is preliminary and has not been reviewed for conformity with U.S. Geological Survey editorial standards and stratigraphic nomenclature

[1]Box 25046 Federal Center, Denver, Colorado 80225

1996

PRELIMINARY GEOLOGIC MAP OF THE MOAPA WEST QUADRANGLE, CLARK COUNTY, NEVADA

DESCRIPTION OF MAP UNITS

[Colors of map units are from the Rock-Color Chart (Rock-Color Chart Committee, 1951). Thick carbonate soils developed on stream terrace and piedmont deposits are mapped because they constitute genuine mappable units, contrary to the convention of not mapping soils. In places, the host alluvial map unit beneath the map-unit soil may be too thin to show on the geologic map, but its presence is implied. In the Correlation of Map Units, the soil units are set apart from host terrace and piedmont deposits in order to show that they developed both constructionally and erosionally at various times. However, in the Description of Map Units, each soil is described with its respective host]

af **Artificial fill**--Ground disturbed and reworked by man for highway, railroad, and construction sites. Cultivated fields on the flood plain of the Muddy River (Qr) not included

Qc **Channel alluvium (late Holocene)**--Tan silt and sand and pale-gray gravel in active channel of Muddy River and its sidestreams. In Muddy River, consists mostly of silt and fine-sandy silt and locally of well-sorted, rounded gravel consisting of Paleozoic carbonate rock and rare volcanic rock. Muddy River has perennial flow derived from many active springs (referred to here as "Muddy River springs") such as Muddy Spring, Warm Springs, and nearby unnamed springs. The naturally shallow, narrow, tightly meandering channel has been mostly straightened and moved by man and is entrenched 3 m (in NW or upstream part) to 7 m (in SE or downstream part) below its Holocene river terrace (Qr) consisting of nearly vertical walls of coherent silt. Where the channel is not a pasture for livestock, it is choked by lush vegetation (especially mesquite and tamarisk). Most of the entrenchment probably has been during the past 125 years, as suggested by Longwell and others (1965), and was caused by overgrazing and channel manipulation. Channel alluvium of tributaries to Muddy River consists mostly of tan to pale-gray sand and gravel in mostly dry, braided stream channels that are but slightly to moderately entrenched mostly less than 3 m below their latest Pleistocene terrace. Thickness unknown, perhaps 1 to 2 m along Muddy River

Qw **Spring-fed wetland deposit (late Holocene)**--Black and dark-gray mud in marsh or swamp and in places tan sandy mud where mixed with eolian sand; surface densely vegetated. Constitutes two small areas fed by small springs less than a kilometer south of Muddy Spring. Probably as thick as 2 m

Qs **Slope wash and talus deposit (Quaternary)**--Hill-slope and valley-side debris, including talus, mapped mostly where location of contacts of underlying Quaternary or Tertiary units uncertain; unit is much more extensive than shown on map. Age mostly late Pleistocene, but in places may be as old as late middle Pleistocene. In upper reaches of some sidestreams, where Quaternary channel dissection has been minimal or absent, the broad slope wash deposit is not dissected, is currently active, and commonly nearly coincides with a broad, ancient (late Tertiary?) constructional slopeform. As thick as several meters

Ql **Landslide deposits (Quaternary)**--Valley-side slump and slide debris deposited by gravity below steep slopes underlain by incompetent rock units, most notably the marl of White Narrows (Twg, Twc) and Muddy Creek Formation (Tmg, Tmr). The most conspicuous landslide area is south and southeast of Muddy Spring, where Muddy River undercuts and causes ground failure in red clay facies of the Muddy Creek Formation and in white clayey facies of the channel-fill member of the marl of White Narrows. The resultant landslides appear to be inactive and may date to the last pluvial (late Pleistocene) during wetter-than-present climate. As thick as 40 m as exposed

Qe **Eolian sand (Quaternary)**--Light-tan, well sorted, medium-grained sand mapped only in one small area about one kilometer south of Hogan Spring. Although not mapped, a thin dusting of eolian silt and sand covers large parts of map area; it readily is reworked into slope wash (Qs) and some of it becomes fixed in soils of various ages. Small, mostly inconspicuous coppice dunes are abundant in many parts of the quadrangle; sand transport was predominantly to east and northeast. As thick as 0.5 m in coppice dunes

Qr **Recent terrace alluvium (Holocene)**--Mostly tan silt and sand, but includes sparse gray gravel in upper reach of Muddy River and mostly tan sandy gravel in sidestream terraces. The valley-wide silt deposit of Muddy River aggraded under paludal conditions throughout the Holocene because the Muddy River had perennial flow and an associated near-surface water table (Quade, 1986; Quade and others, 1995). The mainstream terrace is 3 to 7 m above the channel alluvium (Qc); sidestream terraces are much lower. Sidestream gravels are interbedded with the mainstream silt along the valley side of Muddy River and as a final feature built small sandy gravel fans on top of the mainstream silt deposit. Depositional features on the surface of the Muddy River terrace deposit have been mostly destroyed by intense cultivation, with few exceptions such as between White Narrows and highway 168 where arrow symbols on the map depict many natural distributary channels of the Muddy River prior to disturbances by man. Carbonate-soil development is inconspicuous to absent. Thickness of the Muddy River silt is not known because the recent silt deposit is vertically continuous with the late Pleistocene silt deposit (Qy) and a contact between the two deposits has not been determined. The thickness of the sidestream gravel is less than a meter except where the sidestream deposit thickens against the Muddy River silt deposit

Qy **Young terrace alluvium (late Pleistocene)**--Mostly tan silt and sand along Muddy River and tan to gray sandy gravel along sidestream. A young thick aggradational silt deposit (Qy) of Muddy River underlies the Holocene silt deposit (Qh) but is not distinguished from the Holocene silt because silt deposition was continuous in association with the spring-fed, perennially flowing Muddy River; consequently, the young silt deposit is not designated on the map. However, in the northwest corner of map area, gray gravel from Arrow Canyon (mainstream gravel, Qy) underlies a low terrace upstream of the springs in the Muddy River valley; in this upstream part of the valley, silt deposition was not continuous since the late Pleistocene. Sidestream deposits form a low gravel terrace except where the sidestream deposits thickened against the Muddy River silt deposit; these wedges of sidestream fans in part rise above the Holocene/young silt deposit along the sides of the Muddy River valley. The young terrace deposits are slightly cemented by calcite and in many places hold a vertical face where exposed by stream cutting. River terraces 3-8 m high in Muddy River valley; sidestream terrace heights are 1-2 m. Depositional tops of sidestream terraces are well preserved and show many microrelief features, such as braided-channel remnants. The flat terraces have a carbonate-enriched soil horizon of disseminated, mostly white, powdery carbonate; the surface pavement is firm with varnished cobbles overlying several centimeters of loose, cobbly silt (A horizon). Pavement surface is dark and consists of cherty limestone clasts that show only slight solutional relief (that is, little differential solution of limestone relative to chert on cobble surface), and carbonate undercoating on underside of surface cobbles is mostly a film a small fraction of a millimeter thick. The carbonate soil development is stage II (Machette, 1985; Gile and Grossman, 1979). Where the young terrace is exposed, mostly as sidestream deposits, its age characteristics (for example, soil and morphology) are similar to deposits of the Wisconsin pluvial age nearby (Schmidt,

1994) and in the region. Thickness 1-3 m on sidestream, and possibly as thick as 10 m along the Muddy River

Qi **Intermediate terrace alluvium (late middle Pleistocene)**--Tan to gray, poorly bedded, moderately sorted, mostly clast supported, silty to sandy gravel and well bedded silt, fine sand, and clay. Consists of mainstream and sidestream deposits. Mainstream (Muddy River) deposit consists of gravel interbedded with thick aggradational silt (Quade and others, 1995) inset in the erosional valley of Muddy River (most of the extensive silt deposit has been removed by erosion). Sidestream deposits mostly thin terrace gravel inset in erosional sidestream valleys, but form a thick wedge of sidestream alluvium that intertongues with- and overlies-the thick mainstream deposit as a fan. Clast composition consists of Paleozoic carbonate rocks and sparse Kane Wash Tuff. Deposits not well cemented by calcite but commonly stand with vertical faces that have been case hardened by shallow ground-water carbonate at the exposed face (Lattman and Simonberg, 1971). Forms terraces that are about 30 m high in Muddy River valley but in places the capping silt has been erosionally stripped to the top of a resistant gravel bed that is lower than the full terrace height; sidestream terrace heights are much less, depending on the size of wash. The flat terrace top of the unit, where preserved, is essentially the depositional surface where initial depositional microrelief features are not preserved on the surface; edge of the terrace is erosionally rounded. Sidestream deposits are 1 to 3 m thick, and deposits along the Muddy River are about 20 m thick. This thick silt and gravel deposit of the Muddy River was probably aggraded under the paludal environment of a spring-fed, perennially flowing Muddy River and probably during the Illinoian pluvial age (Schmidt, 1994, 1995).

Qik **Carbonate soil developed on intermediate terrace alluvium (Holocene to late middle Pleistocene)**--In places, as mapped in northwest corner of map area, the initial flat terrace surface has been preserved by a carbonate soil zone, about 2 m thick, of which about 0.3 m is a resistant calcrete; the surface pavement is firm and overlies a 5-cm-thick silty A horizon. About 10 percent of the pavement consists of light-gray soil-carbonate fragments, mostly as carbonate undercoatings on rotated surface cobbles, but the overall color of the surface remains dark from the prevailing dark-brown desert varnish on resistant clasts. Differential surface solutional relief on cherty limestone clasts in pavement is as much as 1 cm, and carbonate undercoating beneath near-surface cobbles is 1 to 2 mm thick. The carbonate soil development is stage III (Machette, 1985; Gile and Grossman, 1979). Soil is mostly not well enough developed to map as an extensive map unit

Qo **Old terrace alluvium (middle and early? Pleistocene)**--Tan to gray, poorly bedded, moderately sorted, mostly clast supported, silty to sandy gravel and interbedded, moderately well-bedded silt, sand, and clay. Consists of mainstream (Muddy River) and sidestream deposits. Mainstream deposit consists of gravel interbedded with thick aggradational silt (Quade and others, 1995) inset in the erosional valley of Muddy River. Sidestream deposits consist mostly of a thin terrace gravel, inset in the erosional sidestream valley but also form thick wedges of alluvium that intertongue with and overlie as a fan the thick mainstream deposit. Clast composition of Muddy River gravel consists of Paleozoic carbonate rocks and sparse Kane Wash Tuff. Deposits poorly to moderately well cemented by calcite and commonly stand with vertical faces with and without case hardening (Lattman and Simonberg, 1971). Mainstream terrace is about 50 m high in Muddy River valley; sidestream terrace heights are much less except at the confluence of the sidestream and mainstream, where the two heights merge. In many places, the initial flat terrace surface has been preserved by a thick carbonate soil zone (Qok). Mainstream alluvium in places is thicker than its exposed 50 m height, and sidestream alluvium is mostly less than 3 m thick

Qok **Carbonate soil developed on old terrace alluvium (Holocene to middle and early? Pleistocene)**--Well developed carbonate soil, commonly 3 m thick, of which the upper 0.5 m is massive calcrete that forms a resistant rimrock along the edge of the old terrace (Qo). The surface pavement is firm, contains resistant surface clasts that are varnished black, and overlies a 15-cm-thick silty A horizon. Exposed surface clasts are about 40 percent carbonate-soil fragments, giving the surface an overall light color regardless of abundant dark, deeply varnished clasts. The carbonate undercoating on the bottoms of near-surface cobbles is about 1 cm thick. Differential solutional surface relief on cherty limestone clasts in pavement is as much as 2 cm. The carbonate soil development is stage IV (soil is plugged and has an incipient laminar development; Machette, 1985; Gile and Grossman, 1979). Unit not widely mapped because soil is not a conspicuous feature of the old deposit and it does not pose serious engineering problems other that the carbonate content of the soil gravel

Tr **Regrade gravel of Moapa (late early Pliocene)**--Gray-weathering (mainstream) and tan-weathering (sidestream), thick-bedded, well sorted, clast supported, commonly coarse gravel containing moderate amounts of interstitial sand and some lenses and thin beds of sand. The coarse gravel contains nearly uniform sizes of clasts from top to base of deposit including many clasts about 10 cm across and a few coarse boulders about 25 cm across. In many places the gravel is a calcrete, well cemented by secondary calcite. Clasts in Muddy River gravel consist dominantly of Paleozoic limestone, dolomite, and chert, minor Kane Wash volcanic rocks, and sparse other volcanic rocks. Clasts in sidestream gravels are strictly locally derived from Paleozoic sedimentary rocks. The regrade gravel terrace lies above and is better preserved by its thick carbonate soil than the terrace of the old alluvium (Qo). In northwestern part of quadrangle, the regrade terrace is about 56 m (620 m altitude) above Muddy River. At the east edge of the quadrangle, 2 km south of the power plant, the regrade terrace is about 53 m (481 m altitude) above Muddy River. The map unit is named for the small post office of Moapa, and is well exposed in the highest terrace west and north of Moapa. The unit results from the natural attempt of ancestral Meadow Valley Wash (controlling mainstream to which Muddy River is tributary; Schmidt, 1994) to carry its alluvial load all the way to the entrenched Colorado River. The aggradational and degradational processes, which followed the draining of the lake that deposited the Muddy Creek Formation, eventually resulted in an alluvial regrading whereby a near-equilibrium of gradient, load, and discharge was attained and the stable alluvial deposit of the regrade gravel of Moapa resulted. Subsequent, further entrenchment of the fluvial system (base-level control by Colorado River) was greatly reduced until the Quaternary, such that the surface of the regrade gravel of Moapa developed a thick carbonate soil similar to, but less developed than, that on the gravel of Whitmore Mesa (Ta). The age of the map unit is Pliocene on the basis of the stage of development of its carbonate soil; the age of is presumably somewhat younger than the regrading of the Colorado River itself, which may have been completed by about 3.8 Ma (Lucchitta, 1979). We suggest an age of 3.5 Ma or somewhat less for the regrading of the ancestral Meadow Valley Wash and Muddy River in the Farrier and Moapa West quadrangles (Schmidt, 1994). The map unit is in most places a few meters to 5 m thick

Trk **Carbonate soil developed on regrade gravel of Moapa (Holocene to late early Pliocene)**--An old, partly to severely eroded carbonate soil developed on the surface of the regrade gravel of Moapa; this soil is less well developed, less resistant, and more eroded than the older Mormon Mesa carbonate soil developed on the Muddy Creek Formation (Tmr) as well exposed 10 km east of Moapa and the map area (Gardner, 1968, 1972b). The carbonate-enriched soil is 3 to 4 m thick but is difficult to estimate because the gravel below the soil is extensively cemented by secondary, non-pedogenic calcite. In many places on the geologic map, the regrade gravel is not mapped beneath the carbonate soil because either, 1) the soil includes the full thickness of the gravel itself, or 2) in commonly steep exposures, the non-petrogenic, lower part of the regrade gravel is too thin to show on the map. The soil calcrete forms a resistant terrace surface and rim rock about 1 to 2 m thick; this resistant rimrock generally restricts rounding of the terrace edges. The soil surface is eroded to near the base of the laminar zone; the full laminar zone has not been observed, but some overlying laminar-zone fragments are more than 10 cm thick and characteristic of a well developed Tertiary soil. Depending upon the depth of erosion, about half the surface consists of resistant, gravelly soil calcrete and the other half consists of a firm, clastic, soil pavement that overlies about 30 cm of silty A horizon. The pavement consists of about 70 percent soil carbonate fragments, mostly fragments of the laminar zone, which gives the surface a very-light color. Where surface rainwater flow is slightly channeled, the soil surface is characteristically, but sparsely, spotted black with concentrations of darkly varnished and polished, angular chert pebbles. The carbonate soil below the relict laminar zone is completely plugged with aphanitic calcite. The maximum carbonate-soil development is stage VI (Machette, 1985)

Aggradational gravel of Whitmore Mesa (early early Pliocene)--The gravel of Whitmore Mesa is an aggradational gravel that prograded out onto the flattish dry lake floor of the top of the Muddy Creek Formation after rapid draining of the Muddy Creek lake but before dissection and erosion of the lake beds; gravel grades upward from sand and gravelly sand to sandy gravel and gravel. The aggradational gravel is an extensive, thick map unit in the marginal parts of the basin both to the north and west of the Moapa West quadrangle in adjoining quadrangles. The name of the unit is from Whitmore Mesa in the adjacent Rox Southeast quadrangle and is described in the geologic map report for the Farrier quadrangle (Schmidt, 1994). In the Moapa West quadrangle the gravel of Whitmore Mesa is thin and not extensive because sources of alluvium are small drainages of the nearby Arrow Canyon Range to the west and because extensive erosion since Whitmore Mesa time has removed most sidestream deposits. In Moapa West quadrangle, map unit is divided into two distinctive deposits: (1) a sidestream alluvial fan deposit and (2) a yellow, basal sand deposit

Tas **Sidestream alluvial-fan deposit**--Tan- to brown-weathering, thick- to thin-bedded, poorly sorted, interbedded gravelly sand and sandy gravel that coarsens upward. This aggradational sidestream gravel contains cobbles and dispersed boulders supported in a matrix of grit to medium sand; boulders range to 30 cm in diameter. Clasts consist of locally derived upper Paleozoic limestone, dolomite, and chert from the adjacent Arrow Canyon Range to the west. A gravelly gypsum layer, 0.5-1 m thick, constitutes the base of the gravel fan. In places the gravel is moderately well cemented by calcite and commonly erodes with high steep slopes. Well exposed in the highly dissected sidestream alluvial fan about 4 km north of the southwest corner of the quadrangle where the fan directly overlies the green-claystone member of the Muddy Creek Formation. The fan deposit is about 25 m thick

Tay **Yellow basal sand**--Tan, fine and medium sand aggraded above the green claystone member of the Muddy Creek Formation and overlain by the marl of White Narrows. Locally, sparse fragments of fossil bone and petrified wood and rare, polished, varicolored, chert pebbles are dispersed in the sand. Exposed in two areas: 1.5-2.5 km southwest of the power plant and 0.5-1.2 km north-northeast of Hogan Spring. Source of yellow sand is uncertain, either an earliest progradational sand associated with aggradational gravel from the Meadow Valley drainage basin to the north, or a locally aggraded sand derived from an earliest shallow erosion of the uppermost Muddy Creek Formation. Yellow sand is as thick as 7 m

Tak **Carbonate soil developed on the aggradational gravel of Whitmore Mesa (Holocene through late early Pliocene)**--A resistant, but partly eroded carbonate soil developed on the uppermost part of the gravel of Whitmore Mesa in the southwest part of the map area, is weathered and eroded down to, and in places below, the soil laminar zone. The surface pavement is very light colored because it consists of about 90 percent light-gray carbonate-soil fragments and only several percent chert fragments and inconspicuous gray Paleozoic carbonate clasts; locally, varnished and polished chert fragments are concentrated in black patches several meters across. The partly eroded soil is about 3 m thick and, where preserved, a rimrock of resistant calcrete is about 1 m thick. This partly eroded soil is similar to the partly eroded soil of the regrade gravel of Moapa in the map area, but in the type area on Whitmore Mesa in the adjacent Rox SE and Farrier quadrangles (Schmidt, 1994), the Whitmore Mesa soil is much less eroded, more developed, thicker, and forms a more resistant terrace top

Marl of White Narrows (early early Pliocene)--White calcic claystone and clayey limestone characterize the unit; this carbonate facies represents the sudden influx of a large discharge of bicarbonate ground water from the carbonate-rock aquifer of the region. Deposition was (1) in graben structures faulted into the full section of the Muddy Creek Formation (Tmr-Tmg) and (2) in degradational channels initiated at fault scarps and high part of tilted fault blocks of the grabens. The marl of White Narrows is divided into two subfacies according to these two depositional environments: (1) Twg, graben fill, deposition within the graben structure directly on the top of the Muddy Creek Formation, that is, on the green claystone (Tmg); and (2) Twc, channel fill, deposition in degradational channels cut below the top of the Muddy Creek Formation, that is, on an immature disconformity below the green claystone (Tmg). Unit informally named herein for exposures at White Narrows in the Muddy River valley in the center of the map area. Gardner (1968) informally named the White Narrows member of the Muddy Creek Formation for "white calcareous silt and clay and light gray impure vuggy limestone" within- and in the vicinity of-the Moapa West quadrangle; his reconnaissance geologic map (1:62,500) applies his member name to rocks herein mapped as the graben-fill unit of the marl of White Narrows

Twg **Graben-fill unit**--Medium- to light-gray and greenish-gray to buff, white-weathering, calcareous fine-grained sediments filling shallow, north-striking grabens displacing the Muddy Creek Formation (Tmr-Tmg) in large parts of the eastern half of the quadrangle. Consists of calcareous claystone, clayey limestone, and limestone containing varying amounts of fluvial sand, reworked eolian sand, and disseminated gypsum; deposition mostly lacustrine, but locally fluvial. In places where the calcareous contribution is low and the clay is mostly derived directly from erosion of adjacent fault blocks of Muddy Creek Formation, the resulting calcic claystone is very pale reddish brown. The sediments are well bedded, with beds 10 to 50 cm thick; some bedding is laminated. Locally limestone beds are thin bedded, algal-matted, porous, and contain trace fossils of carbonate molds and casts of plant fragments; all these features are characteristic of deposition from warm spring water from the regional carbonate aquifer. In a few places, sedimentary structures are visible: shallow current ripples, small current channels, and sparse soft-sediment flowage folds. The age of the basal part of the marl of White Narrows is estimated between 4.0 to 5.0 Ma on the basis of a fossiliferous marl bed, 20 cm thick, and an overlying ash bed, 10 to 90 cm thick, about 2 m above the base of the unit, and about 3 km southwest of the power plant. The fossil-bearing bed (site SBCM 2.12.16) was discovered by R.E. Reynolds (San Bernardino County Museum, Redlands, Calif.) during an environmental survey for the Kern River gas pipeline during 1991. A preliminary age of a diverse faunal collection from the fossil bed containing many small fragments of vertebrate fossils and invertebrate fossils (invisible at the outcrop) is between 4.7 and 5.0 Ma according to Reynolds (written commun., 1992); however,, C.A. Repenning (U.S. Geological Survey, written commun., 1992), on the basis of a pack-rat tooth suggests that the faunal collection possibly could be as old as 4.5 Ma, but "that the oldest record of the contained pack rat is slightly older than the base of the Nunivak event, which is placed at 4.2 Ma." The ash bed was analyzed by A.M. Sarna-Wojcicki (U.S. Geological Survey, written commun., 1994) using glass composition to make a "best-fit correlation" with the glass compositions of tuffs of known age; the method has not been conclusive, but a tentative "best-fit age" agrees within the age range of the fossils. The uppermost part of the map unit is eroded and in places overlain by the regrade gravel of Moapa; the base of the unit overlies the top of the Muddy Creek Formation (Tmg) except locally where the thin basal sand (Tay) of the gravel of Whitmore Mesa intervenes. Thickness greater than 80 m, which is the maximum exposed thickness of the map unit.

Twc **Channel-fill unit**--Medium- to pale-gray and pale-greenish-gray to buff and pale-red-brown, calcareous mudstone, white limestone, and subordinate tan to brown, calcareous, silty to sandy conglomerate filling degradational valleys and channels cut in the Muddy Creek Formation (Tmr); west of the graben structures of the central part of the map area the erosional channels are narrow, steep-walled, and in places contain slump breccias at the base of the fill; east of the graben structure the erosional channels are broad and shallow and contain more gravel. The mudstone consists of marl, silty claystone, clayey siltstone, reworked Muddy Creek Formation, and reworked eolian sand, and in many places contains disseminated gypsum and local lenses of gypsum. Base-level control for the channel fill was the depositional level of the graben fill within the graben structure. Channel fill adjacent to the grabens was mostly a lacustrian back filling of the same fine-grained, calcareous sediment as was filling the grabens (similar to Twg). Upstream in the degradational channels deposition was mostly paludal and fluvial. The conglomerate contains a slight majority of pebble- to boulder-sized clasts, some of which are matrix supported; gravel sources are proximal from west from Arrow Canyon Range for conglomerate west of White Narrows and distal from north from the Meadow Valley Wash drainage for conglomerate east of White Narrows. Lower contact of the unit is a disconformity cutting across the Muddy Creek Formation; contact is widely exposed across a large central part of the quadrangle. The narrow degradational valleys and channels initiated at steep fault scarps of the grabens where the graben-fill unit (Twg) was being deposited; this initial erosion propagated headward in nearly unconsolidated clays of the Muddy Creek Formation for 2 to 3 km to the Paleozoic rock outcrops of the Arrow Canyon Range. The age of the channel-fill unit is the same as that of the graben-fill unit because the marl filling the grabens provided the base level controlling the filling of the degradational valleys and channels; this fill is partly a backfill of the sediments deposited in the grabens and partly a fluvial aggradation of debris from the drainage basin of each erosional channel or valley. Exposed thickness is commonly 20 to 30 m in the western channels and a few meters to about 15 m in the broad eastern channels

Twk **Carbonate soil developed on marl of White Narrows (Holocene to late early Pliocene)**--A carbonate soil probably developed on an old, high erosion surface cut below the top of the marl of White Narrows; only erosional remnants of the soil in mostly small buttes remain. Because both the soil and the parent substratum are resistant carbonate rock, the soil is difficult to map without further study. Because the old erosional surface slopes gently to the broad surface of the regrade gravel of Moapa (Tr), the carbonate soil as preserved probably is about the same age as the soil of the regrade gravel (Trk)

Muddy Creek Formation (upper Miocene)--Fine-grained basin-fill deposits formed in a regionally extensive lake, called here the Muddy Creek lake, after cessation of most extensional deformation. Pale-reddish-brown, gypsiferous and calcareous, lacustrine deposit containing little or no lake-margin alluvium. Mapped as two units in the quadrangle, an uppermost green claystone unit (Tmg) and the principal red claystone unit (Tmr). The green color reflects an inferred reduced state of the clay during deposition (perhaps caused by abundant organic content in this brackish lake), in contrast to the oxidized state of the clay as a red, buried, diagenetic unit (Tmr). The diagenetic red-bed oxidation process was rapid, perhaps aided by a well-dispersed gypsum content in the sediments. The uppermost green-claystone unit presumably was spared red oxidation because once the Muddy Creek lake was drained, the chemistry of the pore water in the uppermost beds, a meter to a few tens of meters thick, was dramatically changed such that the red-bed process did not occur. The preservation of fossils in the unit is exceedingly rare, probably because its high gypsum content reacts chemically to destroy fossil material. Formation is horizontally bedded except (1) for a gentle slope toward the basin axis east of Meadow Valley Wash probably caused by a combination of depositional slope, differential compaction of clayey sediment, and structural sagging and continued slight down-faulting toward the basin axis (east of the map area); and (2) for sparsely gentle to steep dips where bedding is commonly deformed and tilted as much as 45 degrees within about 30 m of faults; most observed faults that cut the Muddy Creek are slightly younger than the age of the depositional top of the formation. Stock (1921) applied the name "Muddy Creek beds" to rocks now called Muddy Creek Formation. Longwell (1928) mapped and described the Muddy Creek formation, using the informal name in the Muddy Mountain area, but later Longwell and others (1965) used the name formally. Gardner (1968) mapped in reconnaissance the Muddy Creek Formation in the entire Muddy River valley including the area of the Moapa West quadrangle. Dicke (1990) measured and described many stratigraphic sections of the formation in adjacent quadrangles to the north and northeast but did not designate a top to the formation. In the current map report, we definite the Muddy Creek Formation in more restricted terms than any of the above authors. The age of the depositional top of the formation is about 5 Ma as based on regional ages and on age of base of the overlying marl of White Narrows. The basal, oldest rocks of the Muddy Creek Formation are not exposed in the map area, but the age of the base is considered to be about 12 Ma in the Lake Mead area if the red sandstone unit of Bohannon (1984, p. 49) is included in the Muddy Creek Formation as used here

Tmg **Green claystone**--A thin, massive- to thick-bedded claystone that is greenish-gray in its lower half and varicolored in shades of reddish brown and yellowish brown in its upper half. Contains disseminated calcite and gypsum. The unit lies conformably on the red claystone unit, with a transition zone only a few centimeters thick. Unit found throughout a large area in the central part of the quadrangle, where it is preserved from erosion by the overlying marl of White Narrows (Twg), but unit also is found in a few outcrops farther west, where it is preserved beneath either the gravel of Whitmore Mesa (Ta) or other marl of White Narrows (Twd). Unit commonly 5 to 15 m thick, but as thick as 30 m

Tmr **Red claystone**--Salmon and pale-reddish-brown, well-bedded, thin- to laminar-bedded claystone containing sparse siltstone and very-fine- to fine-grained sandstone. Rarely, small (centimeters thick by meters wide) remnants of green claystone are interbedded within the thick red claystone unit. Unit commonly has a thin, opaque clay-wash coating on exposed surfaces that makes observation of detailed stratigraphy and structure difficult. Moderately well consolidated sediment stands vertically in recent stream cuts, but with time the outcrops become well rounded. In uppermost part, unit contains as much as 10 percent fine- to medium-grained, calcite-cemented sandstone in lenses and discontinuous tabular beds as thick as 10 cm that weather to platy fragments. Mud cracks and thin gypsum beds are rare, suggesting that the lake in which these sediments were deposited rarely dried out. The exposed red claystone in the map area, representing only the upper part of the unit, abuts or onlaps against the Horse Spring Formation and Paleozoic carbonate rocks. The thickest exposure of red claystone is about 45 m thick in the northwest part of the quadrangle. Two drill holes in southern part of map area, report the depth to the base of the formation: the thickness of the formation, as estimated by extrapolating the altitude of the top of the formation to the drill holes, is 349 m at drill hole HS-8B (section 15, T. 15 S., R. 66 E.) and 382 m at drill hole EH-2A (section 9, T. 15 S., R. 65 E.; Desert Research Institute, University of Nevada, Las Vegas, written commun., 1986)

Horse Spring Formation (middle and lower Miocene)--Synextensional basin-fill deposit that formed during opening and subsidence of the Glendale basin, which underlies eastern two thirds of map area and extends an additional 8 km to the east; rocks in map area are everywhere moderately deformed, commonly dipping 10 to 20 degrees and locally folded. Divided here into two units, an upper, conglomerate member (Thc) consisting of clastic debris shed into the basin and a lower, limestone member (Thl). The formation in the map area is correlated with widely mapped rocks of the same name in the Virgin and Muddy Mountains on the basis of (1) similar lithology and age, (2) similar amounts and types of deformation, and (3) its unconformable stratigraphic position below the slightly deformed Muddy Creek Formation (Longwell, 1928; Longwell and others, 1965; Bohannon, 1984; Beard and Ward, 1993). Drill hole EH-2A bottomed within the Horse Spring Formation and penetrated 823 m of the formation below the unconformity at the bas of the Muddy Creek Formation

Thc **Conglomerate member**--Pale-red-brown, well indurated, very poorly sorted, immature, discontinuously thick-bedded, polymictic, silty sandy conglomerate and conglomeratic sandy siltstone. Well graded from sparse boulders and abundant cobbles (20 percent) and angular pebbles (30 percent) to a matrix (50 percent) of sand and silt, but content is variable both laterally and vertically in section; grading fines upward. Most large clasts float in a fine-grained matrix, and local gravel-rich layers are interbedded with silt-rich layers. Boulders are generally 15-25 cm across, locally as much as 45 cm across. Clasts consist of Paleozoic limestone, dolomite, and chert, and are derived from the adjacent Arrow Canyon Range. Member has limited exposure at a few small outcrops in the map area; its lower contact on laps Paleozoic bedrock and it exposed top is everywhere erosional. In contrast the member is well and widely exposed in the adjacent Farrier quadrangle (Schmidt, 1994) where its age is fixed by two ash-flow cooling units of the Kane Wash Tuff that are interlayered with the conglomerate; the ages are 14.6 and 14.4 Ma (Scott and others, 1995). The exposed thickness of the member in the Moapa West quadrangle, where it crops out 3.5-4 km west of White Narrows, is only a few meters

Thl **Limestone member**--White to pale-pinkish-gray, thin-bedded to laminated, coarsely porous, aphanitic limestone, locally containing fossil algal-mat laminations and abundant molds and casts of plant fossils either as disoriented fragments or in growth position. Lithologically represents a spring-carbonate sequence deposited proximally to springs discharging warm, bicarbonate-rich ground water along a large, but poorly exposed, range-front fault zone on east side of Arrow Canyon Range. Upfaulted and abundantly, but incompletely exposed along the Arrow Canyon Range front, the limestone member is about 60 m thick; in drill hole HS-8B, its full thickness is reportedly 100 m

Bird Spring Formation (Lower Permian; Pennsylvanian, and Upper Mississippian)--Subdivided into the following informal members (in descending order), as defined in the Arrow Canyon quadrangle (Page, 1992) and described in the Arrow Canyon NW quadrangle (Page, 1995, in press): red slope-forming member, massive gray limestone member, dolomitic member, member of Tungsten Gap, and basal limestone member. Thickness of formation in quadrangle is at least 1,020 m

Pb5 **Red slope-forming member (Lower Permian)**-- Consists chiefly of alternating thinly laminated beds of silty limestone, calcareous siltstone, mudstone, and chert. Limestone is micritic, dark to olive gray (fresh), and very light gray to light olive gray and less commonly purplish gray (weathered); it contains calcareous siltstone laminae that weather yellowish gray, dusky yellowish gray, and moderate brown. Chert is olive gray to olive black (fresh), and moderate brown to dusky yellowish brown (weathered). Rocks show some convolute bedding and appear unfossiliferous in hand specimen, although abundant sponge monaxons are visible in thin section (Page, 1993). The lower 20 to 30 m of the member consists mostly of pale-red, silty laminated limestone, calcareous mudstone, and calcareous siltstone containing thin discontinuous beds and isolated lenses of medium-dark-gray, finely crystalline limestone that has planar laminations. Distinctive phosphatic concretions 0.5- to 4-cm in diameter are present at the base of member; concretions are commonly cored by fish-bone fragments. Entire member forms pinkish-reddish-brown slope easily identified on aerial photographs and is equivalent to unit d of the Bird Spring Formation 15 km north of quadrangle in the Meadow Valley Mountains (Pampeyan, 1993). Schmidt (1994) estimated a thickness of 215 m for the entire member in the adjacent Farrier quadrangle; only about 120 m of the unit is exposed in map area

Pb4 **Massive gray limestone member (Lower Permian)**-- Predominantly massive, dark-gray (fresh) and medium-dark-gray to light-olive-gray (weathered), finely to coarsely crystalline, thick to very thick bedded limestone. Contains some discontinuous layers and nodules of dusky-yellowish-brown-weathering chert. The uppermost 13 m of the unit consists of flaggy-weathering, finely crystalline, very thin bedded, fusulinid-rich limestone that is medium gray (fresh) and grayish orange, light brown, moderate brown, and dusky yellowish brown (weathered). The basal 7 m of the unit consists of aphanitic to finely crystalline, cherty limestone (commonly consisting of more than 40 percent chert) that is medium gray and medium dark gray to grayish red (fresh), and light gray, pale red, and pinkish gray (weathered). Member contains abundant fossils, including *Durhamina* corals, *Syringapora* coral mounds, crinoid columnals, *Pseudoschwagerina* fusulinids, bryozoans, brachiopods, and planispiral gastropods tentatively identified as *Onthalothrochus* (C.H. Stevens, written commun. 1992). Upper contact with overlying red slope-forming member is sharp and represents a major Lower Permian sequence boundary (Page, 1993, 1995, in press). Forms massive cliffs and is about 45 m thick

PIPb3 **Dolomitic member (Lower Permian and Upper Pennsylvanian)**--Medium-dark-gray to olive-gray (fresh) and light-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, dolomitic limestone, and dolomite. Light-gray- and yellowish-gray-weathering dolomite and dolomitic limestone characterize the upper half of member. Locally includes beds of pale-red (fresh) and dusky-yellowish-brown to light-brown (weathered), finely to medium crystalline, silty limestone in lower part of member. Fossils include *Paraheritschioides* sp. (C.H. Stevens, written commun., 1995), solitary rugose, and *Syringapora* corals, crinoid columnals, fusulinids, brachiopods, and bryozoans. Permian-Pennsylvanian contact estimated to be about 60-70 m above the base of member based on the stratigraphic position of fusulinids described by Cassity and Langenheim (1966). Member forms step-like ledges and is about 260 m thick

IPb2 **Member of Tungsten Gap (Middle Pennsylvanian)**--Medium-gray (fresh) and dusky-yellowish-brown to moderate-brown (weathered), finely crystalline, thin-bedded, silty dolomitic limestone. Fossils include brachiopod and crinoid columnal fragments. Member is distinctive by its conspicuous desert varnish on weathered surfaces, and it serves as a prominent marker bed within the Bird Spring Formation in the region. This informal member may be equivalent to the Tungsten Gap chert (Castle, 1967; Langenheim and Webster, 1979), and is within unit Bs_c of the Bird Spring Group of Langenheim and others (1962). Forms resistant cliff about 15 to 25 m thick

IPMb1 **Basal limestone member (Middle Pennsylvania to Upper Mississippian)**--Limestone and minor dolomite. 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). It is commonly arenaceous and bioclastic and contains some oolitic beds. Limestone is finely to coarsely crystalline, thin to thick bedded; some beds contain planar laminations and small-scale trough crossbeds. Contains abundant discontinuous layers and nodules of dark-gray (fresh) and dusky-yellowish-brown (weathered) chert; some beds contain more than 50 percent chert. Several medium-gray (fresh) and yellowish-gray to light-gray (weathered) dolomite beds are present in the middle part of the member. Member contains *Syringapora*, crinoid columnals, solitary rugose corals, bryozoans, and brachiopods; *Chaetetes* and fusulinids are present in the upper part. Member equivalent to most of the Bs_c unit of the Bird Spring Group of Langenheim and others (1962). Approximately the basal 14 m of member is reported to be Upper Mississippian (Chesterian) in age based on brachiopods, conodonts, and calcareous foraminifers (Webster, 1969; Brenckle, 1973; Lane and others, 1983). Member forms step-like ledges and is not completely exposed in map area; total thickness of member is from 500 to 570 m in adjacent quadrangles (Page, 1992, 1995, in press)

Mis **Indian Springs Formation (Upper Mississippian)**--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; it contains *Rhipidomella nevadensis*, spiriferid and productid brachiopods, solitary rugose corals, crinoid columnals, and fenestrate bryozoans. Shale is dusky red, grayish red purple, grayish orange, and grayish black, and it is laminated. Quartzite in upper part is olive gray to light gray (fresh) and moderate brown, and moderate yellowish brown to dusky yellowish brown (weathered); quartz grains are fine grained, subrounded, and moderately sorted. Beds range from 0.5 to 1.0 m thick and have planar laminations. Rocks at the basal contact of formation are highly deformed. Formation is equivalent to unit Bs_b of the Bird Spring Group (Langenheim and others, 1962), and reported to be late Chesterian (Webster, 1969; Brenckle, 1973; Lane and others, 1983). Forms slope and is approximately 60 m thick

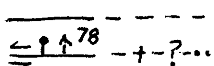
Mbw **Battleship Wash Formation (Upper Mississippian)**--Consists of limestone and minor quartzite. Limestone is slightly arenaceous and bioclastic, medium dark gray (fresh) and light olive gray to purplish gray (weathered), mostly coarsely crystalline, and thin bedded. Basal 2 m of formation consists of thin interbeds of quartzite and sandy limestone. Quartzite is calcareous, medium light gray (fresh), and grayish orange to olive gray (weathered); quartz grains are fine to medium grained. Fossils in formation include *Faberophyllum* and other solitary rugose corals, and spiriferid brachiopods. Formation is equivalent to unit Bs_a of the Bird Spring Group (Langenheim and others, 1962), reported to be latest Meramecian and early Chesterian (Brenckle, 1973; Lane and others, 1983; Poole and Sandberg, 1991). Forms ledgy cliff and is about 80 m thick

Monte Cristo Group (Upper and Lower Mississippian)--Includes, in descending order, Yellowpine Limestone, Bullion limestone, Anchor Limestone, and Dawn

Limestone; only the Yellowpine and the upper part of the Bullion are exposed in this quadrangle. Series designations are from Stevens and others (1991). Total thickness of group is 445 m in the adjacent Arrow Canyon quadrangle (Page, 1992) and 500 m in the Arrow Canyon NW quadrangle (Page, 1995, in press)

Mmcy **Yellowpine Limestone (Meramecian)**--Medium-dark-gray to dark-gray (fresh) and medium-light-gray to light-olive-gray (weathered), medium-crystalline, thin- to thick-bedded limestone. Contains sparse nodules and discontinuous layers of medium-dark-gray (fresh) and dusky-yellowish-brown (weathered) chert. Contains solitary rugose corals, *Syringapora*, and crinoid columnals; a *Lithostrotionella* coral biostrome marks the top of the unit. Forms massive cliffs and is about 100-120 m thick

Mmcb **Bullion limestone (Meramecian)**--Three parts are recognizable in the adjacent Arrow Canyon and Arrow Canyon NW quadrangles (Page, 1992, 1995, in press), but only the upper part is exposed in this quadrangle. Upper part is about 50 m thick and consists of medium-dark-gray (fresh) and light-gray to light-olive-gray (weathered), finely to medium crystalline, thick-bedded limestone that commonly contains discontinuous layers of dusky-yellowish-brown chert. Fauna includes abundant crinoid columnals and brachiopods. Middle part is about 110 m thick and consists of medium-light-gray (fresh) and medium-gray to light-olive-gray (weathered), mostly coarsely crystalline, thin-bedded cherty limestone that commonly contains more than 50 percent chert. Chert is dark gray (fresh) and moderate brown to dusky yellowish brown (weathered) and occurs in beds generally 7-10 cm thick that have planar laminations and small-scale trough crossbeds; chert contains abundant crinoid columnals. Lower part is about 30 m thick and consists of medium-light-gray (fresh) and light-gray (weathered), mostly coarsely crystalline, thick-bedded, relatively chert-free limestone that contains abundant crinoid columnals and some solitary rugose corals. Forms massive cliffs and is about 160-190 m thick

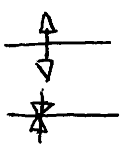


Contact

Fault--Dashed where approximately located; dotted where concealed; queried where uncertain. Bar and ball on downthrown side, where known. Arrow indicates direction and amount of dip of fault plane, cross bar marked 90 indicates vertical fault. Opposed arrows indicate relative direction of strike-slip movement. Arrow oblique to- and perpendicular to-dip arrow shows trend and plunge of slickensides on fault plane

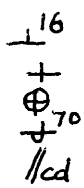
Trace of landslide slip plane

Folds--Most folding, including all large folds in Paleozoic rocks, were folded during Late Cretaceous-early Tertiary Sevier compression; minor small folds, for example, small folds in the limestone member of the Horse Spring Formation, were folded during late Tertiary extension especially near large faults



Anticline--Showing crestline and plunge, where known. Dashed where approximately located; queried where uncertain; dotted where concealed

Syncline-Showing crestline and plunge, where known. Dashed where approximately located; queried where uncertain; dotted where concealed.



Strike and dip of beds

Inclined

Vertical

Horizontal

Overturned

Clastic dike--Formed from downward filling of open fracture. Mostly vertical, several meters long, and several centimeters wide. Fill consists of wall-rock breccia

Spring-carbonate vein--White, finely to coarsely laminated, cyclically laminated, coarse- to fine-crystalline calcite veins. Crystal axes and thus growth directions are perpendicular to vein walls. Crystal size may vary from one laminae to the next, but generally does not. Most vein growth was symmetrical about a central plane; the two sides of the vein are thus mirror images, and its center commonly consists of open space a few millimeters wide. Veins are as wide as 3 m. Carbonate veins were precipitated from regional, warm, bicarbonate ground water in cyclically-opening narrow fractures during regional extension

Single vein--Showing strike and dip of vein; inclined vein shown by tick and number, vertical vein shown by cross bar

Site of multiple veins--Veins mostly narrow and short, with variable strike and dip

R **Red water-course rock**--Mostly red, fractured Paleozoic carbonate rocks and limestone member of the Horse Spring Formation formed during flow of large quantities of warm, oxidizing ground water in a regional aquifer. The typically intense red coloration is probably caused by the oxidation of iron-oxide mineral impurities within the rocks, mostly commonly within fine-grained clastic-bearing carbonate rocks. Fault gouge and breccia of impure carbonate rocks are especially subjected to red oxidation, probably because zones of these rocks were the most common pathways for regional ground water. The red coloration is preserved only on recently exposed rocks, as on youthful canyon walls and stream cuts; with time, the red color alters to dark brown, then to dark gray, and eventually is obliterated

B **Black water-course rock**--Thin coating of black manganese oxide on small open-work fracture sets and cavities in Paleozoic carbonate rocks. The oxide was precipitated from warm ground water of a carbonate-rock aquifer. Manganese oxide precipitation is uncommon and probably represents a local chemical environment with available manganese

W **White water-course rock**--Whitened area of Paleozoic carbonate rocks formed by precipitation of many 2- to 20-cm-wide radial growths of calcite crystals ("roses") in

1- to 5-m-diameter areas. Such whitened rock suggests extensive interaction with warm, carbonate-rock-aquifer water

o EH2 **Exploratory water well**--Wells EH2A, EH4, EH5, and HS8 drilled for Nevada Power Company during 1985-1988; well MVWD drilled for Moapa Valley Water District in 1991. (Some older production wells are indicated as "WW" on the topographic base map)

REFERENCES CITED

Beard, L.S., and Ward, Sonja, 1993, Tertiary sedimentation along the Lake Mead fault system, Virgin Mountains, Nevada-Arizona: Geological Society of America Abstracts with Programs, v. 25, no. 5, p. 8.

Bohannon, R.G., 1984, Nonmarine sedimentary rocks of Tertiary age in the Lake Mead region, southeastern Nevada and northwestern Arizona: U.S. Geological Survey Professional Paper 1259, 72 p.

Brenckle, P.L., 1973, Smaller Mississippian and Lower Pennsylvanian calcareous foraminifers from Nevada: Cushman Foundation for Foraminiferal Research, Special Publication no. 11, 82 p.

Cassity, P.E., and Langenheim, R.L., Jr., 1966, Pennsylvanian and Permian fusulinids of the Bird Spring Group from Arrow Canyon, Clark County, Nevada: Journal of Paleontology, v. 40, p. 931-968.

Castle, R.A., 1967, Mississippian and Pennsylvanian paleontology and stratigraphy at Tungsten Gap North, Arrow Canyon Range, Clark County, Nevada: Urbana, University of Illinois, B.A. thesis, 56 p.

Dicke, S.M., 1990, Stratigraphy and sedimentology of the Muddy Creek Formation, southeastern Nevada: Lawrence, University of Kansas, M.S. thesis, 62 p.

Gardner, L.R., 1968, The Quaternary Geology of the Moapa Valley, Clark County, Nevada: University Park, Pennsylvania, Ph.D. dissertation, The Pennsylvania State University, 162 p., scale 1:41,600.

____1972a, Pediments and terraces along the Moapa Valley, Clark County, Nevada: Geological Society of America Bulletin, v. 83, p. 3479-3486.

____1972b, Origin of the Mormon Mesa caliche, Clark County, Nevada: Geological Society of America Bulletin, v. 83, p. 142-156.

Gile, L.H., and Grossman, P.P., 1979, The desert project soil monograph: Soils and landscapes of a desert region astride the Rio Grande Valley near Las Cruces, New Mexico: U.S. Soil Conservation Service, 984 p.

Lane, H.R., Baesemann, J.F., Brenckle, P.L., and West, R.R., 1983, Arrow Canyon, Nevada--A potential mid-Carboniferous boundary stratotype: Compte Rendu, International Carboniferous Congress, Madrid, 1983, v. 4, p. 429-439.

Langenheim, R.L., Crass, B.W., Kennerly, J.B., McCutcheon, V.A., and Waines, R.H., 1962, Paleozoic section in Arrow Canyon Range, Clark County, Nevada: American Association of Petroleum Geologists Bulletin, v. 46, p. 592-609.

Langenheim, R.L., and Webster, G.D., 1979, Road log, seventh day--Clark County, Nevada, *in* Beus, S.S., and Rawson, R.R., eds., Carboniferous stratigraphy in the Grand Canyon country, northern Arizona and southern Nevada, Field Trip 13: Ninth International Congress of Carboniferous Stratigraphy and Geology, p. 73-78.

Lattman, L.H., and Simonberg, E.M., 1971, Case-hardening of carbonate alluvium and colluvium, Spring Mountains, Nevada: Journal of Sedimentary Petrology, v. 41, p. 274-281.

Longwell, C.R., 1928, Geology of the Muddy Mountains, Nevada: U.S. Geological Survey Bulletin 798, 151 p.

Longwell, C.R., Pampeyan, E.H., Bowyer, Ben, and Roberts, R.J., 1965, Geology and mineral deposits of Clark County, Nevada: Nevada Bureau of Mines and Geology Bulletin 62, 218 p.

Lucchitta, Ivo, 1979, Late Cenozoic uplift of the southwestern Colorado Plateau and adjacent lower Colorado River region: Tectonophysics, v. 61, p. 63-95.

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

Page, W.R., 1992, Preliminary geologic map of the Paleozoic rocks in the Arrow Canyon quadrangle, Clark County, Nevada: U.S. Geological Survey Open-File Report 92-681, 15 p., scale 1:24,000.

__________ 1993, A regional marker unit within the upper Paleozoic Bird Spring Formation, southern Nevada--Evidence for a slope facies: Geological Society of America Abstracts with Programs, v. 25, no. 5, p. 131.

__________ 1995, Preliminary geologic map of the Arrow Canyon NW quadrangle, Clark County, Nevada: U.S. Geological Survey Open-File Report 95-35, scale 1:24,000.

__________ in press, Geologic map of the Arrow Canyon NW quadrangle, Clark County, Nevada: U.S. Geological Survey Geologic Quadrangle Map GQ-1776, scale 1:24,000.

Pampeyan, E.H., 1993, Geologic map of the Meadow Valley Mountains, Lincoln and Clark Counties, Nevada: U.S. Geological Survey Miscellaneous Investigations Series Map I-2173, scale 1:50,000.

Poole, F.G., and Sandberg, C.A., 1991, Mississippian paleogeography and conodont biostratigraphy in the Western United States, *in* Cooper, J.D., and Stevens, C.H., eds., Paleozoic paleogeography of the Western United States-II: Pacific Section, Society of Economic Paleontologists and Mineralogists, v. 67, p. 107-136.

Quade, Jay, 1986, Late Quaternary environmental changes in the upper Las Vegas Valley, Nevada: Quaternary Research, v. 26, no. 3, p. 340-357.

Quade, Jay, Mifflin, M.D., Pratt, W.L., McCoy, William, and Burckle, Lloyd, 1995, Fossil spring deposits in the southern Great Basin and their implications for changes in water-table near Yucca Mountain, Nevada, during Quaternary time: Geological Society of America Bulletin, v. 109, p. 219-230.

Rock-Color Chart Committee, 1951, Rock-color chart: Boulder, Colo., Geological Society of America.

Schmidt, D.L., 1994, Preliminary geologic map of the Farrier quadrangle, Clark and Lincoln Counties, Nevada: U.S. Geological Survey Open-File Report 94-625, 31 p., scale 1:24,000.

____and Dixon, G.L., 1995, Geology and aquifer system of the Coyote Spring Valley area, Southeastern Nevada: U.S. Geological Survey Open-File Report 95-579, 47 p.

Scott, R.B., Gromme, C.S., Best, M.G., Rosenbaum, J.G., and Hudson, M.R., 1995, Stratigraphic relationships of Tertiary volcanic rocks in central Lincoln County, southeastern Nevada, *in* Scott, R.B., and Swadley, WC, eds., Geologic studies in the Basin and Range-Colorado Plateau transition in southeastern Nevada, southwestern Utah, and northwestern Arizona, 1992: U.S. Geological Survey Bulletin 2056A, p. 7-41.

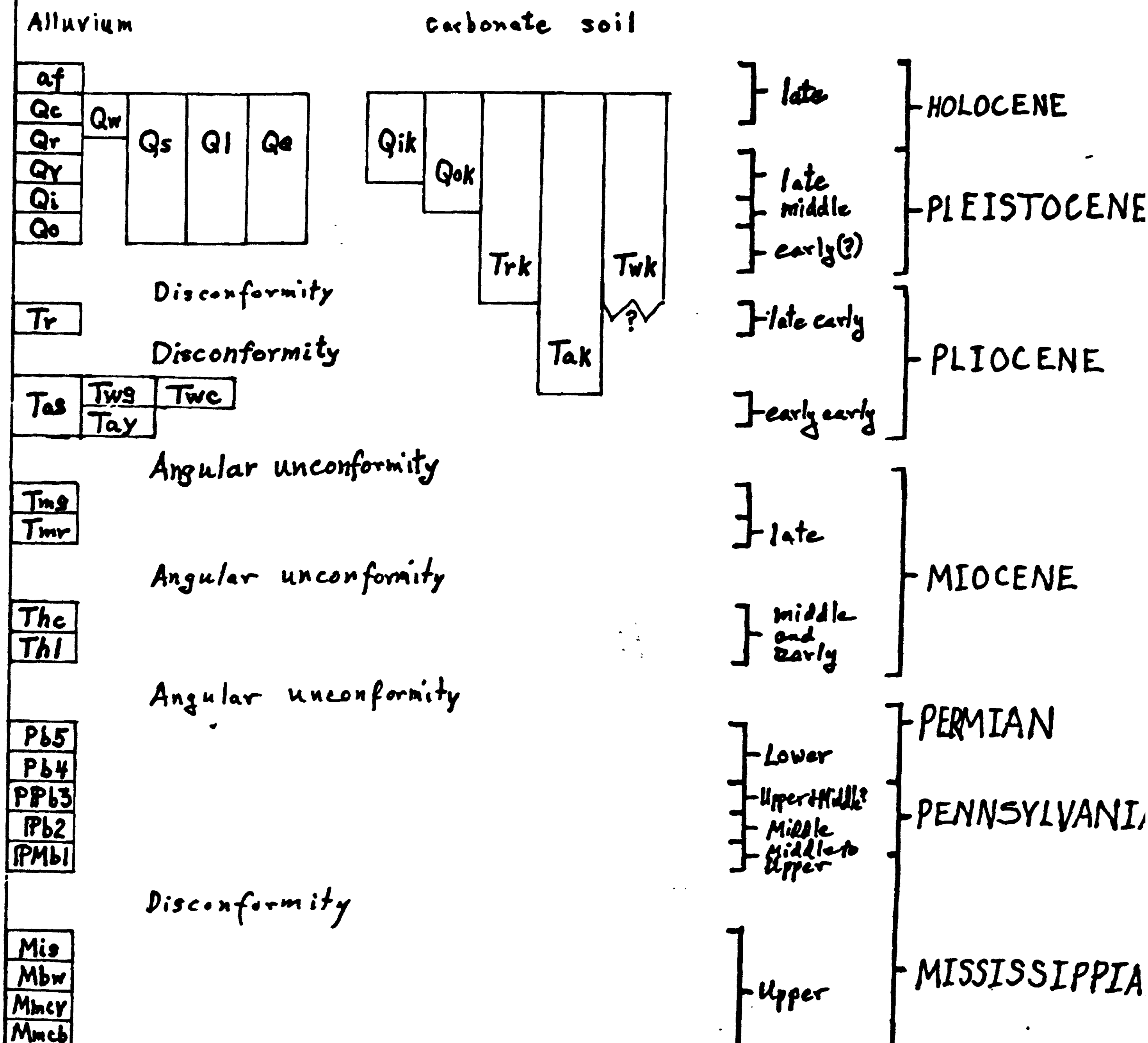
Stevens, C.H., Stone, Paul, and Belasky, Paul, 1991, Paleogeographic and structural significance of an Upper Mississippian facies boundary in southern Nevada and east-central California: Geological Society of America Bulletin, v. 103, p. 876-885.

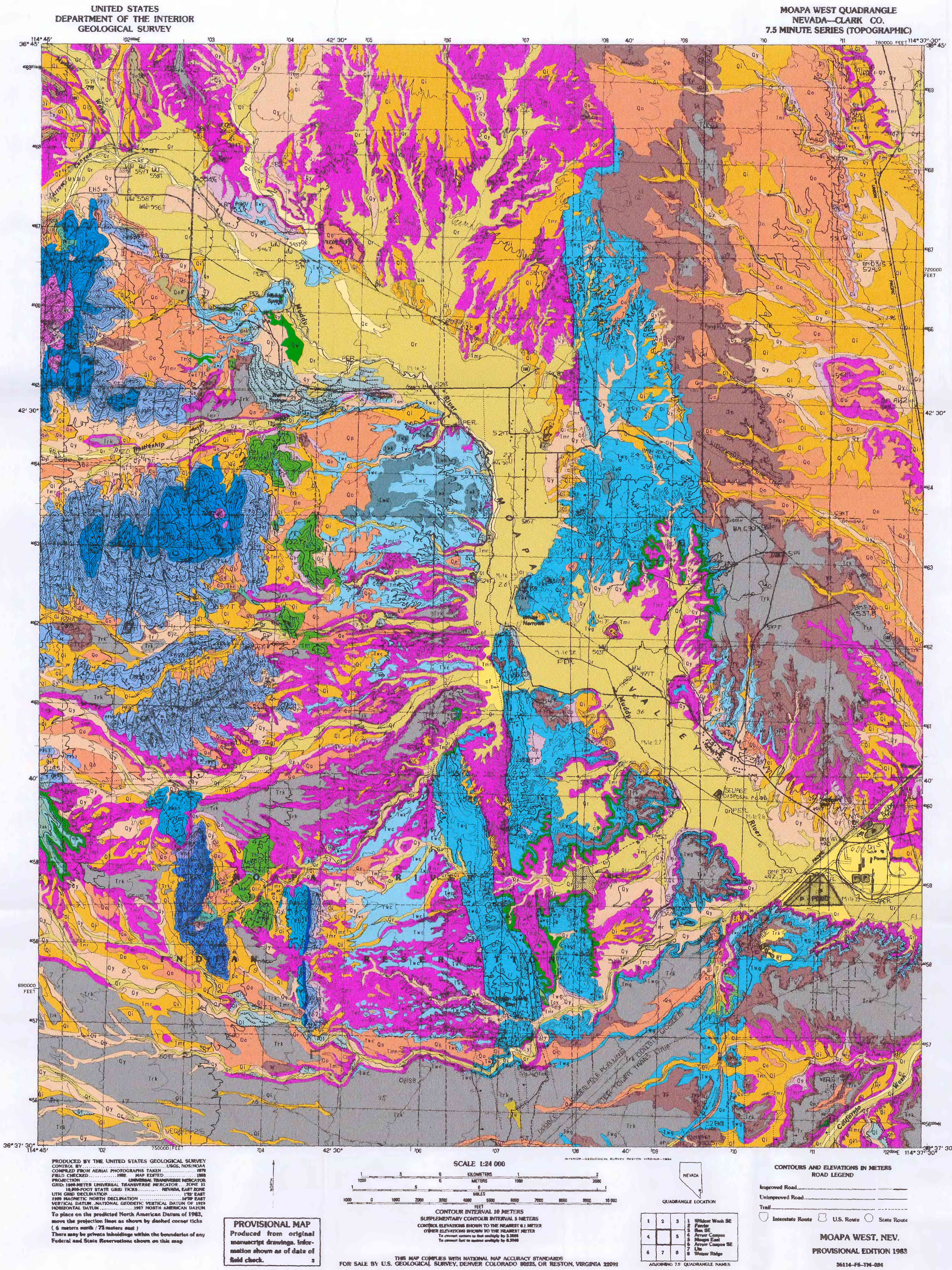
Stock, Chester, 1921, Later Cenozoic mammalian remains from the Meadow Valley region, southeastern Nevada: Geological Society of America Bulletin, v. 32, p. 146-147.

Webster, G.D., 1969, Chester through Derry conodonts and stratigraphy of northern Clark and southern Lincoln Counties, Nevada: Berkeley, University of California Press, University of California Publications in Geological Sciences, v. 79, 121 p.

Moapa West quad.

CORRELATION of MAP UNITS





U.S. DEPARTMENT OF THE INTERIOR
U.S. GEOLOGICAL SURVEY
OPEN-FILE REPORT 96-521

PRELIMINARY GEOLOGIC MAP OF MOAPA WEST QUADRANGLE, NEVADA
1995

by
DWIGHT L. SCHMIDT, WILLIAM R. PAGE
and JEREMIAH B. WORKMAN

Prepared in cooperation with
the SOUTHERN NEVADA WATER AUTHORITY

This report is preliminary and has not been reviewed for conformity with U.S. Geological Survey editorial standards and stratigraphic nomenclature

Map Units

- af
- Qc
- Qw
- Qs
- Ql
- Qe
- Qlk
- Qok
- Trk
- Tak
- Twk
- Qr
- Qy
- Qi
- Qo
- Tr
- Tas
- Tam
- Tay
- Twg
- Twc
- Tg
- Tmg
- Thc
- Tfb
- Thl
- PPb5
- Pb4
- PPb3
- PMb1
- Mis
- Mbw
- Mmcy
- Mmcb