DEPARTMENT OF THE INTERIOR
U.S. GEOLOGICAL SURVEY

PRELIMINARY GEOLOGIC MAP OF THE RIVERSIDE QUADRANGLE, CLARK COUNTY, NEVADA

by

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

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1. Denver, CO
2. Menlo Park, CA

INTRODUCTION

The Riverside quadrangle lies along the east edge of the Basin and Range province in southeastern Nevada. The map area extends from the southwestern part of the Virgin Mountains northward to the edge of Mormon Mesa, and is traversed in its northern part by the narrow, incised valley of the large, perennial Virgin River. Most of the map area lies in the southwestern part of the Mesquite structural basin

The Mesquite basin, about 28 km wide, lies between the Mormon Mountains (maximum altitude 2,260 m) to the northwest and the Virgin Mountains (maximum altitude 2,356 m) to the southeast and east. The Mormon Mountains are composed largely of Paleozoic carbonate rocks and minor Precambrian and Mesozoic rocks, whereas the Virgin Mountains are composed chiefly of Precambrian igneous and metamorphic rocks with lesser areas of Paleozoic carbonate rocks and Mesozoic clastic rocks in approximately equal amounts. Along the west side of the basin, Mormon Mesa, altitude about 560 m, is an erosional remnant of lacustrine and fluvial basin-fill deposits, the flattish top of which is underlain by an ancient, thick, resistant carbonate-rich soil (Gardner, 1972a). The Virgin River flows westward and southward from an altitude of about 550 m where it debouches from its gorge through the Virgin Mountains to about 335 m at its confluence with the Muddy River at the south end of Mormon Mesa. Piedmont plains rise steeply from the river to about 1,000 m altitude against the rugged Virgin and Mormon Mountains. Along the Virgin River at Littlefield, Ariz., near the east edge of the Mesquite basin, the mean annual temperature is 18° C and the mean annual rainfall is 16 cm (U.S. Department of Commerce, 1975).

Identification of the fluvial and other alluvial deposits that post-date the Muddy Creek Formation are based mostly on topographic position, soil development, topographic expression, amount of dissection by washes that head within a deposit (internal dissection) and, to a lesser extent, on lithology and depositional environment. These criteria are described in detail in Hoover and others (1981).

Ages of surficial deposits have not been determined by numerical dating techniques; ages assigned to surficial deposits in this quadrangle are estimated based on similarity of desert varnish development, etching of carbonate clasts, packing of desert pavement, and the stage of soil carbonate development (Gile and others, 1966) to that observed for Quaternary deposits at the Nevada Test Site, about 170 km northwest of the map area, where many numerical ages have been determined (Hoover, 1989).

The Riverside quadrangle lies in a transitional setting between the miogeosynclinal section of Paleozoic and Mesozoic rocks to the west in the southeastern Great Basin Province and the platform sequence of Paleozoic and Mesozoic rocks in the Colorado Plateau Province to the east. The quadrangle is in an area of east-to-west facies changes and westward thickening. The stratigraphic nomenclature established for rocks of the Colorado Plateau Province, chiefly in southern Utah and the Grand Canyon region, differs from that used regionally in the southern Great Basin. For example, more rock units are named and more geologic time is represented in the rock column of the Great Basin. In the Riverside quadrangle, we have incorporated geologic names from both of these provinces, and the nomenclatures have been interchanged. This choice was dictated by our assessment of the local stratigraphy and its similarity to other named sections. Certainly many alternative choices are possible.

The Proterozoic rocks have been mapped and studied by Beal (1965). Where possible, we have tried to conform to his terminology. Parts of the rock descriptions used here are taken from Beal (1965), primarily mineralogical and textural descriptions.

GEOLOGIC HISTORY AND STRUCTURE

The Mesquite basin is a large tectonic basin that was extensionally deformed during late Tertiary time and filled with a thick sequence of basin-fill deposits. The exposed part of the basin fill is the postextensional Muddy Creek Formation, which consists of several hundreds to many hundreds of meters of mostly well bedded, moderately consolidated silt and sand that are probably largely fluvial (Kowallis and Everett, 1986). The Muddy Creek Formation is about 11.5 to 5.5 m.y. old. To the west and southwest of the map area the formation is composed mostly of lacustrine deposits. Muddy Creek lake was abruptly drained when the Colorado River was integrated through the present-day Lake Mead area.

The top of the Muddy Creek Formation and the adjacent piedmont slopes were deeply entrenched by newly established tributary drainages of the Virgin River system after the Muddy Creek lake was drained. The result of the entrenchment was the erosional isolation of large parts of the lake floor and adjacent piedmont slopes. A thick carbonate-rich soil developed during the Pliocene and Quaternary on these flat and gently sloping deposits; the cap rock on Mormon Mesa is a classic example of this ancient carbonate-rich soil.

By the beginning of Quaternary time the Colorado-Virgin River system had entrenched itself to its present depth. All the Quaternary terrace deposits along the perennial Virgin River are the result of cyclical aggradation and degradation caused mostly by climatic fluctuations. The aggradational silt and sand deposits were probably the products of pluvial episodes during the Quaternary (Quade, 1986). The piedmont side streams had base levels controlled by the Virgin River. These side streams deposited inset fan and inset channel gravels in response to climatic fluctuations.

The Quaternary and Tertiary alluvial deposits of the Mesquite area are divided into four catagories according to source of sediment and environment of deposition. For each catagory two to seven generations of deposits have been distinguished by geomorphic and pedogenic criteria.

Mainstream deposits of the Virgin River are predominently sand and gravel and include little silt or clay. The gravel consists of a mixture of subangular Precambrian, Paleozoic, and Mesozoic detritus from the adjacent ranges as well as distinctive well-rounded cobbles of chert and quartzite from the uplands of southwestern Utah. Flights of terraces indicate at least four prior intervals of deposition at levels about 6, 20, 55, and 85 m above the modern channel. The surface at 55 m tops a fill more than 55 m thick (units Qav, Qgv) and records a major period of aggradation during the early middle Pleistocene or early Pleistocene, probably during a major pluvial episode

Alluvium from major tributaries on the north side of the river, such as Toquop Wash, is dominated by rocks eroded from the Mormon Mountains, and includes abundant limestone. Toquop Wash terraces record substantial lateral shifting of the channel and at least five prior intervals of deposition at about 6, 20, 35, 55, and 80 m above the modern channel. Toquop Wash terraces are all graded to corresponding Virgin River terraces except that the 35-m terrace is not preserved along the Virgin River.

Minor tributaries on the north side of the river deposited alluvium derived by erosion of the escarpment of Muddy Creek Formation exposed on the side of Mormon Mesa and by reworking of high terrace deposits of the Virgin River. Such tributaries deposited thin layers of sandy pediment alluvium that includes well-cemented angular boulders eroded from the carbonate-enriched soil on the surface of Mormon Mesa. The deposits cover a bench between the Mormon Mesa escarpment and the inset canyon of the Virgin River, and are graded to resistant ledges of cemented Virgin River terrace gravels 50 to 60 m above the modern Virgin River channel. Only two generations of such deposits have been distinguished.

Tributaries on the south and east side of the Virgin River have deposited coarse alluvium dominated by angular clasts of metamorphic and igneous Proterozoic rocks. These deposits form alluvial fans, thin alluvial mantles on pediment surfaces cut on older alluvium, and stream terraces inset into alluvial fans. At least six prior depositional intervals are recorded. The last five correspond approximately to terrace levels along the Virgin River and Toquop Wash, whereas the oldest depositional interval, represented by alluvium of Bunkerville Ridge (Tab), was probably contemporary with the upper part of the Muddy Creek Formation.

The oldest and most widespread piedmont deposit in the Mesquite area is the alluvium of Bunkerville Ridge (Tab) that underlies about two-thirds of the piedmont slope below the Virgin Mountains in the central part of the area (fig. 4). The alluvium consists of coarse poorly sorted bouldery gravel, sandy gravel, and gravelly sand eroded from the Virgin Mountains during late Tertiary time. The deposit is dissected 20-150 m deep by tributary streams of the Virgin River, and its surface, entirely erosional, has rounded bouldery interfluves. Remnants of a stage IV-V carbonate-rich soil 3-6 m thick underlie these eroded interfluves.

On the lower part of the piedmont slope, remnants of five Pleistocene fan deposits are deeply inset below the ridges of the alluvium of Bunkerville Ridge (Tab) and above the modern depositional surface (Qany). They overlie the easily eroded silt and sand of the Muddy Creek Formation. The fan deposits consist mostly of eroded detritus from the alluvium of Bunkerville Ridge. The oldest of the inset fan deposits (Qof) is preserved only as a few scattered ballenas. None of the original depositional surface is preserved. The next youngest (Qmf) has been reduced to ballenas in the western part of the area but retains a greater proportion of its original depositional surface toward the east (upstream). It is entrenched as much as 55 m and locally contains remnants of a stage IV carbonate-rich soil. The third youngest fan deposit, the alluvium of Nevada Highway 170 (Qah), consists mostly of sandy gravel and has a preserved depositional surface that overlies a stage II-III

carbonate-rich soil capped by a tightly packed cobble and pebble pavement. Modern washes are entrenched 20-40 m below the depositional surface of this deposit. The second youngest deposit, the alluvial fan deposits of Meadowlands Farm (Qam), consists of sandy gravel and has a well-preserved depositional surface that overlies a stage II-III carbonate-rich soil capped by a firm cobble and pebble pavement. Modern washes are entrenched 20-30 m below the depositional surface of this deposit.

Holocene alluvium on the piedmont is restricted to narrow washes entrenched into the alluvium of Bunkerville Ridge (Tab) and Pleistocene alluvial deposits. The older alluvium of Nickel Creek (Qano) of late(?) Pleistocene to early Holocene age forms deposits about 1 m above the younger alluvium of Nickel Creek (Qany). The younger alluvial unit of late Holocene age constitutes the flood plains of the modern piedmont washes.

The narrowness (0.3- to 1-km-wide) of the entrenched valley of the Virgin River demonstrates the dominance of alluviation by the high-gradient, piedmont, side-stream washes over valley-widening lateral erosion by the Virgin River. The Virgin River meanders across the full width of its valley floor, giving it the appearance of an overfit stream. Its channel deposit is the channel sand of the Virgin River (Qsv) that consists of fine to medium sand, silt, and gravel. About 2-4 m above the active river channel are flood-plain deposits of the Virgin River (Qfp) that consist of overbank deposits of sand and subordinate amounts of sandy gravel and gravel.

DESCRIPTION OF MAP UNITS

Qsv **Channel sand of the Virgin River (late Holocene)**--Very pale orange, grayish-orange-pink, and moderate orange-pink mostly fine to medium sand, silt, and small amounts of gravel; unconsolidated, poorly sorted or well sorted, poorly bedded. Gravel is angular to subrounded cobble and pebbles of gneiss, granite, pegmatite, quartzite, limestone and dolomite and well-rounded clasts of brown quartzite and black and green chert. Unit exposed in sand bars of Virgin River channel and as isolated deposits in abandoned channels within floodplain deposits along Virgin River. Surface of unit is characterized by bar-and-swale topography. No soil observed. Informally named for sands deposited along the Virgin River. Thickness more than 2 m

Qfp **Flood plain deposits of the Virgin River (Holocene)**--Very pale orange and grayish-orange-pink sand and small amounts of gravelly sand and gravel; unconsolidated, mostly well sorted, poorly bedded. Unit covers about 60 percent of the floor of the Virgin River valley. Surface of unit is 1-2 m above unit Qsv and is smooth and covered with heavy growth of mesquite where not cultivated. Exposed thickness 2 m

Qany **Younger alluvium of Nickel Creek (late Holocene)**--Very pale orange to yellowish-gray gravel, sandy gravel, and sand; unconsolidated, poorly sorted, poorly bedded. Gravel is angular to subrounded clasts of gneiss, granite, pegmatite, quartzite, limestone, and dolomite. Clasts are mostly cobble and pebble sizes; boulders to 1 m in diameter are locally common. Unit forms channel deposits in active channels incised into older deposits and fan deposits on terraces along the Virgin River. South of Virgin River, deposits are largely gravel and sandy gravel; north of river, deposits (included in unit Qan) are largely sand. Surface of unit is characterized by bar-and-swale topography; no desert varnish on surface clasts. No soil observed. Informally named for deposits along Nickel Creek in central part of quadrangle. Exposed thickness more than 2 m

Qe **Eolian deposits (late Holocene to late Pleistocene)**--Very pale orange and yellowish-gray sand; unconsolidated; well-sorted, no visible bedding. Forms sandsheets and dunes in and at edge of some tributary washes along the north side of the Virgin River. No soil observed. Maximum thickness about 20 m where sandsheets drape over cliffs north of Virgin River

Qtv **Sandy terrace deposits of the Virgin River (early Holocene to late Pleistocene(?))**--Very pale orange and grayish-orange-pink sand and small amounts of gravelly sand and gravel; unconsolidated, mostly well sorted, poorly bedded. Alluvium in this unit contains less gravel than in older terrace deposits (units Qyv, Qgv, and Qov) but is similar to the alluvium on the modern floodplain (unit Qfp). At the mouth of Toquop wash, this unit includes sediment from Toquop wash interfingering with that from the upper Virgin River. Unit is preserved in small, isolated terraces along Virgin River that are about 6 m above the channel (unit Qsv) and commonly covered with a thin sheet of eolian sand (unit Qe). Stage I carbonate soil is 0.3 m thick. Exposed thickness more than 6 m

Qano **Older alluvium of Nickel Creek (early Holocene to late Pleistocene(?))**--Very pale orange, grayish-orange-pink, and yellowish-gray sandy gravel, gravelly sand, gravel, and sand; unconsolidated, poorly to moderately sorted, poor to moderately well bedded. Gravel is angular to subrounded gneiss, granite, pegmatite, quartzite, limestone, and dolomite. Clasts are mostly less than 1 m in diameter; locally boulders to 2 m in diameter. Surface clasts mostly lack desert varnish, but some quartzite and fine-grained igneous and metamorphic clasts have dark brown varnish that was probably inherited from older deposits; light brown stains on some quartzite clasts may be post-deposition or inherited. Soil consists of stage I carbonate-enriched horizon with a maximum thickness of 0.5 m; local lenses of gravel may have patchy rinds of carbonate less than 3 mm thick on bottom of clasts; no B or A horizons observed. Unit forms relatively smooth terraces that may have local, isolated boulders or boulder patches protruding above terrace. Grass and creosote bush prominent on terraces. Forms terrace 0.3 to 1 m above unit Qany along Nickel Creek, terraces and fan deposits along other washes, and debris-flow or bouldery sieve-deposits below mouths of some major washes that originate in the older surficial unit. Informally named for deposits along Nickel Creek. Exposed thickness about 3 m

Qan **Alluvium of Nickel Creek undivided**--Combined map unit where deposits of unit Qany are so closely interspersed with deposits of unit Qano that the two units cannot be mapped separately. Unit Qan is present as braided channel deposits in washes and as fan deposits below the mouth of washes that drain mostly older surficial deposits and the Muddy Creek Formation

Qs **Slump blocks (Holocene to early middle Pleistocene(?))**--Blocks of moderately consolidated gravels from units QTab or Qot and underlying sand slumped from steep scarps that have been undermined by erosion of the softer underlying unit. Some of the blocks have long been inactive as indicated by lack of disruption of unit Qah surrounding the slump blocks, and others have formed recently. Slump block thickness ranges from 5 to 15 m

Qyv **Young terrace alluvium of Virgin River (late Pleistocene)**--Pale red, pale reddish-brown and light brown gravel and sandy gravel; poorly sorted, poorly to well bedded; uncemented to well cemented by calcium carbonate. Gravel clasts are angular to subrounded gneiss, granite, pegmatite, quartzite, limestone, and dolomite mixed with lesser amounts of well rounded light brown quartzite (Cambrian Prospect Mountain(?)), and black and grayish-green chert; most clasts less than 0.3 m; maximum clast size is 1 m. Stage II carbonate-enriched soil horizon about 1 m thick, no A or B horizon observed, but the terrace surface is commonly covered with eolian sand. Forms a narrow terrace about 20 m above the channel of the Virgin River that widens to 700 m wide just west of the map area. Probably correlative with the Lost City terrace alluvium deposited by Muddy Creek in the Moapa Valley, about 30 km to the west (Gardner, 1972). Maximum exposed thickness 20 m

Qyt **Young terrace alluvium of Toquop Wash (late Pleistocene)**--Gravel and sandy gravel similar to that in unit Qyv except that the clasts are primarily from the Mormon Mountains and lack the gneiss, granite, pegmatite and chert common in Virgin River gravel. Soil consists of stage II carbonate-enriched horizon 0.5-1.0 m thick, no B or A horizons observed; surface mostly covered by eolian sand less than 0.3 m thick. Forms terrace at mouth of Toquop Wash in sec. 5, T. 14 S., R. 70 E, at the north central edge of the map. Depositional surface 20 m above present stream level. Informally named for deposits at the mouth of Toquop Wash. Maximum exposed thickness 20 m

Qam **Fan and pediment alluvium of Meadowlands Farm (late Pleistocene)**-- orange pink, grayish-orange-pink, and yellowish-gray gravel, sandy gravel and small amounts of sand; poorly consolidated, poorly sorted, poorly to moderately well bedded. Gravel clasts are angular to subrounded gneiss, granite, pegmatite, quartzite, limestone, and dolomite; clasts mostly less than .5 m in diameter; isolated boulders may be as much as 1 m in diameter. Soil consists of stage III carbonate-enriched horizon 0.8-1.3 m thick; no B horizon observed; Av horizon is 10-25 cm thick. Fan surfaces have moderately packed pavement; pale-brown to grayish-brown, dull to shiny, continuous to patchy varnish films are as thick as .25 mm on quartzite, gneiss, and pegmatite clasts; carbonate clasts in pavement etched to depth of 1 cm or less. Fan surfaces relatively intact and flat, but dissected by steep-sided washes that head above unit; washes that head within unit extend only 1-2 km away from the Virgin River. Creosote bush prevalent. Unit present as terrace remnants 5 to 30 m above major washes and fan surfaces at lower elevations. Graded to upper surface of young Virgin River terrace alluvium (unit Qyv). Interbedded with thin beds of grayish-orange-pink to moderate orange-pink, poorly bedded fluvial sands of ancestral Virgin River in sec. 13 and 23, T. 14 S., R. 69 E. Unit is informally named for good exposures along Gold Butte Road at Meadowland horse farm in sec. 24, T. 14 S., R. 69 E, just south of the point where the Virgin River crosses the western map boundary. Maximum thickness about 20 m.

Qsy **Young sandy pediment and fan alluvium (late Pleistocene)**--Moderate orange-pink to grayish-orange-pink and yellowish-gray sand from the Muddy Creek Formation (unit Tmc) and pebble to boulder-sized clasts from the massive carbonate-enriched soil horizon capping Mormon Mesa. Poorly to moderately consolidated, poorly sorted, poorly to moderately well bedded. Soil consists of stage II carbonate-enriched horizon; 0.5-1.0 m thick, no B or A horizons observed; partly covered by patches of eolian sand (unit Qe) less than 0.3 m thick; unit may include some eolian sand. Fan surfaces rounded 0-10 m from edge of dissecting washes; depositional surface flat and well preserved. Deposited on pediments cut on the weakly consolidated Muddy Creek Formation across the bench between the Mormon Mesa escarpment and the high terraces of the Virgin River. Creosote bush prevalent; yucca sparse. Maximum thickness about 10 m

Qc **Colluvium (early late Pleistocene(?) to middle Pleistocene)**--Moderately consolidated to consolidated, nonbedded debris that consists of talus; angular to subangular pebble- to boulder-sized clasts and minor amounts of sand derived from bedrock and unit Tab. Carbonate-enriched horizon and varnish similar to those of unit Qah; slightly to extensively dissected. Occurs on most steep slopes on unit Tab, but mapped only where extensive or where unit covers contacts of older deposits. Commonly covers unit Tmc below the contact with overlying unit Tab. Maximum thickness probably less than 5 m

Qymt **Younger middle terrace alluvium of Toquop Wash (early middle Pleistocene)**--Gravel and sandy gravel of Mormon Mountain lithologies similar to that in unit Qyt. Moderately to strongly cemented by calcium carbonate. Soil consists of stage III carbonate-enriched horizon 1-2 m thick, no B or A horizons observed. Preserved as discontinuous remnants about 35 m above the Virgin River channel along a former course of Toquop Creek 2 km west of its present course. Surface has a moderately well-packed pavement. Predominently a thin layer of alluvium covering a terrace cut in an older alluvial fill. Maximum exposed thickness 15 m

Qah **Alluvium of Nevada Highway 170 (early middle Pleistocene)**--Pale yellowish-brown, pale-red, and light brownish-gray gravel, sandy gravel and small amounts of sand; poorly to moderately consolidated, poorly sorted, poorly to moderately well bedded. Gravel clasts are angular to subrounded gneiss, granite, pegmatite, quartzite, limestone, and dolomite; clasts are mostly less than 1 m in diameter; boulders 1.5-2 m in diameter scattered throughout unit at higher elevations. Soil consists of stage II to III carbonate-enriched horizon 0.5-1.0 m thick; no B horizon observed; maximum Av horizon thickness is 20 cm. Fan surfaces have moderately to tightly packed pavement; grayish-brown to brownish-black, dull to shiny varnish films as much as .25 mm thick on quartzite, gneiss, and pegmatite clasts; carbonate clasts in pavement etched to depths as much as 2 cm; isolated boulders 1-2 m in diameter protrude through pavement. Fan surfaces rounded as far as 10-30 m from edges of dissecting washes; washes that head above unit have steep sides below rounded surface; moderate internal dissection throughout map area. Creosote bush prevalent; sparse Joshua trees and yucca plants. Unit forms dissected and rounded terraces along major washes and fan deposits that locally surround small hills of unit Tab. Interbedded with thin beds of moderate orange-pink and light brown, poorly bedded fluvial sands of Virgin River for about 1 km south of Virgin River. Informally named for good exposures in roadcuts along Nevada Highway 170 between Riverside and Bunkerville, Nevada, just south of the Virgin River. Maximum thickness more than 35 m

Qsh **Older sandy pediment and fan alluvium (middle Pleistocene)**--Moderate orange-pink to grayish-orange-pink and yellowish-gray sand from the Muddy Creek Formation (unit Tmc) and pebble to boulder-sized clasts from the massive carbonate-enriched soil horizon capping Mormon Mesa. Poorly to moderately consolidated, poorly sorted, poorly bedded. Soil consists of stage III carbonate-enriched horizon; 0.5-1.5 m thick, no B or A horizons observed; locally covered by sheets of eolian sand (unit Qe); unit may include some eolian sand. Surfaces rounded 15-30 m from edge of dissecting washes; moderate internal dissection throughout map area. Remnants of alluvium deposited on pediments cut on the weakly consolidated Muddy Creek Formation (unit Tmc) and sandy Virgin River terrace alluvium (unit Qav) across the bench between the cemented gravel of the high terraces of the Virgin River and the Mormon Mesa escarpment just north of the map area. Downcutting by streams and retreat of the Mormon Mesa escarpment has deprived these surfaces of their sediment and water supply so they are generally inactive and are gradually being destroyed by the expansion of younger, pediment surfaces about 10 m lower (unit Qsy). Probably correlative to the Overton pediment alluvium in the Moapa Valley (Gardner, 1972). Creosote bush prevalent; yucca sparse. Maximum thickness about 20 m

Qav **Sandy terrace alluvium of Virgin River (early middle Pleistocene (?) to early Pleistocene (?))**--Very dark red, grayish-red and grayish-blue-green, discontinuous sand, silt, and clay; unconsolidated to slightly consolidated, moderately to well sorted, moderately well to well bedded. Probably overbank deposits. Soil consists of stage III-IV carbonate-enriched horizon 1-2 m thick that is probably eroded. Best exposed in SW sec. 1 and NW sec. 12, T. 14 S., R. 69 E. with basal elevations of 450 to 510 m. Informally named for deposits north of the Virgin River that interfinger with unit Qgv and underlie unit Qsh. This unit in combination with the channel gravel facies (unit Qgv) record a major filling event when the Virgin River aggraded more than 75 m and overtopped its canyon walls to spread out across a broad floodplain. This fill is probably correlative to the Overton terrace alluvium in the Moapa Valley (Gardner, 1972). Maximum thickness 30 m

Qgv **Middle terrace gravels of ancestral Virgin River (early middle Pleistocene (?) to early Pleistocene (?))**--Pale red, pale reddish-brown and light brown gravel and sandy gravel; slightly to very strongly cemented by calcium carbonate; poorly sorted; poorly to well bedded. Individual beds exceed 8 m thick. Gravel clasts are angular to subrounded gneiss, granite, pegmatite, quartzite, limestone, and dolomite mixed with lesser amounts of well rounded light brown quartzite (Cambrian Prospect Mountain(?)), and black and grayish-green chert; most clasts less than 0.3 m; maximum clast size is 1 m. No soil observed. Forms cliffs along north side of Virgin River and tributary canyons in sec. 11 and 12, T. 14 S., R. 69 E.. Basal elevations increase from 430 to 480 m away from the axis of the ancestral valley. Informally named for deposits north of the Virgin River that interfinger with unit Qav. Narrow, discontinuous terraces at a level about 35 m above the present Virgin River channel were cut on this deposit during erosion of the alluvial fill. These probably correspond to the period of deposition of unit Qymt, but there are no mappable deposits preserved on the cut terraces. Maximum thickness 50 m

Qmt **Middle terrace alluvium of Toquop Wash (early middle Pleistocene)**--Gravel and sandy gravel of Mormon Mountain lithologies similar to that in unit Qyt. Moderately to strongly cemented by calcium carbonate. Soil consists of stage III-IV carbonate-enriched horizon 1-2 m thick, no B or A horizons observed. Preserved as discontinuous remnants about 55 m above the Virgin River channel along a former course of Toquop Creek 2 km west of its present course. Surface has a well-packed pavement. Maximum exposed thickness 20 m

Qmf **Middle mountain fan alluvium (early middle Pleistocene)**--Pale yellowish-brown, pale-red, and light brownish-gray gravel and sandy gravel; moderately consolidated, poorly sorted, poorly to moderately well bedded. Gravel clasts are angular to subrounded gneiss, granite, pegmatite, quartzite, limestone, and dolomite; clasts are mostly less than 1 m in diameter; boulders 1.0-1.5 m in diameter scattered throughout unit at higher elevations. Soil consists of stage IV carbonate-enriched horizon about 25 cm thick over about 85 cm of mixed stage III and stage II carbonate-enriched horizon; no A or B horizons observed. This soil is largely developed in a colluvial mantle 1-2 m thick that covers the rounded radial ridges (ballenas as defined by Peterson, 1981), characteristic of this unit. This surface of this unit is distinctly more rounded than units Qah and Qaj. The amount of original depositional surface remaining decreases westward across the map area. Washes that head above unit have steep sides below rounded surfaces. Fan surfaces have moderately to tightly packed pavement; grayish-brown to brownish-black, dull to shiny varnish films as much as .25 mm thick on quartzite, gneiss, and pegmatite clasts; carbonate clasts in pavement etched to depths as much as 2 cm. Creosote bush prevalent; sparse Joshua trees and yucca plants. Maximum thickness more than 35 m

Qov **Older terrace alluvium of Virgin River (early Pleistocene)**--Pale brown to dark yellowish-brown gravels, sandy gravels and pebbly sand; unconsolidated to weakly consolidated, well sorted, well bedded. Gravel clasts are similar to those of unit Qgv, but clast sizes mostly less than 0.1 m and maximum size less than 0.5 m. Soil consists of stage IV carbonate-enriched horizon 1-2 m thick that was developed in sand has been largely stripped away. Surface is tightly packed pavement of rounded cobbles coated with dark varnish. Exposed only in NW corner of map area in sec. 11, T. 14 S., R. 69 E. with basal elevation of 505 m and deposition surface elevation of 520 m. Extensively preserved 1 km west of the map area. Maximum thickness 20 m

Qot **Old terrace alluvium of Toquop Wash (early Pleistocene)**--Gravel, sandy gravel, and pebbly sand containing rocks from the Mormon Mountains similar to those in unit Qyt. Moderately to strongly cemented by calcium carbonate. Soil consists of stage III-IV carbonate-enriched horizon 1-2 m thick, no B or A horizons observed. Preserved capping a mesa that is 65 m above the Virgin River channel and extends 2.8 km north of the map area along a former course of Toquop Creek 1 km west of its present course. Surface has a well-packed pavement. 35 m of gravel over 15 m of sand.

Qof **Old mountain fan alluvium (early middle Pleistocene)**--Identical to unit Qmf but deposited at a level about 10 m above the depositional surface of unit Qmf. Preserved only in a few isolated remnants near the center of the map area. Maximum thickness more than 35 m

Tab **Alluvium of Bunkerville Ridge (Pliocene)**--Pale brown, pale yellowish-brown, light brownish-gray, and pale red gravel, sandy gravel and gravelly sand. Distal part is clast supported, well consolidated, poorly sorted, well bedded, and maximum clast size of 1 m; proximal part is matrix-supported, well consolidated, poorly sorted, poorly bedded and maximum clast size 8 m; numerous boulders 1-2 m in diameter. Pale red to grayish-orange-pink gravelly sand that contains gravel beds less than 0.5 m thick are present in the lowest part of the unit along the main wash east of Juanita Springs Ranch in sec. 11 and 12, T. 15 S., R. 69 E. and at elevations of 600-650 m east of Nickel Creek. Soil on the depositional surface consists of stage V carbonate-enriched horizon 3-6 m thick that has been stripped away in most places. Generally the unit is eroded into rounded, radial ridges covered with 2-3 m of cemented colluvium bearing thick stage III-IV carbonate-enriched soil horizons; no B horizon observed; sandy and silty Av horizon has maximum thickness of 60 cm. The ridges are separated by deep, well integrated tributary drainages, and relief ranges from 20-60 m within 5-7 km of Virgin Mountains. The level of the ridge tops defines a smooth radial surface that is probably quite close to the original depositional surface of most of the unit. The level of ridge tops near the mountain front in the southeastern part of the map area define another surface that is slightly higher, and the deposits there may be older than the rest of the unit. Top of narrow ridges commonly littered with platy fragments from upper part of carbonate-enriched soil horizon; quartzite, gneiss, and pegmatite clasts on surface irregularly to continuously covered by brownish-black to black, dull to shiny desert varnish as much as 2 mm thick; limestone and dolomite clasts etched to depths of 1.5-3 cm. The base is generally conformable on the top of the Muddy Creek Formation immediately above 1-2 m of conglomerate that resembles modern Virgin River gravel at an elevation of about 580 m. The maximum soil development on this unit is comperable to that on Mormon Mesa, and suggests that deposition ended when the depositional environment changed from closed basin to open basin. Joshua trees, yucca, and creosote bush prevalent on tops of ballenas. Informally named for good exposures in the southern part of the map area north of Bunkerville Ridge along drainages that originate in the Virgin Mountains. Exposed thickness at distal margin 75 m

Muddy Creek Formation (Miocene and lower Pliocene (?))

Tmc **Sandstone, claystone, siltstone, and minor conglomerate**--Moderate orange-pink, moderate reddish-orange, light red, and light brown fine- to medium-grained sandstones and small amounts of siltstone and claystone; partly consolidated, poorly to well bedded; sandstone moderately to well sorted; cross bedding and ripple marks common; individual beds generally die out within 50-200 m, but bed sets may be continuous for 200-500 m or more; cemented by calcite, clay, or gypsum. A few sandstone beds contain insect burrows and root casts and bear the imprint of bird and animal tracks. Fossil remains of *Megatylopus* (camels), *Hemiauchenia* (lamas), *Aelurodon* (dogs), *Indarctos* (bear), *Equinae* (horses), and *Texoceros* (pronghorns) found in the formation on the south side of the Virgin River immediately west of the map area indicate a medial Hemphillian (Upper Miocene) age (R.H. Tedford, American Museum of Natural History, unpublished data, 1978). Siltstones, claystones, and white tuffaceous sandstones and tuffs appear to be more common within 1-1.5 km of Virgin River at elevations of 430-450 m. Contains thin (less than 0.3 m) bed of very light gray, slightly reworked air-fall tuff of very limited extent at 465 m elevation near the southwest corner of sec 1, T. 14 S., R. 69 E.. The ash bed is about 160 m below the top of the Muddy Creek formation at the edge of Mormon Mesa, about 2 km to the west. The ash bed is just below an indistinct contact with overlying unit Qva, and there is a slight possibility that it may lie within unit Qva. Upper 5-10 m of unit Tmc beneath unit Tab contains three marker beds: a lower sandstone, 1-1.5 m thick, that contains rip-up or slump clasts of grayish-green to grayish-blue-green claystone that have a maximum thickness of 0.5 m; a grayish-green to grayish-blue-green massive mudstone 0.5-2 m thick; and at the top, a conglomerate 0.3-2 m thick that contains pebbles and cobbles of well-rounded brown quartzite (Cambrian Prospect Mountain (?)) and black and grayish-green chert and lesser amounts of subangular to subrounded gneiss, granite, gray quartzite, pegmatite, limestone, and dolomite; the three marker beds may or may not be separated and overlain by typical sandstones of the unit and each bed may or may not be present at any location. The lithology of the conglomerate clasts indicate that the conglomerate was deposited by an ancestral Virgin River that was integrated to distant headwaters in Utah and probably is much younger than the the underlying, fine grained part of the Muddy Creek Formation. It probably correlates to the tan quartzite-granite clast gravel (Gardner, 1968, p.55) that is 30 m thick immediately beneath the surface of the southern tip of Mormon Mesa, where it contains horse and puma teeth of Blancan (Pliocene) age (Longwell and others, 1965, McKenna, M.C., 1957, written communication). Outcrops of unit Tmc in northwest part of map are continuous with Muddy Creek Formation of Longwell (1928, 1936, and Longwell and others, 1965). Maximum exposed thickness is about 170 m

Tmca **Altered claystone and sandstone**--Claystone and sandstone of Muddy Creek Formation altered around springs at Juanita Springs Ranch; white, very light gray, and grayish pink; silica and calcium carbonate deposited in pores and fractures

Kaibab Formation (Lower Permian)--Member subdivision follows (Sorauf, 1962)

Pkh **Harrisburg Member**--Marine and nonmarine limestone, gypsum, and siltstone; recessive and forms slopes that are generally covered with light colored talus. Bedding is irregular, discontinuous, uneven, and wavy. Gray to white gray limestone occurs in moderately resistant beds and poorly bedded units that commonly contain abundant chert pods; limestone breccia is common; probably caused by dissolution of gypsum. About 30 m thick

Pkfm **Fossil Mountain Member**--Cherty limestone; fossiliferous, marine, very resistant and forms high ridges located near east edge of quadrangle. Limestone is medium gray and chert is brown to translucent gray. Chert is abundant and occurs in nodules, beds, and elongated masses; chert commonly defines bedding which is parallel, broadly discontinuous, and uneven; bedding thickness is uniform at 10-25 cm. Fossils include abundant corals and marine mollusks. 100-150 m thick

Toroweap Formation (Lower Permian)--Member subdivision follows (Sorauf, 1962).

Ptwr **Woods Ranch Member**--Limestone, dolomite, gypsum, siltstone, and sandstone; white, gray, light gray, and pinkish. Recessive unit between cliff-forming limestone units of Fossil Mountain Member of Kaibab (Pkfm) and Brady Canyon Member of Toroweap (Ptbc). Bedding is irregular, discontinuous, wavy, and uneven. Member is commonly covered by light colored talus. 30-60 m thick

Ptbc **Brady Canyon Member**--Limestone, and chert; limestone is medium gray, chert is brown and light gray; very resistant, forms prominent cliffs and ridges near east edge of quadrangle. Parallel, discontinuous, and even bedding defined by elongate chert bodies; beds are several centimeters to tens of centimeters thick. Chert is abundant, but less so than in the Fossil Mountain Member of the Kaibab (Pkfm); individual chert masses about 0.3 m long on average. Fossiliferous, contains marine mollusks. 90-140 m thick

Pts **Seligman Member**--Limestone, dolomite, gypsum, siltstone, and minor amounts of sandstone; white, light gray, or pale red; marine and nonmarine. Recessive and commonly forms covered slopes below ridges of Brady Canyon Member (Ptbc). Bedding character is like that in Woods Ranch Member (Ptwr). About 45 m thick

Pe **Esplanade Sandstone (Lower Permian)**--Use of term Esplanade Sandstone for these rocks follows that of McKee (1975, 1982). Sandstone; red, light buff, and white; nonmarine. Moderately resistant, but poorly exposed in quadrangle. Bedding is wavy, discontinuous, nonparallel, and uneven; beds range from 0.5 to 2 m thick. Internal, low-angle trough and planar cross-stratification common. Sand grains are fine to very fine grained, grain supported, well rounded, well sorted and composed of quartz; little or no matrix is present; moderately friable to well indurated. 600? m thick

PPb **Bird Spring Formation (Lower Permian and Pennsylvanian)**--Limestone, cherty limestone, arenaceous limestone and calcareous sandstone. Limestone is gray, light gray, and white; arenaceous limestone, is same color when fresh but weathers brown and yellow-brown; cherty limestone is brown. Sandstone is light yellow gray and weathers brown, commonly forms conspicuous ledges. Bedding is parallel, even, and continuous with cross bedding common in sandstone; beds 0.5 to 1 m thick and alternately resistant and moderately resistant, causing stair step erosional form throughout unit. Marine and highly fossiliferous. Basal 10 m of formation is slope-forming silty limestone and reddish-weathering siltstone. As mapped, upper part probably includes rocks that are mapped elsewhere in region as Pakoon Formation, and lower part includes rocks called the Callville Limestone (Hintze, 1986). The Callville Limestone and Pakoon Formation are difficult to differentiate on consistent basis throughout mapped area. The Pakoon Formation is commonly dolomite and weathers white, in contrast with gray of underlying Callville Limestone, but not at all localities. 360 to 400 m thick

Mn **Monte Cristo Limestone (Upper and Lower Mississippian)**--Limestone; medium gray; some brown cherty zones. Lithologically, and in part temporarily, equivalent to the Redwall Limestone of the Colorado Plateau Province. Consists of five marine members described by Hewett (1931) in Goodsprings mining district of Spring Mountains. From youngest to oldest, these are the Yellowpine Member (lithologically equivalent to the Horseshoe Mesa Member of Redwall Limestone; McKee, 1974); resistant, cliff-forming, medium-grained, bioclastic, brownish-gray limestone that weathers to medium gray; minor amounts of brownish chert are present; bedding is indistinct. Arrowhead Member; nonresistant, dark-gray, aphanitic limestone that weathers yellowish brown; forms niche in cliff. Beds are parallel, wavy even, and about 10 to 20 cm thick. Total thickness of member is about 10 m. Bullion Member (lithologically equivalent to the Mooney Falls Member of Redwall Limestone; McKee, 1974); resistant, medium-gray, medium- to coarse-grained, bioclastic limestone that forms cliffs; indistinct bedding. Anchor Member (lithologically equivalent to the Thunder Springs Member of Redwall Limestone; McKee, 1974); resistant, medium-gray, bioclastic, medium- to coarse-grained limestone and brownish chert that form cliffs. Chert found in elongate masses and stringers that define irregular, discontinuous, parallel beds about 10 to 20 cm thick; amount of chert varies from 20 to 50 percent of member. Dawn Member (lithologically equivalent to the Whitmore Wash Member of Redwall Limestone; McKee, 1974); resistant, medium-gray, coarse-grained to very coarse-grained, crystalline and bioclastic limestone that weathers light gray and forms cliffs. Bedding is indistinct. The Monte Cristo Limestone forms single uniform cliff that generally appears unbedded from distance except where chert bands of the Anchor Member are present and where niche of the Arrowhead Member appears. About 225 to 350 m thick

Sultan Limestone (Devonian)--Nomenclature and member subdivision follows regionally recognized descriptions by Hewett (1931), except that no lithology resembling the Ironside Member has been recognized locally. Same rock unit as Muddy Peak Limestone of Longwell (1928) mapped in some parts of southwestern Nevada, and equivalent in part to Temple Butte Limestone on Colorado Plateau

Dsc **Crystal Pass Member**--Limestone and dolomite; light gray; weathers light and medium gray; resistant, forms ledges and small cliffs; marine. Medium- to fine-grained crystalline texture. Bedding is moderately well defined; beds are parallel, even, continuous, and 0.4 to 2 m thick. 60 to 100 m thick

Dsv **Valentine Member**--Limestone and dolomite; medium gray; weathers dark to medium gray; resistant, forms ledges and small cliffs, marine. Medium- to fine-grained crystalline texture. Bedding is moderately well defined; beds are parallel, even, continuous, and 0.4 to 2 m thick. 60 to 100 m thick

Gn **Nopah Formation (Upper Cambrian)**--Dolomite and sandy dolomite; light gray; crystalline texture; moderately resistant; forms cliffs and weathers to uniform pale yellowish gray; marine. Bedding is parallel, even, and continuous; beds few centimeters to several meters thick. Base of unit is marked by thin sandy dolomite that erodes to recessive slope, is yellow to brownish gray, and weathers dark or medium brown. This discontinuous basal unit might be Dunderberg Shale Member, but it is not differentiated on map. Distinguished from underlying dolomite by yellow color and slope-forming beds at base. About 60 m thick

Gd **Dolomite (Upper Cambrian)**--Unnamed Dolomite; light gray; weathers to brownish gray; resistant, forms cliffs, marine. Crystalline texture; medium to fine grained. Bedding is parallel, even, and continuous; beds various between 5 cm and 0.5 m thick. 100 to 130 m thick

Gu **Unnamed Dolomite and Mauve Limestone undivided (Upper and Middle Cambrian)**--Mapped undivided only on cross sections where the units do not extend to the surface.

Muav Limestone (Middle Cambrian)--Subdivision of Muav follows McKee (1974) except for new informally designated unit, the "striped unit," which is not present in Grand Canyon, but has been mapped at top of formation to east in Jacobs Well and Elbow Canyon quadrangles, Arizona by Bohannon, (1991). The Muav Formation is probably lithologically equivalent to part of the Bonanza King Formation west of mapped area, which is Upper and Middle Cambrian

Gmst **Striped unit**--Limestone and dolomite; light-gray to white beds and medium-gray beds are interbedded; moderately resistant to recessive; marine. Limestone and dolomite intergrade laterally and vertically. Light-colored beds are composed of uniform fine- to medium-grained crystalline carbonate minerals with very indistinct fine laminations. Darker beds are composed of fine-grained crystalline carbonate minerals and about 10 percent silt that weathers yellow brown. Small-scale, trough cross-laminations present in darker beds. Bedding is parallel, even, and continuous; interbedding of light and dark layers, each 1 to 3 m thick, present throughout unit. 75 to 100 m thick

Gmh **Havasu Member**--Dolomite and limestone; medium to dark gray; resistant, forms small cliffs and ledges; marine. Limestone and dolomite intergrade laterally and vertically. Bedding is indistinct, parallel, even, and continuous. Consists of fine-grained crystalline carbonate minerals and about 10 to 20 percent yellow-brown-weathering silt. 40 to 50 m thick

Gateway Canyon Member--Subdivided into three informal units

Gmgw **Dolomite**--Recessive light-gray to white, finely laminated dolomite with parallel, continuous, and even beds 20 cm to 1 m thick. 20 m thick

Gmgg **Dolomite and limestone**--Resistant light-gray to brown-gray silty dolomite and limestone that forms ledges and cliffs and contains internal cross-laminations. 10 m thick

Gmgy **Limestone and dolomite**--Light-gray to brown-gray moderately resistant sandy limestone and sandy dolomite that weather to a distinctive orange brown. Fine, parallel to low-angle cross-laminations. 50 m thick

Gmkp **Kanab Canyon and Peach Springs Members, undivided**--Silty limestone and dolomite; brown gray and dark gray; weathers to yellow brown, rust brown, and brown gray; limestone and dolomite intergrade laterally and vertically; resistant, forms cliffs and rugged outcrops; marine. Composed of fine- to medium-grained crystalline carbonate minerals. Bedding is indistinct but parallel, wavy, and continuous on close inspection; beds range from 5 cm to 1 m thick. 75 to 90 m thick

Gmsr **Spencer Canyon, Sanup Plateau, and Rampart Cave Members undivided**--Silty limestone and dolomite; medium to dark gray; weathers to medium gray, yellow gray and brown gray; resistant, forms cliffs and ledges; marine. Composed of fine- to medium-grained carbonate minerals. Bedding is parallel, even, and continuous; beds range from few centimeters to greater than 1 meter; bedding is well defined by interbeds of yellow-brown silty carbonate rocks with medium-gray rocks. 60 to 110 m thick

Gc **Chisholm Shale (Middle Cambrian)**--Shale, quartzite, and limestone; black to dark gray and gray green, marine. Recessive, commonly forms gentle slope that is covered by well-developed soil horizon. Shale is interbedded with minor amounts of yellow-brown quartzite and rare limestone which are relatively resistant and better exposed. Bedding in shale is parallel, even, and continuous; beds range from less than centimeter to about 5 cm thick. 10-15 m thick

Cl **Lyndon Limestone (Middle Cambrian)**--Limestone, marine, dark gray, but is commonly iron stained and weathers to rust colors and orange brown. Resistant, forms low ridges and hogbacks in larger valleys caused by recessive shale above and below. 10 m thick

Cb **Bright Angel Shale (Middle Cambrian)**--Shale, quartzite, limestone, and dolomite; marine, black to dark-gray, but weathers gray and light brown. Shale is interbedded with minor amounts of yellow-brown quartzite and rare limestone. Bedding in lower shale is parallel, even, and continuous; beds range from less than centimeter to about 5 cm thick. Recessive and forms slopes that are commonly covered. 60 to 100 m thick

Ct **Tapeats Sandstone (Middle and Lower Cambrian)**--Sandstone and quartzite; pale red and light brown; weathers to dark red and yellow brown; probably nearshore marine. Resistant, forms steep slopes, cliffs, and knobs. Bedding is parallel, continuous, and even; beds range from 5 to 50 cm thick; most beds have low- to moderate-angle cross-stratification. Sand is well to moderately sorted, fine to medium grained, composed dominantly of quartz, and moderately well rounded. Upper part of formation is yellow brown and lower half of formation is reddish. 65 to 80 m thick

Ym **Mylonite (Middle? Proterozoic)**--Mylonite; strongly laminated, glassy matrix surrounds rounded grains of potassium feldspar. Best developed in granitic gneiss, the only unit in which it is mapped, but mylonitic fabric is present locally in almost all other Proterozoic rock units. Age uncertain, but is younger than granitic gneiss (Xgrgn) and probably amphibolite (Xa)

Ygr **Granite (Middle Proterozoic)**--Biotite-hornblende granite, granite gneiss, and quartz monzonite; epidote, apatite, and opaque minerals are common accessories. Light pinkish gray to brownish gray; predominantly medium grained and rarely coarse grained; holocrystalline in hand specimen, biotite bands present in many outcrops. Forms small pluton in south-central part of quadrangle where it intrudes biotite gneiss (Xgn) and garnet gneiss (Xggn). Assumed to be Middle Proterozoic in age because similar granites are that age in the Gold Butte district 25 km south of quadrangle (Lanphere and Wasserburg, 1963)

Xqm **Quartz Monzonite (Lower Proterozoic)**--Biotite-hornblende quartz monzonite; sphene, apatite, and opaque minerals are common accessories. Light brownish white when fresh, weathers medium yellowish brown; coarse- to medium-grained, slightly to moderately developed foliation caused by alignment of hornblende and biotite. Occurs as dikes that intrude biotite gneiss (Xgn) in southwestern corner of quadrangle

Xggn **Garnet bearing Gneiss (Lower Proterozoic)**--Garnet-biotite gneiss and schist; medium to dark gray with pink banding and splotches; weathers to dark reddish brown. Medium grained; porphyroblastic to crystalloclastic texture; well-developed foliation and incipiently developed compositional layering locally forming bands 1 cm to 10 cm thick. Quartz, biotite, garnet, microcline, and oligoclase occur in order of decreasing abundance. Garnet porphyroclasts are 0.5 mm to 1 cm in diameter, biotite plates are 0.005 mm to 1 mm in diameter, feldspar grains are xenoblastic and 0.5 to 1 mm in diameter, and sillimanite is a rare accessory occurring as minute prismatic crystals. Cut by numerous pegmatites. Occurs beneath Cambrian Tapeats Sandstone (Ct) at many localities

Xgn **Biotite-hornblende Gneiss (Lower Proterozoic)**--Biotite-hornblende gneiss; medium to light gray, weathers dark gray to dark brownish gray. Medium to coarse grained, banded into 2-5 cm compositional layers in many areas; strong foliation elsewhere. Augen-biotite gneiss present locally with coarse pink microcline augens. Quartz, microcline, plagioclase, biotite, and hornblende are ubiquitous; accessories include sericite, apatite, opaque minerals, and sphene. Garnet occurs rarely. Occurs beneath Cambrian Tapeats Sandstone (Ct) at many localities

Xs **Sillimanite bearing Gneiss and Schist (Lower Protozoic)**--Chiefly garnet-biotite-sillimanite-muscovite-quartz gneiss and schist; dark gray. Exposed only in extreme southeast corner of quadrangle

Xa **Amphibolite (Lower Proterozoic)**--Amphibolite and hornblende-plagioclase gneiss; dark gray; medium grained; 0.5-2 cm compositional bands are common and distinguish gneiss from amphibolite. In addition to banding, "salt and pepper" texture is common. Composition varies; in some areas the rock is nearly 100% hornblende; in others hornblende and plagioclase are nearly equal. Present in southeastern part of quadrangle

Xgrgn **Granodioritic Gneiss (Lower Proterozoic)**--Chiefly biotite-hornblende gneiss, includes amphibolite; dark gray, weathers dark brownish gray; medium grained with well developed, alternating light and dark, compositional bands several cm to over 1 m thickness. Commonly contains oligoclase, quartz, microcline, biotite, hornblende and sillimanite. Present in southeast corner of quadrangle

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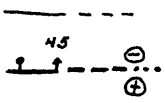


Contact; dashed where approximately located or projected on cross section

Fault; dashed where approximately located; dotted where concealed or projected on cross section; bar and ball on downthrown side; arrow shows direction and amount of dip; + and - show direction of movement into and out of page on cross sections

Strike and dip of inclined beds showing amount of dip

Strike of vertical beds

Strike and dip of overturned beds showing amount of dip

Strike and dip of foliation showing amount of dip

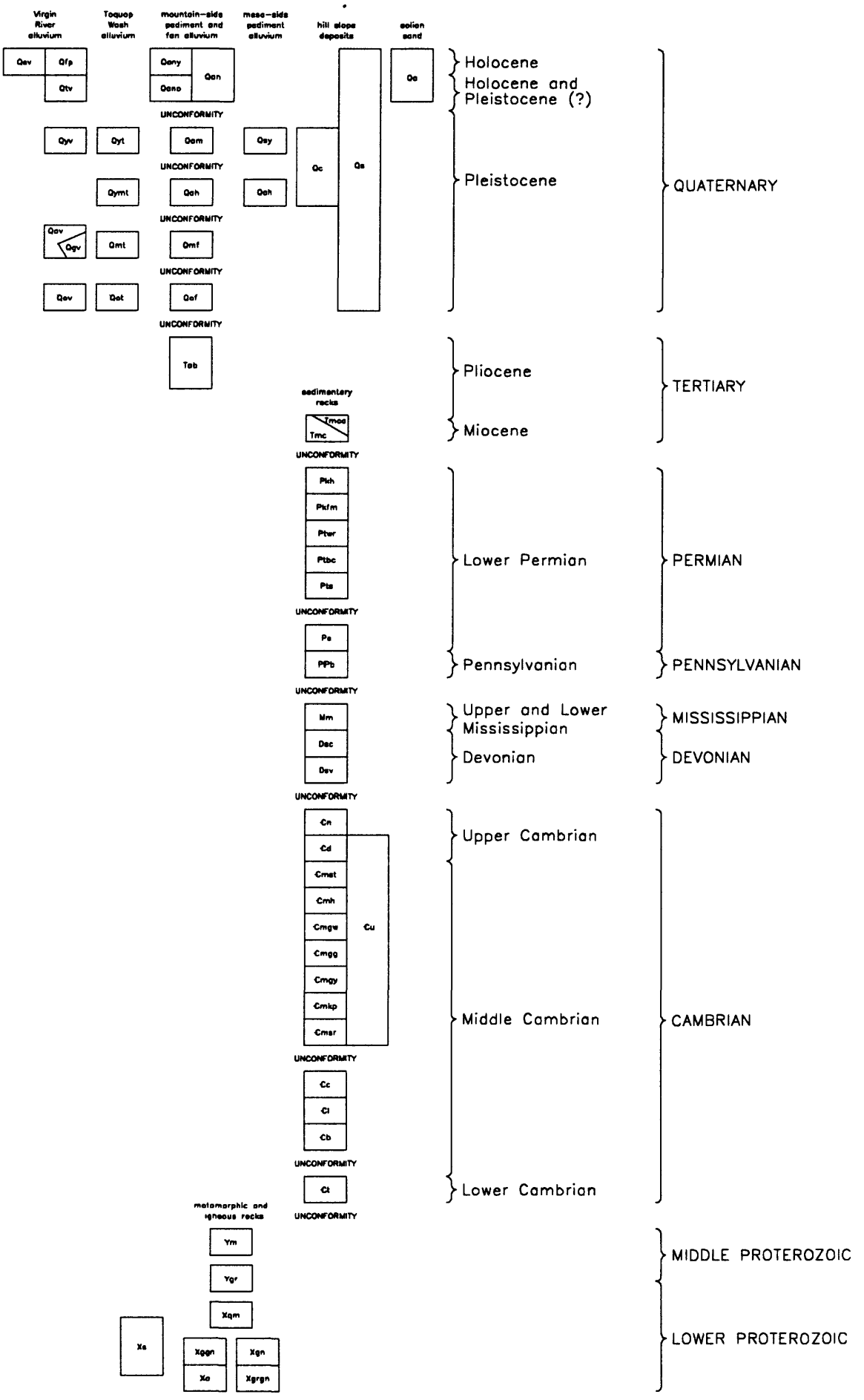
Strike of vertical foliation

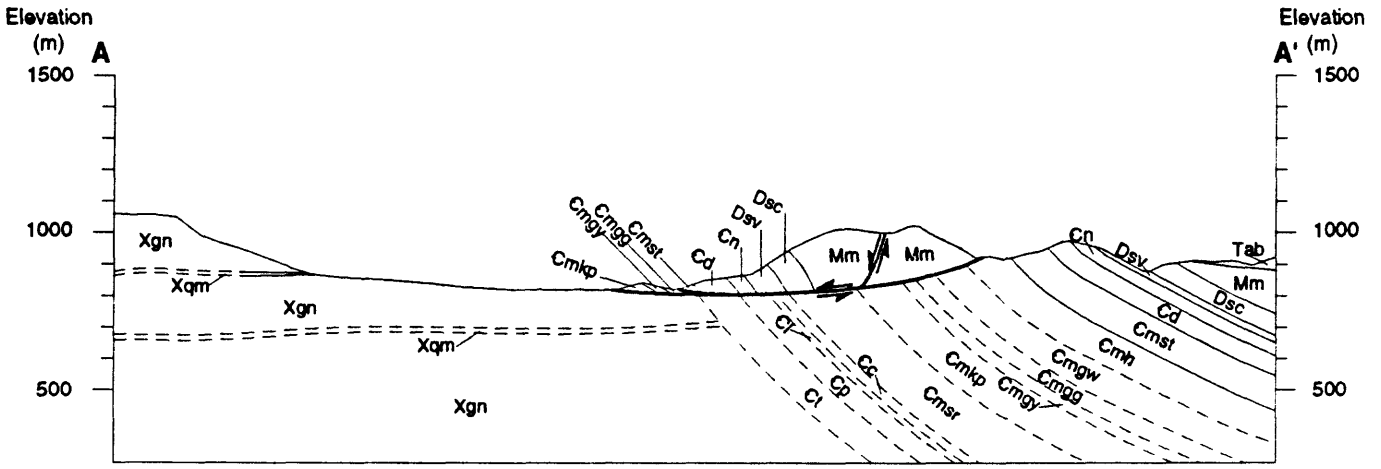
Direction of current movement from cross-bedding showing dip of beds; strike of beds perpendicular to arrow

Direction of current movement from ripple marks; strike of ripple marks perpendicular to arrow

Synclinal axis

CORRELATION OF MAP UNITS

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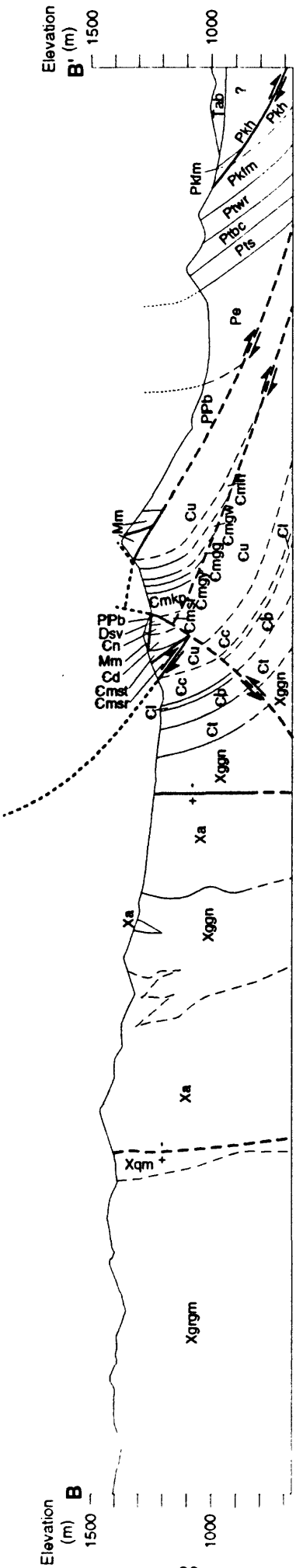
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