U.S. DEPARTMENT OF THE INTERIOR
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PRELIMINARY GEOLOGIC MAP OF THE DEADMAN SPRING QUADRANGLE, LINCOLN COUNTY, NEVADA

By

Robert B. Scott[1], W C Swadley[1], Wanda J. Taylor[2], and Anne E. Harding[1]

[1] U.S. Geological Survey, Denver, CO
[2] Department of Geoscience, University of Nevada, Las Vegas, NV

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

DESCRIPTION OF MAP UNITS

[Ages of surficial units have not been determined by absolute dating techniques; ages are estimates based upon field observations of degree of soil development and local surface dissection. The stage of carbonate morphology reported for soils is a visual estimate using standards defined by Gile and others (1966). Soil horizon terminology follows that of Birkeland (1984). Unit colors are from the Rock-Color Chart (Rock-Color Chart Committee, 1951). Identification of ash-flow tuff units is based where available on ranges of phenocryst abundances from thin section modal analyses of samples in and outside the quadrangle. Isotopic ages are reported with 2 sigma errors. Previous mapping in the area was published at a scale of 1:250,000 (Tschanz and Pampeyan, 1970; Ekren and others, 1977); the geology of the northern part of the quadrangle is based partly on the dissertation map at a scale of 1:24,000 by Taylor (1989). The chemical classification of volcanic units is based on Le Maitre (1989); in cases of a lack of chemical data, adjective forms of rock names are used to reflect estimates of the chemistry based on phenocryst mineralogy; chemical data are from Scott and others (in press) and unpublished data from R.B. Scott]

Qal **Alluvium (late Holocene)**--Grayish-orange to brownish-gray gravelly sand, gravel, and sand; unconsolidated, poorly bedded. Gravelly sand and gravel include angular to subrounded pebbles, cobbles, and boulders of ash-flow tuff, lava, limestone, dolomite, quartzite, and chert. Sand is fine to very coarse, angular, poorly sorted, locally silty. Unit forms channel deposits and low terrace deposits less than a meter high along active washes. Some washes tributary to the White River have deposited steep fans that extend into the valley more than half the width of the valley floor. Where two fans enter from opposite sides, they locally pond short segments of the valley. No soil development observed. Thickness is more than 4 m

Qav **Valley-floor alluvium (late Holocene)**--Sand and silt, very pale orange, unconsolidated, compact; no bedding exposed. Sand is mostly fine with minor amounts of medium and coarse sand, mostly angular. Unit forms the smooth, relatively flat floor of White River Valley; probably deposited largely as slackwater sediments resulting from occasional flooding of valley by tributary washes. Valley floor is locally dissected by shallow brush-filled channels, but valley lacks continuous through-going channels indicating there is only minor, intermittent surface flow along the White River in this segment of the valley. Unit grades laterally into playa deposits (Qp); contact with alluvium (Qal) commonly sharp. Maximum exposed thickness about 1 m

Qp **Playa deposits (late Holocene)**--Fine sand, silt, and clay, yellowish-gray, compact, calcareous; no bedding exposed; dessication cracks common on surface. Unit forms several small playas along the White River Valley where segments of the valley are locally ponded by fans of alluvium (Qal) deposited by tributary streams. As described above, ponding occurs where two tributaries, entering from opposite sides of the valley, deposit fans that extend across the valley floor to join the opposite fan. No soil development observed. Playa deposits are undissected and thickness is unknown

Qe **Eolian deposits (Holocene)**--Yellowish-gray sand, unconsolidated, moderately sorted; mostly medium with minor coarse grains; includes some gravel reworked from adjacent alluvial deposits. Forms one small, irregular dune that overlies terraces along east side of White River Valley and forms several small dunes at the junction of the conglomerate member of the White River formation (Twc) and volcanic bedrock units. Maximum thickness is about 5 m

Qs **Spring(?) deposits (Holocene?)**--White to very light gray, massive, mound-shaped deposits. Consist largely of calcium carbonate that includes minor silt size silicate material. Unit found in two exposures 400 m southeast of Hamilton Spring. Map unit is less than a few meters thick

Qc **Colluvium (Holocene and Pleistocene?)**--Unconsolidated to consolidated talus; angular pebble- to boulder-sized clasts, and minor amounts of silt and sand. Colors are inherited from source rock except where coated with brownish-black desert varnish. Unit is generally nonbedded and locally cemented by secondary carbonate. Unit occurs along base of steep slopes developed on Tertiary volcanic rocks. Unit thickness is generally less than 5 m

Qae **Alluvium (early Holocene and late Pleistocene)**--Pale-grayish-brown to brownish-gray gravelly sand, gravel, and sand; weakly consolidated, poorly bedded, poorly sorted. Gravelly sand and gravel include angular to rounded pebbles, cobbles, and boulders of ash-flow tuff, lava, limestone, dolomite, quartzite, and chert. Sand is fine to very coarse, mostly angular, locally silty. Unit forms terrace deposits along many washes and small inset fans mostly in the eastern part of the quadrangle. Inset fans and terrace deposits commonly stand 1-2 m above active washes. Surface is commonly smooth and undissected. Typical soil development consists of a thin sandy vesicular A horizon, a 0.5-m-thick B horizon that is the same color as the parent material, and a Bk horizon as thick as 0.2 m that has stage I carbonate development. Maximum exposed thickness is about 3 m

Qt_4 **Terrace deposits (early Holocene and late Pleistocene)**--Grayish-brown to yellowish-gray gravel and gravelly sand, moderately to poorly sorted, weakly consolidated, poorly bedded. Gravel includes subangular to rounded pebbles, cobbles, and small boulders of ash-flow tuff, lava, limestone, dolomite, quartzite, and chert. Sand is fine to very coarse, mostly angular. Unit forms small terrace remnants along White River Valley that stand about 2 m above valley-floor alluvium (Qav). Correlates with early Holocene and late Pleistocene alluvium (Qae). No soil development observed. Maximum exposed thickness is 2 m

Qaj **Alluvium of Jumbo Wash (middle Pleistocene)**--Unit named for deposits along and near Jumbo Wash in the Gregerson Basin quadrangle (Scott and others, 1990) about 60 km to the south. Brownish-gray to yellowish-brown gravel and gravelly sand, poorly sorted, moderately consolidated, poorly bedded. Clasts consist of angular to rounded pebbles, cobbles, and boulders as much as 0.6 m in diameter that consist of ash-flow tuff, lava, limestone, dolomite, quartzite, and chert. Unit forms small remnants of inset fans along some of the larger washes. Fan surfaces stand about 2 m above modern washes in the eastern part of map area and as much as 7 m in the western part. A moderately packed stone pavement is locally developed and some surface clasts have a dark-brown desert varnish. Soil development typically includes a silty sand vesicular A horizon, a light-brown cambic B horizon, and a 40- to 50-cm-thick Bk horizon that has stage II carbonate development in the upper part. Thickness 0 to more than 4 m

Qt_3 **Terrace deposits (middle Pleistocene)**--Grayish-brown gravel, poorly to moderately sorted, moderately consolidated, poorly bedded. Consists chiefly of subangular to rounded pebble and cobble gravel with scattered to common boulders as much as a meter in diamater; matrix is poorly sorted sand. Clasts are limestone, dolomite, ash-flow tuff, lava, quartzite, and chert. Unit forms small terrace remnants along White River Valley; remnants stand 4-6 m above valley-floor alluvium (Qav). Deposits commonly capped by a 0.5-m-thick bed of coarse cobbles and small boulders. No soil exposed. Unit correlates with middle Pleistocene alluvium (Qaj). Thickness 0 to more than 6 m

Qaw **Alluvium of Willow Spring (middle Pleistocene)**--Unit named for deposits near Willow Spring in the Delamar 3 SE quadrangle (Swadley and others, 1994) 65 km to the south-southeast. Grayish-brown to yellowish-gray gravel and gravelly sand, poorly sorted, moderately consolidated, poorly bedded. Clasts consist of angular to rounded pebbles, cobbles, and boulders as much as 2 m in diameter that consist of ash-flow tuff, lava, limestone, dolomite, quartzite, and chert. Clasts derived from volcanic rocks are dominant in the eastern part of the map area; clasts of carbonate rocks are dominant in the west. Sand is fine to very coarse, commonly angular, locally silty. Unit forms numerous fan remnants that stand about 2 m above through-flowing washes in the eastern part of the area and as much as 17 m above washes tributary to the White River. Depositional surfaces of fan remnants are largely intact but are moderately dissected by small washes that head within the fan. Areas of fan between the dissecting washes are generally eroded down to the pedogenic carbonate horizon; these surfaces are commonly covered with a sandy gravel lag that includes fragments of pedogenic carbonate. Soil development consists of a locally developed silty sand vesicular A horizon overlying a partly eroded K horizon that is 1-2 m thick and has stage III carbonate development in the upper part. Thickness 0 to more than 26 m

Qt_2 **Terrace deposits (middle Pleistocene)**--Grayish-brown to brownish-gray gravel, poorly sorted, moderately consolidated, poorly bedded. Clasts are subangular to rounded pebbles, cobbles, and boulders of limestone, dolomite, ash flow tuff, lava, quartzite, and chert. Matrix is poorly sorted sand. Unit forms small terrace remnants along White River Valley that stand 13-15 m above valley-floor alluvium (Qav). Observed soil development consists of a poorly preserved stage III K horizon probably less than a meter thick. Unit correlates with middle Pleistocene alluvium (Qaw). Maximum exposed thickness is 15 m

Qt_1 **Terrace deposits (early Pleistocene)**--Grayish-brown gravel, unsorted, moderately consolidated, poorly bedded. Gravel consists of angular to rounded pebbles, cobbles, and boulders as much as 2 m across of ash-flow tuff, lava, limestone, dolomite, quartzite, and chert. Unit occurs as a single terrace remnant along the east side of the White River Valley and stands about 27 m above the valley floor. Many surface boulders have a black desert varnish. No soil observed. Unit correlates with upper part of early Pleistocene and Pliocene? alluvium (QTa). Maximum thickness greater than 27 m

QTa **Alluvium (early Pleistocene and Pliocene?)**--Grayish-brown gravel, poorly sorted, moderately consolidated, poorly bedded. Clasts are angular to rounded pebbles, cobbles, and boulders as much as 1.5 m in diameter that consist of limestone, dolomite, ash-flow tuff, lava, quartzite, and chert. Matrix is poorly sorted sand. Unit forms eroded fan remnants that commonly have little or none of the original fan surface preserved. Remnants are typically deeply dissected with rounded interfluves. Surfaces commonly are littered with gravel lag that includes common boulders and common to abundant fragments of pedogenic carbonate. Adjacent to the White River Valley, unit occurs as thick fan remnants that are deeply inset into the White River Narrows unit; west of the valley, unit forms more extensive fan remnants that overlie a pedimented surface cut on the White River Narrows unit. Soil development consists of partly eroded carbonate horizon about a meter thick that has stage III carbonate in the upper part. The soil commonly conforms to the rounded topography and appears to have developed on an eroded surface. At an exposure 0.6 km southeast of Hamilton Spring, the soil developed in the upper part of unit QTa has a stage IV K horizon more than 2 m thick that is probably significantly older than the typical soil developed on this unit. Thickness more than 30 m

Tpg **Pediment gravel (Pliocene)**--Brownish-gray gravel, poorly sorted, moderately consolidated, poorly bedded. Consists of angular to subrounded pebbles, cobbles, and boulders as much as 2 m in diameter that consist of limestone, dolomite, ash-flow tuff, lava, quartzite, and chert. Unit forms several poorly exposed remnants of a southeast-facing pediment that developed on the White River Narrows unit west of the White River Valley. Soil development consists of a partly eroded stage III K horizon that is poorly exposed locally on ridge crests. Contact with underlying sandstone commonly marked by an accumulation of secondary calcium carbonate in the basal 0.5 m of gravel. Pliocene age inferred from degree of weathering and from field relations with the topographically lower early Pleistocene and Pliocene? alluvium (QTa). Maximum thickness 16 m

White River Narrows unit (Pliocene or older)--Informal map unit consisting of basin-fill sediments deposited in a closed structural basin and now exposed in northwestern Lincoln County and eastern Nye County along the White River Valley northward from the White River Narrows. Unit originally named the White River Narrows Formation by DiGuiseppi and Bartley (1991) who assigned an early to middle Pleistocene age; because DiGuiseppi and Bartley did not provide a type section of the unit, this name cannot be formalized. Age is changed herein to Pliocene or older based on an interpretation of the geomorphic history and ages of overlying surficial deposits (see Stratigraphy discussion below). Unit divided into two informal members

Twc **Conglomerate member**--Conglomerate, conglomeratic sandstone, and sandstone, yellowish-gray to grayish-yellow, poorly sorted, moderately to poorly bedded, moderately to well cemented. Gravel clasts are angular to subrounded pebbles, cobbles, and boulders as much as 3 m across; limestone and dolomite clasts are dominant overall, locally ash-flow tuff and lava clasts are abundant, quartzite and chert are minor but more common west of the White River. Beds generally range from 0.3 to 2 m in thickness, scouring into underlying beds is common. Sandstone is angular, fine to very coarse grained, silty. Member includes a local exposure of a light-gray fine-grained ash bed 0.6 m thick (shown by outcrop symbol A). Ash is hard, well lithified, and weakly calcareous; upper 30 cm and basal 5 cm very sandy. Ash bed is interbedded with conglomerate and conglomeratic sandstone in cliff exposure in the White River Valley, 0.4 km southeast of benchmark 4730. Member is deeply dissected and generally poorly exposed; slopes are commonly covered with bouldery colluvium (not mapped separately). Locally well exposed in cliffs along east side of White River Valley in west-central part of quadrangle. Member grades laterally and downward into sandstone member (Tws). Contact with underlying sandstone member is generally poorly exposed and is approximately located; mapped at base of dominantly conglomeratic section. Contact with underlying Tertiary sedimentary and volcanic units and Paleozoic formations is an angular unconformity. Thickness more than 80 m

Tws **Sandstone member**--Sandstone with interbeds of conglomeratic sandstone and conglomerate. Sandstone is very pale orange to grayish yellow, poorly sorted, angular, silty; mostly in thick uneven beds that are moderately to well cemented. Conglomeratic sandstone is similar but includes scattered angular to subrounded pebbles and cobbles as well as lenses and beds of pebble- to boulder-sized clasts. Conglomerate consists of angular to subrounded pebble- to boulder-sized clasts of limestone, dolomite, ash-flow tuff, lava, quartzite, and chert; sand matrix; moderately cemented. Sandstone member forms steep slopes with scattered to common sandstone ledges; well exposed in cliffs 0.6 km southwest of benchmark 4713 near western border of quadrangle. Maximum exposed thickness about 50 m

Ts **Siltstone and sandstone (Pliocene or older)**--Very light gray to grayish-orange-pink fluvial siltstone, sandstone, and minor layers of pebble conglomerate. Poorly consolidated, moderately sorted, mostly poorly bedded to massive; thin (0.01-0.04 m) beds of moderately to well rounded pebble conglomerate occur in minor, discontinuous channels. Map unit is tilted 10-14° westward, significantly more than the 3-8° dips of the overlying conglomerate member of the White River Narrows unit (Twc). Exposures are sparse and limited to the west side of the North Pahroc Range. Map unit is about 40 m thick

Tsc **Scarp colluvium (Pliocene? and Miocene?)**--Brownish-gray to pale-brown debris, moderately well consolidated, very poorly sorted, and nonbedded. Debris consists chiefly of subangular to rounded boulders of ash-flow tuffs and lava flows exposed in the higher parts of the North Pahroc Range to the east; boulders of the Permian-Pennsylvanian Bird Spring Formation are absent. Boulders are generally monolithologic at each locality and rest in a fine pebble to sand size matrix from the same source. Rounding of boulders occurred primarily by in-place weathering, not by fluvial transport. Unit occurs along the range-front fault scarp on the west side of the White River fault. Maximum exposure of unit is 30 m thick

Tcv **Calcite vein (Miocene?)**--White calcite vein, filling gaps along faults; long axis of crystals are perpendicular to vein walls. Veins are close to vertical. Locally veins are as wide as 3 m

Tgs **Gravity-slide blocks (Miocene?)**--Complex mixture of coherent blocks of volcanic rocks and lesser amounts of jumbled debris. Numerous small faults that cut the slides terminate at the base of the slides. Brecciation of the slide blocks is common and is restricted to the block. Debris is generally cemented by secondary carbonate. Distribution of remnants of the slides suggest that slides were originally greater than 1 kilometer wide. One slide is greater than 2 km across. Identification as gravity-slide blocks is based on geometric relation of blocks that overlie throughgoing structures and on stratigraphy and geographic location of slides relative to potential source areas. Age of map unit is poorly constrained and is based on depth of erosion of original slide mass as well as by ages of underlying and overlying units. Parts of slides that were derived from one or two parent rocks are indicated by map unit symbols enclosed by parentheses; parts of slides consisting of a complex mixture of lithologies are designated by Tgs; in both cases, map unit bounded by an open toothed fault symbol. Map unit occurs in poor exposures in southeast part of quadrangle. Map unit is locally at least 35 m thick

Th **Hiko Tuff (Miocene)**--Rhyolite ash-flow tuff consisting of one compound cooling unit. Hiko Tuff was named by Dolgoff (1963) for the knobby, joint-controlled landforms of the unit in the Hiko Range about 55 km to the southeast. Light-brownish-gray to pinkish-gray and very pale orange, moderately welded to partially welded and devitrified tuff. Most very light gray lenticular pumice fragments are a lighter color than the matrix, but some light-brown pumice fragments are darker; pumice fragments range from 0.2 to 2 cm long in the plane of foliation, and form as much as 15 percent of the rock. Tuff contains about 30-40 percent phenocrysts that consist of about 10-35 percent quartz, 10-35 percent sanidine, 30-65 percent plagioclase, 5-15 percent biotite, less than 5 percent hornblende, a trace of pyroxene, and accessory sphene, zircon, apatite, allanite, and Fe-Ti oxides [hand specimen inspection of samples from this quadrangle and thin section data from other localities reported by Scott and others (in press) and Rowley and others (in press)]. Quartz phenocrysts are a distinct pale purple. Tuff contains trace to 4 percent lithic fragments consisting of fine grained flow-banded volcanic rocks and minor argillite. Lithophysae are sparse. A $^{40}Ar/^{39}Ar$ biotite date by Taylor and others (1989) of the Hiko Tuff is 18.5 $\pm$ 0.4 Ma, but they conclude that the best age estimate may be 18.6 Ma based on additional data. Based on new dating, Rowley and others (in press) and M.G. Best (written commun., 1994) suggest that a more likely age of the Hiko Tuff is about 18.2 Ma. Unit forms gentle dip slopes with little topographic relief. The Hiko Tuff is exposed only west of the White River fault. Source of map unit is the Delamar caldera about 40 km to the southeast (Rowley and Siders, 1988). Unit is probably greater than 80 m thick; its top is not preserved

Thh **Harmony Hills Tuff (Miocene)**--Andesite to trachyandesite ash-flow tuff consisting of one moderately welded simple cooling unit. Mackin (1960) defined the tuff as the youngest member of the Quichapa Formation, subsequently Cook (1965) raised the Harmony Hills Tuff to formation rank, and finally Anderson and Rowley (1975) included the tuff as the youngest formation in the Quichapa Group. The group name is not used here because the formations of the group, the Harmony Hills Tuff, the Condor Canyon Formation (Tc), and the Leach Canyon Formation (Tlc) are unrelated petrologically and probably were erupted from different sources (Scott and others, in press). Unit is devitrified, phenocryst-rich, and massive; the plane of compaction foliation is indistinct. The unit ranges between pale red (weathered) and light olive gray to light gray (fresh). Pumice fragments are sparse. The rock contains about 40-50 percent phenocrysts that consist of 2-10 percent quartz, <3 percent sanidine, 55-70 percent plagioclase, 10-20 percent biotite, <15 percent hornblende, <7 percent pyroxene, and accessory Fe-Ti oxides, zircon, apatite, sphene, allanite, and perrierite and/or chevkinite [hand specimen inspection of samples from this quadrangle and thin section data from other localities reported by Scott and others (in press)]. Biotite books are stacked as much as 4 mm thick. Lithic fragments form less than 2 percent of the rock. Unit forms steep to moderate slopes. Five K-Ar dates provided by Armstrong (1970) and one by Noble and McKee (1972) average 21.6 Ma for the unit; but more recent dating of overlying rocks by Rowley and others (1989) and the age of the underlying Bauers Tuff Member (Tcb) constrain the age of the Harmony Hills Tuff to be between 21.7 and 22.8 Ma. The Harmony Hills Tuff is exposed only in the western half of the quadrangle; there it is as much as 85 m thick in fault slices, but is locally absent

Tb **Basaltic lava flows (Miocene)**--Medium-dark-gray basaltic lava flows, massive in their interiors and more vesicular toward their margins. Basalt contains small phenocrysts ($<$ 2 mm long) that consist of 5 percent blocky clinopyroxene and 10 percent lath-shaped plagioclase phenocrysts in a fine groundmass intergrowth of plagioclase, pyroxene, and opaque phases [hand specimen inspection of samples from this quadrangle only]. Resistant unit forms distinct dip slopes where the younger volcanic units have been eroded; it occurs only along the western part of the quadrangle, where it has a maximum thickness of about 90 m

Tpa **Pahranagat Formation (Miocene)**--Rhyolite ash-flow tuff consisting of one simple cooling unit. Best, Christiansen, and others (1989) first published a report on the Pahranagat Lakes Tuff, the name of which was adopted from Williams (1967). Scott and others (in press) renamed the unit the Pahranagat Formation to include related volcanic units found close to and within the Kawich caldera, source of the formation. The tuff is devitrified, partially welded to moderately welded, and grayish pink to pinkish gray. White pumice fragments are 0.2-5 cm in diameter and form 15-30 percent of tuff. Rock contains 15-35 percent phenocrysts that consist of 20-45 percent quartz, 30-50 percent sanidine, 25-40 percent plagioclase, 1-6 percent biotite, 1-2 percent hornblende and accessory Fe-Ti oxides, zircon, apatite, sphene, and allanite [hand specimen inspection of samples from this quadrangle and thin section data from other localities reported by Scott and others (in press)]. About 1 percent lithic fragments occur in the tuff. The $^{40}Ar/^{39}Ar$ date of sanidine from the tuff is 22.65 $\pm$0.04 Ma (Deino and Best, 1988). This relatively nonresistant unit forms thin benches between steeper cliffs of bounding units. The Pahranagat Formation ranges from about 20 m to 45 m thick

Tc **Condor Canyon Formation (Miocene)**--Rhyolite ash-flow tuff that consists of two simple cooling units, in descending order, the Bauers and Swett Tuff Members. Mackin (1960) named the two tuffs and Cook (1965) named the formation. Rowley and Siders (1988) named the Clover Creek caldera in the Caliente caldera complex as the source of the Bauers Tuff Member, but the source of the Swett Tuff Member, probably an earlier caldera in that caldera complex, has not been recognized. Anderson and Rowley (1975) included the formation in the Quichapa Group, but the group name is not used here. The average K-Ar age of the Bauers is 22.7 Ma (Armstrong, 1970), close to the $^{40}Ar/^{39}Ar$ sanidine date of 22.78 $\pm$0.06 Ma (Best, Christiansen, and others, 1989). This age is about 1 m.y. younger than the average K-Ar age of the Swett Tuff Member (23.7 Ma, Armstrong, 1970). Although the two members of the Condor Canyon Formation are mapped separately throughout most of the quadrangle, the formation is mapped as one unit locally in the western part of the quadrangle where it is about 15 m thick, too thin to depict as members

Tcb **Bauers Tuff Member**--Rhyolite ash-flow tuff, consisting of an uppper part that is pinkish gray, devitrified, and moderately welded to densely welded, and relatively crystal-poor (10 percent phenocrysts); a middle part that is light brownish gray, devitrified, densely welded, and relatively crystal rich (20 percent phenocrysts); and a lower part that is grayish-black to brownish-gray, densely welded, vitropyhyric, and relatively crystal rich (20 percent phenocrysts). Distinctive pinkish-gray flow partings common in the middle part are as long as 0.5 m but only a few millimeters thick; these partings have an appearance similar to smaller ($<$ 8 cm diameter), highly flattened pumice fragments of the middle part. The phenocrysts in the middle part of the Bauers consist of 15-35 percent sanidine, 35-70 percent plagioclase, 0-5 percent pyroxene, and accessory Fe-Ti oxides, zircon, and apatite; the absence of quartz is distinctive [hand specimen inspection of samples from this quadrangle and thin section data from other localities reported by Scott and others (in press); Rowley and others (in press)]. The tuff contains less than a few percent lithic fragments and as much as 10 percent highly flattened lithophysal cavities above the vitrophyre. The Bauers Tuff Member forms steep slopes and minor cliffs and is between 10 and 25 m thick

Tcs Swett Tuff Member--Rhyolite ash-flow tuff, consisting of an upper part that is light red to pale red, devitrified, and moderately to densely welded and a lower part that is dark gray to brownish gray, densely welded, and vitrophyric. The transition from devitrified tuff to underlying vitrophyre is commonly marked by pronounced light-red to grayish-orange-pink mottling and 10-30 percent lithophysal cavities. The thick vitrophyre near the base forms as much as 1/3 of the unit. The rock contains 10-20 percent phenocrysts that consist of 65-85 percent plagioclase, 7-20 percent biotite, as much as 2 percent pyroxene, and accessory Fe-Ti oxides and apatite; the absence of quartz and sanidine is distinctive [hand specimen inspection of samples from this quadrangle and thin section data from other localities reported by Scott and others (in press) and by Rowley and others (in press)]. Lithic fragments are sparse. Unit forms steep slopes or narrow cliffs. Swett Tuff Member ranges between 10 and 15 m thick in the western part of the quadrangle

Tlc **Leach Canyon Formation (Miocene)**--Rhyolite ash-flow tuff consisting of a compound cooling unit. The tuff is partially to moderately welded, devitrified except for sparse local vitrophyre, and very light gray, pinkish gray, and yellowish gray. Mackin (1960) named the formation, and Anderson and Rowley (1975) adopted the name, following the nomenclature of Williams (1967). Anderson and Rowley (1975) included the formation in the Quichapa Group, but the group name is not used here.. Abundant flattened pumice fragments that form 10-20 percent of the rock are commonly light brownish gray and 0.2-2 cm long. The rock contains 15-25 percent phenocrysts that consist of 20-60 percent quartz, 10-40 percent sanidine, 20-55 percent plagioclase, 2-14 percent biotite, traces of hornblende and pyroxene, and accessory Fe-Ti oxides, sphene, zircon, and apatite [hand specimen inspection of samples from this quadrangle and thin section data from other localities reported by Scott and others (in press) and by Rowley and others (in press)]. Lithic fragments are sparse except near the base of the unit. The Leach Canyon forms bold light-colored cliffs and steep slopes. The average of three K-Ar dates (Armstrong, 1970) and one fission track date (Kowallis and Best, 1990) provides an age of about 24.6 Ma but with large errors; a better estimate of the age of the unit is the average age of a coexisting sanidine and biotite pair dated by Armstong at about 23.8 Ma, identical to a new $^{40}Ar/^{39}Ar$ sanidine date for the Leach Canyon Formation of 23.8 Ma (Best and others, 1993). Unit ranges from estimates of 70 to 135 m thick in the southern part of the quadrangle

Tob **Older basalt lava flows (Oligocene)**--Basalt lava flows ranging from olivine-phyric to olivine-pyroxene-plagioclase-phyric to aphyric [based on hand specimen inspection from this quadrangle only]. Olivine-phyric flows are most common and are generally massive, grayish black, and crystal-poor (< 5 percent phenocrysts); however at one locality, on the north side of topographic high 6061 in the southeastern part of the quadrangle, a local picritic flow contains 15-25 percent olivine. Aphyric flows have light-bluish-gray coatings on subhorizontal partings and small (1 mm diameter) vesicles. Margins of flows commonly contain 15 percent vesicles, and locally the upper half of the map unit includes sequences of 2-4 m thick beds of graded, black, moderate-yellow, and moderate-red scoria that contain volcanic bombs as great as 1 m in diameter (also on north slope of topographic high 6061). The lava flows form poorly exposed, steep to moderate, talus-covered slopes, and the scoriaceous beds form distinct bench-and-riser topography. The map unit is exposed only in the southeastern part of the quadrangle where the sequence of flows and scoriaceous beds typically is less than 65 m thick but locally as great as 85 m thick; this thick sequence is probably close to a vent because of the presence of large bombs in scoriaceous beds

Tbl **Blawn(?) Formation (Oligocene)**--Rhyolitic ash-flow tuff consisting of a nonwelded to partially welded, devitrified, yellowish-gray to very light gray cooling unit. Unit is only tentatively correlated with the high-silica rhyolitic tuff of the Blawn Formation (Best and others, 1987; Best, Lemmon, and Morris, 1989) because definitive chemical, petrographic, isotopic age, and paleomagnetic data are not available for definitive correlation. Furthermore, the stratigraphic level of the Blawn Formation is not precise because the age of rocks included in the definition of the unit range from 24 to 18 Ma (Best and others, 1987; Best, Lemmon, and Morris, 1989). Pumice fragments are sparse to common and locally as great as 5 cm in diameter. The rock contains about 15 percent phenocrysts that consist primarily of resorbed quartz, small amounts of feldspars, intermediate amounts biotite, and trace amounts of accessory phases. The quartz phenocrysts are as large as 5 mm in diameter and commonly have a distinctive very pale purple color [based on hand specimen inspection of samples from this quadrangle and semiquantitative thin section data of samples from the Pahroc Spring and Wheatgrass Spring quadrangles (Scott and others, 1992; Scott and others, 1994)]. About 5 percent of the rock consists of inconspicuous volcanic lithic fragments. Unit forms gentle to steep, light-colored slopes and a prominent bench at its base. Blawn Formation ranges from 20 m thick in the south-central part of the quadrangle to 60 m thick in the southeastern part; map unit is absent in the northern part of the quadrangle with the exception of one isolated fault slice

Shingle Pass Tuff (Oligocene)--Rhyolite ash-flow tuff consisting of an upper and a lower member. Originally, Cook (1965) called a rhyolite tuff at Shingle Spring the Shingle Pass Ignimbrite. Subsequently, Ekren and others (1971) recognized as many as three similar rhyolite ash-flows that they called the Single Pass Tuff. Most recently, Best, Christiansen, and others (1989) assigned the name to two petrographically and paleomagnetically correlative rhyolite tuffs and suggested the Quinn Canyon Range as a probable source. Although K-Ar dates for the Shingle Pass Tuff range over almost 4 million years (Marvin and others 1973), $^{40}Ar/^{39}Ar$ sanidine dates provide a more narrow estimate of the age of the two members; the date for the upper member (Tspu) is 26.00 ± 0.06 Ma and the date for the lower member (Tspl) is 26.68 ± 0.06Ma (Best, Christiansen, and others, 1989). In this quadrangle, the two members of the Shingle Pass Tuff are generally separated by a rhyolitic ash-flow tuff, the tuff of Hancock Summit

Tspu **Upper member**--Rhyolite ash-flow tuff consisting of a pale-red, densely welded, devitrified upper part, characterized by hackly, crumbly, weathered surfaces and a thinner, moderate-reddish-orange to brownish-gray, densely welded, vitrophyric lower part, characterized by distinct black fiamme, megascopic black eutaxitic glass shards, and conchoidal fractures. The vitrophyre has grayish-orange-pink mottled areas around devitrification centers. Rock contains 5-10 percent phenocrysts consisting of 1-2 percent quartz, 30-40 percent sanidine, 50-60 percent plagioclase, 5-15 percent biotite, lesser amounts of hornblende and pyroxene, and accessory Fe-Ti oxides, zircon, and apatite [hand specimen inspection of samples from this quadrangle and thin section data from other localities reported by Scott and others (in press)]. Unit forms steep slopes. Unit thins from 40 m in the central-southern to 25 m in the southeastern part of the quadrangle

Tspl **Lower member**--Rhyolite ash-flow tuff consisting of a very light gray to pale-red, moderately welded to densely welded, devitrified upper part characterized by hackly, crumbly, weathered surfaces and a brownish-gray to brownish-black, densely welded vitrophyric lower part characterized by black fiamme or silky white pumice fragments, conspicuous megascopic black eutaxitic glass shards, and conchoidal fractures; the degree of development of the vitrophyre of the lower part is highly variable. The vitrophyre has grayish-pink devitrification centers. Rock contains 15-20 percent phenocrysts consisting of 8-15 percent quartz, 50-60 percent sanidine, 25-35 percent plagioclase, <2 percent biotite and hornblende, as much as 5 percent clinopyroxene, traces of fayalite, and accessory Fe-Ti oxides, zircon, and apatite [hand specimen inspection of samples from this quadrangle and thin section data from other localities reported by Scott and others, (in press)]. The lower member is distinguished from the upper in the field by a lower biotite content than the upper member. The sanidine to plagioclase phenocryst ratio is about 2 in the lower member and about 0.5 in the upper member. Unit forms steep slopes. In the southern part of the quadrangle, the unit ranges from 15-30 m thick, and in the northeastern part of the quadrangle, is locally as great as 17 m thick

Ths **Tuff of Hancock Summit (Oligocene)**--Rhyolitic, devitrified ash-flow tuff ranging from light-brownish-gray to grayish-orange-pink moderately welded tuff to pale-red mostly densely welded tuff; no vitrophyre is present. Best, Christiansen, and others (1989) first used the informal name tuff of Hancock Summit for the moderately welded, relatively quartz-rich rhyolitic ash-flow tuff exposed between the overlying upper member of the Shingle Pass Tuff and the underlying "Isom-type sheet" (p. 127) at Petroglyph Cliff at White River Narrows. Rock contains about 25 percent phenocrysts consisting of about 40 percent quartz, 30 percent sanidine, 20 percent plagioclase, nearly 10 percent biotite, and accessory Fe-Ti oxides, zircon, and apatite [hand specimen inspection of samples from this quadrangle and semiquantitative thin section data of samples from the Pahroc Spring quadrangle (Scott and others, 1992)]. Lithic fragments are sparse. The tuff of Hancock Summit is distinguished from the adjacent members of the Shingle Pass Tuff by a greater quartz phenocryst content, lack of fiamme, absence of a vitrophyre, and massive, poorly foliated appearance. Unit forms rounded slopes. The tuff of Hancock Summit is about 25-30 m thick in the south-central part of the quadrangle, is absent in the southeastern part, and is only contained in fault slices in the northern part

Tsph **Shingle Pass Tuff and tuff of Hancock Summit, undivided (Oligocene)**--Three rhyolitic ash-flow tuff units, in descending stratigraphic order, the upper member of the Shingle Pass Tuff, the tuff of Hancock Summit, and the lower member of the Shingle Pass Tuff are combined where they cannot be shown separately at map scale or where exposures are insufficient. The thickness of this map unit cannot be determined as it is present only in structurally complex areas

Isom Formation (Oligocene)--Trachyte ash-flow tuffs, generally dominated by densely welded vitrophyres. The Isom Formation was originally defined by Mackin (1960), and subsequently redefined by Anderson and Rowley (1975), to consist of three members, in descending order, the Hole-in-the-Wall, Baldhills, and Blue Meadows Tuff Members. The Blue Meadows Tuff Member is absent here because it is restricted to the Markagunt Plateau of southwestern Utah, and the Hole-in-the-Wall Tuff Member is absent in this quadrangle although it is present in the Wheatgrass Spring quadrangle to the south (Scott and others, 1994). Published dates for the Baldhills Tuff Member consist of a whole rock-date of 25.7 $\pm$0.5 (Armstrong 1970) and a plagioclase date of 25.7 $\pm$0.4 (Fleck and others, 1975); an additional plagioclase date of 25.9 $\pm$0.8 Ma was determined by H.H. Mehnert (written commun., 1990) and reported by Scott and others (in press)

Tib **Baldhills Tuff Member**--Trachytic ash-flow tuff consisting of one cooling unit. Devitrified upper parts of the cooling unit are generally grayish red and densely welded; vitrophyric lower parts are dark gray to grayish black and densely welded. The unit contains as much as 15 percent phenocrysts that consist of about 80 percent plagioclase and minor abundances of pyroxene and Fe-Ti oxide [hand specimen inspection of samples from this quadrangle and thin section data from other localities reported by Scott and others, (in press)]. Lithic fragments form about 10 percent of the rock. The cooling units form narrow benches and small cliffs. The thickness of the Baldhills Tuff Member ranges from 0 to about 25 m; in the northern part of the quadrangle the tuff is plastered on a distinct angular unconformity formed by the arched range

Tm **Monotony Tuff (Oligocene)**--Dacite crystal-rich ash-flow tuff consisting of a simple cooling unit. The Monotony Tuff was defined by Ekren and others (1971); Ekren and others (1972, 1974), Best, Christiansen, and others (1989), and Best and others (1992) identified the source of the tuff as the Pancake Range caldera in central Nevada. The upper part of the unit is a devitrified, grayish-orange-pink to light-gray, partially welded to densely welded tuff; the basal part includes a locally developed medium-gray densely welded vitrophyre. Both parts contain 20-50 percent phenocrysts consisting of 5-30 percent quartz, 2-14 percent sanidine, 45-65 percent plagioclase, 5-20 percent biotite, 0-10 percent hornblende, 0-10 percent clinopyroxene, and accessory magnetite, zircon, apatite, and allanite [hand specimen inspection of samples from this quadrangle and thin section data from other localities reported by Scott and others (in press)]. As many as 5 percent distinctive moderate-red andesitic lithic fragments as great as 5 cm long are locally present. The nonresistant partially welded part of the unit forms benches, and the more densely welded part forms steep slopes and small cliffs. K-Ar dates of biotites from the unit range between 26.8 and 29.1 Ma (Marvin and others, 1973). A biotite-hornblende pair gives concordant $^{40}Ar/^{39}Ar$ dates of 27.1 $\pm$0.6 and 26.7 $\pm$0.3 Ma, respectively (Taylor and others, 1989), but a more precise estimate of the age of the Monotony Tuff is based on a laser $^{40}Ar/^{39}Ar$ sanidine date of 27.31 $\pm$0.06 as determined by Best, Christiansen, and others (1989). Unit ranges from 25 to 50 m thick in the southern part of the quadrangle, and is not exposed in the northern part of the quadrangle

Tpcu **Upper member**--Trachytic ash-flow tuff containing 30 percent conspicuous cognate dark flattened pumice lapilli (fiamme) and 25 percent blocky cognate(?) inclusions. The unit is mostly densely welded but locally partially welded at its upper margin, is light red to moderate red to light brown, and is largely devitrified. Fiamme are 1-4 cm in diameter and commonly vitric; 25 percent cognate(?) inclusions are 0.5-1.5 cm in diameter. The inclusions are commonly grayish red whereas the fiamme are moderate red. Very pale orange altered devitrification centers are typically 0.5 cm in diameter. The tuff contains about 10 percent phenocrysts of plagioclase and subordinate pyroxene [based on hand specimen study only]. The upper member is always separated from the lower member by the andesite of Hamilton Spring (Tah) and is restricted to the southern part of the quadrangle. This close spatial (and probable genetic) relationship that exists between the upper member and the underlying andesite (Tah) is similar to the relationship between the Isom-type ash-flow tuffs and andesitic lava flows noted elsewhere (Anderson and Rowley, 1975). Unit has a maximum thickness of about 15 m

Tpcl **Lower member**--Trachyte ash-flow tuff displaying conspicuous fiamme and a thick basal vitrophyre. The upper part of the tuff is largely devitrified, mostly densely welded but partially welded near its upper margin, and light red to moderate red to light brown except for 1-5-cm-diameter black vitric fiamme in most of the densely welded tuff. Very pale orange altered devitrification centers(?) are typically 0.5 cm in diameter. The matrix of the densely welded basal vitrophyre grades downward from grayish orange pink to brownish gray and then to medium dark gray; conspicuous grayish-black fiamme contrast strikingly with the matrix and form about 20-30 percent of the rock; 2- to 10-cm-diameter, grayish-purple to medium-gray cognate blocks form about 25 percent of the rock. The tuff contains 10 percent phenocrysts of plagioclase and subordinate pyroxene, typical of Isom compositional-type ash-flow tuffs [hand specimen inspection of samples from this quadrangle and thin section data from other localities reported by Scott and others (in press)]. The unit forms steep slopes at the vitrophyre and more gentle slopes in the devitrified upper part. The lower member of the Petroglyph Cliff Ignimbrite is widespread throughout the quadrangle and is correlative with the unit exposed at the type section based on unpublished paleomagnetic data (C.S. Grommé, written commun., 1994). The relative thicknesses of the devitrified tuff and basal vitrophyric tuff differ greatly at different localities; near Black Rock Spring, the map unit is only partially welded. The unit is about 50-70 m thick in the southern part of the quadrangle, about 15 m thick near Black Rock Spring, and is about 45 m thick in the northern part

Tppcl **Precursor ash-fall tuff**--Nonwelded to partially welded andesitic ash-fall precursor to the lower member of the Petroglyph Cliff Ignimbrite (Tpcl). Lithologically similar to the overlying member. Light-red, moderate-red, light-brown, and moderate-yellow partly altered, vitric and scoriaceous pumice and ash. Slightly graded bedding between 2 and 25 cm thick. Unit present in one area 1.2 km north of the south border and 4 km west of the east border of the quadrangle; unit is as great as 80 m thick

Tah **Andesitic lava flows of Hamilton Spring (Oligocene)**--Knobby textured, medium-dark-gray, brownish-gray, and dark-greenish-gray andesitic lava flows displaying a massive interior and vesicular margins. The knobby texture is created by the 15-40 percent plagioclase phenocrysts typically 0.5 cm in diameter. The rock also contains about 5 percent clinopyroxene [based on hand specimen study only]. Vesicles are elongate parallel to flow direction and are typically 1-2 cm long. Unit is exposed largely in the south-central part of the quadrangle, where it forms steep cliffs and is 35-60 m thick, but also occurs in the northern part where it is at least 40 m thick

Tppcl **Precursor ash-fall tuff**--Nonwelded to partially welded andesitic ash-fall precursor to the lower member of the Petroglyph Cliff Ignimbrite (Tpcl). Lithologically similar to the overlying member. Light-red, moderate-red, light-brown, and moderate-yellow partly altered, vitric and scoriaceous pumice and ash. Slightly graded bedding between 2 and 25 cm thick. Unit present in one area 1.2 km north of the south border and 4 km west of the east border of the quadrangle; unit is as great as 80 m thick

Tah **Andesitic lava flows of Hamilton Spring (Oligocene)**--Knobby textured, medium-dark-gray, brownish-gray, and dark-greenish-gray andesitic lava flows displaying a massive interior and vesicular margins. The knobby texture is created by the 15-40 percent plagioclase phenocrysts typically 0.5 cm in diameter. The rock also contains about 5 percent clinopyroxene [based on hand specimen study only]. Vesicles are elongate parallel to flow direction and are typically 1-2 cm long. Unit is exposed largely in the south-central part of the quadrangle, where it forms steep cliffs and is 35-60 m thick, but also occurs in the northern part where it is at least 40 m thick

Tbt_1 **Bedded tuff (Oligocene)**--Bedded tuff is locally present between the lower member of the Petroglyph Cliff Ignimbrite (Tpcl) and the mudflow and andesitic lava-flow facies of the formation of Black Rock Spring (Tbrm and Tbrf, respectively). Two types of bedded tuffs occur at this stratigraphic horizon. One type is found in the central part of the quadrangle near Black Rock Spring and consists of medium-gray water-laid(?) sand-size bedded tuff displaying massive bedding and minor subtle crossbedding; clasts consist largely of andesitic material. A second type found in the northeastern part of the quadrangle is a pale-red, rhyolitic, quartz-bearing bedded tuff that contains about 10 percent 0.1-1 cm diameter andesitic clasts and about 20 percent grayish-orange-pink rhyolitic pumice fragments about 0.5-1 cm in diameter; bedding is crude to massive. Unit ranges from about 15-25 m thick

Tot **Orange tuff (Oligocene)**--Moderate-orange-pink, massive, nonwelded ash-flow tuff consisting of two layers separated by thin ash-fall tuff. Unit contains less than 5 percent phenocrysts of plagioclase and pyroxene. Red volcanic lithic fragments are abundant. Unit is exposed only at one locality in the southern part of the quadrangle between the lower member of the Petroglyph Cliff Ignimbrite and the andesite of Mustang Spring where it forms moderate slopes and is about 20 m thick

Needles Range Group (Oligocene)--Crystal-rich dacite ash-flow tuff consisting of three formations in this quadrangle, in descending order, the Lund Formation, the Wah Wah Springs Formation, and the Cottonwood Wash Tuff (Best, Christiansen, and Blank, 1989). The age of the Lund Formation is about 27.9 Ma (average of 4 K-Ar dates), the Wah Wah Springs Formation is about 29.5 Ma (average of 16 K-Ar dates), and the Cottonwood Wash Tuff is about 30.6 Ma (average of 4 dates; Best and Grant, 1987). The Needles Range Formation was originally defined by Mackin (1960), and was elevated to group status by Best and Grant (1987)

Lund Formation--Crystal-rich, dacitic ash-flow tuff consisting of an upper and a lower member. The upper member is normally magnetized, slightly more mafic, and widespread throughout southwest Utah and southeast Nevada; the lower member is reversely magnetized, slightly less mafic, and present locally in the Dry Lake Valley area (C. Sherman Gromné, U.S Geological Survey, written commun., 1995; Larissa Maughn, Brigham Young University, personal commun., 1995). Both of the members are discontinuously exposed in the Deadman Spring quadrangle

Tnlu **Upper member**--Dacite ash-flow tuff that consists of a very light gray to light-gray nonwelded to partially welded simple cooling unit. Pumice fragments are sparse and indistinct. Tuff contains about 30 percent phenocrysts that consist of 15 percent quartz, 5 percent sandidine, 60 percent plagioclase, 15 percent biotite, 5 percent hornblende and clinopyroxene, and traces of accessory phases that include Fe-Ti oxides, sphene, apatite, and zircon [hand specimen inspection of samples from this quadrangle and thin section data from other localities reported by Scott and others (in press)]. Typical biotite books range from 1 to 2.5 mm in diameter and, although most are subparallel to the weak plane of flattening, enough books have nonparallel attitudes to give the rock a slightly random texture when viewed perpendicular to the plane of flattening. Unit is present in the central and southern part of the quadrangle where it forms moderate to steep slopes above and is as great as 25 m thick

Tnll **Lower member**--Dacitic? to rhyolitic? ash-flow tuff that consists of a pinkish-gray to yellow-gray, nonwelded to partially welded and moderately welded, devitrifed upper part and a light-gray, moderately welded, poorly developed, basal vitrophyre. Where the lower member of the Lund Formation is not separated from the rhyolitic tuff (Trt) by the andesite of Mustang Spring (Tms) and the mudflow of Coal Spring (Tco), distinction between the more mafic upper part of the rhyolitic tuff (Trt) and the lower member of the Lund Formation is difficult; in these cases, the two units are lumped as rhyolitic tuff (Trt). Rock contains as much as 15 percent pumice fragments that are as large as 1 cm in diameter; two types of pumices are present - one white, the other light brown. The rock contains about 20-35 percent phenocrysts that consist of about 10-25 percent quartz, 5-10 percent sanidine, 45-60 percent plagioclase, about 10-15 percent biotite, 5-10 percent hornblende, less than 5 percent clinopyroxene, and accessory Fe-Ti oxides, sphene, apatite, and zircon [hand specimen inspection of samples from this quadrangle. Typical biotite books range from 1 to 2 mm in diameter and, although most are subparallel to the weak plane of flattening, enough books have nonparallel attitudes to give the rock a slightly random texture when viewed perpendicular to the plane of flattening. Lithic fragments are sparse. The map unit is present locally in the southern part of the quadrangle and is present at one locality near the northeastern corner of the quadrangle Generally the unit forms moderate slopes. The lower member of the Lund Formation is about 75 m thick in the southern part of the quadrangle

Tnw **Wah Wah Springs Formation**--Crystal-rich, dacite ash-flow tuff, consisting of a moderately to densely welded simple cooling unit. Upper devitrified part of unit is light gray to yellow gray to light brownish gray and lower vitrophyric part is medium gray to dark gray. Pumice fragments are indistinct and sparse; distinctive 0.5-1 cm diameter, very pale orange to yellowish-gray, clay-rich, altered devitrification centers in the vitrophyre may originally have been pumice fragments or lithophysal cavities. The rock contains about 20-45 percent phenocrysts that consist of less than 10 percent quartz, 45-70 percent plagioclase, about 5-15 percent biotite, 10-25 percent hornblende, less than 5 percent clinopyroxene, and accessory Fe-Ti oxides, apatite, and zircon [hand specimen inspection of samples from this quadrangle and thin section data from other localities reported by Scott and others (in press)]. Typical biotite books are 2 mm in diameter and the foliation planes are better developed than those in the Lund Formation (Tnlu and Tnll). Lithic fragments are sparse. Map unit includes a thin (less than 2-m thick) bedded tuff below the tuff of Deadman Spring (Tds) and above the Wah Wah Springs Formation; petrographically the tuff appears to be reworked Wah Wah Springs Formation. Generally the unit forms moderate slopes. The Wah Wah Springs Formation is at least 80-100 m thick in the southern part of the quadrangle, perhaps as much as 250 m thick in the central part but its apparent thickness there probably is exaggerated by unmapped normal faults, and an undetermined thickness in the northern part of the quadrangle where the unit is largely unexposed. At several localities in the southern part, thin exposures of the Wah Wah seem to be caused by attenuating normal faults, only some of which were mapped

Tnc **Cottonwood Wash Tuff**--Crystal-rich, dacite ash-flow tuff that is light gray to yellowish gray and weathers yellowish gray to pale greenish yellow. Unit is devitiried and partially welded to moderately welded. Pumice fragments are indistinct and sparse; 1 cm-diameter, very pale orange, clay-rich, altered devitrification centers(?) are common in some zones. The rock contains about 30-45 percent phenocrysts that consist of 5-15 percent quartz, 55-60 percent plagioclase, about 10-15 percent biotite, 10-15 percent hornblende, less than 5 percent clinopyroxene, and accessory Fe-Ti oxides, apatite, and zircon [hand specimen inspection of samples from this quadrangle and thin section data from other localities reported by Scott and others (in press)]. Typical biotite books are 1-7 mm in diameter, distinctly larger than most books in the Lund Formation (Tnlu and Tnll) and the Wah Wah Springs Formation (Tnw). Lithic fragments are sparse. Generally the unit forms gentle to moderate slopes. Locally in the southern part of the quadrangle, the Cottonwood Wash Tuff appears to be at least 125 m thick, but its base is faulted; at many localities where the tuff is absent or significantly thinner, the unit has probably been structurally attenuated. In the northern part of the quadrangle, the map unit is at least 120 m thick, but there its upper part has been attenuated by faulting

Tbr **Formation of Black Rock Spring (Oligocene)**--Andesitic volcanic complex containing three locally mappable facies, a mudflow facies (Tbrm), a reddish mudflow facies (Tbrrm), and an andesitic lava-flow facies (Tbrf). In localities where exposures are sparse and these facies cannot be mapped separately, the undivided formation of Black Rock Spring (Tbr) is mapped; slopes are commonly covered with a veneer of colluvial andesitic boulders making the distinction between boulders from a lava flow and boulder-size clasts from a mudflow impractical. Also in several areas, the interlayering of mudflow (Tbrm) and lava flow (Tbrf) is too intricate or too small scaled to map separate facies. Taylor (1989, 1990) informally named this unit the conglomerate of Black Rock Spring near Black Rock Spring where only the mudflow facies is represented. Andesite boulders are light gray to dark gray and range from several tens of centimeters to several meters in diameter. Andesitic boulders are comonly flow-banded and vesicles are generally sparse. Autobreccia is present but not common. The andesitic rock contains plagioclase, pyroxene, and opaque phenocryst and groundmass phases [based on hand specimen study only]. Plagioclase phenocrysts are dominant and are as large as 0.5 cm. Groundmass ranges from vitric to medium grained. Map unit pinches out 1.5 km south of Black Rock Spring and is as much as 200 m thick

Tbrm **Mudflow facies**--Light-brownish-gray to pinkish-gray, unsorted to poorly sorted, massive to poorly bedded andesitic rock consisting of about 40 percent fine- to coarse-grained matrix containing about 60 percent pebbles, cobbles, and boulders as great as 6 m in diameter. Mineralogy of the matrix and clasts is similar to that described for the undivided formation of Black Rock Spring (Tbr). Locally the upper part of the mudflow facies includes well bedded, grayish-orange-pink, nonwelded, lithic-rich, andesitic ash-flow and ash-fall tuff. Mudflow facies pinches out within 1.5 km south of Black Rock Spring. Map unit forms moderate slopes and is locally as thick as 100 m

Tbrrm **Red mudflow facies**--Grayish-orange-pink to moderate-orange-pink mudflow that forms a more conslidated layer that forms steeper slopes than the mudflow facies (Tbrm) above and below. Otherwise the lithology of the map unit is indistinguishable from the mudflow facies (Tbrm). This facies is locally mapped near Red Top in the north-central part of the quadrangle. Unit is about 5-10 m thick

Tbrf **Andesitic lava-flow facies**--Light-gray to dark-gray andesitic lava flows that range from common plagioclase- and pyroxene-phyric flows to sparse nearly aphyric flows. Flows are generally flow-banded and nonvesicular but minor vesicular margins occur. Phenocrysts are variable in abundance (0-30 percent); these phenocrysts consist of 70-100 percent plagioclase, 0-30 percent pyroxene, and a few percent opaque minerals [based on hand specimen study only]. Map unit occurs in the northern part of the quadrangle and forms prominent cliffs where overlain and underlain by mudflow facies (Tbrm). Map unit may be as thick as 100 m and its thickness is difficult to determine in faulted areas

Tad **Andesitic dike (Oligocene)**--Medium-light-gray, plagioclase-pyroxene-bearing andesitic dike about 3.5 m wide. Single exposure occurs in the Cottonwood Wash Tuff (Tnc) about 4.4 km south of the northern border and 0.65 km west of the east border of the quadrangle. Dike is possibly a feeder dike of the andesitic lava flows of the formation of Black Rock Spring

Tbt_2 **Bedded tuff (Oligocene)**--Locally present between the overlying lower member of the Petroglyph Cliff Ignimbrite (Tpcl) and the underlying Lund Formation (Tnlu and Tnll). Light-gray bedded tuff is mineralogically and lithologically similar to the Lund Formation. Map unit is poorly exposed and is present only in the southern part of the quadrangle where it is about 20 m thick

Tbt_3 **Bedded tuff (Oligocene)**--Greenish-gray, water-laid, poorly exposed, weakly consolidated, poorly bedded, nonwelded tuff containing abundant clasts of reworked andesite lava flow mixed in a tuffaceous matrix. Unit occurs between the Lund Formation (Tnll) and the underlying andesite of Mustang Spring (Tms) in the southeastern part of the quadrangle along one exposure about 1 km north of the south border and 2.5 km west of the east border. Unit forms gentle slopes and is less than 20 m thick

Tms **Andesitic lava flow of Mustang Spring (Oligocene)**--Grayish-red to brownish-gray to greenish-black, massive andesitic lava flow containing minor vesicular and autobrecciated zones. Rock has about 20 percent phenocrysts of subequal amounts of plagioclase and clinopyroxene [based on hand specimen study only]. Partings in the flow are generally subparallel to the upper and lower contacts. Unit occurs only in the southern part of the quadrangle. Unit generally forms steep to moderate slopes. The map unit is locally as great as 160 m thick and probably has been structurally attenuated locally by normal faulting

Tco **Mudflow of Coal Spring (Oligocene)**--Medium-dark-gray to grayish-green (celadonitic alteration) andesitic clasts in a light-gray matrix of andesitic mudflows. The stratigraphic position of the map unit below the lower member of the Lund Formation (Tnll) and the andesite of Mustang Spring (Tms) indicates that this mudflow is stratigraphically below the mudflow called the conglomerate of Black Rock Spring by Taylor (1989, 1990), Taylor and others (1989), and Bartley and others (1988) that overlies the Lund Formation in this quadrangle. Clasts as small as a few centimeters in diameter are angular to subangular, but larger clasts typically 0.5-3 m in diameter are subrounded to rounded. Larger clasts are monolithologic, nearly holocrystalline coarse-grained andesitic rock containing highly contorted flow bands. Unit is a maximum of about 125 m thick in the southeast part of the quadrangle but pinches out toward the west and is unexposed in the northeast part

Ta **Andesitic lava flow (Oligocene)**--Brownish-gray to pale-brown andesitic lava flow. Plagioclase, pyroxene,and opaque phenocrysts form about 25-35 percent of the rock. In the Deadman Spring NE quadrangle to the east, this map unit locally underlies the mudflow of Coal Spring (Tco). Unit is very poorly exposed, resticted to the east-central part of the quadrangle and is at least 25 m thick

Trt **Rhyolitic tuff (Oligocene)**--Nonwelded to partially welded rhyolitic to dacitic ash-flow tuff consisting of two distinct but undivided cooling units. Taylor (1989) called the unit mapped at this stratigraphic position the tuff of Red Top and the phenocryst modal estimate of the more rhyolitic part of the upper part of the rhyolitic tuff reported below differs significantly from the plagioclase-rich and quartz-poor analyses of the tuff of Red Top reported by Taylor. Where the rhyolitic tuff is not separated from the lower member of the Lund Formation (Tnll) by the andesite of Mustang Spring (Tms) and the mudflow of Coal Spring (Tco), distinction between the more mafic upper part of the rhyolitic tuff and the lower member of the Lund Formation (Tnll) is difficult; in these cases, the two units are lumped as rhyolitic tuff (Trt). The upper cooling unit of the rhyolitic tuff is the most widespread and continuous; it is a very-light-gray rhyolitic devitrified ash-flow tuff that contains about 20 percent phenocrysts that consist of about 15-40 percent quartz, 30-50 percent plagioclase, 5-10 percent sanidine, 15 percent biotite, a few percent hornblende and opaque phases, and a trace of pyroxene [hand specimen study only]. Pumice fragments form 20 percent of the rock and are as great as 2 cm long; lithic fragments are sparse. Quartz pehenocrysts have a slightly pale purple color and are as large as 5 mm across. The lower cooling unit is a light-brownish-gray partially vitric ash-flow tuff containing 15 percent distinctive moderate-orange-pink pumice fragments as large as 3 cm long. Black glass shards are prominent. Lower cooling unit contains about 8 percent phenocrysts that consist of subequal abundances of quartz and plagioclase and lesser abundances of sanidine and biotite. About 10 percent lithic fragments are present. The lower cooling unit is present only in the southern and central part of the quadrangle south of Red Top. In the southeastern part of the quadrangle, the map unit pinches out within 0.5 km of the southern border of the quadrangle; south of that locality, a bedded tuff separates the overlying andesite of Mustang Spring (Tms) and the underlying tuff of Deadman Spring (Tds). In the south-central part of the quadrangle, the map unit extends into the Wheatgrass Spring quadrangle (Scott and others, 1994) less than 1 km. The map unit forms gentle slopes and is highly variable in thickness; it ranges from a few meters thick in some localities to as much as 65 m in others. This variability is related to topography on an angular unconformity above the tuff of Deadman Spring (Tds) and below the rhyolitic tuff in the central and northern part of the quadrangle

Tbt_4 **Bedded Tuff (Oligocene)**--Pinkish-gray bedded tuff that is massive and unsorted in its lower part but well bedded and sorted in its upper part; lower part dominantly contains about 20-30 percent subrounded 1-5 cm moderate-orange-pink clasts of andesite of unknown origin. The rest of the lower part contains about 50 percent phenocryts of quartz, sanidine, plagioclase, and biotite in a matrix of devitrified tuff. The lower part may have been emplaced as a mudflow. Map unit is about 140 m thick

Tds **Tuff of Deadman Spring (Oligocene)**--Moderate-orange-pink to pale-red, devitrified, partially to moderately welded, rhyolitic ash-flow tuff, consisting of one cooling unit. Taylor (1989, 1990) informally defined the tuff of Deadman Spring. Rock contains about 25 percent small pumice fragments that are less than 0.5 cm in diameter, about 15-20 percent phenocrysts that consist of about 60 percent quartz, less than 20 percent feldspar, and 20 percent small biotite crystals that are typically less than 1 mm in diameter [based on hand specimen study only]. Lithic fragments are sparse. Unit forms low hills and gentle to moderate slopes and is exposed throughout the quadrangle. In the southern part of the quadrangle, the unit is about 50 m thick and it becomes progressively thicker to the north, reaching at least 100 m thick, but intense deformation by normal faulting precludes a precise estimate

Tbt_5 **Bedded Tuff (Oligocene)**--Very-light-gray to pinkish-gray massive to bedded lithic-rich nonwelded tuff. About 10 percent of the tuff consists of pumice fragments that are commonly 1 cm in diameter and are commonly altered to moderate-pink to light-gray clay minerals. Map unit occurs between the overlying Wah Wah Springs Formation and underlying Cottonwood Wash Tuff. Tuff contains about 25 percent phenocrysts that consist of 50 percent quartz, 20 percent sanidine, 20 percent plagioclase, 10 percent biotite, and minor opaque phases [based on hand specimen study only]. About 10 percent of the tuff consists of dark-gray volcanic lithic fragments as large as 1 cm in diameter. Map unit was probably emplaced as ash-flow tuffs. Unit erodes readily to form a steep dip slope 4.5 km south of the northern border and 1 km west of the east border of the quadrangle. Bedded tuff is about 130 m thick

Tbt_6 **Bedded tuff (Oligocene)**--Well bedded, yellowish-gray to light-gray ash-fall tuff that occurs below the Cottonwood Wash Tuff (Tnc). Poorly exposed in the south-central part of the quadrangle. Base of the unit is removed by faulting but about 20 m are exposed

Tap **Pyroxene-rich andesitic lava flow (Oligocene)**--Dark-greenish-gray pyroxene-rich andesitic lava flow that contains about 35 percent phenocrysts that consist of 30-60 percent pyroxene and 40-70 percent plagioclase. Flow is massive without vesicular margins. Only three exposures exist, all in the east-central part of the quadrangle. The pyroxene-rich lava flow occurs below the Wah Wah Springs Formation (Tnw) and above the Scotty Wash Quartzite (Msw). Unit forms low hills and is estimated to be about 40 m thick

Lacustrine and fluvial sedimentary rocks (Oligocene)--Unit consists of four interbedded facies that include lacustrine limestone (Tlfl), fluvial boulder conglomerate (Tlfc) facies, fluvial tuffaceous siltstone and sandstone (Tlft), and fluvial nonvolcanic siltstone and sandstone (Tlfs). Two of these facies (Tlfl and Tlfc) occur locally between the Cottonwood Wash Tuff (Tnc), the Windous Butte Formation (Twb), the andesite of Wheatgrass Springs and related andesitic ash-flow (Taa), and Paleozoic strata. The fluvial tuffaceous siltstone and sandstone facies (Tlft) is restricted to intervals bewteen volcanic units, whereas the fluvial nonvolcanic siltstone and sandstone (Tlfs) is resticted between Paleozoic rocks and the first volcanic strata. The limestone facies forms moderate slopes to small cliffs but the clastic facies (siltstone, sandstone, and conglomerate) form readily eroded valleys or benches. Cumulatively the four facies are as much as 360 m thick, but attenuating normal faults are common and the degree of structural thinning cannot be determined

Tlfl **Limestone facies**--Limestone ranges from very light gray, medium dark gray, and brownish gray to pinkish gray and forms 0.1- to 3-m-thick beds in most areas. Thin (1-2 cm) channel-like lenses of reworked volcanic clasts occur in thick limestone beds at several localities. Most of the limestone is nonfossiliferous and has been coarsely recrystallized. Locally unit contains wavy, thinly layered algal(?) structures; in a few localities dark limestone beds contain sparse gastropods and ostracods and light limestone beds locally contain reed-like fossils. In sparse localities, silicification has enhanced preservation of Tertiary reed- and wood-like fossils. Several beds of the limestone facies have petroliferous odors. The limestone facies is as great as 135 m thick

Tlfc **Conglomerate facies**--Boulder conglomerate is characterized by well-rounded boulders of Paleozoic limestone, dolomite, and quartzite as large as 2 m in diameter that litter the surface of the unit as a colluvium. Exposures of the conglomerate facies are sparse. A calcite-cemented matrix of sand- to pebble-sized clasts fills interstices between boulders. Map unit is locally as thick as 180 m

Tlft **Volcanic siltstone and sandstone facies**--Poorly to moderately consolidated, yellowish-gray to very light gray tuffaceous sandstone and siltstone composed of clasts of reworked volcanic phenocrysts, rounded pumice fragments, subrounded fragments of volcanic rocks, and clay minerals. Bedding in these tuffaceous rocks is generally indistinct but locally crossbedded; sorting is poor to moderate. With the exception of sparse exposures limited to cut banks along washes, the unit is recognized by the absence of limestone, conglomerate, or volcanic rock colluvium. Map unit is as great as 135 m thick

Tlfs **Nonvolcanic siltstone and sandstone facies**--Very-pale-orange to yellowish-gray medium bedded, well bedded siltstone and sandstone. Very poor exposure located at 4.5 m south of the north border and 400 m west of the east border of the quadrangle. Thickness of map unit is at least 10 m

Twb **Windous Butte Formation (Oligocene)**--Yellowish-gray to pinkish-gray, partially welded to moderately welded, devitrified rhyolite ash-flow tuff. Cook (1965) first defined the Windous Butte Formation, but the unit was first discussed by Faust and Callaghan (1948). Its age is about 31.3 Ma (Best and others, 1993). Unpublished paleomagnetic data (C.S. Grommé, written commun., 1994) confirm the correlation of this unit with the Windous Butte Formation. Pumice fragments are common in the less welded parts of the unit. Unit contains about 25 percent phenocrysts that consist of about 30 percent quartz, 20 percent sanidine, 30 percent plagioclase, 15 percent biotite, and less than 5 percent hornblende [based on hand specimen study only]. Biotite flakes are as much as 5 mm in diameter. About 3 percent lithic fragments are present. Unit forms hills and moderate slopes. Unit is at least 245 m thick in the northeastern part of the quadrangle but both the upper part and lower part of the unit have been removed by faulting. At many localities on the western side of the North Pahroc Range the unit is absent or much thinner both because it has been attenuated by normal faults and because of stratigraphic thinning. Commonly the limited exposures do not permit discrimination between these possibilities

Tbt_7 **Bedded tuff (Oligocene)**--Poorly bedded, white to very light gray ash-fall tuff that occurs below the Windous Butte Formation (Twb). Poorly exposed in the northeast part of the quadrangle 1.6 km west of the east border and 5.5 km south of the north border of the quadrangle. Base of the unit is removed by faulting but about 85 m are exposed

Twg **Andesitic lava flows of Wheatgrass Spring (Oligocene)**--Andesitic, grayish-red to brownish-gray to greenish-black, massive lava flows containing minor vesicular zones. Rock contains about 15 percent phenocrysts of subequal amounts of plagioclase and clinopyroxene [based on hand specimen study only]. Partings in the flow are generally subparallel to the upper and lower contacts of the unit. Unit locally forms small cliffs and steep to moderate slopes. The thickest exposure of the unit is 235 m but local structural attenuation has greatly thinnned and even removed all of the unit

Taa **Andesitic ash-flow tuff (Oligocene)**--Grayish-black vitrophyric ash-flow tuff that is sparsely plagioclase phyric (less than 2 percent phenocrysts)[based on hand specimen study only]. Tuff contains about 20 percent black pumice fiamme about 0.5-1 cm long and contains about 10 percent limestone and volcanic lithic fragments as large as 2 cm long. Unit appears to be genetically related to the overlying andesite of Wheatgrass Spring (Twg). Exposures are poor and are limited to the north-central part of the quadrangle. Map unit thickness is about 25 m

Pls **Limestone and sandstone (Permain?)**--Light-gray and moderate-brown to yellowish-gray medium-bedded limestone that is interbedded with subordinate medium- to coarse-grained sandstone and limey sandstone. Exposures are poor and limited to one wash 4.3 km east of the west border and 2.5 km north of the south border of the quadrangle. Contains fusulinids, but state of preservation is too poor for identification (C.H. Stevens, personal commun., 1994); unit cannot be correlated with regional units and its age is estimated. Unit appears to be bounded by a graben in older Bird Spring Formation. Map unit is about 35 m thick

Bird Spring Formation (Lower Permian and Middle Pennsylvanian)--At this stratigraphic level near Ely, Nevada, 140 km to the north of the Deadman Spring quadrangle, Stevens (1979) recognized the Pennsylvanian Ely Limestone and the Permian Reipe Spring Limestone separated by a conglomerate marking a distinct unconformity, but 100 km to the south in the southern Delamar Mountains where Page and others (1990) and Swadley and others (1994) have recognized the Bird Spring Formation, the Pennsylvanian-Permian boundary does not appear to be marked by a conglomerate or a mappable unconformity. However, conodont studies indicate that Late Pennsylvanian strata are missing and suggest a possible unconformity. In this quadrangle also we find no mappable unconformity at the Permian-Pennsylvanian boundary and therefore adopt the terminology of the Bird Spring Formation and do not use the Pennsylvanian Ely Springs Limestone and Permian Arcturus Formation terminology used by Taylor (1989, 1990). The Bird Spring Formation in this quadrangle is divided into six informal members: thinly laminated member (Pb_6), slope-forming member (Pb_5), ledge-forming member (Pb_4), sandstone-rich member ($PlPb_3$), limestone-rich member (lPb_2), and chert-rich member (lPb_1). Total thickness of the Bird Spring Formation is estimated to be 1,380 m, but the upper part of the unit has been removed by faulting and minor normal faults have repeated some of the lower parts of the formation

PlPb **Undivided lower part of Bird Spring Formation (Permian and Pennsylvanian)**--May include any parts of members Pb_5 through lPb_1 of the Bird Spring Formation stratigraphically below the thinly laminated member (Pb_6). Descriptions of these units are given below. A sample collected from paleontological site P5, was idenitfied by C.H. Stevens (written commun., 1995) as *Stylastraea dilatata* of probable middle Wolfcampian age representing the *Pseudofusulina huecoensis* zone (Stevens and others, 1979); however, this sample was collected as float that apparently originated uphill west of the site from the undivided lower part of the Bird Spring Formation from the White River fault zone. Although total thickness of map unit may be greater than 1000 m, the individually exposed and faulted blocks of the section are less than about 140 m thick

Pb_6 **Thinly laminated member (Lower Permian)**--Yellowish-gray to light-brown (weathered) and light-gray (fresh) thinly laminated (0.5-1 cm thick) silty limestone. The limestone is micritic and bedding is locally convolute. Thinly laminated member is generally unfossiliferous except for sparse smooth-shelled brachiopods and trace fossils (worm? trails); in thin section sponge spicules are observed. Member is tentatively correlative with the Bunker Hills member of Page (1995) and member d of Pampeyan (1993) and represents a deeper water facies relative to the lower members of the Bird Spring Formation. Map unit thickness is at least 250 m, but the upper part of the member has been removed by faulting on the White River fault

Pb_5 **Slope-forming member (Lower Permian)**--Light-gray to medium-gray with a pinkish-gray mottling (weathered) and olive-gray to medium-gray (fresh) limestone, very light gray to light-gray (weathered) and light-gray to medium-light-gray (fresh) dolomite, and subordinate sandy limestone and dolomite. Dolomite and sandy dolomite and limestone are concentrated at the base of the unit, but limestone is interbedded with dolomite to the top of the unit. The base of the unit is marked by several meters of very light gray dolomite. Unit is medium- to thick-bedded and bedding is commonly indistinct, possibly due to recrystallization or bioturbation. Brachiopods, smooth-shelled pelecypods, fusulinids, and pelmatozoan stems are locally common. In a sample collected at paleontological site P1, abundant large fusulinids are present close to the top of the unit; C.H. Stevens (written commun., 1995) identified *Stewartina convexa*, representing the *Pseudoschwagerina convexa* (now *Stewartina convexa*) zone; this fauna indicates a late Wolfcampian age. Also A.G. Harris and B.R. Wardlaw, in a study of conodonts from a split of the same sample (written commun., 1994), identified *Sweetognathus adenticulatus* Ritter that restricts the faunule to the Sakmarian (= late Wolfcampian). In a sample collected at paleontological site P6, C.H. Stevens (written commun., 1995) also identified *Stewartina?* sp. and *Eoparafusulina* sp., also of Wolfcampian age. Map unit forms gentle to moderate slopes and is about 300 m thick

Pb_4 **Ledge-forming member (Lower Permian)**--Medium-gray to light-gray (weathered) and medium-gray to light-olive-gray (fresh) limestone and minor dolomite that forms a small cliff at many localities and two cliffs in one locality where abundant phylloidal algae are concentrated. Limestone and dolomite are finely to coarsely crystalline. Minor dark-brown chert is present in some cases; bedding is massive in the phylloidal algal mounds but is medium bedded elsewhere above and below the mounds. Above and below the algal mounds, pelmatozoan stems, productid brachiopods, and tabulate corals including *Syringopora* are locally abundant. In a sample from paleontological site P4, C.H. Stevens found *Triticites* sp.a. of Stevens and others (1979) of middle Wolfcampian age (written commun., 1995). Map unit is best developed and thickest in the northern part of the quadrangle; toward the south the phylloidal algal mounds become smaller and then absent. Map unit is about 25 m thick in the southern and 60 m thick in the northern parts of the quadrangle

$PlPb_3$ **Sandstone-rich member (Lower Permian and Pennsylvanian)**--Interbedded pinkish-gray and pale-yellowish-brown to grayish-orange-pink sandstone, grayish-orange-pink sandy limestone, and light-gray to medium-gray limestone and dolomite. Unit is medium bedded. Sandstone beds commonly have low-angle crossbeds that in one locality truncate a recumbently folded slump structure. Sandstone grains are well sorted and grade downward from fine to coarse grained; coarse grains form lag at the base of crossbed sets and in shallow channels. The sandstone member may represent the same stratigaphic level as the unconformity that is better developed near Ely, Nevada, north of the quadrangle where a conglomerate was recognized by Stevens (1979) to mark the Permian-Pennsylvanian boundary. Note that although the stratigraphically higher slope-forming member (Pb_5) is Lower Permian, the underlying limestone-rich member (lPb_2) is Middle Pennsylvanian; Upper Pennsylvanian strata have not been recognized, consistent with the possibly presence of a subtle, unmapped unconformity. Sandstone decreases as limestone and dolomite increase from north to south in the member. Map unit is about 25 m thick in the southern part and 70 m thick in the northern part of the quadrangle

lPb_2 **Limestone-rich member (Middle Pennsylvanain)**--Interbedded medium-gray to light-gray, medium bedded limestone and minor dolomite and sandy limestone. Minor nodules and stringers of pale-brown to dark-brown chert parallel to bedding are present at some localities. The limestones are finely to coarsely crystalline. The member is fossiliferous, containing spiny productids, solitary corals, the tabulate coral *Syringopora*, and branching bryozoans. Fusulinids first occur about 100 m from the top of the member. Pelmatozoan stems are locally common and form a bioclastic grainstone at one locality. A conodont collection from paleontological site P3 (A.G. Harris, written commun. 1994) includes *Neognathodus medexultimus* Merrill which biostratigraphically restricts the age to Desmoinesian and abundant *Adetognathus lautus* (Gunnell) indicates of a relatively shallow water depositional environment. Map unit forms moderate slopes and is about 350 m thick

lPb_1 **Chert-rich member (Middle Pennsylvanian)**--Distinctly banded light-gray to medium-dark-gray and light-brownish-gray, moderately bedded limestone, silty limestone, and minor dolomite with abundant stratiform chert layers. Chert is generally brownish gray to light brown and thinly bedded; several stringers of chert commonly occur in a single bed of thicker carbonate rocks. Silicified fossils are abundant and include productid brachipods, pelmatozoan stems, *Chaetetes* colonial corals, solitary corals, and branching bryozoans. Near the top of the chert-rich member, a zone rich in *Chaetetes* is present at many localities. In a sample collected within a few meters of the top of the chert-rich member from paleontological site P2, A.G. Harris and B.R. Wardlaw (written commun., 1994) identified several conodonts that include *Diplognathodus coloradoensis* (Murray and Chronic) and *Neognathodus medexultimus* Merill which, together, restrict the faunule to the early Desmoinesian; the presence of *Neognathodus medadultimus* Merill, *N. medexultimus*, and *Idiognathodus sinuosus* Ellison and Graves? indicate a platformal or shelfal, normal-marine depositional environment. Member forms significantly steeper slopes and small cliffs compared to the more gradual slopes of the underlying Scotty Wash Quartzite (Msw) and the overlying limestone-rich member (lPb_2). Map unit may be as much as 400 m thick but minor normal faults affect the thickest section to an unkown degree

Msw **Scotty Wash Quartzite (Mississippian)**--Upper part consists of limestone and interbedded shale and a lower part consists of sandstone. In the upper part, light-olive-gray to light-brownish-gray and yellowish-gray (weathered) and olive-gray (fresh) bioclastic limestone interbedded with dusky-yellow (weathered) shale. The limestone consists of coarse pelmatozoan stem, brachipod, bryozoan, and solitary rugose coral fragments. The interbedded shale is poorly exposed and subordinate to the limestone. Upper part forms step (shale) and riser (limestone) topographic forms. The upper part is lithologically similar to the Indian Springs Formation of southern Nevada (Webster, 1969). The lower part consists of pale-brown to dark-yellowish-brown (weathered) and grayish-orange (fresh) quartz sandstone; the quartz sandstone is unfossiliferous, medium to fine grained, well sorted, and thin to thick bedded. Sandstone contains cross stratifications and ripple laminations. Friable layers of the sandstone have carbonate cement and resistant layers have siliceous cement. Lower part forms rounded knobs and intervening sandy colluvium-covered depressions. Map unit thickness is difficult to determine because of significant structural deformation in the lower part characterized by highly discordant attitudes; this deformation is probably related to the incompetence of the underlying Chainman shale (Mc). The upper part may be as much as 150 m thick and the lower part is estimated to be at least 60 m thick. Westgate and Knopf (1932) named the Scotty Wash Quartzite for exposures in the Pioche district, 45 km to the east. Hurtubise (1989) reported the Scotty Wash Quartzite to be about 210 m thick 20 km to the west in the Seaman Range, and Westgate and Knopf (1932) measured at least 212 m of the unit in the Pioche district

Mc **Chainman Shale (Mississippian)**--Micaceous, dark-yellowish-brown and olive-gray, thinly laminated shale. Map unit is poorly exposed and erodes to form valleys. Thickness of the unit cannot be measured because the base of the unit is not exposed and because structural deformation in the overlying Scotty Wash Quartzite is severe and thus is expected in the Chainman Shale. However, based on the regional synthesis of Tschanz and Pampeyan (1970), the thickness of the Chainman Shale in the Deadman Spring quadrangle should be between the 315 m found in the Pioche district and the 415 m at the southern Egan Range

STRATIGRAPHY

Alluvial deposits

Surficial deposits mapped in the quadrangle record six periods of alluvial deposition in the White River Valley during late Tertiary and Quaternary. These deposits have been divided into twelve map units. The periods, numbered in order of decreasing age, and map units consist of (1) a pediment gravel (Tpg), four alluvial fan units and their time-equivalent fluvial terrace deposits that consist of (2) QTa (fan) and Qt_1 (terrace), (3) Qaw (fan) and Qt_2 (terrace), (4) Qaj (fan) and Qt_3 (terrace), and (5) Qae (fan) and Qt_4 (terrace), and (6) modern deposits that consist of alluvium (Qal), valley-floor alluvium (Qav), and playa deposits (Qp). Estimated ages of units are based on field age criteria that include amount of internal dissection, degree of soil development, and topographic sequence (Swadley and others, in press). Fluvial terrace deposits (Qt_1 through Qt_4) are age correlative with alluvial deposits QTa, Qaw, Qaj, and Qae, respectively.

Surficial deposits of the Deadman Spring area correlate with alluvial deposits of Dry Lake Valley on the east side of the North Pahroc Range, as well as those in the more distant Pahranagat and Kane Springs Valleys to the south and southeast (Swadley and others, in press). The inferred ages of the alluvial deposits in these adjacent areas, in turn, are based on correlations with dated alluvial deposits that have similar age criteria in the Nevada Test Site area (Swadley and others, in press).

The alluvial deposits in the White River Valley encompass ages from Pliocene to late Holocene. The oldest deposit, a pediment gravel (Tpg), unconformably rests on the White River Narrows unit west of the White River near the west-central quadrangle border (fig. 1). The pediment surface slopes toward the present valley bottom and is exposed at elevations as low as 1475 m (4840 ft). A projection of the erosional base of the pediment gravel (Tpg) to the center of the modern valley indicates the valley of the White River was eroded to an elevation of about 1440 m (4720 ft) at the time unit Tpg was deposited. This elevation is the approximate elevation of the present valley floor at a point near the lowest exposure of the pediment gravel. Unit Tpg was followed by the deposition of the four alluvial fan units (QTa, Qaw, Qaj, and Qae) by washes tributary to the White River and by terrace deposits (Qt_1-Qt_4) deposited by the White River. Each alluvial fan is inset into the older fan or terrace deposits and all are exposed at elevations as low as the modern flood plain of the White River. These inset relations indicate that the deposition of each of these post-pediment gravel units was preceeded by a period of erosion during which the older alluvial deposits were largely eroded from the White River Valley to depths as great or greater than the present valley floor. The youngest of the alluvial deposits (Qal and Qav) were deposited in the modern channels of the tributary washes and on the present flood plain of the White River, respectively. The small playa deposits (Qp) occur where two tributary stream alluvial fans entered the main valley from opposite sides, partially blocked the valley, and caused local ponding of the White River. At the present time, the White River seems to have insufficient flow to maintain a through channel where the larger tributary washes enter the valley.

The sequence of alluvial fan and terrace deposits along the White River correlate closely with similar alluvial deposits mapped in the region containing different drainage systems to the south and southeast, as described above. This correlation indicates that the series of Quaternary deposits along the White River are related to regional climatic changes and not to a series of bedrock-controlled knickpoints downstream along the White River as suggested by DiGuiseppi and Bartley (1991, p. 53).

White River Narrows unit

This unit, exposed over the western third of the quadrangle, was informally named the White River Narrows Formation by DiGuiseppi and Bartley (1991) for exposures along the southern White River valley, chiefly in this quadrangle and the quadrangle adjacent to the north. They described the formation as alluvial fan and lacustrine(?) sediments that were deposited in a subsiding half-graben bounded on the east by the White River fault and on the west by the Pahroc fault. They assigned a middle and early Pleistocene age to the formation. Mapping in the Deadman Spring quadrangle largely agrees with this interpretation of the structure and the depositional environment of the White River Narrows unit. However, we consider these basim-fill deposits to be older than indicated by DiGuiseppi and Bartley, based on an interpretation of the geomorphic history of the surficial deposits of the White River valley in the Deadman Spring quadrangle.

The age assigned herein to the White River Narrows unit, Pliocene or older, is derived from the age of the overlying surficial deposits. As described above, the valley of the White River contains a sequence of alluvial deposits produced by six erosional-depositional cycles. These deposits are deeply inset into the White River Narrows unit and range in age from late Holocene to Pliocene. Thus, we postulate that the deposition of the White River Narrows unit, the overtopping of the rim of the closed basin, and the subsequent dissection of these sediments to form the earliest White River valley occurred prior to the deposition of the White River Valley alluvial sequence and therefore occurred during or earlier than the Pliocene.

STRUCTURE

Unconformities

The North Pahroc Range in the Deadman Spring quadrangle is a collapsed arch with a complex history of deformation. A series of five angular unconformities in the stratigraphic section date episodes of tectonism; these angular unconformities occur (1) at the Tertiary-Paleozoic boundary, (2) between the tuff of Deadman Spring (Tds) and the overlying rhyolitic tuff (Trt), (3) between the Monotony Tuff (Tm) and the Baldhills Tuff Member of the Isom Formation (Tib), (4) between the Hiko Tuff (Th) and scarp colluvium (Tsc) and gravity slide blocks (Tgs), and (5) between siltstone and sandstone (Ts) and the conglomerate member of the White River Narrows unit (Twc).

(1) The oldest angular unconformity between west-dipping Paleozoic and east-dipping Tertiary strata is not well dated. Interpretations of the ages of similar unconformities include Late Cretaceous-early Tertiary (based on the assumption that the unconformity formed following Sevier compression) and pre-32 Ma (based on the postulate that the unconformity formed following a period of top-to-the-east extension that may have preceded initial 32-Ma volcanism by a few million years) (Taylor and Bartley, 1992; Axen and others, 1993).

(2) The second angular unconformity formed about 29 Ma after Tertiary strata, ranging in age between >32 Ma to <29.5 Ma, were tilted eastward by extension on west-dipping normal faults. The post-29.5-Ma, west-dipping normal faults that affected most of the Tertiary strata did not affect the underlying Permian-Pennsylvanian strata east of the White River fault. In some localities, outliers of Tertiary strata remain unfaulted on the Paleozoic block. These relations suggest that an east-dipping normal fault detached most of the volcanic strata from the horst-like north-south trending block of Paleozoic strata during uplift of the block. Brecciation and alteration of the Paleozoic and Tertiary rocks on the eastern side of the block of Paleozoic rocks are taken as evidence for this normal fault in the northern part of the quadrangle. Timing of the uplift of the Paleozoic block and detachment of Tertiary strata remains uncertain. After younger volcanic strata were deposited between 29 Ma to 27.3 Ma on the resulting irregular surface of the second unconformity, the area east of the Paleozoic block was arched nearly coincident with the modern topographic high of the range at dips of about 20° to the west and 30° to the east.

(3) After the third angular unconformity developed on the arch, still younger volcanic strata were deposited between 25.7 Ma and 18.2 Ma. Following those volcanic events, the arched range collapsed on east-dipping and west-diping normal faults and by gravity sliding on low-angle faults off the high part of the arch to the east. The geometric pattern of the slides on the flanks of the arch make a logical case for a gravity driven mechanism of emplacement in this quadrangle and in the Wheatgrass Spring and Pahroc Spring quadrangles (Scott and others, 1994; Scott and others, 1992). In some cases, young strata in the high part of the range, from which the slides presumable originated, are still preserved; in others, the younger strata have been eroded.

(4) Erosion following this phase of deformation created the fourth angular unconformity during a poorly defined middle Miocene interval.

(5) The fifth angular unconformity developed following 4-6° of westward tilting of a fine-grained sediment that was deposited pior to deposition of the conglomerate member of the White River Narrows unit, which was estimated to have formed in the Pliocene.

(6) Younger Quaternary alluvial deposits are draped on an erosion surface on the conglomerate member, but no tilting was involved.

White River fault

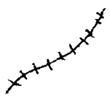
Two lines of evidence that indicate that the major north-northeast-striking, pre-18.2-Ma White River fault experienced left-lateral oblique slip. Splays of the fault dip westward between 47° and 87° and lineations of the slickensided fault surface plunge south-southwest between 37° and 67°. On the western, downthrown side of the White River fault, Tertiary strata are intensely deformed, forming a near chaos. However, a distinct pattern of faulting can be observed in the chaos. Most of these faults strike 15-40° west of the White River fault. Such a pattern is consistent with either tension- or Reidel shear-induced faults on the downdropped block of the left-lateral White River fault.

Low-angle faults

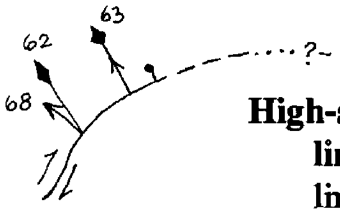
Three low-angle, nearly horizontal faults emplace younger Permian-Pennsylvanian strata over older Pennsylvanian strata at localities about 4.5 km north of the south border of the quadrangle. The attenuation along the faults suggests that they are normal faults, not low-angle compressive thrusts. The absence of relief where these faults underlie Tertiary strata suggests that the structures are significantly older than the Oligocene strata, perhaps coeval with Sevier compression and represent gravitational collapse of an overthickened crust as suggested by Page (in press) for similar structures in the Delamar and Meadow Valley Mountains, 100 km to the south-southeast.

MAP SYMBOLS

Contact

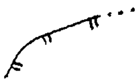


Contact of uncertain nature between units where tectonic thinning is suspected--May be either depositional or tectonic; limited exposures do not allow distinction between the two interpretations. Thicknesses of units separated by this contact are significantly less than thicknesses of these units in undisturbed parts of the stratigraphic sequence. Generally, stratigraphic order of units is preserved. Units adjacent to contact commonly display abundant slickensided surfaces. Attenuating faults may occur within unit and (or) at the contact between units



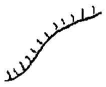
High-angle fault, showing dip (barbed arrow) and trend and plunge of fault-plane lineation (diamond-shaped arrow)--Where fault dip and plunge of fault-plane lineation direction coincide, both symbols are shown on single line; fault dashed where approximately located; dotted where concealed; queried where location uncertain. Bar and ball on downthrown side. Opposed arrows indicate the relative direction of strike-slip component of movement

Low-angle fault below gravity-slide block--Sawteeth on upper plate of slide block. Dashed where approximately located; dotted where concealed.



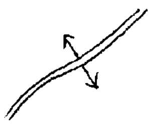
Low-angle normal fault--Double hachures on upper plate. Dotted where concealed

Sheared zone separating strata that have different attitudes---Associated with disharmonic folding

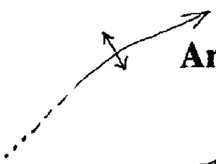


Fault scarp along which younger unit has been deposited--Hachures on side of postfault deposit

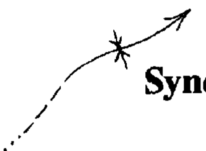
Fault breccia--Massive or sheared; map units within breccia zones are indicated by map unit symbols enclosed by parentheses



Axis of arch of range



Anticlinal axis--Showing direction of plunge. Dashed where approximately located; dotted where concealed



Synclinal axis--Showing direction of plunge. Dashed where approximately located; dotted where concealed

Axis of minor chevron folds

Stratigraphic break within map unit--Includes cooling breaks in lava flows and ash-flow tuffs and selected bedding planes in sedimentary rocks

Strike and dip of sedimentary beds and compaction foliation of ash-flow tuffs

27 **Inclined**

Horizontal

90 **Vertical**

80 **Overturned**

18 **Dip of inclined contact**

Strike and dip of flow foliation

53 **Inclined**

Spring--Symbol added where spring is not shown on topographic base map

X **Prospect**

Shaft

Gravel pit--Excavation post-dates base map and is not shown by topographic contours. Limit of pit is dashed except where it coincides with a mapped geologic contact. Exposures of geologic units within pit largely masked by colluvium, slumping, and effects of excavating

P5 **Paleontological sample location**

A **Local ash bed**

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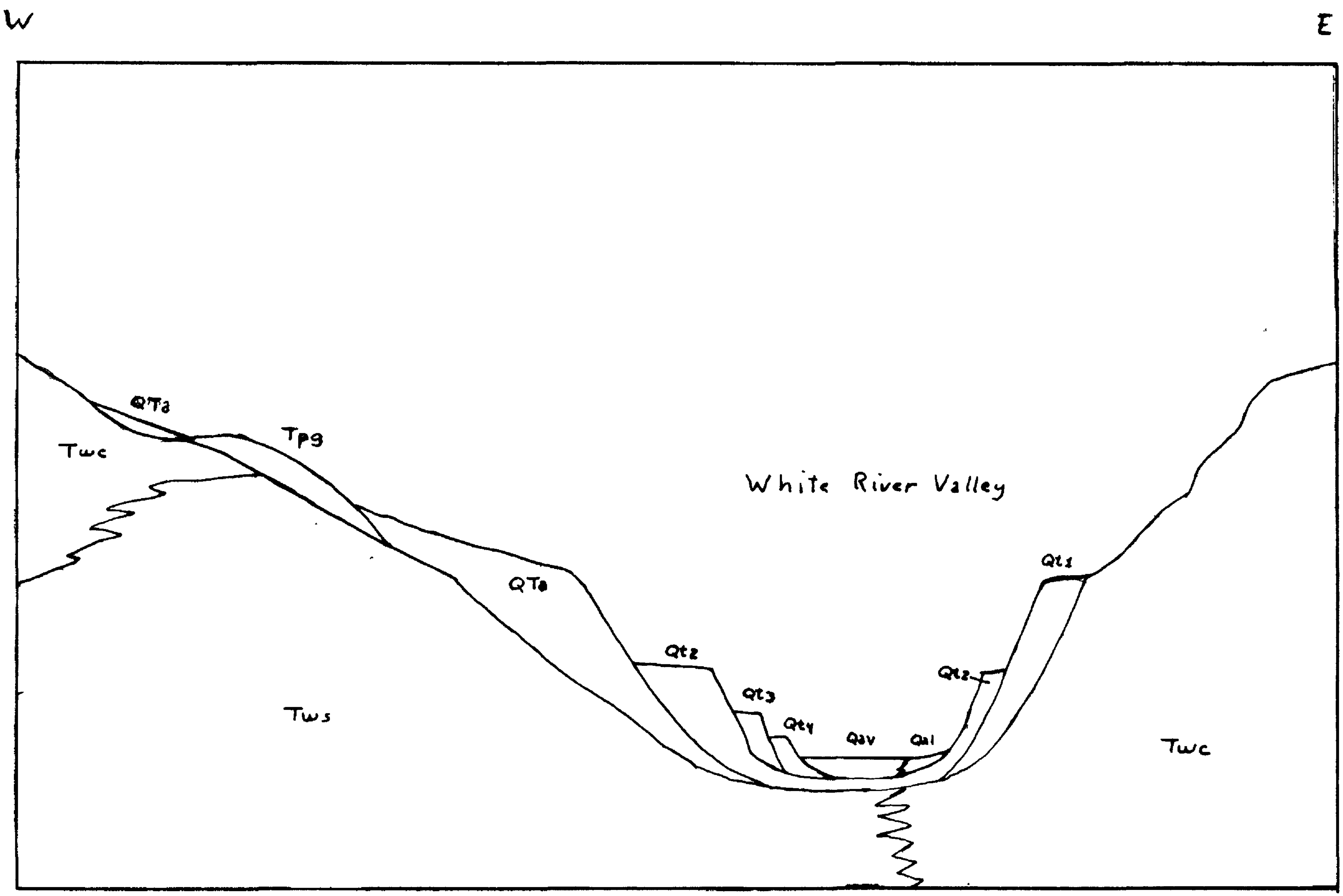
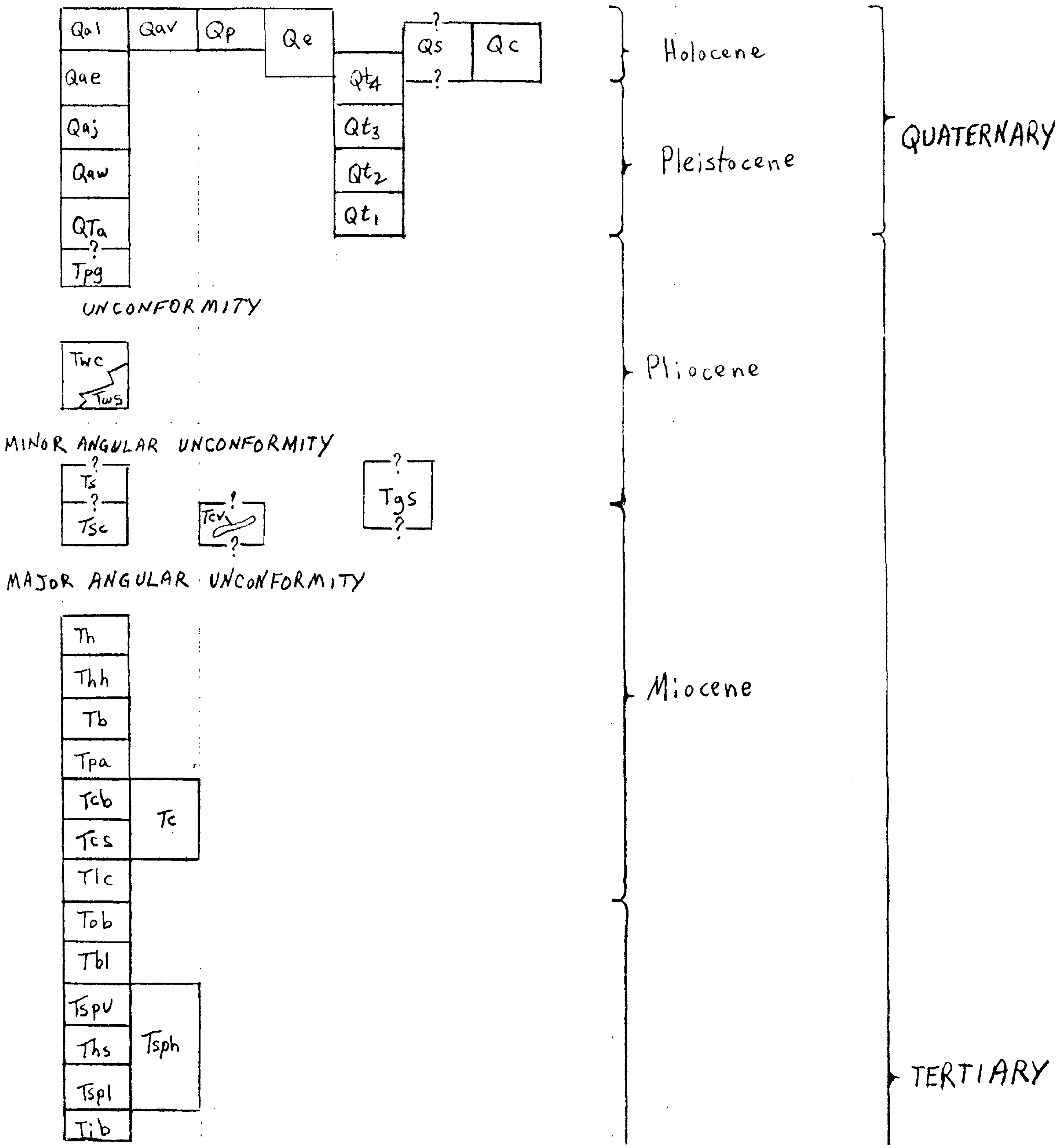
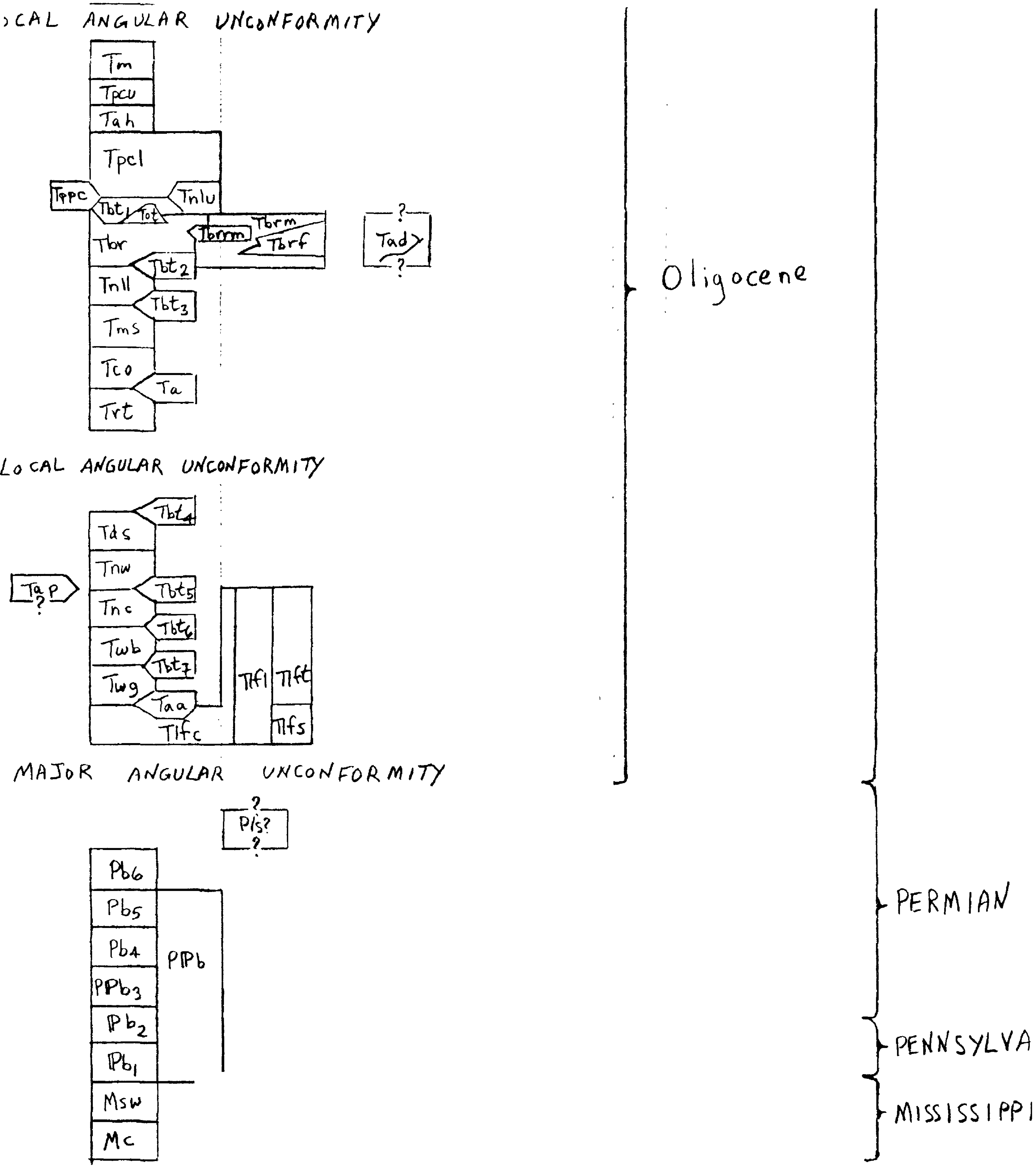


Figure 1. Digrammatic cross section of White River Valley showing the inset relations of the sequence of late Tertiary and Quaternary surficial deposits and the stratigraphic relation between the members of the White River Narrows unit. Symbols are as shown in the Correlation of Map Units. See Stratigraphy section for a discussion of the depositional sequence of surficial deposits and the relations between map units.

CORRELATION OF MAP UNITS




LOCAL ANGULAR UNCONFORMITY
Tm
Tpcu
Tah
Tpcl
Tppc
Tnlu
Tbt1
Tot
Tbrm
Tbrmm
Tbrf
Tbr
Tad
Tbt2
Tnll
Tbt3
Tms
Tco
Ta
Trt
Oligocene
LOCAL ANGULAR UNCONFORMITY
Tbt4
Tds
Tnw
Tap
Tbt5
Tnc
Tbt6
Twb
Tbt7
Twg
Tlfl
Tlft
Taa
Tlfc
Tlfs
MAJOR ANGULAR UNCONFORMITY
Pls?
Pb6
Pb5
Pb4
PPb
PPb3
Pb2
Pb1
Msw
Mc
PERMIAN
PENNSYLVA
MISSISSIPPI