U.S. DEPARTMENT OF THE INTERIOR

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PRELIMINARY GEOLOGIC MAP OF THE DEADMAN SPRING NE QUADRANGLE, LINCOLN COUNTY, NEVADA

by

W. C. Swadley[1], Willliam R. Page[1], and Robert B. Scott[1]

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This map is preliminary and has not been reviewed for conformity with U.S. Geological Survey editorial standards (or with the North American Stratigraphic Code).

[1] Denver, Colorado

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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 in part on estimations of phenocryst abundance as determined by hand specimen study; where available, ranges of phenocryst abundances based on thin section modal analyses from samples outside the quadrangle are provided and referenced. Isotopic ages are reported with 2 sigma errors. Volcanic unit petrologic names are based on the chemical classification of Le Maitre (1989); where chemical data are absent, phenocryst and groundmass mineralogy are used to estimate rock chemical compositions as the basis for proposed rock names. Previous mapping in the area has been published at a scale of 1:250,000 (Tschanz and Pampeyan, 1970; Ekren and others, 1977), and the southwestern part of the quadrangle had been mapped by Taylor (1989) at a scale of 1:24,000.]

Qal **Alluvium (late Holocene)**--Pale-grayish-orange to yellowish-gray sand, gravelly sand, and minor gravel; unconsolidated, locally compacted; moderately to poorly sorted; massive to poorly bedded. Sand is fine to very coarse, commonly angular. Gravel clasts include angular to subrounded pebbles, cobbles, and sparse boulders commonly less than 0.6 m across of dolomite, limestone, ash-flow tuff, lava, and quartzite. Unit consists of fine to medium silty sand containing sparse pebbles where it underlies much of Dry Lake Valley and at the distal edge of the fan apron along the western side of the valley; fine to very coarse sand and gravelly sand where it forms small inset fans nearbed rock exposures, and interbedded unsorted sand, gravelly sand, and gravel where it forms channel deposits of active washes. Most exposures exhibit no soil development. A thin sandy vesicular A horizon is locally developed in some areas. Maximum exposed thickness is about 2 m

Qsd **Silt deposits (Holocene)**--Very pale orange clayey silt, sandy, well compacted, thin-bedded, calcareous; dessication cracks common on surface. Unit occurs in several small closed depressions formed where a wash has been ponded by eolian sand deposits or by deflation of a sand sheet. No soil development. Thickness unknown, probably less than 2 m

Eolian deposits (Holocene)

Qes **Sand sheets**--Pale-grayish-orange to yellowish-gray eolian sand; unconsolidated, moderately to well sorted; no bedding exposed; fine to coarse, chiefly medium, calcarous. Unit forms irregularly shaped vegetation-stabilized deposits on the floor of Dry Lake Valley. Unit not mapped where less than about 0.5 m thick. No soil development observed. Maximum thickness about 4 m

Qee **Elongate dunes**--Yellowish-gray to pale-yellowish-orange eolian sand; unconsolidated, moderately to well sorted; no bedding exposed; fine to coarse, chiefly medium; calcareous. Some dunes exhibit a surface lag of coarse sand. Unit forms vegetation-stabilized linear ridges and irregularly shaped mounds along the floor of Dry Lake Valley. Small dunes less than about a meter high were not mapped. No soil development observed. Maximum thickness about 3 m

Qc **Colluvium (Holocene and Pleistocene)**--Unconsolidated to consolidated colluvium and talus cones; angular pebble- to boulder-sized clasts, and minor amounts of silt and sand. Colors are inherited from source rock except where clasts are coated with brownish-black rock varnish. Unit is generally nonbedded and locally cemented by secondary carbonate. Unit occurs along base of steep slopes developed on Tertiary volcanic and Paleozoic rocks and on shallow slopes where colluvium has not been removed by erosion or weathering. Unit thickness undetermined

Qae **Alluvium (early Holocene and late Pleistocene)**--Grayish-orange to pale-yellowish-brown sand, gravelly sand, and gravel; unconsolidated to weakly consolidated; poorly to moderately sorted; poorly bedded. Sand is angular, fine to very coarse in deposits in the upper parts of the fan apron, and mostly fine to medium in deposits in the lower parts. Gravelly sand includes angular to subrounded pebbles, cobbles, and boulders commonly less than 0.5 m across, of limestone, dolomite, ash-flow-tuff, and lava. Gravel is generally angular to subrounded, has a sand matrix, and occurs more commonly on the upper part of the fan apron. Unit forms large poorly exposed fan remnants in the middle part of the fan apron along the western side of Dry Lake Valley, where it consists chiefly of slightly gravelly fine to medium sand; small fan remnants and inset fans of interbedded sand, gravelly sand, and gravel near bedrock ridges; and small terrace deposits of similar composition along the larger washes. Deposits of map unit stand 1-2 m above active washes; surface of deposit commonly is smooth and undissected. Maximum soil development observed in the area included a thin sandy vesicular A horizon, a B horizon that is the same color as the parent material, and a Bk horizon less than 0.2 m thick that has stage I carbonate development. Maximum exposed thickness about 3 m

Qms **Marsh and spring deposits (early Holocene or late Pleistocene)**--Very light gray calcareous silt and fine sand; weakly consolidated; irregular thin beds. Consists chiefly of sand-sized carbonate-coated and carbonate-cemented aggregates of quartz silt and very fine sand. Analysis of a sample of this unit from a locality 17 km south of the quadrangle (Swadley and Simonds, 1994a) indicated the deposit consists of 42.4 percent carbonate minerals and the following percentages for the clastic part: 3.0 percent coarse and medium sand, 32.7 percent fine and very fine sand, 42.4 percent silt, and 21.9 percent clay. Surface of deposit commonly littered with irregularly shaped carbonate-cemented concretions. Unit crops out in the south-central part of the quadrangle as a discontinuous line of exposures that extends about 20 km south of the mapped area along the western side of Dry Lake Valley. Unit probably deposited in a marsh or wet meadow area fed by springs and seeps along a north-northeast-trending fault. The marsh formed when the local water table was very shallow and was nearly coeval with a pluvial lake that occupied part of Dry Lake Valley (Swadley and Simonds, 1994b). Maximum exposed thickness less than 2 m

Qaw **Alluvium of Willow Spring (middle Pleistocene)**--Unit named for deposits near Willow Spring in the Delamar 3 SE quadrangle (Swadley and others, 1990, in press), about 90 km to the south. Pale-yellowish-orange to light-grayish-brown gravelly sand and gravel; weakly to moderately consolidated, poorly sorted, poorly bedded. Clasts in gravel and gravelly sand consist of angular to subrounded pebbles, cobbles, and boulders commonly less than 1 m across, of limestone, dolomite, ash-flow tuff, lava, and quartzite. Sand component is chiefly angular and medium to very coarse. Unit forms poorly exposed fan remnants mostly adjacent to bedrock ridges in the western part of the quadrangle. Depositional surface of unit is generally intact but commonly 1-2 m of alluvium has been stripped to the upper part of the soil carbonate horizon and is moderately dissected by washes that head within the fan. Surface typically stands 2-8 m above active through-flowing washes. A moderately packed stone pavement is sparsely developed, the surface layer commonly contains sparse to abundant fragments of pedogenic carbonate. Typical soil developed on unit in the region consists of a 4- to 6-cm-thick silty sand vesicular A horizon, a dark-yellowish-orange B horizon, and a 1-m-thick K horizon that has stage III carbonate development in the upper part of the horizon. At most exposures within the quadrangle the original A and B horizons have been eroded; a younger A horizon has developed that includes fragments from the partly eroded K horizon. Unit thickness ranges to more than 10 m

QTa **Alluvium (early Pleistocene and Pliocene?)**--Grayish-brown to brownish-gray gravel; moderately consolidated, unsorted, poorly bedded, sandy matrix. Consists of angular to rounded pebbles, cobbles, and boulders, as large as 2 m, of ash-flow tuff, lava, limestone, dolomite, and quartzite. Unit forms poorly exposed, eroded fan remnants adjacent to bedrock ridges; crops out as rounded ridges that are littered with a lag of bouldery gravel and common to abundant fragments of pedogenic carbonate. Typically, where a soil is exposed on QTa in the region, it consists of a 3- to 5-cm-thick clayey, silty sand vesicular A horizon underlain by a 1- to 2-m-thick K horizon that has stage III carbonate development in the upper part. The unit is commonly deeply eroded and the soil is limited to the ridge tops; the soil conforms to the rounded surface of the interfluves and appears to have developed on an eroded surface. Thickness 0 to more than 10 m

Tb **Basaltic flows (Miocene?)**--Dark-gray basaltic flows, massive in the interior of flows, more vesicular toward margins. Unit is aphyric containing groundmass crystals of plagioclase less than 1 mm in diameter (hand specimen inspection of samples from this quadrangle only). The unit is exposed only in the central part of the quadrangle where it is surrounded by Quaternary deposits. The age of unit is uncertain, but it probably correlates with Miocene basaltic flows that are close to the top of the volcanic section in the adjacent Wheatgrass Spring quadrangle (Scott and others, 1994) and the Pahroc Spring quadrangle (Scott and others, 1992). Unit base and top are unexposed; it has an estimated minimum thickness of about 13 m

Tpa **Pahranagat Formation (Miocene)**--Rhyolite ash-flow tuff consisting of one simple cooling unit. Best, Christiansen, and others (1989) published a report on the Pahranagat Lakes Tuff, which they adopted from Williams (1967) who first described this unit in his dissertation. Scott and others (in press) renamed the unit the Pahranagat Formation to include related volcanic units found close to and within the Kawich caldera, the 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 study 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 ± 0.02 Ma (Deino and Best, 1988). The thickness of the Pahranagat Formation is undetermined because it is only very poorly exposed as fragments in a fault horse in the northwestern part of the quadrangle; it is about 20 m thick in the adjacent Wheatgrass Spring quadrangle to the south (Scott and others, 1994)

Tcb **Bauers Tuff Member of the Condor Canyon Formation (Miocene)**--Rhyolite ash-flow tuff cooling unit that is the upper member of the Condor Canyon Formation (the lower Swett Tuff Member is absent). Cook (1965) named the formation and Mackin (1960) named the two tuff members. The tuff is light brownish gray, devitrified, densely welded, and contains about 20 percent phenocrysts. Distinctive pinkish-gray flow partings are as long as 0.5 m but only a few millimeters thick; these partings are similar to highly flattened pumice fragments that are smaller in diameter (< 8 cm). Phenocrysts 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 study from other localities reported by Scott and others, in press). The tuff contains less than a few percent lithic fragments and as much as 10 percent highly flattened lithophysal cavities toward the base of the unit. The average K-Ar age of the Bauers is 22.7 Ma (Armstong, 1970), similar to the $^{40}Ar/^{39}Ar$ sanidine date of 22.78 ± 0.03 Ma (Best, Christiansen, and others, 1989). The thickness of the Bauers Tuff Member is undetermined beause it is only exposed in a fault horse in the northwestern part of the quadrangle; it is about 20 to 40 m thick in the Wheatgrass Spring quadrangle immediately southwest of this map area (Scott and others, 1994)

Tbl **Blawn(?) Formation (Oligocene)**--Very light gray, partially welded, devitrified rhyolitic ash-flow tuff. Although tuff resembles the high-silica rhyolite tuff of the Blawn Formation (Best and others, 1987; Best, Lemmon, and Morris, 1989), its assignment to this formation is uncertain; the stratigraphic level of the Blawn(?) Formation is not precisely known because it exists only as an isolated fault horse. The rock contains about 15 percent phenocrysts that consist primarily of resorbed quartz, small amounts of feldspars, intermediate amounts of 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 seimiquantitative thin section studies of samples from the Pahroc Spring quadrangle (Scott and others, 1992) and the Wheatgrass Spring quadrangle (Scott and others, 1994). Thickness of the Blawn(?) Formation has not been determined in this quadrangle because of structural and exposure limitations but unit is 25 to 75 m thick in the Wheatgrass Spring quadrangle to the southeast (Scott and others, 1994)

Ti **Isom Formation (Oligocene)**--Trachyte ash-flow tuff consisting of two cooling units in an isolated exposure in the west-central part of the quadrangle where it overlies a thick local stack of lava flows of the andesitic lava flows of Mustang Spring (Tms) with a 23-29° angular unconformity (Scott and others, 1992, 1994). Three members of the Isom Formation are now recognized in the North Pahroc Range, in ascending order, the Baldhills Tuff Member, tuff member of Hamlight Canyon, and Hole-in-the-Wall Tuff Member (Scott and others in press); however, these members are difficult to distinguish from one another in an isolated exposure. Elsewhere in the North Pahroc Range, units normally present above the andesitic lava flows of Mustang Spring are absent above this thick stack of andesitic lava flows; in ascending order the expected sequence is the Monotony Tuff, Baldhills Tuff Member, the lower member of the Shingle Pass Formation, the tuff of Hancock Summit, the upper member of the Shingle Pass, the tuff member of Hamlight Canyon, and the Hole-in-the-Wall Tuff Member (Scott and others, 1994). Because the older units of this sequence are missing, the two cooling units that first cover the andesite stack are probably the youngest units of the Isom Formation, the tuff member of Hamlight Canyon and the Hole-in-the-Wall Tuff Member. Devitrified upper parts of the cooling units range from pale red to light brownish gray and are densely welded for the most part. The vitrophyric lower parts are brownish gray to dark gray and are densely welded. The cooling units both contain 5-15 percent phenocrysts that consist of 70-80 percent plagioclase and minor amounts of pyroxene and Fe-Ti oxide (hand specimen inspection of samples from this quadrangle and thin section study from other localities reported by Scott and others, in press). Lithic fragments form 5-10 percent of the rock. Neither the Hole-in-the-Wall Tuff Member nor the tuff member of Hamlight Canyon have been dated; however, stratigraphic constraints at other localities (Scott and others, in press) suggest that the age of these cooling units is between the age of the Leach Canyon Formation, about 23.8 Ma, and the sanidine date of 26.00±0.03-Ma determined by $^{40}Ar/^{39}Ar$ by Best, Christiansen, and others (1989) for the upper member of the Shingle Pass Tuff. The cooling units forms a small cap-like cliff above the underlying andesite. Map unit is less than about 5 m thick but its top is eroded

Tah **Andesitic lava flows of Hamilton Spring (Oligocene)**--Knobby textured, medium-dark-gray to dark-greenish-gray andesitic lava flows having massive interiors but vesicular margins. Thickest flows have a nearly holocrystalline texture. Rock contains nearly 30 percent plagioclase and about 5 percent clinopyroxene phenocrysts (based on hand specimen study only). Vesicles are typically 1-2 cm long parallel to flow elongation. Unit is exposed only in the northwestern part of the quadrangle where it forms steep slopes; unit top is faulted out but a minimum of about 100 m is exposed

Tpc **Petroglyph Cliff Ignimbrite (Oligocene)**--Trachyte ash-flow tuff consisting of one cooling unit. Partially welded to densely welded trachyte ash-flow tuff containing conspicuous fiamme in a thick vitrophyric base. Pale-red to moderate-red to light-brown devitrified upper part of tuff contains abundant large (1-5 cm diameter) pumice fragments. Pumice fragments are flattened into black fiamme in the most highly welded zone. Very pale orange alteration spots are typically 0.5 cm in diameter. In the vitrophyric lower part of the unit, the matrix of the tuff is grayish orange pink and pale red grading downward into brownish gray and lastly into medium dark gray; conspicuous grayish-black fiamme contrast strikingly with the matrix and form about 20-30 percent of the rock. Volcanic lithic fragments are common, form about 25 percent of the rock, and are grayish purple to medium gray; their mineralogical similarity to the host rock suggests that they may be cognate inclusions. Fiamme deformed about lithic fragments and phenocrysts form a distinctive eutaxitic texture. The ignimbrite has mineralogical and physical charactertistics similar to the trachyte ash-flow tuffs of the Isom Formation and probably belong to the Isom compositional-type magmatic association (Scott and others, in press). Mineralogically, the unit is phenocryst poor, consisting of plagioclase and subordinate pyroxene phenocrysts. The Petroglyph Cliff Ignimbrite has not been dated, but its age is stratigraphically restricted between about 27.3 Ma, the age of the Monotony Tuff (not present in this quadrangle), and about 27.9 Ma, the age of the Lund Formation (Scott and others, in press); although the Lund Formation is not present in this quadrangle, it is present under the Petroglyph Cliff Ignimbrite in the adjoining Deadman Spring quadrangle. In the northwestern part of the quadrangle where single exposure of unit occurs, base of unit is unexposed and minimum thickness is 6 m

Tms **Andesite lava flows of Mustang Spring (Oligocene)**--Grayish-red to blackish-red, blackish-gray to medium-light-gray, and light-brownish-gray, massive to vesicular andesitic lava flows for the most part, but also including autobrecciated andesitic lava flows, minor mudflows consisting of andesitic clasts, and local rhyolitic bedded tuffs. Andesitic lava flows of Mustang Spring is called *flow 3* in this quadrangle by Taylor (1989) and Bartley and others (1988); however, mapping by Scott and others (1994) and R. B. Scott (unpublished mapping) in the Wheatgrass Spring and Deadman Spring quadrangles to the southwest and west, respectively, indicates that their *flow 3* correlates with the andesitic lava flows of Hamilton Spring. Lava flows commonly have massive interiors, but vesicular margins; platy partings parallel to flow foliation in the lava flows are generally subparallel to the margins of the individual flows. Thickest flows have a nearly holocrystalline texture near their centers. Although each flow is relatively uniform in phenocryst abundance and mineralogy, considerable variation occurs between flows; they contain 0-30 percent plagioclase and 0-5 percent clinopyroxene phenocrysts, phenocrysts range from less than 0.5 to 3 mm in diameter, and ratios of phenocrysts vary greatly (based on hand specimen study only). Plagioclase phenocrysts are as large as 0.5 cm in diameter. Vesicular margins display flow elongation of vesicles that are typically 1-2 cm long. Autobreccias contain monolithologic andesitic clasts, and mudflows contain andesitic clasts commonly from one flow but some have mixed sources. Unit also contains a bedded tuff and andesitic conglomerate (Tta) described below. Unit forms steep to moderate slopes; unit top is faulted out but is at least 600 m thick

Tta **Bedded tuff and andesitic conglomerate**--Rhyolitic bedded tuffs include grayish-orange-pink to pinkish-gray massive ash-fall tuffs containing sparse felsic phenocrysts, biotite, and pumice fragments and very light gray to yellowish-gray medium- to thin-bedded ash-fall tuffs containing less than 10 percent phenocrysts of felsic minerals and biotite and abundant to common pumice fragments 0.1-5 cm in diameter. Interbedded with these ash-fall tuffs are medium- to thin-bedded sandstones and conglomerates that have crossbedding and channel-fill features and consist of angular clasts of andesitic rock. Although Taylor (1989) mapped these bedded tuffs as the Lund Formation of the Needles Range Group, these phenocryst-poor and sphene-absent bedded tuffs are distinctly different from the plagioclase- and biotite-rich, sphene-bearing, dacitic Lund Formation (Best, Christiansen, and Blank, 1989; Scott and others, in press). Unit exposed only for 500 m in western part of the quadrangle between andesitic lava flows of Mustang Spring. Unit is as thick as 25 m

Tco **Mudflows of Coal Spring (Oligocene)**--Medium-dark-gray to grayish-green (celadonite alteration) andesitic clasts in a light-gray matrix of andesitic mudflows. Mudflows of Coal Spring have been correlated with the unit called the conglomerate of Black Rock Spring by Taylor (1990), Taylor and others (1989), Taylor (1989), and Bartley and others (1988); however, the mudflows at Black Rock Spring overlie the Lund Formation (Tnl) and the andesitic lava flows of Mustang Spring (Tms) whereas this map unit underlies the the Lund Formation and andesitic lava flows Mustang Spring in the Wheatgrass Spring (Scott and others, 1994) and Deadman Spring quadrangles (R.B. Scott, unpublished mapping). Clasts as small as a few centimeters in diameter are angular to subangular but larger clasts typically 0.5-9 m in diameter are subrounded to rounded. Larger clasts are monolithologic, nearly holocrystalline coarse-grained andesitic rock containing highly contorted flow bands, whereas smaller clasts represent more diverse lithologic types of andesitic flows. Typically, clay- to pebble-size clasts in matrices form about 50-70 percent of the thicker, coarser, and more massive mudflows; in contrast, thinner, finer, crossbedded, and channel-filled parts of the unit have 20-40 percent matrices and pebble- to cobble-size clasts. Because most of the mudflows of Coal Spring occur between andesitic lavas and the unit is thickest at this locality, it probably was derived from relatively local andesitic volcanoes. The unit forms gentle to steep slopes that display slightly resistant ledges that contain abundant large boulders. The unit is a maximum of 670 thick in the central western part of the quadrangle but thins northward over a distance of 6 km to a thickness of no more than 280 m, is absent 6.5 km to the northwest, and pinches out to the southwest over a distance of about 9 km in the northeastern part of the Wheatgrass Spring quadrangle (Scott and others, 1994)

Ta **Andesitic lava flows (Oligocene)**--Brownish-gray to pale-brown local andesitic lava flows. Plagioclase, pyroxene, and opaque phenocrysts form about 25-35 percent of the rock. Flows are massive with flow-banded partings subparallel to flow margins. May correlate with andesitic lava flows of Mustang Spring but these rocks are distinctive by occurring stratigraphically below the mudflows of Coal Spring. Unit forms moderate slopes and is as much as 60 m thick in the western part of the quadrangle but pinches out northward

Trt **Rhyolitic(?) tuff (Oligocene)**--Pinkish-gray to very pale orange, moderately to partially welded, devitrified, rhyolitic(?) ash-flow tuff containing about 25 percent phenocrysts that consist of about 40 percent quartz, 30 percent plagiclase, 10 percent sanidine, 15 percent biotite, and 5 percent unidentified phases (hand specimen study only). Largest quartz phenocrysts are 3.5 mm in diameter and have slightly pale purple color. As much as 15 percent of the rock consists of flattened pumice fragments 1-1.5 cm long. Taylor (1989) called this map unit the tuff of Red Top; yet the phenocryst modal estimate reported here differs significantly from the plagioclase-rich and quartz-poor modal analyses of the tuff of Red Top reported by Taylor (1989). No obvious cooling break was found between this map unit and the underlying tuff of Deadman Spring in this quadrangle, and the possibility exists that this rhyolitic(?) tuff (Trt) is a slightly more mafic upper zone of the similar tuff of Deadman Spring. The map unit forms gentle rounded slopes; unit is as much as 105 m thick in the western part of the quadrangle and pinches out in the southeastern part of the Deadman Spring quadrangle to the west (R.B. Scott, unpublished mapping)

Tds **Tuff of Deadman Spring (Oligocene)**--Moderate-orange-pink, grayish-orange to pinkish-gray, devitrified, partially to moderately welded, rhyolitic ash-flow tuff. Taylor (1989, 1990) first recognized this quartz-rich tuff that overlies the Wah Wah Springs Formation of the Needles Range Group (Tnw). Rock contains about 25 percent small pumice fragments less than 0.5 cm in diameter, about 15-20 percent phenocrysts that consist of about 65 percent quartz, less than 20 percent feldspars, and 15 percent small biotite crystals, typically less than 1 mm in diameter. Lithic fragments are sparse. Unit forms low hills and gentle slopes. Unit is exposed only in the western and northwestern parts of the quadrangle and ranges from 90 to 100 m thick; unit pinches out over 1 km southward where the underlying the Wah Wah Springs Formation (Tnw) thins and Cottonwood Wash Tuff (Tnc) also pinches out over an apparent paleotopographic high in the Scotty Wash Quartzite (Msw)

Needles Range Group (Oligocene)--Crystal-rich dacite ash-flow tuff consisting of two formations in this quadrangle, the Wah Wah Springs Formation and the underlying Cottonwood Wash Tuff (Best, Christiansen, and Blank, 1989). A third formation of the group, the Lund Formation, is absent in this quadrangle but is present in adjacent Wheatgrass Spring (Scott and others, 1994) and Deadman Spring quadrangles (R. B. Scott, upublished mapping). 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 four dates, Best and Grant, 1987). The Needles Range Formation was originally defined by Mackin (1960), but was elevated to group status by Best and Grant (1987)

Tnw **Wah Wah Springs Formation**--Ash-flow cooling unit, consisting of moderately to densely welded tuff. Devitrified part of the unit is light gray to yellow gray to light brownish gray, and the vitrophyric basal part is medium dark gray to dark gray. Pumice fragments are indistinct and sparse; distinctive 0.5-1 cm diameter, very pale orange to yellowish-gray, clay-rich ovoids may be altered pumice fragments or filled lithophysae. 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 study from other localities reported by Scott and others, in press). Typical biotite books are 2 mm in diameter. Lithic fragments are sparse. Generally the unit forms moderate slopes. The Wah Wah Springs Formation is about 170 m thick but pinches out over a paleotopographic high composed of the Windous Butte Formation (Twb) in the northwestern part of the quadrangle

Tnc **Cottonwood Wash Tuff**--Partially welded to densely welded ash-flow cooling unit; the fresh devitrified upper part of the tuff is light gray to yellowish gray and weathers yellowish gray to pale greenish yellow, and the vitrophyric basal part is medium gray to medium dark gray. Pumice fragments are indistinct and sparse, but 1-cm-diameter, very pale orange, clay-rich ovoids, which may be either altered pumice or lithophysae, 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, 5-10 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 study from other localities reported by Scott and others, in press). Typical biotite books are 1-7 mm in diameter, distinctly larger than most books from the Wah Wah Springs Formation (Tnw). Lithic fragments are sparse except near the basal vitrophyric part that locally contains common carbonate lithic fragments as large as 5 cm in diameter. Generally the unit forms gentle to moderate slopes. The Cottonwood Wash Tuff is as thick as 250 m in the northwestern part of the quadrangle, but pinches out toward the south on a paleotopographic high composed of the Scotty Wash Quartzite (Msw)

Tbt **Bedded tuff (Oligocene)**--Light-gray to pinkish-gray ash-fall and reworked bedded tuff. Phenocryst mineralogy of tuff similar to that of Needles Range Group formations. Unit occurs between the Wah Wah Springs Formation (Tnw) and the Cottonwood Wash Tuff (Tnc). Bedding between 0.2 and 2.5 m thick. Unit exposed locally in northwestern part of quadrangle; unit thickness about 5 m

Tlf **Lacustrine and fluvial sedimenatry rocks (Oligocene)**--Interbedded lacustrine limestone and fluvial siltstone, sandstone, and conglomerate. Four mappable sequences of lacustrine and fluvial sedimentary rocks are locally present in the western and northwestern parts of the quadrangle and are separated by the Cottonwood Wash Tuff (Tnc), the Windous Butte Formation (Twb) and the andesitic lava flows of Wheatgrass Spring(?) (Twg) described below. Limestone is the most conspicuous rock in each of the sedimentary sequences because the fluvial parts of the unit are less resistant than is the limestone. The limestone is very light gray to medium dark gray, partly silicified, veined, and discolored. The limestone forms 0.2- to 3-m-thick beds in most areas and contains brownish-black chert, locally common rip-up clasts, reed-like plant fossils, and algal structures. Boulder conglomerate is only sparsely exposed; however, areas underlain by conglomerate are extensive as indicated by unmapped colluvium composed of well-rounded boulders of Paleozoic limestone, dolomite, and quartzite as large as 2 m in diameter. For example, the dominant rock below the Windous Butte Formation (Twb) is boulder conglomerate. The sparsely exposed matrix of the boulder conglomerate is calcite-cemented pebbly sand. Tuffaceous siltstone and sandstone are also common but only sparsely exposed. Intervals covered by unmapped alluvium that are lacking either limestone exposures or colluvial boulders are interpreted to be underlain by poorly consolidated, readily eroded, bedded tuffaceous sandstone and siltstone. These tuffaceous rocks are composed of reworked volcanic phenocrysts, rounded pumice fragments, subrounded fragments of volcanic rocks, and clay minerals. Commonly the tuffaceous rocks are greenish gray, yellowish gray, and very light gray. Bedding is commonly indistinct but locally crossbedded, sorting is poor to moderate, and the degree of consolidation is weak to moderate. The minimum thickness of the uppermost sequence, which is between the Wah Wah Springs Formation (Tnw) and the Cottonwood Wash Tuff (Tnc), is 65 m in the northwestern part of the quadrangle where the top of the sequence is faulted out; this uppermost sequence is absent elsewhere. The sequence between the Cottonwood Wash Tuff (Tnc) and the Windous Butte Formation (Twb) is locally as thick as as 26 m but pinches out at several localites in the northwestern part of the quadrangle. The sequence between the Windous Butte Formation (Twb) and the andesitic lava flows of Wheatgrass Spring(?) (Twg) has a minimum thickness of about 65 m (base unexposed). The base of the lowest sequence, below the andesitic lava flows of Wheatgrass Spring(?) (Twg), is covered by unmapped alluvial boulders and is probably underlain by at least 140 m of predominantly boulder conglomerate

Twb **Windous Butte Formation (Oligocene)**--Yellowish-gray, very pale orange, and pale-red, partially welded to moderately welded devitrified rhyolite ash-flow tuff. Cook (1965) first defined the Windous Butte Formation; but it was first discussed by Faust and Callaghn (1948). Its age is about 31.3 Ma (Best and others, 1993). Unpublished paleomagnetic data (C.S. Grommé, written commun., 1994) confirm the correlation. Pumice fragments are common. 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 (hand specimen study only). Biotite flakes are typically less than 2 mm but as much as 5 mm in diameter. About 3 percent lithic fragments are present. Unit forms low hills and is at least 115 m thick (base unexposed) in the northwestern part of the quadrangle

Twg **Andesitic lava flows of Wheatgrass Spring(?) (Oligocene)**--Grayish-black to grayish-red, locally plagioclase-rich, andesitic lava flows and autobrecciated flows. Phenocrysts form 5-30 percent of the rock; these consist predominantly of plagioclase (about 80 percent), minor clinopyroxene, and minor opaque phases (hand specimen study only). Plagioclase laths are as long as 7 mm in some flows. Correlation with the andesitic lava flows of Wheatgrass Spring in the Wheatgrass Spring quadrangle to the southwest is tentative and is based only on petrographic and stratigraphic similarities. Unit forms steep slopes in the northwestern part of the quadrangle and has a minimum thickness of 140 m in northwestern part of the quadrangle (base of the unit is either unexposed or faulted out)

Msw **Scotty Wash Quartzite (Late Mississippian)**--Quartz sandstone, grayish-orange (fresh), and pale-brown to dark-yellowish-brown (weathered); rock is medium to fine grained, well sorted, thin to thick bedded, cross stratified, and unfossiliferous. The variably friable and resistant sandstone has both calcareous and siliceous cements, respectively. Unit forms rounded knobs and sandy colluvium-covered depressions near the western edge of the quadrangle. The top is eroded and the base of the unit is unexposed in the quadrangle. Westgate and Knoph (1932) named the Scotty Wash Quartzite for exposures in the Pioche district, 40 km to the east. Thickness of unit cannot be determined in this quadrangle because of highly discordant attitudes and probable faults in poor exposures. Hurtubise (1989) reported the Scotty Wash Quartzite to be about 210 m thick 20 km west in the Seaman Range, and Westgate and Knopf (1932) measured 212 m of the unit in the Pioche district but did not find the base of the unit

Mj **Joana Limestone (Mississippian)**--Limestone, dark-gray (fresh) and medium-gray to light-olive-gray (weathered); aphanic to finely crystalline, massive to thick bedded; contains some elongate dusky-yellowish-brown chert nodules and isolated outcrops of jasperoid. Fossils include criniod stems, solitary rugose corals, *Syringapora*, and brachiopods. Unit forms cliffs: only 180 m exposed in map area. Unit top is unexposed. Total thickness of the Joana is reported to be 137 to 153 m in the Seaman Range 20 km to the west (Hurtubise, 1989), and 204 to 214 m in the southern Egan Range 55 km to the north (Kellogg, 1963). Unit is equivalent to the 90-m-thick Bristol Pass Limestone of Westgate and Knopf (1932) in the Pioche district 30 km to the east

MDp **Pilot Shale (Lower Mississippian and Upper Devonian)**--Limestone, silty limestone, siltstone, and shale. Limestone is medium dark gray (fresh) and olive gray, pale red, and grayish red purple (weathered), aphanic to finely crystalline, and very thin bedded. Also present are interbeds of moderate-yellowish-brown to dark-yellowish-orange (fresh) and dark-yellowish-brown (weathered) siltstone and silty limestone, and poorly exposed intervals of dusky-yellowish-brown to dark-yellowish-orange shale. A 1.5-m-thick quartzite bed is present at the top of the unit; quartzite is yellowish gray (fresh), and dusky yellowish brown (weathered), medium grained, rounded to subrounded, moderately sorted, and trough crossbedded. Unit forms ledgy slope; thickness is indeterminable due to faulting, base of unit not exposed. Hurtubise (1989) reported the Pilot Shale to be 32 m thick 20 km west in the Seaman Range

Dw **West Range Limestone (Upper Devonian)**--Limestone, medium-dark gray (fresh) and light-olive-gray, medium light-gray, olive-gray, pale-red, and grayish-red-purple (weathered); aphanic to finely crystalline, nodular; very thin bedded to thin bedded, burrowed; contains criniod stem fragments. Forms ledgy slopes; thickness is indeterminable due to faulting, top of unit not exposed. Westgate and Knopf (1932) reported a thickness of 187 m about 15 km due east at the type locality in the West Range; Hurtubise (1989) estimated a thickness range of 126 to 162 m about 20 km to the west in the Seaman Range

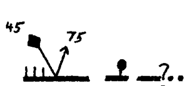
Dg **Guilmette Formation (Upper and Middle Devonian)**--Dolomite, limestone, sandstone, and quartzite. Upper, middle, and lower parts of the formation are recognized but not mapped separately. The upper part is about 400-450 m thick and is mostly dolomite and subordinate limestone and includes about eight quartzite and sandstone beds ranging from 1 to greater than 20 m thick. Dolomite and limestone are mostly dark gray (fresh) and brownish gray and light olive gray to olive black (weathered); finely to coarsely crystalline, thin to thick bedded; commonly contain planar bedding-parallel laminations. Fossils include gastropods, *Amphipora*, and stromatoporoids. Quartzite in the upper part of the formation is light brownish gray (fresh and weathered), to very light gray and white (fresh), and light brown to moderate reddish brown (weathered); fine to medium grained, subrounded, and moderately well sorted. Sandstone is medium gray (fresh), and moderate yellowish brown (weathered), medium grained, subrounded, and moderately well sorted. Quartzite and sandstone are thin to thick bedded, and show trough crossbedding. The top of the Guilmette was mapped at the top of a 2- to 10-m-thick white quartzite that is overlain by the recessive, thinner bedded West Range Limestone (Westgate and Knopf, 1927, p. 7). The middle part of the formation is about 60 m thick and consists of stromatoporoid biostromal dolomite; dolomite is medium dark gray to dark gray (fresh), and medium gray, olive gray and light olive gray (weathered); finely to medium crystalline, and thin to thick bedded. Stromatoporoids are commonly recrystallized to coarsely crystalline yellowish-gray and white dolomite. Biostromal beds are generally less than 1 m thick, some are as thick as 6 m; *Amphipora* and brachiopods are also present. The lower part of the formation is about 150 m thick and consists of dolomite and limestone that are dark gray to medium dark gray (fresh), and medium gray, olive gray, light olive gray, and light gray (weathered); finely to medium crystalline, and mostly thin bedded; commonly laminated and burrow-mottled. Lowermost 30 m is slope-forming "yellow bed" of Tschanz and Pampeyan (1970). Yellow bed consists of dolomite, medium-gray (fresh), and yellowish-gray to light-olive-gray (weathered); argillaceous, silty, aphanic to finely crystalline, and thin bedded. Includes common planar bedding-parallel laminations, some convoluted bedding, and channels less than 0.3 m thick that contain angular intraclasts. Fossils include brachiopods and stromatoporoids. Thickness of Guilmette Formation is estimated to be about 600 to 650 m

Dsi **Simonson Dolomite (Middle Devonian)**--Dolomite, in alternating light and dark beds. Light beds are medium-gray to medium-dark-gray (fresh) and light-olive-gray (weathered) dolomite; dark beds are medium-dark-gray to dark-gray (fresh) and olive-gray to olive-black (weathered) dolomite. Dolomite is finely to medium crystalline, some coarsely crystalline in thin to thick beds, planar bedding-parallel laminations, teepee structures, and some convoluted bedding. Fossils include *Stringocephalus*, *Thamnopora*, and stromatoporoids that commonly occur in biostromes near formation top. Unit forms ledgy cliffs. About 175 m of formation exposed in the quadrangle; base is not exposed

MAP SYMBOLS

Contact

Stratigraphic break within map units--Includes cooling breaks between lava flows and ash-flow tuffs and a sedimentary break between major mudflows



High-angle fault, showing dip (barbed arrow) and trend and plunge of lineation (diamond-shaped arrow)--Dashed where approximately located; dotted where concealed; and queried where uncertain. Bar and ball on downthrown side. Arrows indicate the relative direction of strike-slip component of movement. Hachures indicate postfault deposit along fault scarp

Low-angle fault below landslide block--Sawteeth on upper plate of slide block. Dashed where approximately located

Fissure--Partly filled; apparent offset perpendicular to fissure walls

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

25

Inclined

Vertical

Strike and dip of flow foliation

40

Inclined

jsp

Jasperoid alteration

Prospect

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Correlation of Map Units

Deadman Spring, NE quad
Swadley, Page, + Scott