DEPARTMENT OF THE INTERIOR
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TO ACCOMPANY
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MAP SHOWING OUTCROPS OF PRE-QUATERNARY ASH-FLOW TUFFS AND VOLCANICLASTIC ROCKS, BASIN AND RANGE PROVINCE, UTAH

Compiled by Kurt Roggensack and Jane E. Jenness

INTRODUCTION

This map report is one of a series of geologic and hydrologic maps covering all or parts of States within the Basin and Range province of the western United States. The map reports contain detailed information on subjects that characterize the geohydrology of the province, including the ground-water hydrology, ground-water quality, surface distribution of selected rock types, tectonic conditions, areal geophysics, Pleistocene lakes and marshes, and mineral and energy resources. This work is a part of the U.S. Geological Survey's program for geologic and hydrologic evaluation of the Basin and Range province to identify prospective regions for further study relative to isolation of high-level nuclear waste (Bedinger, Sargent, and Reed, 1984).

This map was prepared from published geologic maps and reports, utilizing the project guidelines defined in Sargent and Bedinger (1984). The map shows the known occurrences of pre-Quaternary ash-flow tuffs and volcaniclastic rocks. The Description of Map Units includes the geologic and, if available, radiometric age, the lithology, thickness where available, and sources of data for the tuff and laharic breccia in outlined and numbered areas in the counties of the study area. The radiometric ages do not necessarily represent the entire age range of the geologic units. Nomenclature of geologic units is from published reports and does not necessarily conform to U.S. Geological Survey usage.

DESCRIPTION OF MAP UNITS

[To convert feet (ft) to meters, multiply feet by 0.3048; to convert miles (mi) to kilometers, multiply miles by 1.609]

PART A.--TUFFS AND VOLCANICLASTIC ROCKS

County-area number	Map symbol	Geologic unit	Geologic and radiometric age in millions of years (m.y.)	Lithology and comments	References for county area
BEAVER COUNTY (B)					
B-1	Tt	Volcanic rocks of Commissary Creek	Miocene	Ash-flow tuffs, lava flows, and volcaniclastic sediments. Tuffs occur throughout sequence; most are loosely consolidated but one near middle is densely welded. Thickness as much as 700 ft.	Best, 1976; Best and Hintze, 1980; Best and others, 1973, 1979; Conrad, 1969; Grant, 1978; Grant and Best, 1979b; Hintze and Best, 1980; Rowley and others, 1979
		Condor Canyon Formation, Bauers Tuff Member	Miocene 22 m.y.	Densely welded, vitric ash-flow tuff; locally includes underlying slightly welded tuff of similar composition. Thickness 10 to 325 ft.	
		Isom Formation	Oligocene 25 m.y.	Densely welded, vuggy, eutaxitic, vitric tuff, locally overlain by andesite lava flow. Tuff is massive, strongly foliated, locally vesicular. Formation as much as 1,000 ft thick.	
		Needles Range Formation, Lund Tuff Member	Oligocene 29 to 30 m.y.	Single cooling unit of multiple dacitic ash-flow tuffs. Ranges from slightly welded near top to densely welded at base; locally 10-ft-thick basal vitrophyre. Thickness 2,300 ft to greater than 3,000 ft in probable moat area of Indian Peak caldera. Outflow facies of member ranges from 40 to about 1,600 ft thick north of cauldron.	
		Tuff of Ryan Spring	Oligocene	Rhyolitic to quartz latitic, ash-flow tuffs; moderately welded, with few crystals and numerous lithic fragments. Minor interbedded volcanic sandstone and debris-flow deposits. Maximum thickness 1,900 ft. Occurs in southern one-half of area; within the Indian Peak caldera separated from underlying Wah Wah Springs Tuff Member of Needles Range Formation by breccia.	

Needles Range Formation, Wah Wah Springs Tuff Member	Oligocene 29 to 30 m.y.	Dacitic ash-flow tuff with numerous crystals. In northern one-half of area, upper part, porous and slightly welded, and lower part compact and densely welded. Member as much as 2,000 ft thick; extensively faulted at north end of area. In Indian Peak caldera, upper part of Wah Wah Springs Member non-lithic, moderately welded, and more than 330 ft thick. Lower part, densely welded, contains landslide breccias, and about 2,500 ft is exposed.
Needles Range Formation, Cottonwood Wash Tuff Member	Oligocene 29 to 30 m.y.	Dacitic ash-flow tuff. Upper part, porous, slightly welded; lower part, compact and densely welded; local basal vitrophyre; brecciated near caldera; thickness as much as 2,100 ft.
Ash-flow tuff	Oligocene(?)	Vitric, locally lithic, moderately welded, latitic ash-flow tuff with few crystals; locally includes basal vitrophyre. Underlies Cottonwood Wash Tuff Member of Needles Range Formation in northwest part of area. Maximum thickness, 300 ft.
Escalante Desert Formation	Oligocene 32.3±1.1 m.y.	Sequence mainly of ash-flow tuff, but also andesitic and rhyolitic lava flows, and volcanic sandstone. Tuffs are rhyolitic to quartz latitic with few crystals and numerous fragments. Formation thickness probably ranges from less than 200 ft to more than 2,600 ft. In northeast part of area formation overlies 150 ft of andesitic lava.
Sawtooth Peak Formation	Oligocene	Moderately welded ash-flow tuff with numerous crystals; locally some vitrophyre and volcanic sandstone at base. In northern part of area, tuff is friable, porous, somewhat foliated, and about 200 ft thick. In southern part, thickness of tuff may exceed 1,000 ft.

B-2	Tt	Rhyolitic tuff and related clastic deposits	Miocene 12 to 22 m.y.	Dominantly slightly welded ash-flow tuff and minor air-fall tuff; interbedded with crudely stratified beds of sandstone and angular volcanic debris. Unit associated with rhyolite of Steamboat Mountain (12 m.y.) and rhyolite units in formation of Blawn Wash; tuffs are from local vents that later were sources of lava flows. Unit locally silicified; 325 to 650 ft thick.	Abbott and others, 1981; Best, 1979; Best and Davis, 1981; Best and others, 1973; Grant, 1978; Grant and Best, 1979a; Lemmon and Morris, 1979a; Morris and others, 1982; Rowley and others, 1979; Steven and Morris, 1983; Steven, Rowley, Hintze and others, 1978
		Formation of Blawn Wash, tuffaceous members	Miocene 20 to 22 m.y.	Lithic, slightly welded ash-flow with few crystals and minor air-fall tuffs; interbedded with water-laid tuff, volcanic sandstone, and conglomerate. Thickness, 325 to 1,300 ft; local zeolitic alteration.	
		Rhyolite of Willow Creek area, tuff member	Miocene 20.8 to 22.4 m.y.	Fine-grained tuff to medium-grained tuff breccia; rhyolitic to dacitic. Thickness probably less than 325 ft; locally intensely argillized.	
		Lapilli tuff	Miocene about 22 to 23 m.y.	Intensely to moderately altered lapilli-rich, tuff with few crystals and water-laid deposits.	
		Condor Canyon Formation, Bauers Tuff Member	Miocene 21.6±0.4 m.y.	Moderately welded ash-flow tuff, locally densely welded and vitric. Thickness, 30 to 390 ft.	
		Leach Canyon Formation	Miocene	Slightly welded, rhyolitic, rhyolitic ash-flow tuff with few crystals. Thickness as much as 390 ft.	
		Isom Formation	Oligocene 25.0±0.4 to 25.8±0.5 and 27.2±0.6 m.y.	Densely welded, ash-flow tuff with few crysals; massive to strongly foliated. Includes at least two cooling units in southern part of area. Thickness, 300 to 500 ft; may be much thicker in southernmost part of area.	
		Needles Range Formation, Wallace Peak Tuff Member	Oligocene 29 to 30 m.y.	Slightly to moderately welded tuff containing pumice lapilli. Thickness as much as 650 ft.	

		Needles Range Formation, Lund Tuff Member	Oligocene 29 to 30 m.y.	Lithologically similar to Lund Tuff Member in county area B-1. Intensely altered locally. Thickness, 800 to 1,650 ft; thickness in possible moat of Indian Peak caldera may be about 2,500 ft. In southwest part of area extensively faulted.	
		Tuff of Ryan Spring	Oligocene	Lithologically similar to Tuff of Ryan Spring in county area B-1. Located in southwestern part of area. Thickness as much as 1,650 ft.	
		Needles Range Formation, Wah Wah Springs Tuff Member	Oligocene 29 to 30 m.y.	Single cooling unit of densely welded, dacitic ash-flow tuff with numerous crystals; has basalt vitrophrye. In southeastern part of area, bleached and fractured zone 10 ft thick in middle of unit. Thickness 350 to 1,500 ft. In southwestern part of area, lithic intracaldera unit of the Indian Peak caldera; location of the ring fracture zone is uncertain. Unit locally propylitized and at other places intensely argillized. Thickness 300 to 650 ft.	
		Needles Range Formation, Cottonwood Wash Tuff Member	Oligocene 29 to 30 m.y.	Lithologically similar to Cottonwood Wash Tuff Member in county area B-1. Crops out in central part of area; thickness as much as 65 ft.	
		Escalante Desert Formation	Oligocene 32.3±1.1 m.y.	Lithology and thickness similar to formation in county area B-1.	
		Ash-flow tuff	Oligocene	Densely welded, easily eroded ash-flow tuff with numerous sheeting fractures. Thickness as much as 650 ft. Crops out in southeast part of area.	
B-3	Tt	Quartz latite of Squaw Peak, tuff member	Miocene	In lower part of unit, slightly indurated, fine- to coarse-grained tuff-breccia, locally includes latite flow 25 to 295 ft thick; perlitic vitrophyre near base. Thickness locally exceeds 985 ft. Tuff member overlain by flow member as much as 660 ft thick.	Lemmon and Morris, 1979a, 1979b, 1983; Rowley and others, 1979; Steven and Morris, 1983; Steven, Rowley, Hintze, and others, 1978; Stringham, 1967; Whelan, 1973

		Isom Formation	Oligocene 25.7 m.y.	Single cooling unit, densely welded ash-flow tuff and basal vitrophyre; thickness as much as 55 ft.	
		Needles Range Formation	Oligocene 29 to 30 m.y.	Moderately welded, dacitic ash-flow tuff with numerous crystals. Probably includes parts of Lund, Wah Wah Springs, and Cottonwood Wash Tuff Members. Thickness as much as 985 ft, but varies considerably.	
	Th	Horn Silver Andesite of Stringham (1967)	Oligocene 30.8 and 34.1 m.y.	Medium- grained agglomerate, medium- and fine-grained tuff, volcanic conglomerate, and sandstone. Contains some lava flows. Thickness locally may exceed 1,640 ft.	
	Tvu	Volcanic rocks	Tertiary	Volcanic rocks; includes ash-flow tuffs and andesite lavas.	
B-4	Tt	Rhyolite tuff of Gillies Hill	Late Miocene	Zeolitically altered ash-flow tuff interlayered with rhyolite lava.	Haugh, 1978; Hintze, 1980; Machette and Steven, 1983
	Tv	Bullion Canyon Volcanics	Miocene and Oligocene	Heterogeneous assemblage of rhyodacite and quartz latite lava flows, flow breccia, and mudflow breccia. Hundreds of feet thick.	
		BOX ELDER COUNTY (BE)			
BE-1	Tt	Ash-flow tuff	Miocene 8.5 m.y.	Welded dacite ash-flow tuff, basal vitrophyre. Thickness about 40 ft.	Compton, 1972; Hintze, 1980
BE-2	Tt	Ash-flow tuff	Miocene 8.5 m.y.	Lithologically similar to tuff in county area BE-1.	Compton, 1972; Hintze, 1980
BE-3	Tt	Ash-flow tuff	Miocene 8.5 m.y.	Lithologically similar to tuff in county area BE-1.	Compton, 1972; Hintze, 1980

IRON COUNTY (I)

I-1	Tv	Mount Belknap Volcanics	Miocene 18.0 to 19.6 m.y.	Outflow facies comprised mainly of Joe Lott Tuff Member, slighty to densely welded, alkali-rhyolite ash-flow tuff. Intracaldera facies, more than 2,970 ft of interlayered ash-flow tuff, rhyolite lava, and volcanic breccia. Entire intracaldera facies hydrothermally altered and bleached. Ash-flow tuffs show various degrees of welding. Mount Belknap Volcanics crops out in northeastern one-third of area. Divided into various geologic units in adjacent county area M-7.	Anderson and others, 1981; Anderson and Rowley, 1975; Cunningham and Steven, 1978, 1979; Hintze, 1980; Rowley, 1975, 1976, 1978; Rowley and others, 1979; Steven, Cunningham, and Anderson, 1979; Steven, Cunningham, Naeser, and Mehnert, 1979; Steven and Morris, 1983; Steven, Rowley, and Cunningham, 1978; Steven, Rowley, Hintze, and others, 1978
		Buckskin Breccia	Early Miocene	Mudflow breccia, flow breccia(?), and ash-flow tuff; as much as 550 ft thick in southeast part of area. Unit interfingers with Mount Dutton Formation east of the study area.	
		Horse Valley Formation	Miocene 19 to 22 m.y.	Lava flows, volcanic mudflow breccia and minor ash-flow tuff, thickness at least 4,920 ft. Intertongues with and overlies the Mount Dutton Formation.	
		Osiris Tuff	Miocene about 22 m.y.	Welded ash-flow tuff as much as 130 ft thick; local basal vitrophyre.	
		Mount Dutton Formation	Miocene and Oligocene 22 to 26 m.y.	Dominantly volcanic mudflow breccia and subordinate flow breccia and lava flows, locally includes minor ash-fall(?) tuff and ash-flow tuff; commonly propylitically altered. Thickness at least 1,970 ft.	
		Bullion Canyon Volcanics	Miocene and Oligocene 22 to 27 m.y.	In descending order: Upper part, intermediate lava flows interbedded with minor ash-flow tuffs. Delano Peak Tuff Member, densely welded, quartz latite ash-flow tuff. Middle and lower parts, mostly intermediate lava flows and mud-flow breccias. Three Creeks Tuff Member, densely welded quartz latite ash-flow tuff. Bullion Canyon Volcanics located in northeastern one-third of area.	

	Tvu	Volcanics	Tertiary	Undescribed.	
	Tt	Quichapa Group: Harmony Hills Tuff	Miocene 19.8 to 21.3 m.y.	Harmony Hills Tuff, moderately welded, slabby, ash-flow tuff, thickness as much as 100 ft.	
		Condor Canyon Formation	Miocene 21.3 to 24.7 m.y.	Condor Canyon Formation: Bauers Tuff and Swett Tuff Members 100 ft and 50 ft thick respectively, both densely welded ash-flow tuffs. Condor Canyon Formation is intercalated with Mount Dutton Formation.	
		Leach Canyon Formation	Miocene 22.3 to 24.0 m.y.	Leach Canyon Formation: Table Butte Tuff and Narrows Tuff Members, slightly to moderately welded ash-flow tuffs; Table Butte Tuff as much as 660 ft thick, Narrows Tuff as much as 330 ft thick.	
		Isom Formation	Oligocene 25 to 26 m.y.	Hole-in-the Wall Tuff Member, densely welded ash-flow tuff, thickness 0 to 25 ft. Baldhills Tuff Member, six or more cooling units of densely welded ash-flow tuff and possible lava flows. Blue Meadows Tuff Member is similar to Baldhills Tuff Member; combined thickness is as much as 350 ft; locally separated by as much as 330 ft of volcanic arenite.	
		Needles Range Formation	Oligocene 29 to 30 m.y.	Moderately welded, ash-flow tuff, local basal vitrophyre; formation as much as 345 ft thick. Locally overlies thin deposits of ash-flow tuff, lava flows, mudflow breccia, and volcanic arenite.	
I-2	Tv	Rhyolitic tuff and related clastic deposits	Miocene 12 to 22 m.y.	Lithologically similar to rhyolitic tuff and clastic deposits in upper part of Tv unit in county area B-2.	Best and Davis, 1981; Cook, 1960, 1965; Hintze, 1980; Mackin, 1960; Rowley and others, 1979

Ox Valley Tuff	Miocene	Probably lithologically similar to Ox Valley Tuff described in county area W-1. Correlative, at least in part, with Kane Wash Tuff in adjacent Nevada.
Racer Canyon Tuff	Miocene 18.2 and 20.3 m.y.	Racer Canyon Tuff consists of rhyolite ash-flow tuff, about 1,500 ft thick, formerly designated as Kane Point Tuff Member of Page Ranch Formation (Mackin, 1960).
Cove Mountain Formation of Cook (1960)	Miocene	Cove Mountain Formation, volcanic sediments and air-fall tuffs, of limited areal distribution. Units locally include basalt flows.
Quichapa Group: Harmony Hills Tuff	Miocene	Harmony Hills Tuff, probably lithologically similar to Harmony Hills Tuff described in county area W-1.
Condor Canyon Formation	Miocene about 22 m.y.	Condor Canyon Formation is comprised of Bauers and Swett Tuff Members. Bauers Tuff Member; firmly welded ash-flow tuff, 65 to 395 ft thick. Swett Tuff Member, ash-flow tuff, 250 ft thick in adjacent Nevada.
Leach Canyon Formation	Miocene	Leach Canyon Formation, slightly welded, rhyolitic ash-flow tuff, as much as 395 ft thick.
Isom Formation	Oligocene about 25 m.y.	Ash-flow tuff and lava flows, thickness locally more than 2,620 ft.
Needles Range Formation, Lund Tuff Member	Oligocene 29 to 30 m.y.	Moderately to densely welded ash-flow tuff; thickness may be as much as 2,475 ft, but uncertain due to extensive faulting. Tuff crops out in northeast part of area, and may have been deposited in moat of Indian Peak caldera that is now mostly concealed.
Tuff of Ryan Spring	Oligocene	Ash-flow tuff, about 1,650 ft thick.
Needles Range Formation, Wah Wah Springs Tuff Member	Oligocene 29 to 30 m.y.	Intracaldera unit, intensely argillized, densely welded, ash-flow tuff. Thickness 330 to 660 ft.

		Escalante Desert Formation, tuff member of Marsden Spring	Oligocene	Densely welded, ash-flow tuff; includes sandstone and conglomerate. Thickness as much as 1,320 ft.	
		Sawtooth Peak Formation	Oligocene	Slightly to moderately welded ash-flow tuff, thickness locally exceeds 660 ft.	
I-3	Tv	Racer Canyon Tuff	Miocene 18.2 and 20.3 m.y.	Moderately welded, dacitic ash-flow tuff. Formerly designated as Kane Point Tuff Member of Page Ranch Formation (Mackin, 1960).	Anderson and Rowley, 1975; Cook, 1957; Hintze, 1980; Mackin, 1960; Mackin and others, 1976; Mackin and Rowley, 1975, 1976; Rowley and others, 1979
		Page Ranch Formation	Miocene	Bedded tuff breccia of possible laharic origin; combined thickness of Page Ranch Formation and overlying Racer Canyon Tuff as much as 600 ft.	
		Rencher Formation	Miocene	Dacite porphyry breccia, tuff breccia, dacite ash-flow tuff, minor sandstone, limestone, and conglomerate. May be as much as 600 ft thick.	
		Quichapa Group: Harmony Hills Tuff	Miocene 20.5 m.y.	Harmony Hills Tuff, welded ash-flow tuff, as much as 250 ft thick.	
		Condor Canyon Formation	Miocene 22 and 23 m.y.	Condor Canyon Formation: Bauers Tuff Member, densely welded ash-flow tuff, thickness 180 ft; volcanic mudflow breccia as much as 250 ft thick. Swett Tuff Member, ash-flow tuff about 50 ft thick.	
		Leach Canyon Formation	Miocene 24 m.y.	Leach Canyon Formation: Table Butte Tuff Member, densely welded ash-flow tuff, as much as 700 ft thick; Narrows Tuff Member, moderately welded ash-flow tuff, as much as 300 ft thick.	
		Mount Dutton(?) Formation	Miocene and Oligocene 21 to 26 m.y.	Volcanic mudflow breccia consisting of angular clasts of mostly andesitic volcanic rock in mud matrix about 400 ft thick.	
	Tvu	Volcanics	Tertiary	Undescribed.	

	Tt	Isom Formation	Late Oligocene 25 to 26 m.y.	Hole-in-the-Wall Tuff Member, slightly to densely welded ash-flow tuff, as much as 125 ft thick. Baldhills Tuff Member, six or more cooling units of densely welded, ash-flow tuff, local basal vitrophyre; as much as 400 ft thick.	
I-4				Description of units is from outcrops in northeastern and western parts of area; remainder of area undescribed.	Anderson and Rowley, 1975; Hintze, 1980; Rowley and others, 1979; Rowley and Threet, 1976
	Tv	Quichapa Group: Harmony Hills Tuff	Miocene about 20.5 m.y.	Welded, ash-flow tuff with numerous crystals; thickness about 100 ft.	
		Condor Canyon Formation, Bauers Tuff Member	Miocene 22.1±0.6 m.y.	Densely welded, ash-flow tuff with basal vitrophyre and few crystals; thickness about 35 ft.	
		Leach Canyon Formation, Table Butte Tuff Member	Miocene	Slightly welded, ash-flow tuff with few crystals; thickness about 100 ft.	
		Leach Canyon Formation, Narrows Tuff Member	Miocene 22.3 and 24.0 m.y.	Moderately welded, ash-flow tuff with basal vitrophyre and few crystals; thickness about 20 ft.	
		Isom Formation, Baldhills Tuff Member	Oligocene 25 to 26 m.y.	Several cooling units, densely welded, ash-flow tuff with few crystals and some lava flows, locally, basal vitrophyre; thickness at least 150 ft.	
		Needles Range Formation	Oligocene about 29 m.y.	Moderately welded, dacitic ash-flow tuff with numerous crystals; local basal vitrophyre; thickness as much as 15 ft.	

JUAB COUNTY (J)

J-1	Tv	Spor Mountain Formation, Beryllium Tuff Member	Early Miocene	Stratified vitric tuff and tuffaceous breccia, containing carbonate, quartzite, and volcanic clasts; much of tuff hydrothermally altered to clay, fluorite, and potassium feldspar. Thickness 60 to 200 ft.	Armstrong, 1970; Lindsey, 1979, 1982; Shaw, 1972; Staatz and Carr, 1964
	Tt	Needles Range(?) Formation	Oligocene 31.4 m.y.	Welded ash-flow tuff, maximum thickness of 100 ft in northern Drum Mountains.	
		Dell Tuff	Oligocene 32 m.y.	Slightly welded rhyolitic ash-flow tuff. Maximum thickness about 600 ft in northernmost part of area.	
		Joy Tuff, Crystal Tuff Member	Early Oligocene and late Eocene 38.0±0.7 m.y., average date	Moderately welded, rhyolitic ash-flow tuff erupted from vents east of Topaz Mountain. Thickness about 600 ft.	
		Mount Laird Tuff	Late Eocene, about 39 m.y.	Rhyodacitic to quartz latitic ash-flow tuff. Maximum exposed thickness 260 ft, but as much as 1,640 ft thick in subsurface of Dugway Valley where unit is interbedded with tuffaceous lake beds (Lindsey, 1979). Crops out in the Drum Mountains.	
J-2	Tt	Ash-flow tuff	Oligocene 30 to 32 m.y.	Rhyolitic and quartz-latitic, welded ash-flow tuff.	Lindsey and others, 1975
J-3	Tt	Ash-flow tuff	Oligocene 30 to 32 m.y.	Rhyolitic, welded, ash-flow tuff.	Lindsey and others, 1975
J-4	Tt	Tuff of Latite Ridge	Oligocene	Welded tuff member, as much as 1,000 ft thick, overlies nonwelded, air-fall tuff member, as much as 600 ft thick. Comprises northernmost outcrops.	Morris, 1975, 1977, 1978
		Fernow Quartz Latite	Oligocene	Partly to densely welded tuff, locally includes thin patches of air-fall tuff at base. Thickness as much as 1,500 ft. Comprises most of outcrops in area.	

J-5	Tg	Goldens Ranch Formation of Muessig (1951)	Tertiary, possibly Oligocene to middle Eocene	Volcaniclastic and pyroclastic rocks and sediments including tuff, conglomerate, and sandstone. Includes some interbedded lava flows. Thickness at least 1,000 ft. Intertongues with agglomerates and breccias of Laguna Springs Volcanic Group and probably with Moroni Formation of Hardy (1962).	Hardy, 1962; Morris and Lovering, 1979; Muessig, 1951; Witkind and others, 1985; I.J. Witkind, and M.P.Weiss, U.S. Geological Survey, unpublished data, 1984
	Tls	Laguna Springs Volcanic Group	Oligocene	Chiefly latitic and andesitic tuffs and interbedded volcanic flows, agglomerate, and breccia. Thickness possibly as much as 1,000 ft.	
J-6	Tm	Moroni Formation of Hardy (1962)	Tertiary, possibly Oligocene to middle Eocene	Volcaniclastic and pyroclastic rocks and sediments; includes tuff, conglomerate, and sandstone. Rhyolitic ash-flow tuffs locally welded. Thickness varies considerably, maximum, as much as 2,000 ft. Probably correlative with Goldens Ranch Formation of Muessig (1951).	Hardy, 1962; Muessig, 1951; I.J. Witkind and M.P. Weiss, U.S. Geological Survey, unpublished data, 1984
J-7	Tg	Goldens Ranch Formation of Muessig (1951)	Tertiary, possibly Oligocene to middle Eocene	Volcanic sediments, chiefly conglomerate and sandstone, and friable tuffs; interbedded volcanic flows. Thickness probably about 1,000 ft.	Muessig, 1951; Witkind and others, 1985
			MILLARD COUNTY (M)		
M-1	Tvu	Volcanics	Oligocene	Undescribed.	Hintze, 1980
M-2	Tt	Ash-flow tuff	Oligocene and Eocene	Sequence of four slightly to densely welded, latitic to dacitic tuffs, locally separated by interbedded laharic breccias and lava flows. Thickness of each tuff unit 100 to 450 ft. Basal tuff is andesitic.	Hintze, 1981; Leedom, 1974; Pierce, 1974
	Tl	Laharic breccia	Oligocene and Eocene	Sequence of laharic breccias interbedded with volcanic rocks. Mafic lava blocks and lapilli in sandy, tuffaceous, well-cemented matrix. Upper part includes pumiceous layers; thickness as much as 100 ft. Middle part contains interbedded lava flows; thickness as much as 1,500 ft. Lower part, matrix consists of finely comminuted rock material, and contains some ash-flow tuff beds; thickness as much as 500 ft.	

M-3	Tt	Tuff	Oligocene	Rhyolitic, welded tuff; as much as 400 ft thick.	Hose, 1965
M-4	Tt	Needles Range Formation, Wah Wah Springs Tuff Member	Oligocene 29 to 30 m.y.	Mostly welded, dacite tuff; as much as 200 ft thick.	Hintze, 1974b; Rowley and others, 1979
M-5	Tt	Isom Formation	Oligocene about 25 m.y.	Densely welded, ash-flow tuff with few crystals. Occurs only in southwestern part of area.	Anderson, 1980; Bushman, 1973; Hintze, 1974a, 1974c, 1974d; Hintze and others, 1981; Rowley and others, 1979; Steven and Morris, 1983
		Needles Range Formation, Wah Wah Springs and Cottonwood Wash Tuff Members	Oligocene 29 to 30 m.y.	Wah Wah Springs Tuff, dacitic welded tuff, as much as 300 ft thick. Cottonwood Wash Tuff, bedded to massive, non-welded, dacitic tuff, contains some interbedded conglomerate; as much as 300 ft thick.	
	Tts	Tunnel Spring Tuff	Oligocene 33 m.y.	Nonwelded, rhyolitic, ash-flow tuff, bedded to massive, jointed; at Crystal Peak, the type section, maximum thickness is 1,000 ft.	
M-6	Tv	Mount Belknap Volcanics	Miocene 18.0 to 19.6 m.y.	In descending order: Upper tuff member, rhyolitic, welded, ash-flow tuff with few crystals; occurs within caldera. Mount Baldy Rhyolite Member, lava flows and feeder dikes, occurs primarily within the caldera. Volcaniclastic rocks, dominantly laharic mudflow breccias, minor landslide debris, and fluviatile sands and gravels. Joe Lott Tuff Member, welded, rhyolitic ash-flow tuff with few crystals; comprises most of outflow facies of Mount Belknap Volcanics. Middle tuff member, welded ash-flow tuff with few crystals; caldera fill. Blue Lake Rhyolite Member, lava flows within caldera.	Caskey and Shuey, 1975; Cunningham and Steven, 1980; Hintze, 1980; Rowley and others, 1979; Steven and Morris, 1981
		Osiris Tuff	Miocene about 22 m.y.	Densely welded, rhyodacitic ash-flow tuff.	

		Bullion Canyon Volcanics	Miocene and Oligocene 27 m.y.	Lava flows of intermediate composition and volcanic breccias overlie Three Creeks Tuff Member, which is densely welded, quartz latitic ash-flow tuff. Radiometric date is from this tuff.	
		Volcanics of Wales Canyon	Oligocene	Lava flows of intermediate composition and welded, ash-flow tuffs. Tuffs formerly called Wales Canyon Tuff Member of Bullion Canyon Volcanics by Caskey and Shuey (1975).	
		Needles Range Formation	Oligocene 29 to 30 m.y.	Wah Wah Springs Tuff Member, which probably comprises all of formation, is welded ash-flow tuff, locally interlayered with volcanics of Dog Valley. Tuff has minimum thickness of 395 ft.	
		Volcanics of Dog Valley	Oligocene	Heterogeneous assemblage of lava flows of intermediate composition, tuff breccias, and local and regional ash-flow tuffs. Thickness of 800 ft as determined from cross-section (Steven and Morris, 1981).	
	Tvu	Volcanics	Oligocene	Undescribed.	
	Tzt	Ash-flow tuff	Miocene(?)	Nonwelded, zeolitic, ash-flow tuff matrix almost completely converted to clinoptilolite.	
M-7	Tv	Dacite of Wah Wah Cove	Oligocene 33.1 and 33.6 m.y.	Massive, dacitic, lapilli tuff, more than 330 ft thick, overlain by more than 1,150 ft of dacite lava flows.	Hintze and others, 1981; Steven and Morris, 1983
			TOOELE COUNTY (T)		
T-1	Tv	Volcanic rocks	Tertiary	Interbedded latite flows, breccia tuff, and glassy welded tuff. Typically, units of water-laid tuff and pebble-conglomerate 20 to 40 ft thick separate flows or breccias. Total thickness 820 to 1,400 ft.	Moore and Sorensen, 1979; Rigby, 1958
T-2	Tv	Volcanic rocks	Tertiary	Breccia, water-laid tuff, and lava flows.	Gilluly, 1932; Moore and Sorensen, 1979

UTAH COUNTY (U)					
U-1	Tl	Laharic breccia	Oligocene or Eocene	Laharic breccia, locally contain lenses of water-laid tuff, tuffaceous sandstone, and gravel.	Moore, 1973
U-2	Tvu	Volcanics	Oligocene	Undescribed.	Hintze, 1980
U-3	Tv	Tintic Delmar Latite	Middle Oligocene 32.2±1 and 32.3±1 m.y.	Consists of a latite-flow member 100 to 200 ft thick and an underlying tuff member 75 to 190 ft thick, comprised of heterogeneous assemblage of volcanic ash, lapilli tuff, and agglomeratic breccia. Unit overlies Pinyon Queen Latite.	Morris, 1964, 1975; Morris and Lovering, 1979; Proctor and others, 1956
		Pinyon Queen Latite	Middle Oligocene	Consists of latite flow as much as 700 ft thick and an underlying assemblage of about 400 ft thick, comprised of heterogeneous assemblage of tuff, breccia, and agglomerate.	
		North Standard Latite	Middle Oligocene	Consists of latite-flow member 300 to 500 ft thick and an underlying tuff member consisting of heterogeneous, tuffaceous agglomerate containing boulders in matrix of volcanic ash and gravel. Incorporates alluvium, colluvium, and fine-grained tuff deposited prior to extrusion of overlying flow member.	
		Big Canyon Latite	Middle Oligocene	Consists of latite-flow member as much as 95 ft thick and an underlying tuff member as much as 125 ft thick, comprised of moderately to very altered air-fall tuff.	
		Latite Ridge Latite	Middle Oligocene	Upper part, welded tuff locally more than 500 ft thick. Lower, part, air-fall and water-laid tuff, as much as 100 ft thick. Unit mostly unaltered.	
	Tt	Copperopolis Latite	Middle Oligocene	In descending order: Middle agglomerate member as much as 4,000 ft thick; upper part of formation not present. Lower flow member as much as 3,000 ft thick. Tuff member, prominently bedded air-fall tuff; thickness as much as 2,000 ft. Lower agglomerate member as much as 3,500 ft thick. Crops out in southernmost part of area.	

U-4	Tls	Laguna Springs Volcanic Group	Oligocene	Chiefly latitic and andesitic tuff interbedded with volcanic flows, agglomerate, and breccia. Thickness possibly as much as 1,000 ft.	Hardy, 1962; Morris and Lovering, 1979; Muessig, 1951; I.J.Witkind, and M.R. Weiss, U.S. Geological Survey, unpublished data
	Tv	Volcanic rocks	Tertiary	Volcaniclastic and pyroclastic rocks and sediments; similar to Goldens Ranch Formation of Muessig (1951) and Moroni Formation of Hardy (1962) in appearance and lithology. Age and correlation uncertain.	
	Tm	Moroni Formation of Hardy (1962)	Tertiary, possibly Oligocene to middle Eocene	Lithologically similar to Moroni Formation in county area J-6.	
			WASHINGTON COUNTY (W)		
W-1	Tv	Ox Valley Tuff	Miocene 12.3 and 15.1 m.y.	Slightly to densely welded, rhyolitic ash-flow tuff. Thickness as much as 400 ft; overlain by rhyodacite lava flows as much as 1,200 ft thick. Located in Bull Valley Mountains. Source may have been Caliente cauldron in eastern Nevada.	Blank, 1959; Cook, 1957, 1960; Ekren and others, 1977; Hintze, 1980; Mackin, 1960; Morris, 1980; Rowley and others, 1979; Stewart and Carlson, 1978 Tobey, 1976
		Racer Canyon Tuff	Miocene 18.2 and 20.3 m.y.	Widespread silicic ash-flow tuff. Formerly designated as Kane Point Tuff Member of Page Ranch Formation (Mackin, 1960). Source probably Caliente cauldron.	
		Page Ranch Formation	Miocene	Poorly bedded tuff breccia restricted to southeast part of area; possibly of laharic origin.	
		Rencher Formation	Miocene	Welded, ash-flow tuff, tuff breccia, breccia, lava flows, air-fall tuffs, volcanic sandstone, limestone, and conglomerate; unit as much as 1,000 ft thick in eastern Bull Valley Mountains.	
		Post-Quichapa tuff	Miocene	Moderately welded, latite tuff, as much as 375 ft thick. Crops out in northwest part of area; overlies Harmony Hills Tuff of Quichapa Group.	

	Quichapa Group:	Miocene 21 to 24 m.y.	
	Harmony Hills Tuff	Miocene	Harmony Hills Tuff, dacitic, as much as 420 ft thick.
	Little Creek breccia	Miocene	Little Creek breccia, andesite lava flows and breccia flows; as much as 1,115 ft thick.
	Condor Canyon Formation, Bauers Tuff Member	Miocene	Bauers Tuff Member, which comprises the entire Condor Canyon Formation, is welded latite tuff, as much as 65 ft thick.
	Leach Canyon Formation	Miocene	Leach Canyon Formation, moderately welded, latite tuff, as much as 375 ft thick.
	Isom Formation, Hole-in-the-Wall Tuff Member, Baldhills Tuff Member, and unnamed lava flow	Late Oligocene 25.7 m.y.	Hole-in-the-Wall Tuff Member, welded, vitric tuff about 20 ft thick. Baldhills Tuff Member, dense, vitric tuff, as much as 20 ft thick. Basal lava flow, extensive, as much as 175 ft thick.
	Needles Range Formation	Oligocene 29 to 30 m.y.	Ash-flow tuff, generally less than 330 ft thick, missing locally.
Tvu	Volcanics	Tertiary	Undescribed.
Tt	Tuffs	Miocene and Oligocene	Unit extended into area from Nevada, where it is described by Ekren and others (1977) as welded ash-flow tuff and interbedded ash-fall tuff; thickness exceeds 500 ft.

Part B.--CALDERAS AND CAULDRONS

Caldera name	Description	References
	BEAVER COUNTY (B)	
Big John caldera	Formed 22 m.y. ago by eruption of Delano Peak Tuff Member of Bullion Canyon Volcanics. More than 1,000 ft of collapse along east and southeast margins of caldera; west margin poorly exposed and may not have been block faulted.	Steven, Cunningham, and Anderson, 1979; Steven, Rowley, and Cunningham, 1978
Indian Peak caldera	Formed 29 m.y. ago by eruption of Wah Wah Springs Tuff Member of Needles Range Formation. Resurgence accompanied emplacement of the Indian Peak pluton. Thick ash-flow tuffs in Escalante Desert Formation, north of Indian Peak, may indicate earlier cauldron.	Best and Davis, 1981; Best and others, 1979; Grant, 1979; Grant and Best, 1979b
Mount Belknap caldera	Formed 19 m.y. ago by eruption of Joe Lott Tuff Member of Mount Belknap Volcanics.	Cunningham and Steven, 1978, 1979; Steven, Cunningham, Naeser, and Mehnert, 1979
	JUAB COUNTY	
Desert caldera	Formed during middle Tertiary by eruption of flows of intermediate composition and silicic ash-flow tuffs; quartz monzonite intrusion of Desert Mountain probably represents a resurgent dome, as indicated by magnetic data.	Shawe, 1972
Dugway Valley cauldron	Formed 38 m.y. ago by eruption of the Joy Tuff. East side of cauldron may coincide with east side of Thomas caldera.	Lindsey, 1982; Shawe, 1972
Keg caldera	Formed during middle Tertiary by eruption of unnamed rhyolitic ash-flow tuff in Keg Mountains. Magnetic data indicate central resurgent intrusion.	Shawe, 1972
Thomas caldera	Formed 39 m.y. ago by eruption of the Mount Laird Tuff and later filled with Joy Tuff and the Dell Tuff. Intrusive equivalents of Mount Laird Tuff occur outside the caldera. Magnetic data indicate core of caldera is intruded by igneous rock.	Lindsey, 1979, 1982; Shawe, 1972

UTAH COUNTY		
Tintic Mountain caldera	Inferred buried caldera of Oligocene age which probably formed by eruption of the Packard and Fernow Quartz Latites. Caldera is 8 1/2 mi in diameter and 3,000 ft deep. Large positive magnetic anomaly centered on the inferred caldera.	Mabey and Morris, 1967; Morris, 1975

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