

Plate 1 Utah Geological Survey Map 272DM Geologic Map of the Goshen Quadrangle



1 870 000 FEET (SLATE JACK CANYON) 3663 IV SW 417 57'30" 419 MONA 5 MI. 424000mE



ADJOINING 7.5' QUADRANGLE NAMES



UTAH GEOLOGICAL SURVEY a division of Utah Department of Natural Resources



Formation			1				Volcanic	rocks of Goshe	n Canyon						
Member	Andesite dikes member Pyroxene latite member			tite member		Hornblende latite member			Shoshonite lava member		Volcanie	c conglomerate	member		
Map Unit Sample Number Rock Type	T GN2011-392 dike	vd GN2011-393 dike	GN2011-346 lava flow	T GN2011-391 lava flow	vp GN2011-399 lava flow	GN2011-400 lava flow	GN2011-390 lava flow	Tvh GN2011-396 lava flow	GN2011-397 lava flow	Tvs GN2011-387 lava flow	GN2011-385 clast	GN2011-386 clast	Tvc GN2011-394 clast	GN2011-398 clast	GN2011- clast
Rock Name Latitude Longitude	andesite 39.89172 -111.91071	andesite 39.88872 -111.91442	latite 39.89072 -111.88579	latite 39.89297 -111.90954	latite 39.87521 -111.92204	latite 39.87445 -111.92010	andesite 39.89438 -111.90976	latite 39.87557 -111.91456	latite 39.87498 -111.91625	shoshonite 39.89710 -111.91986	andesite 39.89463 -111.92067	dacite 39.89463 -111.92067	latite 39.88889 -111.91509	dacite 39.87606 -111.91831	shoshon 39.8912 -111.926
Easting Northing	422139 4416136	421818 4415807	424268 4416004	422240 4416274	421151 4414314	421316 4414228	422223 4416431	421791 4414347	421646 4414283	421363 4416741	421291 4416468	421291 4416468	421761 4415826	421471 4414405	420754 441609
Normalized to 100%	on a volatile fre 60 61	e basis 60 26	56 89	56 91	60 66	60 89	61 52	60 11	61 41	56 01	58 30	65 43	56 81	65 70	56 21
۲iO ₂	0.89	0.83	1.06	1.06	0.91	0.90	0.74	0.84	0.85	1.14	1.02	0.49	1.09	0.47	1.02
N ₂ O ₃	17.64	17.18	17.80	17.97	17.78	17.68	17.92	18.55	18.30	16.84	17.33	17.76	18.00	17.85	17.96
e ₂ O ₃	6.72	6.28	8.61	8.45	5.74	6.46	5.65	7.12	6.60	9.15	7.58	3.79	7.70	4.08	8.12
InO IgO	0.09	0.14	0.13	0.13	0.12	0.09	0.13	0.14	0.05	0.18	0.14	0.06	0.16	0.07	0.20
CaO	5.61	6.34	6.45	6.53	6.03	5.20	5.32	4.88	4.67	6.76	6.15	3.70	6.77	3.87	7.27
la ₂ O	3.64	3.43	3.30	3.26	3.31	3.33	3.45	3.49	3.57	2.96	2.59	3.29	3.32	3.05	2.77
2 ₂ 0	2.75	3.06	2.92	2.93	3.50	3.52	3.26	3.27	3.41	3.03	3.52	3.94	3.20	4.07	3.30
20 ₅	0.45	0.44	0.43	0.43	0.42	0.43	0.36	0.44	0.42	0.36	0.36	0.21	0.42	0.24	0.45
otal	100.00	100.00	100.00	100.00	100.00	100.00	100.00	100.00	100.00	100.00	100.00	100.00	100.00	100.00	100.00
Analytical Total	99.51	99.84	99.98	99.62	99.00	99.91	99.63	98.91	100.00	99.77	99.91	99.58	100.10	99.59	100.05
V	81	79	149	127	71	70	38	54	74	199	150	27	141	12	146
)r	<10	<10	<10	<10	<10	<10	10	<10	<10	20	10	<10	<10	<10	<10
Co	9	10	18	17	11	10	6	13	10	26	20	5	20	3	21
a ?b	20 65	20 74	25 75	24 71	∠o 114	25 114	25 94	25 77	24 95	24 87	24 104	23 145	25 89	23 132	25 112
ŝr	893	733	716	724	737	712	783	692	714	575	586	665	690	650	728
(38	39	34	33	51	43	34	34	35	37	37	27	33	31	35
.r Ib	298 14	306	332	338	376	362	305	320 15	304	246	256	385	298	331	280 13
3a	1190	1210	1385	1380	1310	1245	1220	1565	1565	1210	1275	1605	1545	1500	1405
'n	10	9	8	8	14	14	12	9	9	9	11	15	8	13	9
J	2	2	2	2	3	3	2	2	2	2	3 51	3 61	2	3	2 49
Ce	121	124	92	92	137	132	128	103	104	93	100	116	91	120	99
Pr	15.1	14.2	10.8	10.7	15.7	15.2	14.7	11.9	12.4	10.8	11.5	12.8	10.7	13.3	11.5
Nd Sm	57.3	53.2	41.8	41.3	58.4	56.9	53.7	45.3	45.9	41.2	43.6	46.2	40.9	47.9	44.1
om Eu	2 73	9.6 2.55	8.3 2.45	7.9 2.43	2.66	2 64	9.5 2.46	8.0 2.42	8.5 2.47	8.4 2.22	8.4 2.21	7.6 2.01	٥. ۱ 2 33	8.1 2.17	8.5 2.44
Gd	8.77	8.09	7.09	7.19	9.26	9.07	7.72	7.24	7.21	7.52	7.64	5.91	7.09	6.57	7.49
ſb	1.17	1.11	0.98	1.01	1.33	1.31	1.05	1.01	1.01	1.08	1.10	0.81	1.01	0.90	1.05
Jy	6.99 1 37	7.03 1.40	6.02 1.16	6.06 1.21	8.30 1.72	7.83 1.56	6.16 1.23	6.18 1 22	5.94 1.22	6.63 1.32	6.83 1.36	4.//	6.07 1.21	5.29	6.39 1.26
Er	3.90	4.02	3.25	3.39	4.95	4.51	3.58	3.50	3.40	3.77	3.90	2.69	3.34	3.19	3.58
Γm	0.53	0.57	0.46	0.47	0.70	0.62	0.50	0.48	0.48	0.55	0.55	0.40	0.47	0.45	0.50
/b	3.38	3.76	2.98	3.06	4.57	4.04	3.32	3.23	3.20	3.45	3.56	2.61	3.09	2.99	3.25
lu No	<2	<2	<2	<2	<2	2	2	<2	<2	<2	<2	<2	<2	2	<2
Sn	2	2	1	1	2	2	2	1	1	2	2	2	1	2	2
Cs	0.6	1.1	1.9	1.9	4.1	3.0	2.2	0.6	2.4	2.0	2.4	2.6	2.4	3.0	2.9
п Га	8 0.7	8 0.7	8 0.7	8	10	10	8 0.8	8 0.8	8 0.8	06	07	10	8 07	8	06
14	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2

Reference: McKean and others, 2013





conglomerate member of the volcanic rocks of Goshen Canyon (Tvc). Mount Nebo and Wasatch Range can be seen in the background.

INDEX OF GEOLOGIC MAPPING



GEOLOGIC SYMBOLS

	Contact - Dashed where approximately located
10(9.2)	Normal fault – Dashed where approximately located, dotted where concealed; bar and ball on downthrown side; height of fault scarp and amount of vertical surface offset (in parentheses) shown in feet
	Steeply dipping fault, uncertain sense of displacement – Dashed where approximately located; dotted where concealed and approximately located
¶G	Geophysical fault, concealed and inferred, G = from gravity (Cook and others, 1997), very approximately located, bar and ball on hanging wall
	Axial trace of overturned (reclined) anticline – Dotted where concealed and approximately located
— † — — — — — — — — — — — — — — — — — — —	Axial trace of syncline – Dashed where approximately located; dotted where concealed and approximately located
	Lacustrine shorelines – Major shorelines of the Bonneville lake cycle. Mapped at the wave-cut bench of erosional shorelines and the top of constructional bars and barrier beaches; may coincide with geologic contacts
———В— — — —	Bonneville shoreline, highest shoreline of the Bonneville (transgressive) phase
t	Other transgressive shorelines of the Bonneville phase (present above the Provo shoreline)
P	Provo shoreline, highest shoreline of the Provo (regressive) phase
r	Other mostly regressive shorelines of the Provo phase (present below the Provo shoreline)
	Geomorphic surface, lacustrine sand ridge (see Qlsy)
	Landslide scarp – Hachures on down-dropped side
21	Strike and dip of inclined bedding
65 - 	Strike and dip of overturned bedding
25	Strike and dip of volcanic foliation
\sim	Sand and gravel pit
\succ	Adit
0~~	Spring
\odot	Water well (selected)
+ GN2011-100	Rock sample location and number for geochemical (McKean and others, 2013) and geochronology analysis (UGS and NIGL, 2013).
Qlgb/Tvc	Stacked unit – Denotes thin cover of first unit overlying second unit
A	Line of cross section

GEOLOGIC UNITS (see booklet for complete unit descriptions)

Qal ₁	Level-1 stream alluvium deposits
Qal ₂	Level-2 stream alluvium deposits
Qaly	Young stream alluvium deposits, undivided
Qay	Alluvial flood plain, alluvial fan, and channel deposits
Qaf ₁	Level-1 alluvial-fan deposits
Qaf ₂	Level-2 alluvial-fan deposits
Qafy	Younger alluvial-fan deposits, undivided
Qafd	Distal alluvial-fan deposits
Qafb	Alluvial-fan deposits, transgressive (Bonneville) phase of Lake Bonneville
Qd	Deltaic deposits
Qh	Fill and disturbed land
Qhm	Mine waste disposal ponds
Qlsy	Younger lacustrine sand and silt
Qlmy	Younger lacustrine silt and clay
Qlm	Lacustrine silt and clay, undivided Lake Bonneville
Qlgp	Lacustrine gravel and sand, regressive phase of Lake Bonneville
Qlsp	Lacustrine sand and silt, regressive phase of Lake Bonneville
Qlgb	Lacustrine gravel and sand, transgressive phase of Lake Bonneville
Qlsb	Lacustrine sand and silt, transgressive phase of Lake Bonneville
Qes	Eolian sand and silt deposits
Qms -	Landslide deposits
	Talus deposits
Qsm	Spring and marsh deposits
Qac	Alluvial and colluvial deposits, undivided
Qla	Lacustrine and alluvial deposits, undivided
Qlgb/Tpc	Lacustrine gravel and sand (transgressive phase of Lake Bonneville) over Pinyon Creek Conglomerate
Qlgb/Tvc	Lacustrine gravel and sand (transgressive phase of Lake Bonneville) over volcanic conglomerate
Qlgb/Pz	Lacustrine gravel and sand (transgressive phase of Lake Bonneville) over Paleozoic bedrock
Qlgb/Pz Qlgb/€ac	Lacustrine gravel and sand (transgressive phase of Lake Bonneville) over Paleozoic bedrock Lacustrine gravel and sand (transgressive phase of Lake Bonneville) over Upper-Middle Cambrian bedrock
Qlgb/₽z Qlgb/€ac Qlgb/€t	Lacustrine gravel and sand (transgressive phase of Lake Bonneville) over Paleozoic bedrock Lacustrine gravel and sand (transgressive phase of Lake Bonneville) over Upper-Middle Cambrian bedrock Lacustrine gravel and sand (transgressive phase of Lake Bonneville) over Tintic Quartzite
Qlgb/Pz Qlgb/Cac Qlgb/Ct Tj	Lacustrine gravel and sand (transgressive phase of Lake Bonneville) over Paleozoic bedrock Lacustrine gravel and sand (transgressive phase of Lake Bonneville) over Upper-Middle Cambrian bedrock Lacustrine gravel and sand (transgressive phase of Lake Bonneville) over Tintic Quartzite Jasperoid
Qlgb/Pz Qlgb/Cac Qlgb/Ct Tj Tpc	Lacustrine gravel and sand (transgressive phase of Lake Bonneville) over Paleozoic bedrock Lacustrine gravel and sand (transgressive phase of Lake Bonneville) over Upper-Middle Cambrian bedrock Lacustrine gravel and sand (transgressive phase of Lake Bonneville) over Tintic Quartzite Jasperoid Pinyon Creek conglomerate, only mapped as a stacked unit
Qlgb/Pz Qlgb/Cac Qlgb/Ct Tj Tpc Tvd	Lacustrine gravel and sand (transgressive phase of Lake Bonneville) over Paleozoic bedrock Lacustrine gravel and sand (transgressive phase of Lake Bonneville) over Upper-Middle Cambrian bedrock Lacustrine gravel and sand (transgressive phase of Lake Bonneville) over Tintic Quartzite Jasperoid Pinyon Creek conglomerate, only mapped as a stacked unit Volcanic rocks of Goshen Canyon, andesite dikes member
Qlgb/Pz Qlgb/Cac Qlgb/Ct Tj Tpc Tvd Tvc	Lacustrine gravel and sand (transgressive phase of Lake Bonneville) over Paleozoic bedrock Lacustrine gravel and sand (transgressive phase of Lake Bonneville) over Upper-Middle Cambrian bedrock Lacustrine gravel and sand (transgressive phase of Lake Bonneville) over Tintic Quartzite Jasperoid Pinyon Creek conglomerate, only mapped as a stacked unit Volcanic rocks of Goshen Canyon, andesite dikes member
Qlgb/Pz Qlgb/Cac Qlgb/Ct Tj Tpc Tvd Tvc Tvc Tvp	Lacustrine gravel and sand (transgressive phase of Lake Bonneville) over Paleozoic bedrock Lacustrine gravel and sand (transgressive phase of Lake Bonneville) over Upper-Middle Cambrian bedrock Lacustrine gravel and sand (transgressive phase of Lake Bonneville) over Tintic Quartzite Jasperoid Pinyon Creek conglomerate, only mapped as a stacked unit Volcanic rocks of Goshen Canyon, andesite dikes member Volcanic rocks of Goshen Canyon, volcanic conglomerate member
Qlgb/Pz Qlgb/Cac Qlgb/Ct Tj Tpc Tvd Tvc Tvp Tvp Tvh	Lacustrine gravel and sand (transgressive phase of Lake Bonneville) over Paleozoic bedrock Lacustrine gravel and sand (transgressive phase of Lake Bonneville) over Upper-Middle Cambrian bedrock Lacustrine gravel and sand (transgressive phase of Lake Bonneville) over Tintic Quartzite Jasperoid Pinyon Creek conglomerate, only mapped as a stacked unit Volcanic rocks of Goshen Canyon, andesite dikes member Volcanic rocks of Goshen Canyon, volcanic conglomerate member Volcanic rocks of Goshen Canyon, pyroxene latite member Volcanic rocks of Goshen Canyon, hornblende latite member
Qlgb/P2 Qlgb/Cac Qlgb/Ct Tj Tpc Tvd Tvc Tvp Tvh Tvh Tvs	Lacustrine gravel and sand (transgressive phase of Lake Bonneville) over Paleozoic bedrock Lacustrine gravel and sand (transgressive phase of Lake Bonneville) over Upper-Middle Cambrian bedrock Lacustrine gravel and sand (transgressive phase of Lake Bonneville) over Tintic Quartzite Jasperoid Pinyon Creek conglomerate, only mapped as a stacked unit Volcanic rocks of Goshen Canyon, andesite dikes member Volcanic rocks of Goshen Canyon, volcanic conglomerate member Volcanic rocks of Goshen Canyon, pyroxene latite member Volcanic rocks of Goshen Canyon, hornblende latite member Volcanic rocks of Goshen Canyon, shoshonite lava member
Qlgb/Pz Qlgb/Cac Qlgb/Ct Tj Tpc Tvd Tvc Tvp Tvp Tvh Tvs Tpb Ts	Lacustrine gravel and sand (transgressive phase of Lake Bonneville) over Paleozoic bedrock Lacustrine gravel and sand (transgressive phase of Lake Bonneville) over Upper-Middle Cambrian bedrock Lacustrine gravel and sand (transgressive phase of Lake Bonneville) over Tintic Quartzite Jasperoid Pinyon Creek conglomerate, only mapped as a stacked unit Volcanic rocks of Goshen Canyon, andesite dikes member Volcanic rocks of Goshen Canyon, volcanic conglomerate member Volcanic rocks of Goshen Canyon, pyroxene latite member Volcanic rocks of Goshen Canyon, hornblende latite member Volcanic rocks of Goshen Canyon, shoshonite lava member
Qlgb/P2 Qlgb/Cac Qlgb/Cac Tj Tpc Tvd Tvc Tvp Tvh Tvb Tvh Tvs Tpb Ts Pz	Lacustrine gravel and sand (transgressive phase of Lake Bonneville) over Paleozoic bedrock Lacustrine gravel and sand (transgressive phase of Lake Bonneville) over Upper-Middle Cambrian bedrock Lacustrine gravel and sand (transgressive phase of Lake Bonneville) over Tintic Quartzite Jasperoid Pinyon Creek conglomerate, only mapped as a stacked unit Volcanic rocks of Goshen Canyon, andesite dikes member Volcanic rocks of Goshen Canyon, volcanic conglomerate member Volcanic rocks of Goshen Canyon, pyroxene latite member Volcanic rocks of Goshen Canyon, hornblende latite member Volcanic rocks of Goshen Canyon, shoshonite lava member Packard Quartz Latite, lava flow breccia member Packard Quartz Latite, lava flow breccia member
Qlgb/P ₂ Qlgb/Cac Qlgb/Cac Tj Tpc Tvd Tvc Tvp Tvh Tvb Tvh Tvs Tpb Ts P ₂ Mh	Lacustrine gravel and sand (transgressive phase of Lake Bonneville) over Paleozoic bedrock Lacustrine gravel and sand (transgressive phase of Lake Bonneville) over Upper-Middle Cambrian bedrock Lacustrine gravel and sand (transgressive phase of Lake Bonneville) over Tintic Quartzite Jasperoid Pinyon Creek conglomerate, only mapped as a stacked unit Volcanic rocks of Goshen Canyon, andesite dikes member Volcanic rocks of Goshen Canyon, volcanic conglomerate member Volcanic rocks of Goshen Canyon, pyroxene latite member Volcanic rocks of Goshen Canyon, hornblende latite member Volcanic rocks of Goshen Canyon, shoshonite lava member Packard Quartz Latite, lava flow breccia member Tertiary strata Paleozoic strata, undivided
Qlgb/Pz Qlgb/Cac Qlgb/Ct Tj TpC Tvd Tvc Tvp Tvh Tvb Tvb Tvb Tpb Ts Pz Mh	Lacustrine gravel and sand (transgressive phase of Lake Bonneville) over Paleozoic bedrock Lacustrine gravel and sand (transgressive phase of Lake Bonneville) over Upper-Middle Cambrian bedrock Lacustrine gravel and sand (transgressive phase of Lake Bonneville) over Tintic Quartzite Jasperoid Pinyon Creek conglomerate, only mapped as a stacked unit Volcanic rocks of Goshen Canyon, andesite dikes member Volcanic rocks of Goshen Canyon, volcanic conglomerate member Volcanic rocks of Goshen Canyon, pyroxene latite member Volcanic rocks of Goshen Canyon, hornblende latite member Volcanic rocks of Goshen Canyon, shoshonite lava member Packard Quartz Latite, lava flow breccia member Paleozoic strata, undivided Humbug Formation Deseret Limestone
Qlgb/Pz Qlgb/Cac Qlgb/Cac Tj Tpc Tvd Tvc Tvc Tvp Tvh Tvh Tvs Pz Pz Mh Md	Lacustrine gravel and sand (transgressive phase of Lake Bonneville) over Paleozoic bedrock Lacustrine gravel and sand (transgressive phase of Lake Bonneville) over Upper-Middle Cambrian bedrock Lacustrine gravel and sand (transgressive phase of Lake Bonneville) over Tintic Quartzite Jasperoid Pinyon Creek conglomerate, only mapped as a stacked unit Volcanic rocks of Goshen Canyon, andesite dikes member Volcanic rocks of Goshen Canyon, volcanic conglomerate member Volcanic rocks of Goshen Canyon, volcanic conglomerate member Volcanic rocks of Goshen Canyon, pyroxene latite member Volcanic rocks of Goshen Canyon, hornblende latite member Volcanic rocks of Goshen Canyon, shoshonite lava member Packard Quartz Latite, lava flow breccia member Tertiary strata Paleozoic strata, undivided Humbug Formation Deseret Limestone
Qlgb/Pz Qlgb/Cac Qlgb/Ct Tj TpC Tvd Tvd Tvc Tvp Tvh Tvs Tpb Ts Pz Mh Md Mg	Lacustrine gravel and sand (transgressive phase of Lake Bonneville) over Paleozoic bedrock Lacustrine gravel and sand (transgressive phase of Lake Bonneville) over Upper-Middle Cambrian bedrock Lacustrine gravel and sand (transgressive phase of Lake Bonneville) over Tintic Quartzite Jasperoid Pinyon Creek conglomerate, only mapped as a stacked unit Volcanic rocks of Goshen Canyon, andesite dikes member Volcanic rocks of Goshen Canyon, volcanic conglomerate member Volcanic rocks of Goshen Canyon, pyroxene latite member Volcanic rocks of Goshen Canyon, hornblende latite member Volcanic rocks of Goshen Canyon, shoshonite lava member Packard Quartz Latite, lava flow breccia member Paleozoic strata, undivided Humbug Formation Deseret Limestone Gardison Limestone Fitchville Formation
Qlgb/Pz Qlgb/Pz Qlgb/Cac Tj TpC Tvd Tvc Tvc Tvp Tvh Tvs Tpb Ts Pz Pz Mh Md Md Mg MDf	Lacustrine gravel and sand (transgressive phase of Lake Bonneville) over Paleozoic bedrock Lacustrine gravel and sand (transgressive phase of Lake Bonneville) over Upper-Middle Cambrian bedrock Lacustrine gravel and sand (transgressive phase of Lake Bonneville) over Tintic Quartzite Jasperoid Pinyon Creek conglomerate, only mapped as a stacked unit Volcanic rocks of Goshen Canyon, andesite dikes member Volcanic rocks of Goshen Canyon, volcanic conglomerate member Volcanic rocks of Goshen Canyon, pyroxene latite member Volcanic rocks of Goshen Canyon, hornblende latite member Volcanic rocks of Goshen Canyon, shoshonite lava member Volcanic rocks of Goshen Canyon, shoshonite lava member Packard Quartz Latite, lava flow breccia member Paleozoic strata, undivided Humbug Formation Deseret Limestone Gardison Limestone Fitchville Formation Devonian-Silurian-Ordovician strata, undivided
Qlgb/Pz Qlgb/Pz Qlgb/Cac Tj Tpc Tvc Tvd Tvc Tvp Tvh Tvs Pz Mh Md Mg MDf DOu Dp	Lacustrine gravel and sand (transgressive phase of Lake Bonneville) over Paleozoic bedrock Lacustrine gravel and sand (transgressive phase of Lake Bonneville) over Upper-Middle Cambrian bedrock Lacustrine gravel and sand (transgressive phase of Lake Bonneville) over Tintic Quartzite Jasperoid Pinyon Creek conglomerate, only mapped as a stacked unit Volcanic rocks of Goshen Canyon, andesite dikes member Volcanic rocks of Goshen Canyon, volcanic conglomerate member Volcanic rocks of Goshen Canyon, pyroxene latite member Volcanic rocks of Goshen Canyon, pyroxene latite member Volcanic rocks of Goshen Canyon, shoshonite lava member Paleozoic strata, undivided Humbug Formation Deseret Limestone Gardison Limestone Fitchville Formation Pavonian-Silurian-Ordovician strata, undivided Pinyon Peak Limestone
Qlgb/Pz Qlgb/Pz Qlgb/Cac Tj Tpc Tvd Tvc Tvc Tvp Tvh Tvs Pz Mh Md Md Mg MDf DOu Dp	Lacustrine gravel and sand (transgressive phase of Lake Bonneville) over Paleozoic bedrock Lacustrine gravel and sand (transgressive phase of Lake Bonneville) over Upper-Middle Cambrian bedrock Lacustrine gravel and sand (transgressive phase of Lake Bonneville) over Tintic Quartzite Jasperoid Pinyon Creek conglomerate, only mapped as a stacked unit Volcanic rocks of Goshen Canyon, andesite dikes member Volcanic rocks of Goshen Canyon, volcanic conglomerate member Volcanic rocks of Goshen Canyon, pyroxene latite member Volcanic rocks of Goshen Canyon, hornblende latite member Volcanic rocks of Goshen Canyon, shoshonite lava member Volcanic rocks of Goshen Canyon, shoshonite lava member Packard Quartz Latite, lava flow breccia member Paleozoic strata, undivided Humbug Formation Deseret Limestone Fitchville Formation Pivon Peak Limestone Pinyon Peak Limestone
Qlgb/P ₂ Qlgb/Cac Qlgb/Cac Tj TpC TvC TvC TvD TvC TvD Tvb Tvb Tvs P ₂ Mh Md Mg MDf Md Mg DOu Dp	Lacustrine gravel and sand (transgressive phase of Lake Bonneville) over Paleozoic bedrock Lacustrine gravel and sand (transgressive phase of Lake Bonneville) over Tintic Quartzite Lacustrine gravel and sand (transgressive phase of Lake Bonneville) over Tintic Quartzite Jasperoid Pinyon Creek conglomerate, only mapped as a stacked unit Volcanic rocks of Goshen Canyon, andesite dikes member Volcanic rocks of Goshen Canyon, volcanic conglomerate member Volcanic rocks of Goshen Canyon, pyroxene latite member Volcanic rocks of Goshen Canyon, bornblende latite member Volcanic rocks of Goshen Canyon, shoshonite lava member Volcanic rocks of Goshen Canyon, shoshonite lava member Packard Quartz Latite, lava flow breccia member Paleozoic strata, undivided Humbug Formation Deseret Limestone Fitchville Formation Pavonian-Silurian-Ordovician strata, undivided Pinyon Peak Limestone Victoria Formation Buebell Dolomite and Fish Haven Dolomite, undivided
Qlgb/Pz Qlgb/Pz Qlgb/Cac Tj TpC TvC TvC TvD TvD Tvb Tvb Tvb Tvb Tvb Tvb Mh Md Mg MDf MDf DOu Dp Dv Dv Co	Lacustrine gravel and sand (transgressive phase of Lake Bonneville) over Paleozoic bedrock Lacustrine gravel and sand (transgressive phase of Lake Bonneville) over Thtic Quartzite Lacustrine gravel and sand (transgressive phase of Lake Bonneville) over Thtic Quartzite Lacustrine gravel and sand (transgressive phase of Lake Bonneville) over Thtic Quartzite Lacustrine gravel and sand (transgressive phase of Lake Bonneville) over Thtic Quartzite Lacustrine gravel and sand (transgressive phase of Lake Bonneville) over Thtic Quartzite Lacustrine gravel and sand (transgressive phase of Lake Bonneville) over Thtic Quartzite Lacustrine gravel and sand (transgressive phase of Lake Bonneville) over Thtic Quartzite Jasperoid Phonn Creek conglomerate, only mapped as a stacked unit Volcanic rocks of Goshen Canyon, andesite dikes member Volcanic rocks of Goshen Canyon, pyroxene latite member Volcanic rocks of Goshen Canyon, shoshonite lava member Packard Quartz Latite, lava flow breccia member Packard Quartz Latite, lava flow breccia member Paleozoic strata, undivided Humbug Formation Deseret Limestone Gardison Limestone Pitchville Formation Devonian-Silurian-Ordovician strata, undivided Pinyon Peak Limestone Victoria Formation <td< th=""></td<>
Qlgb/P ₂ Qlgb/P ₂ Qlgb/Cac Tj Tpc Tvd Tvc Tvp Tvh Tvs P ₂ Mh Md Md Mg MDf Md MDf DOu Dp Dv Dv Co Co Co	Lacustrine gravel and sand (transgressive phase of Lake Bonneville) over Paleozoic bedrock Lacustrine gravel and sand (transgressive phase of Lake Bonneville) over Tiptic Quartzite Lacustrine gravel and sand (transgressive phase of Lake Bonneville) over Tiptic Quartzite Jasperoid Pinyon Creek conglomerate, only mapped as a stacked unit Volcanic rocks of Goshen Canyon, andesite dikes member Volcanic rocks of Goshen Canyon, volcanic conglomerate member Volcanic rocks of Goshen Canyon, pyroxene latite member Volcanic rocks of Goshen Canyon, homblende latite member Volcanic rocks of Goshen Canyon, shoshonite lava member Paleozoic strata, undivided Humbug Formation Deseret Limestone Fichtville Formation Piconian-Silurian-Ordovician strata, undivided Pinyon Peak Limestone Victoria Formation Buebell Dolomite and Fish Haven Dolomite, undivided Ophonga Limestone
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GEOLOGIC MAP OF THE GOSHEN QUADRANGLE, UTAH AND JUAB COUNTIES, UTAH

by Adam P. McKean, Barry J. Solomon, and Stefan M. Kirby





MAP 272DM UTAH GEOLOGICAL SURVEY *a division of* UTAH DEPARTMENT OF NATURAL RESOURCES 2015

GEOLOGIC MAP OF THE GOSHEN QUADRANGLE, UTAH AND JUAB COUNTIES, UTAH

by Adam P. McKean, Barry J. Solomon¹, and Stefan M. Kirby

¹Utah Geological Survey, retired

SCALE: 1:24,000

Cover photo: View to the northwest from Government Canyon of Long Ridge and Goshen Valley. Current Creek, which incised through a Lake Bonneville delta, is in the center of the photograph.

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GEOLOGIC MAP OF THE GOSHEN QUADRANGLE, UTAH AND JUAB COUNTIES, UTAH

by Adam P. McKean, Barry J. Solomon, and Stefan M. Kirby

INTRODUCTION

Location and Geography

The Goshen 7.5' quadrangle is located in the southern part of Goshen Valley, south of the southwest arm of Utah Lake between Long Ridge and the East Tintic Mountains. The quadrangle is located in the eastern Basin and Range physiographic province. It contains the towns of Goshen and Elberta and is bisected east to west by U.S. Highway 6 and north to south by State Route 68. Land use in the quadrangle consists primarily of agriculture, pasture land, wetlands, mudflats, and wildlife management areas.

Geologic Summary

Surficial deposits across most of the quadrangle consist of alluvial, lacustrine, and deltaic sediments of late Pleistocene Lake Bonneville (30 to 12 ka), and lacustrine sediments of Utah Lake (since ~13 ka) (Oviatt and others, 1992; Utah Lake age estimated from Godsey and others, 2005; and Machette, 1992). Table 1 provides time constraints and elevations for se-

lect surficial features produced by Lake Bonneville and Utah Lake. The Goshen fault, a newly discovered north-south striking, down-to-the-west Quaternary fault, offsets Pleistoceneand Holocene-age unconsolidated deposits in Goshen Valley and is considered to be active. The fault runs north from Long Ridge approximately 8 miles (13 km) towards the southwest arm of Utah Lake. See the Selected Geologic Hazards section for a more detailed discussion of this new fault.

Paleozoic- and Tertiary-age bedrock is exposed in Long Ridge in the southeastern part of the quadrangle. The Quaternary active Long Ridge fault forms the western and northern structural boundary for the bedrock on Long Ridge. The Paleozoic bedrock is composed of Cambrian through Mississippian marine carbonates and clastics (limestone, dolomite, shale, and sandstone); these rocks represent a long period of slow subsidence along the passive continental margin of North America. An angular unconformity that formed after Late Cretaceous convergence and thrusting of the Sevier orogeny separates the Tertiary and Paleozoic bedrock. Tertiary conglomerates in the quadrangle were deposited as synorogenic alluvial sediments sources from the advancing thrust sheets. During the Eocene-Oligocene, subduction-related intrusions,

Table 1. Ages and elevations of major shorelines of Lake Bonneville and Utah Lake in the Goshen quadrangle.

Lake Cycle and Phase	Shoreline	Ag	Elevation		
	(map symbol)	radiocarbon years (¹⁴ C yr B.P.)	calibrated years (cal yr B.P.) ¹	feet (meters)	
Lake Bonneville					
Transgressive phase	Stansbury	22,000–20,000 ²	26,500–23,900	Not recognized	
	Bonneville (B)	15,000–14,500 ³	18,300–17,600	5080–5140 (1550–1566)	
Regressive phase	Provo (P)	14,500–12,6004	17,600–14,800	4760–4790 (1450–1460)	
Gilbert episode		10,500–10,0005	12,300–11,600	Not present	
Utah Lake	Utah Lake highstand	12,000–11,500 ⁶	13,900–13,400 ⁶	4500-4505 (1372-1373)	

¹ All calibration made using OxCal ¹⁴C calibration and analysis software (version 4.2.2; Bronk Ramsey, 2009; using the IntCal09 calibration curve of Reimer and others, 2009), rounded to the nearest hundred years.

² Oviatt and others (1990).

³ Oviatt and others (1992), Oviatt (1997).

⁴ Godsey and others (2005, 2011) revised the timing of the occupation of the Provo shoreline and subsequent regression; Oviatt and others (1992) and Oviatt (1997) proposed a range from 14,500 to 14,000 ¹⁴C yr B.P.

⁵ Oviatt and others (2005), Oviatt (2014)

⁶ Estimated from data in Godsey and others (2005); Machette (1992) estimated the age of the regression of Lake Bonneville below the Utah Valley threshold at 13,000 ¹⁴C yr B.P. from earlier data.

volcanic eruptions, and associated volcanic sedimentary rocks blanketed the region and filled paleo-valleys (Morris and Lovering, 1979) within the quadrangle. Miocene and younger Basin and Range extension has since created the current basin and range topography.

Previous Work

Previous geologic maps in the Goshen quadrangle include a number of graduate student mapping projects at a variety of map scales (Muessig, 1951; Price, 1951; Madsen, 1952; and Peterson, 1953) (figure 1). Adjacent 7.5-minute quadrangles have been mapped at 1:24,000 scale. These include Eureka (Morris, 1964), Slate Jack Canyon (Jensen, 1986), Mona (Felger and others, 2004), West Mountain (Clark, 2009), Goshen Valley North (Clark and others, 2009), Tintic Mountain (Morris, 1975; Keith and others, 2009), Santaquin (Solomon, 2010), and Allens Ranch (McKean, 2011). Other maps in the area include parts of the Eureka 7.5-minute quadrangle (Keith and Kim, 1990), the Nephi 30' x 60' quadrangle (Witkind and Weiss, 1991), the East Tintic mining district (Morris and Lovering, 1979), surficial geologic maps of the Wasatch fault zone in eastern Utah Valley (Machette, 1992), and the Nephi segment of the Wasatch fault zone (Harty and others, 1997). Morris and Lovering's (1961 and 1979) stratigraphic and volcanic studies provided a valuable framework for identifying the Paleozoic and Tertiary bedrock in the Goshen quadrangle. In the Tintic Mountains, west and southwest of the quadrangle, Morris (1975) inferred a possible Eocene-Oligocene volcanic caldera in the southwest corner of the Goshen quadrangle from stratigraphic relationships, thick volcanic section, and a large positive magnetic anomaly (Mabey and Morris, 1967). No previous mapping of the quadrangle included surficial geologic mapping at a scale of 1:24,000.

METHODS

Geologic mapping of surficial deposits is based on age and depositional environment or origin. The letters of the map units indicate: (1) age, (2) depositional environment or origin, and (3) morphology, texture, lithology, or other distinctive characteristics of the deposits (Doelling and Willis, 1995). Mapping for the project was done on stereographic pairs of aerial photographs from the following sources: (1) black and white aerial photographs at approximately 1:20,000 scale from the Soil Conservation Service (1965), and (2) natural color aerial photographs at approximately 1:24,000 scale from IntraSearch (1980). Geologic contacts were updated using 2009 orthophotography (Utah Automated Geographic Reference Center, 2009). Some contacts are mapped from the soil survey maps of Trickler and Hall (1984). Barry Solomon began surficial geologic mapping on aerial photography for the Goshen quadrangle in 2010, before retiring in early 2011. In 2011, Adam McKean completed the aerial photography and field mapping of surficial and bedrock geologic units for the quadrangle. Stefan Kirby and Adam McKean completed field mapping of the Goshen fault and made additional revisions to surficial geology in 2013 and 2014. The geologic map was made by transferring the geology from the aerial photographs to orthophotography and then to a geographic information system (GIS) database using ArcGIS, at a target scale of 1:24,000.

Cross-section A–A' was created by combining available surface mapping, subsurface information, and gravity data from Cook and others (1997), the Pan-American Center for Earth and Environmental Studies (PACES) (2012) gravity database, and newly acquired Utah Geological Survey (UGS) gravity data. We also used a lithologic log from a water well to help determine the subsurface contacts between the Quaternary and Tertiary basin fill and undifferentiated Tertiary volcanic rocks (table 2).

SELECTED GEOLOGIC HAZARDS

Mapping of the Goshen quadrangle will aid in identifying and delimiting potential geologic hazards in future UGS geologic hazard mapping of the quadrangle. Geologic hazards related to features on this map include surface fault rupture along the Goshen and Long Ridge faults, landslides and rock falls (Qms and Qmt), and potential for debris flows, flooding of streams (Qal₁, Qal₂, Qay, and Qaly), and flooding on alluvial fan surfaces (Qaf₁, Qaf₂, Qafy, and Qafd). Other potential geologic hazards include earthquake-induced ground shaking, liquefaction, tectonic subsidence/tilting, and waves and flooding from Utah Lake. Spring and marsh deposits (Qsm) in areas of shallow groundwater and problem soils like clay-

Table 2. Water well in Goshen quadrangle used to aid construction of cross-section A-A'.

Well ID No. (WIN)	Туре	Well Application Number	Total Depth (ft.)	UTM E	UTM N	Notes
432805	Non- Production Well	0953001M00	1695	416440.7844	4425653.075	Informal name: Slant Road Well Latite with biotite, quartz and plagioclase in matrix noted at 1640 feet to TD

Notes:

Well data from Utah Division of Water Rights, http://www.waterrights.utah.gov/wellInfo/wellInfo.asp Location data based on NAD83

rich lacustrine deposits (Qlm) that may cause foundation problems. Below is a brief discussion of the surface faulting in the quadrangle. See the map unit descriptions and geologic map (plate 1) for more information and locations of the other geologic hazards.

Long Ridge Fault

The Long Ridge fault is a Quaternary normal fault along the north and northwestern side of Long Ridge. On the west side of Long Ridge the fault offsets Holocene lacustrine deposits of Lake Bonneville (<15,000 years), but does not offset the youngest alluvial-fan deposits. On the north side of Long Ridge the fault is concealed by upper Pleistocene Lake Bonneville deposits and younger Holocene alluvium. Based on range-front morphology and springs along the north part of the fault, it is likely a Quaternary fault (Muessig, 1951; Sullivan and Baltzer; 1986, Solomon, 2010). Muessig (1951) and Jensen (1986) refer to this fault as the Goshen fault; we use Long Ridge fault after Black and Hecker (1999).

Goshen Fault

We recently discovered the Goshen fault (named in this study) during a UGS hydrogeologic framework study (in progress) of Goshen Valley. The normal fault was initially noted on a 5-meter resolution digital elevation model (DEM) map of the quadrangle and was subsequently mapped using the DEM. aerial photographs from Soil Conservation Service (1965) and IntraSearch (1980), and orthophotographs from the Utah Automated Geographic Reference Center (2009). The total surface fault rupture length of the Goshen fault is 7.3 miles (11.7 km), but may be up to 8.3 miles (13.4 km). The fault continues north into the Goshen Valley North quadrangle where it is concealed by Utah Lake sediments. Several strands of the Goshen fault have scarps that cut across topography and offset Bonneville delta and lacustrine sediments southwest of the town of Goshen. The scarps, however, are not visible in the youngest alluvial sediments. We measured between 6.2 and 20.3 feet (1.9-6.2 m) of vertical surface offset across the scarp base on 5 profiles (see plate 1 for locations) with a survey-grade global positioning system/global navigation satellite system (GPS/GNSS) instrument. For each profile, vertical offset is the vertical distance between the intersection of the scarp face and upper and lower far-field slopes. Cook and others (1997) mapped the Elberta-Goshen fault, a concealed normal fault, based on gravity data near the trace of the Goshen fault west of the town of Goshen. The gravity field is the subsurface expression of down-to-the-west displacement of the basin floor along the Goshen normal fault.

Goshen Valley Fault Zone

The Goshen Valley fault zone, located on the northwestern margin of the quadrangle, is a concealed fault of uncertain age; its location is inferred from gravity data (Cook and oth3

ers, 1997). It is a down-to-the-east normal fault. It does not appear to offset Quaternary deposits, but does offset Tertiary units. The Slant Road well (informal name for a non-producing water well; WIN: 432805, see table 2), located east of the fault zone, penetrated a latite with biotite, quartz, and plagioclase in the matrix at a depth of 1640 feet (500 m). The reported latite is likely an Eocene-Oligocene volcanic rock similar to those in the Eureka quadrangle immediately to the west (Morris and Lovering, 1979), and could indicate a downto-the-east movement on the fault of at least 1640 feet (500 m) since the Eocene-Oligocene.

Further study of the Long Ridge and Goshen faults is needed to understand the age and reoccurrence history of these faults. Both faults offset Bonneville age deposits but not the youngest alluvial deposits. Both faults also have a similar trend and may share surface fault rupture events. Areas near these fault traces require a detailed fault-setback investigation before development occurs.

MAP UNIT DESCRIPTIONS

OUATERNARY

Alluvial deposits

- Qal₁ Level-1 stream alluvium deposits (upper Holocene) - Moderately sorted sand, silt, and pebble and cobble gravel, and minor clay; subangular to rounded clasts; thin to medium bedded; mapped along the lower reach of Currant Creek near the mouth of Goshen Canyon where level-1 deposits are inset into level-2 deposits; mapped in active channels and floodplains, and on minor terraces less than 5 feet (1.5 m) above active channels; locally includes minor colluvial deposits along steep stream embankments; equivalent to the younger part of young stream deposits (Qaly), but differentiated where level-1 deposits can be mapped separately; exposed thickness less than 15 feet (5 m).
- Qal₂ Level-2 stream alluvium deposits (middle Holocene to upper Pleistocene) – Moderately sorted sand, silt, and pebble and cobble gravel, and minor clay; subangular to rounded clasts; thin to medium bedded; mapped in channels and floodplains, and on minor terraces deposited 5 to 15 feet (1.5-5 m) above the adjacent active channel of Currant Creek near the mouth of Goshen Canyon, where level-1 deposits are inset into level-2 deposits; equivalent to the older part of Qaly, but differentiated where level-2 deposits can be mapped separately; exposed thickness less than 15 feet (5 m).

- Qaly Young stream alluvium deposits, undivided (Holocene to upper Pleistocene) - Moderately sorted pebble and cobble gravel with a matrix of sand, minor silt, and clay; deposited by Currant Creek in Goshen Canyon, in small channels scattered throughout the quadrangle, and along the Kimball Creek channel; locally includes areas of small alluvial-fan and colluvial deposits; includes level-2 stream deposits (Qal₂) incised by active stream channels and partly overlain by level-1 stream deposits (Qal_1) that are too small to show at map scale or where the specific age of post-Lake Bonneville deposits cannot be determined; postdates regression of Lake Bonneville from the Provo shoreline and lower levels in Goshen Valley and Juab Valley, where regressive lacustrine deposits are absent and young stream deposits are at elevations higher than the Provo shoreline; thickness variable, probably less than 15 feet (5 m).
- Qay Alluvial floodplain, alluvial fan, and channel deposits (Holocene to upper Pleistocene) – Moderately sorted sand, silt, and pebble and cobble gravel, and minor clay; subangular to rounded clasts; thin to medium bedded; mapped along the Kimball Creek alluvial floodplain, in the southwest corner of the quadrangle, where the creek collects drainage from alluvial fans emanating from the East Tintic Mountains and Long Ridge; equivalent to young stream and alluvial-fan deposits (Qaly and Qafy); probably less than 15 feet (5 m).
- Qaf₁ Level-1 alluvial-fan deposits (upper Holocene) - Poorly to moderately sorted, weakly to nonstratified, pebble to cobble gravel with a matrix of sand, silt, and minor clay; angular to subrounded clasts; medium to very thick bedded; deposited by debris flows, debris floods, and lower-gradient streams on valley floors mostly in the western part of the quadrangle, although one deposit is located in the northeast corner of the quadrangle; equivalent to the younger part of younger alluvial-fan deposits (Qafy) but differentiated because these small, active, discrete fans are not incised by younger channels, they overlie older alluvial-fans, and they can be mapped separately; exposed thickness less than 10 feet (3 m).
- Qaf₂ Level-2 alluvial-fan deposits (middle Holocene to upper Pleistocene) – Poorly sorted, locally boulder, pebble and cobble gravel with a matrix of sand, silt, and minor clay; angular to subrounded clasts with sparse, well-rounded clasts derived from Lake Bonneville gravel; medium to very thick bedded; one mapped deposit emanating from Currant Creek north of Goshen Reservoir is commonly overlapped by younger alluvial-fan deposits (Qaf₁, Qafy) and is locally incised by Qaly deposits; no Lake Bonneville

shorelines are found on these alluvial fans; equivalent to the older part of Qafy, but differentiated where deposits are graded to slightly above modern stream level and can be mapped separately; exposed thickness less than 15 feet (5 m).

- Qafy Younger alluvial-fan deposits, undivided (Holocene to upper Pleistocene) - Poorly to moderately sorted, pebble to cobble gravel and boulders near bedrock sources with a matrix of sand, silt, and clay; grades to mixtures of sand, silt, and clay on gentler slopes; angular to subrounded clasts; deposited by debris flows, debris floods, and streams at the mouths of mountain canyons throughout the quadrangle, but the largest deposits are on the eastern margin of the East Tintic Mountains where Tertiary volcanic clasts compose 5 to >50% of the deposits; includes level-1 and level-2 alluvial-fan deposits (Qaf1 and Qaf2) that either cannot be differentiated because of map scale or are in areas where the specific age of Holocene deposits cannot be determined; postdates regression of Lake Bonneville from the Provo shoreline and lower levels in Goshen Valley and Juab Valley where regressive deposits are absent and young alluvialfan deposits are at elevations higher than the Provo shoreline: no Lake Bonneville shorelines are found on these alluvial fans; thickness variable, probably less than 40 feet (12 m).
- Qafd Distal alluvial-fan deposits (Holocene to upper Pleistocene) – Poorly to moderately sorted, sand, silt, and clay with pebble gravel; angular to subrounded clasts; deposited by debris flows, debris floods, sheet wash, and streams on the distal edge of alluvial fans; mapped on the distal alluvial fan where a gentler slope and finer grain size differentiates the unit from equivalent younger alluvial-fan deposits up-slope (Qafy); postdates regression of Lake Bonneville from the Provo shoreline and lower lake levels in Goshen Valley and Juab Valley where regressive deposits are likely concealed or absent; no Lake Bonneville shorelines are found on these alluvial fans; thickness probably less than 10 feet (3 m).
- Qafb Alluvial-fan deposits, transgressive (Bonneville) phase of Lake Bonneville (upper Pleistocene) – Poorly to moderately sorted, locally boulder and pebble to cobble gravel with a matrix of sand, silt, and minor clay; angular to subangular clasts, but well rounded where derived from Lake Bonneville gravel; medium to very thick bedded; deposited by debris flows, debris floods, and stream flow in one small deposit on Long Ridge in Goshen Canyon that is graded to the highest (Bonneville) shoreline of Lake Bonneville; the B horizon of paleosols developed on transgressive-phase alluvial-fan deposits commonly shows a slight to moderate accumulation

of clay and may include a pedogenic accumulation of calcium carbonate as filaments in fine-grained soil or thin, discontinuous coatings on gravel; Machette (1992), using the terminology of Birkeland (1984), designated the soil profile of this unit as A/Bt/Bk(or Cox); exposed thickness less than 15 feet (5 m).

Deltaic deposits

Qd Deltaic deposits (upper Pleistocene) - Moderately to well-sorted, subrounded to rounded, fine to coarse sand, silt, and clay with minor pebbly gravel; thin bedded, commonly laminated with ripple marks and softsediment deformation features; locally includes minor reworked deltaic and lacustrine sediments in the form of gravel bars, thin laminations, and shorelines deposited by wave action of a regressing Lake Bonneville; deposited by a paleo-Currant Creek that flowed north from Juab Valley into Goshen Valley through Goshen Canyon; erosional remnants of the delta are incised by Currant Creek $(Qal_1 and Qal_2)$; unit is susceptible to landsliding (see Qms unit description); likely contains multiple Lake Bonneville-phase deposits and potentially deposits from older pre-Bonneville lakes; estimated thickness 150 to 200 feet (45-60 m).

Human-derived

- Qh Fill and disturbed land (Historical) - Undifferentiated artificial fill and disturbed land related to the construction of small dams for livestock watering and livestock waste ponds; also land disturbed by borrow pits and sand, gravel, and aggregate operations commonly in near-shore Lake Bonneville and younger alluvial-fan deposits (Qlgb and Qafy); the outlines of artificial fill and disturbed land are based on 1965 and 1980 aerial photographs, updated using 2009 orthophotography; mapped in several areas across the floor of Goshen Valley; only the larger areas of disturbed land are mapped, and many sites have since been regraded and developed and may contain unmapped deposits of artificial fill; unmapped fill is locally present in most developed areas, but only the larger deposits are mapped; smaller watering ponds are not mapped due to map scale limitations; thickness unknown.
- Qhm Mine waste-disposal ponds (Historical) Earth fill in embankments used to construct small dams for mine wastewater-disposal ponds and related disturbed land within the disposal ponds; saline groundwater is known to have been discharged from the Burgin mine in the East Tintic mining district and allowed to flow to the disposal ponds and evaporate or seep into the subsurface at these sites (Dames and Moore, Inc., 1985; Earthfax Engineering, 1988; Hamaker and Harris, 2007); located 1.2 miles (2 km)

west of Elberta, south of U.S. Highway 6; smaller mine waste-disposal ponds are not mapped due to map scale limitations; maximum thickness about 20 feet (6 m).

Lacustrine deposits

Deposits younger than Bonneville lake cycle, includes Utah Lake highstand: Deposits only mapped near or below the Utah Lake highstand, which is at elevations of about 4500 to 4505 feet (1372–1373 m) in the Goshen quadrangle (table 1).

- Qlsy Younger lacustrine sand and silt (Holocene to upper Pleistocene) - Sand, silt, and clay; sand is fine to very fine and non-stratified; likely deposited as a continuous sheet; mapped as low linear ridges south of Utah Lake in the northeast corner of the quadrangle; ridges may be erosional remnants of more continuous deposits; ridges are flat on top, vegetated, and may trap windblown material; locally organic rich and may include a thin (1 to 3 inch) surficial loess veneer; probably deposited during fluctuations at and above the Utah Lake highstand following the regression of Lake Bonneville from the quadrangle; differentiated from adjoining deposits of Qlm and Qsm by topographic rise and presence of surface water or shallow groundwater in adjoining units; estimated thickness 0 to 10 feet (0-3 m).
- Qlmy Younger lacustrine silt and clay (Holocene to upper Pleistocene) – Silt, clay, and minor fine-grained sand deposited along the margin of Utah Lake in the northeast corner of the quadrangle; locally organic rich, and locally includes pebbly beach gravel; locally includes small areas of spring and marsh deposits (Qsm) and mixed lacustrine and alluvial deposits (Qla); estimated thickness 0 to 10 feet (0–3 m).

Undivided deposits of Bonneville lake cycle:

QIm Lacustrine silt and clay (upper Pleistocene) – Calcareous silt and clay (marl) with minor fine sand; typically laminated or thin bedded, but can be unbedded; ostracodes locally common; deposited below the Provo shoreline in quiet water in southern Goshen Valley; locally concealed by loess veneer, except near the Provo shoreline where the unit grades upslope into, or is overlain and armored by, lacustrine gravel, sand, and silt (Qlgp, Qlsp); includes lacustrine silt and clay of transgressive and regressive phases of the Bonneville lake cycle; unit may include undifferentiated transgressive deposits; exposed thickness less than 15 feet (5 m), but total thickness may exceed several tens of feet. **Deposits of regressive (Provo) phase of the Bonneville lake cycle:** Only mapped below the Provo shoreline, which is at elevations of about 4760 to 4790 feet (1450–1460 m) in the Goshen quadrangle (table 1). The B horizon of paleosols developed on regressive-phase lacustrine deposits commonly shows an intensification of brown colors due to oxidation of iron-bearing minerals or a slight accumulation of clay and may include a pedogenic accumulation of calcium carbonate as filaments in fine-grained soil or thin, discontinuous coatings on gravel; Machette (1992), using the terminology of Birkeland (1984), designated the soil profile of these units as A/Bw/Bk(or Cox) to A/Bt(weak)/Bk(or Cox).

- Qlgp Lacustrine gravel and sand (upper Pleistocene) -Moderately to well-sorted, subrounded to rounded, clast-supported, pebble to cobble gravel and pebbly sand with minor silt; gastropods locally common in sandy lenses; gravel commonly cemented with calcium carbonate (tufa); thin to thick bedded; deposited in shallow water near shore as linear beaches along the Provo shoreline in western and southern Goshen Valley where the unit is commonly found as a veneer of reworked clasts derived from nearby Paleozoic and Tertiary rocks in the East Tintic Mountains; commonly interbedded with or laterally gradational to lacustrine silt and clay of Lake Bonneville (Qlm); unit may include undifferentiated transgressive deposits; exposed thickness less than 15 feet (5 m).
- Qlsp Lacustrine sand and silt (upper Pleistocene) Moderately to well-sorted, subrounded to rounded, fine to coarse sand and silt with minor pebbly gravel; thick to very thick bedded, commonly laminated with some ripple marks and scour features; gastropods locally common; deposited in relatively shallow water near shore north of Goshen Canyon and west of State Route 68 where erosional remnants are incised by young alluvial-fan deposits (Qafy); grades downslope into lacustrine silt and clay (Qlm); locally buried by loess veneer; unit may include undifferentiated transgressive deposits; exposed thickness less than 30 feet (10 m).

Deposits of the transgressive (Bonneville) phase of the Bonneville lake cycle: Mapped between the Bonneville and Provo shorelines. The highest Bonneville shoreline is at elevations of about 5080 to 5140 feet (1550–1566 m) in the Goshen quadrangle (table 1). The B horizon of paleosols developed on transgressive-phase lacustrine deposits commonly shows a slight to moderate accumulation of clay and may include a pedogenic accumulation of calcium carbonate as filaments in fine-grained soil or thin, discontinuous coatings on gravel; Machette (1992), using the terminology of Birkeland (1984), designated the soil profile of these units as A/Bt/Bk (or Cox).

- Lacustrine gravel and sand (upper Pleistocene) -Qlqb Moderately to well-sorted, clast-supported pebble to cobble gravel with a matrix of sand and silt; locally interbedded with thin to thick beds of silt and pebbly sand; clasts commonly subrounded to rounded, but some deposits consist of poorly sorted, angular gravel derived from nearby bedrock outcrops; gastropods locally common in sandy lenses; gravel locally cemented with calcium carbonate (tufa); thin to thick bedded; most transgressive gravel and sand deposits are veneers over bedrock (Qlgb/Tpc, Qlgb/Tvc, $Qlgb/P_{z}$, Qlgb/Cac, and Qlgb/Ct); typically deposited below wave-cut benches close to the Bonneville shoreline and are commonly partly covered by colluvium derived from adjacent oversteepened slopes, although thicker accumulations of transgressive lacustrine gravel and sand bars are west of Elberta and State Route 68; interbedded or laterally gradational with lacustrine sand and silt of the transgressive phase (Qlsb); thickness likely greater than 30 feet (10 m).
- Qlsb Lacustrine sand and silt (upper Pleistocene) Moderately to well-sorted, subrounded to rounded, fine to coarse sand and silt with minor pebbly gravel; thick to thin bedded; commonly has ripple marks and scour features; gastropods locally common; deposited in relatively shallow water near Long Ridge and north of Goshen Canyon in Goshen Valley; exposed thickness less than 30 feet (10 m), but total thickness may exceed several tens of feet.

Eolian deposits

Qes Eolian sand and silt deposits (Holocene to upper Pleistocene?) – Well- to very well sorted, fine- to medium-grained, well-rounded, windblown sand west of State Route 68, south of Elberta and south of Goshen Reservoir; forms small dunes mostly stabilized by vegetation; includes thin sheet-sand deposits; locally overlapped by young alluvial-fan deposits (Qafy); locally derived from Lake Bonneville deltaic and lacustrine sand deposits; typically 0 to 15 feet (0–5 m) thick.

Mass-movement deposits

Qms Landslide deposits (Historical to middle Pleistocene) – Poorly sorted clay- to boulder-sized material in slides, slumps, and minor flows, with grain size varying with the nature of source material; characterized by hummocky topography, main and internal scarps, toe thrusts, back-rotated tilt blocks, and chaotic bedding in displaced bedrock; landslides are mapped in multiple locations in the quadrangle—one deposit on the margin of Long Ridge (southwest of Alcorns Canyon)

where the landslide is offset by the Long Ridge fault, two deposits largely within deltaic Bonneville lake cycle deposits incised by Currant Creek north of Goshen Canyon, and one large landslide that postdates the regression of Lake Bonneville on the northeast slope of the delta that may be earthquake induced and/or Lake Bonneville regression related; in some locations along Currant Creek landslide, slopewash and soil-creep deposits grade into one another in areas of subdued morphology; undivided as to inferred age because research shows that even landslides with subdued morphology (suggesting that they are older, weathered, and have not moved recently) may continue to exhibit slow creep or are capable of renewed movement if stability thresholds are exceeded (Ashland, 2003); age and stability determinations require detailed geotechnical investigations; thickness highly variable.

Qmt Talus deposits (Historical to middle Pleistocene) – Poorly sorted pebble to boulder-sized material and subangular to angular, fresh, active rock fall to partially vegetated stabilized talus slopes composed of locally derived clasts; three deposits are present above and below the highest Bonneville shoreline along the northwestern slope of Long Ridge, west of Goshen Canyon; other small and thin talus deposits are not mapped due to map scale limitations; thickness 3 to 15 feet (1–5 m).

Spring and marsh deposits

Qsm Spring and marsh deposits (Holocene to upper Pleistocene?) – Fine-grained, organic-rich sediment associated with springs, ponds, seeps, and wetlands; commonly wet, but seasonally dry; may locally contain peat deposits as thick as 3 feet (1 m); overlies lacustrine silt and clay (Qlm) and grades laterally into lacustrine sand, silt, and clay (Qlsy and Qlmy) as well as undivided lacustrine and alluvial deposits (Qla); mapped where water table is high, east of the Goshen fault along U.S. Highway 6 and south of Utah Lake in the northeast part of the quadrangle; thickness commonly less than 10 feet (3 m).

Mixed-environment deposits

Qac Alluvial and colluvial deposits, undivided (Holocene to middle Pleistocene) – Poorly to moderately sorted, generally poorly stratified, clay- to boulder-size, locally derived sediment; mapped in drainages in Long Ridge that are in bedrock or are underlain by bedrock at shallow depths beneath a veneer of Quaternary deposits; also mapped along Currant Creek where alluvial, slopewash, and soil-creep deposits grade into one another; small, unmapped deposits are likely in most small drainages; thickness less than 10 feet (3 m). Qla Lacustrine and alluvial deposits, undivided (Holocene to middle Pleistocene) – Sand, silt, gravel, and clay in areas of mixed alluvial and lacustrine deposits that are undifferentiated because the units grade imperceptibly into one another; mapped in Goshen Valley where the unit, on aerial photographs, has faint lacustrine wave-cut notches on older alluvial fans; includes thin lacustrine sands and gravels on alluvial-fan deposits; also mapped where wetlands rework remnants of Bonneville silt and clay (Qlm) in the northeast part of the quadrangle; thickness of lacustrine origin are less than 6 feet (2 m), alluvial deposits are probably less than 40 feet (12 m) thick.

Stacked-unit deposits

Qlgb/Tpc

Lacustrine gravel and sand (transgressive phase of Lake Bonneville) over Pinyon Creek Conglomerate (upper Pleistocene/Oligocene?) – A veneer of lacustrine gravel and sand reworked from extensive underlying agglomerate deposits of the Pinyon Creek Conglomerate (Tpc; only included as a stacked unit) and other bedrock sources of volcanic and non-volcanic clasts; lacustrine deposits are approximately 3 to 6 feet (1–2 m) thick, and estimated exposed thickness of Tpc in the quadrangle is less than 30 feet (10 m).

Qlgb/Tvc

Lacustrine gravel and sand (transgressive phase of Lake Bonneville) over volcanic conglomerate (upper Pleistocene/upper Eocene) – A veneer of moderately to well-sorted lacustrine gravel and sand that overlies and conceals the volcanic conglomerate member of Goshen Canyon; typically forms wave-cut benches close to the Bonneville shoreline that are commonly partly covered by colluvium derived from adjacent oversteepened slopes; mapped on Long Ridge in the southeast corner of the quadrangle; includes locally cemented gravel deposits on bedrock slopes and shoreline bench deposits 3 to 15 feet (1–5 m) thick.

Qlgb/Pz Lacustrine gravel and sand (transgressive phase of Lake Bonneville) over Paleozoic bedrock (upper Pleistocene/Paleozoic) – A veneer of moderately to well-sorted lacustrine gravel and sand that overlies and conceals local Paleozoic bedrock; typically forms wave-cut benches close to the Bonneville shoreline that are commonly partly covered by colluvium and talus derived from adjacent oversteepened slopes; mapped on Long Ridge in the southeast corner of the quadrangle and at the mouth of Government Canyon; some bedrock knobs that are not mapped separately due to map scale limitations are included in the unit; includes locally cemented gravel deposits on bedrock slopes and shoreline bench deposits 3 to 30 feet (1-10 m) thick.

Qlgb/€ac

Lacustrine gravel and sand (transgressive phase of Lake Bonneville) over Upper to Middle Cambrian bedrock (upper Pleistocene/Upper-Middle Cambrian) – A veneer of moderately to well-sorted lacustrine gravel and sand partially concealing Cambrian bedrock (Ajax Dolomite, Opex Formation, and Cole Canyon Dolomite); typically forms wave-cut benches close to the Bonneville shoreline that are commonly partly covered by colluvium and talus derived from adjacent oversteepened slopes; mapped in two locations on Long Ridge east of Goshen Canyon; includes locally cemented gravel deposits on bedrock slopes and shoreline bench deposits 3 to 30 feet (1–10 m) thick.

Qlgb/Ct Lacustrine gravel and sand (transgressive phase of Lake Bonneville) over Tintic Quartzite (upper Pleistocene/Middle-Lower Cambrian) – A veneer of moderately to well-sorted lacustrine gravel and sand partially concealing Tintic Quartzite; typically forms wave-cut benches close to the Bonneville shoreline that are partly covered by colluvium and talus derived from adjacent oversteepened bedrock slopes; mapped in one location on Long Ridge in the southcentral boundary of the quadrangle; includes locally cemented gravel deposits on bedrock slopes and shoreline bench deposits 3 to 15 feet (1–5 m) thick.

TERTIARY

Tj Jasperoid (Tertiary?) – Silicic replacement breccia; varies from completely replaced to outcrops that are commonly very dark red to grayish brown with varying degrees of fractured limestone or dolomitic host rock still visible; smaller jasperiod breccias are not mapped due to map scale constraints; outcrops are typically more resistant than surrounding bedrock and form ridges; mapped in three exposures near First Canyon and Long Ridge; the jasperoids are developed in Deseret Limestone on Long Ridge and probable Deseret Limestone at the mouth of First Canyon; thickness is 3 to 30 feet (1–10 m).

OLIGOCENE

Tpc Pinyon Creek Conglomerate (Oligocene?) – Only mapped as a stacked unit, see unit description for lacustrine gravel and sand (transgressive phase) over Pinyon Creek Conglomerate (Qlgb/Tpc); the agglomerate beds consist mainly of pebble- to boulder-size clasts in a matrix of volcaniclastic fine ash, silt, and sand; other beds contain both fine and coarse fragments almost exclusively from the Laguna Springs Volcanic Group (LSVG) (Morris and Lovering, 1979; McKean, 2011); deeply eroded by streams and truncated by the Bonneville shoreline to the northwest in the adjacent Allens Ranch quadrangle (McKean, 2011); mapped along the east edge of the East Tintic Mountains, north and south of Pinyon Creek in the northwest corner of the Goshen quadrangle; stratigraphically beneath the Miocene (18 Ma) Silver Shield Quartz Latite, and laterally equivalent to or above the Oligocene LSVG in the Eureka quadrangle, which indicates an approximate Oligocene age (Laughlin and others, 1969; Morris and Lovering, 1979; McKean, 2011); estimated exposed thickness less than 30 feet (10 m); estimated thickness in Allens Ranch quadrangle is greater than 150 feet (50 m) (McKean, 2011), and in the East Tintic Mountains the reported thickness is 0 to 1000+ feet (0-305+m) (Morris and Lovering, 1979).

Not in Contact – The Pinyon Creek Conglomerate and volcanic rocks of Goshen Canyon are sourced by different volcanic eruption centers and do not appear to be in direct depositional contact.

EOCENE

Whole-rock geochemical data for volcanic units in the Goshen 7.5-minute quadrangle are presented in table 3 and available in McKean and others (2013). Rock names are from the total alkali-silica classification diagram for volcanic rocks (see figure 2).

Volcanic rocks of Goshen Canyon - The correlation of volcanic rocks on Long Ridge to other volcanic rocks in this region is uncertain. Therefore these rocks are mapped as five informal members of volcanic rocks of Goshen Canyon and include andesite dikes, volcanic conglomerate, pyroxene latite, hornblende latite, and shoshonite lava members. Similar volcanic rocks in Slate Jack Canyon quadrangle, to the immediate south on Long Ridge, were previously mapped as Copperopolis Latite (Jensen, 1986). Other volcanic units mapped in adjacent quadrangles were also mapped as informal members of the Copperopolis Latite (Morris and Lovering, 1979; Kim, 1988; Keith and Kim, 1990; and Keith and others, 1997, 2009). The wide use of the Copperopolis Latite unit name for volcanic rocks with different lithology, geochemistry, and ages across the East Tintic Mountains reduces the certainty at which units can be correlated across the region. For this reason we have chosen to differentiate the Goshen volcanic rocks by lithology and age. The age range of the volcanic rocks of Goshen Canyon is unclear, but in Slate Jack Canyon quadrangle the 34.64 Ma Latite Ridge Latite overlies rocks equivalent to the volcanic conglomerate member (Jensen, 1986; UGS and NMGRL, 2007). The volcanic conglomerate member is older than the

35.65 Ma andesite dikes member, which cuts across the conglomerate (UGS and NIGL, 2013). Therefore the age range of the volcanic rocks of Goshen Canyon is from 34.64 Ma to slightly greater than 35.65 Ma.

- Tvd Andesite dikes member (late Eocene) - Mediumlight-gray to medium-gray porphyritic andesite dikes with phenocrysts (15-25%) of plagioclase and hornblende; hornblende phenocrysts are elongated and range in size from 0.25 to 0.5 inch (3-5 mm), plagioclase phenocrysts are mostly altered to a cloudy white; phenocrysts are embedded in a glassy matrix; contains 1- to 1.5-inch (3-4 cm) xenoliths of biotite gneiss and medium-grained hornblende granodiorite (source unknown); the dikes member forms ridges that stand out from the less resistant volcanic conglomerate member (unit Tvc); the dikes member trends roughly east to west in two parallel strands on Long Ridge south of First Canyon and has an average dip of 45° to 61° south: unit Tvd cross cuts unit Tvc, and Tvd yielded an amphibole ⁴⁰Ar/³⁹Ar age of 35.65 ± 0.13 Ma (UGS and NIGL, 2013) (sample GN2011-393); individual dikes are 30 to 45 feet (10-15 m) wide.
- Tvc Volcanic conglomerate member (upper Eocene) - Gray to brownish-gray volcanic conglomerate with interbedded sandstone lenses; conglomerate is poorly consolidated and composed of intermediatecomposition volcanic clasts in a matrix of sand and ash; matrix is medium- to very coarse grained sand composed of fragments of volcanic rock (lava, tuff, phenocrysts, scoria); bedding of any kind is uncommon, but small, coarse-grained sand and pebble lenses can be found; clasts are angular to subrounded, poorly sorted, and heterolithic; average clast size is 2 to 6 inches (6-15 cm), and large boulders range between 1.5 and 10 feet (0.5-3 m); three dominant clast types: (1) dark-gray, brownish-gray to grayish-redpurple shoshonite and latite clasts with phenocrysts (15-20%) of plagioclase and pyroxene, some pyroxene occurring in glomeroporphyritic clots up to 0.4 inch (1 cm) in diameter; (2) dark-gray andesite clasts similar to the shoshonite and latite dark-gray clasts with phenocrysts (15-20%) of plagioclase and pyroxene; (3) light-gray dacite clasts with phenocrysts (10–20%) of plagioclase, hornblende, and biotite in a fine- to coarse-grained glassy matrix; other minor clasts include scoria lava, dark mafic clasts, and other highly altered clasts; attempts to map the dominant clast type across the conglomerate exposure failed to find any consistent relations; see figure 2 for total alkali-silica classification of volcanic conglomerate clasts, and table 3 for whole-rock geochemistry; some poorly consolidated volcaniclastic sandstones or epiclastic sandstone lenses are interbedded within the conglomerate; they are typically dark-gray, me-

dium- to coarse-grained sand composed of volcanic grains with granules and pebbles of volcanic rock fragments that are angular to subrounded; the poorly sorted sandstone has weak cross-bedding; locally, the sandstone is light gray, has a very low density, and appears to be mixed with an ash-fall tuff; the volcanic conglomerate was most likely deposited in lahars and debris flows on the distal flanks of a volcano; mapped on Long Ridge where the unit typically forms eroded slopes of fine-grained ash and sand covered by pebbles and boulders and uncommon

- lahars and debris flows on the distal flanks of a volcano; mapped on Long Ridge where the unit typically forms eroded slopes of fine-grained ash and sand covered by pebbles and boulders and uncommon resistant ledges; the contact between the conglomerate and the underlying folded and faulted Paleozoic bedrock is an angular unconformity; during the Eocene to Oligocene these volcanic units blanketed and filled roughly east-trending pre-Oligocene paleo valleys (Morris and Lovering, 1979); Tvc is overlain by the Latite Ridge Latite to the south in the Slate Jack Canvon quadrangle (Jensen, 1986), cross-cut by Tvd, and has numerous interbedded lavas flows (Tvp, Tvh, and Tvs) and lava flow breccia (Tpb); corresponds to unit Tcbu of Jensen (1986); age range is from about 34.64 Ma to slightly greater than 35.65 Ma based on radiometric ages of Latite Ridge Latite (UGS and NMGRL, 2007) and cross-cutting Tvd; interbedded sand lenses have an estimated thickness of 3 to 15 feet (1-5 m); estimated exposed unit thickness is at least 900 feet (>275 m).
- Tvp Pyroxene latite member (upper Eocene) - Mediumgray, grayish-red purple to brownish-gray, porphyritic latite lava flows; phenocrysts (20-30%) of plagioclase and pyroxene, some pyroxene are glomeroporphyritic clots up to 0.4 inch (1 cm) in diameter, plagioclase grains are small, typically altered, and set in a glassy matrix; contains multiple lava flows, some small poorly exposed outcrops could alternatively be interpreted as dikes; the phenocryst assemblage is similar to the shoshonite and latite pyroxene and plagioclase-bearing clast type in the volcanic conglomerate member (Tvc), for this reason unit lava flows are difficult to distinguish from interbedded Tvc because they erode into boulders and cobbles similar to clasts of Tvc; lavas form resistant ledges of boulders; the northern exposure has scoria within the flow with opal on some edges; mapped in two small exposures on the Utah and Juab County line on Long Ridge and one small exposure near Currant Creek west of Government Flat; corresponds to the upper lava flow member of the Copperopolis Latite identified by Jensen (1986) to the south in the Slate Jack Canyon quadrangle; no direct age data, but it is interbedded with Tvc and thus the same age between 34.64 Ma to slightly greater than 35.65 Ma; unit thickness is 40 to 90 feet (13-30 m).

- Tvh Hornblende latite member (upper Eocene) Lightbrownish-gray, pale-red to medium-gray porphyritic latite lava flow; phenocrysts (15–30%) of plagioclase, hornblende, and biotite, phenocrysts are typically altered; forms resistant ledges of boulders; two outcrops present: (1) the crest of Long Ridge east of First Canyon, and (2) east of the ridge line on the south edge of the quadrangle; appears to be interbedded with the volcanic conglomerate member (Tvc); no direct age data, but it is interbedded with Tvc and thus the same age between 34.64 Ma to slightly greater than 35.65 Ma; unit thickness is 60 to 100 feet (20–35 m).
- Tvs Shoshonite lava member (upper Eocene) Medium-dark-gray to dark-gray, fine-grained porphyritic shoshonite lava flow; phenocrysts (15–20%) of plagioclase, pyroxene, and hornblende; forms a resistant ridge of weathered boulders; one outcrop north of First Canyon and a second highly altered outcrop in Alcorns Canyon, Long Ridge; believed to be a lava flow but could also be interpreted as a dike; debris eroded from the volcanic conglomerate member (Tvc) conceals the lateral extent and contacts of the unit, the unit appears to be interbedded with Tvc or in direct contact with Tpb; no direct age data; unit thickness is 9 to 15 feet (3–5 m).

Packard Quartz Latite - Morris and Lovering (1979) report that the Packard Quartz Latite (PQL) includes a basal tuff, a lower vitrophyre, a massive lava flow unit, and an upper vitrophyre in the Eureka quadrangle. However, Morris and Lovering (1979) did not map the PQL units separately and more work is needed to better understand the unit. In the East Tintic Mountains additional ash-flow tuffs have been identified in the PQL (Moore and others, 2007; McKean, 2011; Allen, 2012). ⁴⁰Ar/³⁹Ar ages of sanidine in these ash-flow tuffs in the adjacent Allens Ranch quadrangle yielded ages of 35.08 ± 0.03 Ma and 35.21± 0.03 Ma (McKean, 2011; Christiansen and others, 2013). A rhyolite lava member of the PQL above a lava flow breccia in the southeast corner of Boulter Peak quadrangle, west of the Allens Ranch quadrangle, yielded a 40Ar/39Ar sanidine radiometric age of 35.25 ± 0.04 Ma (Allen, 2012; Christiansen and others, 2013).

Tpb Lava flow breccia member (upper Eocene) – The lava flow breccia is loosely welded, light-gray to medium-gray, and has subrounded to angular rhyo-lite clasts comprising 30 to 40% of the unit; clasts are light gray to medium gray with phenocrysts (40–50%) of plagioclase, sanidine, biotite, and quartz in a black glassy matrix; the unit contains volcanic clasts ranging in size from small clasts of 0.4 to 6 inches (1–15 cm) in diameter to large clasts 1.5 to 6 feet (0.5–2 m) in diameter of subrounded breccia; the breccia clasts appear to be devitrified, flow-foliated lavas as well as vitrophyres of the Packard Quartz

Latite; the lava flow breccia has typical characteristics of POL with quartz phenocrysts and concentrations of Ba that are higher than 2000 parts per million (ppm) (Moore and others, 2007; McKean, 2011; Allen, 2012); the matrix is light-gray, fine to coarse volcanic grains; mapped in First Canyon where it forms an erosional saddle strewn with clasts between contact with Paleozoic bedrock below and units Tvs and Tvc above; locally forms some resistant ridges; Tpb is similar to, but not the same as, a lava flow breccia in the southern corner of Boulter Peak and Allens Ranch quadrangles (McKean, 2011; Allen, 2012), and age relations there indicate that the Boulter Peak lava flow breccia is greater than 35.25 Ma (Allen, 2012; Christiansen and others, 2013); Tpb is probably older than the Boulter Peak quadrangle lava flow and the volcanic rocks of Goshen Canyon; estimated thickness is 30 to 90 feet (10-30 m).

Unconformity

Ts Tertiary strata (middle Eocene?) - Orangish-red, red, and light-gray consolidated conglomerate; clasts are white to light-pink quartzite and black chert with lesser dolomite/limestone clasts (no volcanic clasts); rounded to subrounded, pebble to boulder clasts up to 1.5 feet (0.5 m) in diameter; three outcrops at the south boundary of the quadrangle; Ts crops out as rounded hills strewn with clasts; angular unconformities separate the unit from the overlying Tvc and underlying Paleozoic rocks; no direct age control, however, the unit is similar to other Tertiary strata mapped to the west that have U-Pb detrital zircon ages of 38.70 +0.28/ -0.62 Ma from the Vernon Hills, and 46.77 \pm 1.28 Ma from Davis Knolls (Clark and others, 2012; UGS and Apatite to Zircon, Inc., 2013), and it is also similar to Tertiary-Cretaceous strata to the northeast on West Mountain (Clark, 2009); estimated incomplete thickness is 30 to 240 feet (10-80 m).

Unconformity

PALEOZOIC

Pz Paleozoic strata, undivided (Paleozoic) – Highly altered and fractured Paleozoic bedrock where separation into distinct mappable units is impractical; mapped in five exposures on the south boundary of the quadrangle and near the mouth of Government Canyon on Long Ridge; exposed thickness is approximately 100 feet (30 m).

MISSISSIPPIAN

Mh Humbug Formation (Upper Mississippian) – Interbedded light- to blue-gray limestone, and light-brown calcareous quartz sandstone and orthoquartzite; limestone is fine to medium grained, locally with crinoids, spiral gastropods, and fossil hash, and locally dolomitic; sandstone is fine to medium grained with well-sorted and rounded grains, and has low-angle cross-stratified, lenticular beds; weathers to ledges and slopes; mapped on Long Ridge west of Goshen Canyon; lower contact with the Deseret Limestone (Md) is gradational and occurs at the change from limestone to alternating sandstone and limestone (Mh); upper contact is not present in quadrangle; age from Morris and Lovering (1961); measured incomplete thickness is 797 feet (243 m); thickness on West Mountain is 785 feet (240 m) (Clark, 2009), thickness ranges from 900 to 1000 feet (275-305 m) in the southern Wasatch Range (Felger and others, 2004), and in the East Tintic Mountains the reported thickness is 650 feet (200 m) (Morris and Lovering, 1979).

Md **Deseret Limestone** (Upper to Lower Mississippian) – Medium- to dark-gray shaly limestone, cherty limestone, and fossiliferous limestone that is medium- to very thick bedded; subdivided into three parts for description but not for mapping purposes, parts correspond to the members in the East Tintic Mountains (see Morris and Lovering, 1961, 1979).

> Upper part (Uncle Joe Member) is coarse-grained, thick-bedded limestone containing nodular chert and beds of fossilized coquina (shell hash); locally dolomitic; the hash is composed of fragments of broken shells, crinoid columnals, and corals arranged into laminae and cross-beds; cross-beds have similar weathered appearance and can be confused with the sandstone beds of the Humbug Formation. Middle part (Tetro Member) is sequence of very thick bedded, medium- to light-blue-gray cherty limestone; the chert is mostly nodular with some beds (2-4 inches [5-10 cm] thick); most of the chert is dark gray to black in color, but some is white; fossils include rugose corals, crinoids, bryozoans, fossil hash, and uncommon brachiopods (Morris and Lovering, 1961). Lower part (Delle Phosphatic Member) is black carbonaceous shale to shaly limestone that contains one or more layers of pelletal phosphorite; this part of the section is rarely well exposed on the surface and usually weathers to small shale chips of maroon gray to dull orange red (Morris and Lovering, 1961; Sandberg and Gutschick, 1984); shale locally contains cherty beds but not as extensive as the Gardison Limestone.

> Deseret Limestone is mapped on Long Ridge west of Goshen Canyon where it forms slopes and ledges; lower contact is placed at the change from bedded cherty limestone of the Gardison Limestone to shaly limestone (Md); upper contact is gradational and is placed at appearance of first substantial alternating sandstone and limestone sequence of the Humbug

Formation, this may be complicated by occasional sandy limestone beds within the upper Deseret Limestone; age from Sandberg and Gutschick (1984); measured incomplete thickness is 650 feet (200 m); thickness on West Mountain is 765 feet (235 m) (Clark, 2009), thickness ranges from 800 to 900 feet (245–275 m) in the southern Wasatch Range (Felger and others, 2004), and in the East Tintic Mountains the reported thickness is 1000 to 1100 feet (300–340 m) (Morris and Lovering, 1961, 1979).

Gardison Limestone (Lower Mississippian) - Me-Mg dium-gray to dark-blue-gray limestone, cherty limestone, and fossiliferous limestone, and locally dolomitic limestone that is medium- to very thick bedded; ledge forming; chert is present as black, irregularly shaped nodules and thin (1-6 inches [2-15 cm]), discontinuous beds; the bedded chert is characteristic of the upper part of the unit; the upper part of the unit is thicker bedded compared to the thinner bedded lower part; fossils include rugose and colonial corals, brachiopods, crinoids, distinctive gastropods, and bryozoans; contains minor intraformational flat-pebble conglomerate beds; mapped on Long Ridge near Goshen Canyon; the lower contact is distinguished by the characteristic "curly" bed limestone at the top of the Fitchville Formation; however, the "curly" bed described in the East Tintic Mountains (Proctor and Clark, 1956; Morris and Lovering, 1961) is structurally missing or altered beyond recognition in much of the Goshen quadrangle; the most reliable distinction on Long Ridge is the appearance of gastropods in the Gardison Limestone; upper contact is placed at base of Delle Phosphatic Member of the Deseret Limestone; age from Morris and Lovering (1961); exposed thickness at least 165 feet (50 m), potentially structurally attenuated; 450 to 550 feet (140-170 m) thick in the Eureka quadrangle (Morris, 1964), 620 feet (190 m) thick on West Mountain (Clark, 2009), 450 to 650 feet (140-200 m) thick in southern Wasatch Range (Felger and others, 2004), and in East Tintic Mountains the thickness is 500 feet (150 m) (Morris and Lovering, 1961).

MISSISSIPPIAN-DEVONIAN

MDf Fitchville Formation (Lower Mississippian to Upper Devonian) – Light-blue-gray to light-gray limestone and dolomite; medium- to thick-bedded; fossils include rugose and colonial corals, crinoids, brachiopods, and bryozoans; forms ledges on Long Ridge near Goshen Canyon; lower contact is marked at transition from argillaceous limestone of Pinyon Peak Limestone to light-gray limestone and dolomite of Fitchville Formation; age from Morris and Lovering (1961); complete measured thickness is 230 feet (70 m), thickness on West Mountain is 170 feet (50 m) (Clark, 2009), thickness ranges from 100 to 300 feet (30–90 m) in the southern Wasatch Range (Rigby and Clark, 1962), and in the East Tintic Mountains the thickness is 280 to 300 feet (85–90 m) (Morris and Lovering, 1961, 1979).

DEVONIAN

- DOu Devonian-Silurian-Ordovician strata, undivided (Upper Devonian to Upper Ordovician) – Shown on cross section only. Combined units of Pinyon Peak Limestone (Upper Devonian), Victoria Formation (Upper Devonian), and Bluebell Dolomite-Fish Haven Dolomite (Lower Devonian to Upper Ordovician); combined unit thickness 300 to 400 feet (90–120 m).
- Dp Pinyon Peak Limestone (Upper Devonian) - Medium- to light-blue-gray limestone commonly with a faint pink color, fine-grained and thin- to mediumbedded, argillaceous, with few intraformational flatpebble conglomerate beds; fossils include corals, brachiopods, and crinoids (Morris and Lovering, 1961); in some locations the unit is extremely altered and silicification is common on Long Ridge near Goshen Canyon, and it is also locally dolomitized; forms erosional slopes on Long Ridge near Goshen Canyon; lower contact placed above uppermost quartzite cross-beds or sandy dolomites of Victoria Formation at the appearance of the first argillaceous limestone beds of the Pinyon Peak Limestone; age from Morris and Lovering (1961); complete measured thickness is 88 feet (27 m); thickness on West Mountain is 130 feet (40 m) (Clark, 2009), ranges from 70 to 300 feet (20-90 m) in southern Wasatch Range (Rigby and Clark, 1962), and is 70 to 125 feet (20-40 m) in the East Tintic Mountains (Morris and Lovering, 1979).
- Dv Victoria Formation (Upper Devonian) - Gray dolomite interlayered with medium-grained, light-brown, thin- to medium-bedded, rusty-weathering quartzite; dolomite is fine- to medium-grained, commonly with clumps of dolomite crystals up to 0.25 inch (1 cm) in diameter; guartzite beds are typically more resistant than surrounding dolomite; forms ledges where the quartzite is exposed; mapped on Long Ridge near Goshen Canyon; lower unconformable contact placed at base of first quartzite of Victoria Formation; a Late Devonian age is assigned based on the age of the underlying Bluebell Dolomite and overlying Pinyon Peak Limestone (Morris and Lovering, 1961); complete measured thickness is 43 feet (13 m); on West Mountain the unit is missing due to a major unconformity (Clark, 2009), it is very thin to possibly absent in the southern Wasatch Range (Rigby and Clark, 1962), and in the East Tintic Mountains the thickness is 250 to 300 feet (75-90 m) (Morris and Lovering, 1979).

Unconformity

DEVONIAN-SILURIAN-ORDOVICIAN

Bluebell Dolomite and Fish Haven Dolomite, DObf undivided (Lower Devonian to Upper Ordovician) - Light- to dark-gray and dusty blue-gray limestone and dolomite that are thinly laminated and mottled and medium to thick bedded; upper beds can be very dense with brown and white chert stringers common; fossils include crinoids, bryozoans, brachiopods, and coral; contains a thinly laminated "curly" bed 1 to 3 feet (0.3-1 m) thick that consists of light- to darkgray, wavy and contorted laminations with a potential algal origin; this bed is similar to a bed described by Morris and Lovering (1961) in the Bluebell Dolomite; has an intraformational flat-pebble conglomerate and mottled silicified fossil hash with alternating thin, argillaceous, silty laminations; Bluebell and Fish Haven Dolomites are mapped as a combined unit because the formations are not distinguishable from one another throughout the quadrangle without the easily identifiable marker beds reported in the East Tintic Mountains by Morris and Lovering (1961), which is likely the result of numerous internal unconformities; forms ledges on Long Ridge near Goshen Canyon; lower contact mapped at the appearance of the argillaceous Opohonga Limestone; age range from the Early Devonian to the Late Ordovician (Morris and Lovering, 1961); unit thickness varies throughout the quadrangle as an erosional unconformity removed the upper part of the unit (Rigby, 1959); measured thickness of combined unit is 180 to 265 feet (55–81 m); approximately one mile (1.6 km) to the east of the quadrangle on Long Ridge the Fish Haven Dolomite, Bluebell Dolomite, and Opohonga Limestone are missing; both units are absent on West Mountain (Clark, 2009) and in the southern Wasatch Range (Hintze, 1962); in the East Tintic Mountains the Bluebell Dolomite thickness is 335 to 600 feet (100–185 m) and the Fish Haven Dolomite thickness is 200 to 345 feet (60-105 m) (Morris and Lovering, 1979).

ORDOVICIAN

Oo Opohonga Limestone (Lower Ordovician) – Lightblue-gray to light-brown limestone and argillaceous limestone that is thin to medium bedded; weathered lenses and bands of light-blue-gray limestone alternating with seams and beds of pinkish-red and yellow silty and argillaceous limestone give it a striped, mottled, or mosaic appearance (Morris and Lovering, 1961); contains an intraformational flat-pebble conglomerate; the whole section is rarely well exposed and typically weathers to a slope composed of pinkish-red, orangered, and yellow sandy chips; the unit is dolomitic in places; mapped near Goshen Canyon on Long Ridge; the lower contact is placed at the appearance of argillaceous limestone beds above the pink and white cherty dolomite beds of the Ajax Dolomite; age from Morris and Lovering (1961); complete measured thickness is 90 feet (27 m); the unit is absent on West Mountain (Clark, 2009) and in the southern Wasatch Range (Hintze, 1962); in the East Tintic Mountains the thickness is 300 to 850 feet (90–260 m) (Morris and Lovering, 1961, 1979).

CAMBRIAN

- Cac Ajax Dolomite, Opex Formation, and Cole Canyon Dolomite, undivided (Upper to Middle Cambrian) – Only mapped as a stacked unit; see the unit description for lacustrine gravel and sand (transgressive phase of Lake Bonneville) over Cambrian bedrock (Qlgb/Cac).
- €а Ajax Dolomite (Upper Cambrian) - Light- to darkgray, medium- to thin-bedded, well-bedded, ledgeforming, fine-grained dolomite; subdivided into two members for description but not mapping purposes, the three members as described in the East Tintic Mountains by Morris and Lovering (1961) are not consistently identifiable on Long Ridge because of their highly fractured, faulted, and altered appearance (the distinctive middle Emerald Member was not identified); the upper member is a dark bluishgray dolomite that is fine grained and well bedded with some white, pink, brown and black chert lenses that range in size from thin seams to nodules several inches thick and several feet long, pink and white chert nodular/ribbons are characteristic of the uppermost beds; the lower member is light- to dark-gray dolomite that is medium to thin bedded, beds contain small pods of black, brown, and white chert (fewer than upper member), some lighter-colored dolomite beds are mottled or striped with layers of gray-blue dolomite; present along Goshen Canyon; the lower contact with the Opex Formation may occur in the quadrangle, but the highly altered and fractured nature of the Ajax Dolomite and the Opex Formation on Long Ridge makes distinguishing the units difficult; comparing measured sections in the quadrangle with other sections (Morris and Lovering, 1961; Hintze, 1962; Morris and Lovering, 1979), the Ajax Dolomite may be too thick and some of that thickness could be attributed to unidentified Opex Formation mapped as Ajax Dolomite; ideally the contact between the Ajax Dolomite and the Opex Formation occurs with the appearance of interbedded shale and sandstone, sandy dolomite, pisolites, oolites, and an intraformational flat-pebble conglomerate of the Opex Formation; exposed thickness 377 to 650 feet (115–198 m);

on West Mountain the unit is absent (Clark, 2009), exposure in the southern Wasatch Range is uncertain (Hintze, 1962), in the East Tintic Mountains the thickness is 560 to 650 feet (170–200 m) (Morris and Lovering, 1961, 1979).

Not in Contact – Intervening strata not exposed due to faulting.

- Coc Opex Formation and Cole Canyon Dolomite, undivided (Upper to Middle Cambrian) – Mapped where the units are very fractured and faulted, such that parts of the units are distinguishable enough to identify but are not continuous enough to map a contact between the units; mapped in two exposures on Long Ridge near Government Canyon and Government Flat; combined thickness is estimated at 450 feet (180 m).
- €о **Opex Formation** (Upper Cambrian) – Only mapped as combined unit £oc and stacked unit Qlgb/£ac. Light-blue-gray, thin- to thick-bedded dolomite with some interbedded shale and sandstone; contains some sandy dolomite, pisolites, oolites, intraformational flat-pebble conglomerate, and some cross-bedded fossil hash; unit forms slopes; lower contact at the first alternating series of lighter and darker gray dolomite or the last appearance of sandy, shaly dolomite of the Opex Formation; in the quadrangle some Opex Formation may be mapped as Ajax Dolomite because the fractured and altered nature of the bedrock on Long Ridge makes the dolomites difficult to distinguish; age from Morris and Lovering (1961); entire unit not exposed in quadrangle, estimated exposed thickness is 130 to 330 feet (40-100 m); on West Mountain the Opex Formation? thickness is 220 to 472+ feet (65–144+ m) (Clark, 2009), thickness ranges from 400 to 600 feet (120-180 m) in the southern Wasatch Range (Felger and others, 2004), and in the East Tintic Mountains the thickness is 143 to 245 feet (45-75 m) (Morris and Lovering, 1961).
- €с Cole Canyon Dolomite (Upper to Middle Cambrian) - Alternating light-gray, blue-gray to dark-gray dolomite that is fine to medium grained; beds range from thinly laminated to thick and very thick; typically darker beds are mottled and lighter beds are finely laminated, some beds have wavy laminations and a light-gray color; a few units contain small twig-shaped rods of calcite and dolomite that previous mappers have called "twiggy bodies" (Madsen, 1952); forms ledges on Long Ridge near Government Canyon and one very small outcrop on the south boundary of the quadrangle; the lower contact is not exposed in the quadrangle; age from Morris and Lovering (1961); entire unit not exposed in quadrangle, estimated exposed thickness is 430 to 450 feet (130-180 m); on West Mountain the thickness is 287 feet

(88 m) (Clark, 2009), thickness ranges from 350 to 500 feet (105–150 m) in the southern Wasatch Range (Felger and others, 2004), and in the East Tintic Mountains the thickness is 830 to 900 feet (255–275 m) (Morris and Lovering, 1979).

- Not in Contact Intervening strata not exposed due to faulting (see Slate Jack Canyon 7.5-minute quadrangle, Jensen, 1986).
- £t Tintic Quartzite (Middle to Lower Cambrian) -White- to light-pink, weathering to dark-yellowishorange, quartzose to subarkosic, well-cemented sandstone (commonly referred to as an orthoquartzite), fine to medium grained, well bedded, medium sorting, with common cross-bedding; small beds of quartz-pebble conglomerate are common with iron staining in fractures; forms ledges in one exposure on south border of the quadrangle; age from Morris and Lovering (1961); incomplete thickness is up to 160 feet (50 m); on West Mountain the incomplete thickness is up to 700 feet (200 m) (Clark, 2009), thickness ranges from 800 to 1000 feet (245-305 m) in the southern Wasatch Range (Felger and others, 2004), and in the East Tintic Mountains the thickness is 2300 to 3200 feet (700-975 m) (Morris and Lovering, 1979).

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