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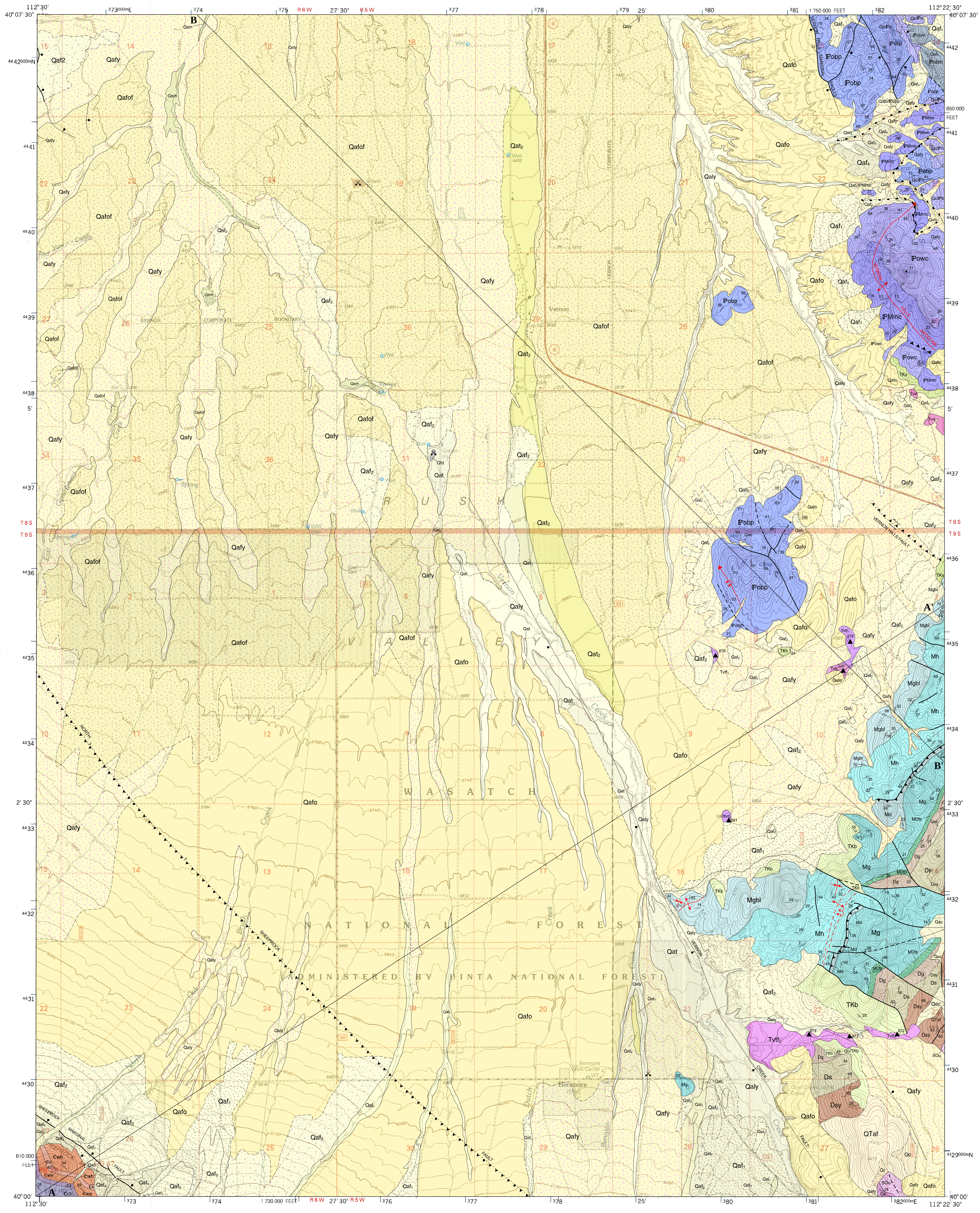

This geologic map was funded by the Utah Geological Survey and the U.S. Geological Survey, National Cooperative Geologic Mapping Program, through USGS STATEMAP award number 08HQAG0096.

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SCALE 1:24,000

1 0.5 0 1 MILE

1000 0 1000 2000 3000 4000 5000 6000 7000 FEET

1 0.5 0 1 KILOMETER

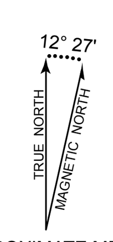
CONTOUR INTERVAL 20 FEET

QUADRANGLE LOCATION

INTERIM GEOLOGIC MAP OF THE VERNON QUADRANGLE, TOOELE COUNTY, UTAH

by
Stefan M. Kirby

2010



APPROXIMATE MEAN DECLINATION, 2009

Base from USGS Vernon 7.5' Quadrangle (1998)
Projection: UTM Zone 12
Datum: NAD 1927
Spheroid: Clarke 1886

Project Manager: Donald Clark
GIS: Richard Emerson and Stefan Kirby
Cartography: Jay Hill

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1	2	3
4		5
6	7	8

1. Onaqui Mountains South
2. Faust
3. Vernon NE
4. Lookout Pass
5. Lofgreen
6. Erickson Knoll
7. Dutch Peak
8. Sabie Mountain

ADJOINING 7.5' QUADRANGLE NAMES

UTAH DNR GEOLOGICAL SURVEY
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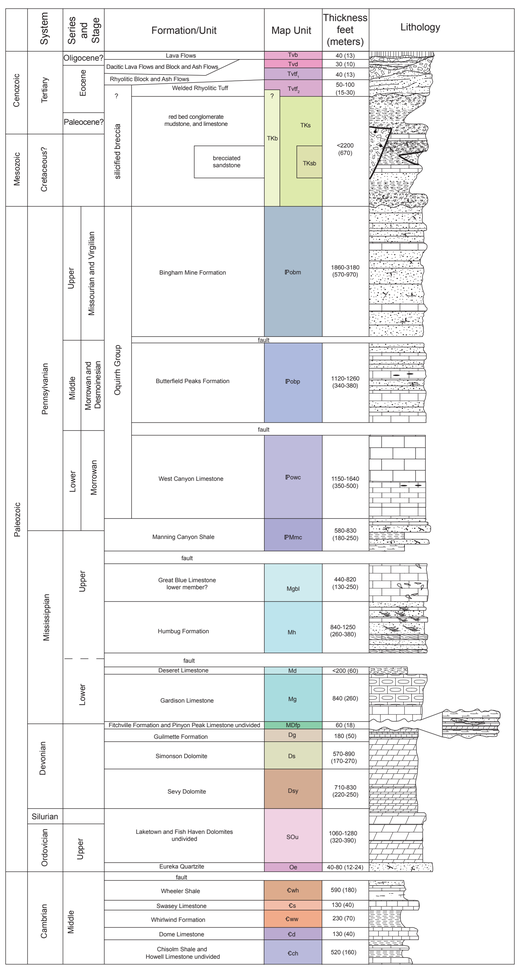
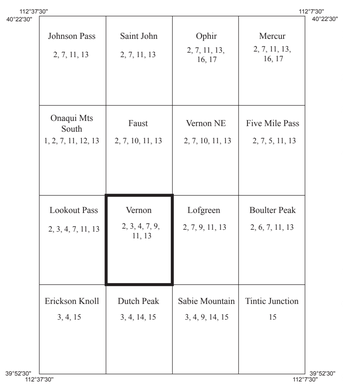
Plate 2
Utah Geological Survey Open-File Report 564
Interim Geologic Map of the Vernon Quadrangle

LITHOLOGIC COLUMN



GEOLOGIC MAP SYMBOLS

- Contact - Dashed where approximately located
- Normal fault - Dashed where approximately located; dotted where concealed; bar and ball on down-thrown block
- Fault - Dashed where approximately located; dotted where concealed; relative motion unknown
- Thrust fault - Dashed where approximately located; dotted where concealed; barb on hanging wall
- Low Angle Normal Fault - Dashed where approximately located; dotted where concealed.
- Anticline axis - Dashed where approximately located; dotted where concealed; arrow indicates direction of plunge
- Syncline axis - Dashed where approximately located; dotted where concealed; arrow indicates direction of plunge
- Overturned anticline axis - Dashed where approximately located; dotted where concealed; arrow indicates direction of plunge
- Overturned syncline axis - Dashed where approximately located; dotted where concealed; arrow indicates direction of plunge
- 19 — Strike and dip of inclined bedding
- 57 — Strike and dip of overturned bedding
- 521 — Microfossil sampling site - Number corresponds with table 3
- 301 — Volcanic rock geochemical sampling site - Number corresponds with tables 1 and 2
- Sand and gravel pit
- Spring
- A — A′ — Line of cross section



Selected geologic map references for the Vernon, Lofgreen, and Vernon NE quadrangles and adjoining areas. Numbers correspond with selected geologic map references.

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14 Mukul, M., and Mitra, G., 1998, Geology of the Sheeprock thrust sheet, central Utah, new insights: Utah Geological Survey Miscellaneous Publication 98-1, 56 p.

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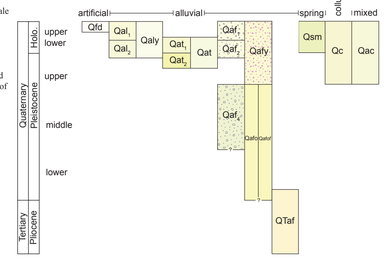
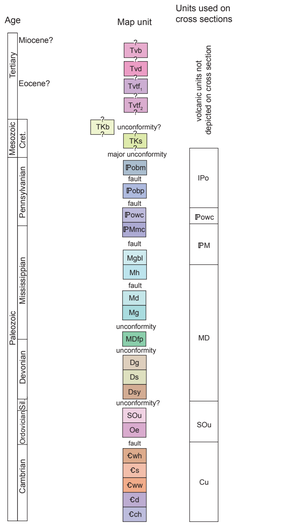
CORRELATION OF UNCONSOLIDATED DEPOSITS



CORRELATION OF BEDROCK UNITS



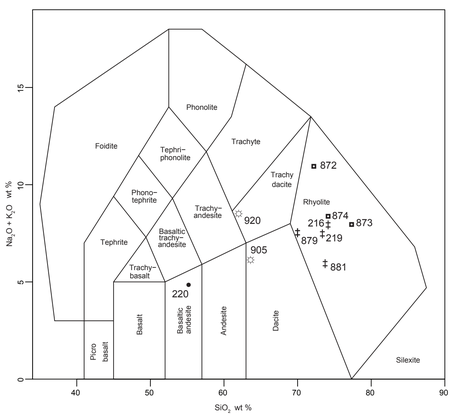


Figure 1. TAS diagram and plot of volcanic rock samples, using the scheme of Middlemost (1994), from the Vernon and Lofgreen quadrangles. Sample location and geochemical data presented in table 1.

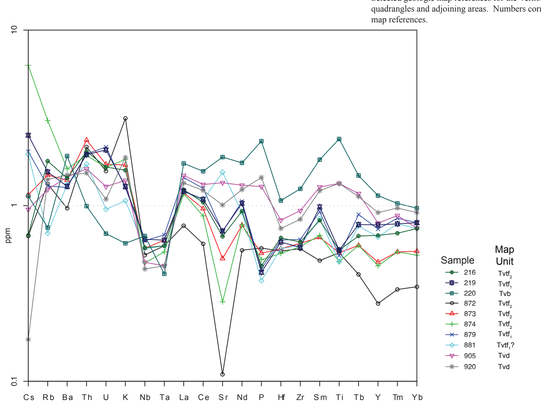
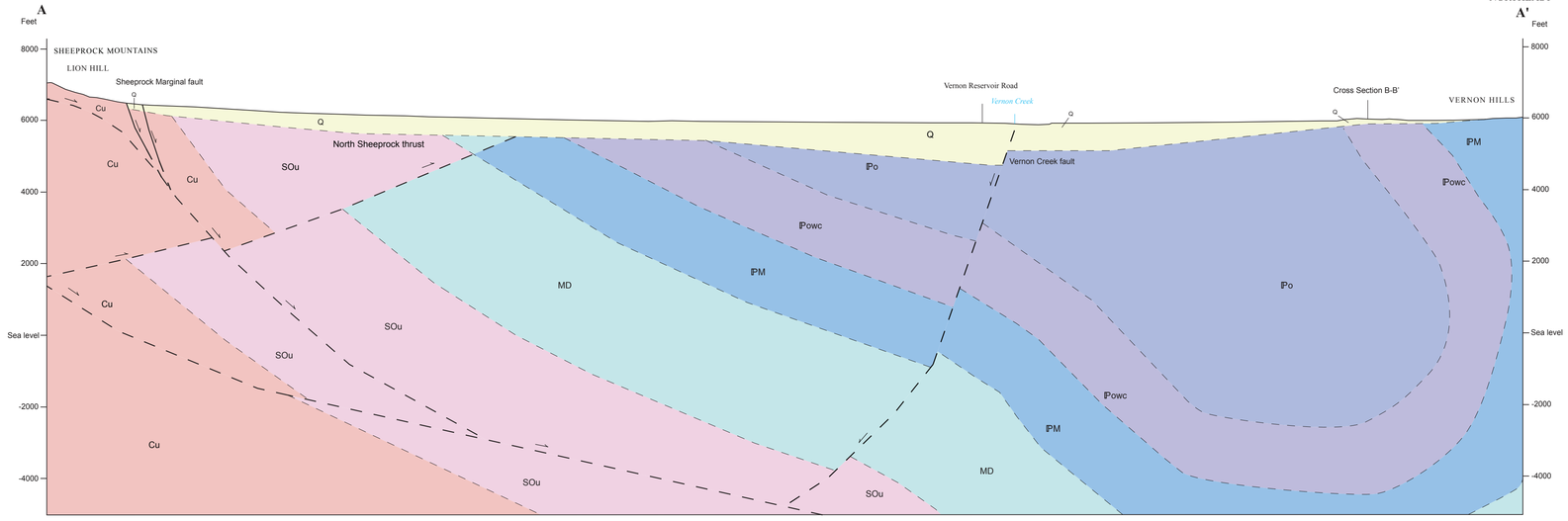


Figure 2. Spider diagram of normalized trace-element composition of volcanic rocks in the Vernon and Lofgreen quadrangles. Data are normalized for upper continental crust using the methods of Taylor and McLennan (1995). Trace geochemical data are presented in table 2.

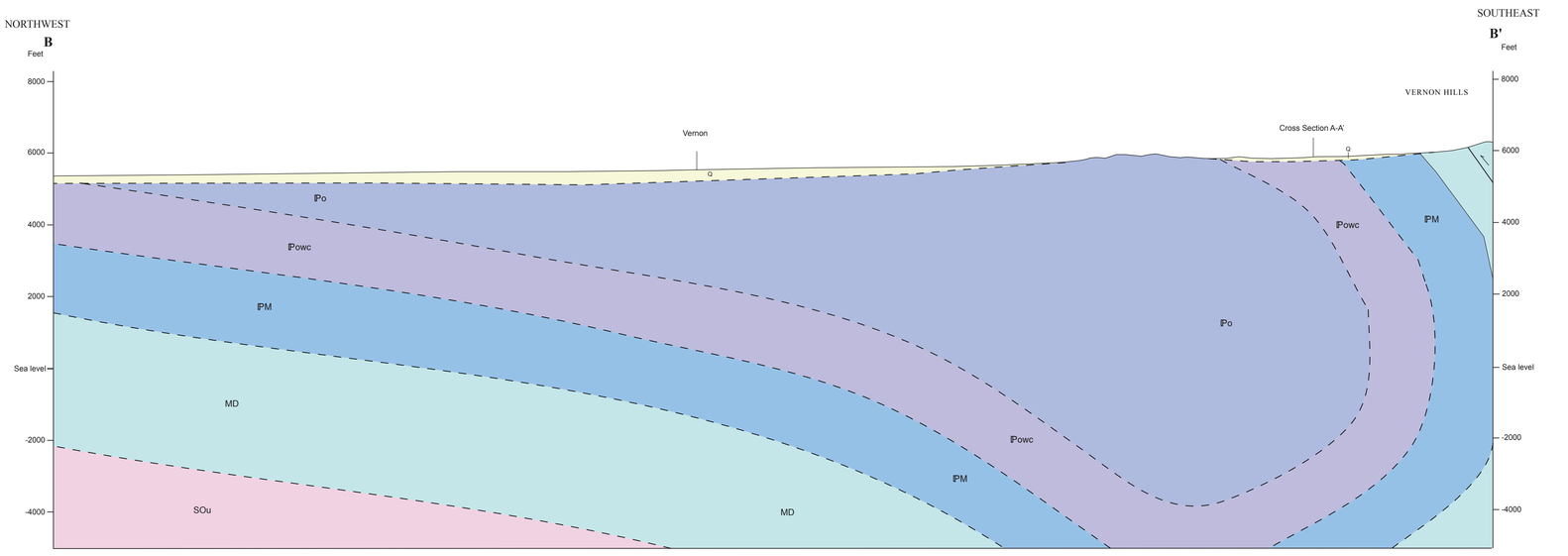
Table 2. *Trace-element geochemistry for volcanic rocks in the Vernon and Lofgreen quadrangles.*

ID	Ba (ppm)	Ce (ppm)	Co (ppm)	Cr (ppm)	Cs (ppm)	Cu (ppm)	Dy (ppm)	Er (ppm)	Eu (ppm)	Ga (ppm)	Gd (ppm)	Hf (ppm)	Ho (ppm)	La (ppm)	Lu (ppm)	Mo (ppm)	Nb (ppm)	Nd (ppm)	Ni (ppm)	Pb (ppm)	Pr (ppm)	Rb (ppm)	Sm (ppm)	Sn (ppm)	Sr (ppm)	Ta (ppm)	Tb (ppm)	Th (ppm)	Tl (ppm)	Tm (ppm)	U (ppm)	V (ppm)	W (ppm)	Y (ppm)	Yb (ppm)	Zn (ppm)	Zr (ppm)
216	789	66.9	3.6	nd	2.51	26	2.3	1.46	0.78	13.7	3.52	3.8	0.47	37	0.26	nd	14.4	24.2	nd	31	6.65	201	3.72	1	234	1.3	0.43	21.8	0.8	0.23	4.65	15	4	14.9	1.63	26	118
219	709	69.6	3.1	10	9.32	15	2.71	1.72	0.84	15.3	3.76	3.6	0.56	38.3	0.28	nd	16.1	26.8	nd	32	7.15	174.5	4.43	2	251	1.4	0.5	20.9	0.9	0.26	5.82	15	3	17.1	1.76	29	110
220	1055	100.5	36.4	360	4.2	51	4.74	2.61	1.92	18.4	7.38	6.2	0.94	52.2	0.32	nd	16.8	45.6	118	16	11.2	84	8.23	2	662	0.9	0.95	10.65	1.1	0.34	1.94	113	2	25.1	2.13	80	237
872	531	38.8	3.5	10	2.49	5	1.21	0.77	0.56	15	1.89	3.2	0.25	23.1	0.14	nd	13.1	14.5	nd	12	4.75	149	2.19	1	38.3	1.3	0.26	23.1	<0.5	0.11	4.41	19	6	6.1	0.76	34	108
873	769	61.6	3.2	10	4.26	5	1.86	1.26	0.75	15.1	2.82	3.3	0.39	35.5	0.22	nd	14.3	20.1	nd	24	6.56	167.5	2.97	1	175	1.4	0.38	25.3	0.5	0.18	4.82	26	6	10.5	1.21	46	116
874	892	56	3.4	10	23.3	5	1.73	1.2	0.73	12.4	2.69	3.1	0.38	35.1	0.21	nd	11.8	20.3	nd	19	6.59	342	3.05	1	99.2	1.2	0.38	20.7	4.1	0.18	4.62	63	21	10	1.15	30	111
879	699	80.3	2.4	nd	7.53	nd	2.73	1.94	1.03	15.1	3.98	3.7	0.6	43.4	0.3	2	15.8	27.5	nd	23	8.78	145	4.16	2	249	1.5	0.57	21.1	0.5	0.28	6.04	20	4	16.2	1.76	41	122
881	728	68.9	2.6	10	7.27	nd	2.42	1.69	0.93	13.9	3.33	3.3	0.56	36.2	0.28	nd	14.2	23.8	nd	22	7.49	78	3.8	1	543	1.3	0.49	18.45	bd	0.26	2.67	21	15	14.6	1.63	35	113
905	800	84.5	12.2	20	3.52	8	3.32	2.05	1.52	17.8	5.04	4.8	0.71	44.6	0.28	nd	11.9	34	7	18	10	138.5	5.75	1	473	1	0.75	17.35	bd	0.29	3.6	102	2	17.5	1.64	67	178
920	823	78.2	12.2	20	0.64	6	3.53	2.29	1.42	16.3	4.89	4.3	0.78	40.4	0.35	nd	10.9	32.1	6	19	9.22	158	5.48	1	353	1	0.72	16.4	0.5	0.32	3.05	84	2	20.1	2.01	66	159

[1] Trace element geochemistry determined by ICP-MS analyses



NORTHWEST — SOUTHEAST



Rugose coral fossils in Mississippian Great Blue Limestone exposed in the southern Vernon Hills. Hammer pick for scale.

Siliceous breccia (map unit TKb) in the southern Vernon Hills. The breccia exists as sharply bounded pods in otherwise unaltered Paleozoic age sedimentary rocks in the Vernon and Lofgreen quadrangles.

Table 1. *Summary of whole-rock geochemical data for volcanic rocks in the Vernon and Lofgreen quadrangles.*

Site ID	East[1]	North	Quad	Map Unit	TAS classification[2]	SiO_2 (%)	Al_2O_3 (%)	Fe_2O_3 (%)	CaO (%)	MgO (%)	Na_2O (%)	K_2O (%)	Cr_2O_3 (%)	TiO_2 (%)	MnO (%)	P_2O_5 (%)	SrO (%)	BaO (%)	LOI[4] (%)	Total (%)
216	382688	4428566	Lofgreen	$Tvtf_2$	Rhyolite	71.54	12.46	1.9	2.19	0.41	2.28	5.37	0.02	0.28	0.03	0.073	0.02	0.09	1.75	98.42
219	381617	4434991	Vernon	$Tvtf_1$	Rhyolite	72.97	13.38	2.12	1.67	0.44	3.27	4.34	0.01	0.28	0.08	0.067	0.03	0.08	0.66	99.41
220	381529	4434651	Vernon	Tvb	Basaltic Andesite	53.99	14.65	8.46	6.72	7.36	2.62	2.06	0.08	1.2	0.13	0.374	0.07	0.14	2.07	99.94
872	382096	4430373	Vernon	$Tvtf_2$	Rhyolite	72.11	13.06	1.92	0.5	0.29	0.21	10.6	nd	0.27	0.02	0.092	0.01	0.06	0.71	99.84
873	381537	4430359	Vernon	$Tvtf_2$	Rhyolite	73.11	13.08	2.28	1.16	0.48	2.15	5.75	nd	0.27	0.04	0.086	0.02	0.09	1.19	99.7
874	381063	4430389	Vernon	$Tvtf_2$	Rhyolite	76.25	11.16	1.72	0.66	0.4	1.7	6.19	nd	0.24	0.03	0.079	0.01	0.11	1.24	99.79
879	380034	4434853	Vernon	$Tvtf_1$	Rhyolite	70.14	14.39	2.09	2.05	0.75	3.1	4.27	nd	0.26	0.07	0.07	0.03	0.08	2.53	99.84
881	380159	4432918	Vernon	Tvtf,?	Rhyolite	70.05	13.37	1.85	2.35	0.7	2.2	3.6	nd	0.24	0.07	0.06	0.08	0.09	4.93	99.59
905	384211	4437458	Lofgreen	Tvd	Dacite	62.83	14.55	5.2	4.85	1.78	2.19	4.7	nd	0.67	0.07	0.206	0.06	0.08	2.12	99.31
920	382814	4437572	Lofgreen	Tvd	Trachydacite	59.93	14.75	5.04	4.98	1.83	1.83	6.35	nd	0.67	0.11	0.232	0.05	0.1	2.71	98.57

[1] Coordinates in UTM NAD 27 zone 12N
[2] Rock type classification based on TAS scheme (Middlemost, 1994)
[3] Major element whole-rock geochemistry in weight percent determined by XRF analyses
[4] LOI is loss on ignition.

Table 3. *Summary of microfossils collected from rocks of the Oquirrh Group in the Lofgreen and Vernon quadrangles. Microfossil analysis and interpretation performed by A.J. Wells, independent paleontologist.*

Site ID	East[1]	North[1]	Map Unit	Quadrangle	Rock description	Fossil types	Fauna	Calcareous algae present	Preservation	Assigned age
720	383405	4441220	IPobm	Lofgreen	Biomicrite: Wackestone	Fusulinid	*Pseudofusulinella*	no	Fair	late Missourian through Virgilian
726	383688	4440907	IPobm	Lofgreen	Biomicrite: Wackestone	Fusulinid	*Pseudofusulinella: P. cf. fergusonensis*	no	Fair	Wolfcampian, Virgilian, Missourian
245	383170	4440190	IPobp	Lofgreen	Biomicrite: Mudstone	Fusulinid	*Profusulinella*	no	Good	early Atokan
586	382346	4439325	IPowc	Vernon	Biomicrite: Wackestone	Foraminifera	Morrowan Forams?	no	Poor	Morrowan?

[1] Coordinates in UTM NAD 27 Zone 12N

INTERIM GEOLOGIC MAP OF THE VERNON QUADRANGLE, TOOELE COUNTY, UTAH

by

Stefan M. Kirby

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OPEN-FILE REPORT 564
UTAH GEOLOGICAL SURVEY
a division of
Utah Department of Natural Resources
2010

INTRODUCTION

Location and Geographic Setting

The Vernon quadrangle covers part of southwestern Rush Valley and includes the community of Vernon in southeastern Tooele County, Utah (plate 1). State Highway 36 extends across the northeast quarter of the quadrangle. The quadrangle includes part of the Vernon Hills along its eastern edge, the valley floor near the community of Vernon, and a small part of the Sheeprock Mountains in the southwest corner of the quadrangle. Vernon Creek flows north across the quadrangle.

Scope of Work

The Vernon quadrangle was mapped in conjunction with the adjoining Lofgreen and Vernon NE quadrangles as part of the 2009 USGS STATEMAP award # 08HQAG0096 made to the Utah Geological Survey (UGS). I mapped geologic contacts directly on available digital orthophotography and 1:24,000-scale Vernon topographic map base using ArcGIS. I also examined available 1:20,000-scale black and white air photos and 5 meter elevation data to delineate unit contacts. I completed several weeks of mapping and field checking of units in the Vernon quadrangle during the spring of 2009.

Geologic Summary

The bedrock exposed in the quadrangle includes sedimentary and volcanic rocks that range from Cambrian to Tertiary in age. Volcanic rocks crop out near the eastern margin of the quadrangle along the flanks of the Vernon Hills. The chemical composition of these rocks ranges from basaltic andesite to rhyolite, and they may be correlative with Eocene to Miocene volcanic rocks in the nearby Oquirrh and East Tintic Mountains (Moore and McKee, 1983; Eric Christiansen, Brigham Young University, written communication, 2008). Many of these volcanic rocks are also exposed in the adjoining Lofgreen quadrangle. The youngest consolidated sedimentary unit is a thick section of folded and faulted red-bed conglomerates that may range from Cretaceous to Tertiary in age, based on correlation with similar regional deposits to the east (Constenius and others, 2006) and south (DeCelles and Coogan, 2006). These deposits are well exposed near Highway 36 and rest in apparent angular unconformity on structurally complicated Paleozoic bedrock. The extent of these deposits in the subsurface is unknown, but boreholes to the northeast in the adjacent Vernon NE quadrangle do not intercept similar deposits (Kirby, in preparation). Formations ranging from Cambrian to Pennsylvanian in age compose the remainder of the exposed sedimentary bedrock. Upper Mississippian and Pennsylvanian rocks crop out north of Highway 36 and are folded into the northwest-plunging Vernon Hills anticline. South of Highway 36, a steeply dipping to overturned and east-dipping section of Ordovician through Pennsylvanian rocks is exposed. The east-dipping overturned rocks include a nearly stratigraphically complete section of Upper Ordovician to Upper Mississipian rock units

that extends partially across the eastern quadrangle boundary into the Lofgreen quadrangle. Bedding-parallel faults omit part of the Deseret Limestone in this section. Several outcrops of silicified breccia lie within the Paleozoic rocks. Northeast-dipping, Middle Cambrian strata are exposed in the far southwest corner of the quadrangle in the Sheeprock Mountains.

Pliocene? to Holocene unconsolidated deposits in the Vernon quadrangle include various alluvial fan and channel deposits, mixed alluvium and colluvium, and spring and marsh deposits. The entire quadrangle is above the highstand of Lake Bonneville (Curry, 1982). Unconsolidated deposits cover most of the quadrangle, and based on well logs rest directly on bedrock of the Oquirrh Group north of Vernon, where total thickness of the unconsolidated deposits may be greater than 500 feet (150 m) (Utah Division of Water Rights, 2009). The thickness of unconsolidated deposits likely decreases towards the Sheeprock Mountains in the south and the Vernon Hills in the east. A broad area in the northern half of the quadrangle consists of smooth, gently-sloping surfaces mapped as fine-grained older alluvial fan deposits. These deposits are incised by Holocene and late Pleistocene drainages and therefore predate the transgression and highstand of Lake Bonneville. In the southern Vernon Hills and southwest corner of the quadrangle, unconsolidated deposits of cobble- to boulder-size material lacking a consistent alluvial slope may be the eroded remnants of a contiguous alluvial surface that extended into the adjoining Lofgreen quadrangle.

The early tectonic history of the quadrangle is recorded by exposed Cambrian to Pennsylvanian strata that were deposited first across a broad subsiding carbonate platform and later within the rapidly subsiding Oquirrh basin. These rocks were then folded and faulted by dominantly east-directed thrust faulting and compression during the Late Jurassic to Eocene Sevier orogeny (Armstrong, 1968; DeCelles and Coogan, 2006, and references therein). East-dipping overturned rocks exposed in the Vernon Hills may be evidence of a major west-directed back thrust and shear fault (Vernon Hills fault) exposed to the east in the Lofgreen quadrangle. The presence of the North Sheeprock fault is indicated by exposures of Lower Cambrian quartzite near Upper Ordovician rocks just south of the Vernon quadrangle in the adjoining Dutch Peak quadrangle (Mukul and Mitra, 1998). This fault is inferred to extend into the southwest quarter of the quadrangle, where it separates Middle Cambrian and Precambrian rocks of the Sheeprock Mountains from Upper Ordovician and younger rocks to the north. Folded conglomerates may have been deposited during and/or just prior to thrusting and large-scale folding within the Sevier orogenic belt. Steeply dipping, roughly east-west striking faults cut overturned Paleozoic strata in the Vernon Hills and may record east-west directed shear during later stages of the Sevier orogeny. East-west striking faults sharply bound several outcrops of silicified breccia and suggest a linked origin for these two features. During the Eocene, crustal shortening was followed by Sevier belt collapse/relaxation and significant regional volcanism (Constenius, 1996; Constenius and others, 2003). Extension remains the dominant tectonic style in the area, but it has varied in magnitude, style, and extent across Eocene to Holocene time. Normal faulting typical of modern Basin-and-Range extension began after 20 Ma (Stewart, 1998 and references therein). Down-to-the-southwest normal faulting along the buried Vernon Creek fault

may have occurred during the late Tertiary. Available gravity data (Everitt and Kaliser, 1980) show little apparent bedrock offset across the Vernon Creek fault. Fault scarps of the Sheeprock marginal fault (Everitt and Kaliser, 1980) cut late Pleistocene and Holocene alluvial fan deposits in the southwest corner of the quadrangle. Scarp heights range between 9 and 20 feet (3-7 m) and at least one scarp cuts post-Bonneville-age fan deposits, suggesting at least one surface faulting event during the Holocene (Everitt and Kaliser, 1980). More detailed trenching studies of the Sheeprock marginal fault zone have not been performed and numerical age control is lacking for surface faulting along this structure. In the northeast corner of the quadrangle, a sharp contact between Pennsylvanian-age bedrock and adjoining older fan deposits is interpreted to be the result of Quaternary-age normal faulting.

Previous Investigations and Mapping Background

Several investigators have mapped the geology of the Vernon quadrangle at various scales smaller (less detailed) than 1:24,000, including Cohenour (1959), Groff (1959), Bucknam (1977), Moore and Sorensen (1979), Everitt and Kaliser (1980), Christie-Blick (1983), Moore and McKee (1983), and Mukul and Mitra (1998). Adjoining mapping relevant to both bedrock and unconsolidated deposits includes Gilluly (1932), Disbrow (1957), Cohneour (1959), Groff (1959), Armin and Moore (1981), Pampeyan (1989), and Tooker and Roberts (1998). Christie-Blick (1983) discussed the geology of the north flank of the Sheeprock Mountains, and fault scarps along the Sheeprock Mountains are discussed by Everitt and Kaliser (1980). Hood and others (1969) discussed the hydrogeology of the quadrangle.

MAP UNIT DESCRIPTIONS

QUATERNARY

Qfd **Artificial fill and disturbed areas** (Historical) – Excavations and associated fill at small gravel pits near Vernon; material includes sand, gravel, angular cobble-size clasts, silt, and clay; variable thickness 0 to 50 feet (0-17 m).

Qal_1 **Level-1 stream deposits** (upper Holocene) – Moderately to well-sorted sand, pebble and cobble gravel, silt, and minor clay in active stream channels and flood plains; deposit is alternately clast or matrix supported; mapped along the lower reaches of Vernon Creek and along smaller streams draining areas of shallow ground water and marshes west and north of Vernon; includes deposits on active flood plains and minor terraces less than 10 feet (3 m) above stream level and locally includes small colluvial deposits along steep stream embankments; deposits equivalent to and grade into the younger part of young alluvial deposits (Qaly); exposed thickness less than 15 feet (5 m).

Qal_2 **Level-2 stream deposits** (middle Holocene to upper Pleistocene) – Moderately to well-sorted sand, pebble and cobble gravel, silt, and minor clay in major

drainages above active stream channels and flood plains (Qal_1); deposit is alternately clast or matrix supported; unit includes inactive stream and flood-plain deposits more than 10 feet (3 m) above incised active channel and flood-plain deposits of Qal_1; mapped along major drainages where modern stream deposits have incised and inactivated lower Holocene stream and flood-plain deposits along the lower part of the Vernon Creek drainage in the Vernon quadrangle; includes deposits on largely inactive flood plains and minor terraces; locally includes small colluvial deposits along steep stream embankments; deposits equivalent to and grade into the older part of young alluvial deposits (Qaly); exposed thickness less than 15 feet (5 m).

Qaly **Younger alluvial deposits, undivided** (Holocene and upper Pleistocene) – Moderately to well-sorted sand, pebble and cobble gravel, silt, and minor clay; deposited along major drainages; locally includes small alluvial-fan and colluvial deposits; includes level-2 stream deposits (Qal_2) incised by active stream channels and partly overlain by level-1 stream deposits (Qal_1) that cannot be differentiated because of map scale or in areas where the specific age of Holocene deposits cannot be determined; postdates regression of Lake Bonneville; thickness variable, probably less than 15 feet (5 m).

Qat (Qat_1, Qat_2) **Stream-terrace deposits** (middle Holocene to upper Pleistocene) – Moderately to well-sorted sand, pebble and cobble gravel, silt, and minor clay; deposited on two levels of gently sloping terraces; includes inactive stream and flood-plain deposits; all terrace deposits lie above active stream and flood-plain levels, with subscripts denoting relative height above modern stream channels, 1 being the lowest level; level 1 deposits (Qat_1) lie 10 to 20 feet (3-6 m) above modern streams and are incised by them; level 2 deposits lie 20 to 40 feet (6-12 m) above modern streams; where subscripts are absent, closely spaced terrace levels cannot be differentiated or only one terrace level exists that cannot be given a relative age; thickness variable 5 to 20 feet (1.5-5 m).

Qaf_1 **Level-1 alluvial-fan deposits** (upper Holocene) – Poorly to moderately sorted, crudely stratified or massive, pebble to cobble gravel with boulders near bedrock exposures, sand, silt, and minor clay; clasts angular to subrounded and commonly matrix supported; deposited principally by debris flows and sheet floods at the mouths of small, intermittent stream channels draining bedrock or near the mouth of other channels in older alluvial-fan and other unconsolidated deposits; locally incised in and/or overlying older alluvial-fan deposits; deposits equivalent to, and grade into the younger part of young alluvial-fan deposits (Qafy); differentiated from other alluvial-fan deposits due to a relatively smooth undissected fan surface radiating away from a defined fan apex; exposed thickness less than 10 feet (3 m).

Qaf_2 **Level-2 alluvial-fan deposits** (middle Holocene to upper Pleistocene) – Poorly to moderately sorted, crudely stratified or massive, pebble to cobble gravel with boulders near bedrock exposures, sand, silt, and minor clay; clasts angular to subrounded and commonly matrix supported; deposited principally by debris

flows and sheet floods; locally incised in and/or overlying older alluvial-fan deposits; deposits equivalent to, and grade to the older part of Qafy, locally above younger Qafy deposits; fan surface is abandoned and commonly dissected and irregular; deposits grade above modern stream (Qal_1) or alluvial-fan level (Qaf_1); exposed thickness less than 15 feet (5 m).

Qafy **Younger alluvial-fan deposits** (Holocene to upper Pleistocene) – Poorly to moderately sorted, crudely stratified or massive, pebble to cobble gravel with boulders near bedrock exposures, sand, silt, and minor clay; clasts angular to subrounded and commonly matrix supported; deposited principally by debris flows and sheet floods at the mouths of intermittent stream channels draining bedrock, near the mouth of other channels in older alluvial-fan and other unconsolidated deposits, or across large alluvial slopes where individual fan surfaces cannot be differentiated; includes level-1 and -2 alluvial-fan deposits (Qaf_1 and Qaf_2) that postdate Lake Bonneville or in areas where the specific age of deposits cannot be determined; thickness variable, probably less than 40 feet (12 m).

Qaf_4 **Alluvial-fan deposits, pre-Bonneville lake cycle** (upper? to middle? Pleistocene) – Poorly sorted, clast-supported pebble to cobble gravel, with matrix-supported interbeds in the upper part; locally bouldery in a matrix of sand, silt, and clay; clasts angular to subrounded; medium to very thick bedded; equivalent to the youngest part of older alluvial-fan deposits (Qafo) but differentiated where pre-Bonneville deposits can be subdivided based on fan morphology, degree of dissection, and incision of younger deposits into older deposits; exposed thickness less than 30 feet (10 m).

Qafo **Older alluvial-fan deposits, pre-Bonneville lake cycle** (upper? to lower Pleistocene) – Poorly sorted, pebble to cobble gravel, locally bouldery, in a matrix of sand, silt, and clay; mapped in areas where pre-Bonneville lake cycle alluvial-fan deposits are undifferentiated because they are poorly exposed or lack distinct geomorphic expression; unit is locally overlain by or grades into pre-Bonneville alluvial fan deposits (Qaf_4) where relative fan chronology is apparent; unit is incised by and alternately overlain by syn- and post-Bonneville alluvial fan units (Qafy, Qaf_1, and Qaf_2); thickness probably less than 60 feet (20 m).

Qafof **Older alluvial deposits, fine-grained** (upper? to lower Pleistocene) – Poorly sorted sand, silt, gravel, and clay in a silt or sand matrix; deposited principally as debris flows and sheet-floods across broad alluvial slopes; unit is incised or overlain by post-Bonneville alluvial units (Qafy, Qaly, Qal_1, Qal_2, Qat_1, and Qat_2); mapped in the Vernon quadrangle in areas of pre-Bonneville alluvial-fan deposits where unit is differentiated from Qafo because of a greater component of silt and sand and a shallow depositional slope; unit forms relatively smooth, rounded, and partly hummocky low-gradient surface near Vernon that is incised by alluvial channels that grade to near the Bonneville level to the north; total thickness up to 40 feet (13 m).

Qsm **Spring and marsh deposits** (Holocene) – Moderately to well-sorted silt, sand, clay, and dark organic-rich material in areas of high water tables, perennial spring flow, and seasonal standing water in the Vernon quadrangle; total thickness up to 30 feet (10 m).

Qc **Colluvial deposits** (Holocene and upper Pleistocene) – Pebble, cobble, and boulder gravel, commonly clast supported, in a matrix of sand, silt, and clay; angular to subangular clasts, poorly sorted, poorly stratified, locally derived sediment deposited by slopewash and soil creep; includes landslides, rock falls, and debris flows too small to map separately; most bedrock is covered by at least a thin veneer of colluvium, and only the larger, thicker deposits are mapped; thickness less than 15 feet (5 m); also mapped as stacked units (Qc/IPo, Qc/TKb) where colluvial deposits thinly mantle underlying bedrock.

Qac **Younger alluvial and colluvial deposits** (Holocene and upper Pleistocene) – Poorly to moderately sorted pebble or in places cobble gravels, sand, silt, and clay; generally locally derived and mapped in areas where alluvium and colluvium cannot be subdivided; unit deposited by alluvial, fluvial, and slope wash, and by soil creep in topographically confined parts of the Vernon Hills and near Vernon as low-gradient alluvial and colluvial surfaces that lack alluvial-fan morphology; total thickness 0 to 40 feet (0-13 m).

Qc/IPo **Colluvium over Pennsylvanian Oquirrh Group undivided** (Holocene to upper Pleistocene/Pennsylvanian) – Locally derived angular cobble- to gravel-size blocks, sand, silt, and clay deposited primarily by slope-wash processes along swales, slopes, and drainages; mapped where colluvium thinly mantles and partially obscures outcrops and bedding in Oquirrh bedrock in the northern Vernon Hills; thickness 0 to 10 feet (0-3 m).

Qc/TKb **Colluvium over siliceous breccia and sinter** (Holocene to upper Pleistocene/Tertiary to Cretaceous) – Locally derived angular cobble- to gravel-size blocks, sand, silt, and clay deposited primarily by slope-wash processes along swales, slopes, and drainages; mapped where colluvium thinly mantles and partially obscures outcrops of siliceous breccia in the Vernon Hills; thickness 0 to 10 feet (0-3 m).

Qaf_2/IPMmc **Level-2 alluvial-fan deposits over Manning Canyon Shale** (middle Holocene to upper Pleistocene/Lower Pennsylvanian? to Upper Mississippian) – Poorly to moderately sorted, crudely stratified or massive, pebble to cobble gravel with boulders near bedrock exposures, sand, silt, and minor clay; clasts angular to subrounded and commonly matrix supported; deposited principally by debris flows and sheet floods; deposits equivalent to, and grade to the older part of Qafy; fan surface is abandoned and commonly dissected and irregular; deposits grade above modern stream (Qal_1) or alluvial fan level (Qaf_1); mapped where alluvial

fans thinly mantle and partially obscure outcrops of Manning Canyon Shale in the Vernon Hills; thickness 0 to 10 feet (0-3 m).

Qafo/IPo **Older alluvial-fan deposits, pre-Bonneville lake cycle over Pennsylvanian Oquirrh Group undivided** (upper? to lower Pleistocene/Pennsylvanian) – Poorly sorted, pebble to cobble gravel, locally bouldery, in a matrix of sand, silt, and clay; mapped in areas where pre-Bonneville lake cycle alluvial-fan deposits are undifferentiated because they are poorly exposed or lack distinct geomorphic expression; mapped where alluvial fans thinly mantle and partially obscure outcrops of Oquirrh Group bedrock in the Vernon Hills; thickness 0 to 10 feet (0-3 m).

QUATERNARY-TERTIARY

QTaf **Oldest alluvial-fan deposits** (lower Pleistocene? to upper Pliocene?) – Poorly sorted boulder, cobble, and pebble gravel, sand, silt, and clay; unit composed of unconsolidated boulders, cobbles and gravels; clasts include quartzite, diamictite, and various Paleozoic carbonates apparently sourced from bedrock exposed to the south in the northern Sheeprock Mountains and Sabie Mountain; unit is the highest standing unconsolidated unit but does not have consistent slope characteristic of alluvial fans; instead unit forms rounded hills in the southern part of the Lofgreen and the southeastern part of the Vernon quadrangle that overly various bedrock; alluvial fan units (Qafo and Qaf_4) are topographically below and inset in this unit; stratigraphy and extent of unit suggest these deposits may be a remnant of a previously extensive alluvial pediment developed on the northern flank of the Sheeprock Mountains and Sabie Mountain northeast of the Vernon Creek fault; absolute age is unknown but this unit may be much older than all other unconsolidated deposits; thickness up to 300 feet (100 m).

TERTIARY

Tvb **Basaltic andesite** (Miocene? or Oligocene? or Eocene?) – Dark-gray or black, very fine grained basaltic andesite lava flow (figures 1 and 2; tables 1 and 2); contains abundant olive-green to orange-brown altered granular olivine phenocrysts 1mm or less in diameter; unit crops out as a lava flow remnant on a small knob and adjoining slope on the west flank of the Vernon Hills in the Vernon quadrangle where it appears to abut and overlie $Tvtf_1$; unit also crops out on the east flank of the Vernon Hills north of Highway 36 in the Lofgreen quadrangle; age based on potential correlation with the Mosida Basalt (19.6 Ma), a geochemically similar unit that may occupy a comparable stratigraphic position to the east in the East Tintic Mountains (Eric Christiansen, Brigham Young University, written communication, 2009); total exposed thickness is approximately 40 feet (13 m).

Tvd **Dacite and trachydacite** (Eocene?) – Light-gray to reddish-brown porphyritic dacite and trachydacite lave flows; contains abundant altered white plagioclase phenocrysts 1-4 mm in length, and minor hornblende phenocrysts less than 2 mm in length, also contains a few angular black or dark-gray porphyritic lithic fragments up to 4 mm in length, possibly correlative with $Tvtf_1$ or $Tvtf_2$; unit crops out as several topographically low remnants along the flanks of the Vernon Hills in the Vernon quadrangle; unit appears to be shallowly dipping and overlie and/or abut exposures of TKs sedimentary deposits; age of unit is unconstrained but assumed to be Eocene based on correlation with similar volcanic units exposed, to the east in the East Tintic Mountains (Eric Christiansen, Brigham Young University, written communication, 2009); radiometric age is pending; maximum exposed thickness is about 30 feet (10 m).

$Tvtf_1$ **Younger rhyolite** (Eocene?) – White to light-gray or locally dark-gray, typically massive crystal-rich, lithic or vitric tuff; glass-rich matrix ranges from densely welded and banded to largely unwelded and ashy with no apparent flow banding; contains angular to subangular lithic clasts, up to 10 mm in diameter, of older volcanic units $Tvtf_2$ and dark gray to black angular vitrophyre clasts up to 20 mm in diameter; unit contains no lithic clasts similar to Tvd or Tvb units; unit crops out along the flanks of the Vernon Hills in the Lofgreen and Vernon quadrangles; apparently underlies Tvb in the Vernon quadrangle; absolute age of unit is uncertain but superposition places this unit in the Eocene after emplacement of $Tvtf_2$ and before Tvb; unit is similar in appearance and geochemistry to the Packard Quartz Latite (35 Ma) exposed to the east in the Lake and East Tintic Mountains (Eric Christiansen, Brigham Young University, written communication, 2009); radiometric age is pending; exposed thickness is 40 feet (13 m).

$Tvtf_2$ **Older rhyolite** (Eocene?) – Pale-red to pink or gray, welded phenocrystic tuff; major phenocrysts include euhedral plagioclase up to 3 mm in length, biotite, and hornblende; unit is generally densely welded with thin vitrophyric bands, small-scale flow banding is apparent in many exposures; unit crops out in the Vernon quadrangle in the southwestern part of the Vernon Hills; K-Ar biotite age of 38.0 $\pm$ 0.5 Ma from Moore and McKee (1983) is likely from this unit near the Vernon Creek Ranch in the Vernon quadrangle; new radiometric age pending; exposed thickness 50 to 100 feet (15-30 m).

TERTIARY-CRETACEOUS

TKb **Siliceous breccia and sinter** (Miocene? or Oligocene? to Cretaceous?) – Dark-brown silicified angular breccia; forms pods and fault-bounded blocks within otherwise unaltered Paleozoic sedimentary units; occasionally relict bedding is preserved from the host rock, more commonly all textural features of the host rock have been overprinted and heavily silicified; the largest outcrop in the southern Vernon Hills is bounded by and possibly linked to east-west striking steeply dipping faults that cut overturned Paleozoic-age sedimentary rocks,

suggesting a syn- or post-thrusting age for this unit; no other cross-cutting relationship that constrains the age of these deposits has been found, and they may alternately be related to regional volcanism during the Eocene to Miocene; exposed thickness of several hundred feet (~100 m).

TKs **Unnamed sedimentary rocks** (Eocene? to Cretaceous?) – Red, brown, or pale-gray interbedded conglomerate, limestone, mudstone, siltstone, and tuffaceous sandstone; clast-supported conglomerate consists of subangular to rounded pebbles, cobbles, and boulders of quartzite, carbonate, and sandstone in a sandy, gritty, calcareous or arkosic matrix; clasts as much as 1 foot (0.3 m) in diameter; conglomerate clasts include a range of Paleozoic sedimentary rock sources including medium-gray cherty limestone, dark-gray dolomite, well-bedded light-gray dolomite, fossiliferous limestone, tan calcareous sandstone, and cross-bedded quartzite; volcanic clasts are conspicuously absent from the conglomerate; limestone intervals are commonly 10 to 20 feet (3-6 m) thick consisting of medium-bedded tan to pale-gray sparsely fossiliferous micrite; mudstone intervals are red to red-brown, in part sandy and crudely bedded; siltstone intervals are purple to pale red and thin bedded; unit unconformably overlies Great Blue Limestone, West Canyon Limestone, and Manning Canyon Shale in central portion of the Vernon Hills north and south of State Highway 36; radiometric age is pending; TKs is steeply to moderately dipping; estimate of exposed thickness is complicated by folding, but unit may be just less than 2200 feet (670 m) thick.

PENNSYLVANIAN

IPobm **Bingham Mine Formation of the Oquirrh Group** (Upper Pennsylvanian [Virgilian-Missourian]) – Brown- to tan-weathering, fine- to medium-grained calcareous and quartzitic sandstone, and interbedded thin- to medium-bedded, medium-gray, fine-grained sandy and cherty limestone intervals; calcareous and quartzitic sandstone dominate this unit, limestone is less common; sandstone is typically light brownish gray, planar bedded; locally displaying low-angle cross-stratification and small-scale cross-bedding; both calcareous and quartzitic sandstone exist in nearly equal proportions; limestone intervals typically medium gray, medium to thick bedded, commonly sandy with very fine to fine-grained sand; fossils include rugose corals, crinoids, brachiopods, fossil hash, and fusulinids in localized beds; the Bingham Mine Formation is delineated from the underlying Butterfield Peaks Formation by a comparatively greater amount of sandstone versus limestone; the lower contact is not exposed in the Vernon Hills and the Bingham Mine Formation is apparently in fault contact with the underlying Butterfield Peaks Formation; Missourian and Virgilian age of unit is from fusulinid samples collected in the field (table 3); in the Vernon Hills an incomplete section of the Bingham Mine Formation is 1860 to 3180 feet (570-970 m) thick; the formation is about 7300 feet (2200 m) thick in the Oquirrh Mountains (Tooker and Roberts, 1998).

IPobp **Butterfield Peaks Formation of the Oquirrh Group** (Middle to Lower Pennsylvanian [Desmoinesian-Morrowan]) – Interbedded, brown- to gray-weathering, fine- to medium-grained calcareous and quartzitic sandstone, and medium-gray, fine- to medium-grained limestone and sandy limestone; unit characterized by repeated intervals of quartzitic or calcareous sandstone overlain by intervals of gray limestone or sandy limestone; contains minor siltstone; sandstone is typically light brownish gray, planar bedded; locally displaying low-angle cross-stratification and small-scale cross-bedding; both calcareous and quartzitic sandstone exist in nearly equal proportions; limestone intervals typically medium gray, medium to thick bedded, commonly sandy with very fine- to fine-grained sand; fossils include rugose corals, crinoids, brachiopods, fossil hash, and fusulinids in localized beds; locally contains black chert nodules and thin chert beds; limestone and sandy limestone commonly grade upward to finer grained, platy-weathering limestone and argillaceous limestone and siltstone; siltstone is tan to brown gray and thin bedded; generally poorly exposed and commonly bioturbated; forms ledgey slopes and ridges in the northern Vernon Hills; age of Butterfield Peaks exposures in the Vernon Hills is Atokan and taken from fusulinid samples collected in the field (table 3). Incomplete thickness of 1120 to 1260 ft (340-380 m) in the Vernon Hills; apparently in fault contact with the West Canyon Limestone below and the Bingham Mine Formation above; Tooker and Roberts (1998) reported the formation is about 9000 feet (2750 m) thick in the Oquirrh Mountains.

IPowc **West Canyon Limestone of the Oquirrh Group** (Lower Pennsylvanian [Morrowan]) – Medium- to thick-bedded, light- to medium-gray, fine- to medium-grained limestone, sandy limestone, and fossiliferous limestone; locally laminated with brown silt and very fine grained sand; fossils include crinoid columns, brachiopods, rugose corals, and fusulinids in localized beds; lower contact is gradational and conformable and mapped at the transition from continuous limestone strata of the West Canyon Limestone to the predominantly interbedded clastic strata of the Manning Canyon Shale; upper contact with the Butterfield Peaks Formation is a fault in the Vernon Hills; Morrowan age of the unit in the Vernon Hills is based on a single poor foraminifera sample (table 3); forms prominent cliffs and east-dipping, ledgey slopes in the northern Vernon Hills; the exposed and likely incomplete thickness of West Canyon Limestone in the Vernon Hills is 1150 to 1640 feet (350-500 m) thick; regional thickness is 1000 to 1440 feet (305-440 m) (Davis and others, 1994; Tooker and Roberts, 1998; Biek, 2004).

PENNSYLVANIAN-MISSISSIPPIAN

IPMmc **Manning Canyon Shale** (Lower Pennsylvanian? to Upper Mississippian) – Generally dark-colored, lithologically diverse unit of interbedded quartzite, shale, sandstone, limestone, and siltstone; shale and calcareous siltstone are dark brown to grayish brown to grayish red, commonly weathering to brown orange; quartzite is dark-brown weathering, blocky, medium to well bedded, with some well-

developed cross-beds; quartzite hand samples commonly have a distinctive vitreous pleochroism; fine-grained sandstone and calcareous sandstone are medium bedded and display some cross-beds and low-angle cross-stratification; argillaceous and rarely fossiliferous limestone is medium gray and thin to medium bedded, and commonly found in the upper several hundred feet of the unit; all Manning Canyon lithologies tend to be laterally discontinuous, however shale and quartzite sections are more continuous than either limestone or sandstone lithologies; structural disruption of the Manning Canyon Shale in the Vernon Hills is common and small scale faults, heavily fractured zones, and folds are apparent in many exposures; the base of the Manning Canyon Shale is not exposed in the Vernon Hills and may be a thrust fault of regional extent; age taken from regional work by Davis and others (1994); exposed thickness between 580 and 830 feet (180-250 m); regional thickness of 1000 to 1650 feet (300-500 m)(Biek and others, 2009).

MISSISSIPPIAN

Mgbl **Great Blue Formation, lower member** (Upper Mississippian) – Medium- to blue-gray, medium-grained, moderately to well-bedded limestone and fossiliferous limestone; fossils include ubiquitous rugose corals, crinoid columns, brachiopods, and fossil hash; unit crops out as ledgey slopes and small cliffs in the central part of the Vernon Hills; lower contact is conformable and gradational; marked by the transition from the interbedded sandstone and limestone lithologies of the underlying Humbug Formation to continuous limestone typical of the Great Blue Formation; upper contact and the upper member of the Great Blue Limestone are not exposed and potentially fault-truncated in the Vernon Hills; nearby in the Onaqui and Oquirrh Mountains the upper member of the Great Blue is mapped where the intervening Long Trail Shale member of the Great Blue Formation is present (Clark and others, 2009); exposed thickness ranges from 440 to 820 feet (130-250 m); Gilluly (1932) described a section measuring approximately 500 feet (150 m) in the southwestern part of the Oquirrh Mountains, and Biek (2004) estimated a thickness of 300 feet (90 m) in the Lake Mountains.

Mh **Humbug Formation** (Upper Mississippian) – Interbedded calcareous quartz sandstone, quartzite, sandy limestone, and limestone; sandstone is pale yellowish brown to olive gray, weathering to light to dark brown, medium to thin bedded, variably calcareous or siliceous, with well developed planar and low-angle cross-stratification; quartzite is less common and very pale brown to tan and vitreous; sandy limestone and limestone are light to dark gray, medium to thin bedded, and fine grained with well-developed cross-stratification and cross-bedding; fossil debris including crinoids and rugose corals are common in carbonate parts of the unit; quartzitic or calcareous sandstone interbeds with gray limestone or sandy limestone throughout the Humbug Formation; formation weathers to ledgey slopes; lower contact is a bedding-parallel fault; age from Morris and others (1961); exposed thickness in the Vernon Hills is between 840 and 1250 feet (260-

380 m); regional thickness is 350 to 1550 feet (107-472 m) (Hintze and Kowallis, 2009).

Md **Deseret Limestone** (Upper to Lower Mississippian) – Dark-brown to reddish-brown poorly exposed phosphatic shale, dark-brown to black chert and quartzite, and medium-bedded, medium-gray limestone; locally some calcareous sandstone and quartz sandstone interbeds in lower part; basal slope-forming interval (20 to 30 feet [6-9 m]) includes thin-bedded, black phosphatic chert of the Delle Phosphatic Member of the Deseret Limestone; unit typically forms slopes between Gardison Limestone and calcareous sandstone of the Humbug Formation in the Vernon Hills; exposures in the Vernon Hills include some limestone and are marked by a bedding-parallel fault which omits much of the limestone typical of the upper portion of the Deseret Limestone as mapped to the east and north (Gilluly, 1932; Morris and others, 1961); age from Morris and others (1961) and Sandberg and others (1982); thickness is up to 200 feet (60 m) in the Vernon Hills; regional thickness is about 500 to 1175 feet (150-360 m) (Hintze and Kowallis, 2009).

Mg **Gardison Limestone** (Lower Mississippian) – Medium- to thick-bedded, medium-gray to medium-dark-gray limestone, cherty limestone, and fossiliferous limestone; chert occurs as black, irregularly shaped nodules and thin, discontinuous beds most common in the upper Gardison; fossils include rugose and colonial corals, brachiopods, gastropods, and bryozoans replaced by white calcite; Gardison crops out as dark- to medium-gray ledges, cliffs, and slopes; upper contact appears conformable and abrupt, and is marked by cliffy chert-banded limestone of the uppermost Gardison, directly overlain by dark-weathering, slope-forming phosphatic shale, discontinuous dark-brown quartzites, and thinly bedded dark limestone of the lowermost Deseret Limestone; lower contact of the Gardison Limestone may be a regional unconformity separating the continuous limestone of the Gardison Limestone from interbedded and lithologically diverse Fitchville-Pinyon Peak unit (MDfp); age from Morris and others (1961); thickness is approximately 840 feet (260 m) in the Vernon Hills; regional thickness is 300 to 1100 feet (90-340 m) (Hintze and Kowallis, 2009).

MISSISSIPPIAN-DEVONIAN

MDfp **Fitchville Formation and Pinyon Peak Limestone, undivided** (Lower Mississippian to Upper Devonian) – Fine- to coarse-grained, lithologically diverse, interbedded dolomite, limestone, and intraformational breccia, with a few interbeds of red or brown sandstone and quartzite; carbonate parts of this unit may include both Fitchville and Pinyon Peak lithologies, whereas thin sandstone and quartzite interbeds, particularly where these beds are dolomitic, may correlate with the Victoria Formation; lower contact is marked by an unconformable transition from continuous dark-gray dolomite of the underlying Guilmette Formation to interbedded light-gray thinly bedded recrystallized limestone, medium-grained dark-gray dolomite, and thin discontinuous sandstones or

quartzites of the Fitchville-Pinyon Peak unit; thickness is approximately 60 feet (18 m); regional thickness is much greater, between 180 and 390 ft (55-120 m), but may include lithologies stratigraphically above or below this interval as mapped in the Vernon Hills (Pampeyan, 1989; Mukul and Mitra, 1998).

DEVONIAN

Dg **Guilmette Formation** (Upper Devonian) – Dark-gray, medium- to fine-grained, dolomite and subordinate limestone; moderately to weakly bedded, sparsely fossiliferous dark-gray dolomite with a few thin, dark-gray, fine-grained limestone beds near the top of the unit; forms even slopes and well-spaced ledges in the central Vernon Hills; lower contact is conformable and gradational and marked by change in color and gradual increase in bed thickness from the pale-brown to gray, generally well-bedded dolomites of the Simonson Dolomite to the dark-colored and weakly bedded dolomite characteristic of the Guilmette Formation; upper contact is alternately marked by discontinuous thin red sandstone or quartzite or pale- to medium-gray, well-bedded, coarse-grained limestone of the overlying Fitchville-Pinyon Peak unit; upper contact may represent a regional unconformity; age taken from regional fossil correlation data presented by Sandberg and others (1982); unit thickness 180 feet (50 m).

Ds **Simonson Dolomite** (Middle Devonian) – Light-brown to pale- and medium-gray, fine- to medium-grained, massive or thin-bedded dolomite; generally more lithologically variable and less well bedded than the underlying Sevy Dolomite; lower contact with Sevy Dolomite is apparently conformable and gradational and mapped as a gradual change in color, increase in bedding thickness, and reduction of finely bedded intervals more typical of the underlying Sevy Dolomite; upper contact appears conformable and is principally marked by the appearance of dark-gray medium-grained dolomite of the Guilmette Formation; age taken from regional fossil correlation data presented by Sandberg and others (1982); thickness in the Vernon Hills is between 570 and 890 feet (170-270 m).

Dsy **Sevy Dolomite** (Lower Devonian) – White to very-light or medium-gray, medium- to fine-grained, finely-bedded dolomite; displaying well developed fine-scale planar bedding and lamination; unit is rarely fossiliferous; few thin, less than 1 foot (0.3 m) thick, beds of sandy dolomite; unit crops out as small ledges and float-covered hills in the southeastern part of the Vernon Hills; upper contact with the Simonson dolomite is gradational but marked by a transition to more massive, less well bedded, bioturbated, pale gray or brownish dolomite; lower contact with the dark gray dolomites of the Laketown and Fish Haven Dolomites is sharp and may represent a regional unconformity; age taken from regional fossil correlation data presented by Sandberg and others (1982); thickness in the Vernon Hills is between 710 to 830 feet (220-250 m); near the Vernon Hills regional thickness is between 360 and 1100 feet (110-335 m) (Pampeyan, 1989; Mukul and Mitra, 1998).

SILURIAN-ORDOVICIAN

SOu **Laketown and Fish Haven Dolomites, undivided** (Silurian to Upper Ordovician) – Dark- to medium-gray, granular or massive, moderately or poorly bedded cherty dolomite; with common pink to dark-gray chert bands or blebs; fossils include rugose corals and rare stromatolites in the lower part of the unit and chain corals (*Halysites*) near the abrupt upper contact with the light-colored, well-bedded Sevy Dolomite; poorly bedded parts of this unit appear bioturbated; contact with the underlying Eureka quartzite is faulted; unit forms small, blocky outcrops up to 10 feet (3 m) high and steep slopes along the southeastern flank of the Vernon Hills; age of unit in the Vernon Hills is taken from Groff (1959); exposed thickness is 1060 to 1280 feet (320-390 m); total thickness is approximately 770 feet (235 m) in the Vernon Hills; near the Vernon Hills regional thickness is between 630 and 1600 feet (190-490 m) (Cohenour, 1959; Groff, 1959; Pampeyan, 1989; Mukul and Mitra, 1998).

ORDOVICIAN

Oe **Eureka Quartzite** (Upper Ordovician) – Light-colored, medium- to well-bedded, medium-grained, vitreous orthoquartzite; commonly displays well-developed trough cross-bedding and planar bedding; unit crops out as small blocky cliff bands less than 10 feet (3 m) high at isolated locales in the southern Vernon Hills; base of unit is not exposed and is truncated by faulting; age of unit in the Vernon Hills taken from nearby work to the west by Cohenour (1959); exposed thickness 40-80 feet (12-24 m); regional thickness is between 120 and 645 feet (35-195 m) (Cohenour, 1959; Mukul and Mitra, 1998).

CAMBRIAN

Cwh **Wheeler Formation** (Middle Cambrian) – Red-brown to medium- or dark-gray, thin- to medium-bedded calcareous shale and limestone; lower contact with the underlying Swasey Limestone is abrupt and conformable and marked by the first calcareous shale overlying the medium-gray, resistant cliff- and ledge-forming Swasey Limestone; upper contact is not exposed and unit is truncated by normal faulting along the northern flank of the Sheeprock Mountains; age based on regional work by Hintze and Davis (2003); exposures to the southwest in Millard County contain *Peronopsis* trilobite fauna (Hintze and Davis, 2003); exposed thickness approximately 590 feet (180 m).

Cs **Swasey Limestone** (Middle Cambrian) – Medium-gray, medium- to thin-bedded, blocky, cliff- and ledge-forming limestone; includes sections of silty, ribbon limestone and wackestone; mapped along the northeast margin of the Sheeprock Mountains, in the southwestern corner of the Vernon quadrangle; age based on regional work by Hintze and Davis (2003); exposures to the southwest in Millard

County contain *Elrathia* trilobite fauna (Hintze and Davis, 2003); thickness approximately 130 feet (40 m).

Cww **Whirlwind Formation** (Middle Cambrian) – Light-olive-gray to red or brown shale and argillite interbedded with thin-bedded limestone; forms topographically concave slope between the Swasey and Dome Limestones; upper and lower contacts are sharp and marked by the transition to continuous ledge- and cliff-forming limestones of the Dome and Swasey Limestones; mapped along the northeast margin of the Sheeprock Mountains, in the southwestern corner of the Vernon quadrangle; age based on regional work by Hintze and Davis (2003); exposures to the southwest in Millard County contain *Ehmaniella* trilobite fauna; thickness approximately 230 feet (70 m).

Cd **Dome Limestone** (Middle Cambrian) – Medium-gray, medium- to thin-bedded, blocky-limestone, that forms small ledges; mapped along the northeast margin of the Sheeprock Mountains, in the southwestern corner of the Vernon quadrangle; lower contact is sharp and marked by first continuous argillite and shale of the underlying undivided Chisolm and Howell Formations; age based on regional correlation with work by Hintze and Davis (2003); thickness is approximately 130 feet (40 m).

Cch **Chisolm Formation and Howell Limestone, undivided** (Middle Cambrian) – Chisholm Formation consists of lower and upper brown to partly reddish shales that regionally contain *Glossopleura* trilobite fauna, separated by dark-gray, oncolitic limestone; the underlying Howell Limestone forms ledges that are light to dark gray immediately beneath the Chisolm Formation; the lower contact with the underlying Pioche Shale is exposed just south of the Vernon Quadrangle boundary in the Dutch Peak quadrangle; age based on regional work by Hintze and Davis (2003); thickness is approximately 520 feet (160 m).

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