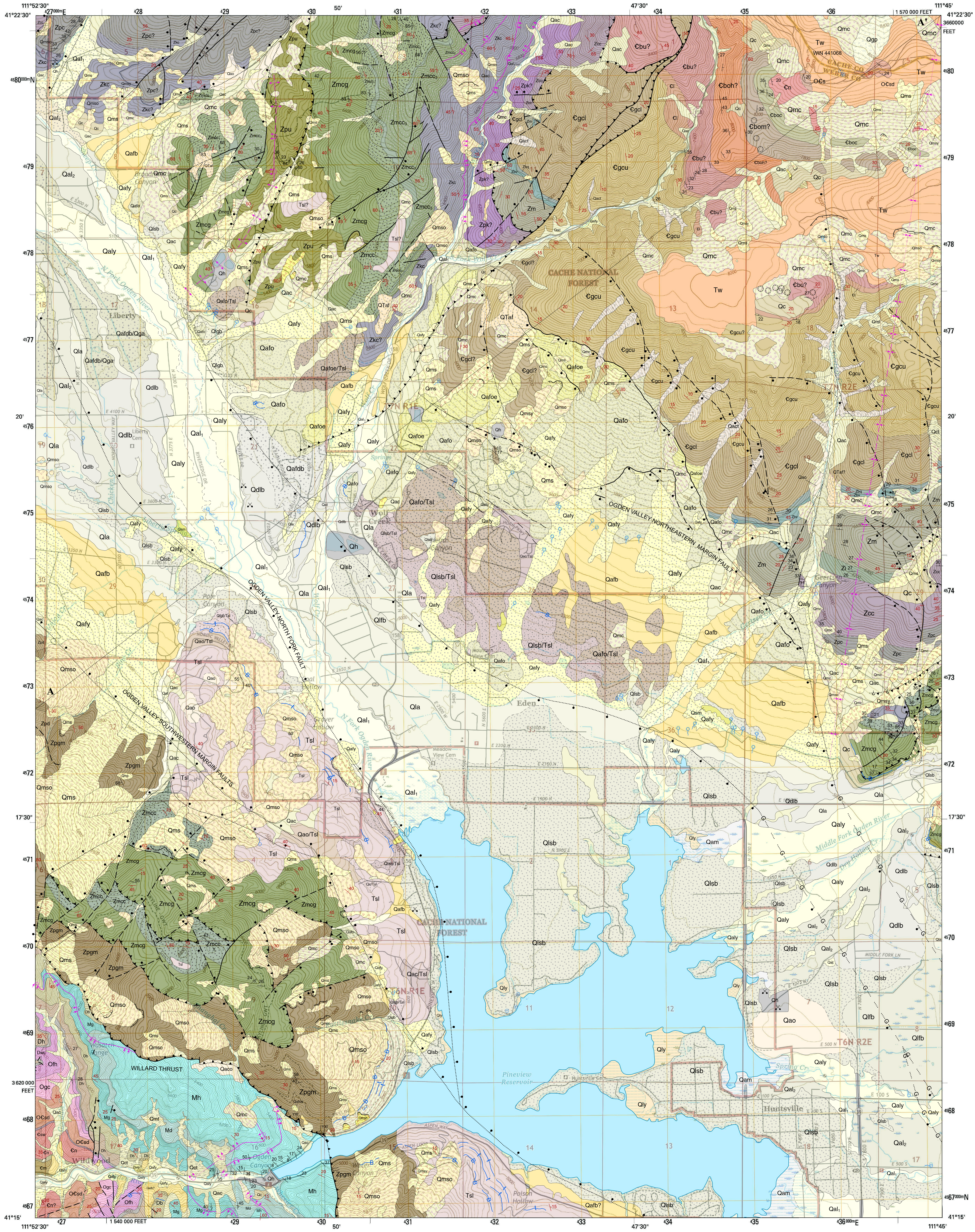
UTAH GEOLOGICAL SURVEY
a division of
Utah Department of Natural Resources



This open-file release makes information available to the public that has undergone only minimal peer review and may not conform to Utah Geological Survey technical, editorial, or policy standards. The map may be incomplete, and inconsistencies, errors, and omissions have not been resolved. The Utah Department of Natural Resources, Utah Geological Survey, makes no warranty, expressed or implied, regarding the suitability of this product for a particular use, and does not guarantee accuracy or completeness of the data. The Utah Department of Natural Resources, Utah Geological Survey, shall not be liable under any circumstances for any direct, indirect, special, incidental, or consequential damages with respect to claims by users of this product. For use at 1:24,000 scale.

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 G23AC00466 (2023–2025). The views and conclusions contained in this document are those of the authors and should not be interpreted as necessarily representing the official policies, either expressed or implied, of the U.S. Government.

10°52′
TRUE NORTH
MAGNETIC NORTH
APPROXIMATE MEAN DECLINATION, 2025

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 40 FEET

INTERIM GEOLOGIC MAP OF THE HUNTSVILLE QUADRANGLE, WEBER AND CACHE COUNTIES, UTAH

by

Greg N. McDonald[1], Adam P. McKean[1], Zachary W. Anderson[1], Elizabeth A. Balgord[2], and W. Adolph Yonkee[2]

2025

[1]Utah Geological Survey, Salt Lake City, Utah
[2]2Department of Earth and Environmental Sciences, Weber State University, Ogden, Utah

UTAH
MAP LOCATION

Base from USGS US Topo Huntsville 7.5′ Quadrangle (2017)
Projection: UTM Zone 12
Datum: NAD 1983

Program Manager: Stefan M. Kirby
Project Manager: Lauren J. Reheer
GIS and Cartography: Adam P. McKean and Subigya Shah
Geology Review: Lauren J. Reeher and Stefan M. Kirby
GIS and Cartography Review: Josh A. Dustin and Keilee A. Higgs

Utah Geological Survey
1594 West North Temple, Suite 3110
Salt Lake City, UT 84116
(801) 537-3300
https://geology.utah.gov

https://doi.org/10.34191/OFR-772DM

1	2	3
4		5
6	7	8

1. Mantua
2. James Peak
3. Sharp Mountain
4. North Ogden
5. Browns Hole
6. Ogden
7. Snow Basin
8. Durst Mountain

ADJOINING 7.5′ QUADRANGLE NAMES

LIST OF MAP UNITS

Qal$_1$	Level-1 stream and floodplain deposits
Qal$_2$	Level-2 stream and floodplain deposits
Qaly	Young stream and floodplain deposits
Qat	Stream terrace deposits
Qao	Older alluvial deposits
Qaf$_1$	Level-1 alluvial-fan deposits
Qaf$_2$	Level-2 alluvial-fan deposits
Qafy	Young alluvial-fan deposits
Qafp?	Alluvial-fan deposits related to Provo shoreline and regressive phase of Lake Bonneville
Qafb Qafb?	Alluvial-fan deposits related to Bonneville shoreline and transgressive phase of Lake Bonneville
Qafo	Older alluvial-fan deposits
Qafoe	Eroded old alluvial-fan deposits
Qc	Colluvial deposits
Qgp	Glacial deposits, undivided, Pinedale age
Qga	Glacial outwash
Qh	Fill and disturbed land
Qly	Lacustrine fine-grained deposits of Pineview Reservoir
Qlgb	Lacustrine gravel and sand related to the Bonneville shoreline and transgressive phase of Lake Bonneville
Qlsb	Lacustrine sand and silt related to the Bonneville shoreline and transgressive phase of Lake Bonneville
Qlfb	Lacustrine fine-grained deposit related to the Bonneville shoreline and transgressive phase of Lake Bonneville
Qms	Landslide deposits
Qmsh	Historical landslide deposits
Qmsy	Younger landslide deposits
Qmso	Older landslide deposits
Qmt	Talus deposits
Qac	Alluvial and colluvial deposits
Qaco	Older alluvial and colluvial deposits
Qact	Alluvium, colluvium and talus deposits
Qafdb	Alluvial-fan and delta deposits related to Bonneville shoreline and transgressive phase of Lake Bonneville
Qam	Alluvial and marsh deposits
Qct	Colluvial and talus deposits
Qdlb	Lake Bonneville delta and lacustrine deposits
Qla	Lacustrine and alluvial deposits
Qmc	Mass-movement and colluvial deposits
Qsm	Spring and marsh deposits
Qac/Tsl	Alluvium and colluvium over Salt Lake Formation
Qao/Tsl	Older alluvial deposits over Salt Lake Formation
Qafo/Tsl	Older alluvial-fan deposits over Salt Lake Formation
Qafoe/Tsl	Eroded old alluvial-fan deposits over Salt Lake Formation
Qc/Tsl	Colluvial deposits over Salt Lake Formation
Qlgb/Qmso	Lacustrine gravel and sand related to the Bonneville shoreline and transgressive phase of Lake Bonneville over older landslide deposits
Qlgb/Tsl	Lacustrine gravel and sand related to the Bonneville shoreline and transgressive phase of Lake Bonneville over Salt Lake Formation
Qlsb/Tsl	Lacustrine sand and silt related to the Bonneville shoreline and transgressive phase of Lake Bonneville over Salt Lake Formation
Qafdb/Qga	Alluvial-fan and delta deposits related to Bonneville shoreline and transgressive phase of Lake Bonneville over younger glacial outwash
QTaf QTaf?	Quaternary-Pliocene alluvial-fan deposits
Tsl	Salt Lake Formation
Tw	Wasatch Formation

WILLARD THRUST HANGING WALL

O€s	St. Charles Formation
€n	Nounan Formation
€boc	Calls Fort Shale Member of Bloomington Formation
€bom?	Middle limestone member of Bloomington Formation?
€boh?	Hodges Shale Member of the Bloomington Formation?
€bu?	Blacksmith and Ute Formations?
€l	Langston Formation
€gcu €gcu?	Upper member of Geertsen Canyon Quartzite of Brigham Group
€gcl €gcl?	Lower member of Geertsen Canyon Quartzite of Brigham Group
Zbq	Quartzite member of Browns Hole Formation of Brigham Group
Zbv	Volcanic member of Browns Hole Formation of Brigham Group
Zm	Mutual Formation of Brigham Group
Zi	Inkom Formation of Brigham Group
Zcc	Caddy Canyon Quartzite of Brigham Group
Zpk?	Papoose Creek Formation of Brigham Group and Kelley Canyon Formation?
Zpc Zpc?	Papoose Creek Formation of Brigham Group
Zkc Zkc?	Kelley Canyon Formation
Zmcc	Conglomerate member of Maple Canyon Formation
Zmcc$_1$	Lower conglomerate member of Maple Canyon Formation
Zmcc$_2$	Argillite member of Maple Canyon Formation
Zmcc$_3$	Upper conglomerate member of Maple Canyon Formation
Zmcg	Green arkose member of Maple Canyon Formation
Zp	Perry Canyon Formation, undivided (cross section only)
Zpu	Upper member of Perry Canyon Formation
Zpgm	Graywacke and mudstone member of Perry Canyon Formation
Zpd	Diamictite member of Perry Canyon Formation
YXf	Facer Formation

WILLARD THRUST FOOTWALL

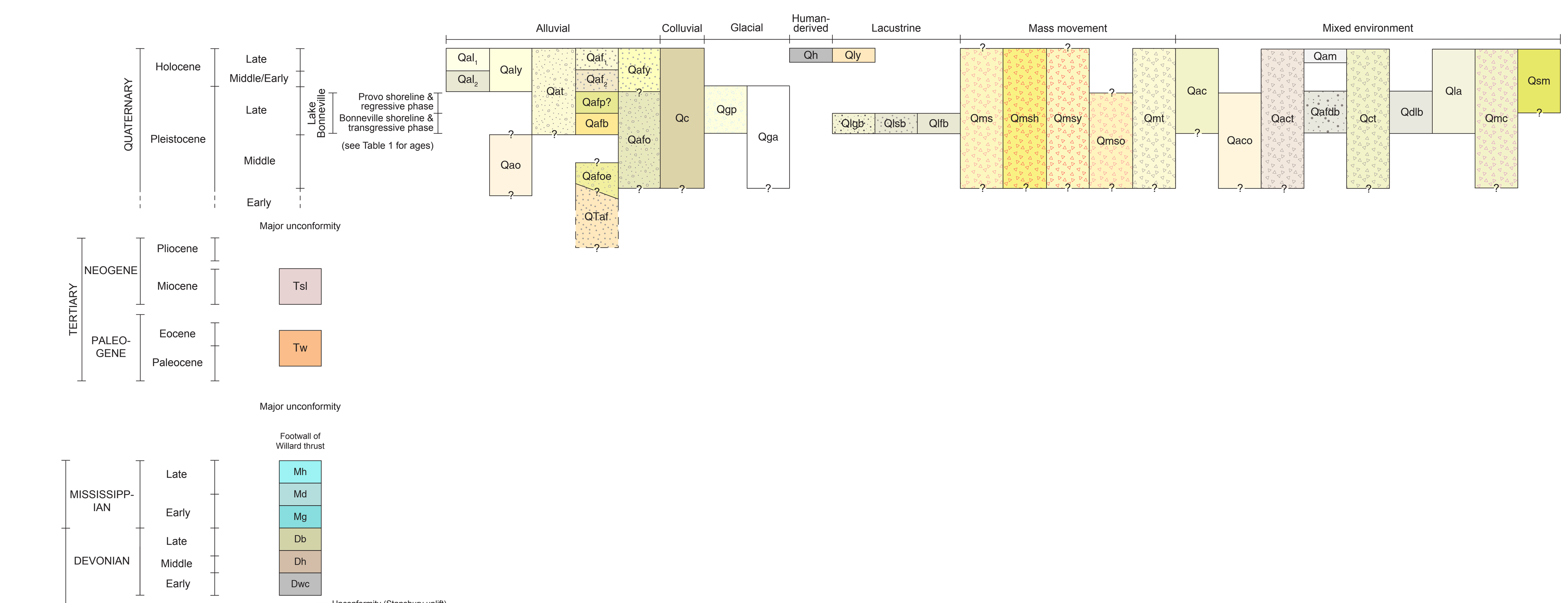
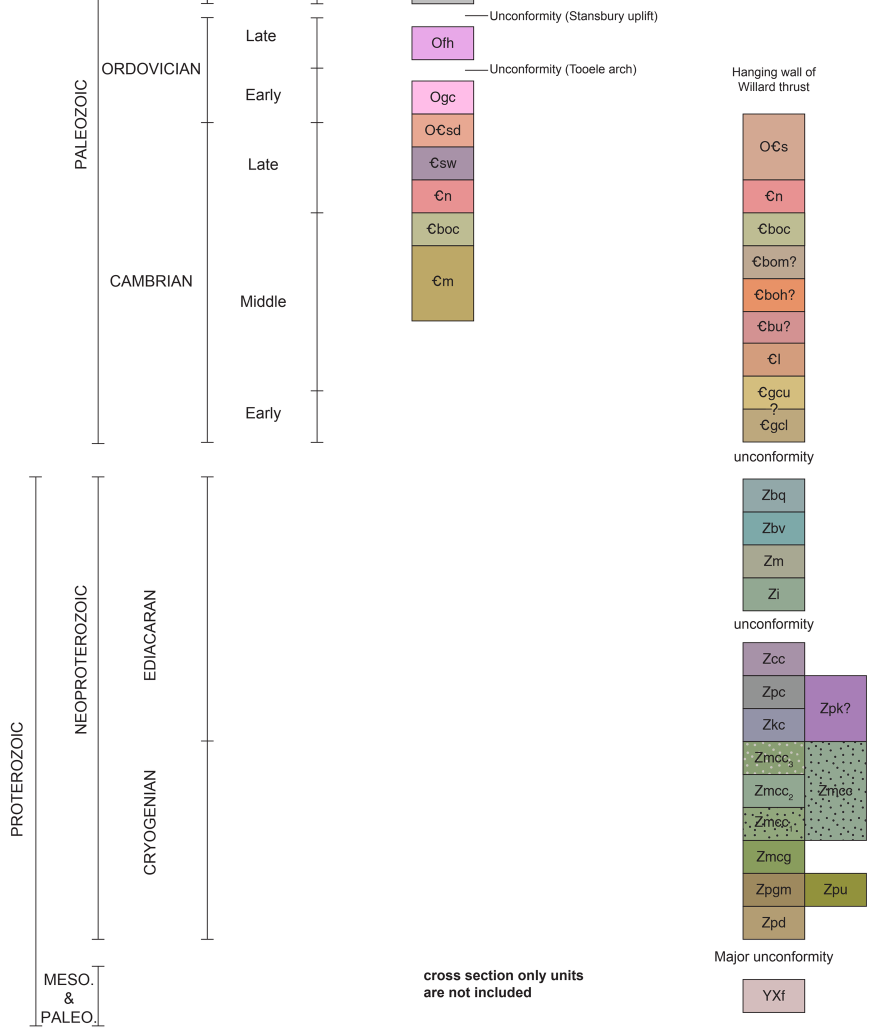
Mh	Humbug Formation
Md	Deseret Limestone
Mg	Gardison Limestone
Db	Beirdneau Sandstone
Dh	Hyrum Dolomite
Dwc	Water Canyon Formation
Ofh	Fish Haven Dolomite
Ogc	Garden City Formation
O€sd	Dolomite member of St. Charles Formation
€sw	Worm Creek Quartzite Member of St. Charles Formation
€n	Nounan Formation
€boc	Calls Fort Shale Member of Bloomington Formation
€m	Maxfield Limestone
€o	Ophir Formation (cross section only)
€t	Tintic Quartzite (cross section only)
Xfc?	Farmington Canyon Complex? (cross section only)

LITHOLOGIC COLUMN

AGE		FORMATION - MEMBER	MAP SYMBOL	THICKNESS Feet (Meters)	LITHOLOGY/NOTES
Neogene	Miocene	Salt Lake Formation	Tsl	0–1500+ (0–450+)	Unconformity
Paleogene	Eocene-Paleo.	Wasatch Formation	Tw	500 (150)	Major unconformity
Ordov.	Early	St. Charles Formation	O€s	100* (30)	494 Ma U-Pb max. depositional age (Cothren et al., 2022)
Cambrian	Late	Nounan Formation	€n	660 (200)	
Cambrian	Middle	Bloomington Formation – Calls Fort Shale Member	€boc	313 (95)	
Cambrian	Middle	Bloomington Formation – middle limestone member?	€bom?	600 (182)	
Cambrian	Middle	Bloomington Formation – Hodges Shale Member?	€boh?	1250 (380)	
Cambrian	Middle	Blacksmith and Ute Formations?	€bu?	530 (160)	
Cambrian	Middle	Langston Formation	€l	89 (27)	
Cambrian	Early	Brigham Group – Geertsen Canyon Quartzite – upper member	€gcu	2400–2700 (730–820)	*Skolithos* and *Diplocraterion*
Cambrian	Early	Brigham Group – Geertsen Canyon Quartzite – lower member	€gcl	1475–1700 (450–520)	Unconformity
Neoproterozoic	Ediacaran	Brigham Group – Browns Hole Formation – quartzite member	Zbq	100–150 (30–45)	
Neoproterozoic	Ediacaran	Brigham Group – Browns Hole Formation – volcanic member	Zbv	180–560 (55–140)	580 Ma hornblende Ar/Ar (Crittenden and Wallace, 1973) 609 Ma apatite U-Pb (Verdel, 2009) 613 Ma detrital apatite U-Pb (Provow et al., 2021)
Neoproterozoic	Ediacaran	Brigham Group – Mutual Formation	Zm	1200 (370)	
Neoproterozoic	Ediacaran	Brigham Group – Inkom Formation	Zi	250–280 (75–85)	Unconformity
Neoproterozoic	Ediacaran	Brigham Group – Caddy Canyon Quartzite	Zcc	1000–1500 (300–460)	
Neoproterozoic	Ediacaran	Brigham Group – Papoose Creek Formation	Zpk? / Zpc	950 (290)	
Neoproterozoic	Ediacaran	Kelley Canyon Formation	Zpk? / Zkc	2000 (600)	
Neoproterozoic	Cryogenian	Maple Canyon Formation – conglomerate member – upper conglomerate member	Zmcc / Zmcc$_3$	100–1000 (30–300)	
Neoproterozoic	Cryogenian	Maple Canyon Formation – conglomerate member – argillite member	Zmcc / Zmcc$_2$		
Neoproterozoic	Cryogenian	Maple Canyon Formation – conglomerate member – lower conglomerate member	Zmcc / Zmcc$_1$		
Neoproterozoic	Cryogenian	Maple Canyon Formation – green arkose member	Zmcg	500–1000 (150–300)	
Neoproterozoic	Cryogenian	Perry Canyon Formation – upper member	Zpu	500 (150)	
Neoproterozoic	Cryogenian	Perry Canyon Formation – graywacke and mudstone	Zpgm	800–1000 (250–300)	667 Ma detrital zircon U-Pb (Balgord et al., 2013)
Neoproterozoic	Cryogenian	Perry Canyon Formation – diamictite	Zpd	200–400 (60–120)	703 Ma detrital zircon U-Pb (Balgord et al., 2013) Major unconformity
Meso. to Paleoproterozoic		Facer Formation	YXf	~50* (~15)	
					Willard thrust
Mississippian	Late	Humbug Formation	Mh	1000 (300)	
Mississippian	Late/Early	Deseret Limestone	Md	200–230 (60–70)	
Mississippian	Early	Gardison Limestone	Mg	300–400 (90–120)	
Devonian	Late	Beirdneau Sandstone	Db	250-300 (75–90)	
Devonian	Middle	Hyrum Dolomite	Dh	200–250 (30–75)	
Devonian	Early	Water Canyon Formation	Dwc	30–100 (9–30)	Unconformity (Stansbury uplift)
Ordovician	Late	Fish Haven Dolomite	Ofh	200–250 (60–80)	Unconformity (Tooele arch)
Ordovician	Early	Garden City Formation	Ogc	200–400 (60–120)	
Cambrian	Late	St. Charles Formation – dolomite member	O€sd	200–600 (60–185)	
Cambrian	Late	St. Charles Formation – Worm Creek Quartzite Member	€sw	20–30 (6–10)	
Cambrian	Late	Nounan Formation	€n	500–750 (150–230)	
Cambrian	Middle	Bloomington Formation – Calls Fort Shale Member	€boc	80–200 (25–60)	
Cambrian	Middle	Maxfield Limestone	€m	350* (100)	*Ehmaniella* sp. and *Glossopleura* sp

Not to scale
* indicates incomplete thickness
cross section only units are not included

CORRELATION OF GEOLOGIC UNITS

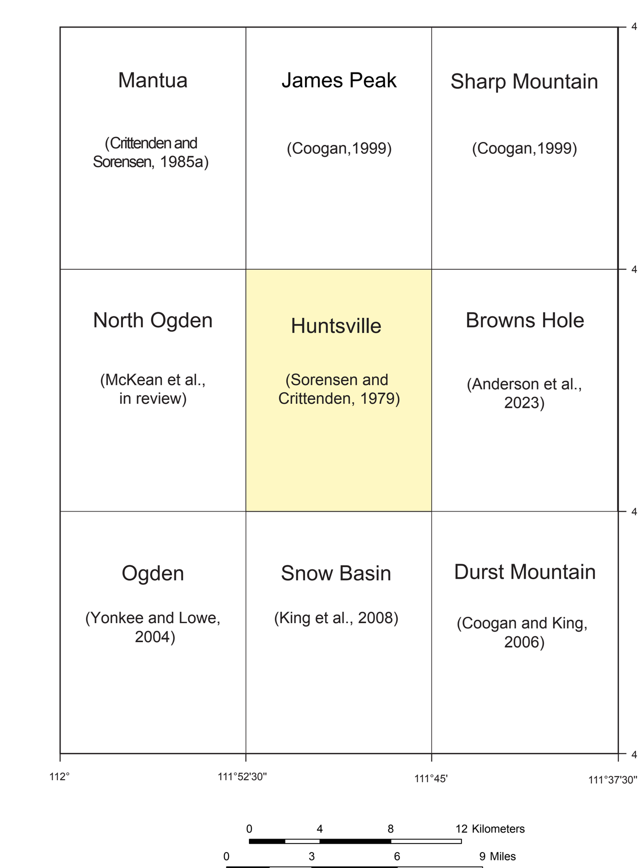


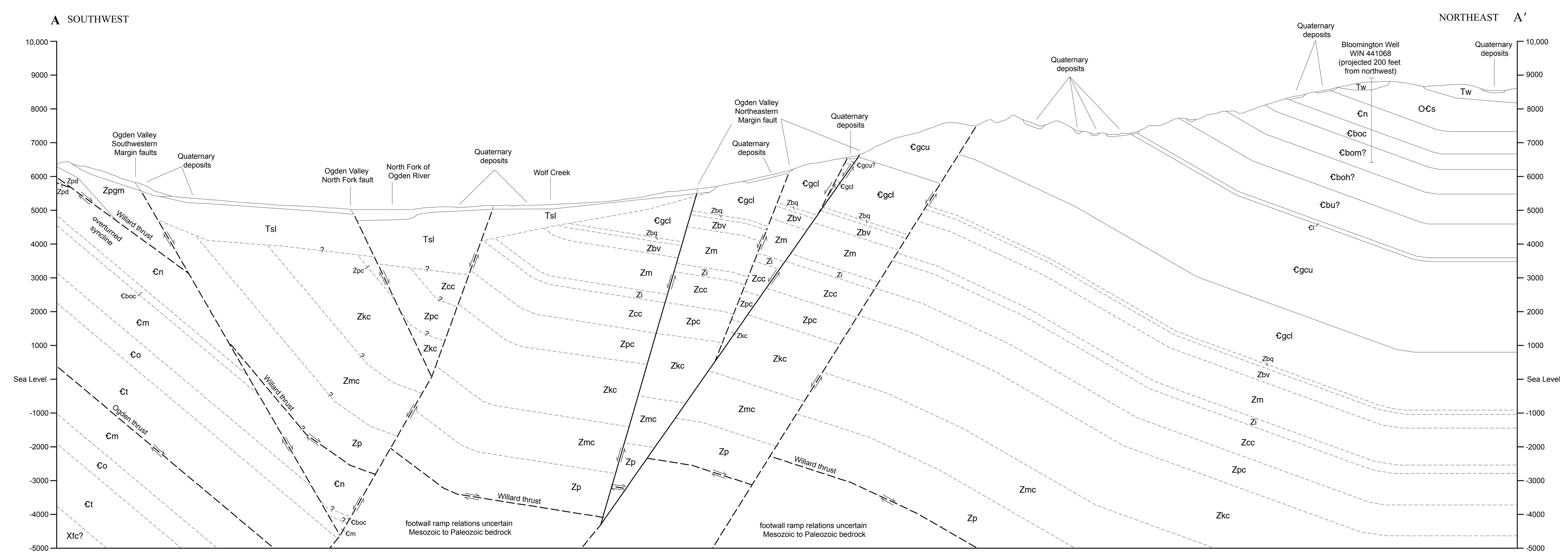
Figure 1. Index map showing selected geologic maps available for the Huntsville and surrounding 7.5' quadrangles.

GEOLOGIC SYMBOLS

	Contact – Dashed where approximately located, dotted where concealed
	Fault – Sense of offset not known or complex; dashed where approximately located, dotted where concealed; arrows show dip of fault
	Normal fault – Dashed where approximately located, dotted where concealed; bar and ball on downthrown side; arrows show dip of fault; arrows on cross section indicate direction of relative movement
	Normal fault, concealed – Location inferred from gravity data (Jordan et al., 2019); bar and ball on downthrown side
	Thrust fault – Dashed where approximately located, dotted where concealed; saw teeth on upper plate; queried where uncertain; arrows on cross section indicate direction of relative movement
	Lineament
	Lacustrine shorelines – Major shorelines of Lake Bonneville; mapped at the top of wave-cut bench for erosional shorelines and at the top of constructional bars and barrier beaches; may coincide with geologic contacts
t	Transgressive shorelines (present above the Provo shoreline and below the Bonneville shoreline)
B	Bonneville shoreline (highstand)
	Alluvial terrace scarp
	Landslide scarp – Dashed where approximately located; hachures on down dropped side
A—A'	Line of cross section
	Hinge line of anticline – Dashed where approximately located; dotted where concealed
	Hinge line of overturned anticline – Dotted where concealed
	Hinge line of syncline – Dashed where approximately located; dotted where concealed
	Hinge line of overturned syncline – Dotted where concealed

Structural measurements – red symbols and dips are from Sorensen and Crittenden (1979)

65 65	Strike and dip of inclined bedding
	Strike of vertical bedding
45	Strike of approximate bedding
78 78	Strike and dip of overturned bedding
20	Strike and dip of cleavage
	Spring (selected)
	Water well (selected)
	Prospect
	Adit
	Sand and gravel pit
	Sinkhole



Created using data from Jordan et al. (2019) and water well data from Rich Emerson (personal communication 3/28/2025)
Thin surficial deposits simplified for clarity

INTERIM GEOLOGIC MAP OF THE HUNTSVILLE QUADRANGLE, WEBER AND CACHE COUNTIES, UTAH

by

Greg N. McDonald[1], Adam P. McKean[1], Zachary W. Anderson[1], Elizabeth A. Balgord[2], and W. Adolph Yonkee[2]

[1]Utah Geological Survey, Salt Lake City, Utah
[2]Department of Earth and Environmental Sciences, Weber State University, Ogden, Utah

Suggested citation:

McDonald, G.N., McKean, A.P., Anderson, Z.A., Balgord, E.A., and Yonkee, W.A., 2025, Interim geologic map of the Huntsville quadrangle, Weber and Cache Counties, Utah: Utah Geological Survey Open-File Report 772DM, 26 p., 2 plates, scale 1:24,000, https://doi.org/10.34191/OFR-772DM.

Disclaimer

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 G23AC00466 (2023–2025). The views and conclusions contained in this document are those of the authors and should not be interpreted as necessarily representing the official policies, either expressed or implied, of the U.S. Government.

UTAH DNR GEOLOGICAL SURVEY

OPEN-FILE REPORT 772DM
UTAH GEOLOGICAL SURVEY
UTAH DEPARTMENT OF NATURAL RESOURCES
2025

Blank pages are intentional for printing purposes.

INTRODUCTION

The Huntsville 7.5' quadrangle lies within Ogden Valley, a back valley of the Wasatch Range in Weber County, Utah, about 6 miles (10 km) east-northeast of Ogden City. Settled in 1849, Ogden Valley was a pioneer frontier settlement and served primarily as a small farming community until recently. The area is currently characterized by rapid suburban growth. The quadrangle is centered on Ogden Valley with the Wasatch Range on the east and west side of the valley. The Ogden Valley floor lies at an elevation of about 4900 feet (1494 m) with surrounding mountains reaching elevations of more than 9500 feet (2896 m). Pineview Dam, built in 1937 at the head of Ogden Canyon, impounds all surface flow from Ogden Valley and forms the distinctly shaped, three-armed Pineview Reservoir. In the northwest part of the quadrangle, the North Fork of the Ogden River flows south toward Pineview Reservoir. The Middle and South Forks of the Ogden River bisect the quadrangle and enter Pineview Reservoir. Several smaller ephemeral and perennial streams are present in the quadrangle including three perennial streams, Wolf, Geertsen Canyon, and Bennett Creeks. The quadrangle in Ogden Valley includes the communities of Huntsville, Eden, and Liberty. Part of Powder Mountain ski resort, which draws year-round visitation and recreation, is present in the northeast corner of the quadrangle. The valley's climate is semiarid with most summer precipitation occurring as brief, intense thunderstorms of short duration and winter precipitation occurring as snowfall. Records at Pineview Dam collected since the mid-1900s indicate average annual precipitation of about 30 inches and about 120 inches of snow per year (Western Regional Climate Center, 2019); precipitation on higher slopes of the valley is greater.

This new map provides geologic data for a variety of derivative uses. The surficial mapping focused on geologic hazards relevant to the ongoing growth and development of Ogden Valley. Many of the geologic processes that shaped the valley's scenic and rugged landscape over millions of years are still active today and are potentially hazardous to property and life. Principal hazards include those associated with landsliding, debris flows, problem soils, flooding, earthquake ground shaking, liquefaction, shallow groundwater, and rockfalls. Prudent development addresses geologic hazards early in the planning process, redesigning subdivisions and other development around geologic problems, as post-development repair of damage caused by a geologic hazard is costly and often impractical. This mapping will be used by the Utah Geological Survey (UGS) Geologic Hazards Mapping Initiative (Christenson and Ashland, 2007; Castleton and McKean, 2012) as the first step in creating geologic hazard maps to assist homeowners, local municipalities, developers, planners, designers, and engineers with proper development to reduce risk and best use the land.

GEOLOGIC SETTING

Ogden Valley is a roughly 15-mile-long (25 km), 4-mile-wide (6 km), northwest-southeast- trending structural graben in the northern Utah Wasatch Range of the Basin and Range physiographic province. The mountains surrounding the valley are composed of tilted and deformed Mesozoic, Paleozoic, Neoproterozoic sedimentary bedrock, and Neoproterozic to Paleoproterozoic metamorphic bedrock that are structurally overlain in places by Paleozoic to Mesoproterozoic rocks of the Willard thrust sheet (Crittenden, 1972b; Yonkee et al., 1989; Evans and Neves, 1992; Yonkee, 1992; DeCelles, 2004; Yonkee, 2005; Yonkee et al., 2013; Yonkee and Weil, 2015; Yonkee et al., 2019). The older rocks are erosionally beveled and in places unconformably overlain by Paleogene and Neogene rocks (Coogan and King, 2016). The stratigraphic units in the hanging wall and footwall of the Willard thrust are different and organized as such in the unit descriptions below.

Proterozoic and Paleozoic bedrock units present in the mountains surrounding Ogden Valley have significant impact on the surficial deposits and their associated engineering geologic properties and geologic hazards. Some bedrock in the quadrangle is prone to landslides. Bedrock in the southwest corner of the Huntsville quadrangle includes Cambrian through Mississippian clastic and carbonate rocks that are overlain by Proterozoic metasedimentary rocks of the Willard thrust sheet. Notable landslide-prone units in the Willard sheet include argillic members of the Maple Canyon Formation and Perry Canyon Formation that are present in the mountains west of Pineview Reservoir where large-scale landslide complexes compose much of the range. These large landslide complexes typically contain inset landslides with geomorphology indicative of recent activity. The north and northeast part of the Huntsville quadrangle includes younger Neoproterozoic to Late Cambrian bedrock units of the Willard thrust sheet composed mostly of quartzite, dolomite, limestone, argillite, and phyllite. The Neoproterozoic Kelley Canyon Formation outcrops along the east margin of Ogden Valley where it is highly altered and weathers to clay-rich, landslide-prone residual deposits that contain persistently active landslides. Individual landslide slumps form complex masses where discrete movements are difficult to discern, resulting in irregularly shaped landslide complexes. The Middle Cambrian upper part of the Geertsen Canyon Quartzite forms the prominent rock cliff above the Wolf Creek development and is prone to rockfall.

Paleogene-Neogene rocks in the Huntsville quadrangle unconformably overlie older bedrock units and include clastic deposits (Eocene-Late Paleocene Wasatch Formation) shed off the Sevier orogeny thrust sheets and volcaniclastic rocks deposited during Cenozoic basin and range extension (Miocene Salt Lake Formation and Early Oligocene–Late Eocene Norwood Formation). In Ogden Valley the strata previously mapped as Norwood Formation has been reinterpreted as Salt Lake Formation (see Tsl unit description; Cornwall et al., 2025; Mayfield et al., 2025). The Wasatch Formation forms elevated surfaces in the northeast part of the quadrangle in the Powder Mountain area. The Salt Lake Formation is present under and along the margins of Ogden Valley. On the west and south margins of the quadrangle, it forms low-relief hills that extend into Morgan Valley and may be underlain by Norwood Formation. On the east side of the valley, the Salt Lake Formation is exposed in sparse, isolated outcrops. The Wasatch and Salt Lake Formations are prone to landsliding and have swelling clays with numerous documented occurrences of damaging landslides.

Surficial deposits in the Huntsville quadrangle include Quaternary alluvial, colluvial, deltaic, glacial, marsh, and mass-movement deposits. Older alluvial deposits in the form of terraces, elevated and/or isolated surfaces, or deflated cobbly/bouldery mantles, are scattered around the valley. Younger alluvial channel and fan deposits are associated with both ephemeral and perennial drainages entering the valley. Major drainages include the North, Middle, and South Forks of the Ogden River, and Wolf Creek.

Late to Middle Pleistocene glacial deposits in the Huntsville quadrangle include a till in a cirque in the Powder Mountain area in the northeast corner of the quadrangle, and outwash sourced from the upper drainage basins of the North Fork Ogden River in the northwest part of the quadrangle. These glacial deposits are likely associated with the youngest glacial cycle that occurred in northern Utah, the Pinedale glaciation, that occurred about 14 to 29 ka and reached its maximum extent about 19 to 22 ka in the Wasatch Range (data from Lisiecki and Raymo, 2005; Laabs et al., 2011; Laabs and Munroe, 2016; Quirk et al., 2018, 2020). Beyond the quadrangle boundaries, glacial deposits and features associated with the penultimate glaciation event, Bull Lake glaciation (~130–191 ka), are present (data from Gosse and Phillips, 2001; Sharp et al., 2003; Lisiecki and Raymo, 2005; Pierce et al., 2018; Quirk et al., 2018).

Lacustrine and related deposits and landforms in the Huntsville quadrangle are associated with the transgression and highstand of Late Pleistocene Lake Bonneville. These include nearshore and moderately deep water, delta, and alluvial-fan sediments. Lake Bonneville occupied much of the Great Basin from about 30 to 13 ka, covering much of northwest Utah and adjacent parts of Idaho and Nevada (Oviatt, 2015). Lake Bonneville attained its highest elevation, the Bonneville highstand, around 18 ka, when a catastrophic failure of its threshold caused lake levels to drop about 300 feet (150 m) to the Provo level. Given Ogden Valley's elevation, the lake transgressed into and occupied the lower valley for roughly 4000 years before the flood dropped the lake to the Provo level at an elevation several tens of feet below the valley floor (Table 1; Oviatt, 2015). Thus, Provo-level and lower regressive deposits are limited to alluvium graded to the Provo level lake west and down-canyon from Pineview Reservoir.

The most widespread and prominent Lake Bonneville-related landforms in the quadrangle are deltaic and nearshore deposits that form prominent benches at an elevation of about 5060 feet (1540 m), or about 100 feet (30 m) below the Bonneville highstand elevation (about 5180 to 5190 feet [~1580 m]). We assume that these deposits and surfaces formed due to a significant transgressional standstill that occurred at this elevation. In contrast, the Bonneville highstand is marked only by a few subtle, mostly erosional shorelines etched into bedrock on hillsides around the valley, typically without associated distinctive lacustrine shoreline deposits. The central part of the valley, including the town of Huntsville, is a relatively flat-lying, gently west dipping, elevated surface composed of lacustrine/fluvial deposits that have been incised by the three forks of the Ogden River. These deposits are graded to an elevation nearly 100 feet (30 m) higher than the Provo shoreline of Lake Bonneville (about 4850 feet [1480 m]), and about 100 feet (30 m) lower than the previously described bench. The nature of these deposits, including their elevation and gradient, implies that they were deposited during the transgression of Lake Bonneville.

Quaternary faults are mapped along both the east and west margins of Ogden Valley. Mapped fault scarps offset deposits of suspected Late Pleistocene age, but do not show evidence of Holocene activity. The well-located Ogden Valley Northeastern Margin fault scarps are locally present on the east side of Ogden Valley between Wolf Creek and Geertsen Canyon. These prominent scarps and lineaments are localized, and discontinuous and may in part be related to older landslide movement and faulting. Ogden Valley North Fork fault and Ogden Valley Southwestern Margin fault are inferred Quaternary faults that are mapped along the west margin of Ogden Valley. These faults project up valley to the north beyond the Huntsville quadrangle to fault scarps cutting glacial deposits of late Pleistocene age in the northwest part of the valley in the North Ogden (McKean et al., in review) and Mantua quadrangles.

PREVIOUS WORK

Previous geologic maps of various age, scale, and purpose cover part of the Huntsville quadrangle (Figure 1). Early work by Eardley (1944, 1955) provided a framework for the bedrock and surficial geology of the area. Lofgren (1955) created a generalized geologic map that considered Tertiary (Neogene and Paleogene) and Quaternary strata and deposits. Several academic theses have included detailed geologic mapping and/or refinement of bedrock stratigraphy (Coody, 1957; Laraway, 1958; Eriksson, 1960; Nelson, 1971; Doyuran, 1972; Blau 1975; Pavlis, 1979; Rauzi, 1979). Crittenden et al. (1971) refined Precambrian stratigraphy and nomenclature for the region. The U.S. Geological Survey performed 1:24,000-scale mapping for many quadrangles in the region including Huntsville (Sorensen and Crittenden, 1972, 1974, 1979) (see Figure 1). King et al. (2008) included the very southern part of the Huntsville quadrangle in their mapping of the Snow Basin quadrangle. Coogan and King (2016) performed a cursory revision of the bedrock mapping by Sorenson and Crittenden (1974) in compiling the Ogden 30' x 60' quadrangle. Carly et al. (1973) mapped soils in Ogden Valley for use in agriculture purposes. Sullivan et al. (1988) investigated Ogden Valley as part of a regional seismotectonic assessment of Wasatch back valley faults and potential seismic hazard associated with U.S. Bureau of Reclamation dams. A recent groundwater characterization study of Ogden Valley area by Jordan et al. (2019) and Powder Mountain area Inkenbrandt et al., (2016) described groundwater conditions in the area. Most recently McDonald (2020) mapped the surficial geology of the Huntsville quadrangle at 1:24,000 scale. We incorporated and revised the previous surficial and bedrock mapping for this project.

METHODS

Mapping of surficial deposits is based on age and depositional environment or origin (Doelling and Willis, 1995). The letters of the map units indicate (1) age (e.g., Q = Quaternary), (2) depositional environment or origin determined from landform morphology, bedding, or other distinctive characteristics of the deposits, (3) grain size(s), and (4) age as related to the phases of Lake Bonneville. For example, unit Qal_1 is a Quaternary surficial deposit of alluvial origin (al), and the number one indicates it is young and potentially historically active. Numbering of alluvial terrace deposits is the exception and does not relate to Lake Bonneville deposits. The letters “y” and “o” in place of a subscript indicate deposits younger and older than Lake Bonneville (Late Pleistocene), respectively. Unit numbers indicate relative age with “1” being the youngest and increasing with age.

Mapping for the project was done using stereographic pairs of aerial photographs, including black-and-white aerial photographs at an approximate scale of 1:20,000 from the U.S. Department of Agriculture (USDA) Agricultural Commodity Stabilization Service (1946, 1958) As well as black-and-white aerial photographs at an approximate scale of 1:15,840 from the USDA U.S. Forest Service (1963). Natural color aerial photographs were used at a scale of 1:12,000 from the USDA U.S. Forest Service (1980). Contacts were revised using 2018 NAIP imagery, Hexagon, and Google orthophotographs (Utah Geospatial Resource Center [UGRC], 2018a, 2018b, 2021a, 2021b), and lidar from various collection years (UGRC, 2006, 2011, 2016). The geologic map was made by transferring the geology from the aerial photographs to a geographic information system (GIS) database in ArcGIS for a target scale of 1:24,000 using 1990s digital orthophoto quadrangles (DOQ) (UGRC, 1990s) and 2018 NAIP orthophotographs (UGRC, 2018a). Field data were collected using an iPad and ArcGIS Collector and Field Maps applications between 2021 and 2025. Field mapping of Quaternary deposits of Ogden Valley by McDonald occurred between 2001–2004 and 2021–2025. Field mapping by other authors was completed in 2021–2025.

MAP UNIT DESCRIPTIONS

QUATERNARY

Alluvial Deposits

Qal_1 **Level-1 stream and floodplain deposits** (Late Holocene) – Poorly to moderately sorted pebble and cobble gravel, locally contains boulders, with a matrix of sand and silt; contains thin discontinuous sand lenses; subangular to subrounded clasts; angular to subangular grains; composition depends on source area; thin to medium bedded with planar bedding and cross-bedding; locally includes muddy overbank and organic-rich marsh deposits; mapped in channels and active floodplains of major valley-bottom streams in Ogden Valley including the North, Middle, and South Forks of the Ogden River, and Wolf Creek, and other small creeks and on terraces less than 10 feet (9 m) above active stream channels; inset into Lake Bonneville deposits; equivalent to the younger part of young stream and floodplain deposits (Qaly), but differentiated because active channels and bar-and-swale geomorphology of Qal_1 visible on historical aerial photos (USDA, 1946, 1958); some stream deposits are human-modified (channelized, including channel embankments), but are too small to map separately as Qh; estimated thickness less than 20 feet (6 m).

Qal_2 **Level-2 stream and floodplain deposits** (Middle Holocene to Late Pleistocene) – Poorly to moderately sorted silt, sand, and cobble gravel, locally contains boulders, with a matrix of sand and silt; subangular to rounded clasts; thin to medium bedded with planar bedding and cross-bedding; angular to subangular grains; composition depends on source area; locally includes muddy overbank and organic-rich marsh deposits; mapped where alluvium is adjacent to and slightly higher and distinguishable from active channels but too low to be mapped as terraces; forms terraces that are 10 to 30 feet (3–9 m) above adjacent channels and floodplains of North and South Forks of the Ogden River; inset into Lake Bonneville deposits; equivalent to the older part of Qaly, but differentiated from level-1 stream deposits (Qal_1) where characterized by subdued bar-and-swale topography and incised by Qal_1 deposits; thickness generally less than 20 feet (6 m).

Qaly **Young stream and floodplain deposits** (Holocene to Late Pleistocene) – Poorly to moderately sorted pebble and cobble gravel, locally contains boulders, with a matrix of sand and silt; subangular to subrounded clasts; angular to subangular grains; composition depends on source area; thin to medium bedded with planar bedding and cross-bedding; mapped in channels and active floodplains of North Fork of Ogden River, Ogden River, and other small creeks; includes small alluvial-fan and colluvial deposits; inset into Lake Bonneville deposits; mapped where Qal_1 and Qal_2 deposits cannot be mapped separately due to lack of bars and swales and because individual deposits are too small to show separately at map scale; postdates regression of Lake Bonneville from the Provo and lower shorelines; thickness variable, probably less than 20 feet (6 m).

Qat **Stream terrace deposits** (Holocene to Late Pleistocene?) – Poorly to moderately sorted, pebble and cobble gravel, locally contains boulders, with a matrix of sand and silt; contains thin sand lenses; subangular to rounded clasts; thin to thick bedded with planar bedding and cross-bedding; typically about 5 to 30 feet (1–10 m) above modern channels; thickness generally less than 10 feet (3 m) thick.

Qao **Older alluvial deposits** (Middle to Early Pleistocene?) – Poorly to moderately sorted, pebble and cobble gravel, locally contains boulders, with a matrix of sand and silt; contains thin sand lenses; subangular to rounded clasts; subangular to subrounded grains; deposits are typically isolated remnants in the valley or along valley margin drainages; located above and presumed older than Lake Bonneville-age alluvium and likely same age as Qafo but lacking alluvial-fan morphology; 10 to 50 feet (3–15 m) thick.

Qaf_1 **Level-1 alluvial-fan deposits** (Late Holocene) – Poorly to moderately sorted, pebble to cobble gravel, with boulders near bedrock sources, with a matrix of sand, silt, and clay, distal parts of this unit are finer-grained; angular to subrounded clasts; weakly to non-stratified; deposited by debris flows, debris floods, sheet floods, and perennial and intermittent streams at the mouth of canyons and incised drainages; forms fans, locally with distinct levees, and channels at mouths of mountain-front canyons; mapped on the Geertsen Canyon alluvial fan where the youngest (level 1) deposits can be shown separately at map scale; equivalent to the younger part of young alluvial-fan deposits (Qafy) and mapped where active fans can be shown separately; younger than Qaf_2 based on incision into older unit; estimated thickness less than 15 feet (5 m).

Qaf_2 **Level-2 alluvial-fan deposits** (Middle Holocene to Late Pleistocene) – Poorly to moderately sorted, pebble to cobble gravel, with boulders near bedrock sources, with a matrix of sand, silt, and clay, which becomes finer-grained away from source; clasts angular to subrounded; weakly to non-stratified; deposited by debris flows, debris floods, sheet floods, and perennial and intermittent streams at the mouth of canyons and incised drainages; mapped along North Fork of Ogden River where these older alluvial fan deposits can be shown separately at map scale; equivalent to the older part of young alluvial-fan deposits (Qafy) and mapped separately where incised by younger streams; estimated thickness less than 20 feet (6 m).

Qafy **Young alluvial-fan deposits** (Holocene to Late Pleistocene?) – Poorly to moderately sorted, pebble to cobble gravel with boulders near bedrock exposures, with a matrix of sand, silt, and minor clay, which becomes finer-grained away from source; clasts angular to subrounded; weakly to non-stratified; deposited by debris flows, debris floods, sheet floods, snow avalanches, and perennial and intermittent streams; mapped at the mouth of canyons and incised drainages, notably at the mouth of Geertsen Canyon where a large, nearly 1.5-mile-wide (2.5 km) by over 1- mile-long (1.5 km) fan exists; elsewhere, smaller alluvial fans grade into active stream channels or lacustrine surfaces; includes both ages of younger alluvial-fan deposits (Qaf_1 and Qaf_2) across large alluvial slopes where individual fan surfaces cannot be differentiated consistently; where possible, adjacent alluvial fans are mapped separately with a contact between them; locally may include some undifferentiated thin Bonneville transgressive deposits or pre-Bonneville alluvial-fan deposits; postdates Lake Bonneville highstand (Table 1), may coincide with the youngest part of the regression of Lake Bonneville; Lake Bonneville shorelines are not present on these alluvial fans; thickness variable, greater than 30 feet (9+ m).

Qafp? **Alluvial-fan deposits related to Provo shoreline and regressive phase of Lake Bonneville** (Late Pleistocene) – Poorly to moderately sorted, pebble to cobble gravel, with boulders near bedrock exposures, in a matrix of sand, silt, and minor clay; clasts angular to subrounded, well rounded where derived from Lake Bonneville gravel; weakly to non-stratified; deposited by debris flows, debris floods, sheet floods, and streams near the Provo shoreline; mapped in Ogden Canyon where an alluvial fan may be graded to the Provo shoreline of Lake Bonneville; correlative with Lake Bonneville overflowing and regressive phase alluvial-fan deposits (afp, af3) of other maps in adjacent areas (Nelson and Personius, 1993); incised by younger alluvial deposits (Qafy); exposed thickness less than 30 feet (9 m).

Qafb, Qafb?

Alluvial-fan deposits related to Bonneville shoreline and transgressive phase of Lake Bonneville (Late Pleistocene) – Poorly to moderately sorted, pebble to cobble gravel with boulders near bedrock exposures, in a matrix of sand, silt, and minor clay; clasts angular to subrounded but well rounded where derived from Lake Bonneville gravel; deposited principally by debris flows, debris floods, sheet floods, and streams; incised by younger alluvial fans (Qaf_1, Qaf_2, Qafy) and grades to near and slightly below the elevation of the Bonneville shoreline; mapped in Ogden Valley and Ogden Canyon where it is correlative with Lake Bonneville transgressive phase alluvial-fan deposits (afb and af3) of other maps in adjacent areas (Nelson and Personius, 1993); differentiated from Qafp by relation to the Bonneville shoreline; mapped as queried where alluvial fan is above the Provo but below the Bonneville shoreline, may represent transgressive alluvial-fan deposits; thickness less than 30 feet (9 m).

Qafo **Older alluvial-fan deposits** (Late to Middle Pleistocene?) – Poorly to moderately sorted, clast to matrix supported pebble to cobble gravel with boulders, with a matrix of sand, silt, and clay; clasts are angular to well rounded; weakly to non-stratified; forms dissected, isolated alluvial deposits that predate Lake Bonneville; thin to thick planar beds, likely Early to Middle Pleistocene-age and may include deposits previously mapped as Huntsville Fanglomerate (Eardley, 1955; Lofgren; 1955; Coody, 1957) and may include deposits where fan age is uncertain, or for composite fans, where parts of fans with different ages cannot be shown separately at map scale; incised by Qafy; thickness variable, 10 to 50 feet (3–15 m) thick.

Qafoe **Eroded old alluvial-fan deposits** (Middle to Early Pleistocene?) – Poorly sorted, clast- to matrix-supported pebble to cobble gravel with boulders, with a matrix of sand, silt, and clay; subangular to subrounded clasts; poorly bedded; surface may be cobble/boulder-armored; deposits are elevated, isolated remnant fan deposits that may include deposits previously mapped as Huntsville Fanglomerate (Eardley, 1955; Lofgren; 1955; Coody, 1957); deposits lack alluvial-fan morphology and are often truncated/inset by younger alluvial deposits; eroded alluvial-fan remnant deposits are above and apparently older than pre-Lake Bonneville older alluvial-fan deposits (Qafo); thickness variable, 10 to 50 feet (3–15 m) or more thick.

Colluvial Deposits

Qc **Colluvial deposits** (Holocene to Middle Pleistocene?) – Poorly to moderately sorted, clay- to boulder-size, locally derived sediment; angular to subangular clasts; generally poorly stratified; deposited by slope wash and soil creep on steep slopes and in shallow depressions; may include landslides, rockfalls, debris flows, and alluvial-fan deposits that are too small to map separately; most bedrock is covered by at least a thin veneer of colluvium, but only the larger, thicker deposits are mapped; thickness between 6 to 20 feet (2–6 m).

Glacial Deposits

Glacial deposits mapped in the Huntsville quadrangle are assumed to correlate with the Pinedale and Bull Lake glaciations. No ages of the glacial deposits from Huntsville or surrounding quadrangles are available and cross-cutting relationships are uncertain. Therefore, some deposits are mapped as undivided with respect to age.

The Pinedale glaciation is roughly correlative in age to Marine Oxygen Isotope Stage (MIS) 2 (14 to 29 ka; data from Lisiecki and Raymo, 2005). In the Wasatch Range, maximum ice extent during the Pinedale glaciation occurred about 20 to 21 ka (Laabs and Munroe, 2016; Quirk et al., 2018, 2020) with deglaciation and minor moraine-building pauses lasting through about 13 ka (Laabs et al., 2011; Laabs and Munroe, 2016; Quirk et al., 2018). These ages coincide well with ages of the Pinedale glaciation in the Wind River and Teton Ranges (about 13 to 30 ka; Gosse et al., 1995; Phillips et al., 1997; Pierce et al., 2018 and references therein). Recalculated and new ^{10}Be ages from Big Cottonwood, Little Cottonwood, American Fork, and Bells Canyons show glaciers readvanced around 17.5 ka to near the maximum positions and retreated to approximately half of their maximum lengths around 15 ka, followed by rapid deglaciation that coincided with the beginning of the regressive phase of Lake Bonneville around 14.8 ka (Quirk et al., 2018, 2020).

The Bull Lake glaciation is roughly correlative in age to MIS 6 (130 to 191 ka; data from Lisiecki and Raymo, 2005). Bull Lake glacial deposits are typically higher on ridges and farther away from cirques, suggesting larger ice volumes during this glacial cycle than the Pinedale. However, many of the Bull Lake glacial features were obliterated by the younger Pinedale glaciation. Minimal chronology data exist for the Bull Lake glaciation in the Wasatch Range. Quirk et al. (2018) reported a ^{10}Be exposure age of 132.2 ± 5.9 ka from a striated bedrock surface in Big Cottonwood Canyon and interpreted this as a minimum age for the onset of Bull Lake deglaciation. In the Wind River and Teton Ranges, Gosse and Phillips (2001), Sharp et al. (2003), and Pierce et al. (2018, and references therein) suggest a Bull Lake glacial maximum of about 140 to 160 ka.

Qgp **Glacial deposits, undivided, Pinedale age** (Late Pleistocene) – Unsorted, non-stratified boulder, cobble, and pebble gravel with a matrix of sand and silt; angular to rounded clasts (rounded where they have been sourced from Tertiary Wasatch Formation); mapped near Powder Mountain in the northeast part of the Huntsville quadrangle; mapped as undivided glacial deposits because deposits lack distinct geomorphic shapes of end, recessional, and lateral moraines; likely deposited during Pinedale glaciation, which roughly correlates to the colder and wetter Marine Isotope Stage (MIS) 2 (14 to 29 ka; Lisiecki and Raymo, 2005); estimated thickness up to 50 feet (15 m).

Qga **Glacial outwash** (Late to Middle? Pleistocene) – Stacked unit only. Poorly to moderately sorted, clast-supported cobble and pebble gravel, locally contains boulders, with a minor matrix of sand and silt; clasts subangular to rounded; thin to thick parallel bedding and cross-bedding; deposited by glacial meltwater streams along the North Fork of Ogden River below large lateral and end moraines; may include Pinedale and/or Bull Lake-age deposits (see age discussion above); estimated thickness less than 50 feet (15 m).

Human-Derived

Qh **Fill and disturbed land** (historical) – Undifferentiated artificial (human-made) fill and disturbed land related to construction, water storage and debris flood control structures and aggregate mining operations; extents are based on lidar data (UGRC, 2006, 2011, 2016) and aerial imagery (UGRC, 2018a, 2018b, 2021a, 2021b); only larger areas of disturbed land are mapped; deposits of unmapped fill and disturbed lands are present in most developed areas and contain changing mix of cuts and fills; smaller ponds are not mapped due to map scale limitations; thickness variable and unknown.

Lacustrine Deposits

Qly **Lacustrine fine-grained deposits of Pineview Reservoir** (historical) – Moderately sorted silt, sand, and clay, locally includes locally sourced pebbles and cobbles; sand is fine to coarse grained and subangular to angular; likely includes reworked deposits from incised Lake Bonneville deposits (Qlsb); mapped where lacustrine sediments form thin beaches around Pineview Reservoir; thickness less than 10 feet (3 m).

Deposits related to the Bonneville shoreline and transgressive phase of Lake Bonneville: Mapped between the Bonneville and Provo shorelines. The Bonneville shoreline is at elevations between 5180 and 5190 feet (1579–1582 m) in the Huntsville quadrangle (Table 1).

Qlgb **Lacustrine gravel and sand** (Late Pleistocene) – Moderately to well-sorted, clast-supported pebble to cobble gravel with a matrix of sand and pebbly sand; locally interbedded with thin beds and lenses of silt and clay; clasts commonly subrounded to rounded but some deposits consist of poorly sorted, angular gravel derived from nearby bedrock outcrops; bedding is planar and cross-bedded; locally deposits form veneers over shallow bedrock; commonly interbedded with or laterally gradational into lacustrine sand and silt (Qlsb); estimated thickness is less than 20 feet (6 m).

Qlsb **Lacustrine sand and silt** (Late Pleistocene) – Moderately to poorly-sorted, subrounded to rounded, fine to coarse sand and silt with minor pebbly gravel; thin to thick bedded; sedimentary structures includes ripple marks and scour features; includes thin clay and silt interbeds deposited off shore; mapped below Bonneville shorelines; deposited in relatively shallow water nearshore, laterally gradational with transgressive gravel and sand (Qlgb) and fine-grained deposits (Qlfb); thickness is less than 30 feet (9 m).

Qlfb **Lacustrine fine-grained** (Late Pleistocene) – Moderately to well-sorted and moderately bedded to thinly laminated clay, silt, and sand deposited during the transgression and highstand of Lake Bonneville; deposited in shallow to moderately deep water; typically overlies pre-Bonneville alluvium and may overlie Middle Pleistocene Little Valley lake cycle (Scott et al., 1983; Oviatt et al., 1999) fine-grained deposits in the central part of the valley; 5 feet (2 m) thick or greater.

Mass-Movement Deposits

Qms **Landslide deposits** (historical? to Middle Pleistocene?) – Poorly sorted clay- to boulder-size material in slides and slumps; composition varies with the source material; characterized by hummocky topography, main and internal scarps, toe thrusts, back-rotated blocks, and chaotic bedding in displaced bedrock; mapped in multiple areas in the quadrangle and sourced from older mass-movement deposits or mass-movement-prone surficial deposits and/or bedrock; in highly vegetated areas, lidar-derived elevation models were used to distinguish individual landslides in larger landslide complexes based on geomorphology and cross-cutting relationships; where possible adjacent landslides are mapped separately with a contact between them; 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; many small or thin landslides may be present throughout the quadrangle but not mapped due to map scale; thickness highly variable, can be up to several hundred feet thick.

Qmsh **Historical landslide deposits** (historical to Middle Pleistocene?) – Poorly sorted clay- to boulder-sized material in slides, slumps, flows, and landslide complexes; generally characterized by hummocky topography, head, lateral, and/or internal scarps, and chaotic bedding in displaced blocks; composition depends on local sources; morphology becomes more subdued with increasing age and/or rate of movement; includes landslides having historical movement that has been observed, documented, or is apparent on aerial imagery; thickness highly variable; can be up to 100 feet thick or more.

Qmsy **Younger landslide deposits** (historical? to Middle Pleistocene?) – Poorly sorted clay- to boulder-size material in slides and slumps; composition varies with the source material; characterized by hummocky topography, main and internal scarps, toe thrusts, back-rotated blocks, and chaotic bedding in displaced bedrock; mapped in multiple areas in the quadrangle and sourced from older mass-movement deposits or mass-movement-prone surficial deposits and/or bedrock; in highly vegetated areas, lidar-derived elevation models were used to distinguish individual landslides in larger landslide complexes by geomorphology and cross-cutting relationships; 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; morphology suggests likely post-Lake Bonneville movement with relatively sharp and pronounced landslide deformation features and may include parts that are historically active; many small or thin landslides may be present throughout the quadrangle but not mapped due to map scale; thickness highly variable, likely up to several tens of feet thick.

Qmso **Older landslide deposits** (Late to Middle Pleistocene?) – Poorly sorted clay- to boulder-size material, colluvium, and brecciated bedrock; characterized by subdued eroded scarps with benches and steps in topography reminiscent of eroded slide blocks or back-rotated surfaces; much of the hummocky surface and identifiable features have been removed by erosion or filled by other types of deposition; mapped where deposits generally have a more subdued morphology and are likely early Holocene and Pleistocene in age; include very large complexes underlain by argillite-rich bedrock where entire hillsides appear to be part of a landslide complex but where defining their boundaries are often difficult; in highly vegetated areas, lidar-derived elevation models were used to distinguish individual landslides in the complex by geomorphology and cross-cutting relationships; where possible adjacent landslides are mapped separately with a contact between them; landslides with subdued morphology (suggesting that they are older, weathered, and have not moved recently) may continue to have slow creep or are capable of renewed movement if stability thresholds are exceeded (Ashland, 2003); age and stability determinations require detailed geotechnical investigations; thickness variable, can be up to several hundred feet thick.

Qmt **Talus deposits** (historical? to Middle Pleistocene?) – Very poorly sorted, angular pebble- to cobble- and boulder-size rocks, with pebble-size to minor finer-grained matrix; deposited principally by rockfall on, and/or at the base of steep slopes in the Wasatch Range; includes unvegetated potentially active rockfall to partially vegetated stabilized slopes; locally includes minor colluvium; other small and thin talus deposits not mapped due to map scale; 0 to 30 feet (0–9 m) thick.

Mixed-Environment Deposits

Qac **Alluvial and colluvial deposits** (Holocene to Late Pleistocene?) – Poorly to moderately sorted, generally poorly stratified, clay- to boulder-size, locally derived sediment; rounded to angular clasts; mapped where alluvium and colluvium grade into one another or are intermixed and cannot be shown separately at map scale, locally may include mass-movement deposits too small to map separately; mapped at the base of steep slopes in the Wasatch Range and in small drainages where alluvium and colluvium from the sides of the drainage are intermixed; small, unmapped deposits are likely present in most small drainages; thickness less than 20 feet (6 m).

Qaco **Older alluvial and colluvial deposits** (Late to Middle? Pleistocene) – Poorly to moderately sorted, generally poorly stratified, clay- to boulder-size, locally derived sediment; rounded to angular clasts; forms incised surfaces as much as several tens of feet above modern drainages; mapped on range front drainages where incised alluvium and colluvium grade into one another or are intermixed and cannot be shown separately at map scale; thickness less than 30 feet (9 m).

Qact **Alluvium, colluvium and talus deposits** (Holocene to Middle Pleistocene?) – Unsorted to variably sorted silt, sand, gravel, clay, cobble and boulder in variable proportions and roundness; deposited by rockfall, debris flows, debris floods, sheet floods, snow avalanches, and perennial and intermittent streams in steep drainages; includes ephemeral stream alluvium; mapped in steep, rocky drainages associated with resistant bedrock units where incised alluvium, colluvium, and talus grade into one another or are intermixed and cannot be shown separately at map scale; 0 to 20 feet (0–6 m) thick.

Qafdb **Alluvial-fan and delta deposits related to Bonneville shoreline and transgressive phase of Lake Bonneville** (Late Pleistocene) – Poorly to moderately sorted cobbly gravel in a matrix of sand, silt, and clay; angular to subrounded clasts; moderately to well bedded; typically consists of well-sorted, finer-grained deltaic deposits over coarser-grained, poorly sorted alluvium and glacial outwash; deposited upstream from and into Lake Bonneville as the lake transgressed to the Bonneville shoreline; mapped in Ogden Valley where a distinct contact between alluvial and deltaic facies is not apparent; thickness between 10 to 50 feet (3–15 m).

Qam A**lluvial and marsh deposits** (historical) – Moderately to well-sorted sand, silt, clay, and organic-rich sediment associated with wetlands and alluvial channels; locally contains peat deposits; commonly wet, but seasonally dry; mapped where alluvial streams pond and develop wetlands near Pineview Reservoir, distinguished from alluvial units (Qal_1, Qaly) by wetland-like vegetation on aerial photographs; estimated thickness less than 15 feet (5 m).

Qct **Colluvial and talus deposits** (Holocene to Middle Pleistocene?) – Very poorly sorted, gravel-size angular debris with a finer-grained matrix; composed of slope wash, soil creep, and rockfall deposits that are mixed and grade into one another; typically distinguished from talus (Qmt) due to the presence of vegetation and lower angle slopes; typically deposited at the base of steep slopes in the Wasatch Range; 0 to 30 feet (0–9 m) thick.

Qdlb **Lake Bonneville delta and lacustrine deposits** (Late Pleistocene) – Moderately to well sorted sand, gravelly sand, silty sand, and cobbles deposited in Lake Bonneville deltas and nearshore as the lake transgressed; subrounded to rounded clasts; moderately to well bedded; forms prominent landforms where the North and Middle Forks of the Ogden River and Wolf Creek entered Lake Bonneville; 0 to 30 feet (0–9 m) thick.

Qla **Lacustrine and alluvial deposits** (Holocene to Late Pleistocene) – Poorly to moderately sorted clay, silt, sand, and gravel; subangular to rounded clasts; moderately to well-bedded; mapped where alluvial streams and fans interfinger, rework, and incorporate Lake Bonneville-age deposits; 1 to 10 feet (0.3–3 m) thick.

Qmc **Mass-movement and colluvial deposits** (Holocene to Middle Pleistocene?) – Poorly sorted to unsorted unstratified clay- to boulder-size material; angular to rounded clasts; mixed landslide, slump, slope wash, and soil creep deposits that grade into one another; typically has a slightly hummocky appearance on lidar-derived elevation models; lacks clear landslide scarps and lateral margins; typically forms on slopes overlying clay-bearing, landslide-prone bedrock units—notably Miocene volcaniclastics and argillic Proterozoic formations; age and stability determinations require detailed geotechnical investigations; thickness 0 to 40 feet (0–12 m).

Qsm **Spring and marsh deposits** (Holocene to Late Pleistocene?) – Unsorted, fine-grained, organic-rich sediment associated with springs, seeps, ponds, and wetlands; may be seasonally dry; mapped in marshy and/or spring-sapped areas; at least 5 feet (2 m) thick.

Stacked-Unit Deposits

The term "stacked" means a thin covering of one unit over the other. This is shown by the overlying map unit (listed first) then a slash, then the underlying unit. See individual map unit descriptions for more information regarding materials.

Qac/Tsl

Alluvium and colluvium over Salt Lake Formation (Holocene to Middle Pleistocene? over Miocene) – Unsorted to variably sorted silt, sand, gravel, clay, cobbles and boulders in variable proportions and roundness over Salt Lake Formation; often white to brown tuffaceous soil developed from the Salt Lake Formation is present in the stack unit; stacked unit identifies potential geologic hazards and conditions associated with underlying Salt Lake Formation; alluvium and colluvium cover typically less than 6 feet (2 m) thick.

Qao/Tsl

Older alluvial deposits over Salt Lake Formation (Late to Middle Pleistocene? over Miocene) – Poorly to moderately sorted pebble to boulder gravel with a matrix of silt, sand and clay with pebble to cobble lag over Salt Lake Formation; often white to brown tuffaceous soil developed from the Salt Lake Formation is present in the stack unit; stacked unit identifies potential geologic hazards and conditions associated with underlying Salt Lake Formation; alluvium cover typically less than 10 feet (3 m) thick.

Qafo/Tsl

Older alluvial-fan deposits over Salt Lake Formation (Late to Middle Pleistocene? over Miocene) – Poorly to moderately sorted pebble to cobble gravel with a matrix of silt, sand, and clay with pebble lag over Salt Lake Formation; often white to brown tuffaceous soil developed from the Salt Lake Formation is present in the stack unit; stacked unit identifies potential geologic hazards and conditions associated with underlying Salt Lake Formation; alluvium cover typically less than 10 feet (3 m) thick.

Qafoe/Tsl

Eroded old alluvial-fan deposits over Salt Lake Formation (Middle to Early Pleistocene? over Miocene) – Poorly sorted cobble gravel with a matrix of sand, silt, and clay over Salt Lake Formation; often white to brown tuffaceous soil developed from the Salt Lake Formation is present in the stack unit; stacked unit identifies potential geologic hazards and conditions associated with underlying Salt Lake Formation; alluvium cover typically less than 10 feet (3 m) thick.

Qc/Tsl **Colluvial deposits over Salt Lake Formation** (Holocene to Middle Pleistocene? over Miocene) – Poorly to moderately sorted, clay- to boulder-size, locally derived sediment over Salt Lake Formation; often white to brown tuffaceous soil developed from the Salt Lake Formation is present in the stack unit; stacked unit identifies potential geologic hazards and conditions associated with underlying Salt Lake Formation; colluvial thickness typically between 6 to 20 feet (2–6 m).

Qlgb/Qmso

Lacustrine gravel and sand related to the Bonneville shoreline and transgressive phase of Lake Bonneville over older landslide deposits (Late Pleistocene over Late to Middle Pleistocene?) – Moderately to well-sorted, clast-supported pebble to cobble gravel with a matrix of sand and pebbly sand over poorly sorted clay- to boulder-size material, colluvium, and brecciated bedrock; mapped where younger Lake Bonneville deposits overly older landslide deposits in Ogden Valley; landslide age and stability determinations require detailed geotechnical investigations; estimated lacustrine gravel and sand thickness is less than 20 feet (6 m), older landslide deposits thickness variable, can be up to several hundred feet thick.

Qlgb/Tsl

Lacustrine gravel and sand related to the Bonneville shoreline and transgressive phase of Lake Bonneville over Salt Lake Formation (Late Pleistocene over Miocene) – Moderately to well-sorted, clast-supported pebble to cobble gravel with a matrix of sand and pebbly sand over Salt Lake Formation; often white to brown tuffaceous soil developed from the Salt Lake Formation is present in the stack unit; mapped where younger Lake Bonneville deposits overly Salt Lake Formation on the west margin of Ogden Valley; deposited in transgressive Lake Bonneville nearshore environments; stacked unit identifies potential geologic hazards and conditions associated with underlying Salt Lake Formation; estimated lacustrine gravel and sand thickness is less than 20 feet (6 m).

Qlsb/Tsl

Lacustrine sand and silt related to the Bonneville shoreline and transgressive phase of Lake Bonneville over Salt Lake Formation (Late Pleistocene over Miocene) – Moderately to poorly sorted, subrounded to rounded, fine to coarse sand and silt with minor pebbly gravel over Salt Lake Formation; often white to brown tuffaceous soil developed from the Salt Lake Formation is present in the stack unit; mapped where younger Lake Bonneville deposits overly Salt Lake Formation in Ogden Valley; deposited in transgressive Lake Bonneville nearshore environments; stacked unit identifies potential geologic hazards and conditions associated with underlying Salt Lake Formation; estimated lacustrine sand and silt thickness is less than 30 feet (9 m).

Qafdb/Qga

Alluvial-fan and delta deposits related to Bonneville shoreline and transgressive phase of Lake Bonneville over younger glacial outwash (Late Pleistocene over Late to Middle? Pleistocene) – Alluvial-fan and delta deposits that are poorly to moderately sorted cobble gravel in a matrix of sand, silt, and clay over glacial outwash that is poorly to moderately sorted, clast-supported cobble and pebble gravel, locally contains boulders, with a minor matrix of sand and silt; typically better sorted and finer-grained deltaic deposits over coarser-grained and unsorted gravel outwash; deposited upstream from and into Lake Bonneville as the lake transgressed to the Bonneville highstand shoreline; mapped where a distinct contact between the alluvial and deltaic facies is not apparent on the North Fork of the Ogden River drainage; alluvial and delta deposits about 10 feet (3 m) thick; the glacial outwash is likely thicker than 20 feet (6 m).

QUATERNARY-PLIOCENE (TERTIARY)

QTaf, QTaf?

Quaternary-Pliocene alluvial-fan deposits (Middle Pleistocene? to Pliocene?) – Poorly sorted, pebble to cobble gravel, locally contains boulders, in a matrix of sand, silt, and clay; subangular to subrounded clasts; poorly bedded; surfaces often boulder- and cobble-lag armored; mapped on the east side of Ogden Valley as isolated remnants inset into canyon walls or elevated ridges; remnant fans lack fan morphology; queried where unit uncertain; thickness variable, 10 to 100 feet (3–30 m) thick.

Major unconformity

NEOGENE-PALEOGENE (TERTIARY)

Tsl, Tsl?

Salt Lake Formation (Miocene) – Light-gray to light-brown, altered tuff (claystone), tuffaceous siltstone, sandstone, and conglomerate; locally light red or green; mapped on margins of Ogden Valley where it forms colluvium-covered slopes; often white to brown tuffaceous soil developed on the unit, brown soil often has polygonal desiccation cracks;

prone to landslides and slumps; unconformably overlies older bedrock, base not exposed in quadrangle; previously mapped as Early Oligocene–Late Eocene Norwood Formation, preliminary research suggest much of the Norwood Formation in Ogden Valley is actually Salt Lake Formation with U-Pb detrital zircon ages of 8–10 Ma (Cornwall et al., 2025; Mayfield et al., 2025); exposed thickness in quadrangle 0 to 1500+ feet (0–450+ m) (Sorenson and Crittenden, 1979); Coogan and King (2016) estimated the thickness in western Ogden Valley up to 2000 feet (600 m).

Unconformity

Tw **Wasatch Formation** (Eocene to Paleocene) – Moderate reddish-orange to pale yellowish-orange, cobble to boulder conglomerate with varying amounts of mudstone and sandstone; forms cobble- and boulder-strewn slopes in the quadrangle; unconsolidated to consolidated claystone, sandstone, limestone, and dolomite reported in lithologic logs from water wells drilled near Powder Mountain ski resort (see logs for well identification number [WIN] 436846 and 441068, Utah Division of Water Rights well database [UDWR], 2022); clasts are tan, gray, purple, and green quartzite and well-indurated sandstone, sourced dominantly from the Brigham Group, with minor clasts of Paleozoic carbonates; lower contact is sharp, unconformable; deposited over considerable paleotopography evidenced by varying thicknesses; estimated up to 500 feet (150 m) thick in the quadrangle; 0 to 2000 feet (0–610+ m) thick in adjoining Browns Hole quadrangle (Anderson et al., 2023).

Major unconformity

WILLARD THRUST HANGING WALL

ORDOVICIAN-CAMBRIAN

O€s **St. Charles Formation** (Early Ordovician to Late Cambrian) – Combined dolomite member and Worm Creek Quartzite Member due to development concealing the Worm Creek Quartzite Member outcrop previously mapped by Sorensen and Crittenden (1979); dolomite member is a dark to very light-gray dolomite; thin- to thick-bedded dolomitic grainstone; locally interclastic, oolitic, thrombolytic, fossiliferous, contains twiggy bodies, is mottled, and variably recrystallized; interbedded reddish shale and siltstone near base that marks the conformable contact with the Worm Creek Member of the St. Charles Formation (not exposed); Worm Creek Quartzite Member is a light-gray to light-brown calcareous sandstone and sandy dolomite; well sorted, thin bedded; well-rounded grains; lower contact is often poorly exposed or covered by colluvium; mapped in the northeast corner of the quadrangle where it forms ledges and slopes; in the northern Bear River Range, Cothren et al. (2022) reported U-Pb maximum depositional ages of 492.83 ± 0.71 Ma and 494.16 ± 0.46 Ma from the top and base of the Worm Creek Member, respectively; Cothren et al. (2022) also report trilobites ranging from *Dunderbergia* to *Elvinia* biozones; exposed incomplete thickness of 100 feet (30 m), Sorenson and Crittenden (1979) reported a total thickness of dolomite member 500 to 800 feet (150–245 m) and Worm Creek Quartzite Member thickness of 20 feet thick (6 m) in the quadrangle.

CAMBRIAN

€n **Nounan Formation** (Late Cambrian) – Light-gray, thick- to massively bedded, partially to completely recrystallized sparry dolomite with bleached, brecciated, and vuggy zones; grainstone to rudstone with local intraclastic and oolitic beds; upper part becomes lighter in color and heavily recrystallized with thrombolytic boundstones, and intraclastic dolomitic rudstone beds; mapped in the northeast part of the quadrangle where it forms steep slopes and minor ledges; lower contact at transition to shale (€boc); in the northern Bear River Range, Cothren et al. (2022) reported U-Pb maximum depositional ages of 494.16 ± 0.46 Ma from the top of the Nounan/base of Worm Creek Member of St. Charles Formation and 494.35 ± 0.46 Ma from a sandstone bed ~37 m below the upper contact; Cothren et al. (2022) also reported trilobite taxa ranging from *Crepicephalus* to *Dunerbergia* biozones, and reported the beginning of the Steptoean Positive Isotopic Carbon Excursion (SPICE) at the base of the Pabian Stage; measured thickness in the northeast part of the quadrangle is 660 feet (200 m); total thickness reported by Sorensen and Crittenden (1979) is 500 to 760 feet (150–230 m).

€boc **Calls Fort Member of Bloomington Formation** (Middle Cambrian) – Tri-part stratigraphic package of tan and greenish brown to dark blue, thinly laminated upper and lower shale with a medial zone of gray to light blue, medium- to thickly bedded interclastic, fossiliferous, oolitic limestone; shale intervals form vegetated swales and medial limestone forms ledges and small cliffs; lower contact at change from lower shale to limestone; in the Wellsville Mountains, shale members are Middle Cambrian (*Bolaspidella* zone) in age (Oviatt, 1986; Jensen and King, 1999,

Table 2); *Bolaspidella* sp. trilobite fossils reported by Rigo (1968, sample USGS No. 5965-CO) in the Causey Dam quadrangle to the east; measured thickness in the northeast part of the quadrangle is 313 feet (95 m).

Ꞓbom? **Middle limestone member of Bloomington Formation?** (Middle Cambrian) – Medium to dark blue, medium to thick bedded dolomitic ooid grainstone with minor intraclastic beds; variably sparry; upper part is a ridge-forming, thick-bedded, very light blue to white, thrombolytic, intraclastic, and variable dolomitic boundstone; distinct interval of black and translucent bedded and nodule chert in upper one-third; contains abundant "twiggy" structures (as described in Lochman-Balk [1976] and Yonkee and Lowe [2004]) near base in oolitic grainstone; recessive micritic dolomite interbeds throughout; forms karsts that are covered with distinctive red muddy soil formation; distinct fetid smell on fresh surfaces; lower contact is conformable and mapped at slope break where resistant oolitic limestone and dolomite change to less resistant limestone and shale of Hodges Shale Member; queried because unit nomenclature, designation, and correlation are uncertain and tentatively based on trilobite assemblages in the unit below (see Ꞓboh); Sorensen and Crittenden (1979) included this interval in an undivided unit that included limestone and Hodges Shale Member of Bloomington Formation and Blacksmith and Ute Formations; Coogan and King (2016) mapped approximately this same interval as middle limestone member of Bloomington Formation; in the neighboring Browns Hole quadrangle, Anderson et al. (2023) followed Rigo (1968) and interpreted this interval as the Blacksmith Formation based on lithofacies and regional correlations throughout the Bear River Range; measured thickness of 600 feet (182 m) in the northeast part of the quadrangle.

Ꞓboh? **Hodges Shale Member of the Bloomington Formation?** (Middle Cambrian) – Dark greenish brown to reddish-orange fissile shale with interbedded light gray to blue-gray limestone and minor dolomite; shale is commonly poorly exposed and forms vegetated swales; carbonates are thin to medium bedded, micritic, intraclastic, bioclastic, onkolitic, and oolitic with interbeds of mottled shaley limestone; rare fine-grained sandstone beds near the base; lower contact at transition from shale to limestone; beds with visible trilobites present near the base with fauna belonging to *Ehmaniella* and *Bolaspidella* biozones (unpublished data; Fred Sundberg, written communication, 2025); queried because trilobite data is preliminary and previous unit designations are conflicting; Sorensen and Crittenden (1979) included this interval in an undivided unit that included limestone and Hodges Shale Member of Bloomington Formation and Blacksmith and Ute Formations; Coogan and King (2016) mapped approximately this same interval as Hodges Shale Member of Bloomington Formation; in the neighboring Browns Hole quadrangle, Anderson et al. (2023) followed Rigo (1968) and interpreted this interval as part of the Ute Formation based on lithofacies and regional correlations throughout the Bear River Range; measured thickness of 1250 feet (380 m) in the northeast part of the quadrangle.

Ꞓbu? **Blacksmith and Ute Formations?** (Middle Cambrian) – Light-gray to grayish-blue, thin- to medium-bedded limestone with interbedded shaley limestone and dark greenish brown to reddish-orange fissile shale; upper part is slope-forming, thin to medium bedded, light gray micritic to bioclastic limestone interbedded with thin shale beds and shaley limestone; lower part is dominantly medium bedded limestone with lesser interbedded shale and shaly limestone; limestone beds in lower part commonly contain interclastic, oolitic, onkolitic, and bioclastic beds; lower contact conformable and mapped at first shale above Langston Formation; Rigo (1968) reported *Glossopleura* sp. from the basal Ute Formation in the northeast part of the quadrangle; queried because trilobite data from overlying unit is preliminary and previous unit designations are conflicting; Sorensen and Crittenden (1979) included this interval in an undivided unit that included limestone and Hodges Shale Member of Bloomington Formation and Blacksmith and Ute Formations; Coogan and King (2016) mapped approximately this same interval as two distinct units, the Blacksmith and Ute Formations; in the neighboring Browns Hole quadrangle, Anderson et al. (2023) followed Rigo (1968) and interpreted this interval as Ute Formation based on lithofacies and regional correlations throughout the Bear River Range; measured thickness of 530 feet (160 m) in the northeast part of the quadrangle.

Ꞓl **Langston Formation** (Middle Cambrian) – Light to dark orange-brown weathering sandy dolomite, shaley limestone and limestone; light- to dark-gray on fresh surfaces; sandstone is thin to medium bedded with planar and cross-bedded laminae; limestone is thin to medium bedded micritic to minorly bioclastic with mottled shale; lower part forms recessive slopes with sandstone float and is commonly poorly exposed; lower contact conformable and gradational; measured thickness of 89 feet (27 m) in northeast part of quadrangle.

Ꞓgcu, Ꞓgcu?

Upper member of Geertsen Canyon Quartzite of Brigham Group (Middle to Early? Cambrian) – Dominantly grayish-yellow to grayish-orange, fine- to medium-grained, well-sorted, well-rounded, quartz arenite; medium to thick bedded with trough and planar tabular cross-beds with scoured bases; top part contains intervals of siltstone up to 3 feet

(1 m) thick; lower part contains increasing abundance of coarse to very coarse sandstone and matrix- to clast-supported pebble to small cobble conglomerate with well-rounded clasts of red sandstone, tan quartzite, reddish chert, and white quartz; generally very resistant, forms broken cliffs and steep slopes; lower contact is conformable and placed at base of 50- to 200-foot (15–65 m) thick pebble conglomerate interval that commonly forms lowest cliff band and marks the change from more arkosic sandstone of the lower member below to quartz arenite above; Early Cambrian age based on *Skolithos* and *Diplocraterion* trace fossils present in upper part, age of lower part not constrained; queried where uncertain; Sorenson and Crittenden (1979) report a 2400 to 2700 foot thickness (730–820 m) in the quadrangle; in the Browns Hole quadrangle Anderson et al. (2023) reported approximately 2000 to 3200 feet (610–970 m) thick.

Ꞓgcl, Ꞓgcl?

Lower member of Geertsen Canyon Quartzite of Brigham Group (Early Cambrian) – Moderate red to very pale orange, fine-grained to granule, subrounded to angular, poorly sorted sandstone with minor pebble conglomerate; subfeldspathic to feldspathic arenite (arkose) with feldspar abundance decreasing up section and quartz increasing; feldspar grains locally up to 0.4 inch (1 cm) in length; medium bedded with beds containing cross and planar laminae as well as massive beds; forms slopes with upper part commonly poorly exposed; lacks trace fossils; lower contact is sharp, disconformable, and may represent the Cambrian-Precambrian boundary; age is poorly constrained; Sorenson and Crittenden (1979) report a 1475 to1700 foot thickness (450–520 m) in the quadrangle; in the Browns Hole quadrangle Anderson et al. (2023) reported 1050 to 1320 feet (320–400 m) thick.

Unconformity

NEOPROTEROZOIC

Zbq **Quartzite member of Browns Hole Formation of Brigham Group** (Neoproterozoic, Ediacaran) – Very pale orange to pale yellowish-orange quartz arenite; thin to medium bedded with laterally continuous beds; horizontal and trough-cross stratification and ripple laminations; fine- to very coarse grained, with subrounded to rounded grains; moderately sorted with occasional coarse grains; forms steep slopes and small ledges, crops out moderately well; lower contact is abrupt but commonly poorly exposed, may be an unconformity (Provow et al., 2021), or may be conformable; Sorenson and Crittenden (1979) report a 100 to 150 foot thickness (30–45 m) in the quadrangle; in the Browns Hole quadrangle Anderson et al. (2023) reported about 175 feet (55 m) thick.

Zbv **Volcanic member of Browns Hole Formation of Brigham Group** (Neoproterozoic, Ediacaran) – Grayish-red-purple to moderate reddish-brown volcaniclastic sandstone and conglomerate interbedded with dark-gray basanite (basalt) flows; basal part contains sandstone and mudstone that are dark gray to blackish-red, thickly laminated to thinly bedded and fine grained, moderate to well sorted, and quartzose to lithic with varying amount of chert and volcanic grains; grades up section into grayish-red-purple volcaniclastic sandstone and volcaniclastic pebble to cobble conglomerate; conglomerate clasts are dominantly rounded cobbles of porphyritic andesite, trachyandesite, and vesicular basalt (Verdel, 2009; Provow et al., 2021) with minor amount of maroon quartz sandstone and volcaniclastic sandstone; individual conglomerate beds are poorly sorted, structureless, up to 2 feet (60 cm) thick; laterally discontinuous aphanitic basanite flows near top of unit interbedded with recessive-weathering volcaniclastic sandstone and mudstone; hematitic staining common in volcaniclastic intervals; poorly exposed, forms vegetated slopes and minor ledges; lower contact is sharp, conformable, and marked by appearance of hematite-stained sandstone with volcanic lithic grains, and color change from the lighter tan and reds of the Mutual Formation to dark reddish brown of the Browns Hole Formation; about 230 feet (70 m) exposed west of Geertsen Canyon; Sorenson and Crittenden (1979) report a 180 to 560 foot thickness (55–140 m) in the quadrangle; in the Browns Hole quadrangle Anderson et al. (2023) reported about 350 to 370 feet (105–115 m) thick near Middle Fork of Ogden River.

This unit provides the only radiometric age control in the Brigham Group in northern Utah, however all dated samples come from the neighboring Browns Hole quadrangle. Crittenden and Wallace (1973) reported a $^{40}Ar/^{39}Ar$ hornblende total gas age of 570 ± 14 Ma (corrected to 580 Ma for updated K-Ar decay constant, ± 2 sigma) for a trachyte clast from the volcaniclastic conglomerate. The total gas age, however, does not account for potential argon loss and could yield an erroneously young age. Verdel (2009) reported a U-Pb apatite age of 609 ± 25 Ma (2 sigma) from a basalt flow near the top of the unit. Provow et al. (2021) reported a maximum depositional age of 613 ± 12 Ma (2 sigma) based on U-Pb analysis of detrital apatite from a volcaniclastic sandstone about 30 feet (10 m) up section from the lower contact. They suggest the 613 Ma age is close to true depositional age based on textural properties of the apatite grains and mineralogical composition of the lithic grains within the sandstone.

Zm **Mutual Formation of Brigham Group** (Neoproterozoic, Ediacaran) – Pale-pink, grayish-red-purple, to dark red, medium- to very coarse grained, well-indurated quartzose sandstone interbedded with minor pebble conglomerate and dark reddish-purple argillite; weathers to darker shades of reddish purple; sandstone is moderately to poorly sorted with subrounded grains; medium to thick bedded with horizontal and trough cross-stratification; forms prominent cliffs and ledges; lower contact is conformable and mapped at a major slope break where mixed argillite and sandstone of the Inkom Formation (Zi) become dominated by sandstone; in the Browns Hole quadrangle Crittenden (1972a) reported local feldspathic zones; Sorenson and Crittenden (1979) report a 1200 foot thickness (370 m) in the quadrangle; in the Browns Hole quadrangle Anderson et al. (2023) reported approximately 940 feet (285 m) thick near Middle Fork of Ogden River.

Zi **Inkom Formation of Brigham Group** (Neoproterozoic, Ediacaran) – Grayish-yellow to reddish-orange mudstone, sandstone, and minor pebble conglomerate; lower part is recessive yellowish-brown, thinly to thickly laminated mudstone and argillite; up section unit becomes silty argillite interbedded with red and tan, ripple-laminated siltstone and sandstone; sandstone is dominantly quartzose but locally contains feldspar and lithic grains; forms recessive slope; mapped in one location east of Gertsen Canyon; lower contact is sharp and unconformable with the Caddy Canyon sandstone; estimated thickness about 250 to 280 feet (75–85 m).

Unconformity

Zcc **Caddy Canyon Quartzite of Brigham Group** (Neoproterozoic, Ediacaran) – Variably colored, vitreous well-cemented sandstone (commonly referred to as an orthoquartzite) with minor discontinuous beds of pale-red, clast-supported pebble conglomerate and purple argillite; sandstone is white, pale yellowish brown, pale olive, greenish gray, dark gray, and grayish purple; fine to medium grained, moderate to well sorted; low- to high-angle cross-bedding, with medium to thick beds; includes minor interbedded argillite layers and pebble conglomerate lenses; ledge forming; mapped in in the northern part of the quadrangle and near Middle Fork; lower contact with the Papoose Creek Formation is gradational and placed where interbedded argillite beds diminish and quartzite beds dominate (McKean et al., 2018; Anderson et al., 2023); prior mapping in the area included the Papoose Creek Formation within the Caddy Canyon Quartzite and/or Kelly Canyon Formation (Coogan and King, 2016); age-based stratigraphic position relative to radiometric ages from overlying Browns Hole Formation (Sorenson and Crittenden, 1979; Provow et al., 2021) and underlying Perry Canyon Formation (Balgord et al., 2013); estimated thickness 1000 to 1500 feet (300–460 m), variable due to faulting and folding; total thickness is 1000 to 1600 feet (300–500 m) in the adjacent Mantua quadrangle (Crittenden and Sorenson, 1985a); in the Browns Hole quadrangle about 900 to 1000 feet (270–300 m) thick near Middle Fork of Ogden River (Anderson et al., 2023).

Zpk? **Papoose Creek Formation of Brigham Group and Kelley Canyon Formation?** (Neoproterozoic, Ediacaran) – Undivided unit where mapping of the Papoose Creek and Kelly Canyon Formation's contact is uncertain; mapped in the north-central part of the quadrangle; queried because unit designation is uncertain due to poor exposures in structurally complex areas, or areas previously mapped as other units that were not field checked; see units Zpc and Zkc for descriptions and unit thicknesses.

Zpc, Zpc?

Papoose Creek Formation of Brigham Group (Neoproterozoic, Ediacaran) – Rhythmically interbedded very pale orange quartzose sandstone, moderate to dark yellowish-brown mudstone, and moderate to dusky red argillite; sandstone is fine to medium grained with coarse-grained interval in the middle of the unit and in beds near top where unit interfingers with Caddy Canyon Quartzite (Zcc); thin to thick bedded with distinct lenticular and flaser bedding and syneresis cracks; horizontal, ripple, and cross-laminations present; forms colluvium covered slopes; lower contact is conformable, gradational, and mapped at a lithologic change from argillite and minor sandstone below to dominantly sandstone above; queried where unit designation is uncertain due to poor exposures in structurally complex areas, or areas previously mapped as other units that were not field checked; unmapped Papoose Creek Formation may be present in the Caddy Canyon Quartzite and/or Kelly Canyon Formation in this area (Coogan and King, 2016); thickness of approximately 950 feet (290 m) exposed in the northwest part of the map; 750 to 950 feet (225–290 m) thick in the Browns Hole quadrangle (Anderson et al., 2023).

Zkc, Zkc?

Kelley Canyon Formation (Neoproterozoic, Ediacaran) – Gray to olive-gray weathering, slope-forming argillite, slate, and phyllite with minor layers of fine-grained quartzite, limestone, and shaley limestone; alternating yellowish-gray to greenish-gray silt and dark-gray to olive-gray limestone; finely laminated; mapped in the northern part of quadrangle and near Middle Fork; unmapped Papoose Creek Formation may be present in the Caddy Canyon Quartzite and/or Kelly Canyon Formation in this area (Coogan and King, 2016); lower contact at transition from argillite to conglomeratic sandstone of the Maple Canyon Formation; in Browns Hole and near Middle Fork of Ogden River, a limestone marker bed is present near the base (McKean et al., 2018; Anderson et al., 2023) and is interpreted to be correlative with the Marinoan "cap carbonate" found globally in Neoproterozoic rocks overlying "Snowball Earth" glacial deposits, which marks the end of the Cryogenian and start of the Ediacaran Period at 635 Ma (Hoffman et al., 1998; Fairchild and Kennedy, 2007; Allen and Etienne, 2008; Le Heron et al., 2011); Sorenson and Crittenden (1979) report a thickness of 2000 feet (600 m) in the quadrangle, thickness variable due to faulting and folding; Crittenden and Sorenson (1985a) report a thickness of 600 feet (180 m) in the Mantua quadrangle; Coogan and King (2016) report 1000 feet (300 m) in the Mantua quadrangle. approximately 2000 to 2170 feet (610–655 m) thick in the Browns Hole quadrangle (Anderson et al., 2023).

Maple Canyon Formation – Locally divided by Sorensen and Crittenden (1979) with an upper tri-part stratigraphic package (Zmcc, where undivided) of upper conglomeratic sandstone ($Zmcc_1$), medial argillite, siltstone, and sandstone ($Zmcc_2$), and basal conglomeratic sandstone ($Zmcc_3$). Below the tri-part packages, they describe a green arckose member (Zmcg), then a lower argillite member (Zmca). The lowest member (argillite member) of the Maple Canyon Formation was mapped by Coogan and King (2016) as the upper member of the Perry Canyon (Zpu). We follow Coogan and King (2016) and map the argillite member of Sorensen and Crittenden (1979) as the upper member of the Perry Canyon, but follow Sorensen and Cirttenden's (1979) nomenclature with the upper four members of the Maple Canyon Formation.

Zmcc
$Zmcc_3$
$Zmcc_2$
$Zmcc_1$ **Conglomerate member of Maple Canyon Formation** (Neoproterozoic, Cryogenian) – Tri-part stratigraphic package of upper conglomeratic sandstone ($Zmcc_1$), medial argillite, siltstone, and sandstone ($Zmcc_2$), and basal conglomeratic sandstone ($Zmcc_3$); forms a prominent topographic pattern of ridge, swale, and ridge; upper ($Zmcc_1$) and basal ($Zmcc_3$) packages are well-indurated grayish-yellow coarse-grained quartzose sandstones and matrix- to clast-supported pebble conglomerate, medium to thick bedded, horizontal and trough cross-stratified; conglomerate clasts are dominantly white vein quartz and white quartzite with minor light- to dark-red sandstone, greenish-gray sandstone, and red or black chert; medial package ($Zmcc_2$) is grayish-yellow to moderate reddish-orange argillite with grayish-orange siltstone and sandstone that crops out as poorly exposed recessive swales; contacts between each unit are sharp and conformable; lower contact sharp, conformable, commonly poorly exposed; mapped as undivided conglomerate member (Zmcc) in southwest corner of the quadrangle and Middle Fork area, subdivided in north part of the quadrangle into $Zmcc_1$, $Zmcc_2$, $Zmcc_3$; estimated composite thickness in the south of the quadrangle 100 to 500 feet (30–150 m) (Sorensen and Crittenden, 1979) to greater than 1000 feet (300 m) in the north of the quadrangle (Coogan and King, 2016), unit thickness varies due to faulting and folding.

Zmcg **Green arkose member of Maple Canyon Formation** (Neoproterozoic, Cryogenian) – Very pale orange to grayish-brown to very pale green, medium- to coarse-grained, subarkosic to quartzose sandstone; minor pebble conglomerate and light-green mudstone interbeds; sandstone is moderately sorted, contains subrounded to subangular grains of quartz, feldspar, lithic chert, and is medium to thick bedded with horizontal, planar, and trough cross-stratification; generally poorly exposed and forms slopes commonly covered in sandstone blocks; where exposed, lower contact is placed at the change from sandstone to argillite, phyllite and meta-siltstone of the Perry Canyon Formation; Sorensen and Crittenden (1979) reported 500 to 1000 feet (150–300 m) thick, thickness varies due to faulting and folding.

Perry Canyon Formation – Regionally divided into seven informal members by Balgord et al. (2013), from top to bottom: (1) graywacke, (2) diamictite, (3) mafic volcanic and intrusive rocks (greenstone), (4) slate, (5) pebbly slate, (6) quartzite-grit, and (7) arkosic grit. In the following descriptions, the prefix "meta," which signifies their metamorphic grade of greenschist facies, has been omitted for simplicity. The informal members present in the Huntsville quadrangle are, from top to bottom: (1) graywacke and mudstone, (2) diamictite, and (3) upper members. Upper member may include any of the units above the diamictite. Due to the interbedding and poor exposure in the North Ogden quadrangle, the graywacke and mudstone units of Crittenden and Sorenson (1985b) are combined in this report. Euhedral zircon grains from volcaniclastic rocks to the northwest in the Willard quadrangle yielded U-Pb maximum depositional age of 667 ± 5 Ma for the graywacke member (sample 38EAB09 in Balgord et al., 2013), and a maximum depositional age of 703 ± 6 Ma for the diamictite member (sample 36EAB09) (Balgord et al., 2013).

Zp **Perry Canyon Formation, undivided** (Neoproterozoic, Cryogenian) – On cross section only. Graywacke and mudstone, diamictite, and upper members combined. Estimated combined thickness 1000 to 1375 feet (300–420 m).

Zpu **Upper member** (Neoproterozoic, Cryogenian) – Pale- to moderate-blue, thinly bedded argillite to phyllite and meta-siltstone with medial lens of thin- to medium-bedded, pale greenish yellow, arkosic psammite (meta-sandstone); commonly folded and foliated; forms slopes and is generally poorly exposed; prone to slope failures; originally mapped by Crittenden (1972a) and Sorensen and Crittenden (1979) as the lowest member (argillite member) of the Maple Canyon Formation; mapped as upper member of formation of Perry Canyon by Coogan and King (2016) and in this report because of differences in composition from Perry Canyon Formation members on the west side of the quadrangle and the lower members are not exposed on the east and north side of the quadrangle; lower contact not exposed in the quadrangle, typically underlain by the Willard thrust; Balgord et al. (2013) reported a maximum depositional age of <667 ± 5 Ma from U-Pb analyses on detrital zircons from lower one-third of the upper member in Perry Canyon (geographic location), the upper part of which likely correlates to this section in the quadrangle; Crittenden (1972a) and Sorensen and Crittenden (1979) reported a thickness of 500 feet (150 m), which should be considered a minimum due to folding and faulting; structurally thickened map pattern on southwest side of Middle Fork of Ogden River in Browns Hole quadrangle suggests thickness of ~750 feet (230 m) (Anderson et al., 2023).

Zpgm **Graywacke and mudstone** (Neoproterozoic, Cryogenian) – Interlayered olive-gray to medium-gray feldspathic to lithic wacke, dark yellowish- brown to olive-gray argillite, dark gray pebbly slate, schistose slate, and mudstone; moderately to poorly sorted; locally contains isolated lenses of diamictite; graywacke and argillite form normally graded beds interpreted to be turbidites (Balgord et al., 2013); graywacke contains subangular to subrounded grains of quartz, feldspar, and volcanic lithics in a micaceous, altered matrix; pyrite cubes up to 0.5 inch (1 cm) are widespread and typically altered; mudstone and pebbly slate contain subangular to subrounded grains of quartz in the fine-grained matrix; cleavage is best developed in argillite; forms ledges and slopes and is prone to slope failure; lower contact is mapped above the diamictite; may also locally be in contact with the units typically below the diamictite such as the slate, pebbly slate, quartzite-grit, and arkosic grit members of Balgord et al. (2013) found in the nearby areas (McKean et al., 2018); estimated thickness is 800 to 1000 feet (250–300 m) thick, potentially exaggerated by folding and faulting; in the Willard quadrangle the graywacke member thickness is ~650 feet (~200 m) (McKean et al., 2018).

Zpd **Diamictite** (Neoproterozoic, Cryogenian) – Dark gray diamictite with minor interbedded argillite, feldspathic to lithic wacke, and conglomerate; diamictite contains subrounded to subangular pebbles to boulders of granite, gneiss, quartzite, volcanic rocks (including trachyte, rhyolite, and basalt), and sedimentary rocks; matrix is micaceous and sandy (Balgord et al., 2013, see Figures 6 and 11); diamictite is typically unstratified, but locally displays sandy wisps and crude layering defined by clast-rich zones; interpreted as glacio-marine deposits (Balgord et al., 2013); forms rocky ledges and slopes partly covered by unmapped colluvium; prone to slope failure; only mapped in the west-central part of the quadrangle; lower contact not exposed in the quadrangle, lower contact in the North Ogden quadrangle is only visible in a few locations above the Willard thrust fault where it is marked by the greenstone member or directly overlies the Facer Formation in unconformity; where exposed, estimated thickness in the quadrangle is approximately 200 to 400 feet (60–120 m); regional thicknesses are variable with a thickness of approximately 1000 feet (~300 m) in the Willard quadrangle (McKean et al., 2018) and on Fremont Island (Balgord et al., 2013), and only 200 to 400 feet (60–120 m) thick in the Ogden 30′ x 60′ quadrangle (Coogan and King, 2016); interpreted as correlative with diamictite of the Mineral Fork Formation exposed on Antelope Island in the footwall of the Willard thrust fault (Balgord et al., 2013) where it is 0 to 200 feet (0–60 m) thick (Doelling et al., 1990).

Major Unconformity

MESOPROTEROZOIC AND PALEOPROTEROZOIC

Facer Formation – As described by Crittenden and Sorensen (1980), the Facer Formation is a collection of greenschist to amphibolite facies metamorphic units including quartzite, pelitic schist and phyllite, quartz muscovite schist, amphibolite (meta-diorite), gneiss, (meta-) carbonate, (meta-) conglomerate, pegmatite, vein quartz, and minor fuchsite-bearing quartzite and quartz-hematite schist. Only present in the quadrangle as two small fault slices along the Willard thrust in Ogden Canyon. To the north in the Mantua quadrangle, muscovite from a schist yielded a K-Ar age of 1342 ± 10 Ma and a Rb-Sr age of 1660 ± 50 Ma; muscovite from a pegmatite in the upper Facer Formation yielded a K-Ar age of 1357 ± 10 Ma and a Rb-Sr age of 1580 ± 50 Ma (Crittenden and Sorensen, 1980). Hornblende from meta-diorite that intrudes the gneiss in the Mantua quadrangle yielded a K-Ar age of 1681 ± 12 Ma (Crittenden and Sorensen, 1980). The wide age range between the K-Ar muscovite and hornblende ages may be due to a younger metamorphic/alteration event or may indicate that the schist and pegmatite are significantly younger than the meta-diorite and gneiss. To the northwest in the Willard quadrangle, a $^{206}Pb/^{207}Pb$ age from zircons in a quartzite within the gneiss have a minimum age of 1582 ± 10 Ma and a population of Paleoproterozoic grains (~2000 to 2500 Ma) (sample 32EAB09 in Balgord, 2011). A pegmatite sample in the gneiss in the Mantua quadrangle has similar age populations (sample 41EAB09 in Balgord, 2011). Further work is needed to better constrain the age, geologic history, correlation, and characteristics of the various units within the Facer Formation.

YXf **Facer Formation** (Mesoproterozoic to Paleoproterozoic) – Greenish-gray to dark-greenish-gray and maroon phyllite (meta-siltstone to mudstone); only present in the quadrangle as two small fault slices along the Willard thrust in Ogden Canyon; age from Crittenden and Sorensen (1980), Balgord (2011), and McKean et al. (2018); incomplete thickness is approximately 50 feet (15 m).

WILLARD THRUST FOOTWALL

PALEOZOIC

MISSISSIPPIAN

Mh **Humbug Formation** (Late Mississippian) – Interbedded, medium- to dark-gray limestone and light-brown, calcareous, quartz sandstone; both are medium bedded with light-brown weathering; limestone is fine to medium grained, with shell hash, and is locally dolomitic; sandstone is fine to medium grained with moderately sorted and rounded grains, and low angle cross-stratification; weathers to ledges and slopes; mapped in Ogden Canyon; lower contact with the Deseret Limestone is gradational and occurs near the change from limestone (Md) to alternating sandstone and limestone (Mh); regional age from Morris and Lovering (1961); estimated thickness is 1000 feet (300 m) (Sorensen and Crittenden, 1979), thickness varies due to faulting and folding, upper contact not exposed due to Willard thrust.

Md **Deseret Limestone** (Late to Early Mississippian) – Medium- to dark-gray, medium- to very thick bedded limestone and dolomite and basal black shale; nodular to lensoid thin beds of chert that are mostly dark gray to black and brown; fossils include rugose corals, crinoids, brachiopods, bryozoans, and fossil hash; beds of coquina (fossil hash) composed of fragments of shells, crinoid columnals, and corals in laminae and low angle cross-beds; basal Delle Phosphatic Member (not mapped separately) is a poorly exposed, black, phosphatic shale and shaly limestone; slope to ledge former; mapped in Ogden Canyon; the lower contact is placed below the basal Delle Phosphatic Member at the change to fossiliferous limestone of the Gardison Limestone (Mg); regional age from Sandberg and Gutschick (1984); estimated thickness is between 200 to 230 feet (60–70 m) (Sorensen and Crittenden, 1979).

Mg **Gardison Limestone** (Early Mississippian) – Medium-gray to dark-gray limestone, fossiliferous limestone, and locally dolomitic limestone; medium to very thick bedded; fossils include rugose and colonial corals, brachiopods, crinoids, distinctive gastropods, and bryozoans; contains nodular chert in the upper part and minor intraformational (flat-pebble) conglomerate beds; ledge forming; mapped in Ogden Canyon; the lower contact is defined by the sandy dolomite and limestone of the Beirdneau Sandstone; regional age from Morris and Lovering (1961); estimated thickness 300 to 400 feet (90–120 m), thickness varies due to faulting and folding; Sorensen and Crittenden (1979) report a thickness of 300 to 850 feet (90–260 m) in the quadrangle; Yonkee and Lowe (2004) reported 660 feet (200 m) thick in the Ogden quadrangle.

DEVONIAN

Db **Beirdneau Sandstone** (Late Devonian) – Yellow- to red- to light-gray sandy to silty dolomite and limestone, sandstone, shale, siltstone, and flat-pebble conglomerate; dolomite and limestone are thin to medium bedded with well-rounded quartz grains in medium-size beds; the sandstone is orange-gray, thin to medium bedded, fine to medium grained, and moderate to well sorted; shale is red to yellow; siltstone is variably calcareous to dolomitic, with mud cracks and soft sediment deformation features; forms ledges and slopes; mapped in Ogden Canyon; lower contact marked by a transition from sandy dolomite to ledge-forming dolomites of Hyrum Dolomite (Dh); Late Devonian age from Williams (1971); estimated thickness 250 to 300 feet (75–90 m) (Sorensen and Crittenden, 1979), thickness varies due to faulting and folding; Yonkee and Lowe (2004) reported 170 to 330 feet (50–100 m) thick in the Ogden quadrangle.

Dh **Hyrum Dolomite** (Late to Middle Devonian) – Medium- to dark-gray dolomite and minor silty limestone; medium to thick bedded; fine to medium grained; some layers contain light-gray, slightly silty laminations; locally contains calcite-filled vugs and chert nodules; forms ledges; mapped in Ogden Canyon; lower contact with Water Canyon Formation placed at change to sandy dolomite; Late and Middle Devonian age from Williams (1948, 1971); estimated thickness 200 to 250 feet (30–75 m), varies due to faulting and folding; Sorenson and Crittenden (1979) reported a thickness of 350 feet (107 m) in the quadrangle; in the adjacent Ogden quadrangle Yonkee and Lowe (2004) reported a thickness of 130–260 feet (40–80 m).

Dwc **Water Canyon Formation** (Early Devonian) – Light- to yellow-gray, sandy to silty dolomite; thin to medium bedded; slope forming; mapped in Ogden Canyon; lower contact unconformable and mapped at change from massive dolomite to well-layered dolomite of Fish Haven Dolomite (Ofh); Silurian Laketown Dolomite and other Silurian strata are locally missing due to Stansbury uplift (see Rigby, 1959; Morris and Lovering, 1961; Rigby and Clark, 1962; Tooker, 1999); Early Devonian age (Williams, 1948; Taylor, 1963; Williams and Taylor, 1964; Oviatt, 1986); estimated thickness 30 to 100 feet (9–30 m), varies due to faulting and folding; Sorenson and Crittenden (1979) reported a thickness of 90 feet (27 m) in quadrangle; thickness 30 to 100 feet (9–30 m) in Ogden Canyon (Yonkee and Lowe, 2004).

Unconformity (Disconformity related to the Stansbury uplift; see Rigby, 1959; Morris and Lovering, 1961; Rigby and Clark, 1962; Tooker, 1999)

ORDOVICIAN

Ofh **Fish Haven Dolomite** (Late Ordovician) – Medium- to dark-gray dolomite, medium to thick bedded; contains fossil corals, crinoids, and twiggy bodies; forms cliffs; mapped in Ogden Canyon; lower contact is an unconformity with Garden City Formation that is mapped at change from well-bedded lighter dolomite (Ogc) to more massive darker dolomite (Ofh); regionally the Middle Ordovician Swan Peak Quartzite underlies this unit but is missing due to an unconformity related to the Ordovician Tooele arch; Late Ordovician age (Williams, 1948; Gelnett, 1958; Budge, 1972; Budge and Sheehan, 1980); estimated thickness 200 to 250 feet (60–80 m), varies due to faulting and folding; Sorenson and Crittenden (1979) reported a thickness of 200 to 225 feet (60–69 m) in the quadrangle; 130–260 feet thick (40–80 m) in Ogden quadrangle (Yonkee and Lowe, 2004).

Unconformity (Disconformity related to the Tooele arch; see Hintze, 1959; Morris and Lovering, 1961, and references therein; Ethington et al., 2016)

Ogc **Garden City Formation** (Early Ordovician) – Tan to light-gray, silty dolomite, dolomite, silty limestone and siltstone, thin to thick bedded; contains fossils of crinoids, brachiopods, and gastropods; forms slopes and ledges; mapped in Ogden Canyon; lower contact with St. Charles Formation (O€s) is gradational and is placed above the massive dolomite; Early Ordovician age (Ross, 1951; Taylor et al., 1981; Oviatt, 1986); estimated thickness 200 to 400 feet (60–120 m), varies due to faulting and folding; Sorenson and Crittenden (1979) reported a thickness of 200 to 250 feet (60–75 m) thick in quadrangle; in the Ogden quadrangle Yonkee and Lowe (2004) report a thickness of 200 to 400 feet (60–120 m).

ORDOVICIAN-CAMBRIAN

O€sd **Dolomite member of St. Charles Formation** (Early Ordovician to Late Cambrian) – Light- to dark-gray dolomite; thick bedded; brachiopod fossils near base (lower 50 feet [15 m], Crittenden and Sorensen, 1985b); forms cliffs; mapped in Ogden Canyon; lower contact conformable with calcareous sandstone of the Worm Creek Quartzite Member; regional age earliest Ordovician and Late Cambrian (Taylor et al., 1981); estimated thickness 200 to 600 feet (60–185 m), varies due to faulting and folding; Sorenson and Crittenden (1979) reported a thickness of 500 to 725 feet thick (150–245 m) in the quadrangle (Sorenson and Crittenden, 1979); in the Ogden quadrangle Yonkee and Lowe (2004) report a thickness of 500 to 720 feet (150–220 m).

CAMBRIAN

€sw **Worm Creek Quartzite Member of St. Charles Formation** (Late Cambrian) – Light-gray to light-brown calcareous sandstone and sandy dolomite; well sorted, thin bedded; well-rounded sand grains; mapped in Ogden Canyon; lower contact is conformable and placed at mottled dolomite of the Nounan Formation; Late Cambrian age (Oviatt, 1986); estimated thickness 20 to 30 feet (6–10 m); Sorenson and Crittenden (1979) reported a thickness of 20 feet thick (6 m) in the quadrangle.

Ꞓn, Ꞓn?

Nounan Formation (Late Cambrian) – Light- to dark-gray dolomite and minor silty dolomite, mottled with shale; locally includes twiggy bodies; forms cliffs; mapped in Ogden Canyon; lower contact with Bloomington Formation is conformable and mapped at appearance of shaley limestone; queried where unit designation uncertain (from Sorenson and Crittenden, 1979); Late Cambrian age (Williams, 1948; Maxey, 1958; Oviatt, 1986); estimated thickness 500 to 750 feet (150–230 m), varies due to faulting and folding; Sorenson and Crittenden (1979) reported a thickness of 500 to 800 feet (150–245 m) in the quadrangle; in the Ogden quadrangle the thickness is 500 to 720 feet (150–220 m) (Yonkee and Lowe, 2004).

Ꞓboc **Calls Fort Shale Member of Bloomington Formation** (Middle Cambrian) – Olive-green to light-brown shaley limestone, shale, ribbon limestone with abundant orange-weathering silty ribbons, oncolitic limestone, oolitic limestone, and flat-pebble conglomerate; forms slopes and ledges; lower contact with Maxfield is conformable and marked at transition from shale to limestone; Rigo (1968) reported *Eldoradia* sp. trilobite fossil, indicating a late Middle Cambrian age; estimated thickness 80 to 200 feet (25–60 m), varies due to faulting and folding; Sorenson and Crittenden (1979) reported a thickness of 75 to 300 feet (23–90 m) thick in quadrangle; in the Ogden quadrangle thickness is 100 to 200 feet (30–60 m) (Yonkee and Lowe, 2004).

Ꞓm **Maxfield Limestone** (Middle Cambrian) – Argillaceous limestone and dolomite with interlayered shale, ribbon limestone, oncolitic limestone, and oolitic limestone; forms slopes and ledges; Yonkee and Lowe (2004) mapped three informal members in the Ogden quadrangle, which maybe identifiable here but not mappable; descriptions for each member are: (1) upper limestone and dolomite member is light- to dark-gray dolomite, oolitic dolomite, and minor limestone; medium to thick bedded; twiggy bodies (that could represent burrows), cliff former; gray boundstone near the top; lower part, light- to medium-gray oolitic limestone, limestone with yellow weathering silty ribbons, and minor dolomite, dark gray cherty dolomite; forms ledges; (2) middle argillaceous limestone member is brown to orange-gray, interlayered argillaceous limestone, shale, ribbon limestone, oncolitic limestone, oolitic limestone and flat pebble conglomerate; forms slopes to ledges; (3) lower limestone member is light- to medium-gray, ribbon limestone with abundant orange-weathering silty ribbons and minor oolitic limestone; thin to medium bedded; thin argillaceous limestone near middle of member separates upper and lower ledges; lower contact with the Ophir Shale is not present in the quadrangle; Middle Cambrian age from Morris and Lovering (1961), Hintze (1962), and *Ehmaniella* sp. and *Glossopleura* sp. trilobites in Ogden Canyon (Rigo, 1968); incomplete estimated thickness of 350 feet (100 m), varies due to folding and faulting; Sorenson and Crittenden (1979) reported a thickness of 950 feet (290 m) thick in the quadrangle; 600 to 100 feet (180–300 m) thick in the Ogden quadrangle.

Ꞓo **Ophir Formation** (Middle Cambrian) – On cross section only. Upper and lower olive-green shale with a middle light-medium-gray limestone; age from Morris and Lovering (1961), Hintze (1962), and Middle Cambrian *Ehmaniella* sp. and *Glossopleura* sp. trilobites in Ogden Canyon (Rigo, 1968); estimated thickness from the North Ogden quadrangle is 100 to 700 feet (30–200 m) (McKean et al., in review), in the Ogden quadrangle thickness is 300 to 700 feet (90–200 m) (Yonkee and Lowe, 2004).

Ꞓt **Tintic Quartzite** (Middle to Lower Cambrian?) – On cross section only. White- to light-pink on fresh surfaces, weathers dark-yellowish-orange, quartzose to subarkosic, well-cemented sandstone (commonly referred to as an orthoquartzite) that is fine to medium grained, thick bedded, moderately sorted, with common cross-beds; small beds of conglomerate composed of subrounded to angular quartz-pebble clasts are common; basal part of the formation contains green to purple to light brown arkosic sandstone, quartz-pebble conglomerate, and micaceous siltstone; trace fossils in the upper part of the formation in the Ogden Canyon area include *Skolithus* tubes and *Plagiogmus* traces that indicate Middle Cambrian age (Peterson and Clark, 1974); estimated thickness in the North Ogden quadrangle is 1100 to 1500 feet (335–450 m) (McKean et al., in review); in the Ogden quadrangle the thickness is 1300 to 1500 feet (400–450 m) (Yonkee and Lowe, 2004).

Major Unconformity

PALEOPROTEROZOIC

Xfc? **Farmington Canyon Complex?** (Paleoproterozoic) – On cross section only. Undivided pegmatite, plagioclase hornblende amphibolite, and granitic gneiss; age is Paleoproterozoic based on geochronologic data from nearby areas, Barnett et al. (1993) reported $^{207}Pb/^{206}Pb$ monazite metamorphic ages from gneisses that ranged from 1640 to 1720 Ma. Nelson et al. (2002, 2011) reported a mean monzonite microprobe age of 1705 ± 90 Ma from a gneiss; Mueller et al. (2011) reported a $^{207}Pb/^{206}Pb$ age of 2450 Ma for zircon in gneiss in the Bountiful Peak quadrangle and an aggregate mean U-Pb age of 1674 ± 12 Ma for metamorphic zircon overgrowths; Yonkee et al. (2024) reported igneous zircon $^{207}Pb/^{206}Pb$ ages of 2450 and 2460 Ma for granitic gneiss bodies on Antelope Island and in the Ogden 7.5-minute quadrangle, respectively; an igneous zircon $^{207}Pb/^{206}Pb$ age of 1660 Ma for a late stage pegmatitic granite body on Antelope Island, a wide range of detrital (inherited) zircon grain $^{207}Pb/^{206}Pb$ ages ranging from Archean to ca. 2000 Ma for quartz-rich and layered gneiss samples on Antelope Island, and $^{207}Pb/^{206}Pb$ age ages spanning ca, 1600 to 1800 Ma for metamorphic zircon rims in gneiss samples from Antelope Island; thickness is unknown.

ACKNOWLEDGMENTS

This geologic map was funded by the Utah Geological Survey and the U.S. Geological Survey (USGS), National Cooperative Geologic Mapping Program through USGS STATEMAP award number G23AC00466 (2023–2025). Discussions with many individuals helped in the development of this map including Lucy Jordan (UGS retired), Christian Hardwick and Greg Gavin (UGS) and Rich Emerson with Cascade Water Resources. Thank you to the many private landowners who allowed us to access their property for our geologic mapping. UGS staff members Lauren Reeher, Stefan Kirby, Stephanie Carney, and Darlene Batatian also improved this map through their reviews.

REFERENCES

Allen, P.A., and Etienne, J.L, 2008, Sedimentary challenge to Snowball Earth: Nature Geoscience, v. 1, p. 817–825.

Anderson, Z.W., McDonald, G.N., Balgord, E.A., and Yonkee, W.A., 2023, Interim geologic map of the Browns Hole quadrangle, Weber and Cache Counties, Utah: Utah Geological Survey Open-File Report 760, 13 p., 2 plates, https://doi.org/10.34191/OFR-760.

Ashland, F.X., 2003, Characteristics, causes, and implications of the 1998 Wasatch Front landslides, Utah: Utah Geological Survey Special Study 105, 49 p., https://doi.org/10.34191/SS-105.

Balgord, E.A, 2011, Stratigraphic, geochronologic and geochemical analysis of the Neoproterozoic Perry Canyon Formation, northern Utah—implications for Rodinian rifting and snowball Earth: Pocatello, Idaho State University, M.S. thesis, 137 p.

Balgord, E.A., Yonkee, W.A., Link, P.K., and Fanning, C.M., 2013, Stratigraphic, geochronologic, and geochemical record of the Cryogenian Perry Canyon Formation, northern Utah—implications for Rodinian rifting and Snowball Earth glaciation: Geological Society of America Bulletin, v. 125, p. 1442–1467.

Barnett, D., Bowman, J.R., and Smith, H.A., 1993, Petrologic and geochronologic studies in the Farmington Canyon Complex, Wasatch Mountains and Antelope Island, Utah: Utah Geological Survey Contract Report 93-5, 35 p., https://doi.org/10.34191/CR-93-5.

Blau, J.G., 1975, Geology of southern part of the James Peak quadrangle, Utah: Logan, Utah State University, M.S. thesis, 55 p., scale 1:12,000.

Bronk Ramsey, C., 2009, Bayesian analysis of radiocarbon dates: Radiocarbon, v. 51, no. 1, p. 337–360.

Budge, D.R., 1972, Paleontology and stratigraphic significance of Late Ordovician and Silurian corals from the eastern Great Basin: Berkeley, University of California, Ph.D. dissertation, 572 p., 22 plates.

Budge, D.R., and Sheehan, P.M., 1980, The Upper Ordovician through Middle Silurian of the eastern Great Basin, Part 1, Introduction—Historical perspective and stratigraphic synthesis: Milwaukee Public Museum Contributions in Biology and Geology 28, 26 p.

Carley, J., Campbell, L., Jensen, E., and Fish, R., 1973, A soil survey and soil interpretations of Ogden Valley, Weber County portion of the Morgan Soil Survey Area, Morgan and Weber Counties, Utah: U.S. Department of Agriculture, Soil Conservation Service and Forest Service, in cooperation with Utah Agricultural Experiment Station, Research Report 14, 115 p.

Castleton, J.J., and McKean, A.P., 2012, The Utah Geological Survey geologic hazards mapping initiative, *in* Hylland, M.D., and Harty, K.M., editors, Selected topics in engineering and environmental geology in Utah: Utah Geological Association Publication 41, p. 51–67.

Christenson, G.E., and Ashland, F.X., 2007, A plan to reduce losses from geologic hazards in Utah—recommendations of the Governor's Geologic Hazards Working Group 2006–2007: Utah Geological Survey Circular 104, 30 p., https://doi.org/10.34191/C-104.

Coody, G.L., 1957, Geology of the Durst Mountain-Huntsville area, Morgan and Weber Counties, Utah: Salt Lake City, University of Utah, M.S. thesis, 60 p.

Coogan, 1999, Preliminary geologic maps of the Sharp Mountain and James Peak quadrangles, Utah: Utah Geological Survey unpublished maps, scale 1:24,000.

Coogan, J.C., and King, J.K., 2006, Interim geologic map of the Durst Mountain quadrangle, Morgan and Weber Counties, Utah: Utah Geological Survey Open-File Report 498, scale 1:24,000, 29 p., https://doi.org/10.34191/OFR-498.

Coogan, J.C., and King, J.K., 2016, Interim geologic map of the Ogden 30- x 60-minute quadrangle, Box Elder, Cache, Davis, Morgan, Rich, and Summit Counties, Utah, and Uinta County, Wyoming: Utah Geological Survey Open-File Report 653DM, 1:62,500 scale, 3 plates, 147 p., https://doi.org/10.34191/OFR-653DM.

Cornwall, B., Mayfield, E., Balgord, E., Yonke, A., Perez Consuegra, N., Wilfong, C., Anderson, Z., McKean, A., and McDonald, G., 2025, Revised age and geologic significance of the Norwood Tuff, Morgan Valley, northern Utah [abs.]: Geological Society of America, Rocky Mountain Section, 75th Annual Meeting May 18-20, 2025, https://www.geosociety.org/GSA/GSA/Events/Abstracts.aspx.

Cothren, H.R., Farrell, T.P., Sundberg, F.A., Dehler, C.M., and Schmitz, M.D., 2022, Novel age constraints for the onset of the Steptoean Positive Isotopic Carbon Excursion (SPICE) and the late Cambrian time scale using high-precision U-Pb detrital zircon ages: Geology, v. 50, p. 1415–1420, https://doi.org/10.1130/G50434.1.

Crittenden, M.D, 1972a, Geologic map of the Browns Hole quadrangle, Utah: U.S. Geological Survey GQ-968, 1 plate, scale 1:24,000.

Crittenden, M.D., Jr., 1972b, Willard thrust and Cache allochthon, Utah: Geological Society of America Bulletin, v. 83, p. 2871–2880.

Crittenden, M.D., Jr., Schaeffer, F.E., Trimble, D.E., and Woodward, L.A., 1971, Nomenclature and correlation of some upper Precambrian and basal Cambrian sequences in western Utah and southeastern Idaho: Geological Society of America Bulletin, v. 82, no. 3, p. 581–602.

Crittenden, M.D., Jr., and Sorensen, M.L., 1980, The Facer Formation, a new early Proterozoic unit in northern Utah: U.S. Geological Survey Bulletin 1482-F, 28 p.

Crittenden, M.D., Jr., and Sorensen, M.L., 1985a, Geologic map of the Mantua quadrangle and part of the Willard quadrangle, Box Elder, Weber, and Cache Counties, Utah: U.S. Geological Survey Miscellaneous Investigations Series Map I-1605, 1 plate, scale 1:24,000.

Crittenden, M.D., Jr., and Sorensen, M.L., 1985b, Geologic map of the North Ogden quadrangle and part of the Ogden and Plain City quadrangles, Box Elder and Weber Counties, Utah: U.S. Geological Survey Miscellaneous Investigations Series Map I-1606, 1 plate, scale 1:24,000.

Crittenden, M.D., Jr., and Wallace, C.A., 1973, Possible equivalents of the Belt Supergroup in Utah, *in* Bishop, D.T., and Powell, J.D., editors Belt Symposium: Moscow, Idaho, University of Idaho-Moscow, v. 1, p. 116–138.

DeCelles, P.G., 2004, Late Jurassic to Eocene evolution of the Cordilleran thrust belt and foreland basin system, western U.S.A.: American Journal of Science, v. 304, p. 105–168.

Doelling, H.H., Willis, G.C., Jensen, M.E., Hecker, S., Case, W.F., and Hand, J.S., 1990, Geologic map of Antelope Island, Davis County, Utah: Utah Geological and Mineral Survey Map 127, 27 p., 2 plates, scale 1:24,000, https://doi.org/10.34191/M-127.

Doelling, H.H., and Willis, G.C., 1995, Guide to authors of geologic maps and text booklets of the Utah Geological Survey: Utah Geological Survey Circular 89, 98 p., https://doi.org/10.34191/C-89.

Doyuran, V., 1972, Geology and ground-water resources of Ogden Valley, Utah: Salt Lake City, University of Utah, Ph.D. dissertation, 134 p., 4 plates, various scales.

Eardley, A.J., 1944, Geology of the north-central Wasatch Mountains, Utah: Geological Society of America Bulletin, v. 55, p. 819–894, 1 plate, scale 1:125,000.

Eardley, A.J., 1955, Tertiary history of north-central Utah, *in* Eardley, A.J., editor, Tertiary and Quaternary geology of the eastern Bonneville Basin: Guidebook to the geology of Utah, no. 10, p. 37–44.

Eriksson, Y., 1960, Geology of the upper Ogden Canyon, Weber County, Utah: Salt Lake City, University of Utah, M.S. thesis, 55 p., 6 plates [map, diagrams, and photographs], scale 1:24,000.

Ethington, R.L., Ritter, S.M., Clark, D.L., and Kowallis, B.J., 2016, Conodont biostratigraphy of the Ordovician Opohonga Limestone in west-central Utah: Palaios, v. 31, p. 221–230.

Evans, J.P., and Neves, D.S., 1992, Footwall deformation along Willard thrust, Sevier orogenic belt—implications for mechanisms, timing, and kinematics: Geological Society of America Bulletin, v. 104, p. 516–527.

Fairchild, I.J., and Kennedy, M.J., 2007, Neoproterozoic glaciation in the Earth System: Journal of the Geological Society, v. 164, p. 895–921, https://doi.org/10.1144/0016-76492006-191.

Gelnett, R.H., 1958, Geology of the southern part of Wellsville Mountain, Wasatch Range, Utah: Logan, Utah State University, M.S. thesis, 73 p., scale 1:24,000.

Godsey, H.S., Currey, D.R., and Chan, M.A., 2005, New evidence for an extended occupation of the Provo shoreline and implications for regional climate change, Pleistocene Lake Bonneville, Utah, USA: Quaternary Research, v. 63, p. 212–223.

Godsey, H.S., Oviatt, C.G., Miller, D.M., and Chan, M.A., 2011, Stratigraphy and chronology of offshore to nearshore deposits associated with the Provo shoreline, Pleistocene Lake Bonneville, Utah: Palaeogeography, Palaeoclimatology, Palaeoecology, v. 310, issues 3–4, p. 442–450.

Gosse, J.C., Klein, J., Evenson, E.B., Lawn, B., and Middleton, R., 1995, Beryllium-10 dating of the duration and retreat of the last Pinedale glacial sequence: Science, v. 268, p. 1329–1333.

Gosse, J.C., and Phillips, F.M., 2001, Terrestrial in situ cosmogenic nuclides—theory and application: Quaternary Science Reviews, v. 20, issue 14, p. 1475–1560.

Hintze, L.F., 1959, Ordovician regional relationships in north-central Utah and adjacent areas, *in* Williams, N.C., editor, Guidebook to the geology of the Wasatch and Uinta Mountains transition area: Intermountain Association of Petroleum Geologists, Tenth Annual Field Conference, p. 46–53.

Hintze, L.F., 1962, Precambrian and lower Paleozoic rocks of North-Central Utah, *in* Hintze, L.F., editor, Geology of the southern Wasatch Mountains and vicinity, Utah—a symposium: Brigham Young University Geology Studies, v. 9, pt. 1, p. 8–16, scale 1:125,000.

Hoffman, P.F., Kaufman, A.J., Halverson, G.P., and Schrag, D.P., 1998, A Neoproterozoic Snowball Earth: Science, v. 281, p. 1342–1346, https://doi.org/10.1126/science.281.5381.1342.

Inkenbrandt, P.C., Kirby, S.M., and Dame, B., 2016, Hydrogeology of the Powder Mountain area, Weber and Cache Counties, Utah: Utah Geological Survey Special Study 156, p. 37, 3 appendices, https://doi.org/10.34191/SS-156.

Jensen, M.E., and King, J.K., 1999, Geologic map of the Brigham City 7.5-minute quadrangle, Box Elder and Cache Counties, Utah: Utah Geological Survey Map 173, 46 p., 2 plates, scale 1:24,000, https://doi.org/10.34191/M-173.

Jordan, J.L., Smith, S.D., Inkenbrandt, P.C., Lowe, M., Hardwick, C.J., Wallace, J., Kirby, S.M., King, J.K., and Payne, E.E., 2019, Characterization of the groundwater system in Ogden Valley, Weber County, Utah, with emphasis on groundwater-surface-water interaction and the groundwater budget: Utah Geological Survey Special Study 165, 222 p., 3 plates, 5 appendices, https://doi.org/10.34191/SS-165.

King, J.K., Yonkee, W.A., and Coogan, J.C., 2008, Interim geologic map of the Snow Basin quadrangle and part of the Huntsville quadrangle, Davis, Morgan, and Weber Counties, Utah: Utah Geological Survey Open-File Report 536, 1 plate, 30 p., https://doi.org/10.34191/OFR-536.

Laabs, B.J.C., Marchetti, D.W., Munroe, J.S., Refsnider, K.A., Gosse, J.C., Lips, E.W., Becker, R.A., Mickelson, D.M., and Singer, B.S., 2011, Chronology of latest Pleistocene mountain glaciation in the western Wasatch Mountains, Utah, U.S.A.: Quaternary Research, v. 76, p. 272–284.

Laabs, B.J.C., and Munroe, J.S., 2016, Late Pleistocene mountain glaciation in the Lake Bonneville Basin, *in* Oviatt, C.G., and Schroeder, J., editors, Lake Bonneville—a scientific update: Amsterdam, Netherlands, Elsevier, Developments in Earth Surface Processes, v. 20, chapter 17, p. 462–503.

Laraway, W.H., 1958, Geology of the South Fork of the Ogden River area, Weber County, Utah: Salt Lake City, University of Utah, M.S. thesis, 66 p., scale ~1:20,000.

Le Heron, P.D., Cox, G., Trundley, A., and Collins, A.S., 2011, Two Cryogenian glacial successions compared—aspects of the Sturt and Elatina sediment records of South Australia: Precambrian Research, v. 186, p. 147–168, https://doi.org/10.1016/j.precamres.2011.01.014.

Lisiecki, L.E., and Raymo, M.E., 2005, A Pliocene–Pleistocene stack of 57 globally distributed benthic $\delta^{18}O$ records: Paleoceanography, v. 20, PA1003, 17 p., https://doi.org/10.1029/2004PA001071 [summary of data available online, http://lorraine-lisiecki.com/stack.html, accessed May 28, 2019].

Lofgren, B.H., 1955, Resume of the Tertiary and Quaternary stratigraphy of Ogden Valley, Utah, *in* Eardley, A.J., editor, Tertiary and Quaternary geology of the eastern Bonneville Basin: Guidebook to the geology of Utah, no. 10, p. 70–84.

Lochman-Balk, C., 1976, The Cambrian section of the central Wasatch Mountains, *in* Hill, J.G. editor, Symposium on geology of the Cordilleran Hingeline: Rocky Mountain Association of Geologists, p. 103–108.

Maxey, G.B., 1958, Lower and Middle Cambrian stratigraphy in northern Utah and southeastern Idaho: Geological Society of America Bulletin, v. 69, p. 647–688.

Mayfield, E., Cornwall, B., Balgord, E., Yonke, A., Perez Consuegra, N., Wilfong, C., Anderson, Z., McKean, A., and McDonald, G., 2025, Revisiting the Norwood tuff—unveiling Yellowstone Hotspot ashes in Ogden Valley, northern Utah: Geological Society of America, Rocky Mountain Section 75th Annual Meeting May 18–20, 2025, https://www.geosociety.org/GSA/GSA/Events/Abstracts.aspx.

McDonald, G.N., 2020, Interim geologic map of surficial deposits in the Huntsville quadrangle, Weber and Cache Counties: Utah Geological Survey contract deliverable to the U.S. Geological Survey, 19 p., 1 plate, scale 1:24,000.

McGee, D., Quade, J., Edwards, R.L., Broecker, W.S., Cheng, H., Reiners, P.W., and Evenson, P., 2012, Lacustrine cave carbonates—novel archives of paleohydrologic change in the Bonneville Basin (Utah, USA): Earth and Planetary Science Letters, v. 351–352, p. 182–194.

McKean, A.P., Balgord, E.A., Yonkee, W.A., and Hiscock, A.I., 2018, Geologic map of the Willard quadrangle, Box Elder County, Utah: Utah Geological Survey Map 278DM, GIS data, 18 p., 2 plates, scale 1:24,000, https://doi.org/10.34191/M-278DM.

McKean, A.P., Kleber, E.J., McDonald, G.N., Balgord, E.A., and Yonkee, W.A., in review, Interim geologic map of the North Ogden quadrangle, Weber and Box Elder Counties, Utah: Utah Geological Survey, 2 plates, scale 1:24,000.

Miller, D.M., 2016, The Provo shoreline of Lake Bonneville, *in* Oviatt, C.G., and Shroder, J.F., Jr., editors, Lake Bonneville—a scientific update: Amsterdam, Netherlands, Elsevier, Developments in Earth Surface Processes, v. 20, chapter 7, p. 127–144.

Morris, H.T., and Lovering, T.S., 1961, Stratigraphy of the East Tintic Mountains, Utah: U.S. Geological Survey Professional Paper 361, 145 p., 5 plates.

Mueller, P.A., Wooden, J.L., Mogk, D.W., and Foster, D.A., 2011, Paleoproterozoic evolution of the Farmington zone—implications for terrane accretion in southwestern Laurentia: Lithosphere, v. 3, p. 401–408, data repository item 2011350 available online, http://www.geosociety.org/pubs/ft2011.htm.

Nelson, A.R., and Personius, S.F., 1993, Surficial geologic map of the Weber segment, Wasatch fault zone, Weber and Davis Counties, Utah: U.S. Geological Survey Miscellaneous Investigations Series Map I-2199, 1 plate, scale 1:50,000, 22 p.

Nelson, M.E., 1971, Stratigraphy and Paleontology of Norwood Tuff and Fowkes Formation, northeastern Utah and southwestern Wyoming: Salt Lake City, University of Utah, Ph.D. dissertation, 168 p.

Nelson, S.T., Harris, R.A., Dorais, M.J., Heizler, M., Constenius, K.N., and Barnett, D., 2002, Basement complexes in the Wasatch fault, Utah, provide new limits on crustal accretion: Geology, v. 30, no. 9, p. 831–834, https://doi.org/10.1130/0091-7613(2002)030<0831:BCITWF>2.0.CO;2.

Nelson, S.T., Hart, G.L., and Frost, C.D., 2011, A reassessment of Mojavia and a new Cheyenne Belt alignment in the eastern Great Basin: Geosphere, v. 7, no. 2, p. 513–527, https://doi.org/10.1130/GES00595.1.

Oviatt, C.G., 1986, Geologic map of the Honeyville quadrangle, Box Elder and Cache Counties, Utah: Utah Geological and Mineral Survey Map 88, 2 plates, scale 1:24,000, 13 p., https://doi.org/10.34191/M-88.

Oviatt, C.G., 2015, Chronology of Lake Bonneville, 30,000 to 10,000 yr B.P.: Quaternary Science Reviews, v. 110, p. 166–171, appendix A supplementary data available online, http://dx.doi.org/10.1016/j.quascirev.2014.12.016.

Oviatt, C.G., Currey, D.R., and Miller, D.M., 1990, Age and paleoclimatic significance of the Stansbury shoreline of Lake Bonneville, northeastern Great Basin: Quaternary Research, v. 33, p. 291–305.

Oviatt, C.G., Thompson, R.S., Kaufman, D.S., Bright, J., and Forester, R.M., 1999, Reinterpretation of the Burmester Core, Bonneville basin, Utah: Quaternary Research, v. 52, p. 180–184.

Pavlis, T.L., 1979, Stress history during growth of a noncylindrical fold [Ogden Canyon, Utah]: Salt Lake City, University of Utah, M.S. thesis, 2 plates, scale 1:10,000.

Peterson, D.O., and Clark, D.L., 1974, Trace fossils *Plagiogmus* and *Skolithos* in the Tintic Quartzite (Middle Cambrian) of Utah: Journal of Paleontology, v. 48, no. 4, p. 766–768.

Phillips, F.M., Zreda, M.G., Gosse, J.C., Klein, J., Evenson, E.B., Hall, R.D., Chadwick, O.A., and Sharma, P., 1997, Cosmogenic ^{36}Cl and ^{10}Be ages of Quaternary glacial and fluvial deposits of the Wind River Range, Wyoming: Geological Society of America Bulletin, v. 109, no. 11, p. 1453–1463.

Pierce, K.L., Licciardi, J.M., Good, J.M., and Jaworowski, C., 2018, Pleistocene glaciation of the Jackson Hole area, Wyoming: U.S. Geological Survey Professional Paper 1835, 55 p.

Provow, A.W., Newell, D.L., Dehler, C.M., Ault, A.K., Yonkee, W.A., Thomson, S.N., and Mahan, K.H., 2021, Revised maximum depositional age for the Ediacaran Browns Hole Formation—implications for western Laurentia Neoproterozoic stratigraphy: Lithosphere, v. 2021, no. 1, p. 1–14, https://doi.org/10.2113/2021/1757114.

Quirk, B.J., Moore, J.R., Laabs, B.J.C., Caffee, M.W., and Plummer, M.A., 2018, Termination II, Last Glacial Maximum and late glacial chronologies and paleoclimate from Big Cottonwood Canyon, Wasatch Mountains, Utah: Geological Society of America Bulletin, v. 130, no. 11/12, p., 1889–1902.

Quirk, B.J., Moore, J.R., Laabs, B.J.C., Plummer, M.A., and Caffee, M.W., 2020, Latest Pleistocene glacial and climate history of the Wasatch Range, Utah: Quaternary Science Reviews, v. 238, p. 1–17, https://doi.org/10.1016/j.quascirev.2020.106313.

Rauzi, S.L., 1979, Structural geology of eastern part of James Peak quadrangle and western part of Sharp Mountain quadrangle, Utah: Salt Lake City, Utah State University M.S. thesis, 73 p., scale 1:12,000.

Reimer, P., Austin, W., Bard, E., Bayliss, A., Blackwell, P., Bronk Ramsey, C., Butzin, M., Cheng, H., Edwards, R., Friedrich, M., Grootes, P., Guilderson, T., Hajdas, I., Heaton, T., Hogg, A., Hughen, K., Kromer, B., Manning, S., Muscheler, R., Palmer, J., Pearson, C., van der Plicht, J., Reimer, R., Richards, D., Scott, E., Southon, J., Turney, C., Wacker, L., Adolphi, F., Büntgen, U., Capano, M., Fahrni, S., Fogtmann-Schulz, A., Friedrich, R., Köhler, P., Kudsk, S., Miyake, F., Olsen, J., Reinig, F., Sakamoto, M., Sookdeo, A., and Talamo, S., 2020, The IntCal20 Northern Hemisphere radiocarbon age calibration curve (0–55 cal kBP): Radiocarbon, v. 62, no. 4, p. 725–757, https://doi.org/10.1017/RDC.2020.41.

Rigby, J.K., 1959, Upper Devonian unconformity in central Utah: Geological Society of America Bulletin, v. 70, no. 2, p. 207–218.

Rigby, J.K., and Clark, D.L., 1962, Devonian and Mississippian systems in central Utah: Brigham Young University Geology Studies, v. 9, pt. 1, p. 17–25.

Rigo, R.J., 1968, Middle and Upper Cambrian stratigraphy in the autochthon and allochthon of northern Utah: Brigham Young University Geology Studies, v. 15, part 1, p. 31–66.

Ross, R.J., Jr., 1951, Stratigraphy of the Garden City Formation in northeastern Utah and its trilobite faunas: New Haven, Connecticut, Yale University, Peabody Museum Bulletin 6, 161 p.

Sandberg, C.A., and Gutschick, R.C., 1984, Distribution, microfauna, and source-rock potential of Mississippian Delle Phosphatic Member of Woodman Formation and equivalents, Utah and adjacent states, *in* Woodward, J., Meissner, F.F., and Clayton, J.L., editors, Hydrocarbon source rocks of the greater Rocky Mountain region: Rocky Mountain Association of Geologists Field Conference Guidebook, p. 135–178.

Scott, W.E., McCoy, W.D., Shroba, R.R., and Rubin, M., 1983, Reinterpretation of the exposed record of the last two cycles of Lake Bonneville, western United States: Quaternary Research, v. 20, p. 261–285.

Sharp, W.D., Ludwig, K.R., Chadwick, O.A., Amundson, R., and Glaser, L.L., 2003, Dating fluvial terraces by ^{230}Th/U on pedogenic carbonate, Wind River Basin, Wyoming: Quaternary Research, v. 59, p. 139–150.

Sorensen, M.L., and Crittenden, M.D., Jr., 1972, Preliminary geologic map of the Wasatch Range near North Ogden [North Ogden quadrangle and part of Huntsville quadrangle], Utah: U.S. Geological Survey Miscellaneous Field Studies Map MF-428, scale 1:24,000.

Sorensen, M.L., and Crittenden, M.D., Jr., 1974, Preliminary geologic map of the Huntsville quadrangle, Weber and Cache Counties, Utah: U.S. Geological Survey Miscellaneous Field Studies Map MF-592, scale 1:24,000.

Sorensen, M.L., and Crittenden, M.D., Jr., 1979, Geologic map of the Huntsville quadrangle, Weber and Cache Counties, Utah: U.S. Geological Survey Geologic Quadrangle Series Map GQ-1503, scale 1:24,000.

Sullivan, J.T., Nelson, A.R., LaForge, R.C., Wood, C.K., and Hansen, R.A., 1988, Central Utah regional seismotectonic study for USBR dams in the Wasatch Mountains: Denver, U.S. Bureau of Reclamation Seismotectonic Report 88-5, 269 p., scale 1:250,000.

Taylor, M.E., 1963, The Lower Devonian Water Canyon Formation of northeastern Utah: Logan, Utah State University, M.S. thesis, 63 p.

Taylor, M.E., Landing, E., and Gillett, S.L., 1981, The Cambrian-Ordovician transition in the Bear River Range, Utah-Idaho—A preliminary evaluation, *in* Taylor, M.E., editor, Short papers for the second international symposium on the Cambrian System: U.S. Geological Survey Open-File Report 81-743, p. 222–227.

Tooker, E.W., 1999, Geology of the Oquirrh Mountains, Utah: U.S. Geological Survey Open-File Report 99-571, 150 p., scale 1:50,000.

U.S. Department of Agriculture (USDA) Agricultural Commodity Stabilization Service, 1946, Aerial photography, Project AAJ, black and white, approximate scale 1:20,000.

U.S. Department of Agriculture (USDA) Agricultural Commodity Stabilization Service, 1958, Aerial photography, Project AAJ, black and white, approximate scale 1: 20,000.

U.S. Department of Agriculture (USDA) U.S. Forest Service, 1963, Aerial Photography, Project ELK, black and white, approximate scale 1;15,840.

U.S. Department of Agriculture (USDA) U.S. Forest Service, 1980, Aerial Photography, Project 614190 Wasatch-Cache National Forest, Utah, color, scale 1;12,000.

Utah Division of Water Rights (UDWR), 2022, Utah Division of Water Rights water well database: https://www.waterrights.utah.gov/wellInfo/wellInfo.asp, accessed August 2022.

Utah Geospatial Resource Center (UGRC), State Geographic Information Database, mid-1990s, 1 meter black and white digital orthophoto quads: http://gis.utah.gov/data/aerial-photography/mid-1990s-1-meter-black-white-orthophotography/, accessed August 2021.

Utah Geospatial Resource Center (UGRC), State Geographic Information Database, 2006, 2 meter lidar elevation data: https://gis.utah.gov/data/elevation-and-terrain/2-meter-lidar/, accessed August 2021.

Utah Geospatial Resource Center (UGRC), State Geographic Information Database, 2011, 1 meter lidar elevation data: https://gis.utah.gov/data/elevation-and-terrain/2011-lidar/, accessed August 2021.

Utah Geospatial Resource Center (UGRC), State Geographic Information Database, 2016, Bear Lake, Bear River, Cache Valley & Upper Weber Valley lidar elevation data: https://gis.utah.gov/products/sgid/elevation/lidar/#2016-bear-lake-bear-river-cache-valley--upper-weber-valley, accessed August 2021.

Utah Geospatial Resource Center (UGRC), State Geographic Information Database, 2018a, National Agricultural Imagery Program, 2018 0.6-meter resolution color aerial photography: https://gis.utah.gov/data/aerial-photography/naip/.

Utah Geospatial Resource Center (UGRC), State Geographic Information Database, 2018b, Google licensed imagery, natural-color aerial photography, imagery dated September 10, 2018: Utah Automated Geographic Reference Center, https://gis.utah.gov/data/aerial-photography/, accessed August 2021.

Utah Geospatial Resource Center (UGRC), State Geographic Information Database, 2021a, Hexagon 15 cm licensed imagery, natural-color aerial photography: Utah Automated Geographic Reference Center, https://gis.utah.gov/data/aerial-photography/, accessed August 2021.

Utah Geospatial Resource Center (UGRC), State Geographic Information Database, 2021b, Hexagon 30 cm licensed imagery, natural-color aerial photography: Utah Automated Geographic Reference Center, https://gis.utah.gov/data/aerial-photography/, accessed August 2021.

Verdel, C.I, 2009, I—Cenozoic geology of Iran—an integrated study of extensional tectonics and related volcanism, II—Ediacaran stratigraphy of the North American Cordillera—new observations from eastern California and northern Utah: Pasadena, California Institute of Technology, Ph.D. dissertation.

Western Regional Climate Center, 2019, Period of record monthly climate summary for Pine View Dam (426869): https://wrcc.dri.edu/cgi-bin/cliMAIN.pl?ut6869.

Williams, J.S., 1948, Geology of the Paleozoic rocks, Logan quadrangle, Utah: Geological Society of America Bulletin, v. 59, no. 11, p. 1121–1164, scale 1:125,000.

Williams, J.S., 1971, The Beirdneau and Hyrum Formations of north-central Utah: Smithsonian Contributions to Paleobiology, no. 3, p. 219–229.

Williams, J.S., and Taylor, M.E., 1964, The Lower Devonian Water Canyon Formation of northern Utah: University of Wyoming Contributions to Geology, v. 3, no. 2, p. 38–53.

Yonkee, W.A., 1992, Basement-cover relations, Sevier orogenic belt, northern Utah: Geological Society of America Bulletin, v. 104, p. 280–302.

Yonkee, W.A., 2005, Strain patterns within part of the Willard thrust sheet, Idaho-Utah-Wyoming thrust belt: Journal of Structural Geology, v. 27, p. 1315–1343.

Yonkee, W.A., Czeck, D.M., Nachbor, A.C., Barszewski, C., Pantone, S., Balgord, E.A., and Johnson, K.R., 2013, Strain accumulation and fluid-rock interaction in a naturally deformed diamictite, Willard thrust system, Utah (USA)—implications for crustal rheology and stain softening: Journal of Structural Geology, v. 50, p. 91–118.

Yonkee, W.A., Eleogram, B., Wells, M.L., Stockli, D.F., Kelley, S., and Barber, D.E., 2019, Fault slip and exhumation history of the Willard thrust sheet, Sevier fold-thrust belt, Utah—relations to wedge propagation, hinterland uplift, and foreland basin sedimentation: Tectonics, v. 38, p. 2850–2893, https://doi.org/10.1029/2018TC005444.

Yonkee, A., and Lowe, M., 2004, Geologic map of the Ogden 7.5′ quadrangle, Weber and Davis counties, Utah: Utah Geological Survey Map 200, 42 p., 2 plates., https://doi.org/10.34191/M-200.

Yonkee, W.A., Parry, W.T., Bruhn, R.L., and Cashman, P.H., 1989, Thermal models of thrust faulting—constraints from fluid-inclusion observations, Willard thrust sheet, Idaho-Utah-Wyoming thrust belt: Geological Society of America Bulletin, v. 101, no. 2, p. 304–313, https://doi.org/10.1130/0016-7606(1989)101<0304:TMOTFC>2.3.CO;2.

Yonkee, W.A., and Weil, A.B., 2015, Tectonic evolution of the Sevier and Laramide belts within the North American Cordillera orogenic system: Earth-Science Reviews, v. 150, p. 531–593.

Yonkee, A., Willis, G.C., Balgord, E., Doelling, H.H., and Jensen, M.E., 2024, Geology of Antelope Island State Park, *in* Sprinkel, D.A., Chidsey, T.C., Jr., Anderson, P.B., and Willis, G.C., editors, Geology of Utah's parks and monuments, Utah Geological Association Publication 28 (fourth edition), p. 471–515.

Table 1. *Ages of major shoreline occupations of Lake Bonneville and shoreline elevations in the Huntsville quadrangle.*

Lake Cycle and Phase	Shoreline (map symbol)	Age		Shoreline Elevation feet (meters)
		radiocarbon years (^{14}C yr B.P.)	calibrated years (cal yr B.P.)[1]	
Lake Bonneville				
Transgressive phase	Stansbury shorelines	22,000–20,000[2]	26,000–24,000	Not present[3]
	Transgressive shorelines (t)	20,000–15,000[4]	24,000–18,000	4880–5180 (1487–1578)
	Bonneville (B)	~15,000[5]	~18,000	5180–5190 (1578–1582)
	flood			
Overflowing phase	Provo (P)	15,000–12,600[6]	18,000–15,000	Not recognized[7]
Regressive phase	Regressive shorelines (r)	12,600–11,500[6]	15,000–13,000	Not recognized[7]

[1] Radiocarbon ages (^{14}C yr B.P.) must be calibrated to compare to calendar years, or calibrated years before present (cal yr B.P.), meaning years before 1950. All calibrations made using OxCal ^{14}C calibration and analysis software (version 4.4; Bronk Ramsey, 2009; using the IntCal20 calibration curve of Reimer et al., 2020), rounded to the nearest 500 years.
[2] Oviatt et al. (1990).
[3] Stansbury shoreline is provided for reference only as it is below the lowest elevations in the quadrangle
[4] Oldest and youngest age from the youngest Stansbury shoreline and oldest Bonneville shoreline, respectively (see references 2 and 5)
[5] Bonneville shoreline highstand duration may have been shorter than our rounding error of 500 years; age represents lake culmination (Oviatt, 2015; Miller, 2016, and references therein).
[6] See Godsey et al. (2005, 2011), Oviatt (2015), Miller (2016) for the timing of the occupation of the Provo shoreline and subsequent regression of Lake Bonneville to near Great Salt Lake level. Alternatively, data in Godsey et al. (2005) may suggest that regression began earlier, shortly after 16.5 cal ka (see sample Beta-153158, with an age of 13,660 ± 50 ^{14}C yr B.P. [16.5 cal ka] from 1.5 m below the Provo shoreline). Also, lacustrine carbonate deposits in caves reported by McGee et al. (2012) seem to support an earlier Lake Bonneville regression beginning around 16.4 cal ka.
[7] The Provo shoreline formed at elevations of about 4820–4880 feet (1469–1487m) which are present in the quadrangle, but the shoreline and lower elevation regressive phase shorelines were either weakly developed or poorly preserved and cannot be identified.