Utah Geological Survey
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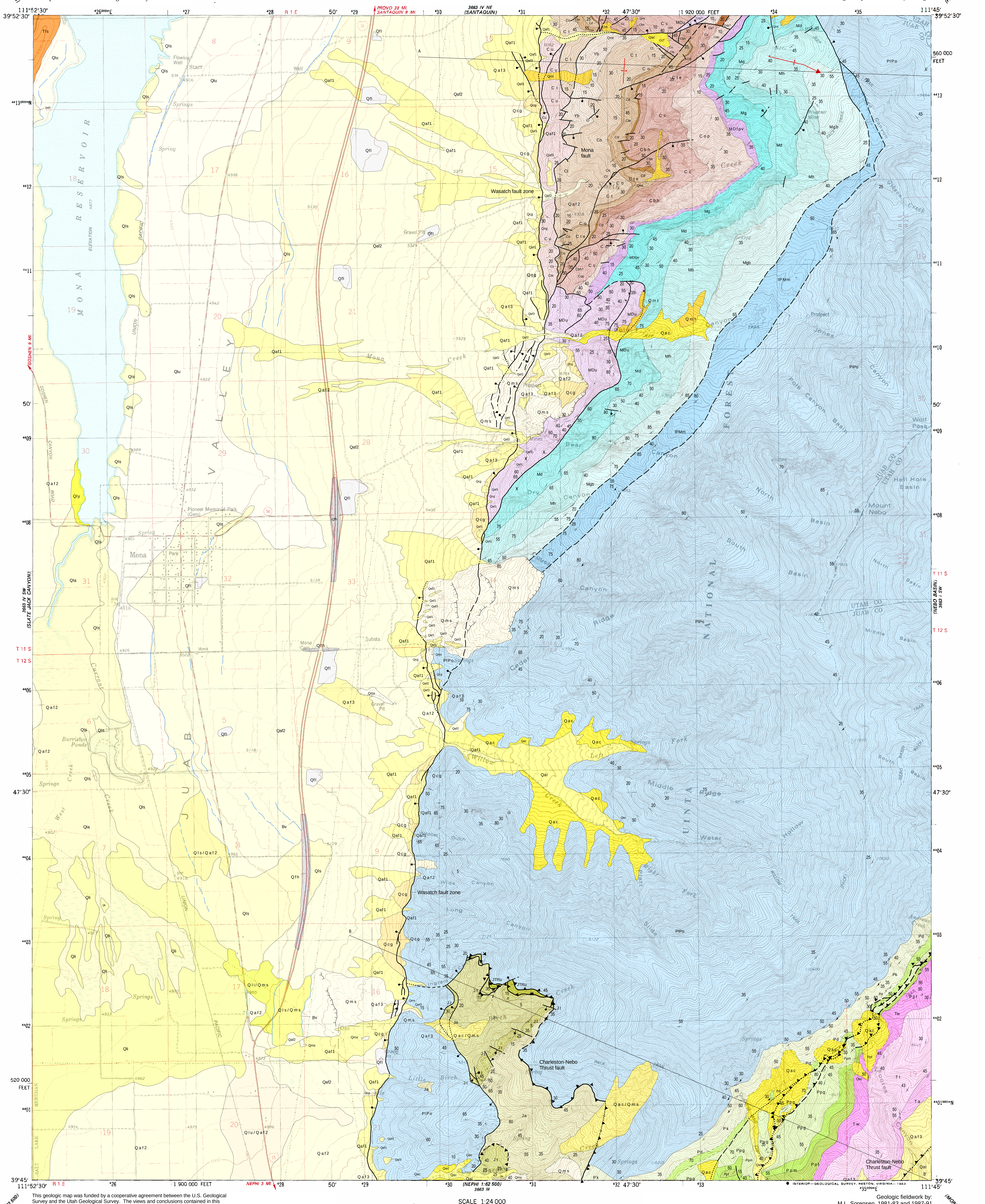
in cooperation with U.S. Geological Survey

Plate 1
Utah Geological Survey Open-File Report 428
Provisional Geologic Map of the Mona Quadrangle



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SCALE 1:24 000

1 MILE

1000 0 1000 2000 3000 4000 5000 6000 7000 FEET

1 KILOMETER

CONTOUR INTERVAL 40 FEET

Geologic fieldwork by:
M.L. Sorensen, 1981-83 and 1987-91
(assisted by H. Pietropaoli, 1982)
M.N. Machette, 1992
T.J. Felger, 1988-91

Provisional Geologic Map of the Mona Quadrangle, Juab and Utah Counties, Utah

by
Tracey J. Felger, Michael N. Machette, and Martin L. Sorensen

2004

PROVISIONAL GEOLOGIC MAP OF THE MONA QUADRANGLE,

JUAB AND UTAH COUNTIES, UTAH

by

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ABSTRACT

The Mona quadrangle in central Utah includes part of the southern Wasatch Mountains, Wasatch fault, and northern Juab Valley. Bedrock in the eastern half of the quadrangle consists of approximately 29,000 feet (8,840 m) of carbonate and clastic sedimentary rocks that range in age from Precambrian to Jurassic. A small area of Tertiary volcanic rocks is exposed in the northwestern corner of the quadrangle. Most of the western half of the quadrangle is occupied by Juab Valley, which contains as much as 5,200 feet (1,585 m) of Tertiary and Quaternary deposits.

The steeply west-dipping Wasatch fault zone trends slightly east of north through the quadrangle and separates Juab Valley on the west from the Wasatch Mountains on the east. Recent movement on the fault is demonstrated by fault scarps that are preserved on Holocene (and older) alluvium at the mouths of almost all drainages along the front of the Wasatch Range.

Precambrian and Paleozoic rocks east of the Wasatch fault are underlain at shallow depth by the flat-lying Charleston-Nebo thrust fault. The Charleston-Nebo fault also is present at considerably greater depth beneath Juab Valley. Between Birch and Gardner Creeks, a window through the Charleston-Nebo fault exposes Mesozoic rocks in the lower plate of the thrust. The sequence of rocks that forms the upper plate of the thrust appears to be the remnant east limb of a large anticline with a north-trending, near-horizontal fold axis and an axial plane that is overturned to the east in the southern part of the quadrangle.

Lead, silver, and zinc have been produced from deposits in the Mona quadrangle, but the value of total production from the district is estimated at less than $400,000 and there has not been any production recorded since 1917. Gypsum is present at three patented claims within the quadrangle, and there is a high potential for other, as yet undiscovered, deposits within the quadrangle. Earthquakes, mass wasting, karst development, and ground-water contamination are the principal geologic hazards in the Mona quadrangle.

INTRODUCTION

The Mona quadrangle is located in central Utah just north-northeast of Nephi, county seat of Juab County, Utah. The quadrangle is bisected by the north-trending Wasatch fault, which separates Juab Valley on the west from the Wasatch Range on the east. Topographic relief in the quadrangle is about 7,000 feet (2,135 m); the maximum elevation of 11,928 feet (3,636 m) is on the Juab-Utah County Line at Mount Nebo. There are well-maintained paved roads in Juab Valley, but access in the northern upland area is limited to an abandoned jeep trail between North Creek and Pole Canyon; several pack trails provide access in the southern part of the upland area.

The area of the Mona quadrangle has been included in many geologic studies that have ranged in scope from narrowly defined investigations to regional geologic compilations. A partial list of these studies includes:

Loughlin, G.F.	1919	lamprophyre dikes near Mt. Nebo
	1920	regional and economic geology
Eardley, A.J.	1933	regional stratigraphy
	1934	regional structure
Phillips, K.A.	1940	economic geology, Mt. Nebo district
Smith, C.V.	1956	geology, North Canyon area

Johnson, K.D.	1959	geology, Mt. Nebo-Salt Creek area
Cook and Berg	1961	regional gravity survey
Bullock, K.C.	1962	economic geology, Mt. Nebo district
Hintze, L.F.	1962	regional geology
Phillips, W.R.	1962	igneous rocks, central Utah
Black, B.A.	1965	Nebo overthrust
Cluff and others	1973	study of Wasatch fault
Hintze, L.F.	1980	geologic map, Utah
Sorensen and others	1983	economic appraisal
Korzeb and Neubert	1984	economic geology
Le Vot, Michel	1984	regional geology
Witkind and Weiss	1991	geology of Nephi 30' x 60' quadrangle
Jackson, M.E.	1991	study of Wasatch fault
Machette and others	1992	study of Wasatch fault

Geologic maps for quadrangles adjoining the Mona quadrangle have been published by Meibos (1983), Jensen (1986), Banks (1991), and Biek (1991)

This map is a product of a cooperative project between the Utah Geological Survey and the United States Geological Survey. Field work for this project began in 1987 and was completed in 1991.

STRATIGRAPHY

Within the Mona quadrangle, Quaternary surficial deposits overlie volcanic rocks of Tertiary age and carbonate and clastic sedimentary rocks that range in age from Precambrian to Jurassic. Formations were identified on the basis of stratigraphic position, lithology, and by comparison with nearby, previously mapped areas, particularly in the East Tintic Mountains (Morris and Lovering, 1961; Morris, 1964a, 1964b). Stratigraphic thicknesses reported here for the various units are based on measurements made on the geologic map. Age assignments for the various formations are those currently recognized by the U. S. Geological Survey; their inclusion here does not signify any new evidence for those ages. Adjacent formations are considered to be separated by normal sedimentary contacts except where noted to the contrary in the following descriptions or in the accompanying correlation of map units.

Rocks of the Pennsylvanian and Permian Oquirrh Formation underlie about half of the upland area in the quadrangle. Formations older than the Oquirrh form a northeast-trending sequence in the northeast part of the quadrangle. Permian and Triassic formations form a northeast-trending overturned sequence at the southeastern corner of the quadrangle. Triassic and Jurassic rocks are exposed in a window through the Charleston-Nebo thrust in the south-central part of the quadrangle.

Rocks of Ordovician, Silurian, and Early and Middle Devonian age are not present in this part of the Wasatch Mountains, apparently because of pre-Late Devonian uplift and erosion (Rigby, 1959). In the Mona quadrangle, rocks assigned to the undivided Upper Devonian and Mississippian unit (MDu) paraconformably overlie the Upper Cambrian Opex Formation.

Proterozoic

Big Cottonwood Formation (Yb) (Middle and Late Proterozoic)

The Big Cottonwood Formation comprises quartz-pebble conglomerate, micaceous shale or phyllite, quartzite, siltstone, and sandstone. The conglomerates typically consist of white, gray, and light-green quartz pebbles in a matrix of medium- to dark-maroon or purple, medium- to coarse-grained sand. Shale and siltstone generally are dark, range in color from light to very dark maroon and from light grayish green to dark green, and locally include fine- to medium-size sand grains. Sandstones mostly are medium to dark maroon or purple. Quartzite generally occurs in dark shades of gray, green, maroon, and purple. Sandstone, quartzite, and conglomerate commonly are feldspathic. In general, fine-grained rocks in the formation resemble rocks of the type area in Big Cottonwood Canyon and coarse-grained rocks more closely resemble rocks of the Mutual Formation. In the Mona quadrangle, exposures of the Big Cottonwood Formation occur low on the mountain front between Starr and North Creeks. The formation is bounded on the west and truncated at the base by the Mona fault and is disconformably overlain by the Tintic Quartzite. The Big Cottonwood Formation typically forms subdued, low-lying outcrops, although coarse-grained quartzites and conglomerates locally form rugged, cliffy outcrops. The exposed thickness of the Big Cottonwood Formation in the Mona quadrangle is 450 to 500 feet (140-150 m).

There are diverse opinions regarding the age of the Big Cottonwood Formation. Harrison and Peterman (1984, plate 1) correlate the Big Cottonwood with part of the Uinta Mountain Group and assign both units to the Middle Proterozoic because of an isotopic age (Crittenden and Peterman, 1975) determined for rocks at the top of the Uinta Mountain Group. Elston and others (1993, p. 470) also correlate the Big Cottonwood with part of the Uinta Mountain Group, but assign both units to the Upper Proterozoic because of their interpretations of lithostratigraphic, paleontologic, and paleomagnetic data. Reed (1993) correlates the Big Cottonwood with part of the Uinta Mountain Group and assigns the Big Cottonwood Formation to both the Middle and Upper Proterozoic based on his interpretation of diverse data, and it is this assignment that we accept for this paper.

Cambrian

Tintic Quartzite (Ct) (Lower and Middle Cambrian)

The Tintic Quartzite consists of pale-pink, gray, and white quartzite that locally grades to darker shades of these colors. Tintic rocks are medium- to coarse-grained, well-bedded, cross-bedded, and texturally mature, commonly include white quartz pebbles, and locally are conglomeratic. Quartz-pebble conglomerate near the base of the unit locally includes maroon or green pebbles that probably were reworked from the Big Cottonwood Formation. Quartzite in the uppermost part of the Tintic is fine to medium grained and contains thin intercalations of micaceous, commonly fucoidal shale. The gradational contact between the Tintic and the overlying Ophir Formation was placed at the top of the highest massive quartzite bed and is generally coincident with a change from tan- or brown-weathering shales in the Tintic to the greenish-brown or greenish-gray shales of the Ophir. The Tintic forms a northeast-trending belt of outcrops that extends from midway between Pole and North Canyons to the northern boundary of the quadrangle. A second, structurally lower section of Tintic lies just south of the mouth of Starr Creek. The weathering characteristics of the Tintic Quartzite are very similar to those of the Big Cottonwood Formation in that both weather to form low-lying outcrops, but the Tintic Quartzite more commonly forms cliffs.

Measurements made on the map indicate the Tintic thins to the north. The unit is at least 1,000 feet (305 m) thick near the mouth of North Creek (900 feet [274 m] from Ophir Shale to diabase flow, plus at least 100 feet [30 m] to concealed base of Tintic), and is approximately 800 feet (245 m) thick in the higher of the two zones of Tintic on the south wall of Starr Creek.

The informally designated diabase flow member of the Tintic quartzite was reported on by Abbott (1951), who described the rock as a diabase flow, 21 to 65 feet (6-20 m) thick, composed of large phenocrysts of labradorite in a matrix of labradorite, augite, magnetite, and alteration products of those minerals. Within the Mona quadrangle, the diabase is best exposed at stream level near the mouth of North Canyon. There and elsewhere it occurs in discontinuous outcrops approximately 100 feet (30 m) above the base of the Tintic. The diabase is dark maroon to dark purple and contains plagioclase phenocrysts in a dark, aphanitic groundmass. A dark maroon band approximately 0.75 inches (2 cm) wide occurs in quartzite immediately beneath the flow and is interpreted to be a baked zone. The alignment of phenocrysts parallel to the underlying contact imparts a weak fabric to diabase in the lower part of the flow.

Cambrian strata, undivided (Cu) (Middle and Upper Cambrian)

This undivided unit comprises, in ascending order, the Ophir Formation, Teutonic Limestone, Dagmar Dolomite, Herkimer Limestone, Bluebird and Cole Canyon Dolomites, Opex Formation, and Ajax(?) Dolomite. The unit crops out between Pole Canyon and Starr Creek in a north-trending zone that is bounded by the Wasatch and Mona faults. Previous workers have identified rocks in this zone as Quaternary fault breccia (Smith, 1956), fault breccia (Hintze, 1962), and Mississippian and Devonian rocks, undivided and Devonian, Ordovician, Cambrian, Proterozoic, and Archean rocks, undivided (Witkind and Weiss, 1991). We infer a middle or late Cambrian age for these rocks because of their strong resemblance to parts of the Cambrian succession, particularly the Teutonic and Herkimer Limestones and Opex Formation. Limestone and dolomite that commonly are argillaceous are the predominant lithologies in the undivided Cambrian unit.

Ophir Formation (Co) (Middle Cambrian)

The Ophir Formation was subdivided in the East Tintic Mountains (Morris, 1957, p. 4-6; Morris and Lovering, 1961, p. 19-22) into a lower shale member, a middle limestone member, and an upper shale member. In the Mona quadrangle the lower part of the Ophir mostly consists of greenish-brown to greenish-gray and tan to reddish-brown shale and siltstone. Thin interbeds of slightly calcareous sandstone occur near its base and thin interbeds of dark blue-gray limestone and rusty-weathering argillaceous limestone occur in the middle and upper parts of the shale. The middle part of the Ophir comprises thin-bedded, dark-blue-gray limestone that weathers to a light-tan color in its uppermost 10 feet (3 m), interbedded with gray to grayish-tan argillaceous limestone. The upper part of the Ophir contains shale and thin-bedded, micaceous, slightly calcareous siltstone. The Ophir generally forms a gently sloping bench between the underlying quartzites and overlying limestones. The upper contact of the Ophir was placed at the base of the lowest massive limestone of the Teutonic Limestone. The Ophir thins southward, from 275 feet (85 m) on the north wall of Starr Creek to 175 feet (55 m) on the north wall of North Creek. The variation in thickness may be due to structural thinning.

Teutonic Limestone (Cte) (Middle Cambrian)

The Teutonic Limestone is a dark, mottled, massive, ledge- or cliff-forming, thin- to medium-bedded limestone with lesser dolomite. Teutonic rocks are dark gray or blue gray, commonly include thin interbeds of silty limestone that weather to shades of gray, tan, and orange, and are sparsely fossiliferous. The upper contact was placed where the dark limestone of the Teutonic is overlain by laminated, creamy-white dolomite. The Teutonic Limestone is approximately 400 feet (120 m) thick between North and Starr Creeks.

Dagmar Dolomite (Cd) (Middle Cambrian)

The Dagmar Dolomite is a highly distinctive, light-gray to creamy-white, thin-bedded to laminated dolomite. Rocks in this unit typically have a hackly texture on the weathered surface and a blocky fracture that produces small, nearly square joint blocks. The Dagmar is both underlain and overlain by dark-gray carbonate rocks. Its upper contact was placed where the highest creamy-white dolomite is overlain by dark dolomite assigned to the Herkimer Limestone. The Dagmar forms ledges that are easily distinguished by their color, laminated bedding, and blocky fracture. The unit ranges in thickness from 10 feet (3 m) in exposures south of North Creek to as much as 30 feet (10 m) in exposures on the south wall of Starr Creek.

Herkimer Limestone and Bluebird Dolomite, undivided (Cbh) (Middle Cambrian)

The Herkimer Limestone and Bluebird Dolomite were not separated during mapping because of uncertainty in correctly identifying outcrops south of Starr Creek. The lower part of this undivided unit consists of thin- to medium-bedded, medium- to dark-gray and blue-gray limestone and dolomite, with intercalated gray or tan argillaceous limestone and dolomite. Oolitic textures are locally prominent and intraformational conglomerates are common throughout. These rocks commonly are massive and closely resemble rocks in the underlying Teutonic Limestone, as well as rocks in the upper part of this undivided unit. The upper part of the undivided Herkimer and Bluebird consists of medium- to thick-bedded, very dark-gray dolomite that commonly contains small (less than 0.4 inch [<1 cm] length) rods or twig-like structures of white dolomite. The upper contact of this undivided unit was placed at the base of the lowest overlying pale-gray or creamy-white dolomite assigned to the Cole Canyon Dolomite. The Herkimer Limestone and Bluebird Dolomite are moderately resistant to weathering and generally underlie moderate to steep slopes with local ledges and cliffs. The thickness of the undivided Bluebird and Herkimer varies between 400 and 500 feet (120-150 m) with an average thickness of 450 feet (140 m).

Cole Canyon Dolomite (Cc) (Middle Cambrian)

The Cole Canyon Dolomite comprises alternating zones of light and dark dolomite. The light-colored dolomite is very light gray to white or creamy white, medium bedded to locally laminated, and closely resembles the Dagmar Dolomite. The dark-colored dolomite is medium gray to very dark gray, commonly mottled, locally contains small rods or twig-like structures of white dolomite, and closely resembles the upper part of the undivided Herkimer Limestone and Bluebird Dolomite. The uppermost Cole Canyon includes massive outcrops of thin-bedded dolomite with abundant argillaceous partings and horizons. The upper contact of the Cole Canyon was placed between the highest dark-blue-gray dolomite and the lowest thin-bedded limestone and shale of the Opex Formation. The Cole Canyon is relatively resistant to erosion and commonly forms ledges or cliffs. The thickness of the unit varies between 350 and 500 feet (105-150 m) with an average thickness of 475 feet (145 m).

Opex Formation (Co) (Upper Cambrian)

The Opex Formation consists of interbedded limestone and shale with discontinuous intercalations of dolomitic sandstone and argillaceous dolomite. The limestone is thin bedded, light gray to light blue gray, locally oolitic, and includes abundant intraformational limestone conglomerate. Medium-gray shale and argillite weather to shades of tan and yellow. The Opex Formation is more easily eroded than the flanking formations and commonly forms slopes of low relief. North of Starr Creek the upper contact of the Opex was placed where thin-bedded argillaceous and arenaceous rocks of the Opex are overlain by chert-rich dolomite of the Ajax(?) Dolomite. Elsewhere in the quadrangle, a major unconformity (Rigby, 1959) separates the Opex from overlying thick-bedded, medium- to dark-gray Devonian dolomite. The thickness of the Opex ranges between 400 and 600 feet (120-180 m) in most exposures. The unit appears to be as thick as 1,000 feet (300 m) on the north and south walls of North Canyon where it may have been thickened by intraformational faulting.

Ajax(?) Dolomite (Ca) (Upper Cambrian)

A tentative assignment to the Ajax(?) Dolomite was made for rocks at one locality at the east end of Starr Creek, at the north boundary of the quadrangle, where outcrops of dolomite with very abundant chert occur as small, isolated ledges in an area of deep soil and colluvium. The dolomite is thin bedded, medium gray, weathers to a slightly lighter shade of gray, and is coarsely crystalline. Chert in these rocks varies in color from gray to near white and occurs in thin lenticular nodules up to 2 feet (0.6 m) long and 1 inch (2.5 cm) thick. The area of outcrop is terminated at the top by a fault. Map relations suggest a maximum thickness of 150 feet (45 m).

Devonian and Mississippian

Victoria Formation, Pinyon Peak Limestone, and Fitchville Formation, undivided (MDfpv) (Upper Devonian and Lower Mississippian)

This unit comprises a lower dolomite, a middle quartzite, and an upper dolomite. Near its base, the lower dolomite is slightly argillaceous and medium gray in color. Overlying exposures of the lower dolomite commonly are light gray in color, but locally are mottled light or dark gray. The uppermost part of the lower dolomite consists of rubbly slopes underlain by easily weathered light-gray dolomite. All of these rocks are medium to coarsely crystalline, locally include crinoid columnals and unidentified fossil ‘hash’, and do not appear to contain any detrital sand grains.

The middle quartzite is 4 to 5 feet (1.2-1.5 m) thick in most exposures and locally is as thick as 10 feet (3 m). The lithologically and texturally mature quartzite is very light grayish white to tan in color, thin bedded, and is characterized by very well-rounded and very well-sorted, medium- to coarse-grained white quartz grains that are cemented by a light-colored, slightly calcareous, silicic cement. In most outcrops the quartzite occurs as an uninterrupted series of beds, although north of Pole Canyon a 1- to 2-foot-thick (0.3-0.6 m) dark-gray dolomite occurs in the middle of an 8- to 10-foot-thick (2.4-3 m) quartzite.

The basal part of the upper dolomite forms massive, light-gray exposures of silty and sandy dolomite and commonly includes one or more beds of non-argillaceous, very finely crystalline, medium blue-gray limestone. The balance of the upper dolomite consists of light-gray argillaceous dolomite without noticeable sand grains.

These three subunits were combined to form an undivided unit during mapping because of the similarity of the upper and lower dolomites and the inability to distinguish them in areas where the quartzite subunit was missing or covered. Comparison with stratigraphic sections exposed in the East Tintic Mountains (Morris and Lovering, 1961) suggests that within the undivided Upper Devonian and Lower Mississippian unit (MDfpv), the lower dolomite and middle quartzite together correspond to either an atypically sandy section of Pinyon Peak Limestone or a combination of Pinyon Peak Limestone and Victoria Formation, and the upper dolomite corresponds to Pinyon Peak Limestone overlain by Fitchville Formation.

Despite the apparent conformity of bedding in the lower part of the undivided unit with respect to that in the underlying Opex Formation, the two rock sequences are separated by an unconformity of regional extent and importance. The underlying rocks are Late Cambrian in age; the oldest part of the overlying sequence is Late Devonian in age. Comparison with the stratigraphic section exposed in the East Tintic mining district (Hintze, 1988, p. 149) suggests that approximately 2,400 feet (730 m) of section is absent from the Mona quadrangle, apparently as a result of Late Devonian uplift and erosion (Rigby, 1959; Morris and Lovering, 1961). The upper contact of this unit was placed between the highest light-gray argillaceous dolomite and overlying dark blue-gray, flaggy limestones or very dark-gray, non-argillaceous dolomite. The thickness of the unit ranges from 250 to 350 feet (75-100 m).

Mississippian

Gardison Limestone (Mg) (Lower Mississippian)

The Gardison Limestone typically is a medium- to dark-gray or blue-gray limestone with a distinctive platy weathering habit that yields 1- to 6-inch-thick (2.5-15 cm) limestone plates. North of Pole Canyon, the lowermost Gardison is a very coarsely crystalline, very dark-gray to black, cliff-forming dolomite. Elsewhere, the lower part of the Gardison is much like exposures throughout the unit and is well bedded, locally very fossiliferous, and commonly contains abundant black chert in ribbon-like beds as thick as 1 to 2 inches (2.5-5 cm). Although predominantly limestone, the Gardison also includes lesser amounts of dolomite, whose color and bedding characteristics are the same as those of the limestone. The upper contact of the Gardison was placed between the highest bench-forming cherty limestone and the phosphatic pelletal shale at the base of the Deseret. The thickness of the Gardison Limestone varies from 450 to 650 feet (140-200 m) with an average thickness of 550 to 600 feet (170-185 m).

Deseret Limestone (Md) (Lower and Upper Mississippian)

The Deseret Limestone begins at the base with the Delle Phosphatic Member (Sandberg and Gutschick, 1984). In the Mona quadrangle, the Delle is as much as 20 feet (6 m) of sooty black mudstone and shale that commonly includes one or several thin beds of dark phosphatic pelletal or oolitic material. The remainder of the Deseret consists of dolomite and limestone in approximately equal amounts in the lower and middle parts of the formation and mostly dolomite in the upper part. Both the limestone and dolomite are mostly light to medium gray, well bedded, coarse grained, and contain substantial amounts of tan-weathering black chert as lenses or discontinuous ribbon beds. The upper contact of the Deseret is placed at the base of the lowest sandstone or quartzite bed of the overlying Humbug Formation. The Deseret is resistant to weathering and forms cliffs and ledges where bedding is flat-lying and bold ribs where bedding stands at steep angles. The thickness of the formation varies from 800 to 900 feet (245-275 m).

Humbug Formation (Mh) (Upper Mississippian)

The Humbug Formation consists of quartz sandstone interbedded with limestone and, to a lesser degree, dolomite. Contacts between carbonate rocks and sandstones are sharp. The sandstones are medium to light gray on fresh surfaces and weather to shades of tan or reddish brown. Quartz grains in these sandstones are medium grained, well rounded, and generally held by a calcareous cement. The limestone and dolomite mostly weather to shades of light to medium gray or bluish gray, but silty carbonate rocks weather tan. The upper contact of the Humbug is placed at the top of the highest sandstone or quartzite bed and the base of the dark limestones of the Great Blue Limestone. The Humbug generally forms moderate to steep slopes with local cliffs or ledges. Measurements made on the map indicate its thickness ranges from 900 to 1,000 feet (275-305 m) with an average thickness of approximately 950 feet (290 m).

Great Blue Limestone (Mgb) (Upper Mississippian)

The Great Blue Limestone is thin- to medium-bedded, gray or blue-gray limestone that generally forms steep slopes with local ledges and cliffs. Fossils and beds and lenses of chert occur locally. The Great Blue ends upward at a fault that separates the Great Blue from greenish-brown shales and sandstones of the overlying Manning Canyon Shale. The thickness of the Great Blue varies markedly, from 200 to 300 feet (60-90 m) in Pole Canyon to 700 to 750 feet (215-230 m) in Bear Canyon. Elsewhere the unit thickness varies between 400 to 650 feet (120-200 m). These variations in thickness appear to be due to the removal of Great Blue by faulting and may be due in part to attenuation during folding.

Mississippian and Pennsylvanian

Manning Canyon Shale (IPMm) (Upper Mississippian and Lower Pennsylvanian)

The easily eroded Manning Canyon Shale is exposed in a northeast-trending, heavily vegetated trough flanked by resistant carbonate units. The Manning Canyon consists of mudstone, shale, and sandstone. The mudstone and shale are black or very dark brown on fresh surfaces and lighter shades of brown or greenish brown on weathered surfaces. Sandstone in the formation consists of well-sorted, coarse- to medium-grained quartz, and is brown or greenish brown on fresh surfaces and olive brown or greenish gray on weathered surfaces. The upper and lower contacts of the formation are faults that appear to be approximately parallel to bedding in the flanking units, although the variation of thickness in the underlying Great Blue Limestone demonstrates crosscutting relationships along the fault at the base of the Manning Canyon. The top of the Manning Canyon is placed at the base of the lowest blue limestone or sandy limestone of the Oquirrh Formation. The thickness of the Manning Canyon is poorly known. Deformation within the Manning Canyon is pervasive and precludes meaningful estimates of thickness.

Pennsylvanian and Permian

Oquirrh Formation (IPPo) (Pennsylvanian and Lower Permian)

More than half of the upland area in the Mona quadrangle is underlain by the Oquirrh Formation, consisting of limestone with interbedded sandstone and shale. The limestone is thin to thick bedded and generally weathers light gray or blue gray, although silty or sandy limestone weathers to shades of tan or brown. Quartzitic sandstone interbeds are medium to coarse grained and weather gray or light tan. Shale interbeds are a minor component that occur particularly in the upper part of the formation. The Oquirrh is resistant to erosion and forms steep slopes to vertical cliffs. Johnson (1959) reported the presence of abundant Desmoinesian foraminifers in rocks he considered to be basal Oquirrh and suggested that older Oquirrh rocks had been removed by faulting. Limestone collected during the present study from the apparent base of the Oquirrh Formation between Couch Canyon and Cedar Ridge contains conodonts of early Morrowan age (A.G. Harris, written communication, 1994), indicating little, if any, section has been faulted from the base of the Oquirrh at this locality. The upper contact of the Oquirrh is placed at the first appearance of gray dolomite above the dark blue-gray limestones of the Oquirrh. Measurements made on the map between Couch Canyon and Andrews Creek suggest a total thickness of 15,000 to 16,000 feet (4,573-4,878 m) for the Oquirrh Formation in the Mona quadrangle.

Permian

Kirkman Limestone (Pk) (Lower Permian)

Outcrops of Kirkman Limestone form a belt that begins at Gardner Creek and trends northeast to Andrews Creek in the southeast corner of the quadrangle. The Kirkman mostly comprises light-gray argillaceous dolomite with minor interbedded tan siltstone and silty dolomite. Near its base, the Kirkman includes an interval of dark-gray dolomite with very abundant black chert; white chert is present in minor amounts throughout the remainder of the unit. The sparsely fossiliferous Kirkman is resistant to erosion and forms steep slopes and cliffs. The contact between the Kirkman and the overlying Diamond Creek Sandstone was placed between the highest dolomite and lowest sandstone beds. Measurements made on the map suggest the thickness of the Kirkman varies from 450 to 1,150 feet (140-350 m), but the formation probably has been repeated by unrecognized thrust faults.

Diamond Creek Sandstone (Pd) (Lower Permian)

Like the units above and below it, the Diamond Creek Sandstone is exposed near the southeast corner of the quadrangle, where it forms saddles and slopes with low ledges. The Diamond Creek comprises yellow- to tan-weathering, locally cross-bedded sandstone consisting of well-rounded, well-sorted, fine- to medium-grained quartz grains bound by calcareous cement. The conformable contact between the Diamond Creek Sandstone and the overlying Grandeur Member of the Park City Formation was placed between the highest sandstone and lowest dolomite beds. The apparent thickness of the formation varies from 225 to 325 feet (70-100 m).

Park City Formation

Grandeur Member (Ppg): (Lower Permian) The Grandeur Member of the Park City Formation is exposed near the southeast corner of the quadrangle where it forms a northeast-trending belt of gentle to moderate slopes with ledges and low cliffs. The Grandeur Member comprises interbedded dolomite, cherty dolomite, sandstone, and limestone. The dolomite is light to medium gray, generally well bedded, and includes many small lenses of white chert. Near the base of the Grandeur, the dolomite is tan and contains very abundant small lenses of black chert. Sandstone interbeds composed of well-rounded and well-sorted quartz grains occur throughout the unit. The uppermost part of the Grandeur consists of 25 feet (8 m) of light-gray limestone containing very abundant silicified brachiopods. The thickness of the Grandeur varies markedly throughout its area of exposure, ranging from approximately 150 feet (45 m) east of Footes Canyon where it has been thinned by faulting to as much as 500 feet (150 m) at the south quadrangle boundary where it has been repeated by folding.

Phosphoria Formation

Meade Peak Phosphatic Shale Member (Ppm): (Lower Permian) The Meade Peak Phosphatic Shale Member of the Phosphoria Formation comprises thinly interbedded tan to medium-brown dolomite and black chert. The base of the Meade Peak is formed by a horizon of pelletal or oolitic phosphatic material. The upper Meade Peak contact is placed where tan cherty dolomite is overlain by light-gray to cream-colored dolomite of the Franson Member of the Park City Formation. Outcrops of the Meade Peak commonly are cut by closely spaced fractures and generally form moderate slopes with local ledges. The thickness of the Meade Peak varies from 70 to 400 feet (21-122 m).

Park City Formation

Franson Member (Ppf): (Lower Permian) The Franson Member of the Park City Formation consists of medium- to very thick-bedded dolomite that is light gray, light tan, or creamy white, and commonly contains small irregular bodies of white or tan chert. The uppermost part of the Franson usually is marked by a light-gray fossiliferous limestone that contains abundant brachiopods and bryozoans. The contact between the Franson and the overly Woodside Formation is placed where gray fossiliferous limestone or tan argillaceous limestone is overlain by red sandstone and shale. The Franson is approximately 500 feet (150 m) thick except for exposures near Footes Canyon, where part of the Franson has been removed by a thrust fault.

Triassic

Woodside Formation (TRw) (Lower Triassic)

The Woodside Formation forms a northeast-trending belt of subdued outcrops that underlies well-vegetated saddles and slopes in the southeast corner of the quadrangle. The Woodside comprises red-, reddish-gray-, and light-brown-weathering mudstone, siltstone, and micaceous quartzitic sandstone that is cemented by calcite. The contact of the Woodside with the overlying Thaynes Limestone is gradational and is placed at the first appearance of thin-bedded, light-gray to tan limestone. The thickness of the Woodside varies from 400 to 700 feet (120-215 m), probably as a result of stratigraphic repetition along unrecognized thrust faults.

Thaynes Formation (TRt) (Lower Triassic)

The Thaynes Formation consists of lower and upper dominantly limestone intervals separated by epiclastic rocks. Limestone in the lower interval is very argillaceous, weathers greenish tan and reddish brown, and commonly includes interbedded reddish-brown sandstone and siltstone. The middle epiclastic interval is a thin sequence of interbedded, red-weathering siltstone and sandstone that closely resembles rocks in the underlying Woodside Formation. The upper limestone interval weathers greenish brown in its lower part and light gray in the upper part. Limestone throughout the formation is flaggy-weathering and contains brown and white chert nodules. The contact between the Thaynes and the overlying Ankareh Formation is placed between the top of the highest bed of light-gray limestone and the base of the lowest reddish-brown siltstone or sandstone. The thickness of the Thaynes varies from 1,100 to 1,300 feet (335-395 m).

Ankareh Formation (TRa) (Middle and Upper Triassic)

The Ankareh Formation crops out as gentle, rubbly slopes in the southeastern corner of the quadrangle. The formation consists of reddish-brown to tan sandstone, siltstone, and mudstone. The sandstone forms low ledges and commonly displays cross-bedding. Approximately 750 feet (230 m) of the Ankareh Formation are exposed in the quadrangle.

Jurassic and Triassic

Jurassic and Triassic strata, undivided (JTRu) (Middle and Upper Triassic and Lower and Middle Jurassic)

This unit consists of undivided Twin Creek Limestone, Navajo Sandstone, and Ankareh Formation. Outcrops in two thrust slices north of Birch Creek are assigned to this undivided unit because the component formations there are unmappable at the 1:24,000 scale.

Jurassic

Navajo Sandstone (Jn) (Lower Jurassic)

Outcrops of the Navajo Sandstone are restricted to the area of Birch Creek, where they appear in a window through the Charleston-Nebo thrust. The Navajo consists of quartz sandstone that is buff to tan except near the base of the unit, where it may be red or reddish brown. Grains composing the sandstone are well rounded, well sorted, fine to medium grained, and cemented by calcite. The formation forms ledges and cliffs and locally displays very large-scale cross-bedding. The Navajo has a thickness of at least 800 feet (245 m) at Birch Creek.

Twin Creek Limestone (Jt) (Middle Jurassic)

The Twin Creek Limestone overlies Navajo Sandstone in several faulted sections near Birch Creek, where they appear in a window through the Charleston-Nebo thrust. A faulted section of the Twin Creek overlies Arapien Shale on the north side of Gardner Creek. The Twin Creek generally forms steep, sparsely vegetated slopes with local ledges and cliffs. The Twin Creek Limestone in the Mona quadrangle is approximately 400 feet (120 m) thick.

The lower half of the Twin Creek consists of oolitic limestone, overlain by finely crystalline limestone, which is overlain by argillaceous limestone. These limestones are mostly brown to olive gray on weathered surfaces and locally are fossiliferous. The lower half of the Twin Creek is overlain by approximately 50 feet (15 m) of interbedded olive-green argillaceous limestone and brown quartzitic sandstone. The upper Twin Creek consists of dark gray-brown to light- and medium-gray limestone that locally is fossiliferous. The top of the Twin Creek is placed at the top of a persistent bed of red mudstone that caps the upper limestone section. The Twin Creek Limestone in central Utah has been divided into five members by Sprinkel (1982) (see also, Imlay, 1967). Although the Gypsum Spring, Sliderock, Rich, Boundary Ridge, and Watton Canyon Members were identified during this study, they were not mapped separately due to the thinness of the units and their incomplete exposure.

Arapien Shale (Ja) (Middle Jurassic)

The Arapien Shale is exposed in a structural window between Birch and Gardner Creeks and in a smaller window along Little Birch Creek. The Arapien consists of thinly laminated, gray-green to olive-green argillaceous limestone, with local thin beds of red mudstone and gray limestone, and pods of gypsum. The top of the Arapien is not exposed in the Mona quadrangle and the exposed thickness of the Arapien within the quadrangle is not known due to stratigraphic uncertainties and structural complications.

Tertiary

Laguna Springs Volcanic Group (Tls) (Oligocene)

Outcrops of the Laguna Springs Volcanic Group occur in the northwest corner of the Mona quadrangle, west of Mona Reservoir, where they form the east flank of Long Ridge. These rocks were mapped by Muessig (1951) who used the name "Laguna Latite Series" for them and correlated them with rocks in the East Tintic Mountains that initially were named the Laguna Springs Latite by Morris and Lovering (1961) and which later were revised as the Laguna Springs Volcanic Group by Morris and Lovering (1979).

According to Muessig (1951, p.119) the Laguna Springs in the Mona quadrangle mostly consists of andesite breccia composed of angular to subangular andesite fragments that range from silt-size to blocks that are more than 10 feet (3m) in diameter. Within this agglomerate, the lithology of the blocks, clasts, and particles is consistent, regardless of size. Rocks in this unit mostly are dark to very dark gray, with lesser amounts of red and tan colored rocks. The andesites are composed of small phenocrysts of plagioclase, biotite, hornblende, and augite in a very fine-grained to aphanitic groundmass. The thickness of the Laguna Springs in the Mona quadrangle is not known, but elsewhere on Long Ridge may be as great as 1,000 feet (305m) (Muessig, 1951, p. 119).

Quaternary

Quaternary surficial deposits in the area represent a variety of origins and textures that are largely dependent upon their position in the landscape. Coarse-grained deposits are concentrated in alluvial fans and colluvial aprons near the mountain front, whereas fine-grained deposits are preserved in the distal parts of alluvial channels and along the bottom of ancient Lake Bonneville (generally below 5,090 feet [1,552 m] elevation) in Juab Valley.

Alluvial Deposits (Qal, Qac, Qaf_{1-3})

Three types of alluvial deposits are mapped: (1) stream alluvium, (2) mixed alluvium and colluvium, and (3) alluvial-fan deposits. The stream alluvium (Qal) is concentrated along modern stream channels (as flood-plain alluvium) and in slightly elevated terraces, usually east of the Wasatch fault zone. The alluvial deposits consist of sandy, well-rounded stream gravels that grade downstream into pebbly sand and finer materials. The alluvial-fan deposits consist of angular, coarse-grained, sandy gravel, commonly with a large component of debris-flow material (silty gravel). The fans debouch from the mouths of the large streams along the range front to form a steep coalesced piedmont that extends nearly to the center of Juab Valley. Mixed alluvium and colluvium are mapped as a single unit (Qac) in and adjacent to stream canyons and on steep slopes within the Wasatch Range.

Three ages of alluvial fans are mapped: (1) Qaf_1, probably mostly late Holocene; (2) Qaf_2, latest Pleistocene and Holocene; and (3) Qaf_3, middle and late Pleistocene. These deposits are differentiated on the basis of their surficial expression (micro-relief, loess cover, and degree of dissection), soil development, and topographic position.

Lacustrine Deposits (Qly, Qls, Qli, Qlu, Qla)

Five types of lacustrine deposits are mapped: young deposits related to Mona Reservoir (Qly) and four facies of older material (Qls, Qli, Qlu, Qla) deposited mainly during the transgressive phase of the last deep-water cycle of Lake Bonneville (the Bonneville lake cycle). According to the synthetic paleohydrograph for the Bonneville Basin (Currey, 1990), Lake Bonneville probably entered Juab Valley (via Currant Creek, the outlet for Mona Reservoir) at about 18 ka, when it reached an altitude of 4,870 feet (1,485 m). By about 15.5 ka, the lake had risen to its overflow elevation of about 5,092 feet (1,552 m) at Red Rock Pass in southern Idaho (Currey and Oviatt, 1985) and had formed the Bonneville shorelines (Bv) in Juab Valley. By about 14.5 ka, the lake overflowed the pass, downcut a deep (355 feet [108 m]) channel and stabilized at about 4,737 feet (1,444 m) (Currey and Oviatt, 1985) to form the highest of the Provo shorelines. By about 14.2 ka, Lake Bonneville entered a closed basin, rapidly restricting phase (the regressive phase). The Provo level is well below the lowest elevation in the northern part of Juab Valley, so Lake Bonneville could only have occupied this part of Juab Valley for several thousand years (about 18 ka to 14.5 ka). As a result of this temporary incursion and the lake's shallow depth and restricted fetch, lacustrine features such as bars, spits, and shorelines are poorly developed in the area. Although Bonneville shoreline levels are mapped (from aerial photographs) to altitudes of almost 5,100 feet (1,555 m), the best shorelines are preserved north of Mona Reservoir on the west side of Juab Valley.

Mass-Movement Deposits (Qms, Qmt)

Two types of mass movement deposits are mapped: (1) talus and rock-fall debris (Qmt), and (2) landslide deposits (Qms). The talus and rock falls consist of angular blocks of resistant bedrock on or at the bases of steep slopes, typically along the Wasatch fault zone or along steep canyons in the adjacent range. The landslides are generally large and were derived in large part from mass movement in the Manning Canyon Shale, which crops out in the north part of the Mona quadrangle, or from the Arapien Shale, which is exposed in the south part of the quadrangle.

There are three massive and many smaller landslides in the mapped area: (1) the Mona landslide, which is about 1 mile (1.6 km) north of Willow Creek, (2) the Birch Creek landslide (at the mouth of Birch Creek), and (3) an unnamed landslide between Bear and Mona Creeks. Of these three, the Birch Creek landslide extends farthest into the basin as evidenced by large, lacustrine mud-covered (Qli) boulders west of U.S. Route 91 (the north-south highway through Mona). In addition, there are remnants of another (probably massive) landslide that is almost entirely buried by alluvium of Willow Creek. The rounded morphology of the landslides and the presence of erosional shorelines of the Bonneville lake cycle on the Birch Creek landslide suggest that they are latest Pleistocene or older in age.

Colluvial Deposits (Qcg)

Colluvium is present along steep slopes at the western base of the Wasatch Range. The lithology of the colluvium reflects the source material, and grain size is typically coarse (boulder to pebble size). Many of the moderate (10° to 25°) to steep (25° to 35°) slopes in the range are covered by a thin mantle of colluvium, which is unmappable at this scale.

Artificial Fill (Qfh, Qfl)

Artificial fill (Qfh) has been placed along most of the elevated sections of road in the area, along reservoirs as embankments, and in sloping areas as pads for construction projects. Only the largest of these have been mapped, and the mapped distribution does not accurately portray recent construction. In addition, areas of disturbed ground underlain by artificial fill or re-graded material (Qfl) are mapped in abandoned gravel or borrow pits.

STRUCTURE

The western half of the Mona quadrangle is occupied by Juab Valley, which is in the easternmost Basin and Range physiographic province. The valley, approximately 5 miles (8 km) wide near Mona, is bordered on the west by Long Ridge and the West Hills, and on the east by the Wasatch Range. Juab Valley is an asymmetric basin that contains as much as 5,200 feet (1,585 m) of Tertiary and Quaternary valley fill and whose deepest part consists of a graben that formed in response to extensional movement on the Wasatch fault (Zoback, 1992). The eastern half of the Mona quadrangle is occupied by the southern Wasatch Range, which is in the westernmost part of the Middle Rocky Mountains physiographic province. The southern Wasatch Range and the northern part of Juab Valley are underlain at shallow depth by the Charleston-Nebo thrust fault (Zoback, 1992) and are part of a large eastward- or southeastward-transported thrust sheet (Witkind and Weiss, 1991).

Folds

The east limb of a large anticline is exposed in the southern Wasatch Range; this limb is upright in the northern part of the Mona quadrangle but overturned to the east in exposures to the south. North of North Creek, rocks younger than the Manning Canyon Shale have moderate east dips, but south of North Creek they are mostly overturned with steep to moderate west dips. Rocks older than the Manning Canyon Shale maintain southeast dips in most exposures, suggesting differential movement of rocks above and below the Manning Canyon during folding.

North of North Creek, rocks of the Deseret Limestone, Humbug Formation, and Great Blue Limestone have been folded into an open syncline with a shallow southeast plunge. This gently folded section is separated from rocks of the Oquirrh Formation by a faulted section of Manning Canyon Shale.

Faults

High-angle faults: The Wasatch fault zone extends from southern Idaho to central Utah, a distance of 213 miles (343 km), and in the Mona quadrangle separates the Wasatch Range on the east from Juab Valley on the west (see Machette and others, 1991 for an overview of the fault zone). This range-bounding fault on the east side of Juab Valley is part of the Nephi segment of the Wasatch fault zone, which extends from Nephi northward to Payson, stepping across the Wasatch Range and into Santaquin Canyon at the latitude of Mendenhall Creek (Machette and others, 1992), about 5 miles (8 km) northeast of Mona. A minimum vertical separation of 12,000 feet (3,659 m) is estimated for the Juab Valley segment of the fault and is derived by adding the approximate depth to bedrock west of the fault (5,200 feet [1,585 m]; Zoback, 1992) and the topographic relief east of the fault (7,000 feet [2,134 m]). Examination and interpretation of gravity, seismic, and well data suggest the Wasatch fault zone in the area of the quadrangle is a planar structure with a 50 to 55 degree west dip (Zoback, 1992). Recent movement on the fault is demonstrated by fault scarps that are preserved on Holocene (and older) alluvium at the mouths of almost all drainages along the front of the Wasatch Range.

The Nephi segment has a history of recurrent faulting in the Pleistocene and Holocene. Morphometric studies (M.N. Machette, unpublished data, 1992), reconnaissance mapping (Machette and others, 1992), and trenching investigations at North Creek (Schwartz and others, 1983) and Red Canyon (Jackson, 1991) near Nephi document three episodes of surface faulting on the Nephi segment in the past 5,300 ± 300 years. Although radiocarbon dating limits the most recent faulting event to the past 1,050 years (Machette and others, 1992), the fresh appearance of the scarp and its presence on all but the most recent deposits suggests that the event may have occurred within the past 300 to 400 years. Machette and others (1991) suspect that this segment is one of the more recently active segments of the Wasatch fault zone. The amount of offset in Holocene deposits (3 events resulting in 23 feet (7 m) displacement in about 5,000 years time) (Machette and others, 1992) suggests that the Nephi segment of Wasatch fault zone has a slip rate of about 0.06 inch/year (1.4 mm/yr), which is comparable to the other active segments of the fault zone to the north. However, 150,000 to 250,000-year-old alluvial deposits (Qaf3) along the segment have only been offset 100 feet (30 m) (Machette and others, 1992), which yields a late Quaternary slip rate of about 0.005 to 0.008 inches/year (0.12-0.20 mm/yr), and suggests that the fault zone is subject to highly variable slip rates through time.

Moderate-angle, sub-bedding plane faults: Within the quadrangle, the Manning Canyon Shale has a faulted lower contact and probably has a faulted upper contact. From Couch Canyon to North Creek, the contacts of the Manning Canyon are generally subparallel to the adjacent units. North of North Creek the Manning Canyon has been faulted out and the Deseret Limestone and Humbug Formation are faulted against Oquirrh Formation.

Low-angle faults: The Charleston-Nebo thrust fault is interpreted as the structurally lowest and easternmost of the six or more imbricate thrust faults exposed in central Utah (Morris, 1983; Tooker, 1983). Rocks exposed in the Mona quadrangle are in the upper plate of the Charleston-Nebo thrust, except for an area between Birch and Gardner Creeks where a window through the Paleozoic rocks of the upper plate exposes Mesozoic rocks of the lower plate. Geologic mapping in the Nephi quadrangle (Biek, 1987, 1991) indicates the thrust occurs at an elevation of approximately 5,400 feet (1,646 m) at the south boundary of the Mona quadrangle. Proximity to the thrust probably accounts for the numerous small folds and low-angle faults that disrupt the section in the southeast corner of the Mona quadrangle. Similarly, the brecciated nature of the Oquirrh Formation outcrops at Willow Creek, 1.75 miles (2.8 km) north of the window, suggests that there also the thrust is relatively near the surface.

There is little information concerning the Charleston-Nebo thrust west of the Birch Creek window. The fault that bounds the west side of the Birch Creek window is a normal fault that dips approximately 40 degrees to the southwest. Although the most recent movement on this fault was down-to-the-southwest, it is possible that prior to dip-slip movement this fault was actually part of the Charleston-Nebo thrust and that the steep southwest dip of the fault may indicate a ramp that was present in the Charleston-Nebo thrust. Alternatively, the steep dip of the fault may have resulted from drag during movement on the Wasatch fault, which is only 0.5 mile (0.8 km) to the west.

West of the Wasatch fault, the Charleston-Nebo thrust is buried beneath fill in Juab Valley. Interpretations of seismic, gravity, and drill hole data by Zoback (1992) indicate the thrust is approximately 1 mile (1.6 km) below the valley floor in the western part of the valley, and reflectors suggest the surface of the thrust is horizontal to gently west-dipping.

Other Faults

The Mona fault is a problematic structure whose relationship to the Wasatch fault is poorly understood. The west-dipping fault is exposed between North and Starr Creeks, where it separates Cambrian carbonate rocks from Precambrian and Cambrian quartzite. Rocks in the Mona fault block are limestone and dolomite that closely resemble Middle Cambrian carbonate lithologies. Transport direction on the Mona fault is not known, but if the rocks in the Mona fault block were part of the now-missing west limb of the overturned Nebo anticline, then movement on the Mona fault would have been normal, down-to-the-west, and the Mona fault might be a splay of the Wasatch fault. Conversely, the Mona block may be a remnant of one of several small-displacement thrusts that are exposed in the upper plate of the Charleston-Nebo thrust fault in the North Oquirrh Mountains (Tooker, 1983), in which case transport on the Mona fault would have been as a southeast-directed thrust fault. Finally, the Mona fault may be an uplifted, formerly deep part of an older Wasatch fault zone that has undergone some degree of eastward rotation. If this is the case, the Mona fault represents a rotated high-angle normal fault that has been exhumed by uplift of the Wasatch Range.

Rocks near the mouth of Pole Canyon occupy a structural setting similar to that of the rocks in the Mona block. At Pole Canyon, at least three fault-bounded sections of undivided Devonian and Mississippian rocks are underlain by faults that appear to dip westward at moderate to steep angles. The plates are partially overlapping and are structurally beneath the Mona block. As with the Mona block, these plates may have been emplaced by either normal or thrust fault movement.

ECONOMIC RESOURCES

The Mount Nebo mining district includes the uplands in the eastern half of the Mona quadrangle. The district was organized in 1870 for gypsum, lead, and silver (Heikes, 1920, p. 334). Production figures indicate lead, silver, and zinc have been the principal metals produced and that the value of total production from the district is less than $400,000 (Bullock, 1962). There has not been any recorded production since 1917. The principal mines, prospects, and mineralized areas have been described in detail by Korzeb and Neubert (1984). An assessment of the mineral resource potential of the Mona quadrangle is included in a report by Sorensen and others (1983), who assign a high potential for as-yet undiscovered deposits of lead-zinc-silver, gypsum, and commercial-grade limestone and dolomite.

Lead, Zinc, and Silver

The Privateer Mine, originally known as the Eva Mine, was the principal producer in the district and is located high on the north wall of North Creek. According to Loughlin (1920, p. 332-333), galena, lead carbonate minerals, and secondary zinc minerals occurred as replacement deposits in a favorable dolomite horizon near the top of the Deseret Limestone. A recent study (Sorensen and others, 1983) estimates that approximately 1,000 tons (907 metric tons) of ore having average assay values of 3.6 oz per ton (193 gm/metric ton) silver, 2.83 percent lead, and 1.97 percent zinc remain at the Privateer. The Highland Mines are approximately 3,000 feet (915 m) north of the Privateer in a fault-bounded spur of the Deseret Limestone. According to Phillips (1940), the most profitable part of the deposit occurred in the same horizon as at the Privateer, but very little ore was recovered.

Korzeb and Neubert (1984) describe four small mines near the mouth of Bear Canyon, but do not cite production figures for them. Bullock (1962) describes these same properties as having reached peak production in 1907 and being abandoned in 1929. Further development work has been done, but production figures are not known.

Uranium

Uranium mineralization locally occurs in the lower part of the Twin Creek Limestone. North of Little Birch Creek, exploration pits in a block of lode claims expose small amounts of uranium oxidation and weathering products (Korzeb and Neubert, 1984). Because the mineral occurrence is low grade and confined to a narrow zone, the potential for undiscovered resources is low (Sorensen and others, 1983).

Gypsum

Gypsum is present at three patented claims in the Gardner Creek area where it occurs as lenses in the Arapien Shale (Korzeb and Neubert, 1984). The potential for other deposits of gypsum in the Arapien is high (Sorensen and others, 1983).

Sand and Gravel

Sand and gravel is excavated by open-pit methods at several localities in the western half of the quadrangle (Utah State Dept. Highways, 1971). Most of the gravel pits are operated by the Utah Department of Highways and serve as a source of road fill. The gravel pits are mainly in alluvial-fan deposits, but the large, re-graded borrow pit on the north side of Little Birch Creek was excavated in angular gravel (colluvium) derived from Oquirrh Formation along the adjacent Wasatch fault zone.

WATER RESOURCES

The ground-water resources of northern Juab Valley were studied and described by Hashmi (1957) and by Bjorklund (1967). Analyses of water samples collected from springs and streams near the base of the mountain front between North and Little Birch Creeks are presented by McHugh (1984). Price (1984) reports surface-water data for a large area that includes the Mona quadrangle.

North Creek, Bear Canyon, and Willow Creek are perennial creeks. Their waters are captured near the mouths of their respective canyons and directed westward by irrigation ditches. Springs present in some of the smaller drainages along the west face of the Wasatch Range flow into small pipelines that lead to Juab Valley. Mona obtains its water supply from Clover Creek Spring, located 2 miles (3 km) east of Mona in the NW1/4 section 3, T. 12 S., R. 1 E. (Bjorkland, 1967, p 45). Many springs discharge along the axis of Juab Valley from west of Birch Creek to north of Mona Reservoir.

GEOLOGIC HAZARDS

Earthquakes, mass wasting, karst development, flooding, soil liquifaction, and ground-water contamination are the principal geologic hazards in the Mona quadrangle. The Mona quadrangle is located in a broad, north-trending zone of higher-than-normal seismicity termed the Intermountain seismic belt, and is bisected by the Wasatch fault zone. Although large earthquakes have not occurred on this part of the Wasatch fault zone in historical times, fault scarps in Holocene alluvium and an average recurrence interval of about 2,500 years (Machette and others, 1992) attest to the potential for future large earthquakes and surface rupturing in the area. On the basis of the fault's paleoseismic history (Machette and others, 1991), this segment of the fault is capable of generating large earthquakes (moment magnitude 7+) in the future. In the Mona quadrangle, earthquakes originating along the Nephi segment of the Wasatch fault zone constitute the most prominent geologic hazard. Earthquakes can cause violent ground shaking, broad zones of surface rupturing, soil liquefaction, and differential settling; they also can cause rock falls, snow avalanches, landslides, and debris flows. There is a moderate potential for seismically induced soil liquefaction along the axis of Juab Valley, mostly at or below 4,980 feet (1,518 m) elevation (Anderson and others, 1990, vol. 2, pl. 2). Landslides can occur independent of earthquakes as a result of incompetent or poorly consolidated strata becoming saturated with rain or snow melt, particularly on steep, sparsely vegetated slopes.

Sinkholes and contaminated ground water are associated with areas underlain by the evaporite-rich Arapien Shale. The Arapien is exposed in the southern part of the quadrangle near Gardner Creek. Ground water moving through the Arapien can dissolve any evaporites present, causing the formation of sinkholes through surface collapse and resulting in the contamination of the ground water.

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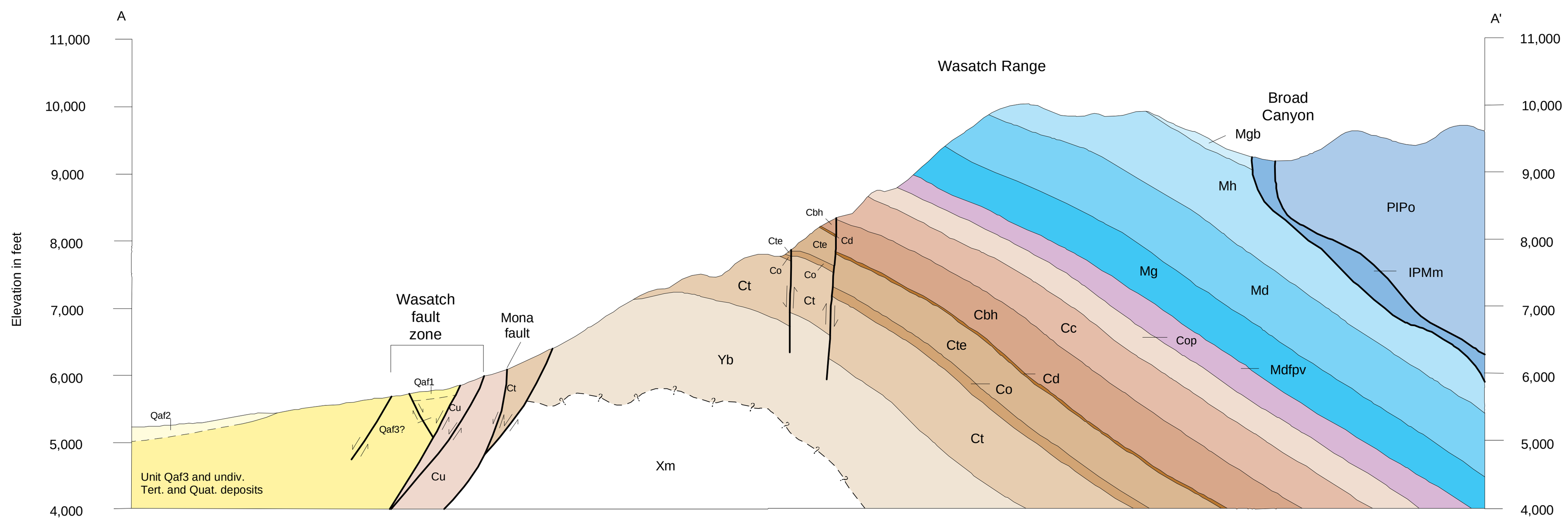

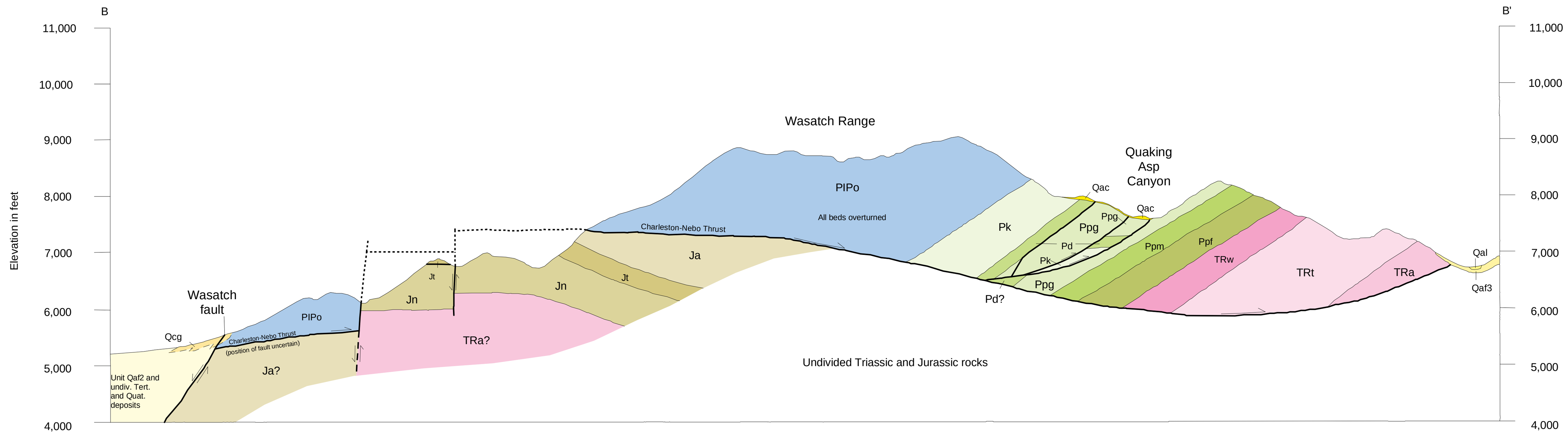

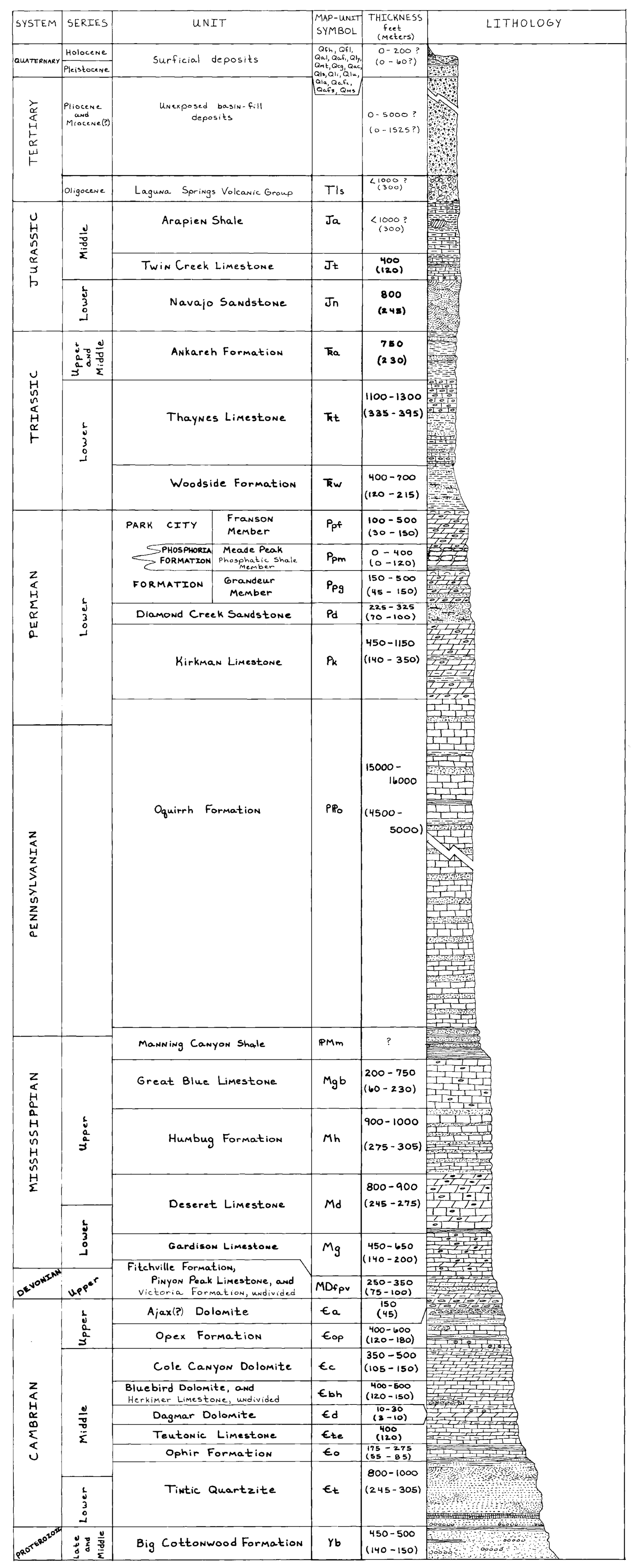

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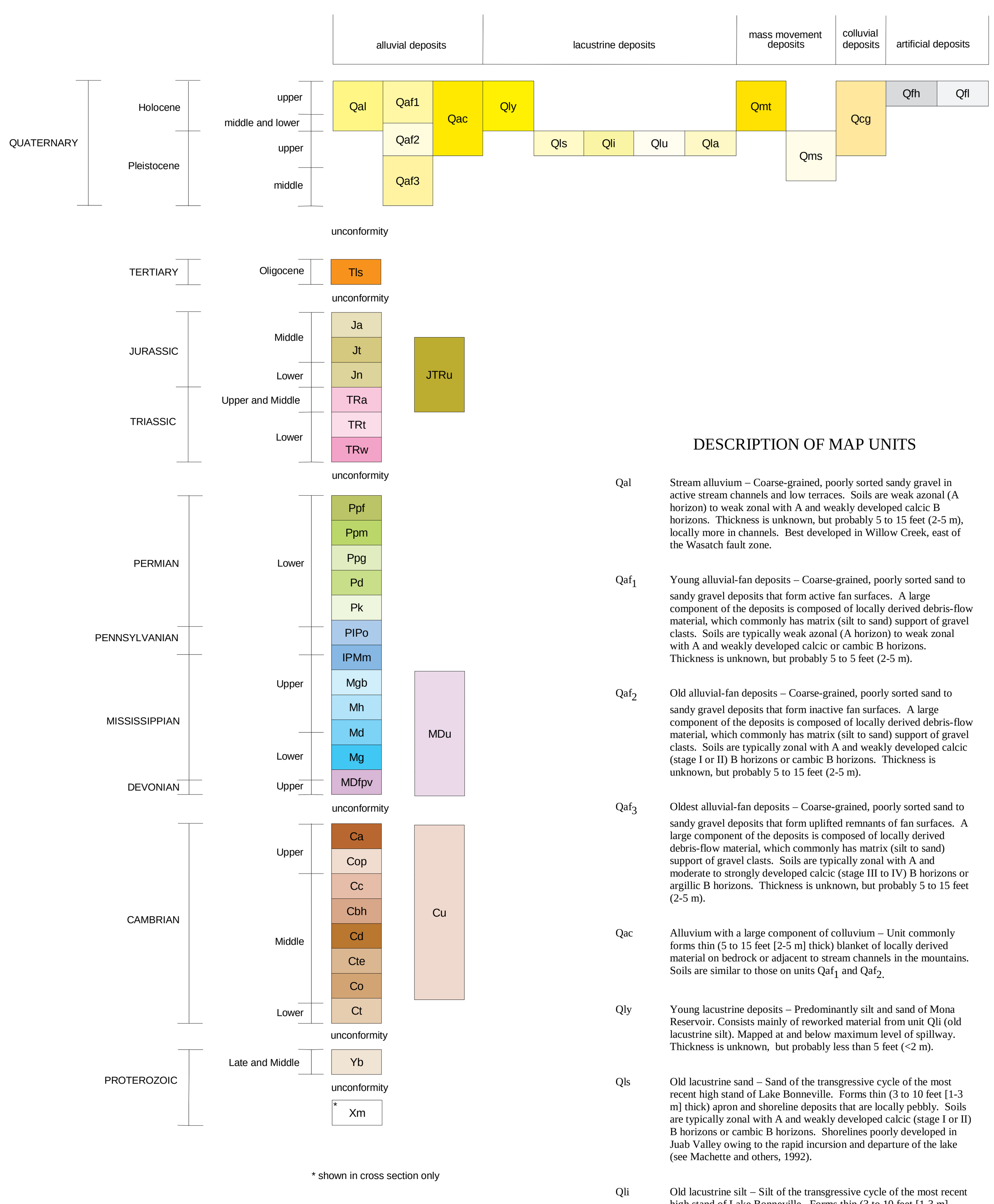

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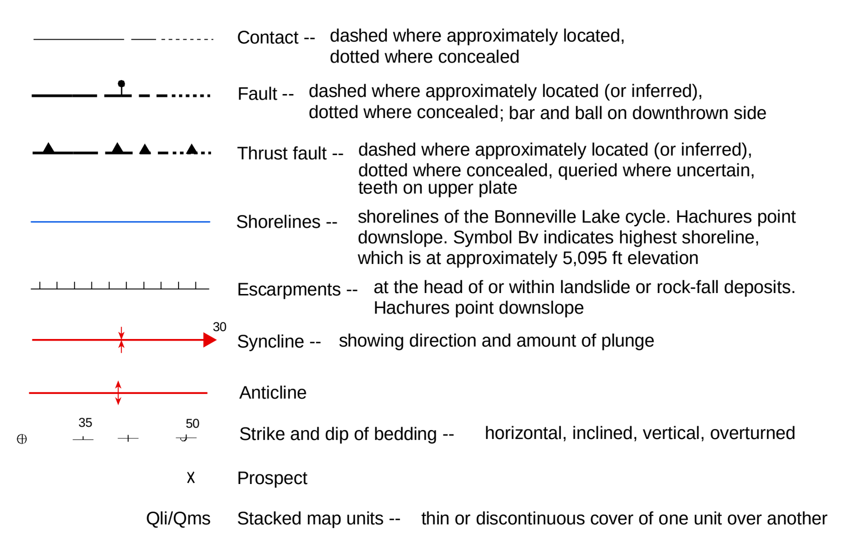

DESCRIPTION OF MAP UNITS

Qal — Stream alluvium – Coarse-grained, poorly sorted sandy gravel in active stream channels and low terraces. Soils are weak azonal (A horizon) to weak zonal with A and weakly developed calcic B horizons. Thickness is unknown, but probably 5 to 15 feet (2-5 m), locally more in channels. Best developed in Willow Creek, east of the Wasatch fault zone.

Qaf_1 — Young alluvial-fan deposits – Coarse-grained, poorly sorted sand to sandy gravel deposits that form active fan surfaces. A large component of the deposits is composed of locally derived debris-flow material, which commonly has matrix (silt to sand) support of gravel clasts. Soils are typically weak azonal (A horizon) to weak zonal with A and weakly developed calcic or cambic B horizons. Thickness is unknown, but probably 5 to 5 feet (2-5 m).

Qaf_2 — Old alluvial-fan deposits – Coarse-grained, poorly sorted sand to sandy gravel deposits that form inactive fan surfaces. A large component of the deposits is composed of locally derived debris-flow material, which commonly has matrix (silt to sand) support of gravel clasts. Soils are typically zonal with A and weakly developed calcic (stage I or II) B horizons or cambic B horizons. Thickness is unknown, but probably 5 to 15 feet (2-5 m).

Qaf_3 — Oldest alluvial-fan deposits – Coarse-grained, poorly sorted sand to sandy gravel deposits that form uplifted remnants of fan surfaces. A large component of the deposits is composed of locally derived debris-flow material, which commonly has matrix (silt to sand) support of gravel clasts. Soils are typically zonal with A and moderate to strongly developed calcic (stage III to IV) B horizons or argillic B horizons. Thickness is unknown, but probably 5 to 15 feet (2-5 m).

Qac — Alluvium with a large component of colluvium – Unit commonly forms thin (5 to 15 feet [2-5 m] thick) blanket of locally derived material on bedrock or adjacent to stream channels in the mountains. Soils are similar to those on units Qaf_1 and Qaf_2.

Qly — Young lacustrine deposits – Predominantly silt and sand of Mona Reservoir. Consists mainly of reworked material from unit Qli (old lacustrine silt). Mapped at and below maximum level of spillway. Thickness is unknown, but probably less than 5 feet (<2 m).

Qls — Old lacustrine sand – Sand of the transgressive cycle of the most recent high stand of Lake Bonneville. Forms thin (3 to 10 feet [1-3 m] thick) apron and shoreline deposits that are locally pebbly. Soils are typically zonal with A and weakly developed calcic (stage I or II) B horizons or cambic B horizons. Shorelines poorly developed in Juab Valley owing to the rapid incursion and departure of the lake (see Machette and others, 1992).

Qli — Old lacustrine silt – Silt of the transgressive cycle of the most recent high stand of Lake Bonneville. Forms thin (3 to 10 feet [1-3 m] thick) apron that formed in offshore and nearshore quiet-water conditions. Soils are typically zonal with A and weakly developed calcic (stage I or II) B horizons or cambic B horizons.

Qlu — Old lacustrine deposits, undivided – Predominantly silt and sand of the transgressive cycle of the most recent high stand of Lake Bonneville. Mapped in areas of poor exposure. Soils are similar to those on unit Qls (old lacustrine sand). Thickness is unknown, but probably less than 15 feet (<5 m).

Qla — Old lacustrine and alluvial deposits, undivided – Unit mapped where lacustrine deposits are thin (less than 3 feet [<1 m] thick) or where units intertongue at unmappable scales. Soils are similar to those on unit Qls (old lacustrine sand). Thickness is unknown, but probably less than 15 feet (<5 m).

Qmt — Talus (rock-fall deposits) – Angular blocks of resistant bedrock on or at the bases of steep slopes, typically along the Wasatch fault zone or along steep canyons in the adjacent range. Older deposits generally have abundant cover of lichens or other weathering features. Thickness is variable, commonly 5 to 15 feet (2-5 m) except where thicker at the bases of slopes.

Qms — Landslide deposits – There are three massive and many smaller landslides in the mapped area: (1) the Mona landslide, about 1 mile (1.6 km) north of Willow Creek, which derived from mass movement in the Manning Canyon Shale, (2) the Birch Creek landslide (at the mouth of Birch Creek), which probably derived from mass movement in the Arapien Shale, and (3) an unnamed landslide between Bear and Mona Creeks. In addition, there are remnants of another (probably

Qcg — Gravelly colluvium – Poorly sorted, angular to rounded gravel with matrix of sand and silt. Commonly forms thin (5 to 15 feet [2-5 m] thick) blanket of locally derived material on bedrock at base of steep parts of range front. Soils are similar to those on units Qaf_1 and Qaf_2 (alluvial-fan deposits).

Qfh — Artificial fill – Mapped along highways and railroad grades.

Qfl — Disturbed ground – Areas of artificial fill or re-graded material in abandoned gravel or borrow pits.

Tls — Laguna Springs Volcanic Group – Dark- to very dark-gray and red or tan andesitic agglomerate; andesitic clasts consist of small phenocrysts of plagioclase, biotite, hornblende, and augite in a very fine-grained to aphanitic groundmass. Thickness in quadrangle is not known but elsewhere on Long Ridge may be as thick as 1,000 feet (305 m).

Ja — Arapien Shale – Thin-bedded gray-green to olive-green argillaceous limestone; local red mudstone, gray limestone, and gypsum. Thickness in quadrangle is not known.

JTRu — Twin Creek Limestone, Navajo Sandstone, and Ankareh Formation, undivided.

Jt — Twin Creek Limestone – Upper half of unit: thin bed of red mudstone underlain by dark gray-brown to light- and medium-gray limestone. Lower half of unit: interbedded olive-green argillaceous limestone and brown sandstone, underlain by, in descending order, argillaceous limestone, finely crystalline limestone, and oolitic limestone, all of which weather to brown or olive gray. All limestones are locally fossiliferous. Thickness is approximately 400 feet (120 m).

Jn — Navajo Sandstone – Buff to tan quartzitic sandstone; red or reddish-brown near base, massive in outcrop, locally with large-scale cross-bedding. Thickness may be as much as 800 feet (245 m).

TRa — Ankareh Formation – Reddish-brown to tan mudstone, siltstone, and sandstone. Incomplete thickness in quadrangle is 750 feet (230 m).

TRt — Thaynes Limestone – In descending order: light-gray-weathering limestone; greenish-brown weathering limestone; red-weathering siltstone and sandstone; greenish- to reddish-brown-weathering argillaceous limestone, locally with interbedded reddish-brown sandstone and siltstone. All limestone is flaggy weathering and contains brown and white chert nodules. Thickness is 1,100 to 1,300 feet (335-395 m).

TRw — Woodside Formation – Interbedded mudstone, siltstone, and micaceous quartzitic sandstone, all weathering to shades of red, reddish gray, and light brown. Underlies vegetated saddles and slopes. Apparent thickness varies from 400 to 700 feet (120-215 m) due to structural complications.

Ppf — Franson Member, Park City Formation – Medium- to very thick-bedded, light-gray- or tan-weathering dolomite, commonly with white or tan chert nodules; uppermost part of unit marked by light-gray fossiliferous limestone with abundant brachiopods and bryozoans. Apparent thickness varies from less than 100 to 500 feet (<30-150 m) due to structural complications.

Ppm — Meade Peak Phosphatic Shale Member, Phosphoria Formation – Thinly-interbedded tan to brown dolomite and black chert, present in approximately equal amounts. Pelletal or oolitic phosphate at base of unit. Exposed thickness varies from 0 to 400 feet (0-120 m).

Ppg — Grandeur Member, Park City Formation – Well-bedded, light- to medium-gray dolomite and cherty dolomite interbedded with quartzitic sandstone with well-sorted and well-rounded grains. Small nodules of white chert common in dolomite throughout unit, except near base, where dolomite is tan and contains abundant black chert. Uppermost part of unit marked by light-gray fossiliferous limestone. Thickness varies from 150 to 500 feet (45-150 m) due to structural complications.

Pd — Diamond Creek Sandstone – Yellow- to tan-weathering, calcareous, quartzitic sandstone with well-rounded and well-sorted grains; massive in outcrop, locally cross-bedded. Exposed thickness varies from 450 to 1,150 feet (140-350 m).

PIPo — Oquirrh Formation – Interbedded limestone and sandstone with minor amounts of shale. Limestone is thin- to thick-bedded, light-gray- or blue-gray-weathering; silty or sandy limestone weathers to tan or brown. Quartzitic sandstone is medium to coarse grained, weathers to gray or tan. Upper part of unit includes tan-weathering silty limestone with locally abundant fusulinids. Thickness in Mona quadrangle is 15,000 to 16,000 feet (4,573-4,878 m).

IPMm — Manning Canyon Shale – Very dark-brown to black mudstone and shale with interbedded brown to greenish-brown quartzitic sandstone composed of well-sorted, well-rounded, coarse- to medium-size quartz grains. Thickness not known, but may be about 1,000 feet (305 m).

MDu — Great Blue Limestone, Humbug Formation, Deseret Limestone, Gardison Limestone, Fitchville Formation, Pinyon Peak Limestone, and Victoria Formation, undivided.

Mgb — Great Blue Limestone – Thin- to medium-bedded light gray or blue-gray limestone; massive in outcrop, locally fossiliferous and cherty. Thickness varies from 200 to 750 feet (60-230 m) due to structural complications.

Mh — Humbug Formation – Interbedded sandstone, limestone, and dolomite. Tan- to reddish-brown-weathering sandstone mostly consists of well-rounded, medium-size quartz grains and calcareous cement; thin- to medium-bedded limestone and dolomite are light- to medium-gray or blue-gray weathering; silty or sandy carbonate rocks are tan weathering. Thickness ranges from 900 to 1,000 feet (275-305 m).

Md — Deseret Limestone – Interbedded dolomite and limestone; both are light- to medium-gray, well-bedded, coarsely crystalline, and contain abundant lenses or beds of black chert. Black mudstone and shale with dark phosphatic pelletal and oolitic material at base of unit. Thickness varies from 800 to 900 feet (245-275 m).

Mg — Gardison Limestone – Platy-weathering, coarsely-crystalline, locally very fossiliferous, medium- to dark-gray or blue-gray limestone and dolomite, both with abundant beds of black chert. Thickness varies from 450 to 650 feet (140-200 m) with an average of 550 to 600 feet (170-185 m).

MDfpv — Fitchville Formation, Pinyon Peak Limestone, and Victoria Formation, undivided – Upper and lower dolomite intervals, separated by 5- to 10-foot-thick (1.5-3 m) interval of quartzite. Upper dolomite interval is light gray, argillaceous, silty and sandy near base, and includes several zones of very finely crystalline, medium blue-gray limestone. Middle quartzite is thin bedded, well bedded, with very well-sorted, medium to coarse quartz grains. Lower dolomite interval is light gray, medium to coarsely crystalline, locally fossiliferous, and slightly argillaceous near the base. Thickness varies from 250 to 350 feet (75-100 m).

Cu — Ajax(?) Dolomite, Opex Formation, Cole Canyon Dolomite, Bluebird Dolomite, Herkimer Limestone, Dagmar Dolomite, Teutonic Limestone, and Ophir Formation, undivided.

Ca — Ajax(?) Dolomite – Thin-bedded, coarsely-crystalline, medium-gray dolomite with very abundant, discontinuous thin beds of gray to white chert. Thickness is 150 feet (45 m).

Cop — Opex Formation – Interbedded limestone and shale with minor dolomitic sandstone and argillaceous dolomite. Limestone is thin bedded, light gray to light blue gray, locally oolitic, with abundant intraformational conglomerate. Shale and argillite are medium gray and weather to tan, buff, and yellow. Thickness is generally 400 to 600 feet (120-180 m).

Cc — Cole Canyon Dolomite – Zones of medium-bedded to locally laminated, very light-gray to creamy-white dolomite that alternate with zones of medium- to thick-bedded, medium-gray to very dark-gray, commonly mottled dolomite, locally with small twig-like structures of coarsely crystalline white dolomite. Thickness varies from 350 to 500 feet (105-150 m).

Cbh — Bluebird Dolomite and Herkimer Limestone, undivided – Upper part consists of medium- to thick-bedded, very dark-gray dolomite with small twig-like structures of coarsely crystalline white dolomite. Lower part is interbedded, medium- to dark-gray or blue-gray, thin- to medium-bedded dolomite and limestone, locally oolitic, with

Cte — Teutonic Limestone – Thin- to medium-bedded, dark-gray to blue-gray limestone and interbedded dolomite, commonly with interbedded gray-, tan-, and orange-weathering argillaceous limestone. Thickness is approximately 400 feet (120 m).

Co — Ophir Formation – Upper and lower shale members separated by medial limestone member. Upper shale member is thin bedded, micaceous, slightly calcareous, and greenish gray. Medial limestone member is thin-bedded, dark blue-gray limestone and interbedded gray to grayish-tan quartzitic sandstone. Lower shale member is greenish brown to greenish gray, with thinly-interbedded dark blue-gray limestone near its top and thinly-interbedded slightly-calcareous sandstone near its base. Thickness varies from 175 to 275 feet (55-85 m).

Ct — Tintic Quartzite – Pink, buff, gray, and white quartzite that is well-bedded, texturally mature, commonly cross-bedded, and locally conglomeratic. Includes dark-maroon to dark-purple altered basalt(?) flow near base. Thickness varies from 800 to 1,000 feet (245-305 m).

Yb — Big Cottonwood Formation – Shale, siltstone, sandstone, quartzite, and quartz-pebble conglomerate, generally dark-colored in shades of gray, green, maroon, and purple. Exposed thickness in quadrangle is 450 to 500 feet (140-150 m).

Xm — Early Proterozoic high-grade metamorphic rocks – Shown in cross section only.