INTERIM GEOLOGIC MAP OF UNCONSOLIDATED DEPOSITS IN THE PAYSON LAKES QUADRANGLE, UTAH COUNTY, UTAH

by

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INTRODUCTION

Location and Geographic Setting

The Payson Lakes quadrangle covers part of the Wasatch Range south of Utah Valley (figure 1). The Wasatch Range in the quadrangle includes the northeastern part of the Mount Nebo Wilderness. The centerpiece of the Wilderness is Mount Nebo, the highest peak in the Wasatch Range, which rises to 11,928 feet (3636 m) about 3.5 miles (5.6 km) south of the southwest corner of the Payson Lakes quadrangle. The Loafer Mountain State Wildlife Management Area is in the north-central and northeast part of the quadrangle, and the Uinta National Forest occupies most of the remainder of the quadrangle, including Dry Mountain, which forms a prominent ridge in the Wasatch Range on the western edge of the quadrangle. Most privately held land in the quadrangle is in its northwest corner, which includes part of the community of Spring Lake.

The Payson Lakes quadrangle is largely uninhabited and is a popular recreational destination. One of its attractions is the Nebo Loop Scenic Byway, which traverses the central and eastern part of the quadrangle. The Byway runs between the cities of Payson to the north and Nephi to the south, provides access to lakes and campgrounds, and includes several scenic overlooks. The Byway runs through Payson Canyon in the northern part of the quadrangle, and is also accessible from Santaquin to the west through Santaquin Canyon. Peteetneet Creek in Payson Canyon and Summit Creek in Santaquin Canyon are the primary streams in the quadrangle, flowing respectively north and northwest from the Wasatch Range into Utah Valley. U.S. Interstate 15, the major transportation corridor in the region, runs diagonally from southwest to northeast through Payson and Santaquin, northwest of the Payson Lakes quadrangle.

Previous Investigations

Although geologic studies of the Payson Lakes quadrangle began almost a century ago, most focused on bedrock geology and geologic structure, providing only a superficial overview of the geology of unconsolidated deposits. The earliest published study was an investigation of lamprophyre dikes in the Wasatch Range (Loughlin, 1919). Several theses and dissertations mapped the geology of parts of the Wasatch Range in the Payson Lakes quadrangle (Eardley, 1930; Metter, 1955; Demars, 1956; Peterson, 1956; and Le Vot, 1984), and Rigby (1959) and Witkind (1994) mapped selected areas of the Payson Lake quadrangle at scales varying from 1:26,000 to 1:54,000. Hintze (1962) and Witkind and Weiss (1991) compiled geologic maps of the region that include the Payson Lakes quadrangle at respective scales of 1:125,000 and 1:100,000, providing valuable overviews of regional geology, although many questions remain regarding stratigraphic relationships and geologic structure.

Surficial geologic maps by Bissell (1963) (1:48,000 scale) and Miller (1982) (1:100,000 scale) were early attempts to identify the texture of unconsolidated deposits of Utah Valley, which extend into the northwest corner of the Payson Lakes quadrangle near Spring Lake. Those studies placed the deposits in a stratigraphic framework of map units, but interpretations of Quaternary geology, and particularly of Lake Bonneville stratigraphy, continued to evolve until Machette (1992) mapped the surficial geology of eastern Utah Valley (figure 2). Machette (1992) also mapped unconsolidated deposits in the Wasatch Range in the northern one-third of the Payson Lakes quadrangle, but not in detail. The contacts between some lacustrine units mapped by Miller (1982) and Machette (1992) were interpreted from the U.S. Soil Conservation Service (SCS) soil maps (Swenson and others, 1972), but the SCS maps were not detailed enough to aid my mapping of the Payson Lakes quadrangle.

The geology of several adjacent 7-1/2 minute quadrangles has been mapped at a scale of 1:24,000 (figure 2). These include the Spanish Fork Peak (Rawson, 1957; Baker, 1972), Mona (Felger and others, 2004), Spanish Fork (Solomon and others, 2007), and West Mountain (Clark, 2009) quadrangles. I also mapped the geology of unconsolidated deposits in the Santaquin quadrangle (Solomon, 2010) as well as the Payson Lakes quadrangle. Differences between geology along the edges of the Payson Lakes and some adjacent quadrangles are mostly due to the greater level of detail mapped in the Payson Lakes quadrangle, but in a few cases are due to different geologic interpretations.

Purpose and Scope

The population of the Payson Lakes quadrangle is largely transient because land use is primarily recreational. However, the quadrangle is only a short commute from the urbanized Wasatch Front, and its rapidly growing population will place increased demands on fragile environments and road usage. The steep terrain is subject to slope instability and landsliding, and maintaining the safety of people in such terrain requires information about the nature and distribution of potentially unstable geologic materials. This geologic map will serve as a guide to the distribution of unconsolidated geologic deposits that may be subject to landsliding and other geologic hazards. Mapping of bedrock geology, including geologic structures such as faults, was beyond the scope of this project.

Because I mapped unconsolidated deposits, and older maps concentrated on bedrock geology, my map includes significant revisions from previous studies. The most prominent revision is the identification of numerous large landslides throughout the quadrangle. These landslides are mostly derived from the Paleocene and Upper Cretaceous North Horn Formation and Oligocene and Eocene volcanic and volcaniclastic sedimentary rocks, and account for the numerous small lakes in the quadrangle that are found in closed depressions within hummocky terrain characteristic of landslides. I also reinterpreted deposits in upper Payson Canyon and on the northwest flank of Dry Mountain, originally mapped respectively by Peterson (1956) and Demars (1956) as complexly faulted Paleozoic rocks, as mass-movement deposits of large bedrock blocks (QTmb). These mass-movement deposits, as well as some landslides derived from Cretaceous and younger rocks, were likely emplaced downslope beginning in the late Tertiary, coincident with the uplift of mountain ranges along the Wasatch fault zone. Although Hintze (1962) mapped some glacial deposits in the Wasatch Range, I mapped additional glacial deposits and glacial geomorphic features. Finally, I remapped the Quaternary geology of Machette (1992) between Loafer and Payson Canyons and near Spring Lake, providing additional detail, new interpretations of the age of some pre-Bonneville alluvial-fan deposits, and new configurations of some strands of the active Wasatch fault zone.

Mapping was performed between July 2009 and June 2010 using standard field mapping methods. I used 1:20,000-scale black-and-white aerial photographs flown in

1965 and 1:15,840-scale color aerial photographs flown in 1988 and 1989 for the U.S. Department of Agriculture to map the geology of unconsolidated deposits prior to most development in the quadrangle. Air photo mapping was later field checked.

Geologic Summary

Bedrock Geology

Bedrock (R) is exposed in the Wasatch Range south of Utah Valley. The oldest bedrock consists of sedimentary rocks of Permian to Proterozoic age carried on thrusts of the Charleston-Nebo salient in the Cordilleran fold and thrust belt (Hintze, 1962; Witkind and Weiss; 1991; Constenius and others, 2003). These rocks are locally overlain by the Paleocene and Upper Cretaceous North Horn Formation and by Oligocene and Eocene volcanic and volcaniclastic sedimentary rocks. Strata were deformed by Early Cretaceous to late middle Eocene (ca. 100-40 Ma) contractional folding and faulting of the Sevier orogeny (Willis, 1999; DeCelles, 2006; Schelling and others, 2007), extensional faulting during late Eocene to middle Miocene (ca. 38-18 Ma) "collapse" (Constenius, 1996; Constenius and others, 2003), and middle Miocene to recent (ca. 17-0 Ma) Basin-and-Range faulting (see, for example, Zoback and others, 1981; Smith and Bruhn, 1984). The most prominent and youngest aspect of extensional faulting in the map area is the Wasatch fault zone, which separates Utah Valley from the Wasatch Range.

Post-Bedrock Geology

Deposits younger than bedrock in the Payson Lakes quadrangle range in age from Pliocene (?) to Holocene. The oldest of these deposits are large rotated bedrock blocks (megabreccias) (QTmb) and translational earth and debris slides (QTms) that have moved downslope along steep range fronts. The bedrock blocks are composed largely of Paleozoic quartzite, dolomite, and limestone on the northwest margin of Dry Mountain near Spring Lake, and in upper Payson Canyon. The largest of the earth and debris slides are derived from the North Horn Formation and younger tuffaceous and volcaniclastic sedimentary rocks east of Dry Mountain, although several smaller deposits are derived from Paleozoic rocks. Displacement of rotational and translational mass-movement deposits is thought to have started in the late Tertiary (possibly Pliocene) and continued intermittently during the Pleistocene as movement along the Wasatch fault zone uplifted the range front relative to the valleys.

Coalesced middle to upper Pleistocene alluvial-fan deposits (Qaf_4, Qaf_5) underlie piedmont slopes on valley margins. The fans were deposited during the interlacustral episodes between the last three major lake cycles in the Bonneville Basin (the Pokes Point, Little Valley, and Bonneville lake cycles) and during episodes older than the Pokes Point lake cycle (Machette, 1992). The Pokes Point lake cycle occurred during marine oxygen-isotope stage 12, about 430,000 years ago (Oviatt and others, 1999), and the Little Valley lake cycle, largely contemporaneous with the Bull Lake glaciation (see Chadwick and others, 1997), occurred late in marine oxygen-isotope stage 6, which ended about 130,000 years ago (Scott and others, 1983). The highest levels of the Pokes Point and Little Valley lake cycles are below the elevation of the subsequent Lake

Bonneville highstand (Scott and others, 1983) and thus are buried throughout most of the Bonneville basin. Remnants of the fans are exposed above the highest Lake Bonneville shoreline on the piedmont between Payson and Loafer Canyons (table 1).

Surficial deposits associated with late Pleistocene Lake Bonneville (Qlgb, Qlsb, Qlmb, Qlgp) are mapped near Spring Lake in the northwest corner of the Payson Lakes quadrangle. Lake Bonneville was largely contemporaneous with the last glacial advance, the Pinedale glaciation (marine oxygen-isotope stage 2; Oviatt and others, 1992, 1999). Lips and others (2005) estimated that the Pinedale maxima occurred from about 17 to 15 ka based on ^{10}Be exposure ages measured from moraines at Little Cottonwood Canyon in the Wasatch Range near Salt Lake City. Glacial deposits of Bull Lake and/or Pinedale age (Qg) are found southwest of Santaquin Canyon in the southwest corner of the quadrangle, and east of Loafer Canyon in the northeast corner of the quadrangle.

Other surficial deposits in the quadrangle are mostly younger than Lake Bonneville and reflect post-glacial landscape evolution. Catastrophic overflow of the lake's threshold in southern Idaho (Jarrett and Malde, 1987; O'Conner, 1993) and warming climatic conditions reduced the size of Lake Bonneville as it regressed beyond the boundaries of the Payson Lakes quadrangle. With the regression of Lake Bonneville, streams incised in response to the lowering base level, depositing alluvium (Qal_1, Qal_2, Qaly) in channels and floodplains and alluvial fans (Qaf_1, Qaf_2, Qafy) at canyon mouths. Locally, steeper slopes failed (Qms), and parts of older, weakened landslide deposits reactivated and moved downslope, with some slope failures perhaps associated with earthquakes on the Wasatch fault zone; this process of landsliding continues sporadically today. Wind eroded fine-grained desiccated Bonneville lakebeds, locally depositing a thin but widespread mantle of calcareous loess on other stable geomorphic surfaces. The loess is friable to moderately firm, homogenous, nonstratified, and porous, and forms steep to vertical faces where exposed in stream cuts; most argillic B horizons of late Pleistocene-age soils in the region are formed in this loess (Machette, 1992), which is typically 3 to 5 feet (1-1.5 m) thick.

Lake Bonneville

Although deposits and shorelines of Pleistocene Lake Bonneville dominate the regional surficial geology, they are mapped only in the northwest corner of the Payson Lakes quadrangle. However, relationships between Lake Bonneville deposits and shorelines and other unconsolidated deposits in adjacent quadrangles are useful in determining the age of such deposits in the Payson Lakes quadrangle. This section places those relationships, discussed in relevant map unit descriptions, in a regional context.

Lake Bonneville was a large pluvial lake that covered much of northwestern Utah and adjacent parts of Idaho and Nevada. The lake began to rise above levels comparable to those of Holocene Great Salt Lake after about 35,000 calendar years ago (CRONUS-Earth Project, 2005). Four regionally extensive shorelines of Lake Bonneville are found in the Bonneville Basin. Gilbert (1890) identified the earliest three of these shorelines (the Stansbury, Bonneville, and Provo shorelines) in the first comprehensive study of Lake Bonneville over a century ago, and Eardley and others (1957) later defined the youngest shoreline (the Gilbert shoreline). Currey (1980) published an important summary of the lake, refining many previously published interpretations of lake-level change in the Bonneville basin, and mapped at a reconnaissance scale all four major shorelines in the vicinity of Great Salt Lake. Oviatt and Thompson (2002) reviewed additions to the geologic literature of Lake Bonneville published after 1980, summarizing many recent changes in the interpretation of Lake Bonneville radiocarbon chronology, and research has continued since. I include more recent changes in Lake Bonneville chronology in table 1, which shows references for the following discussion of the lake.

Each shoreline is actually a composite of multiple shorelines that formed as the lake level fluctuated within a short vertical interval. Only the two highest and most prominent (the Bonneville and Provo shorelines) are present in the Payson Lakes quadrangle. The earliest of the regional shorelines is the Stansbury, which resulted from a climatically induced lake-level oscillation from about 27,000 to 24,000 years ago (unless otherwise noted, dates in this section are calendar dates) during expansion (transgression) of Lake Bonneville. The Stansbury shoreline formed at elevations below those of the Payson Lakes quadrangle.

The lake continued to rise, entering the quadrangle from the northwest at an elevation of about 4750 feet (1450 m). In the Bonneville Basin, the lake reached its highest level about 18,300 years ago near Zenda, in southern Idaho. This highstand created the Bonneville shoreline, which can be traced over most of northwest Utah (table 1). In the Payson Lakes quadrangle, the Bonneville shoreline forms a bench on the northwest margin of Dry Mountain.

About 17,400 years ago, catastrophic overflow and rapid downcutting through the Zenda threshold resulted in lowering of the lake by 340 feet (100 m) (Jarrett and Malde, 1987), perhaps in less than one year (O'Conner, 1993). Lake Bonneville then stabilized at a new lower threshold near Red Rock Pass, Idaho. At this lower level the lake etched the Provo shoreline, which in the Payson Lakes quadrangle is only mapped in its northwest corner. The lake oscillated at or near the Provo level as intermittent landsliding and subsequent scour of alluvium in the outlet channel near Red Rock Pass caused the lake level to fluctuate (Currey and Burr, 1988).

About 14,600 years ago, climatic factors induced further lowering of the lake level within the Bonneville basin (Godsey and others, 2005), the lake level eventually fell below elevations in the Payson Lakes quadrangle, and levels never rose to such elevations again. As Lake Bonneville fell below the elevation of the natural threshold of Utah Valley at the northern end of the valley, Utah Lake became isolated from the main body of Lake Bonneville (Machette, 1992). By about 13,500 years ago, the level of Lake Bonneville had fallen below the elevation of present Great Salt Lake (Currey and others, 1988; Godsey and others, 2005), but a subsequent minor expansion of Lake Bonneville between about 12,500 to 11,500 years ago formed the Gilbert shoreline (Oviatt and others, 2005). During the Gilbert expansion of Lake Bonneville, Utah Lake drained into Lake Bonneville through the Jordan River, thus preventing the Gilbert expansion from reaching Utah Valley (Machette, 1992). However, the Pleistocene highstand of Utah Lake formed at this time north of the Payson Lakes quadrangle (table 1). After formation of the Gilbert shoreline, Lake Bonneville fell to near the current level of Great Salt Lake, leaving Great Salt Lake and Utah Lake as its two most prominent remnants.

Isostatic rebound following overflow of Lake Bonneville, as well as displacement along the Wasatch fault zone, uplifted regionally extensive shorelines in the Bonneville basin (Crittenden, 1963; Currey, 1982; Bills and others, 2002). The amount of isostatic uplift increases toward the center (deepest part) of the basin where the volume of removed water was greatest; Crittenden (1963) originally estimated a maximum isostatic uplift of 210 feet (64 m) near the Lakeside Mountains west of Great Salt Lake, but Currey (1982) estimated maximum isostatic uplift of 240 ft (74 m) using additional topographic data and aerial photographs. Machette (1992) reported combined isostatic and fault uplift of the Bonneville and Provo shorelines as much as 110 feet (34 m) and 65 feet (20 m), respectively, along the Wasatch fault zone in eastern Utah Valley. In the Payson Lakes quadrangle, near the margin of the Bonneville Basin where water depth was much less than at the basin's center, uplift of both shorelines was significantly less than that recorded by both Currey (1982) and Machette (1992). The maximum elevation of the Bonneville shoreline in the Payson Lakes quadrangle (in the footwall of the Wasatch fault zone near Spring Lake) is about 5150 feet (1570 m) compared to its threshold elevation of 5092 feet (1552 m) at Zenda, and the maximum elevation of the Provo shoreline in the quadrangle (in the hanging wall of the Wasatch fault zone near Spring Lake) is about 4750 feet (1450 m) compared to its threshold elevation of 4737 feet (1444 m) at Red Rock Pass (table 1). Thus, uplift of the Bonneville and Provo shorelines in the quadrangle is about 58 feet (18 m) and 13 feet (4 m), respectively.

Paleoseismology

Utah Valley is a structural basin whose eastern margin was formed by late Cenozoic (younger than 18 Ma) displacement along the Wasatch fault zone (WFZ). The WFZ is 230 miles (370 km) long, extends from southern Idaho to central Utah, and comprises 10 segments (Machette and others, 1991) that are each independently capable of generating large surface-rupturing earthquakes. Parts of two segments, the Provo and Nephi segments, are mapped in the Payson Lakes quadrangle. A large earthquake generated by either segment would produce significant seismic hazards.

The boundary between the Provo and Nephi segments is an en echelon, overlapping right step. The Provo segment (Machette, 1992) bounds most of the eastern side of Utah Valley, and its southern end extends southward into Payson Canyon, in the north-central part of the Payson Lakes quadrangle. The Nephi segment (Harty and others, 1997) bounds the eastern side of the southern tip of Utah Valley, extends beyond the Provo segment west of Dry Mountain in the northwest corner of the Payson Lakes quadrangle, and continues into Juab Valley in the Santaquin quadrangle (Solomon, 2010).

Two paleoseismic investigations were conducted on the Provo segment in the adjacent Spanish Fork quadrangle (Solomon and others, 2007). The first investigation was conducted in 1987, when the U.S. Bureau of Reclamation (USBR) excavated two trenches on a valley splay of the Provo segment (Woodland Hills fault), northwest of the mouth of Maple Canyon. The trenches revealed evidence for three or four surface-faulting events since about 130 ka, based on correlations of faulted alluvial-fan soils with similar soils in the area (Machette, 1992; Machette and others, 1992). The slip rate at the site was estimated to be from 0.01-0.02 mm/year with an average recurrence interval of about 40 to 65 thousand years (Machette and others, 1992). Movement on the fault splay near the Bonneville shoreline apparently occurred during only some of the events on the main fault to the east, with the most recent event on the splay occurring about 1.0 ka, prior to the most recent event (about 0.6 ka) on the main fault near Mapleton in the Spanish Fork Peak quadrangle (Lund, 2005; see also Machette, 1992, p. 11).

The USBR also excavated two trenches in alluvial-fan deposits on the main fault at the mouth of Water Canyon, about 1.25 miles (2 km) northeast of the previous trenches

(Ostenaa, 1990). The Water Canyon trenches revealed evidence for at least three Holocene surface-faulting events. Two events occurred in the last 1000 years, conflicting with evidence of only one event in the same time period from other trenches on the Provo segment. This conflict may be explained by fault overlap of the Nephi and Provo segments, with surface-faulting events on both segments occurring at the Water Canyon site (Ostenaa, 1990; Machette, 1992).

Two recent paleoseismic investigations were also conducted on the Nephi segment to resolve questions raised in earlier studies related to the timing, displacement, and magnitude of prehistoric surface-faulting earthquakes. The northern end of the Nephi segment in the adjacent Santaquin quadrangle (Solomon, 2010) consists of two strands (northern and southern) separated by a 3-mile-wide (5-km) right step. The Utah Geological Survey excavated two trenches across a fault scarp on the northern strand of the fault near Santaquin (DuRoss and others, 2008), and the U.S. Geological Survey excavated two trenches across a fault scarp on the southern strand at Willow Creek in the Mona quadrangle (Machette and others, 2007).

DuRoss and others (2008), using the relationships of Hanks and Kanamori (1979) and Wells and Coppersmith (1994), estimated a moment magnitude of 7.0 for the most recent surface-faulting earthquake on the northern strand of the Nephi segment. Their paleoseismic data indicate that this earthquake produced about 9.8 ± 0.7 feet (3.0 ± 0.2 m) of net vertical tectonic displacement of the ground surface (DuRoss and Others, 2008). The earthquake occurred 500 +100/-150 years ago, and a poorly constrained minimum time estimate for the previous earthquake is at least 1.5 ka and likely greater than 6.1 to 7.0 ka (DuRoss and others, 2008). They estimated that the long-term vertical geologic slip rate is 0.5 mm/yr and the average recurrence interval is 6000 ± 400 years (DuRoss and others, 2008).

Preliminary interpretations of the timing of major surface-faulting earthquakes at Willow Creek on the southern strand of the Nephi segment indicate that the three most recent of these events occurred about 0.3, 1.23, and less than 2.32 ka (Machette and others, 2007). The maximum average recurrence interval for the two most recent events is less than 1.0 ky, and Holocene slip rates along the fault are estimated to be from 2.0 to 2.5 mm/yr. These data indicate that the southern strand of the Nephi segment has experienced the most recent major surface-faulting event of any segment of the WFZ, and also has the highest documented Holocene slip rate of any segment. Machette and others (2007) caution, however, "that further estimates of repeat times and slip rates await refinement and synthesis of radiocarbon dates and luminescence age estimates from both [Willow Creek] trenches."

Slope Failures

Geologic materials susceptible to slope failure are common in the Payson Lakes quadrangle. Of particular significance are shale in the Pennsylvanian to Mississippian Manning Canyon Shale, mudstone and claystone in the Cretaceous to Tertiary North Horn Formation, and Tertiary tuffs and tuffaceous sedimentary rocks. Large prehistoric landslides derived from these geologic units are widespread in the quadrangle, and smaller recent landslides derived from these units and from colluvium are found locally on steep slopes and along drainages. Once slope failures occur, the resulting landslide deposits have an enhanced susceptibility to move again. Renewed movement of landslides, both historic and prehistoric, along the Wasatch Front in 1998 suggested to Ashland (2003) that these landslides were marginally stable to possibly metastable prior to 1998, possibly as a result of hillside modifications. Therefore, both geologic units that have failed and the resulting landslide deposits, regardless of age, pose an increased risk of future slope failures.

The potential for renewed movement in existing landslides in the Payson Lakes quadrangle is illustrated by historic landsliding in Spanish Fork Canyon, about 10 miles (15 km) east of Payson Canyon. Two of the most spectacular historic Utah landslides occurred in Spanish Fork Canyon, and the North Horn Formation was a significant source rock for both landslides: the Thistle landslide and the Shurtz Lake landslide. Shroder (1971) first mapped the prehistoric Thistle landslide and recognized evidence of repeated movement. In April 1983, the landslide moved again (Duncan and others, 1986), resulting in the most expensive individual landslide in North American history, in terms of both direct and indirect costs (Schuster, 1996). A similar scenario was encountered nearby in 1997, when prehistoric landslide deposits near Shurtz Lake were reactivated (Ashland, 1997), and both the Thistle and Shurtz Lake landslides moved once more in 1998 following a period of above-normal precipitation (Ashland, 2003).

Debris flows are also a hazard in the Payson Lakes quadrangle. On September 12, 2002, debris flows triggered by intense thunderstorms followed a wildfire that burned much of Dry Mountain during late summer 2001, exposing soils with a very high erosion potential (McDonald and Giraud, 2002). Major debris flows (Qmd_1) originated in five tributaries, four in the Santaquin quadrangle and one in the northwest corner of the Payson Lakes quadrangle, and deposited debris on alluvial fans (Qafy, Qaf_1) west of Dry Mountain. Debris and floodwater flowed into developed areas, causing property damage in two subdivisions. Conditions conducive to debris flows, including steep mountain canyons with an abundant source of debris from colluvium, landslides, and soft bedrock units, are common throughout the Payson Lakes quadrangle, and the presence of both historic and prehistoric debris flows indicate the high hazard potential.

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MAP UNIT DESCRIPTIONS

QUATERNARY

Alluvial deposits

Qal_1 **Level-1 stream deposits** (upper Holocene) – Moderately sorted pebble and cobble gravel with a matrix of sand, silt, and minor clay; contains thin discontinuous sand lenses; subangular to rounded clasts; thin to medium bedded. Mapped along Peteetneet Creek in Payson Canyon and Jones Ranch Creek in the east-central part of the quadrangle; mapped in active channels and floodplains, and on minor terraces less than 5 feet (1.5 m) above active channels; locally includes minor colluvial deposits along steep stream embankments; equivalent to the younger part of young stream deposits (Qaly), but differentiated where level-1 deposits can be mapped separately. Exposed thickness less than 15 feet (5 m).

Qal_2 **Level-2 stream deposits** (middle Holocene to upper Pleistocene) – Moderately sorted pebble and cobble gravel in a matrix of sand, silt, and minor clay; contains thin discontinuous sand lenses; subangular to rounded clasts; thin to medium bedded. Mapped at the distal part of a level-2 alluvial fan (Qaf_2), in the southern end of an abandoned channel that once contained a stream that flowed northward into Spring Lake on the adjacent Spanish Fork quadrangle (Solomon and others, 2007); equivalent to the older part of Qaly, but differentiated where level-2 deposits can be mapped separately. Exposed thickness less than 10 feet (3 m).

Qaly **Young stream deposits, undivided** (Holocene to upper Pleistocene) – Moderately sorted pebble and cobble gravel with a matrix of sand and minor silt and clay. Mapped in Loafer and Santaquin Canyons; locally includes areas of small alluvial-fan and colluvial deposits; includes level-2 stream deposits (Qal_2) incised by active stream channels and partly overlain by level-1 stream deposits (Qal_1) that are too small to show at map scale or where the specific age of post-Lake Bonneville deposits cannot be determined. Thickness variable, probably less than 15 feet (5 m).

Qalo **Old stream deposits** (middle Pleistocene) – Slightly indurated sand and well-rounded gravel with red-brown, oxidized clay film on clasts. Mapped on the northern edge of the quadrangle in the saddle between Payson Canyon and the piedmont north of Loafer Mountain where the unit intertongues with or is overlain by middle Pleistocene fan alluvium (Qaf_5); may be related to a regional period of erosion, with similar landforms and deposits including a possible pediment west of Dry Mountain (Solomon, 2010) and pediment-mantle alluvium near Thistle Canyon deposited on the Oligocene and Eocene Moroni Formation (Harris, 1953; Witkind and Page, 1983; Witkind and Weiss, 1991); Machette (1992) stated that the deposits near Payson Canyon are probably equivalent to, and older than, the latest middle Pleistocene Little Valley lake cycle of Scott and others (1983); the old stream deposits are apparently related to headward erosion of Peteetneet

Creek and subsequent capture of an ancient stream tributary of Payson Canyon east of Tithing Mountain (discussed in further detail by Machette, 1992). Thickness as much as 30 feet (10 m).

Qat **Stream terrace deposits, regressive (Provo) phase of Lake Bonneville** (upper Pleistocene) – Poorly to moderately sorted pebble and cobble gravel with a matrix of sand, silt, and minor clay; contains thin discontinuous sand lenses; subangular to rounded clasts; thin to medium bedded. Mapped on gently sloping terraces 5 to 15 feet (1.5-5 m) above, and incised by, Peteetneet Creek; the terraces occur as discontinuous remnants mapped along the creek northward into the Spanish Fork quadrangle (Solomon and others, 2007), where they are incised by level-1 stream deposits (Qal_1) but appear to grade to alluvial-fan deposits of the regressive phase of Lake Bonneville (Qafp) at the mouth of Payson Canyon. Exposed thickness less than 15 feet (5 m).

Qaf_1 **Level-1 alluvial-fan deposits** (upper Holocene) – Poorly to moderately sorted, weakly to non-stratified, pebble to cobble gravel with a matrix of sand, silt, and minor clay; clasts commonly well-rounded, derived from Lake Bonneville gravel; medium to very thick bedded. Deposited by debris flows, debris floods, and streams at the mouth of a canyon on the northwest flank of Dry Mountain near Spring Lake; although mapped by Machette (1992) as young alluvial-fan deposits (Qafy), the fan is equivalent to the younger part of those deposits and is differentiated because it is not incised by younger channels, can be mapped separately, and is overlain by a 2002 debris flow (Qmd_1) (McDonald and Giraud, 2002), indicating active fan deposition. Exposed thickness less than 10 feet (3 m).

Qaf_2 **Level-2 alluvial-fan deposits** (middle Holocene to upper Pleistocene) – Poorly sorted pebble and cobble gravel, locally bouldery, with a matrix of sand, silt, and minor clay; clasts angular to subrounded, with sparse well-rounded clasts derived from Lake Bonneville gravel; medium to very thick bedded. Mapped on the northwest flank of Dry Mountain near Spring Lake, emanating from small canyons and commonly overlapped by younger alluvial-fan deposits (Qaf_1, Qafy); no Lake Bonneville shorelines are found on these alluvial fans; deposited by debris flows, debris floods, and streams; mapped by Machette (1992) as alluvial-fan deposits of the regressive phase of Lake Bonneville (Qafp) graded to regressive-phase silt and clay (Qlmp), but I map the fans overlying transgressive-phase silt and clay (Qlmb), with the Provo shoreline about 1000 feet (300 m) beyond the distal end of the fans; equivalent to the older part of Qafy, but differentiated where deposits are graded to slightly above modern stream level and can be mapped separately. Exposed thickness less than 15 feet (5 m).

Qafy **Young alluvial-fan deposits, undivided** (Holocene to upper Pleistocene) – Poorly to moderately sorted, pebble to cobble gravel with boulders near bedrock sources, with a matrix of sand, silt, and clay, grading to mixtures of sand, silt, and clay on gentler slopes. Mapped at the undifferentiated distal ends of fans (Qaf_1, Qaf_2) on the northwest flank of Dry Mountain near Spring Lake, emanating from side canyons near Walker Flat in Payson Canyon, and at the mouth of Box

Canyon on the piedmont west of Loafer Canyon; deposited by debris flows, debris floods, and streams; includes level-1 and level-2 alluvial-fan deposits (Qaf_1, Qaf_2) that either cannot be differentiated because of map scale or are in areas where the specific age of Holocene deposits cannot be determined; no Lake Bonneville shorelines are found on these alluvial fans. Thickness variable, probably less than 40 feet (12 m).

Qafp **Alluvial-fan deposits, regressive (Provo) phase of Lake Bonneville** (upper Pleistocene) – Poorly to moderately sorted, pebble to cobble gravel, locally bouldery, in a matrix of sand, silt, and minor clay; clasts typically angular but well rounded where derived from Lake Bonneville gravel; medium to very thick bedded. Mapped near Spring Lake as the southern extension of a larger deposit in the adjacent Spanish Fork quadrangle (Solomon and others, 2007), in fault contact with transgressive sand and silt (Qlsb) on its upslope edge and covered by young alluvial fans (Qafy) downslope; deposited by debris flows, debris floods, and stream flow; equivalent to the younger part of level-3 alluvial-fan deposits, which are not mapped in the Payson Lakes quadrangle but are mapped elsewhere in Utah Valley by Machette (1992); differentiated because regressive-phase alluvial-fan deposits lie between the Provo and Bonneville shorelines and overlie transgressive deposits, and regressive-phase alluvial-fan deposits can be mapped separately. The B soil horizon of paleosols developed on regressive-phase alluvial-fan deposits commonly shows an intensification of brown colors due to oxidation of iron-bearing minerals or a slight accumulation of clay, and may include a pedogenic accumulation of calcium carbonate as thin, discontinuous coatings on gravel; Machette (1992), using the terminology of Birkeland (1984), designated the soil profile of this unit and others of similar age as A/Bw/Bk(or Cox) to A/Bt(weak)/Bk(or Cox). Exposed thickness less than 30 feet (10 m).

Qaf_4 **Level-4 alluvial-fan deposits, pre-Bonneville lake cycle to Little Valley lake cycle** (upper to middle Pleistocene) – Poorly sorted, clast-supported pebble to cobble gravel, with matrix-supported interbeds in the upper part; locally bouldery in a matrix of sand, silt, and clay; clasts angular to subrounded; medium to very thick bedded. Mapped on the southern end of the piedmont between Payson and Loafer Canyons above the Bonneville shoreline, and similar deposits near the mouth of Loafer Canyon in the Spanish Fork quadrangle are cut by the shoreline (Solomon and others, 2007); the deposits are more extensive than those mapped by Machette (1992) and extend into the Spanish Fork quadrangle, although not mapped by Solomon and others (2007); level-4 deposits are found on gentler slopes than are level-5 deposits (Qaf_5), are less dissected, and are inset into the older fans. Machette (1992) stated that correlative deposits likely underlie Lake Bonneville deposits, forming the piedmont slopes within Utah Valley, and probably grade laterally to lacustrine sediment of the Little Valley lake cycle below an elevation of about 4900 feet (1490 m) (Scott and others, 1983); equivalent to the younger part of older alluvial-fan deposits, which are not mapped in the Payson Lakes quadrangle but are mapped elsewhere in Utah Valley by Machette (1992), but differentiated where pre-Bonneville alluvial-fan deposits can be divided into level 4 and level 5 based on fan morphology, degree of dissection, and incision of younger into older deposits. The B soil horizon of paleosols developed on level-4 alluvial-fan deposits commonly shows a moderate accumulation of clay, gravel is typically coated with calcium carbonate, and calcium carbonate may occur in significant accumulations between clasts; Machette (1992), using the terminology of Birkeland (1984), designated the soil profile of this unit and others of similar age as A/Bt(moderate)/Bk(stage II-III)/Cox. Exposed thickness less than 15 feet (5 m).

Qaf_5 **Alluvial-fan deposits; pre-Little Valley lake cycle** (middle Pleistocene) – Poorly sorted, clast-supported pebble to cobble gravel, with matrix-supported interbeds in the upper part; locally bouldery, in a matrix of sand, silt, and clay; deposits are deeply dissected, lack fan morphology, and are typically preserved remnants of high surfaces on bedrock. Mapped on the piedmont between Payson and Loafer Canyons, incised by level 4 alluvial-fan deposits (Qaf_4); Machette (1992) reported that level 5 alluvial fan-deposits exposed in a stream gully on the divide east of Peteetneet Creek (W½ section 35, T. 9 S., R. 2 E., SLBLM) contain isolated pods of 0.62 Ma Lava Creek B volcanic ash (Izett and Wilcox, 1982, Utah locality 9); correlative alluvial deposits likely underlie Lake Bonneville deposits and probably grade laterally to lacustrine sediment of the Pokes Point and other lake cycles older than the Little Valley lake cycle (Scott and others, 1983; Machette and Scott, 1988), although not observed in Utah Valley (Machette, 1992); equivalent to the older part of older alluvial-fan deposits, which are not mapped in the Payson Lakes quadrangle but are mapped elsewhere in Utah Valley by Machette (1992), but differentiated where Little Valley and post-Little Valley deposits can be separated based on fan morphology, degree of dissection, and incision of younger into older deposits. The B soil horizon of paleosols developed on level-5 alluvial-fan deposits commonly shows a strong accumulation of clay, gravel is typically coated with calcium carbonate, and calcium carbonate may occur in significant accumulations between clasts; Machette (1992), using the terminology of Birkeland (1984), designated the soil profile of this unit and others of similar age as A/Bt(moderate)/Bk(stage II-III)/K(stageII)/Cox. Exposed thickness less than 60 feet (20 m).

Colluvial deposits

Qc **Colluvial deposits** (Holocene to upper Pleistocene) – Pebble, cobble, and boulder gravel, commonly clast supported, in a matrix of sand, silt, and clay; angular to subangular clasts, poorly sorted, poorly stratified, locally derived sediment deposited by slopewash, and soil creep on steep slopes; the largest deposits are mapped (1) along the Right Fork Sullivan Canyon near glacial deposits (Qg) in the southwest corner of the quadrangle, (2) west of Holman Creek near the contact between the Oquirrh Formation and the North Horn Formation (Hintze, 1962; Witkind and Weiss, 1991), and (3) at the head of Rock Canyon on the southwest flank of Loafer Mountain; includes landslides, rock falls, and debris flows too small to map separately; most bedrock is covered by at least a thin veneer of colluvium, and only the larger, thicker deposits are mapped. Maximum thickness about 15 feet (5 m).

Fill deposits

Qfd **Disturbed land** (Historical) – Land disturbed by a gravel pit west of Holman Creek, in the south-central part of the quadrangle; although the surrounding bedrock is mapped as Oquirrh Formation by Hintze (1962) and Witkind and Weiss (1991), the operations appear to be in the North Horn Formation, which they map about 400 feet (120 m) to the east; the outline of the gravel pit is based on 1998 aerial photographs. Thickness unknown.

Glacial deposits

Qg **Glacial deposits, undivided** (upper to middle Pleistocene) – Includes till (moraine deposits) and outwash of various ages (Pinedale and/or Bull Lake ages) deposited west of Santaquin Canyon in the southwest corner of the quadrangle and north of Loafer Mountain in the northeast corner of the quadrangle, where distinct shapes of end, recessional, and lateral moraines are not visible; Hintze (1962) first mapped the two southernmost deposits near Santaquin Canyon and the two southernmost deposits near Loafer Mountain; near Santaquin Canyon, the glacial deposits are downslope of five east-facing cirques in the adjacent Santaquin quadrangle (Solomon, 2010) separated by sharp-edged arêtes, and near Loafer Mountain, the glacial deposits are downslope of three east-facing cirques in the adjacent Birdseye quadrangle separated by similar arêtes, with cirques in both areas reaching elevations greater than 9000 feet (2700 m); till is non-stratified, poorly sorted clay, silt, sand, cobbles, and boulders; outwash is stratified and variably sorted, but better sorted and bedded than till due to alluvial reworking; all glacial deposits locally include mass-movement and colluvial deposits (Qms, Qc) too small to show separately at map scale. Thickness less than 150 feet (45 m).

Lacustrine deposits

Deposits of the regressive (Provo) phase of the Bonneville lake cycle: Only mapped below the Provo shoreline ("P" shoreline on map), which is at elevations from about 4730 to 4750 feet (1440-1450 m) northwest of Dry Mountain in the northwest corner of the Payson Lakes quadrangle (table 1). The shoreline forms a gravel beach that is mapped to the west in the Santaquin quadrangle (Solomon, 2010), but is not mapped to the northeast in the Spanish Fork quadrangle (Machette, 1992; Solomon and others, 2007) despite extending a short distance before being incised and covered by younger alluvium (Qal_2, Qaly) near the community of Spring Lake. The B soil horizon of paleosols developed on regressive-phase lacustrine deposits commonly shows an intensification of brown colors due to oxidation of iron-bearing minerals or a slight accumulation of clay, and may include a pedogenic accumulation of calcium carbonate as filaments in fine-grained soil or thin, discontinuous coatings on gravel; Machette (1992), using the terminology of Birkeland (1984), designated the soil profile of these units as A/Bw/Bk(or Cox) to A/Bt(weak)/Bk(or Cox).

Qlgp **Lacustrine gravel and sand** (upper Pleistocene) – Moderately to well-sorted, subrounded to rounded, clast-supported, pebble to cobble gravel and pebbly sand with minor silt. Gastropods locally common in sandy lenses; gravel commonly cemented with calcium carbonate (tufa); thin to thick bedded. Deposited in shallow water near shore as a linear beach along the Provo shoreline in the northwest corner of the quadrangle near Spring Lake; commonly interbedded with or laterally gradational to lacustrine silt and clay of the regressive phase (Qlmp) in adjacent quadrangles (Solomon and others, 2007; Clark, 2009; Solomon, 2010). Exposed thickness less than 15 feet (5 m).

Deposits of the transgressive (Bonneville) phase of the Bonneville lake cycle: Mapped between the Bonneville and Provo shorelines. The highest Bonneville shoreline ("B" shoreline on map) is at elevations from about 5120 to 5150 feet (1560-1570 m) at the base of Dry Mountain in the northwest corner of the Payson Lakes quadrangle (table 1). The B soil horizon of paleosols developed on transgressive-phase lacustrine deposits commonly shows a slight to moderate accumulation of clay and may include a pedogenic accumulation of calcium carbonate as filaments in fine-grained soil or thin, discontinuous coatings on gravel; Machette (1992), using the terminology of Birkeland (1984), designated the soil profile of these units as A/Bt/Bk(or Cox).

Qlgb **Lacustrine gravel and sand** (upper Pleistocene) – Moderately to well-sorted, clast-supported pebble to cobble gravel with a matrix of sand and silt; locally interbedded with thin to thick beds of silt and pebbly sand; clasts commonly subrounded to rounded, but some deposits consist of poorly sorted, angular gravel derived from nearby bedrock outcrops; gastropods locally common in sandy lenses; gravel locally cemented with calcium carbonate (tufa); thin to thick bedded. Mapped near the Bonneville shoreline at the base of Dry Mountain, forming a wave-built bench; bedding ranges from horizontal to primary dips of 10 to 15 degrees on steeper slopes; interbedded with or laterally gradational to lacustrine sand and silt of the transgressive phase (Qlsb). Exposed thickness less than 30 feet (10 m).

Qlsb **Lacustrine sand and silt** (upper Pleistocene) – Moderately to well-sorted, subrounded to rounded, fine to coarse sand and silt with minor pebbly gravel. Thick to very thick bedded; commonly has ripple marks and scour features; gastropods locally common. Deposited in relatively shallow water northwest of Dry Mountain between the Provo and Bonneville shorelines; previously mapped near the Bonneville shoreline as transgressive lacustrine gravel (Qlgb) by Machette (1992), and near the Provo shoreline in the adjacent Spanish Fork quadrangle as regressive silt and clay (Qlmb) by Solomon and others (2007), but soil surveys (Swenson and others, 1972) indicate a significant component of sand and silt; overlies coarse-grained beach gravel (Qlgb), implying deposition in increasingly deeper water of a transgressing lake. Exposed thickness less than 15 feet (5 m).

Qlmb **Lacustrine silt and clay** (upper Pleistocene) – Calcareous silt (marl) and clay with minor fine sand; typically thick bedded or very thick bedded; ostracodes locally common. Mapped near Dry Mountain downslope and overlying coarser grained transgressive deposits (Qlsb, Qlgb); deposited in deeper water offshore. Exposed thickness less than 15 feet (5 m).

Mass-movement deposits

Qmd_1 **Modern debris-flow deposits** (upper Holocene) – Unsorted cobble and boulder gravel in a matrix of sand, silt, and clay. Mapped in seven narrow canyons in the Wasatch Range and on the level-1 alluvial fan (Qaf_1) at the base of Dry Mountain; the seven debris flows in the Wasatch Range all appear relatively young, with overlapping levees and channels, including one deposit with a fresh landslide scar at its head (SE¼ section 35, T. 10 S., R. 2 E., SLBLM) that appears on the 1998 air photos and likely served as the initial source of debris shortly before the photo was taken; the debris flow on the alluvial fan was one of five fire-related debris flows occurring on September 12, 2002 (McDonald and Giraud, 2002) (the other four are mapped on the Santaquin quadrangle by Solomon, 2010). Thickness less than 20 feet (6 m).

Qmd_2 **Older debris-flow deposits** (upper to middle Pleistocene) – Unsorted cobble and boulder gravel in a matrix of sand, silt, and clay; mapped at the head of a gully that drains into Summit Creek in the adjacent Santaquin quadrangle (Solomon, 2010); the toe of the deposit is truncated in the Santaquin quadrangle by young stream deposits (Qaly), indicating a minimum age of late Pleistocene, and may be older, coinciding with pre-Lake Bonneville partial reactivations of older landslide deposits in the Santaquin quadrangle. Thickness less than 60 feet (20 m).

Qms **Younger landslide deposits** (Historical to middle Pleistocene) – Poorly sorted clay- to boulder-sized material in slides, slumps, and minor flows, with grain size varying with the nature of source material; characterized by relatively fresh main scarps and, on larger landslides, hummocky topography, and chaotic bedding in displaced bedrock; smaller landslides such as along Mud Hollow and north of Red Lake are slope failures in unmapped colluvium, and larger landslides are commonly failures of Cretaceous and Tertiary bedrock. Thickness highly variable, commonly less than 30 feet (10 m).

Qmt **Talus deposits** (Holocene to middle Pleistocene) − Very poorly sorted, angular debris (gravel to boulders) and minor amounts of finer-grained interstitial sediment typically deposited by rock fall on and at the base of steep slopes; mapped in upper Santaquin Canyon, derived from Paleozoic bedrock. Generally less than 20 feet (6 m) thick.

Mixed-environment deposits

Qac **Alluvial and colluvial deposits, undivided** (Holocene to middle Pleistocene) – Poorly to moderately sorted, generally poorly stratified, clay- to boulder-size, locally derived sediment in deposits of alluvium, slopewash, and creep that grade into one another; small, unmapped deposits are likely in most small drainages.

Mapped in bedrock-floored drainages scattered throughout the quadrangle and two larger deposits underlain by shallow bedrock; the largest deposit, on the east side of Dry Mountain near Big Springs, is underlain by soft, shallow Cretaceous and Tertiary bedrock that easily weathers and erodes; the deposit on the piedmont between Payson and Loafer Canyons contains a significant component of alluvium forming fans shed by streams draining bedrock across the Wasatch fault zone, but the fans cannot be differentiated at the map scale. Thickness less than 10 feet (3 m).

Qmc **Landslide and colluvial deposits, undivided** (Holocene to middle Pleistocene) – Deposits of landslides (slides and slumps), slopewash, and soil creep that grade into one another in areas of subdued morphology, where mapping colluvium separately from landslides is not possible at map scale; composition and texture depend on local sources; mapped in scattered areas of the Wasatch Range. Thickness less than 40 feet (12 m).

Qmtc **Talus and colluvium, undivided** (Holocene to upper Pleistocene) – Very poorly sorted, angular to subangular cobbles and boulders and finer-grained interstitial sediment, deposited principally by rock fall on steep bedrock slopes, that grades downslope into colluvial deposits; only thicker and larger deposits in Picayune Canyon mapped. Generally less than 20 feet (6 m) thick.

QUATERNARY-TERTIARY

QTmb **Megabreccia deposits** (Pleistocene to Pliocene?) – Includes large bedrock blocks, rubble, and younger Quaternary landslide deposits too small to map separately; bedrock blocks are composed largely of Paleozoic quartzite, dolomite, and limestone on the northwest margin of Dry Mountain and on the east side of Payson Canyon; respectively mapped by Demars (1956) and Peterson (1956) as highly faulted and deformed bedrock, but prominent arcuate main scarps lie to the east of each deposit, which have more subdued upper surfaces than surrounding bedrock and lie in amphitheaters at least 150 feet (45 meters) below the scarps; displacement of the deposits are thought to have started in the late Tertiary (possibly Pliocene) and continued intermittently during the Pleistocene as movement along the Wasatch fault zone uplifted the range front relative to the valleys. Thickness as much as 200 feet (60 m).

QTms **Older landslide deposits** (Pleistocene to Pliocene?) – Poorly sorted clay- to boulder-sized material in slides, slumps, and minor flows, with grain size varying with the nature of source material; characterized by hummocky topography, main and internal scarps, and chaotic bedding in displaced bedrock; mapped in the Wasatch Range northeast of Santaquin Canyon; most of the landslides are derived from Cretaceous and Tertiary rocks and are characterized by hummocky terrain with depressions that enclose the many small lakes typical of the quadrangle; the large landslide between Payson and Loafer Canyons, south of the piedmont, is derived from the Manning Canyon Shale; older landslide deposits are typically much larger than younger landslide deposits (Qms) and have carbonate soils similar to those on alluvial-fan deposits older than Lake Bonneville (Qaf_4, Qaf_5); displacement of the older landslide deposits is thought to have started in the late Tertiary (possibly Pliocene) and continued intermittently during the Pleistocene as movement along the Wasatch fault zone uplifted the range front relative to the valleys. Thickness highly variable, but the largest deposit is several hundred feet thick.

Major unconformity

TERTIARY-PRECAMBRIAN

R **Rock** (Tertiary to Precambrian) − Mapping of bedrock structure and stratigraphy is beyond the scope of this project. Hintze (1962) and Witkind and Weiss (1991) compiled geologic maps of the region that include the Payson Lakes quadrangle at respective scales of 1:125,000 and 1:100,000, providing valuable overviews of regional geology, although many questions remain regarding stratigraphic relationships and geologic structure. For more information, refer to these maps as well as others cited in the Previous Investigations section of this report. According to these maps, Cretaceous and Tertiary rocks are most common in the south half of the quadrangle, Paleozoic rocks are most common in the north half of the quadrangle and underlying most of Dry Mountain, and Precambrian rocks are most common at the base of the western side of Dry Mountain.

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Table 1. ***Ages of major shorelines of Lake Bonneville and Utah Lake and shoreline elevations in the Payson Lakes quadrangle.***

Lake Cycle and Phase	Shoreline (map symbol)	Age: radiocarbon years B.P.	Age: calendar years B.P.	Elevation feet (meters)
Lake Bonneville				
Transgressive Phase	Stansbury	22,000-20,000[1]	27,000-24,000[2]	Not present
	Bonneville (B) —flood—	15,000-14,500[3]	18,300[4]-17,400[5]	5120-5150 (1560-1570)
Regressive Phase	Provo (P)	14,500-12,000[6]	17,400[5]-14,400[7]	4730-4750 (1440-1450)
	Gilbert	10,500-10,000[8]	12,500-11,500[9]	Not present
Utah Lake				
	Utah Lake highstand (U)	12,000-11,500[10]	-----	Not present

[1] Oviatt and others (1990).
[2] Calendar calibration using Fairbanks and others (2005; http://www.radiocarbon.ldeo.columbia.edu/research/radcarbcal.htm).
[3] Oviatt and others (1992), Oviatt (1997).
[4] Oviatt (written communication, 2009), using Stuiver and Reimer (1993) for calibration.
[5] CRONUS-Earth Project (2005), using Stuiver and others (2005) for calibration.
[6] Godsey and others (2005) revised the timing of the occupation of the Provo shoreline and subsequent regression; Oviatt and others (1992) and Oviatt (1997) proposed a range from 14,500 to 14,000 ^{14}C yr B.P. Oviatt and Thompson (2002) summarized many recent changes in the interpretation of the Lake Bonneville radiocarbon chronology.
[7] Godsey and others (2005), using Stuiver and Reimer (1993) for calibration.
[8] Oviatt and others (2005).
[9] Calendar calibration of data in Oviatt and others (2005), using Stuiver and Reimer (1993) and Hughen and others (2004).
[10] Estimated from data in Godsey and others (2005); Machette (1992) estimated the age of the regression of Lake Bonneville below the Utah Valley threshold at 13,000 ^{14}C yr B.P. from earlier data.

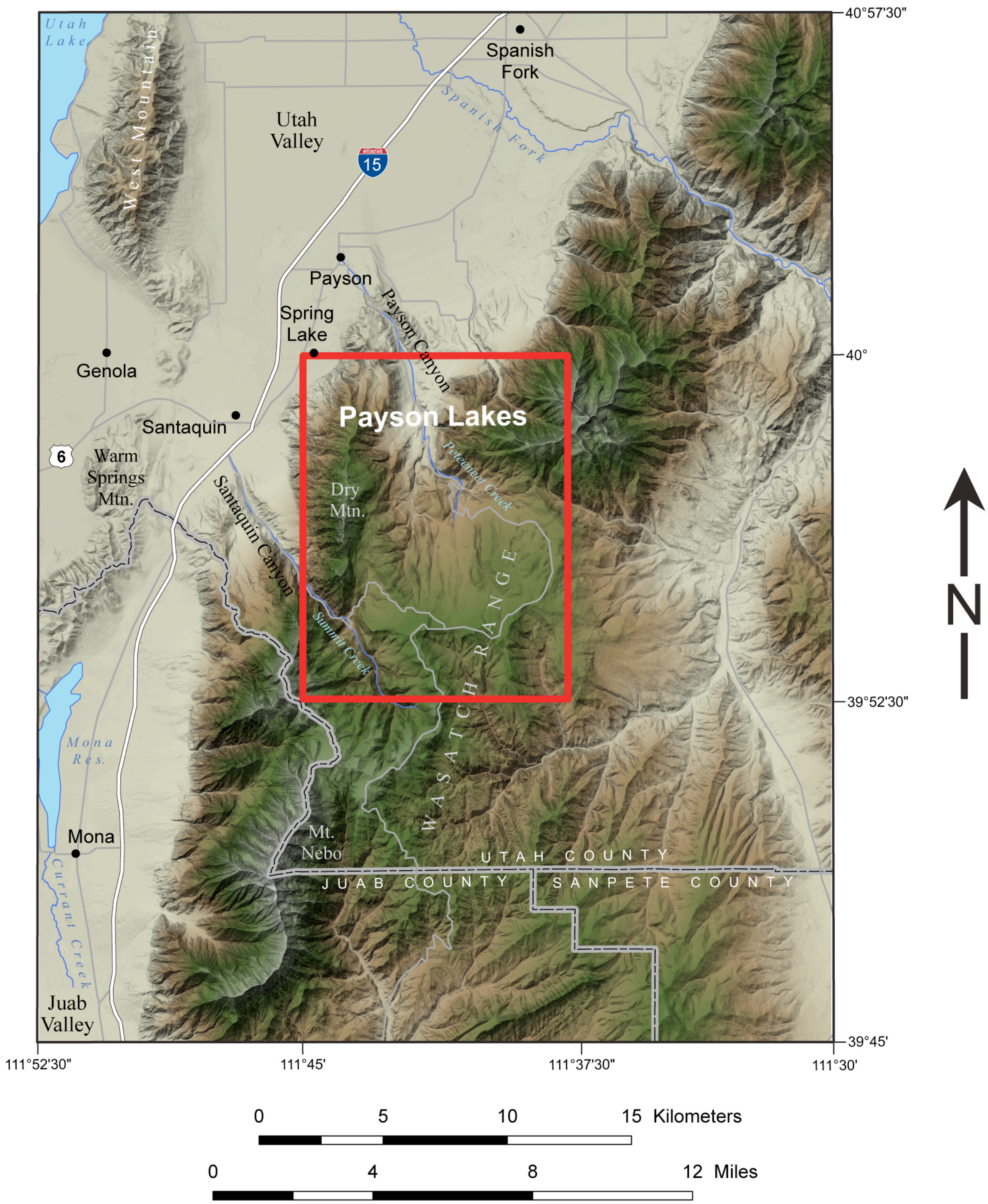


Figure 1. Index map showing the primary geographic features in the vicinity of the Payson Lakes quadrangle.

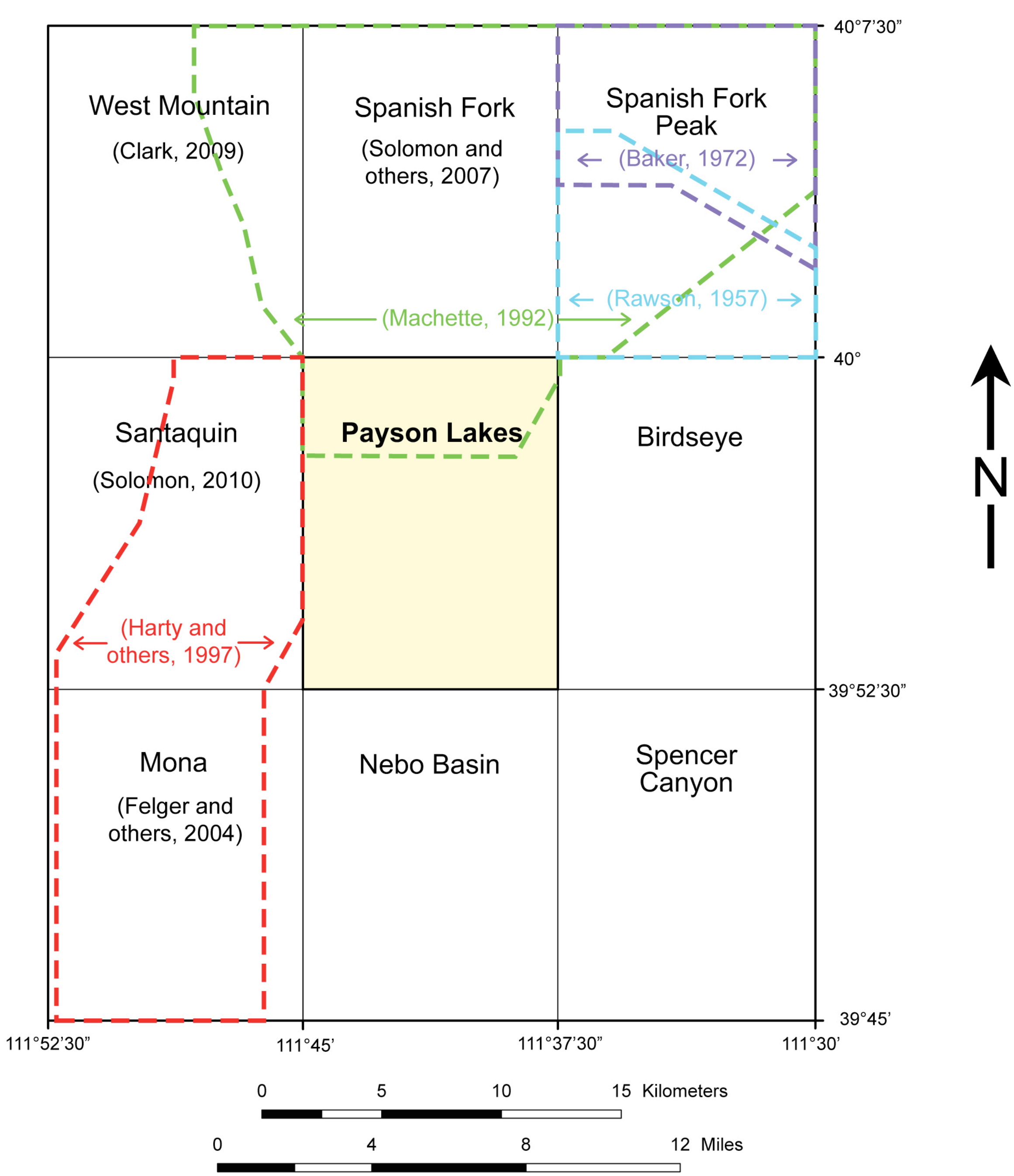


Figure 2. Index map showing selected geologic maps available for the Payson Lakes and surrounding 7.5′ quadrangles.

GEOLOGIC SYMBOLS

Contact

Normal fault – Dashed where approximately located, dotted where concealed; bar and ball on downthrown side

Cirque

Arête crest

Lacustrine shorelines – Mapped at the wave-cut bench of erosional shorelines and the top of constructional bars and barrier beaches; may coincide with geologic contacts:

Lake Bonneville shorelines –

B — Bonneville shoreline

P — Provo shoreline

Landslide scarp – Hachures on down-dropped side

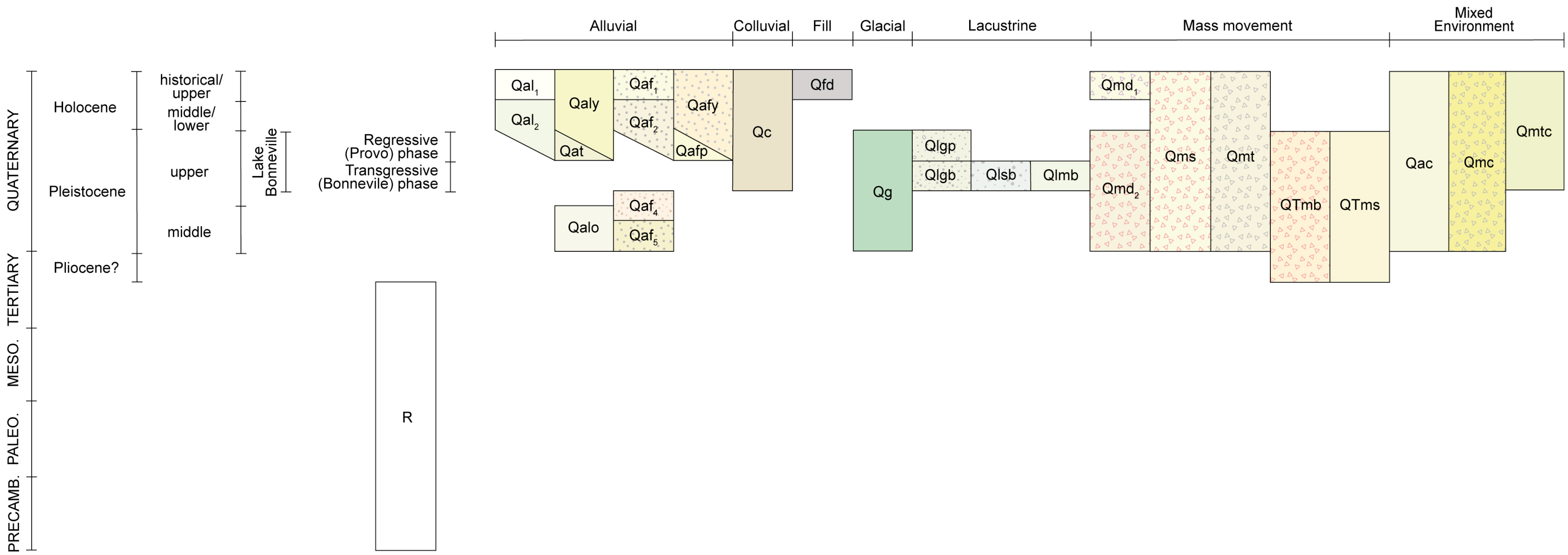
Spring

Prospect

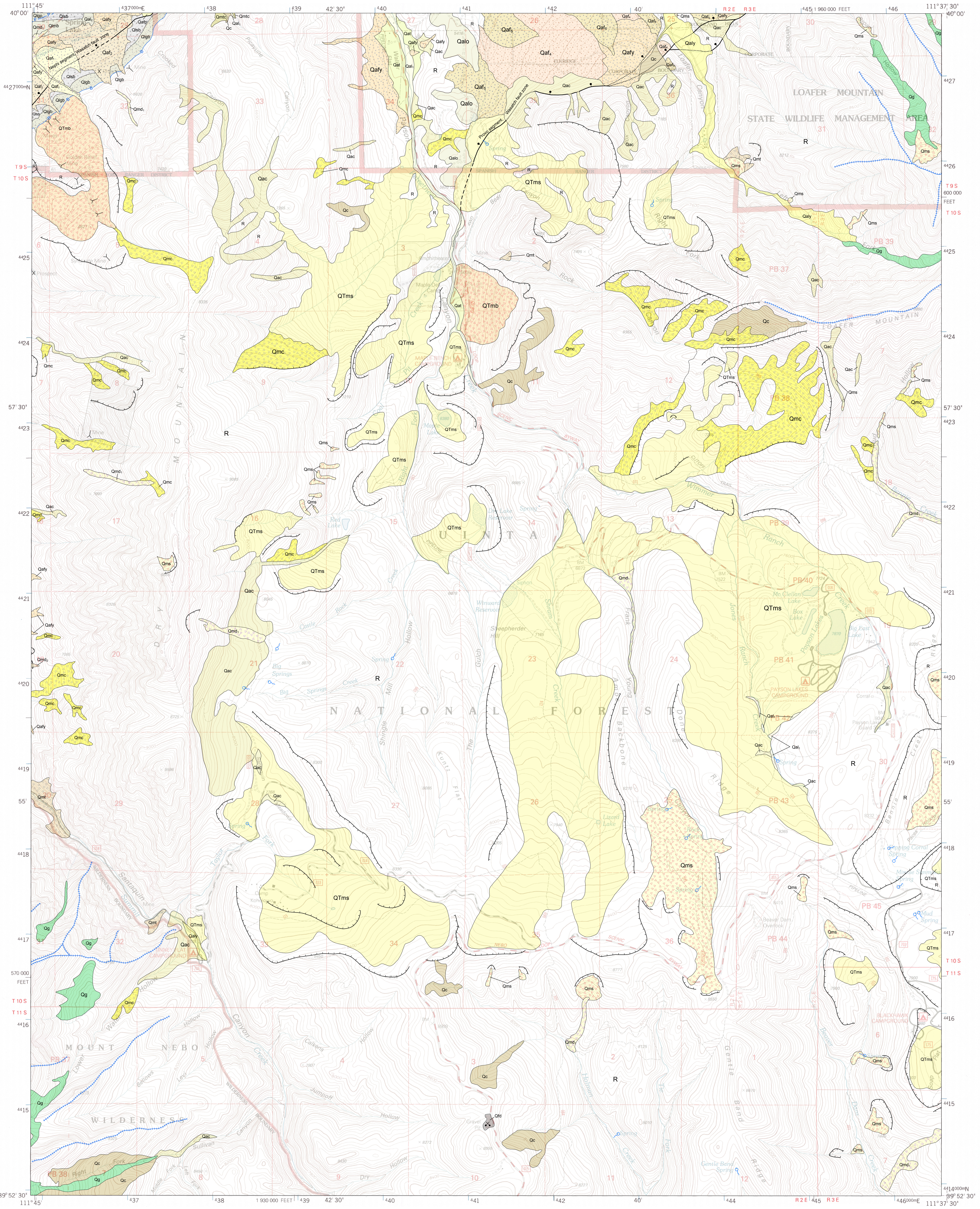
Adit

Sand and gravel pit

CORRELATION OF MAP UNITS
Payson Lakes Quadrangle



UTAH GEOLOGICAL SURVEY
a division of
Utah Department of Natural Resources



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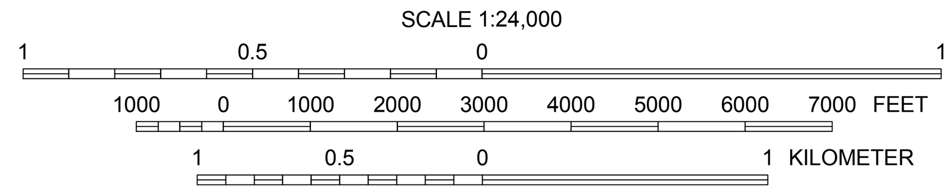
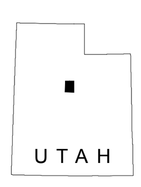
SCALE 1:24,000



CONTOUR INTERVAL 40 FEET

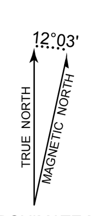


QUADRANGLE LOCATION

INTERIM GEOLOGIC MAP OF UNCONSOLIDATED DEPOSITS IN THE PAYSON LAKES QUADRANGLE, UTAH COUNTY, UTAH

by
Barry J. Solomon

2010



APPROXIMATE MEAN DECLINATION, 2010

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

Cartography: Jay Hill

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1	2	3
4		5
6	7	8

1. West Mountain
2. Spanish Fork
3. Spanish Fork Peak
4. Santaquin
5. Birdseye
6. Mona
7. Nebo Basin
8. Spencer Canyon

ADJOINING 7.5' QUADRANGLE NAMES