Hydrogeologic Framework of the Upper Clark Fork River Area: Deer Lodge, Granite, Powell, and Silver Bow Counties

by

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Author's Note: This map is part of the Montana Bureau of Mines and Geology (MBMG) Groundwater Assessment Atlas for the Upper Clark Fork Area groundwater characterization. It is intended to stand alone and describe a single hydrogeologic aspect of the study area, although many of the area's hydrogeologic features are interrelated. For an integrated view of the hydrogeology of the Upper Clark Fork Area the reader is referred to Part A (descriptive overview) and Part B (maps) of the Montana Groundwater Assessment Atlas 5.

INTRODUCTION

The Upper Clark Fork groundwater characterization area includes Deer Lodge, Granite, Powell, and Silver Bow Counties. The distribution of geologic units shown in the main figure (fig. 1) displays the variety of rock types in different parts of the study area. The geologic units have been simplified from more detailed maps (fig. 2). Rock units were grouped according to rock type and age that correspond to discernable aquifers (fig. 3).

The Upper Clark Fork River area consists of bedrock-cored mountains separating intermontane valleys and a few canyons along major streams. Bedrock defines all valley and canyon margins and crops out within some valleys where basin-fill units have been eroded. The intermontane valleys, such as the Deer Lodge, Philipsburg, Flint Creek, Summit (Butte-Silver Bow), Avon Valley, and Blackfoot River valleys (fig. 4), are structural depressions (basins) in which locally great thicknesses of weakly indurated Tertiary sedimentary rocks accumulated. As much as 200 ft of unconsolidated sediments at land surface overlie the Tertiary rocks. Many pre-Tertiary sedimentary rock units present in the study area have been faulted, uplifted, and eroded into remnants (Fields and others, 1985; Fritz and others, 2007). Valleys and canyons are the primary areas of human habitation and groundwater development. Separate populated canyon areas are mostly along short segments of the Clark Fork, Blackfoot, and Little Blackfoot Rivers, and Flint and Rock Creeks (fig. 4).

METHODS AND DATA SOURCES

Geologic maps for the study area were compiled and simplified from sources shown in figure 2. A description of the rock units and their relation to map units are shown in figure 3. Contacts between a few units were redrawn so that they were continuous across map boundaries. Where detailed mapping was available at larger scales, it was generally used instead of regional, smaller scale mapping. New mapping of some surficial deposits in the Ovando to Helmville area of the Blackfoot River valley was prepared from field visits (fig. 2; L. Smith, unpublished mapping). All geologic maps were compiled from digitized versions, and simplified using Arc/Info (tm).

GEOLOGIC OVERVIEW

Bedrock, as used here for the rocks in the study area, consists of consolidated rock that is hard enough to fracture. Consolidation is caused by cementation, compaction, heat, or the growth of interlocking mineral grains, processes known as induration. The general distinction is that groundwater mostly travels along fractures through indurated rocks, whereas in weakly indurated to unconsolidated rocks, groundwater can only travel through interconnected pore spaces between mineral grains. Significant rates of groundwater movement in most bedrock units is therefore dependent on the locations and continuity of fractures, which are mostly related to folds, faults, and joints (commonly related to cooling and uplift of igneous rock). Highly to moderately indurated rocks include: Archean gneiss and metasedimentary rocks of the Belt Supergroup (combined in the unit "Yb"); Tertiary and Cretaceous intrusive (TKi) and most extrusive (volcanic, TKv) igneous rocks; and Paleozoic sedimentary rocks (Pz). The less consolidated rocks, such as Cretaceous and Jurassic (KJs) sedimentary formations, include sandstones and limestones that are generally less indurated than the older sedimentary rocks, producing water from both intergranular space and fractures. Bedrock is exposed around the valley margins, and is present beneath basin-fill units.

Basin-fill deposits, as defined here, consist of Tertiary sedimentary rocks (Ts) and unconsolidated deposits. Tertiary sedimentary rocks include claystone, shale, siltstone, sandstone, locally thick conglomerate, minor coal and limestone, and volcaniclastic units. Within the Tertiary sedimentary deposits are some minor flows of consolidated volcanic rock. The oldest Tertiary sediments accumulated initially in an early Tertiary basin that was likely segmented into multiple intermontane basins during the middle to late Tertiary (Fields and others, 1985; Rasmussen, 1989; Fritz and others, 2007; Janecke, 2007). Additional basin fill was deposited during further subsidence of the intermontane basins. Current streams are removing basin fill. In outcrop, the Tertiary strata range from unconsolidated to moderately consolidated.

The Tertiary deposits have low permeability in many areas, but can be productive aquifers where permeable sandstones and conglomerates are laterally continuous and receive sufficient recharge. In many areas Tertiary rocks with low permeability (claystone, shale, or siltstone) underlie alluvium, forming a low permeability base to a shallow aquifer. Within the Tertiary deposits, geologic maps and subsurface data do not contain the detail to distinguish packages of coarse-grained aquifer materials from the fine-grained non-aquifer materials. However, as shown diagrammatically on cross section B–B', sufficient subsurface data may allow productive Tertiary aquifers to be locally mapped (fig. 5b).

Unconsolidated basin-fill sediments include sand and gravel- to boulder-sized material (combined on the map as "Qsc") and clayey and silty gravel and bedded silt and clay (represented as "Qsf"). Unconsolidated units were deposited both during and after periods of glaciation. Glaciers occupied higher portions of many mountain valleys depositing till, mostly gravelly clay and silt that is not an aquifer. Therefore, most of the till is mapped as Qsf, except in areas of the Butte 1° x 2° sheet, where it was not mapped separately from other Quaternary sediments (Lewis, 1998). Bedded silt and clay were deposited in some valleys during stands of Glacial Lake Missoula, a glacial-age lake impounded on the Clark Fork River upstream of the current Montana/Idaho border (Alt, 2001). The lake attained an altitude of at least 4,200 ft, so only covered a small portion of the Clark Fork River valley downstream from Drummond.

DESCRIPTIONS OF SELECTED AREAS

Deer Lodge Valley

The Deer Lodge Valley lies between the Flint Creek Range and the unnamed mountain range north of Butte. The northern boundary is north of Deer Lodge where the Clark Fork River cuts west through pre-Tertiary rocks, and east of Anaconda where the drainage cut a canyon through volcanic rocks (fig. 4). The valley contains floodplains and terraces along the Clark Fork River and its major tributaries. Above the floodplains and terraces are prominent valley-center sloping benches developed on Tertiary basin fill. The valley margins are bedrock.

A variety of bedrock units and igneous intrusive and extrusive rocks make up the mountains and underlie the valley (Konizeski and others, 1968; Rasmussen, 1989; Fritz and others, 2007). The intermontane basin between bedrock outcrops is almost entirely filled by Tertiary sedimentary rocks, to a depth exceeding 9,000 ft based on oil and gas exploration wells (McLeod, 1987; figs. 5a,b). The Deer Lodge Valley has the thickest section of Tertiary strata in the Upper Clark Fork River area. Local aquifers in Tertiary rock units include sandstone, pebbly sandstone, and conglomerate.

Surficial units of Quaternary sand and gravel make up 10- to 70-ft-thick-sequences in valley bottoms and in broad glacial outwash deposits. Most of the coarse-grained deposits are on floodplains and adjacent terraces of the Clark Fork River and its tributaries. Silty sandy and gravelly alluvial-fan deposits accumulated during the waning stage of glaciation in tributary valleys. Glacial till was deposited by valley glaciers along the east flank of the Flint Creek Range near the mouths of some side tributaries to the Clark Fork River. Outwash deposits, coarse-grained alluvium deposited downslope from glaciers, are extensive in the Anaconda area (Warm Springs Creek valley) and along other streams in the Flint Creek Range. The coarse-grained surficial deposits are significant aquifers.

Summit valley and the Divide area

The Summit valley is the headwater of the Clark Fork River; Butte, Montana is located at its northern end. The adjacent Divide valley between Fleecer Mountain and Timber Butte appears structurally and stratigraphically similar to the Summit valley (fig. 5c). In the valleys, unconsolidated Quaternary sand and minor amounts of gravel (coarse-grained alluvium) were deposited along stream valleys and as alluvial fans. The thickness of unconsolidated Quaternary deposits in both valleys is generally less than 50 ft. However, distinguishing Quaternary from underlying weakly consolidated Tertiary sedimentary rocks using descriptions from most water-well logs is difficult.

Basin-fill deposits are hundreds to thousands of feet thick and rest on Tertiary and Cretaceous granitic and volcanic rock (fig. 5c). Most of the basin-fill sediment in the Summit valley is coarse-grained sand derived from disaggregated granitic rock, and therefore has a texture that promotes indistinct sedimentary layering in surface and subsurface lithologic logs. In addition to granitic rock, volcanic rocks with compositions similar to the nearby granite rim the Summit valley. Belt Supergroup bedrock in the Highland Mountains forms the southern margin.

The Tertiary fill of the Divide area is better exposed and better studied than in the Summit valley (Berg and Hargrave, 2004; Vuke, 2004; C. Elliott, unpublished geologic mapping). In addition to granitic rocks, bedrock in the mountains surrounding the Divide area includes volcanic and sedimentary rocks, which causes the basin fill to be relatively fine-grained compared to that of the Summit valley. The Tertiary units are dominated by mudstones and fine-grained sandstones. Where saturated with water, a few sheet sandstones and conglomerates and lenticular sandstones in the units are aquifers.

Flint Creek Basin

The valley between the Flint Creek Range on the east and the John Long Mountains on the west and downstream from Maxville to the confluence of Flint Creek and the Clark Fork River is known as the Flint Creek basin. Precambrian Belt and Paleozoic bedrock units rim most of the basin; Mesozoic and Tertiary sedimentary rocks crop out on hills east of Flint Creek, and underlie much of the basin. Tertiary sedimentary rocks of the Cabbage Patch beds and overlying Flint Creek and Barnes Creek beds are as much as 2,500 ft thick in parts of the basin and are described in detail by previous workers (Gwinn, 1961; Rasmussen, 1989; Stalker, 2004; Portner and Hendrix, 2005). Unconsolidated Quaternary deposits are aquifers where saturated and permeable.

Philipsburg Valley–Upper Flint Creek

The town of Philipsburg is the largest population center in the valley between the Flint Creek Range and the John Long Mountains. The Philipsburg Valley contains 0–40 ft of Quaternary alluvial sediment deposited along streams cut into Tertiary sedimentary rocks of unknown thickness. The east-side valley margin was glaciated during the last glaciation, producing ice-sculpted topography and rolling hills in side drainages on the west slopes of the Flint Creek Range. Prominent benches between tributaries to Flint Creek are mostly underlain by Tertiary sedimentary rocks.

Outwash deposits in Fred Burr Creek and other drainages are aquifers. Substantial bouldery sand and gravel downstream from Boulder Creek suggest that these outwash deposits may have resulted from rapid draining of a glacially dammed lake during the last glaciation (Beaty, 1961, 1965). Where saturated and permeable, basin-fill deposits are aquifers.

Avon Valley

The Avon Valley is an intermontane valley with a dispersed rural population. The valley has 0–30 ft of alluvial and floodplain deposits along major stream channels resting on hundreds of feet of Tertiary siltstones and sandstones. The Tertiary basin fill includes light gray, medium-grained poorly consolidated sandstones and granule conglomerates, claystone, and shale. Tertiary volcanic rocks and Mesozoic, Paleozoic, and Precambrian sedimentary bedrock units border and underlie the valley. Alluvial sand and gravel along drainages and in Tertiary sedimentary and volcanic rocks are aquifers; a few wells are completed in fractured bedrock around the perimeter of the valley.

Blackfoot–Nevada Valley

The Blackfoot–Nevada Valley is drained by the Blackfoot River and Nevada Creek; the communities of Ovando and Helmville are the main population centers. The upper reaches of Nevada Creek, above Nevada Reservoir, are in the northern end of the Avon Valley. Basin fill consists of Tertiary sedimentary rocks, glacial till, and outwash deposits north of the confluence of the Blackfoot River with Nevada Creek. Quaternary alluvium lines modern stream valleys inset into older deposits. The valley is surrounded by Precambrian Belt bedrock and Tertiary volcanic and intrusive rocks.

The Tertiary sedimentary rocks include claystones, siltstones, and sandstones. Geophysical profiles across Kleinschmidt Flat and water-well logs suggest that in this area, glacial outwash overlies more than 4,000 feet of Tertiary basin fill (fig. 4; Aguirre and others, 2000). Tertiary claystones and siltstones exposed throughout the Blackfoot–Nevada Valley probably have low permeability. Carbonaceous shales with leaf and twig fossils are common. Tertiary sandstones include fine-, medium-, and coarse-grained beds in outcrop with a few granule- to pebble-sized beds (McCune, 2008). The sandstones are likely aquifers in the subsurface; however, the lateral continuity of the beds is unknown.

In the northern half of the valleys glacial till predominates. Between ridges of till are pothole lakes, including Browns and Kleinschmidt Lakes; the lakes are expressions of shallow groundwater in till and glacial outwash. Glacial outwash, possibly several hundreds of feet thick, was locally deposited north of the Blackfoot River and especially near the North Fork of the Blackfoot, on Kleinschmidt Flat (Roberts and Waren, 2001; Aguirre and others, 2000).

DATA SOURCES

Original versions of the geologic maps are available through the MBMG and US Geological Survey as attributed in figure 2. Base layers of physiography, hydrography, townships, and cultural features were derived from Natural Resource Information System datasets.

ACKNOWLEDGMENTS

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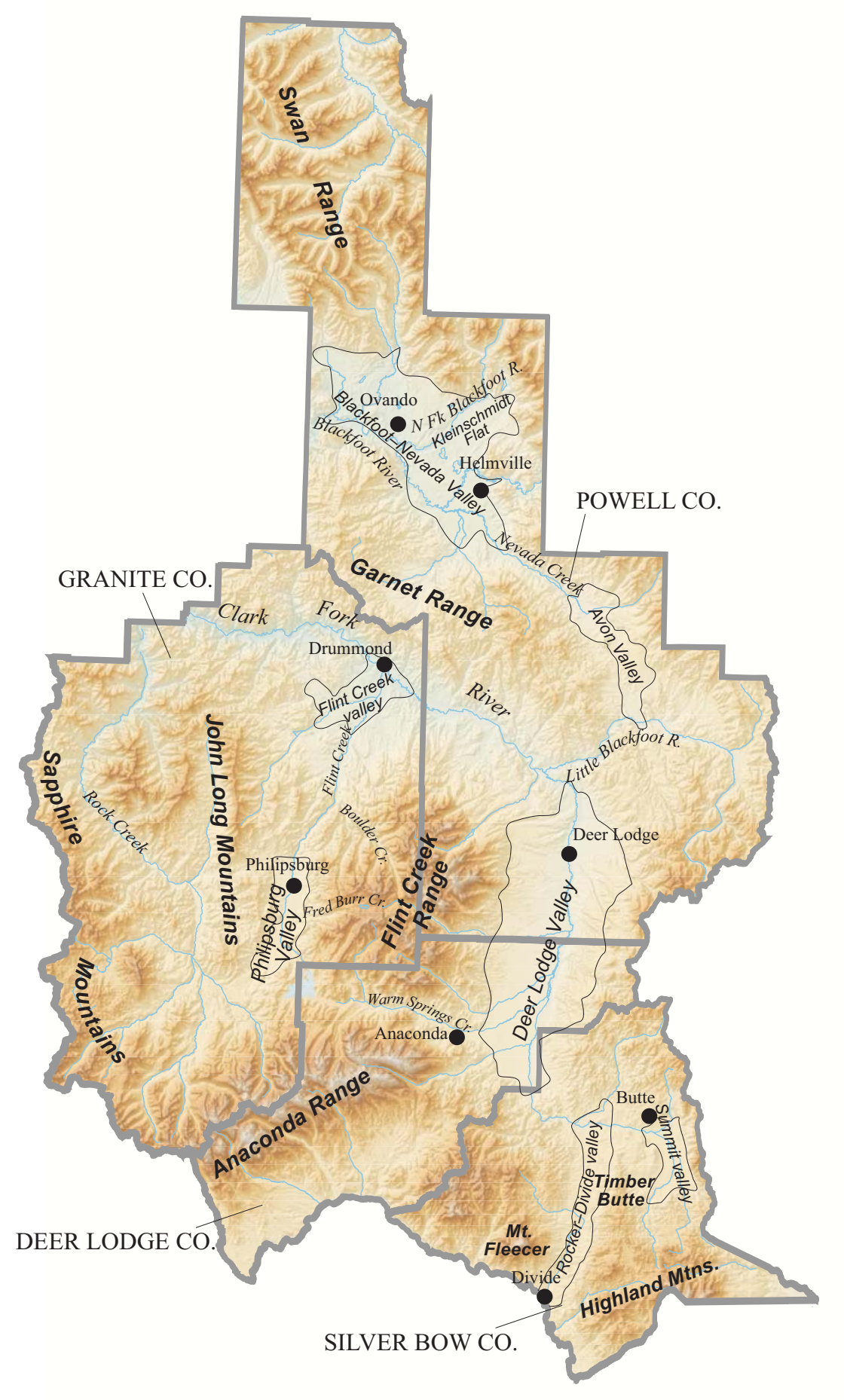


Figure 4. Index map showing the principal roads and cities, valleys, basins, drainages, and physiographic locations.

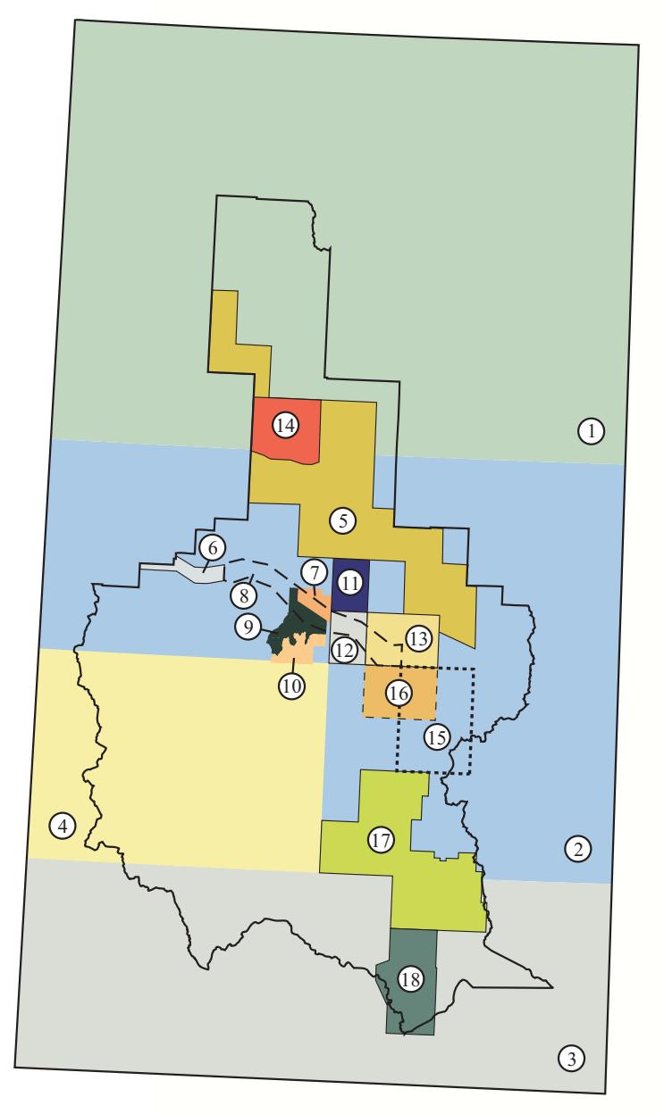


Figure 2. Index to previous maps from which contacts were compiled:

1. *Mudge and Earhart (1983)*
2. *Lewis (1998)*
3. *Ruppel and others (1993)*
4. *Lonn and others (2003)*
5. *Witkind and Weber (1982)*
6. *Berg (2006)*
7. *Rasmussen (1969)*
8. *Berg (2005)*
9. *Portner and Hendrix (2005)*
10. *Gwinn (1961)*
11. *Brooks and Sears (in press) Bailey Mtn.*
12. *Brooks and Sears (in press) Griffin Creek*
13. *Sears and others (2000)*
14. *L.N. Smith (unpubl. mapping)*
15. *Derkey and others (1993)*
16. *Berg (2004)*
17. *Berg and Hargrave (2004)*
18. *Vuke (2004)*

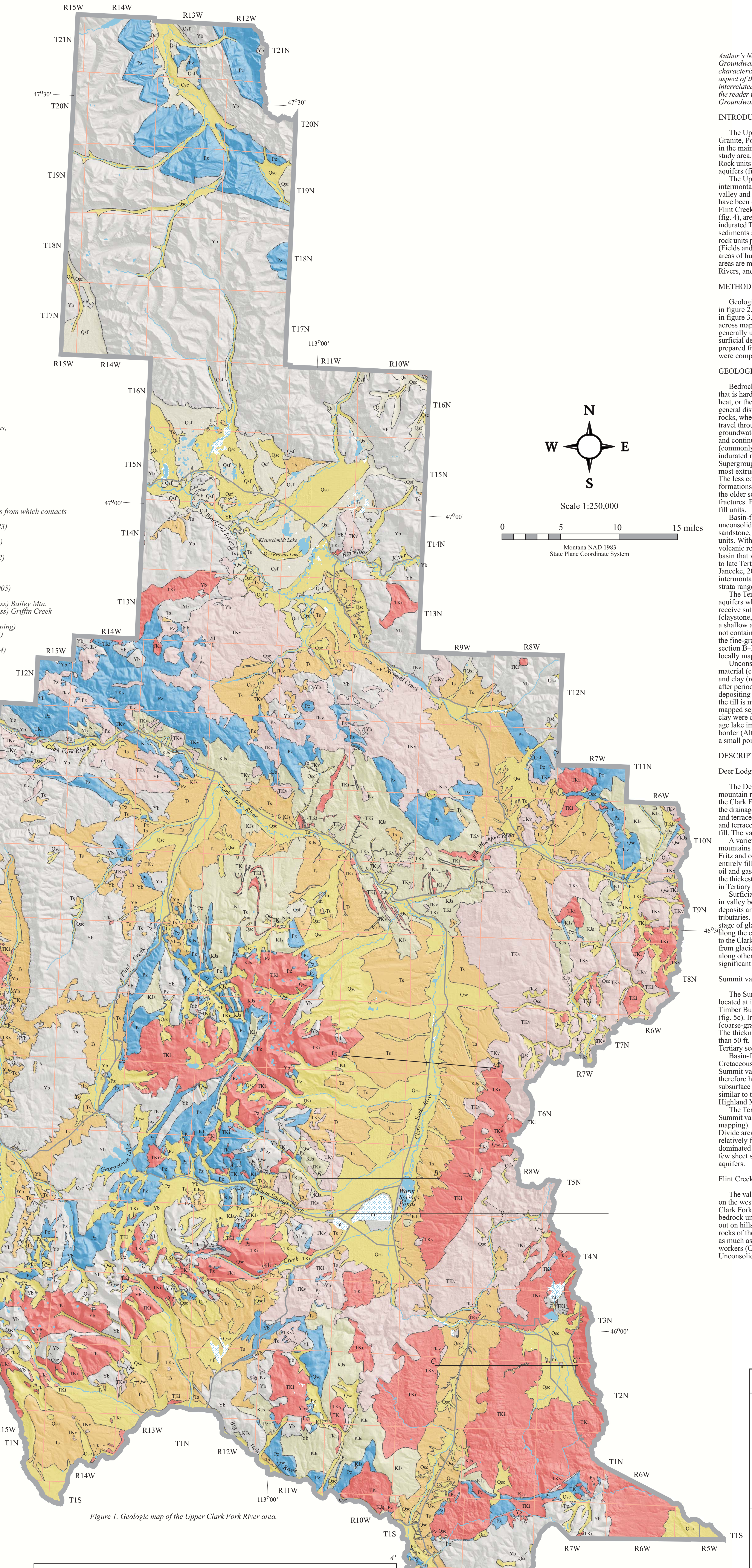


Figure 1. Geologic map of the Upper Clark Fork River area.

Descriptions of geologic units in which wells were completed. Geologic codes (e.g. 112TILL) are those used in the GWIC database.

Qsc	*Quaternary sediments, coarse-grained* Sandy and gravelly alluvium in recent river valleys. Mostly gravel and some sand at or near the land surface, deposited by rivers and glacial meltwater streams; deposits are most notable in the Ovando area and beneath Kleinschmidt Flat where they are estimated to be between 100 and 500 ft thick (Witkind and Weber, 1982).
Qsf	*Quaternary sediments, fine-grained* Poorly sorted mixture of gravel, sand, silt, and clay deposited directly by glacial ice and in other ice-marginal environments (112TILL); some deposits of stratified drift are encased in till; till forms prominent moraines in locations along the margins of both the Flint Creek and Anaconda Ranges, but are not shown on this map; in the Ovando area till overlies and underlies glaciofluvial and glacial-lake deposits near Kleinschmidt Flat (Witkind and Weber, 1982); local clay-rich deposits (with varied sand and silt content) are of probable glacial-lake origin (112SICL).
Ts	*Tertiary sedimentary rocks* Poorly to well-consolidated; sandstones and conglomerates (120SNGR), or claystones, coalbeds, and shales (120SICL); some sedimentary lithologies are mixed or indeterminate (120SDMS); makes up much of the fill in the Deer Lodge, Flint Creek, Philipsburg, Blackfoot–Nevada, and Avon basins.
TKv	*Tertiary and Cretaceous volcanic rocks* Volcaniclastic rocks, tuffs, welded tuffs; andesitic and basaltic flows (mostly unnamed except for the Lowland Creek Volcanics, 124LDCK); the Elkhorn Mountain Volcanics composed of andesitic and basaltic tuffs, breccias, and flows (211ELKM); some of the intrusive rocks may be of Tertiary age.
TKi	*Tertiary and Cretaceous intrusive rocks* Intrusive igneous rocks of compositions ranging from monzogranite to granodiorite, diorite and gabbro (Lewis, 1998); includes the Boulder Batholith (211BDBT) and the Anaconda and Flint Creek Batholiths (211PLNC).
KJs	*Cretaceous and Jurassic sedimentary and metasedimentary rocks* Structurally deformed Mesozoic sandstones, mudstones, shales, and minor limestones in mountain areas, around valleys, and underneath basin-fill deposits; metamorphosed where in contact with the intrusive bodies, as in the western margin of the Deer Lodge Basin; includes the Upper Cretaceous Colorado Group (211CLRD) and Golden Spike Formation (211GSPK); and the Lower Cretaceous Blackleaf Formation (217BCKF), Carter Creek Formation (217CRCK), the Kootenai Formation (217KOTN), and undifferentiated sedimentary rocks (217SDMS).
Pz	*Paleozoic sedimentary and metasedimentary rocks* Structurally deformed Paleozoic limestones, dolomites, sandstones, shales, and mudstones in mountain areas, around valleys, and underneath basin-fill deposits; includes the Permian Phosphoria Formation (310PSPR), Mississippian Madison Group (330MDSN), Devonian Three Forks and Jefferson Formations (337TRFK, 341JFRS), and the Cambrian Hasmark Formation (370HMRK), and undifferentiated Paleozoic (300SDMS) and Cambrian (370CMBR) sedimentary rocks.
Yb	*Belt Supergroup and Archean rocks* Metamorphosed limestone, dolomite, siltstone, and sandstone; rocks of the middle Belt carbonate (400MCRB), Missoula (400MSSL), and Shepard (400SPRD) units; and undifferentiated units of the supergroup (400BELT); these rocks have been folded, faulted, and fractured; prominent in the Sapphire Range, Flint Creek Range, Philipsburg Valley, Rock Creek area, and in the Big Hole River area, and underlying those valleys adjacent to these areas.

Explanation:

▬	Study area boundary
—	Township boundary
—	Major road
〰	Principal river or stream
●	Lake or reservoir
▨	Intermittent lake, tailings pond, or wetland
▨	Mine land areas

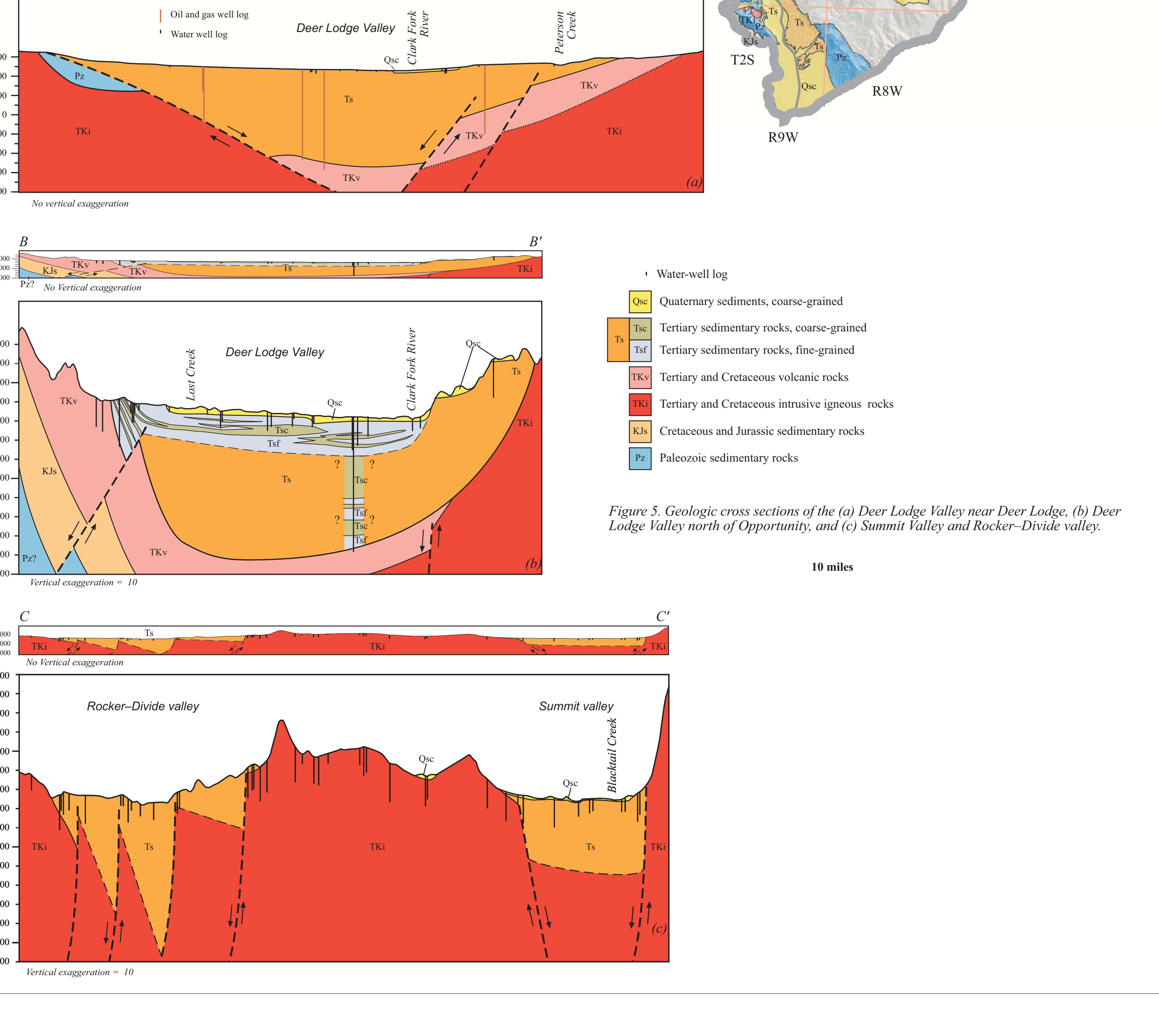
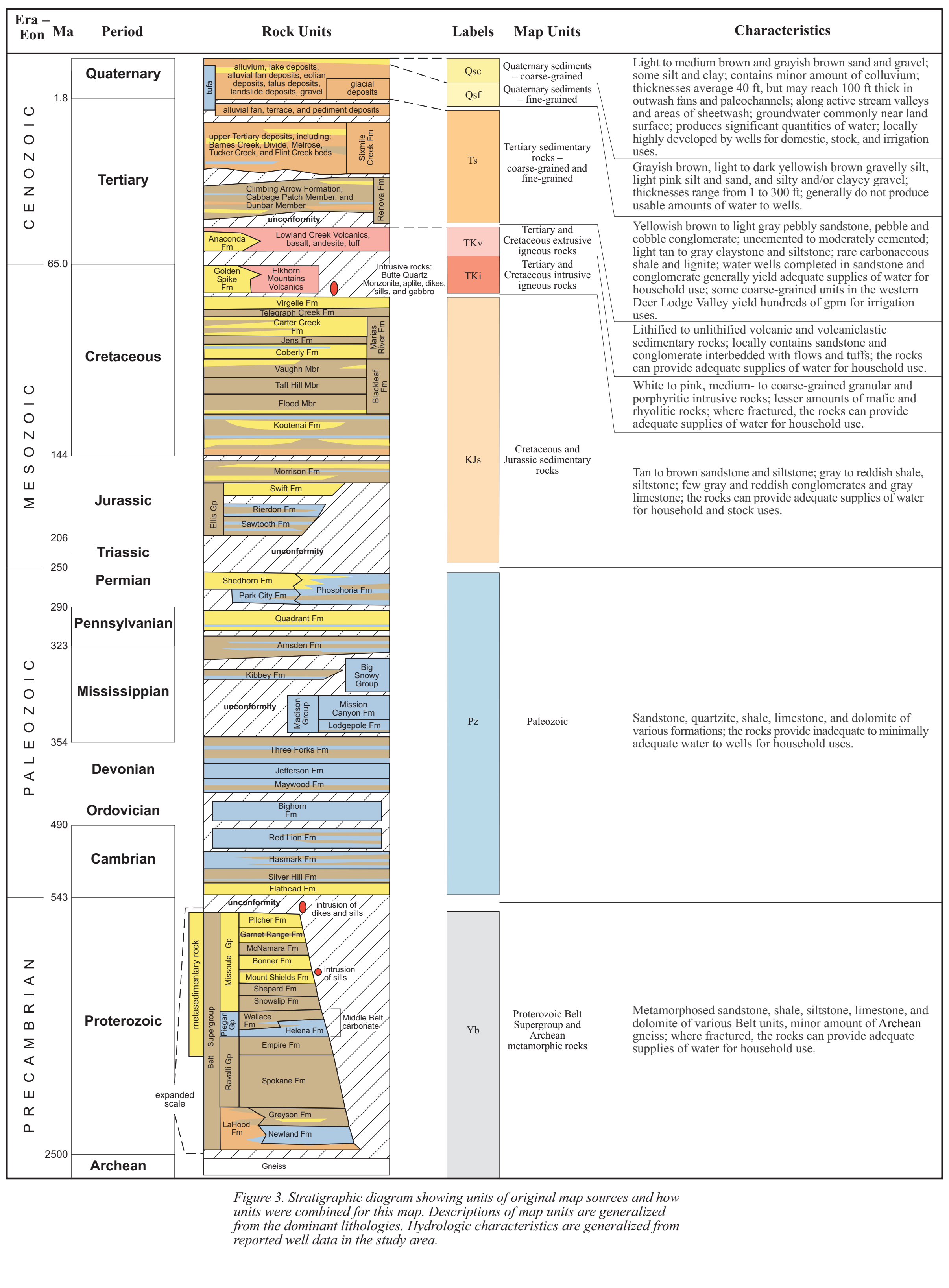


Figure 5. Geologic cross sections of the (a) Deer Lodge Valley near Deer Lodge, (b) Deer Lodge Valley north of Opportunity, and (c) Summit Valley and Rocker–Divide valley.



Labels	Map Units	Characteristics
Qsc	Quaternary sediments – coarse-grained	Light to medium brown and grayish brown sand and gravel; some silt and clay; contains minor amount of colluvium; thicknesses average 40 ft, but may reach 100 ft thick in outwash fans and paleochannels; along active stream valleys and areas of sheetwash; groundwater commonly near land surface; produces significant quantities of water; locally highly developed by wells for domestic, stock, and irrigation uses.
Qsf	Quaternary sediments – fine-grained	Grayish brown, light to dark yellowish brown gravelly silt, light pink silt and sand, and silty and/or clayey gravel; thicknesses range from 1 to 300 ft; generally do not produce usable amounts of water to wells.
Ts	Tertiary sedimentary rocks – coarse-grained and fine-grained	Yellowish brown to light gray pebbly sandstone, pebble and cobble conglomerate; uncemented to moderately cemented; light tan to gray claystone and siltstone; rare carbonaceous shale and lignite; water wells completed in sandstone and conglomerate generally yield adequate supplies of water for household use; some coarse-grained units in the western Deer Lodge Valley yield hundreds of gpm for irrigation uses.
TKv	Tertiary and Cretaceous extrusive igneous rocks	Lithified to unlithified volcanic and volcaniclastic sedimentary rocks; locally contains sandstone and conglomerate interbedded with flows and tuffs; the rocks can provide adequate supplies of water for household use.
TKi	Tertiary and Cretaceous intrusive igneous rocks	White to pink, medium- to coarse-grained granular and porphyritic intrusive rocks; lesser amounts of mafic and rhyolitic rocks; where fractured, the rocks can provide adequate supplies of water for household use.
KJs	Cretaceous and Jurassic sedimentary rocks	Tan to brown sandstone and siltstone; gray to reddish shale, siltstone; few gray and reddish conglomerates and gray limestone; the rocks can provide adequate supplies of water for household and stock uses.
Pz	Paleozoic	Sandstone, quartzite, shale, limestone, and dolomite of various formations; the rocks provide inadequate to minimally adequate water to wells for household uses.
Yb	Proterozoic Belt Supergroup and Archean metamorphic rocks	Metamorphosed sandstone, shale, siltstone, limestone, and dolomite of various Belt units, minor amount of Archean gneiss; where fractured, the rocks can provide adequate supplies of water for household use.

Figure 3. Stratigraphic diagram showing units of original map sources and how units were combined for this map. Descriptions of map units are generalized from the dominant lithologies. Hydrologic characteristics are generalized from reported well data in the study area.