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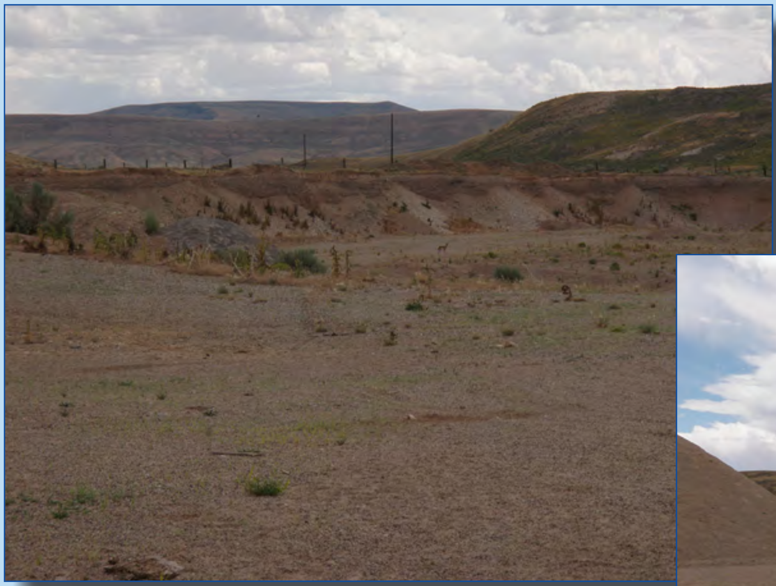
Map of Sand and Gravel Mines, Prospects, and Occurrences, and the Geologic Units That Host Them in the Wyoming Landscape Conservation Initiative (WLCI) Study Area, Southwestern Wyoming



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U.S. Department of the Interior
U.S. Geological Survey

Cover. Abandoned gravel quarry near Leefe, Wyoming, with a pronghorn (*Antilocapra americana*) for scale. Photographs taken August 6, 2010, by A.B. Wilson.

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By Anna B. Wilson

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Map of Sand and Gravel Mines, Prospects, and Occurrences, and the Geologic Units That Host Them in the Wyoming Landscape Conservation Initiative (WLCI) Study Area, Southwestern Wyoming

By Anna B. Wilson

Introduction

The Wyoming Landscape Conservation Initiative (WLCI) is a long-term science based effort to assess and enhance aquatic and terrestrial habitats at a landscape scale in southwest Wyoming, while facilitating responsible development through local collaboration and partnerships. The role of the U.S. Geological Survey (USGS) is to build the scientifically defensible foundation on which WLCI planners, decision-makers, and resource managers may base their activities (Bowen and others, 2015). Understanding the distribution of mineral resources is integral to understanding where mineral development (mining) might be concentrated in the future and how that mining might affect habitats. This map and report focus on naturally occurring sand and gravel that are used as construction aggregate.

Construction Aggregate

Construction aggregate includes naturally occurring sand and gravel as well as crushed stone. These materials are relatively inexpensive to mine: transportation is often the largest part of the cost. To be economic, most aggregate sources need to be as close as possible to their end-use location unless there is a cost-effective way to move the product. Generally, more populated and developed areas use more construction aggregate than less populated areas. In 2016, Wyoming, the 48th most densely populated state in the U.S., appears to have been the 37th most productive state for construction sand and gravel and the 34th most productive for construction aggregate (USGS, 2017a). In terms of value, in 2016, Wyoming ranked 28th for sand and gravel and 42nd for overall construction aggregate (USGS, 2017a). These rankings indicate that, relative to other states, Wyoming's sand and gravel commands a higher price and construction aggregates are lower priced. The Wyoming State Geological Survey website has a summary of construction aggregate resources (Luhr, 2015) and more general construction aggregate information on their website (Wyoming State Geological Survey, 2017).

Sand and Gravel versus Crushed Stone

There are two different sources of construction aggregate: (1) naturally occurring sand and gravel from mostly unconsolidated sediments that can be dug out of a pit without any blasting or cutting, and (2) crushed rock from quarries where rock is drilled, blasted, excavated, and crushed. To the extent practical, this map and pamphlet depict only the naturally occurring sand and gravel, not crushed stone. However, there may be some crushed stone locations inadvertently shown for reasons described below.

Methodology

Three databases were used to depict the locations of the sand and gravel mines, prospects, and occurrences: Mineral Resources Data System (MRDS) (USGS, 2017b), Mineral Deposit Database project (USMIN) (USGS, 2017c), and Wyoming Industrial Minerals Map (Wyoming State Geological Survey Map Series 47 by Harris, 2004, herein referred to as MS47). While there is general correspondence among them, some data vary, suggesting that none of the datasets is to be viewed as perfectly accurate. The general patterns of distribution are similar at small scales (large areas shown with little detail), but at large scales (small areas shown with much detail) they are considerably different. These data are overlain on the State geologic map (Love and Christiansen, 1985; reissued in digital form by Green and Drouillard, 1994). Many of the sites in the databases are located within geologic units that can be expected as sources for sand and gravel. However, a significant number are not (see table 1). Suitability of these outliers as naturally occurring sand and gravel sources should only be considered on a case-by-case basis.

Sites

Every effort was made to show sites that would be mined as naturally occurring sand and gravel, not as rock that requires crushing. However, in some cases, deposits that require crushing were not coded as crushed stone in their respective databases. Some gravel pits marked on the USGS topographic maps and reported in the literature occasionally include rock that would have to be broken or crushed and should rightly be labeled “quarry.” Verifying this for each of the nearly 1,800 records is beyond the scope of this report. Also, occasionally, a mining operation may produce both sand and gravel and crushed stone. Therefore, it is assumed that locations that plot outside expected (unlithified) geologic units are not naturally occurring sand and gravel.

Clustering of locations in more than one dataset is an indication that the data may be realistic. Isolated points in one dataset, but not the other datasets, may be an indication of a poor location, erroneous data, a newly permitted site with no active mining, misclassified, or misinterpreted sites; or it may simply be an oversight as to why it was not included in the other datasets.

Within WLCI, there are 403 MRDS records (USGS, 2017b) for sand and gravel sites (including mines, prospects, and occurrences). Many of these sites (magenta and pink points on the map sheet) are shown on 1:24,000-scale topographic quadrangles as gravel or borrow pits (and therefore included in the USMIN database, USGS, 2017c), others are shown on county-wide maps (for example, Root and others, 1973), or are mentioned in other publications (for example, Osterwald and others, 1966).

A dataset of prospect- and mine-related features shown on USGS topographic maps released in 2016 (U.S. Geological Survey, 2017c) contains 670 sites within WLCI. The USMIN locations are from USGS topographic maps and are marked on the map sheet accompanying this report as black and gray points. Each site was coded as to the deposit type: borrow pit, gravel pit, and for the polygon data, gravel/borrow pit—undifferentiated, and sand pit (Horton and San Juan, 2017). For reasons previously mentioned, some of these locations may include crushed stone.

A “pits” data layer included in the 1:500,000-scale Wyoming State Geological Survey Industrial Minerals and Construction Materials map (Harris, 2004) contains 724 pits in the WLCI area. They are shown on the map sheet as green points, but little emphasis should be placed on them unless they plot in the vicinity of sites in the other two datasets. The locations in that publication for these 724 pits (described as “pit or quarry for sand, gravel, or unspecified aggregate” in the map explanation) are unverifiable as no references are assigned to each record. Because the locations are unverifiable, they are not used to isolate rock units with sand and gravel potential unless there is corroborating data in each of the other two datasets.

Geology of Sand and Gravel

Two Types of Geologic Mapping—Bedrock and Surficial

There are two types of geologic mapping at 1:500,000 scale for the State of Wyoming: bedrock (Love and Christiansen, 1985; also available in digital form by Green and Drouillard, 1994); and surficial (Case and others, 1998). The former emphasizes the bedrock at any given location, even if it is covered with soil or unconsolidated material. The latter emphasizes whatever ground cover is at the surface. Both maps are 1:500,000 scale and are of necessity at that scale generalized and therefore may not show smaller bodies or irregular outlines.

Bedrock geologic mapping, although it emphasizes consolidated (lithified) formal lithostratigraphic units (for example Tb, Bridger Formation) does include substantial surficial material (such as Qa, Quaternary alluvium and colluvium) where it obscures the bedrock. Thick river gravels (alluvium), glacial deposits, sand dunes (eolian sands), and many other materials are additional examples of surficial material shown on bedrock geologic maps. Geologic map units are coded for the entire State of Wyoming (modified from Love and Christianson, 1985; Green and Drouillard, 1994). Local internal variations in lithology mean that, for example, a geologic map unit containing conglomerate in the northeastern part of the state may not contain conglomerate in the southeastern part.

The vast majority of the sand and gravel sites (Harris, 2004; USGS, 2017b, c) fall within (or very close to) one of the mapped “bedrock” geologic units (table 1) described in the following section (Love and Christiansen, 1985; Green and Drouillard, 1994). Three site locations in MRDS plot in water. It isn’t known if these sites are mislocated, or if the location from which they were mined is now flooded, or if the mapping is of insufficient detail. It is not possible to be certain that any site on the map sheet exists within the geologic unit in which it is mapped because of the generalizations required to depict geology at 1:500,000 scale and because of the inability to verify exact locations of each site. Studying the locations on satellite imagery shows that almost half the records have absolutely no surface disturbance and therefore may never have been mined. In the cool, semiarid Wyoming climate, even mine sites that have been fully reclaimed or abandoned for decades would still show visible surface scars. Therefore, the supposed presence of sites where no disturbance is visible suggests that either the site is mislocated, was located at a different scale and therefore is not accurate, or it has never been developed or mined. Commonly, housing developments, shopping complexes and other commercial venues are built on former or mined-out gravel pits, obliterating any sign of prior mining operations. However, in Wyoming, the vast majority of these “phantom” sand and gravel operations are in undeveloped areas along highways or other substantial access roads and should be visible on imagery if the ground had ever been disturbed.

Surficial geology (Case and others, 1998) shows the unconsolidated materials below the top soil layers, but above the bedrock. At least one record in each of the three databases plots within 18 of the mapped surficial units (table 1). Some of the units are areally limited or contain only one site. Most of these units are described similarly to other units (for example, alluvium is mentioned in 11 of the units) and there is vast overlap in their composition. Surficial geology is just that, the top layer of unlithified material on the bedrock surface. For the most part, such accumulations of material are too thin to be a source of sand and gravel unless the geologic unit below is also suitable. For these reasons, the surficial geology is not a good indicator of where sand and gravel resources are likely to occur.

Table 1 includes the number of site records in each of the three datasets that plot within each geologic unit. Units shaded orange or yellow are described below. Units shaded gray are not discussed as there is little evidence or certainty that they could host an unlithified deposit. Columns on the right show which surficial units overlap the bedrock units containing sand and gravel sites listed in the databases.

Bedrock Map Units Likely to Host Naturally Occurring Sand and Gravel

Alluvial Sand and Gravel (Qa)

Alluvial sand and gravel deposits occur along most of the larger streams and rivers (mapped as alluvial and colluvium, unit Qa, Love and Christiansen, 1985; Green and Drouillard, 1994; and Harris, 2004). Such stream and river deposits are the major sources of sand and gravel in southwestern Wyoming. More than a quarter of all the sites containing sand and gravel in WLCI (in each of the three databases) are found in the areas mapped as Quaternary alluvium. These are mostly Recent (Holocene), unconsolidated stream deposits that contain varying proportions of subrounded to subangular clasts of gravel, sand, silt, and clay (Harris, 2004). Likely, many more deposits in other units shown on the map sheet may actually occur in alluvial sand or gravel units too small to show on a geologic map at 1:500,000 scale. In WLCI, the major source areas for river deposits are the Bear River at Evanston, and the North Platte River at Saratoga and Fort Steele.

Quaternary Gravel, Pediment (Terrace) and Fan Deposits (Qt)

Quaternary terrace gravels contain sand and gravel with a variable proportion of finer material (mapped as terrace gravels, unit Qt, Love and Christiansen, 1985; Green and Drouillard, 1994; Harris, 2004). These gravels may cap benches and terraces and often form a surface layer more resistant to erosion than surrounding rock units. Terrace deposits include braided stream and sheet flood deposits along mountain flanks and terrace sand and gravel from Pleistocene basins. The quality of terrace deposits as sand and gravel sources varies significantly. Locally, these clean, well-graded, and hard gravels are good sources of construction materials. Large areas of terrace gravels in the study area are in western Sublette County.

Glacial Deposits (Qg)

Glacial deposits such as Pleistocene glacial moraine, outwash, and related rocks sometimes containing a high proportion of coarse material (unit Qg on Love and Christiansen, 1985; Green and Drouillard, 1994; Harris, 2004) are local sources of sand and gravel. Large quantities of these glacially sorted gravels are found in the higher mountains in the study area and have been used for local construction projects such as roads. Locally, these sites could be a source of gravel, but the presence of clays and large boulders may be problematic and may reduce the value.

Windblown (Eolian) Sand (Qs)

Sand dunes and dune fields (both active and stabilized) are common throughout the study area, especially in the central part. The windblown (eolian) sand (mapped as dune sand and loess, unit Qs, Love and Christiansen, 1985; Green and Drouillard, 1994; Harris, 2004) might be expected to be a ready source of sand for use in aggregate and some construction needs. However, for many reasons, these sands and dunes have not been a major supply source of sand (Gibbons and others, 1990). They commonly are too rounded (referred to as dead sand) and lack the angular shape (referred to as sharp sand) that is desired for many applications. Much of the windblown sand is composed of almost half feldspar grains instead of quartz (silica) (Gibbons and others, 1990), which makes them physically and chemically less resistant than pure silica. They are frequently too fine grained, too far from markets, are in designated Wilderness Areas, contain too much clay or iron, or they are not high enough in silica content for industrial applications. There has been little need to use this loose windblown sand, especially as it is far from the markets; however, if demand increased, it could be a resource.

Surficial Deposits, Undivided (Qu)

Sand and gravel accumulations of various origins are mapped in southernmost Uinta County (mapped as undivided surficial deposits, unit Qu, Love and Christiansen, 1985; Green and Drouillard, 1994; Harris, 2004). Two pits, probably part of the same deposit, are associated with the easternmost extent of the bodies, in the southeast corner of Uinta County.

Older Terrace Gravel (QTg)

Pliocene to Pleistocene terrace gravel is present mostly in the southwestern area of the map. This unit may include partially consolidated gravels, boulder and cobble gravels on terraces and pediments, and well-rounded clasts with protoliths as old as Precambrian (mapped as terrace gravel, unit QTg, Love and Christiansen, 1985; Dover and M'Gonigle, 1993; Green and Drouillard, 1994; Harris, 2004). Suitability of these deposits varies widely, yet they appear to have been a source of gravel northeast of Cokeville, and where they are in close proximity to Interstate 80 (I–80) east of Evanston. These gravels may be thick and interbedded with sand lenses. The older gravels may be partly consolidated and occur along some major streams.

Units Unlikely to Host Natural Sand and Gravel Deposits, But May Be Aggregate Sources

Also within WLCI, additional sand and gravel sites noted in the three databases (MRDS, USMIN, and MS47) plot within units unlikely to host natural sand and gravel. Most of these units older than Quaternary are lithified rock, not unconsolidated. As such, they would require at least minimal crushing, although many of these units are composed of relatively soft rocks and would crumble easily. They may be crushed by ripping with heavy equipment and not require any drilling or blasting. For the purposes of this study, any sand and gravel extracted from these rocks, however, would be considered "aggregate" or "crushed stone" and not "naturally occurring sand and gravel" and as such are not included in this report. In addition to the two Quaternary units, only Tertiary and older units that have at least one deposit in each of the three databases (MRDS, USMIN, and MS47) are described below. Some of the areas depicted may be mapped as bedrock, but are overlain by thin surficial deposits. This group of deposits is additionally complicated because of regional lithologic differences within mapped geologic units. These units are identified in the text that follows with the label from Love and Christiansen (1985) or Green and Drouillard (1994) for ease of correlation with those sources. They are shown on the map sheet in paler shades without dark outlines or specific unit labels as the identity of each of the units is not critical to understanding the distribution of the likely sites (described above, in the previous section).

Quaternary

Playa lake and other lacustrine deposits (unit Ql), chiefly clay, silt, and fine sand, and may include travertine deposits (MRDS ID numbers 10254664, 10303535 plot in this unit), are generally ill suited for use as sand and gravel. Travertine may be crushed for use as aggregate and any unconsolidated materials could be used locally as sand and gravel.

Landslide deposits (unit Qls) are also ill suited for use as sand and gravel, even if they are unconsolidated, as they contain many different materials both compositionally and texturally. They are included in this category only because the mapping does not always differentiate the sources at sufficient detail.

Tertiary

Upper Miocene and Miocene tuffaceous sandstone and claystone (units Tmu and Tm) in the southern Rock Springs uplift and siliceous, arkosic, and locally radioactive sandstone, claystone, and conglomerate at the south end of Wind River Range may be potential hosts to some sand and gravel.

Root and others (1973, Construction Materials plate) suggest that the Bishop Conglomerate (unit Tbi), present in the southwest part of Sweetwater County "…could be a major source of highway construction material." It is composed of poorly sorted, moderately to firmly cemented fine gravels, sand and boulders of red quartzite roundstone, gray chert and limestone with gray to white tuffaceous sandstone matrix; these rocks are present only in the southwestern part of WLCI. To make gravel from this unit, the rock would need to be crushed, although it may crumble by ripping with heavy equipment without the need to drill or blast.

The Bridger Formation (unit Tb) appears to be a host for many of the deposits classified as sand and gravel in the study area, but it is unlikely that the material would be classified as naturally occurring sand and gravel. As of 1973, Root and others (see Construction Materials plate) noted, "…lenses of limestone or marlstone could contribute to the supply of construction material, however, none with sufficient thickness or areal extent [were] known." In the ensuing 40 years, it is clear from the number of sites plotting within the unit, especially in the western part of Sweetwater County, that it has, nevertheless, been prospected and, perhaps, mined.

In the northwest part of WLCI, there are many borrow (barrow) pits in the Laney Member of the Green River Formation (unit Tgl). Not an especially promising unit otherwise, but because this rock is close to the Jonah field (a natural gas field) where there is great demand for construction materials, it is being exploited. Whether this is because the rock is actually suitable or just because it is present locally is not clear.

One site is listed in each of the three databases as being in the Luman Tongue of the Green River Formation (unit Tglu). It may well be that the sites are in the residuum overlying the lithified rocks, but we are not able to confirm this. Residuum may be mixed with alluvium, eolian, slope wash, and grus deposits, and (or) bedrock outcrops (Case and others, 1998).

The Fontenelle Tongue or Member of Green River Formation and New Fork Tongue of Wasatch Formation (unit Twg) are mapped together without differentiation (Love and Christiansen, 1985). Several deposits appear to plot within this unit; they have the same caveats as for each of the previously discussed Tertiary units.

In the Thrust belt (Love and Christiansen, 1985), the Wasatch Formation (unit Tw) and the main body (unit Twm) may source several sand and gravel sites around the margins of Fossil and Green River basins.

North of Rock Springs, the Fort Union Formation (unit Tfu) is host to several sites classified in the databases as sand and gravel. Fort Union is mostly sandstone, shale, and coal. It is doubtful that the sites plotting within it are naturally occurring sand and gravel, and use of it as crushed stone is unlikely. It is included here only because of the many site records that appear to plot within the unit.

Cretaceous and Older

Cretaceous and older units are even less likely to contain unlithified rocks that could be sources of naturally occurring sand and gravel. Each of the units listed hosts at least one sand and gravel deposit in the three deposit databases. The deposits are either sourced in these units, are in units too small to be mapped at 1:500,000 scale (Love and Christiansen, 1985), are within surficial deposits (Case and others, 1998) overlying these bedrock units, or are misclassified. These older host rocks include the Lewis Shale (Kle); the Mesaverde Group (Kmv) including the uppermost Almond Formation (Kal), the middle Rock Springs Formation (Kr), and lowermost, the Blair Formation (Kbl); Hilliard Shale (Kh); Baxter Shale (Kba); Frontier Formation (Kf); Steele Shale (Ks); Niobrara Formation (Kn); undivided units containing both Steele Shale and Niobrara Formation (Ksn); Cloverly and Morrison Formations (KJ); Jurassic Stump Formation, including the Preuss Sandstone or Redbeds, and the Twin Creek Limestone (Jst); and the Chugwater Formation (₸c).

Additional Considerations

Miocene to Pleistocene older conglomerate (QTc; Love and Christiansen, 1985) occurs only in two isolated locations in the study area, both in the Medicine Bow Mountains. The larger deposit seems to be on Kennaday Peak, not in an easily accessible area. Although there is potential for use as a source of sand and gravel, it has not to our knowledge been exploited. In many cases, only those parts of formations that contain mapped conglomerates or gravels are shown on Harris (2004).

Additional rock units listed in table 1 (shaded gray) are lithified and, therefore, unlikely to be sources of naturally occurring sand and gravel. Units highlighted in gray have no sand and gravel sites in two or more databases. Therefore, these locations are not described in the text.

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Table 1. Number of deposits from each of the three databases whose coordinates fall within each geologic unit. Those of Love and Christiansen (1985) or Green and Drouillard (1994) are on the left-hand columns. The Symbol_Orig column and Unit_Name column refer to Love and Christiansen(1985) and correspond with the map sheet. On the right-hand columns are the corresponding surficial units from Case and others (1998) that contain the Mineral Resources Data System (MRDS), Mineral Deposit Database project (USMIN), and the Wyoming Industrial Minerals Map (Wyoming State Geological Survey Map Series 47, herein referred to as MS47 sites) on the left. Orange shading indicates likely host units. Units shaded yellow are less likely or unlikely to host unlithified sand and gravel deposits. Gray shading indicates units that do not contain any sand and gravel in the indicated host rock. [Ma, million years]

Surficial units (Case and others, 1998) are of interest because they may contain sites identified as sand and gravel deposits. These surficial units are not shown on the accompanying map, but the number of deposits in each of the three databases (MRDS, USMIN, and MS47) that plot within each is listed after the unit description. Eight deposits plot under water—possibly because the location is inaccurate, or it is very close to a water body, or the open pit where the deposit was mined is now flooded.

Unit labels are given below:

Units that may be sources of sand and gravel

- ti—Terrace deposits mixed with scattered deposits of alluvium, residuum, eolian, slope wash, and outwash (95/403 in MRDS, 182/670 in USMIN, 136/724 in MS47).
- ri—Residuum mixed with alluvium, eolian, slope wash, grus, and (or) bedrock outcrops (80/403, 118/670, 165/724).
- ai—Alluvium with scattered deposits of terrace, slope wash, eolian, residuum, grus, and glacial (68/403, 107/670, 142/724).
- sci—Slope wash and colluvium mixed with scattered deposits of slope wash, residuum, grus, glacial, periglacial, alluvium, eolian, and (or) bedrock outcrops (33/403, 59/670, 93/724).
- Ri—Bedrock and glaciated bedrock including hot spring deposits and volcanic necks; mixed with scattered shallow deposits of eolian, grus, slope wash, colluvium, residuum, glacial, and alluvium (31/403, 51/670, 46/724).
- bi—Bench including eolian, slope wash, outwash, and bench and (or) mesa (23/403, 37/670, 30/724).
- fi—Alluvial fan and gradational fan deposits mixed with scattered deposits of slope wash, residuum, and eolian (21/403, 47/670, 40/724).
- gi—Glacial deposits mixed with scattered slope wash, residuum, grus, alluvium, colluvium, and landslide deposits, and (or) bedrock outcrops (13/403, 6/670, 7/724).
- li—Landslide deposits mixed with scattered residuum and slope wash deposits, Tertiary landslides, and bedrock outcrops; landslides too small and numerous to show separately (11/403, 17/670, 16/724).
- oai—Glacial outwash and alluvium mixed with scattered glacial, terrace, hot spring, residuum, slope wash, and grus deposits, and (or) bedrock outcrops (8/403, 5/670, 11/724).
- ei—Eolian deposits mixed with scattered residuum, alluvium, and slope wash deposits (7/403, 6/670, 6/724).

Relatively unimportant units as sources of sand and gravel:

- xi—Truncated bedrock mixed with scattered shallow eolian, terrace, residuum, alluvium, old alluvial plain, bench, and slope wash deposits (4/403, 11/670, 3/724).
- pea—Playa deposits mixed with scattered alluvium, residuum, and eolian deposits; playa deposits too small to show separately (3/403, 4/670, 2/724).
- mi—Mesa deposits, including scattered residuum and eolian deposits (2/403, 7/670, 1/724).
- Mi—Mined areas mixed with scattered residuum and slope wash deposits, and (or) bedrock outcrops (2/403, 3/673, 3/724).
- fdi—Dissected alluvial fan and gradational fan deposits mixed with scattered residuum and slope wash deposits (1/403, 3/673, 2/724).
- tdi—Dissected terrace deposits mixing with alluvium, residuum, eolian, and slope wash deposits (1/403; 2/673, 4/724).
- tre—Shallow terrace deposits mixed with scattered residuum and eolian deposits (0/403, 3/673, 4/724).

Table 1. Number of deposits from each of the three databases whose coordinates fall within each geologic unit.—Continued

MRDS	USMIN	MS47	Symbol_Orig	Unit_Name	Surficial Units MRDS	Surficial Units USMIN	Surficial Units MS47
121	169	219	Qa	Alluvium and colluvium	ai, bi, fi, gi, li, Mi, oai, ri, Ri, sci, tdi, ti	ai, bi, fdi, fi, li, Mi, oai, pea, ri, Ri, sci, ti	ai, Ai, bi, fdi, fi, gi, li, Mi, oai, ri, Ri, sci, ti
30	59	50	Qt	Gravel, pediment, and fan deposits	ai, bi, oai, ri, sci, ti, xi	ai, bi, oai, ri, sci, tdi, ti, xi	ai, bi, fi, oai, ri, sci, tdi, ti, xi
6	6	6	Qg	Glacial deposits	ai, gi, oai	ai, gi	ai, gi, oai, Ri
6	6	5	Qs	Dune sand and loess	ei, Ri	ei, Ri	ei, pea, Ri, ti
2	2	2	Qu	Undivided surficial deposits	li	li	li
8	16	9	QTg	Terrace gravel (Pleistocene and [or] Pliocene)	bi, ti	bi, ti	bi
2	0	0	Ql	Playa lake and other lacustrine deposits	ri, pea		
0	0	1	Qls	Landslide deposits			ai
10	31	28	Tm	Miocene rocks	ai, fi, ri, Ri, sci	ai, fi, ri, sci, ti	ai, fi, ri, Ri, sci
5	17	19	Tmu	Upper Miocene rocks	ai, bi, fi, sci, ti	ai, fdi, fi, ri, sci, ti, tre	ai, bi, ri, Ri, sci, tre
8	10	2	Tbi	Bishop Conglomerate	li, Ri, ri	li, mi, Ri	Ri, ri
39	53	84	Tb	Bridger Formation	ai, bi, mi, pea, ri, Ri, sci, ti	ai, bi, mi, ri, Ri, sci, ti	ai, aR, bi, ei, mi, ri, Ri, sci, ti,
71	124	50	Tgl	Laney Member of Green River Formation	ai, bi, ei, pea, ri, Ri, sci, ti	ai, pea, ri, Ri, sci, tdi, ti	ai, aR, bi, ei, LAKE, ri, Ri, sci, tdi, ti
1	1	1	Tglu	Luman Tongue of Green River Formation	ri	ri	ri
6	9	27	Twg	Wasatch and Green River Formations—New Fork Tongue of Wasatch Formation and Fontenelle Tongue or Member of Green River Formation	ai, gi, sci, ti	ri, sci, ti	ai, ri, sci, ti
9	11	17	Tw	Wasatch Formation	bi, li, Ri, ri, ti	bi, fi, li, ri, Ri, ti	ai, fi, Ri, ri, sci, ti
19	38	27	Twm	Wasatch Formation, main body	ai, ei, li, ri, sci, ti	ai, bi, ei, li, ri, sci, ti	ai, li, pea, ri, Ri, sci, ti
6	15	9	Tfu	Fort Union Formation	ai, bi, ri, sci, ti	ai, ri, Ri, sci	ai, ri, sci, ti
1	1	6	Kle	Lewis Shale	xi	tdi	ri, ai
0	2	7	Kmv	Mesaverde Formation Group		tdi	sci, Ri, ri

Table 1. Number of deposits from each of the three databases whose coordinates fall within each geologic unit.—Continued

MRDS	USMIN	MS47	Symbol_Orig	Unit_Name	Surficial Units MRDS	Surficial Units USMIN	Surficial Units MS47
1	5	9	Kal	Mesaverde Group—Almond Formation	ri	Ri, ri	ai, ri, Ri
5	2	8	Kr	Mesaverde Group—Rock Springs Formation	ri	ri	fi, ri
2	1	6	Kbl	Mesaverde Group—Blair Formation	ri, sci	sci	ri, sci
5	15	11	Kh	Hilliard Shale	fi, xi	ai, fi, ti, xi	ai, fi, ri, sci, tdi
6	2	5	Kba	Baxter Shale	ai, ri, sci	ri	bi, ri
3	7	5	Kf	Frontier Formation	ai, bi	ai, bi	bi, li, Ri
2	2	9	Ks	Steele Shale	Mi, sci	Mi, sci	Mi, ri, Ri, sci
1	4	1	Kn	Niobrara Formation	li	li, bi	ri
3	5	13	Ksn	Steele Shale and Niobrara Formation	ai, sci	ai, ri, sci	ai, ri, sci, ti
1	1	1	KJ	Cloverly and Morrison Formations	xi	xi	sci
5	11	3	Jst	Stump Formation, Preuss Sandstone or Red-beds, and Twin Creek Limestone	Ri, li	li, Ri,	ai, li, Ri
1	3	2	TRc	Chugwater Group or Formation	sci	sci	ri
385	628	642		TOTAL number of records in each of the three main datasets plotting within each unit			
0	1	0	Tsl	Salt Lake Formation		Ri	
0	1	3	Tte	Teewinot Formation		ai	ai, li, ti
0	1	0	Twr	White River Formation		ri	
0	0	1	Toe	Oligocene and (or) upper and middle Eocene rocks			Ri
4	0	1	Tf	Fowkes Formation	ri		ri
0	0	1	Tgw	Wilkins Peak Member of Green River Formation			ri
2	0	8	Tgwt	Wilkins Peak Member and Tipton Shale Member or Tongue of Green River Formation	ai, Ri		ai, fi, Ri, sci
0	0	1	Tgt	Tipton Shale Member or Tongue of Green River Formation			sci
1	0	1	Twn	Niland Tongue of Wasatch Formation	ri		ri
0	2	5	Twdr	Wind River Formation—at base locally includes equivalent of Indian Meadows Formation		ri	bdi, ri

Table 1. Number of deposits from each of the three databases whose coordinates fall within each geologic unit.—Continued

MRDS	USMIN	MS47	Symbol_Orig	Unit_Name	Surficial Units MRDS	Surficial Units USMIN	Surficial Units MS47
0	0	9	Twlc	La Barge and Chappo Members of Wasatch Formation			ti, sci, ri, li
0	2	2	Tbs	Battle Spring Formation		ri, sci	bi, sci
1	5	0	Tgrw	Green River and Wasatch Formations	ri	ri, ai	
1	0	2	Tp	Pass Peak Formation and equivalents	ri		ri
0	0	1	Th	Hoback Formation			li
0	6	3	Tha	Hanna Formation		ri	fdi, ri
0	0	1	Kmb	Medicine Bow Formation			ri
0	3	3	Kss	Sage Junction, Quealy, Cokeville, Thomas Fork, and Smiths Formations		fi, Ri	fi, sci, ti
1	2	0	TKe	Evanston Formation	Ri	Ri, ai	
0	0	2	Ke	Mesaverde Group—Ericson Sandstone			ri
0	0	1	TKf	Ferris Formation			ri
0	1	4	Kc	Cody Shale		ti	ai, sci, ti
0	4	1	Ka	Aspen Shale		Ri, bi, ai	Ri
0	0	2	Kbr	Bear River Formation			Ri
0	0	2	Kg	Gannett Group—Includes Smoot Formation, Draney Limestone, Bechler Conglomerate, Peterson Limestone, and Ephraim Conglomerate			Ri, sci
0	0	1	Kmt	Mowry and Thermopolis Shales			sci
1	1	0	Kft	Frontier Formation, and Mowry and Thermopolis Shales	fdi	sci	
0	0	2	KJs	Cloverly, Morrison, and Sundance Formations			sci, ri
0	0	1	Js	Sundance Formation			sci
1	0	1	Jsg	Sundance and Gypsum Spring Formations	gi		gi
0	0	4	JTRn	Nugget Sandstone			Ri, li
0	0	1	JTRnd	Nugget Sandstone, Ankareh Formation, Thaynes Limestone, Woodside Shale, and Dinwoody Formation			li
0	0	3	TRad	Ankareh Formation, Thaynes Limestone, Woodside Shale, and Dinwoody Formation			Ri, li
0	1	0	TRPcg	Chugwater and Goose Egg Formations		sci	

Table 1. Number of deposits from each of the three databases whose coordinates fall within each geologic unit.—Continued

MRDS	USMIN	MS47	Symbol_Orig	Unit_Name	Surficial Units MRDS	Surficial Units USMIN	Surficial Units MS47
0	0	2	PM	Tensleep Sandstone and Amsden Formation			sci, fi
1	2	0	PℙM	Wells and Amsden Formations (in the Thrust Belt), or Casper Formation and Madison Limestone (elsewhere)	Ri	Ri	
1	2	0	Mm	Madison Limestone or Group	sci	sci	
0	3	1	Pzr	Madison Limestone, Darby Formation, Bighorn Dolomite, Gallatin Limestone, Gros Ventre Formation, and Flathead Sandstone; Madison Limestone and Cambrian rocks		fi	sci
0	1	0	MzPz	Mesozoic and Paleozoic rocks		sci	
1	1	0	OЄ	Bighorn Dolomite, Gallatin Limestone, and Gros Ventre Formation (in the Thrust Belt); Bighorn Dolomite, Snowy Range Formation, Pilgrim Limestone, Park Shale, Meagher Limestone, Wolsey Shale, and Flathead Sandstone (in the Yellowstone region)	Ri	Ri	
0	2	0	Wg	Granitic rocks of 2,600-Ma age group		Ri	
0	0	2	Wgn	Granite gneiss			ui, sci
0	0	1	Xgy	Granitic rocks of 1,700-Ma age group			sci
0	1	2	Xdl	Metasedimentary rocks—Deep Lake Group		gi	ri
3	0	7	water	Water	fi, ri, ti		fi, LAKE
18	42	82		TOTAL number of records in each of the three datasets plotting within each minor unit			
403	670	724		TOTAL number of RECORDS in each dataset			
				Units highlighted in gray have no mines in two or more databases. Therefore, these locations in the one remaining dataset are suspect and the unit is not described in the text. Units with only one dataset showing 0 are evaluated on a case-by-case basis.			

For more information concerning the research in this report, contact the
Center Director, USGS Geology, Geophysics, and Geochemistry Science
Center
Box 25046, Mail Stop 973
Denver, CO 80225
(303) 236-1800

Or visit Geology, Geophysics, and Geochemistry Science Center website at
https://www.usgs.gov/centers/gggsc

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