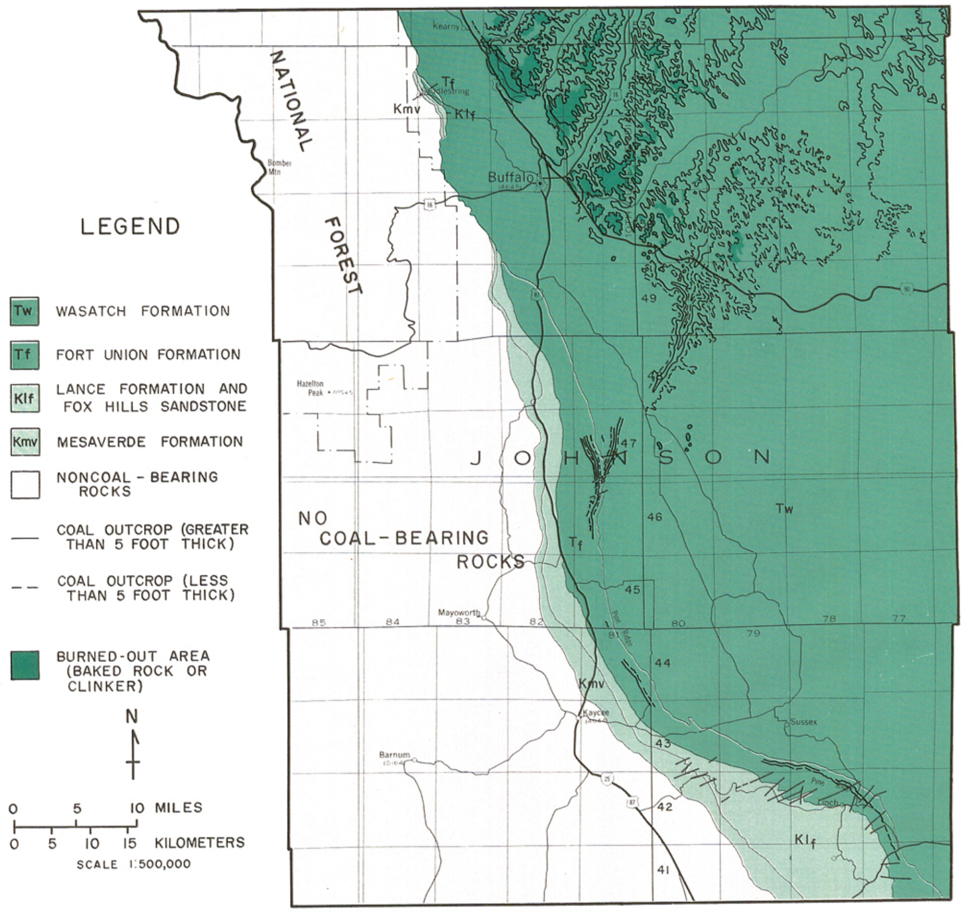


Coal Outcrops & Burned-Out Areas

Coal Resources

Between 38 and 65 million years ago, densely vegetated swamps frequently covered what is now Johnson County. In these swampy conditions, dying trees and grasses continually fell to the bottom of the swamp where they accumulated as thick layers of dead plant material called peat. As thousands of years passed, sediment was intermittently deposited atop these peat accumulations. Pressure resulting from the weight of these added sediments compressed the peat beds. Heat associated with the increasing depth of burial transformed the peat into coal beds that now crop out over much of the county.

Coals are apparently thickest and most persistent in northern and central Johnson County although this may only result from the lack of detailed mapping in other areas. The coal beds are flat-lying or dip very gently westward on the east side of the county, but change to easterly dips on the west side of the county, locally steepening to 10 to 20 degrees. Noncoal-bearing rocks only crop out along the western quarter of the county.

The Tertiary Fort Union and Wasatch Formations contain all of the thick coals that crop out in Johnson County. In fact, these two formations are two of the most prolific coal-bearing formations in Wyoming. In Johnson County, the Wasatch Formation contains six to eleven persistent, lignitic to subbituminous coal beds, one of which, the Healy seam, ranges up to 220 feet thick in the Lake de Smet area. Normally, these coal beds range between a couple of feet thick to 30 feet thick.

The upper half of the older Fort Union Formation contains as many as eight, persistent, subbituminous coal beds which range from a couple feet thick to as much as 50 feet thick. Coals occur in the lower half of the Fort Union Formation as well, but they are thinner and much less persistent than those in the upper part of the formation.

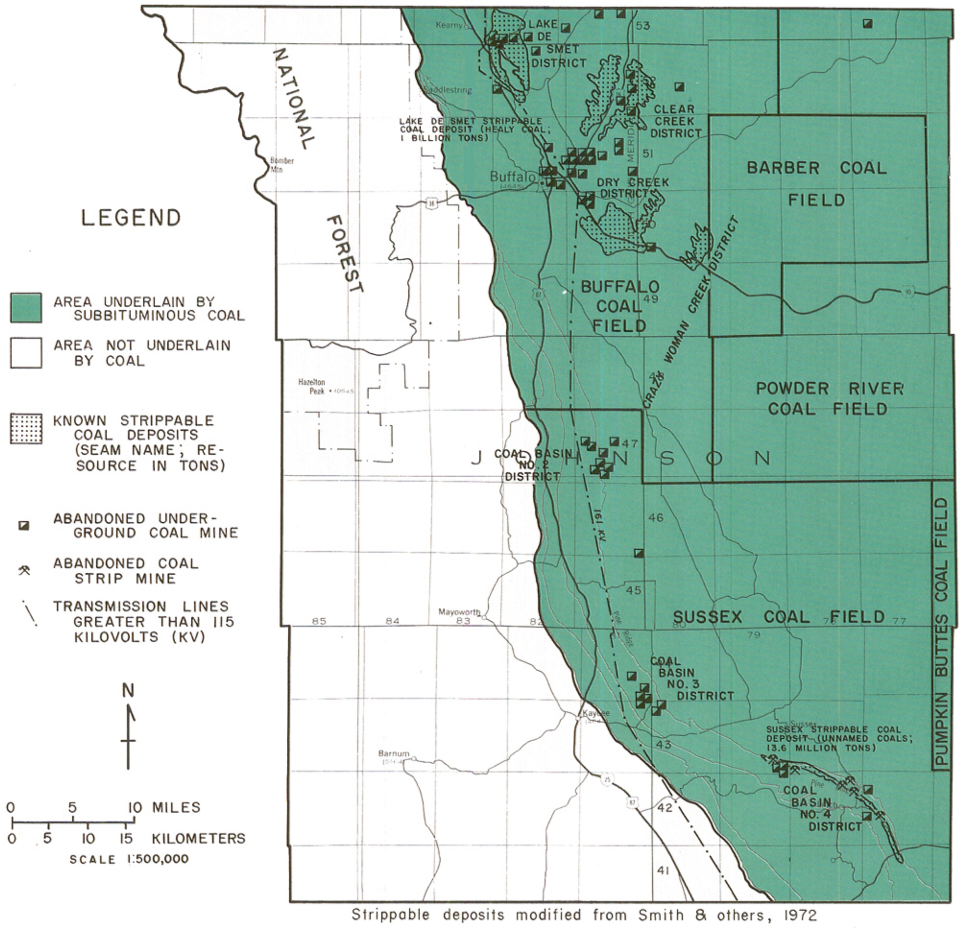
Although the Cretaceous Lance and Mesaverde Formations exhibit some fairly thick, low rank coals on the southern and eastern flanks of the Powder River Basin, there is no evidence that anything but very thin, discontinuous coals occur in these formations in Johnson County.

Many outcropping coals have been burned through natural causes over large areas of the county. Despite this burning, more than 12 billion tons of coal still underlie Johnson County at depths up to 3000 feet. While over seven billion tons of this resource estimate occur under less than 1000 feet of rock, only 2.3 billion tons of that is believed minable by underground methods.

Another one billion tons of that resource lies under less than 200 feet of rock and is believed recoverable by strip mining.

According to published data, nine percent of Wyoming's remaining identified coal resources and four percent of its known strippable coals are in Johnson County.[1] Although coal-bearing rocks underlie 59 percent of the county, known strippable deposits only underlie 6.5 square miles or 4,170 acres (0.2 percent of Johnson County).

[1]Glass, G. B., 1975, Review of Wyoming Coalfields, 1975: Geological Survey of Wyoming, Laramie, 21 p.



Strippable deposits modified from Smith & others, 1972

Coal Mining

History & Forecast for Coal Mining

Although recorded coal mining in Johnson County dates back to 1888, no significant production has ever come from the county. Annual production peaked in 1922 at only 16,221 tons. Soon after World War II, production began a rapid decline that culminated in the closing of Johnson County's last coal mine in 1957.

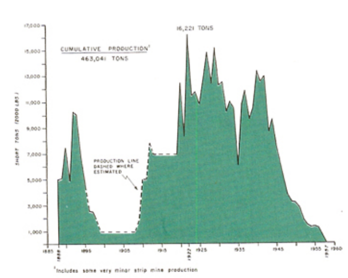
The county's cumulative coal production from 70 years of mining is only 462,041 tons, of which underground mining accounts for 99.9 percent of the total. During the county's long mining history, no less than 66 mines were operated at first to supply Buffalo and Fort McKinney and later to supply other communities and ranches in and around the county. Small wagon mines were operated all along the coal outcrops in central and southern Johnson County with the larger mines centered around Buffalo.

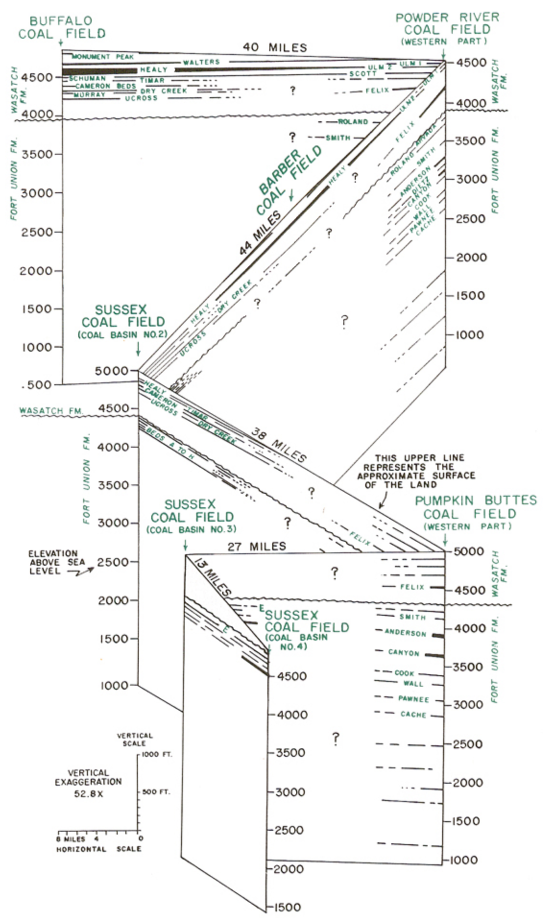
Although demand for the county's coals has not yet developed, the many companies that hold large state and federal coal leases in the county indicates a continued interest. One hundred fifty-two state coal leases totaling 125,486.98 acres were held by 16 lessees in 1975; seven of these controlled 90 percent of the leases. Six federal leases held by two lessees totaled another 13,969.31 acres for a total of 139,456.29 acres under government lease. Additionally, other companies have federal coal prospecting permits in the county and have applied to have them converted into leases.

Low heat values coupled with a lack of adequate transportation systems continues to handicap development of the county's coal. Future utilization will probably center on mine-mouth coal gasification, liquefaction or power plant facilities rather than on mines which merely ship the coal to more distant markets.

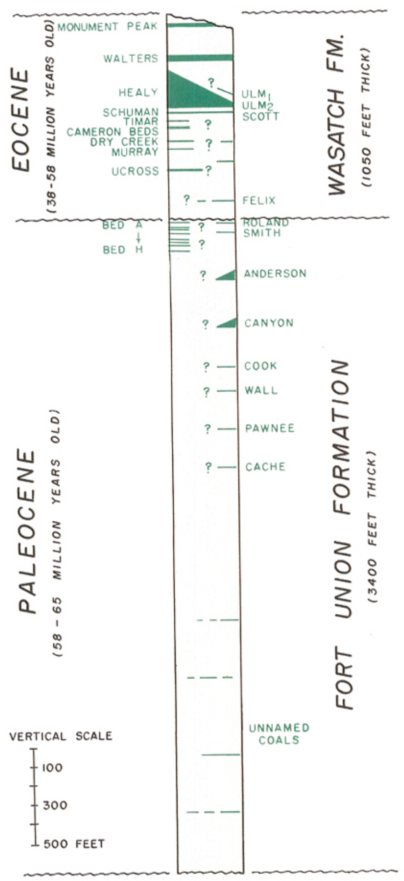
Texaco, the largest federal leaseholder, recently submitted a proposal to the Energy Research and Development Administration (ERDA) for partial funding of a demonstration coal gasification plant. Coal for that plant, whether constructed in Sheridan or Johnson County, would come from the Lake DeSmet area. Should Texaco get the go-ahead on its plant, they would mine two to three times the cumulative coal production of the county in one year. Several other large lessees are also rumored to be studying or planning coal strip mines for possible use in the Johnson County area. The time frame for these plants remains vague, but an interest in Johnson County coals cannot be denied.

Annual Production from Underground Mines

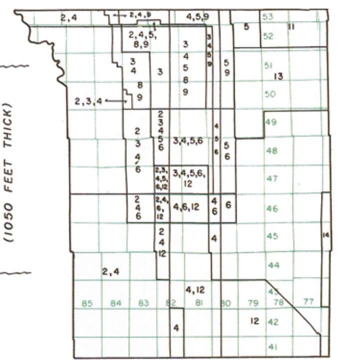




Correlation of Major Beds



Stratigraphic Column of Coal-Bearing Rocks



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*Not included on map.

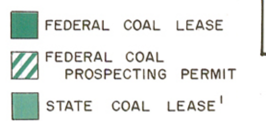
Coal Analyses

		WASATCH FORMATION				FORT UNION FORMATION			
		HEALY (12)[1]		LOWER CAMERON (5)[1]		BED E[3] (2)[1]		BED B[4]	LOWERMOST BED[5]
	As received	Range	Average	Range	Average	Range	Average	Single Analysis	Single Analysis
PROXIMATE	MOISTURE (%)	23.6-31.2	29.1	26.8-31.1	28.8	18.8-23.5	21.1	28.8	23.6
PROXIMATE	VOLATILE MATTER (%)	28.6-33.1	30.5	28.7-32.8	29.8	35.7-35.6	35.6		
PROXIMATE	FIXED CARBON (%)	35.4-32.8	34.2	34.7-27.9	31.7	37.9-35.7	36.8		
PROXIMATE	ASH (%)	2.2-9.7	6.3	7.2-12.5	9.6	5.2-14.6	6.5		
ULTIMATE[2]	HYDROGEN (%)	6.1-6.7	6.5	6.0-6.6	6.4	6.5	6.5	6.7	7.8
ULTIMATE[2]	CARBON (%)	45.4-48.3	46.6	42.7-44.6	43.6	51.2	51.2		
ULTIMATE[2]	NITROGEN (%)	0.7-1.0	0.8	0.5-0.8	0.6	.7	.7		
ULTIMATE[2]	OXYGEN (%)	34.2-40.6	38.8	37.5-40.7	39.1	35.9	35.9		
ULTIMATE[2]	SULFUR (%)	0.3-1.0	0.6	0.4-1.4	0.9	0.5-0.6	0.5	0.6	0.7
	HEAT VALUE (BTU/POUND)	7515-8270	7910	7344-7627	7492	7980-9157	8729	7931	8446

[1]Number of samples averaged for proximate analysis.
[2]Ultimate analysis does not add up to 100% because fewer analyses were averaged.
[3]Bed E of Wegemann (1912) in Coal Basin No. 2 of the Sussex Field.
[4]Bed B of Wegemann (1912) or Bed E of Hose (1955) in Coal Basin No. 2 of the Sussex Field.
[5]Lowermost bed of Wegemann (1912) in Coal Basin No. 4 of the Sussex Field.

(Table compiled from channel, tipple or core samples analyzed by the U. S. Bureau of Mines. Only a few of the analyses represent the full thickness of a given bed. Also with the exception of one tipple sample, noncoaly partings and dirty (bony) coal were removed from each sample before analysis. Considerable core loss was noted in 8 core samples of the Healy coal).

State & Federal Coal Leases

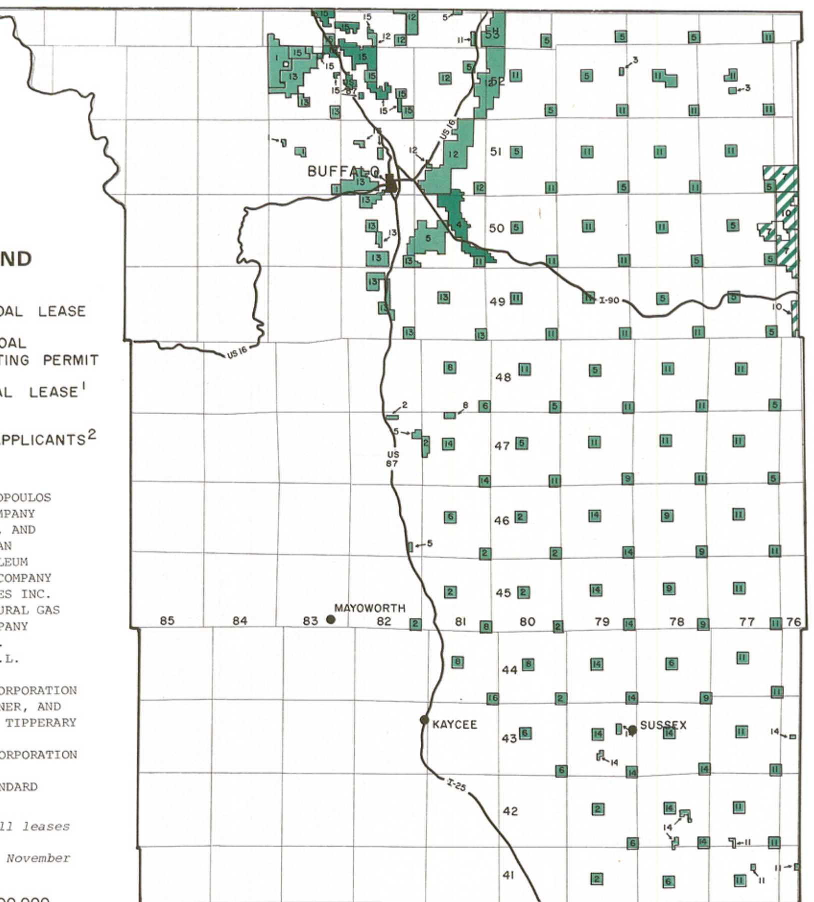


LESSEES OR APPLICANTS[2]

1. A.G. ANDRIKOPOULOS
2. ARK LAND COMPANY
3. BEARD, J.M., AND D.J. LEEMAN
4. BELCO PETROLEUM
5. CARTER OIL COMPANY
6. DOL RESOURCES INC.
7. EL PASO NATURAL GAS
8. GKM AND COMPANY
9. LEEMAN, D.J.
10. LOCKNART, E.L.
11. MAPCO, INC.
12. MOBIL OIL CORPORATION
13. STOLTZ, WAGNER, AND BROWN AND TIPPERARY RESOURCES
14. TEMPORARY CORPORATION
15. TEXACO
16. WESTERN STANDARD

[1]*A few very small leases are not shown*
[2]*Leases current November 31, 1975*

Scale 1:500,000



BASED ON CAMERON ENGINEERS, 1973 MAP TITLED: COAL MINERAL RIGHT OWNERSHIP, POWDER RIVER BASIN AND ON CONNIE MULL MINING AND OIL LEASE SERVICE, 1974-1975 MINING LEASE REPORTS

The Geological Survey of Wyoming, 1976

Johnson County includes portions of the west-central Powder River Basin and eastern Bighorn Mountains. The county may be divided into three geographic areas which are characterized by differences in geologic structure, geomorphology and the extent of Phanerozoic and Precambrian rock outcrops. These areas are the western Precambrian mountains, the central Paleozoic and Mesozoic mountain front and the eastern Powder River Basin.

The Bighorn Mountains lie in the northwest portion of the county. The irregular county line between Johnson and Big Horn counties is at the crest of the range. The Bighorn Mountains rise from an average basal elevation of 5,000 feet to 13,175 feet at the summit of Cloud Peak, the highest peak in the range. The Bighorns were uplifted approximately sixty million years ago during a mountain building episode termed the Laramide Orogeny. As the range was uplifted, erosion removed the arched sedimentary rocks and exposed the Precambrian core.

Stearns (1971) has proposed a model of faulting and folding which seems to be characteristic of numerous ranges in Wyoming. The model suggests that the Precambrian basement (granite, gneiss, schist) was sufficiently rigid to resist folding under the temperatures and pressures characteristic of Laramide deformation. Instead, the basement was faulted and large blocks of the basement rock were rotated and uplifted. The overlying sediments were drape-folded over the basement blocks (see cross-section below).

This model seems to fit the geologic structure in northwestern Johnson County. The Bighorn Mountain blocks were rotated so that maximum faulting occurred along the eastern margin. The sedimentary rocks along the mountain front reflect this as they dip steeply into the adjacent Powder River Basin. Sedimentary rocks along the western side of the mountains dip gradually to the west (in Big Horn County) on the gentle back-slope of the rotated basement block.

The Precambrian rocks in the Bighorns of northwest Johnson County consist of igneous and metamorphic rocks. The Precambrian has been mapped as intrusive mafic, undivided igneous and metamorphic, intrusive felsic rocks with quartz and metamorphic rocks. The greater portion of the main divide (north of Canyon Creek, culminating in Cloud Peak, and extending several miles on either side of the divide) consists of gray, massive, coarsely crystalline, hard granite. This granite merges laterally into other varieties such as a massive red granite along Medicine Lodge, Trapper and Paintrock Creeks (in Big Horn County). The entire granite complex may be part of a much larger mass of batholithic proportions. Numerous diabase dikes with a northeast trend traverse the granite throughout the range.

Glacial sediments overlie Precambrian rocks at many localities throughout the Bighorn Mountains. These sediments reflect at least three episodes of Pleistocene glaciation. The crest of the range has been deeply glaciated as evidenced by cirques, tarn lakes and many other geomorphic features characteristic of alpine valley glaciation.

In the southern portion of the range there are numerous outliers of the Miocene Arikaree and Oligocene White River Formations, lying unconformably on Precambrian. These rocks are erosional remnants of blankets of Tertiary sediments which once covered the range.

A north-south trending zone of sedimentary rocks lies adjacent to the eastern Precambrian margin. These Paleozoic and Mesozoic strata dip steeply into the adjacent Powder River Basin. In the southwest corner of Johnson County outcrop width increases, reflecting gentle dip off a shallow subsurface basement block. This block is a southern continuation of the Precambrian Bighorn block.

The "Horn", in T.46N., R.83W., is a prominent feature of western Johnson County. The Horn is a south-plunging anticline which has been eroded to the Precambrian. The Horn stands 2,000 feet above the surrounding terrain. It is bounded on the southwest by the Horn Fault which has more than 4,000 feet of throw.

The Redwall and Mayoworth Mesa are two distinctive geomorphic features adjacent to the mountain front. The Redwall is a discontinuous outcrop of the Chugwater Formation. More resistant strata stand with as much as 300 feet of relief. The famous "Hole-in-the-Wall" was formed by stream erosion through a resistant hogback.

Mayoworth Mesa, in T.45N., R.82 and 83W., is a flat topographic feature covered with as much as 20 feet of Quaternary alluvium (recent gravels). The gravels were deposited during floods of the North Fork of the Powder River.

The Paleozoic and Mesozoic strata flanking the Bighorn Mountains are subdivided into groups, formations and members. Disconformities within the section usually separate formations of different rock type. Contiguous formations which are genetically related by similar rock type or origin may be designated a "group". In a similar sense, formations may be subdivided into members.

The Cambrian System in Johnson County consists of the Flathead Sandstone, the Gros Ventre Formation and Gallatin Limestone. These strata were deposited 500 to 600 million years ago. The Flathead Sandstone overlies Precambrian igneous and metamorphic rocks. The Flathead is typically red, coarse-grained to conglomeratic and resistant to weathering and erosion. The Flathead was deposited in a shallow marine sea which transgressed over the ancient Precambrian terrain.

The Gros Ventre Formation consists of a lower sandstone unit, overlain by an upper shale and limestone unit. The lower sandstones are typically red and non-resistant. The upper shales are soft, gray-green and interbedded with gray limestones and thin sandstones. In outcrops, the Gros Ventre typically forms gentle slopes covered with vegetation.

The Gallatin Limestone consists of approximately 50 feet of gray, slabby limestone interbedded with distinctive flat-pebble conglomerates. These conglomerates were formed during periods of high energy, such as storms, when waves ripped up portions of the shallow substrate. These clasts, or flat-pebbles, were subsequently deposited in quieter water with a fine grained matrix.

The Ordovician Bighorn Dolomite overlies the Cambrian System. The Bighorn, deposited approximately 450 million years ago, is a massive ledge-former up to 350 feet thick. The Bighorn consists of a lower gray to red quartz sandstone, a middle dense, massive dolomite and an upper slabby dolomite. Weathering surfaces are distinctively pitted and irregular.

In the northern portion of Johnson County, the Bighorn is disconformably overlain by the Jefferson (or Darby) Formation of Devonian age. The Jefferson consists of limestone with thin interbeds of shale and sandstone. Throughout the rest of Johnson County, the Ordovician Bighorn is disconformably overlain by the Mississippian Madison Limestone. The Madison is a cliff-former which consists of approximately 500 feet of slabby to massive, gray, selectively dolomitized, fossiliferous limestone.

The Pennsylvanian Amsden Formation overlies the Mississippian Madison. The Amsden, deposited approximately 300 million years ago, consists of approximately 250 feet of siltstone, sandstone, claystone and dolomite. Along the flanks of many ranges in northern Wyoming, the Amsden typically forms a dip-slope and valley between the Madison Limestone and Tensleep Sandstone.

The Pennsylvanian Tensleep is overlain by a thick sequence of red Permo-Triassic strata. The Permian Goose Egg and Triassic Chugwater Formations form a distinctive outcrop band due to their bright red color and non-resistant nature. Sandstones and siltstones are the predominant rock type. A distinctive limestone, the Alcova Limestone Member of the Chugwater Formation, typically forms a low ridge which serves as a good marker bed.

The Jurassic Sundance and Morrison Formations overlie the Permo-Triassic strata. The Sundance Formation consists of approximately 300 feet of shale, calcareous sandstone and siltstone. The Morrison Formation consists of shales and sandstones which were deposited in a non-marine environment. Well-preserved dinosaur bones and varicolored shales are a noted feature of the Morrison Formation.

Jurassic strata are overlain by several thousand feet of Cretaceous shales and sandstones. These strata were deposited from 135 to 65 million years ago, during major marine transgressions into the western interior of the United States. At times, the marine seaway extended from the Arctic Ocean to the Gulf of Mexico. In width, it extended from Utah to Iowa. Alternate transgressions and regressions of the seaway caused shifting of the shoreline laterally and vertically through time. Many of these sedimentary deposits are now outstanding sandstone reservoirs for oil and gas.

The eastern portion of Johnson County is in the Powder River Basin. The axis of the basin trends diagonally across the middle of the county adjacent to the Bighorn Mountains (see Petroleum and Natural Gas Plate). Thus, the basin is asymmetrical with approximately 18,000+ feet of strata in the deeper portions.

Cretaceous marine sediments are overlain by the Paleocene Fort Union Formation. The Fort Union was deposited after a hiatus which reflects Laramide deformation in latest Cretaceous and earliest Tertiary time. The Fort Union contains many coal deposits which were deposited as swamps in a warm, subtropical, Paleocene environment.

The eastern portion of Johnson County is covered by the Tertiary Wasatch Formation (Eocene). The Wasatch was deposited 50 million years ago in a mixture of alluvial, fluvial and paludal environments. The Kingsbury Member of the Wasatch Formation is a basal conglomerate representing coarse sediment eroded from the Rocky Mountain highlands during the Laramide Orogeny.

Other Tertiary sediments in Johnson County include the Oligocene White River Formation and Pliocene Moncrief Conglomerate. Numerous outliers of these units occur west and southwest of Buffalo. They represent a period of erosion and deposition which nearly buried the Rockies, prior to latest Tertiary renewal of regional uplift.

The geological history of tectonism and sedimentation in Johnson County is long and complex. The energy and minerals potential of the county has yet to be realized. Many stratigraphic and structural problems are lacking adequate explanation. The reader interested in more details is directed to the references below.

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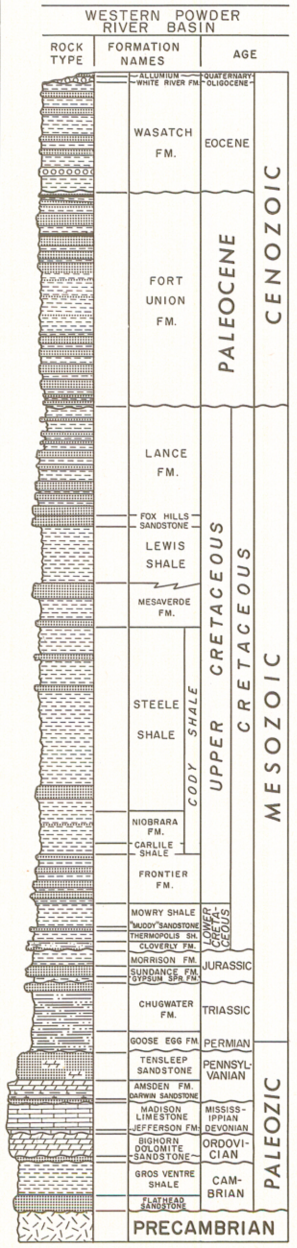
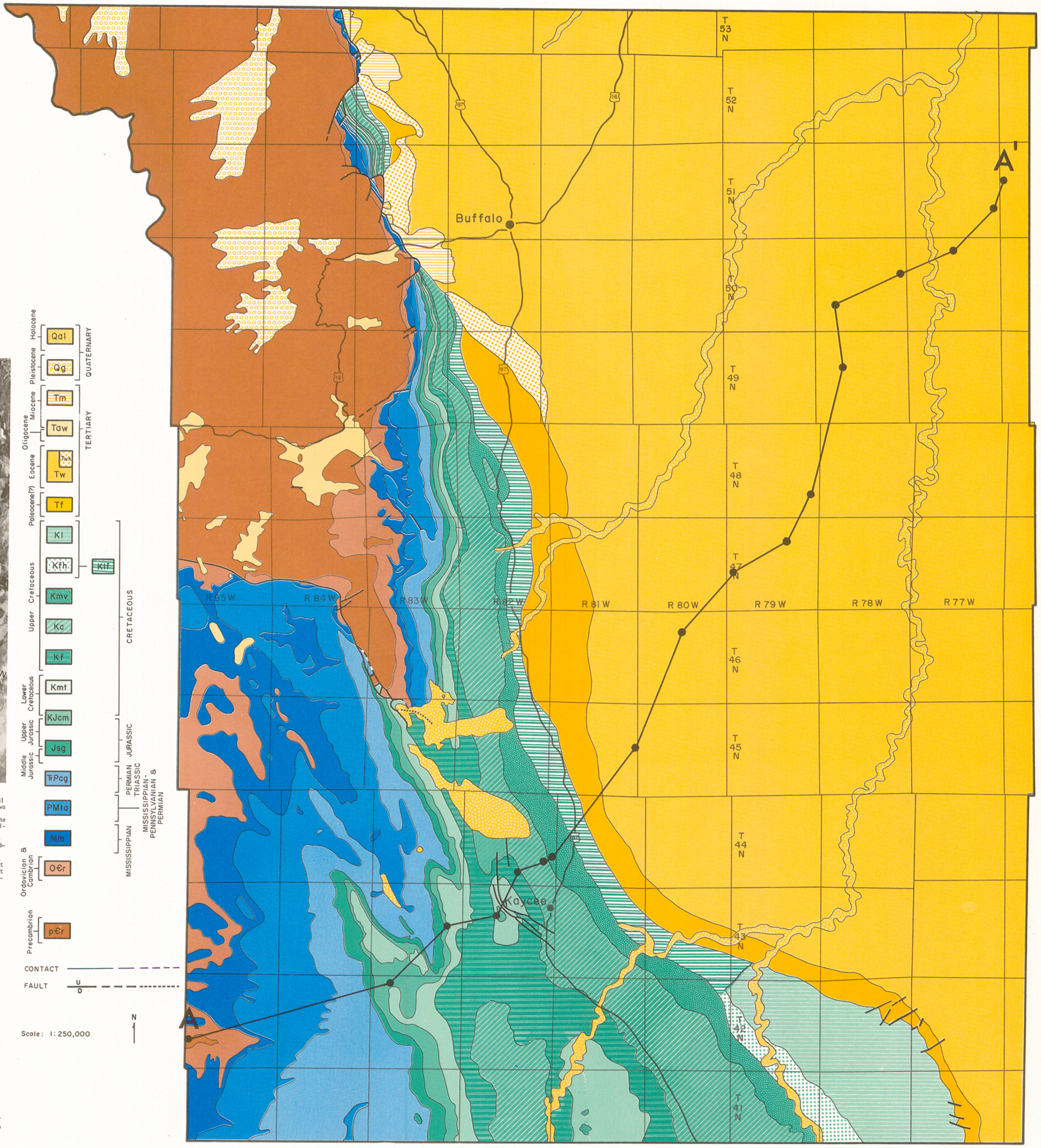
Stratigraphic Column



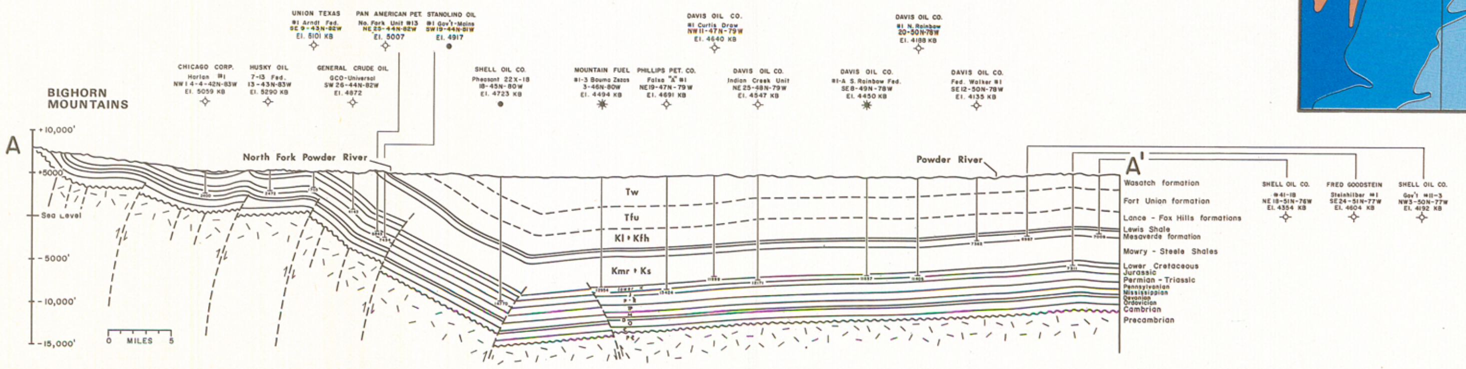
LEGEND

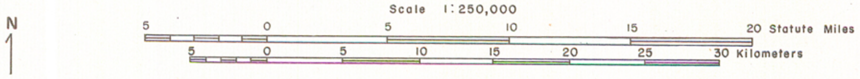
- CONGLOMERATE
- LIMESTONE
- SANDSTONE
- DOLOMITE
- SHALE
- GYPSUM
- COAL
- IGNEOUS & METAMORPHIC ROCKS
- UNCONFORMITY (A SURFACE OF EROSION)
- FM. = FORMATION

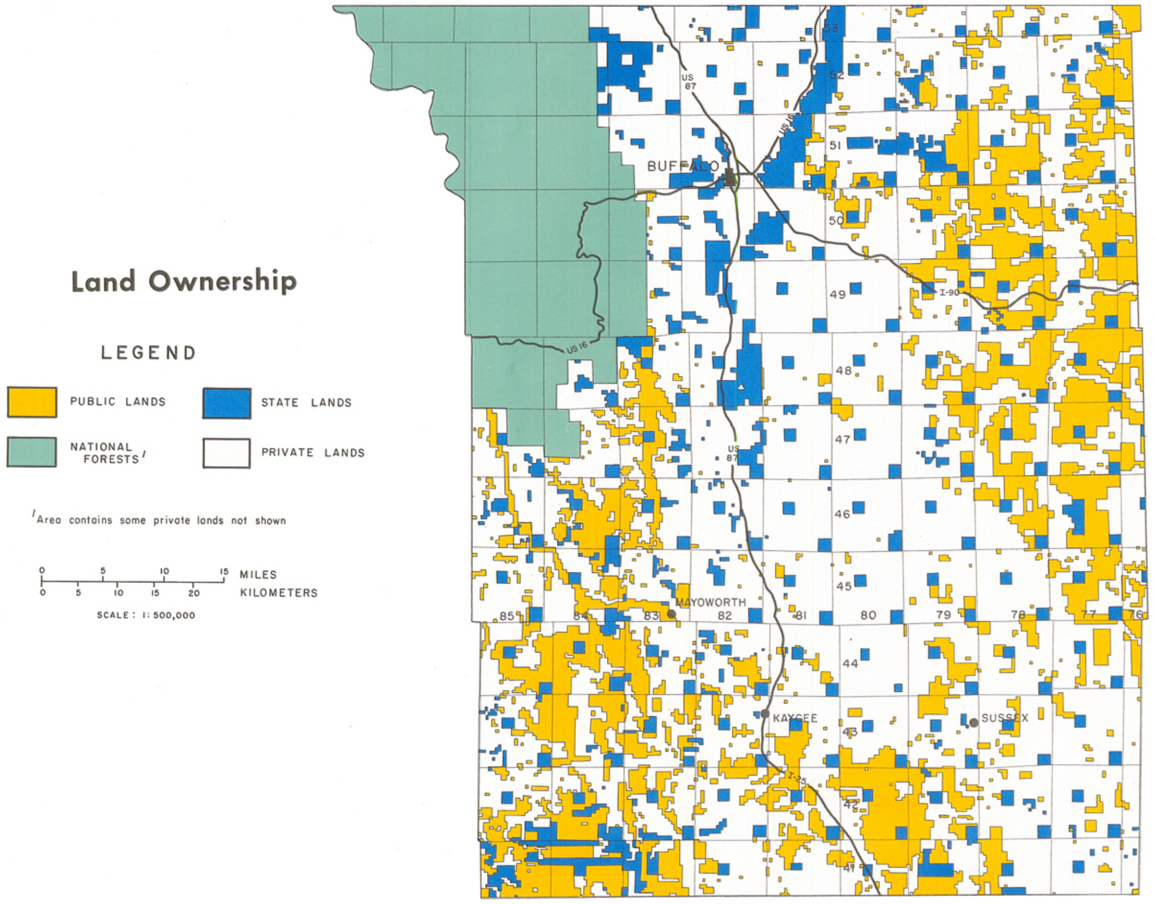
Aerial photographs are a valuable geological tool. They are particularly useful in environmental and structural analyses of large areas. The Skylab photo above shows a portion of the southern Bighorn Mountains and western Powder River Basin. The photo demonstrates the rugged, timbered character of Precambrian rocks in the Bighorn Mountains versus the low-relief, untimbered character of the flat-lying Tertiary sediments of the Powder River Basin. The "Horn", referred to in the text, is shown in the southwest quarter of the photo. Strata dipping steeply into the Powder River Basin show as curved lines trending northeast-southwest across the photo. Patchy timbered areas in the north-central part of the photo show effect of clear-cut logging. Drainages, such as the north fork of the Powder River (flowing southeast adjacent to the western side of the "Horn") and the middle fork of Crazy Woman (flowing east into the Powder River Basin in the middle of the photo) show dramatic changes in channel characteristics as they flow out of the mountains. The dark areas in the southeast corner of the photo are shadows from clouds.

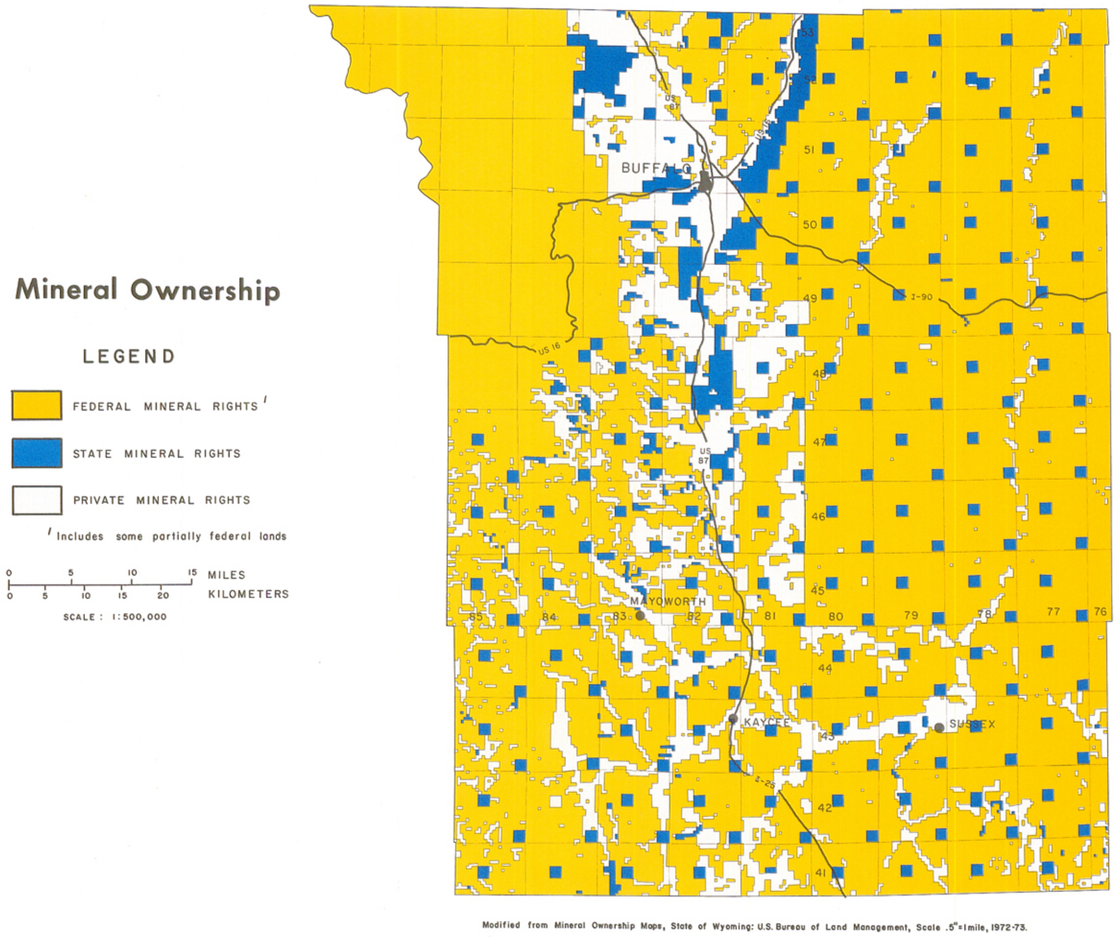


EAST-WEST CROSS-SECTION OF POWDER RIVER BASIN IN JOHNSON COUNTY









Modified from Mineral Ownership Maps, State of Wyoming: U.S. Bureau of Land Management, Scale .5"=1mile, 1972-73.

Land Ownership

Originally all of Johnson County was in the public domain, acquired by the United States under the Louisiana Purchase of 1803. Since then, 60.1 percent has passed into private hands and 8.3 percent into State ownership.

Much of the land passed into private ownership as a result of several Homestead Acts. After complying with the provisions of these Acts, a homesteader could pay a small fee to acquire at least a surface deed to lands of his own choice. Because these deeds were referred to as patents such lands are called "patented lands".

Homesteading these patented lands in Wyoming, even by the 1890's, was not without incident as more than one range war between cattlemen, sheepmen and homesteaders roared through the history of the State. The most notorious war took place in Johnson County in 1892. Cattlemen, ostensibly upset over rustling, joined with some hired Texas gunmen and planned to ride on Buffalo and either drive out or hang a list of settlers they believed to be rustlers. After reportedly killing two settlers at the KC Ranch near present Kaycee, the "invaders" were surrounded by a posse about 50 miles south of Buffalo. Meanwhile, an urgent plea by Wyoming's governor sent U.S. troops to quell the invasion. The "invaders" in the Johnson County War were captured and taken to Fort McKinney. Range wars in Wyoming's history persisted as cattlemen and sheepmen frequently clashed even into the early 1900's.

Over the years private land ownership patterns in the county have become very complex making it difficult to generalize beyond saying that most of the larger areas of private land center in northcentral and central Johnson County. More detailed information and plat maps are available in the office of the County Clerk in Buffalo.

Certain "school lands", usually sections 16 and 36, were conveyed to the State by the federal government at the time of statehood. Later, other State lands were acquired under the Carey Act of 1894. Carey Act lands were desert lands given to the State for future development through irrigation projects. Once these lands were reclaimed by irrigation, they were to be conveyed to settlers in 160 acre tracts. Some of these lands are still awaiting irrigation before they can be parcelled out.

In the case of Johnson County, large contiguous blocks of State land in the northwestern part of the county resulted from substitutions and trades, most notably for the State lands originally located in what is now the Bighorn National Forest. These are some of the largest contiguous tracts of State land in Wyoming. State lands, incidentally, are administered by the Board of Land Commissioners in Cheyenne.

The federal government still owns 31.6 percent of the land in Johnson County. This federal land is generally located around the margins of the county with very little federally owned land in northcentral and central Johnson County. The federal land is principally under the jurisdiction of the U.S. Department of Interior's Bureau of Land Management or the Department of Agriculture's National Forest Service. The Casper District Office of the Bureau of Land Management manages National Resource Land or public domain land in the county. The National Forest Service has jurisdiction over the Bighorn National Forest, which occupies a portion of northwestern Johnson County.

The predominant surface land use within Johnson County is as range for more than 50,000 head of cattle and 100,000 head of sheep. The State Board of Equalization reported over 1.5 million acres of the county were used for grazing in 1974. They reported another 50,000 acres were irrigated farm, irrigated pasture or dry farm land. Residential, commercial, municipal, uncultivated land, reservoirs and the National Forest account for most of the additional acreage in the county.

Cattle graze on broad rolling plains in a scene common to Johnson County. Eighty-five percent of the county's land is used as rangeland for cattle and sheep.

Johnson County Statistics

Land Area: 4,095 square miles
2,620,817 acres

Surface Ownership		Mineral Ownership (Estimated)	
Federal:	827,928 acres (31.6%)	Federal:	1,913,944 (73.0%)
State:	217,247 acres (8.3%)	State:	206,873 (7.9%)
Private:	1,575,642 acres (60.1%)	Private:	500,000 (19.1%)

Population Characteristics:

Total population 1970: 5,587
Total population 1974: 5,300 est.
Percentage of change 1970-1974: -5.1%

Per capita income 1970: $3,421
Per capita income 1973: $4,834

Economic and Government Statistics:

Assessed valuation

Total gross valuation		Mineral valuation	
1972:	$38,617,029	1972:	$13,996,040 (36.2%)
1973:	$38,425,368	1973:	$12,544,992 (32.6%)
1974:	$41,586,483	1974:	$13,363,657 (32.1%)
1975:	$49,203,181	1975:	$20,411,993 (41.5%)

Oil: $19,814,440 (97.1%)
Gas: 219,385 (1.1%)
Misc. Minerals: 378,168 (1.8%)
(includes bentonite)

Modified from: "Wyoming Data Handbook, 1975" published by Dept. of Administration and Fiscal Control, Cheyenne, Wyo., August, 1975.

Majestically, the Bighorn Mountains of northwestern Johnson County rise from the rolling prairie lands of the county. The mountains, a part of the Bighorn National Forest, account for almost 327,000 acres or 12 percent of the county.

Mineral Ownership & Valuation

An estimate of Johnson County's mineral ownership shows about 73 percent or over 1.9 million acres is federally owned, 19.1 percent is in private (fee) ownership, and 7.9 percent is State-owned. As these figures illustrate, the dominance of federally owned lands enhances their importance in the mineral development of the county.

Like the surface ownership, mineral rights can be sold or leased by the owner. Records of private mineral ownership are kept in the County Clerk's office in Buffalo. In the case of the State and federal lands, however, mineral rights are seldom sold. They are generally only leased.

The Mineral Leasing Act grants statutory authority for leasing public domain (federal land) mineral rights. The law gives the U. S. Department of Interior authority over the mineral leasing program. Within the Department of Interior, the Bureau of Land Management is authorized to issue mineral leases. When another federal agency, such as the National Forest Service, has administrative jurisdiction over the lands, it must give its consent before any leasing is permitted. In addition to managing these federal mineral lands, the U. S. Bureau of Land Management also maintains the official federal land status records. In the case of Johnson County, these records are available in the Casper District office. The Billings office of the U. S. Geological Survey's Minerals Branch, Conservation Division administers all federal exploration permits and mining applications on federal leases in the county.

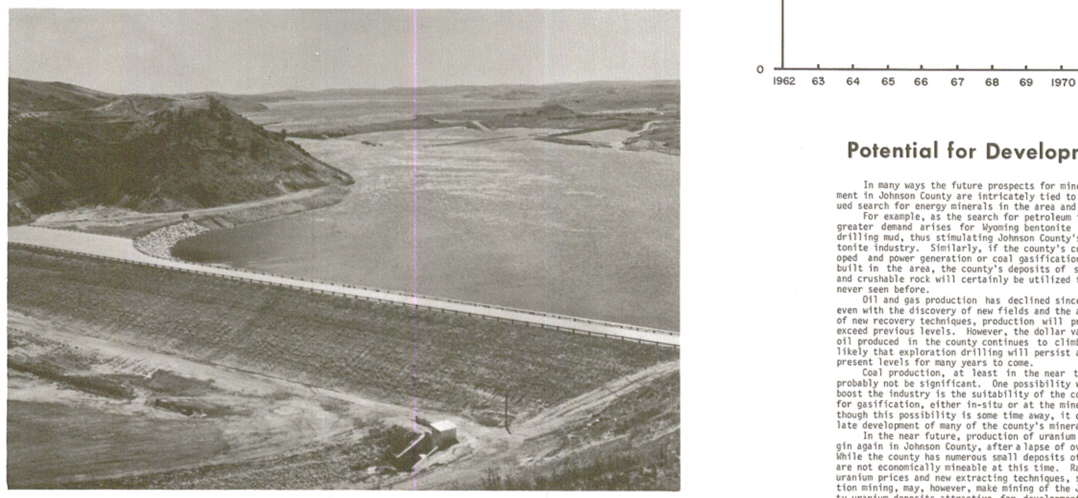
The State Board of Land Commissioners in Cheyenne is responsible for granting and maintaining records of mineral leases on all State lands.

Mineral leases differ from tract to tract. Some leased rights include the opportunity to drill and explore for oil and gas, some are just for coal, others are for uranium or bentonite. As new economic mineral deposits are discovered, new arrangements are worked out with the lessor for exploitation and development.

Of the minerals produced in the county, oil had the highest assessed valuation for tax purposes in 1975 at $19,814,440, natural gas was next at $219,385, followed by several other minerals that totaled $378,168. These other minerals include bentonite, sand and gravel and scoria. Collectively, mineral valuation made up 41.5 percent or $20,441,993 of the county's gross valuation of more than $49 million. These assessed values, incidentally, are determined on the basis of the previous year's production.

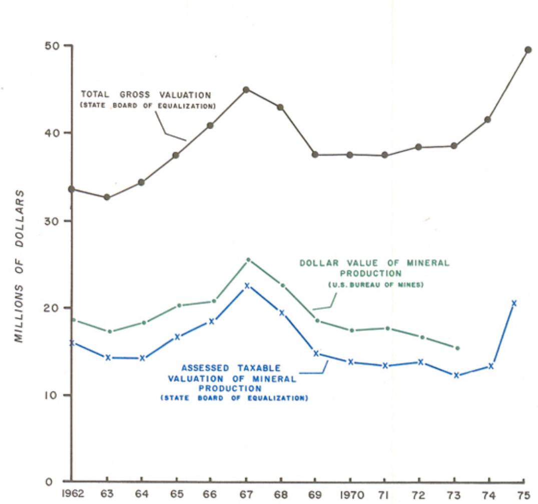
Although the assessed taxable valuation of oil and gas increased more than 50 percent over 1974, the increases were a result of price increases rather than increases in production. In fact, production remained essentially unchanged in this time period. Stable or slightly higher prices for oil and gas should maintain the county's valuation at or above the 1975 level at least in the near future. Anticipated coal production is probably still years away and will not be a significant part of the mineral valuation until sometime in the late 1970's or 1980's. Uranium activity could also begin to contribute to the county's general economy within the next five to ten years.

Annual mineral lease payments, even on unmined coal tracts, royalties and taxes paid on oil, gas and bentonite production contribute to the State and county's economy.



Although not presently providing water for industrial users, Lake DeSmet may one day supply water to a coal gasification plant in the area. Texaco, its present owner, controls an estimated one billion tons of coal adjacent to the lake and has applied to the Energy Research and Development Administration for federal funds to build a demonstration coal gasification plant in the area. (Photo courtesy of Texaco, Inc.)

Dollar Value & Assessed Taxable Valuation



Potential for Development

In many ways the future prospects for mineral development in Johnson County are intricately tied to the continued search for energy minerals in the area and the world.

For example, as the search for petroleum intensifies, greater demand arises for Wyoming bentonite for use in drilling mud, thus stimulating Johnson County's small bentonite industry. Similarly, if the county's coal is developed and power generation or coal gasification plants are built in the area, the county's deposits of sand, gravel and crushable rock will certainly be utilized to an extent never seen before.

Oil and gas production has declined since 1966, and even with the discovery of new fields and the application of new recovery techniques, production will probably not exceed previous levels. However, the dollar value of the oil produced in the county continues to climb and it is likely that exploration drilling will persist at least at present levels for many years to come.

Coal production, at least in the near term, will probably not be significant. One possibility which might boost the industry is the suitability of the county's coal for gasification, either in-situ or at the mine mouth. Although this possibility is some time away, it could stimulate development of many of the county's mineral resources.

In the near future, production of uranium ore will begin again in Johnson County, after a lapse of over 11 years. While the county has numerous small deposits of ore, many are not economically mineable at this time. Rapidly rising uranium prices and new extracting techniques, such as solution mining, may, however, make mining of the Johnson County uranium deposits attractive for development within the next 20 years.

The county is rich in some construction materials, largely clinker and crushable aggregate. It also has quantities of high calcium limestone which would be in demand for use in sulfur scrubbers, if large scale power generating plants are developed in the county.

For more detailed analyses of future prospects see the coal, oil and gas and minerals plates.

LAND USE

CRS-4 JOHNSON COUNTY, WYOMING

A map of any area as large as Johnson County compiled and checked within the span of one year cannot be checked and rechecked sufficiently to eliminate all error. With this in mind, the map represents a "best estimate" of the general and predominant land use in Johnson County, as of the summer of 1975. Most of the photography used in this compilation was flown in 1973. Later revisions of the map were completed by comparison with available aerial photography flown in May, 1975. Field checking was done during the summer of 1975.

Because of the final map scale, only those land use classes of reasonable aerial extent could be included. This excluded isolated urban dwellings and businesses, ranch houses and buildings, feedlots, small stockponds and the like.

It should also be noted that the gradational nature of many of the land use units (especially in the grassland subclasses) requires that many of the boundary locations be only approximate.

REFERENCES

Anderson, J. R., Hardy, E. E., and Roach, J. T., 1972, A Land-use Classification for use with Remote Sensor Data. U.S. Geological Survey Circular 671, 16 p.

Marrs, R. W., 1975, Special report: Land-use in the Moorcroft and Keyhole Reservoir Areas, Crook County, Wyoming: University of Wyoming, Department of Geology, August, 1975, 17 p.

Map Key

URBAN AND BUILT UP LAND

1-1 Subclass Residential: Areas of high-density and areally extensive habitation as in Buffalo and Kaycee. Individual ranch and farm sites were not mapped.

1-2 - Subclass Commercial: High-density, areally extensive commercial structures, places of business and small industry.

1-4 - Subclass Extractive: All extractive enterprises such as open gravel pits, rock quarries, and oil and gas wells. Gravel pits and rock quarries are designated by solid lines. Oil and gas production areas, rather than being mapped as individual wells, were mapped as "fields".

1-5 - Subclass Transportation: Major maintained county, state and federal highways.

1-5a - Four-lane interstate highways.

1-5b - All two-lane highways including most major state and county roads.

1-6 - Subclass Recreation: Public and private recreation areas including golf courses, athletic fields, picnic and camping areas, and fairgrounds.

AGRICULTURAL

2-1 - Subclass Irrigated and Sub-irrigated Cropland Pastureland: Agricultural land (harvest and/or pastureland) which has been periodically maintained or improved by artificially supplying water or by using naturally high groundwater supplies in floodplains to grow native hay, alfalfa, etc. Dual use of irrigated land and floodplain is common.

2-4 - Subclass Dryland Crop: Crops dependent on rain and/or snowfall for their water needs. These croplands quite often can be identified by the parallel strips of fallow and cultivated land.

RANGELAND

3-1 - Subclass Moist Shrub Grassland: Areas of lush shrubs, greasewood, berry bushes and deciduous trees which predominate in the low spots and valleys. The suffixes b and c (good and fair respectively) which are based on near infrared reflectivity indicate the quality of range.

3-2 - Subclass Semi-arid Shrub Grassland: Most common in areas of drier range where dry shrubs, coniferous trees and bushes are interspersed with range flora. The suffixes b and c (good and fair respectively) which are based on near infrared reflectivity indicate the quality of range.

3-3 - Subclass Grassland: Encompasses vast areas of land use on the semi-arid prairie lands. In rating the quality of range an arbitrary classification was employed based on near infrared reflectivity of the soils. The higher the reflectivity, the lower the range classification. The highest reflectivities were found in areas of active and near-active erosion. The smoother, more rolling plains received higher classifications. Those with the least dissection and sufficient water received the highest rating.

3-3b - good rangeland

3-3bc - good to fair rangeland

3-3c - fair rangeland

3-3cd - fair to poor rangeland

3-3d - poor rangeland

In most cases the boundaries between grassland types are only approximately located.

3-4 - Subclass Mountain Meadows: Rangeland at higher elevations bordered on three or more sides by dense coniferous growth. This range is predominantly used for summer pasture of sheep and cattle brought up from the warmer, drier lowland range. Subclasses are based on reflectivity, topography and lushness of growth. The areas with substantial sagebrush growth received a lower rating.

3-4b - good mountain meadow, low relief, low erosion with a substantial supply of moisture

3-4c - fair mountain meadow, high relief predominating, higher erosion with numerous barren exposed areas and a lesser supply of moisture. This rangetype may have up to 10% coniferous cover over a total area. The conifers may occur in small dense growths or as separately spaced trees.

3-4d - poor mountain meadow, barren rock and talus in many places with sparse lichen growth, grasses and small shrubs. This type generally occurs above the tree line in a zone next to barren rock.

3-5 - Subclass Natural Floodplain: The floodplain is defined as the area periodically inundated under high water conditions. However, the area denoted as floodplain on this map includes more infrequent high water marks also.

3-5a - floodplain with greater than 10% deciduous cover (mostly cottonwoods)

3-5b - floodplain with less than 10% deciduous cover

The floodplain may also support a variety of shrubs; but, differences in shrubs are not denoted in the classification.

3-7 - Subclass Naturally Disturbed Vegetation: Vegetated land which has been subjected to changes in ground and/or surface waters. These areas contain numerous barren soils which often are the result of adverse alkalinity or too great an influx of recent sediment. Consequently this range subclass often exists as a mixed land use type with floodplain and near floodplain areas.

3-8 - Subclass Previously Cultivated: Land which was formerly under cultivation, showing no signs of recent agricultural activity. It is apparently being allowed to return to its natural state.

FOREST LAND

4-1 - Subclass Deciduous: Denotes the densest growths of deciduous trees which primarily occur in and along the floodplains and within urban districts.

4-2 - Subclass Coniferous: Coniferous forest areas which have been subdivided on the basis of crown density. Without specific ground-truth statistics this cannot be expected to accurately depict the health and/or productivity of the forest.

4-2b - densest conifer cover (greater than 90%) with few open meadow spaces or barren rock exposures.

4-2c - moderately dense conifer cover (greater than 60%). The remainder is open meadow and/or barren rock with limited use as rangeland.

4-2d - least dense conifer cover (10 to 60%). This forest type often occurs in actively eroding areas.

4-3 - Subclass Mixed: Areas of greater than 10% deciduous cover coexisting with conifers.

4-4 - Subclass Clear-cut: All areas cleared of timber in the recent past for lumbering purposes. A dual use at this time is as mountain meadow because of the abundance of range flora at many of the clear-cut sites.

WATER

5-2 - Subclass Lakes and Reservoirs: Large natural lakes, man-made lakes and reservoirs.

NONVEGETATED LAND

7-1 - Subclass Playas: The playa lakes indicated might be better identified at this time as shallow marshes. These lakes support various waterfowl, reeds and marsh grasses. In drier years, these lakes may dry up leaving little or no vegetation cover and, thus, are properly classed as playas.

7-3 - Subclass Barren Rock: Includes exposed crystalline or sedimentary bedrock, talus fields, or other exposed modern sediments. These barren rocks have less than 5% organic cover including lichens, grasses, shrubs or trees. The most extensive areas of barren rock occur above the tree line.

KEY TO OTHER MAP SYMBOLS

Boundary of land use units

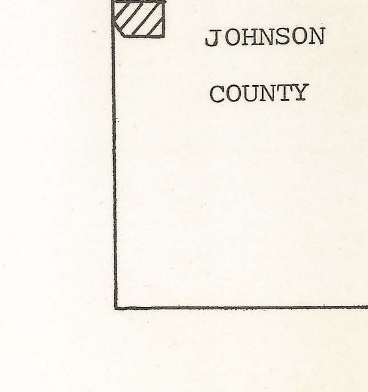
Airstrip.

Oil or Gas Field Boundary.

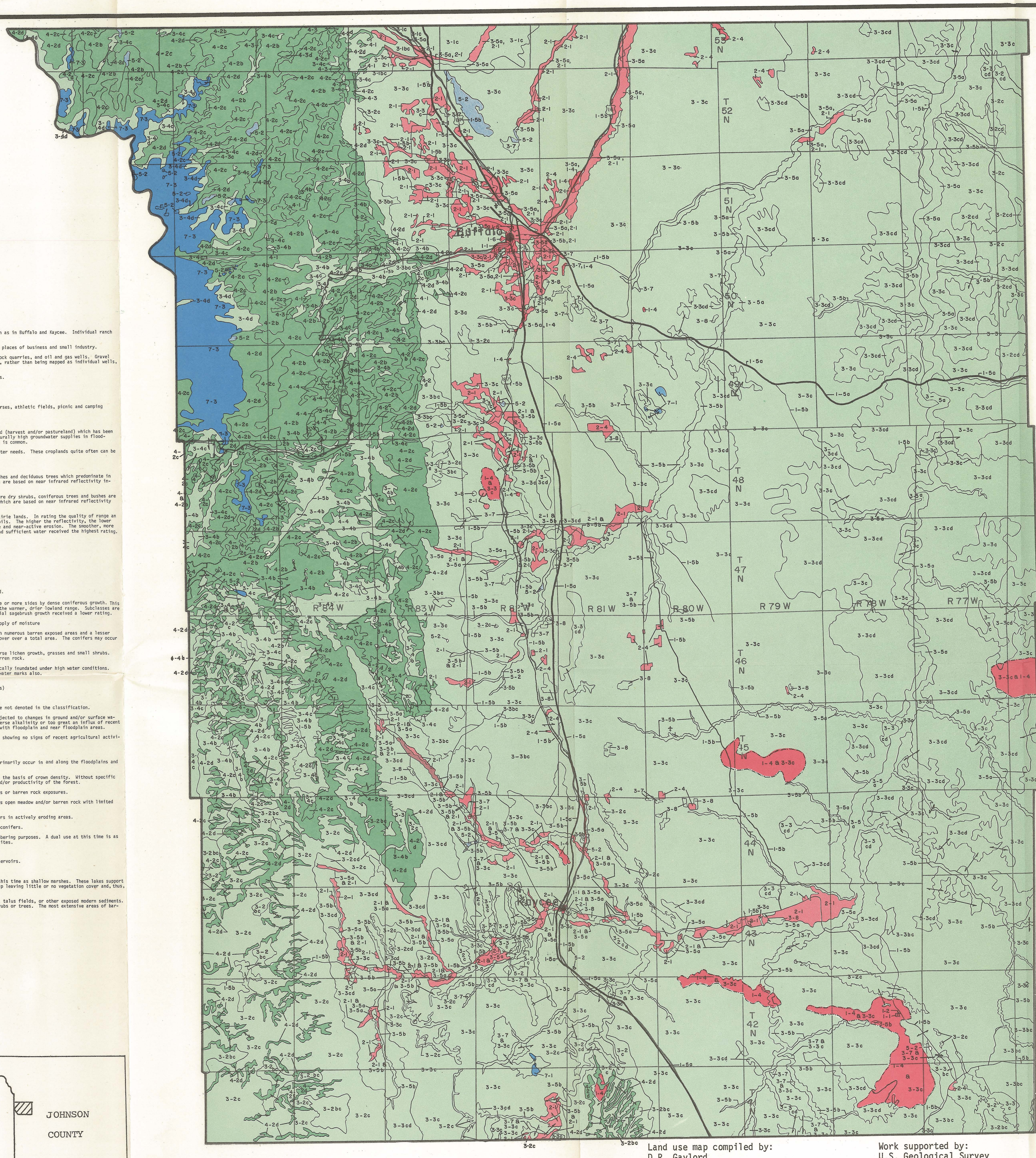
NOTE:

The Johnson County land use map was compiled from interpretations of Skylab color infrared photography (S-190A, Track 5, Pass 10, June 13, 1973, Roll 15, Frames 229-231) and high-altitude color infrared aerial photography (NASA Flights 72-138, August 11, 1972; 73-147, August 30, 1973; no. 239 June 20, 1973; no. 248, August 7, 1973; no. 310, May 7, 1975). The map was first compiled at 1:250,000-scale by stereo photointerpretation of Skylab photography. This interpretation served to define general land use classes and mappable units. The Skylab photointerpretation was field-checked, revised as necessary and recompiled at 1:100,000-scale using the field-checked interpretation together with 1:120,000-scale stereo photography. This recompilation served to fill in areas obscured by clouds on the Skylab photography and to improve the accuracy of map-unit boundaries. Areas not covered stereoscopically by high-altitude aerial photography (see reliability index) were transferred directly from the field-checked Skylab map to the final map.

Land use quality estimates based on infrared reflectance of vegetation and other features may reflect the prevailing condition of the ground surface at the time of overflight rather than that currently predominating. This situation is most likely to occur in areas of rapid land use change.

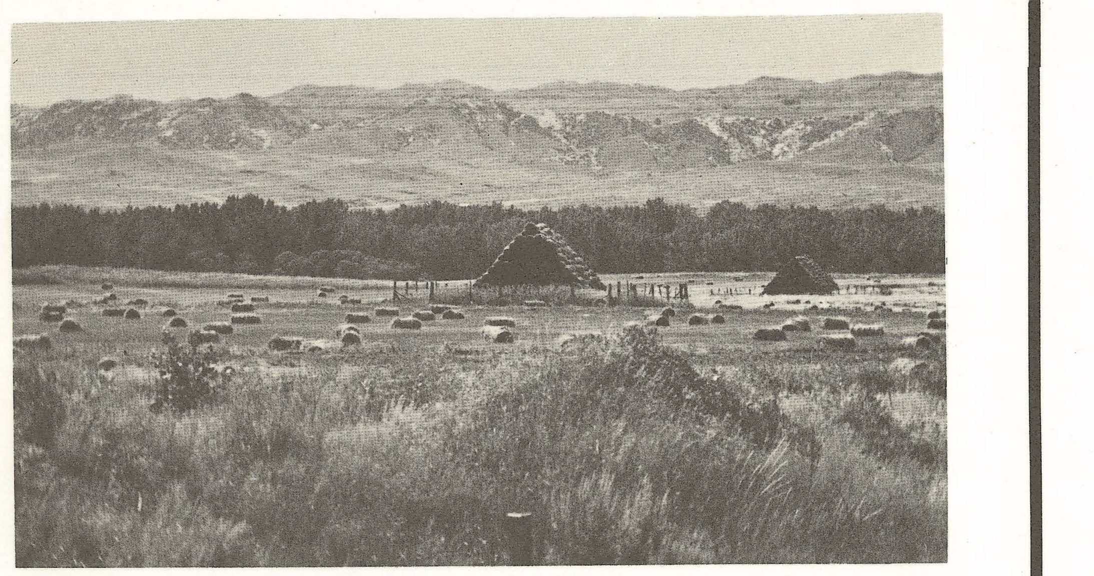


Stereoscopic color-infrared aerial photography was not available for that portion of Johnson County shown cross-hatched.



Land use map compiled by:
D.R. Gaylord,
Department of Geology,
University of Wyoming

Work supported by:
U.S. Geological Survey
Environmental Geology Branch
Grant 14-08-0001-G-163

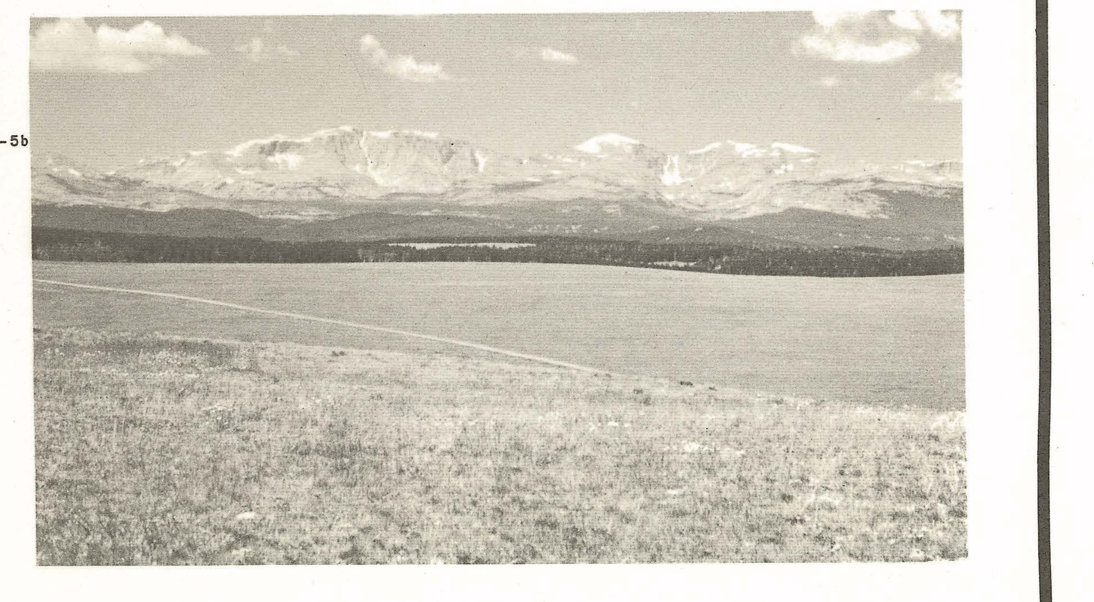


Irrigated cropland (2-1) and floodplain (3-5a) with fair grassland (3-3c) in foreground. Well dissected grassland (3-3c) and fair and semi-arid shrub grassland (3-2c) are in the background of this scene across the Powder River floodplain (SW sec. 14, T.43N., R.80W.).

Well dissected, actively eroding, fair-to-poor grassland (3-3cd) seen looking west from SE¼ sec. 15, T.43N., R.78W. The Sussex area (with irrigated cropland (2-1) and Powder River floodplain (3-5a)) can be seen in the distance.

Good mountain meadow (3-4b) in foreground with crystalline bedrock exposures in fair mountain meadow (3-4c). Conifer cover is fair (4-2c). Taken from sec. 15, T.50N, R.84W.

Clearcut (4-4) area with abundant wood debris in foreground. Note sparse growth of aspen (4-1) in near background of picture with alternating dense conifers (4-2b) and a mountain meadow (3-4b) in the background. Picture was taken looking south from sec. 13, T.49N., R.84W.



Smooth, rolling mountain meadow (3-4b) in foreground with dense conifer growth (4-2b) and barren exposed rock (7-3) in the background. Picture was taken looking WNW from Elgin Park towards Cloud Peak area, sec. 36, T.50N., R.84W.

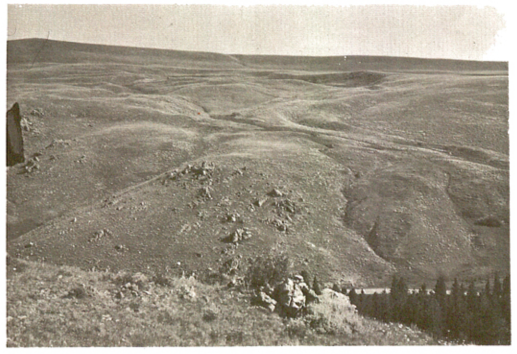
The Geological Survey of Wyoming, 1976

This dissected surface is typical of the intricate dendritic drainage that has developed in portions of eastern Johnson County. This photo was taken looking north-northeast in sec. 7, T.47N., R.78W.

A broad, gently sloping, mountain valley (sec. 28, T.47N, R.85W.) showing the typical rolling topography common in the southern Bighorn Mountains.

Dipslopes along the eastern flank of the Bighorn Mountains form in units such as Triassic red-beds (center) and the underlying Madison Limestone (left background). Photo taken looking north along the east flank of the "Horn" (sec. 26, T.46N, R.83W.).

Glacially eroded topography of the Cloud Peak Wilderness Area as viewed from the east (sec. 21, T.50N., R.84W.). Much of the rolling terrain in the foreground has been planed by glaciers which once headed in the Cloud Peak area.



View looking north (from SW, sec. 11, T.50N., R.84W.) across the valley of Hunter Creek. Here a large earth flow system has developed and is now encroaching upon the road below the Hunter Creek Ranger Station.

The landforms map represents the earth's surface configuration. On it, various landform units are defined on the basis of regional and local topography, pattern and texture and on the basis of differences in the geomorphologic processes that produce the surface configurations. Boundaries of landform units should represent the line of sharpest contrast between landform types. However, because the change from one landform type to another is not always abrupt, a degree of uncertainty remains in the placement of some unit boundaries.

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Cooke, R. U., and Doornkamp, J. C., 1974, Geomorphology in environmental management: Oxford University Press, London, 413 p.

Curran, H. A., Justus, P. S., Perdew, E. L., and Prothero, M. B., 1965, Atlas of Landforms (2nd ed.): John Wiley and Sons, New York, 140 p.

Map Key

I. Erosional Landforms (forms created by destructive action of denuding factors).

A. Forms of fluvial origin.

- Widely-spaced dendritic drainage. First- and second-order drainages are well developed and show signs of recent erosion. Third-order drainages occur at about 1/4 or 1/5 mile intervals and show few active gulleys.
- Moderately intricate dendritic drainage. First-, second- and third-order drainages are well-developed and are actively eroding. Topography is correspondingly steeper than for widely-spaced dendritic drainage (1). Drainage spacing is about 1/4-mile, but fourth-order drainages are fairly well-developed.
- Very intricate dendritic drainage. Highly dissected topography in which first-, second-, third- and fourth-order drainage channels are being eroded. Steep-sided, fourth-order drainage channels (20 per mile) are deeply incised).
- Widely-spaced trellis drainage. NW-SE trending second-order drainages are spaced 1/2 to 3/4 miles apart and are flanked by relatively smooth, gentle slopes. Few third-order drainages are apparent.
- Moderately intricate trellis drainage. Strongly-oriented, NW-SE trending, second-order drainages are complimented by parallel to sub-parallel third-order drainages which are dominantly orthogonal to the second-order drainages. The parallel to sub-parallel arrangement is largely controlled by the uniform slopes flanking the larger drainages.
- Very intricate trellis drainage. Highly-dissected slopes flank the NE-SW trending, second-order drainages. Third- and fourth-order channels are deeply incised in the relatively short slopes. The smaller channels are largely dendritic in pattern although their direction is influenced by the predominant slope directions.
- Areas of knobby topography dominated by small buttes (erosional remnants capped by resistant layers of red baked shale).
- Mesas and plateau areas formed from partially dissected pediments and other fragments of earlier surface planation.
- Steep, broken, slopes and irregular topography cut by steep sided, irregular stream valleys.
- Dip-slopes. Smooth slope supported by a resistant rock layer lying at an angle to the regional slope. The slope of the surface conforms closely to the dip of the resistant rock layer.
- Granitic terrain. Irregular, rounded topography with bare rock summits. Large-scale rock-fabrics are sometimes reflected in the topography as linear features.

B. Forms of fluvio-glacial origin.

- Steep, glacial topography consisting largely of aretes, horns, cols, and steep sided glacial valleys.
- Rounded glacial topography. Rounded bare-rock ridges and knolls marginal to the steeper glacial topography. Low relief, numerous small lakes, and proximity to other glacial features suggests glacial scouring of these areas.

II. Depositional Landforms (forms created by accumulative action of water, wind, ice or mass movement).

A. Deposition by water.

- Floodplains of major streams and rivers. These areas are generally confined to first-order streams and are marked by lush natural vegetation and crops that grow in the level bottomlands where alluvium has accumulated.
- Broad, gently sloping, valley floors. These occur in mountainous areas where both alluvium and colluvium are introduced from the surrounding drainages. However, the drainage profile is considerably steeper than in the floodplain areas, and the coarser material that accumulates is generally well-drained and forms only a shallow soil.
- Gentle, colluvial slopes and alluvial fans flanking major streams and rivers.
- Steep slopes and colluvial deposits that are accumulated along deeply incised valleys. These are probably formed jointly by mass wasting and fluvial processes.
- Remnants of large stream terraces, alluvial fans, or other ancient platform deposits. These have highly dissected edges but maintain their planar configuration over much of the exposed surface.

B. Deposition by ice.

- Moraines and glacial outwash material forming areas of hummocky, low-dip topography extending outward from regions of glacially eroded topography. These areas are being reworked through fluvial processes.

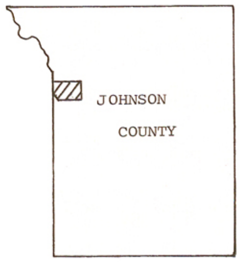
C. Deposition by mass wasting processes.

- Landslides, earth slumps, and mud flows which form characteristic tongues and hummocky topography along steep slopes. Only the largest of these features were at the 1:250,000 scale of this compilation.

III. Key To Map Symbols.

- Boundary of landform unit.
- Narrow, steep-walled canyon.
- Abrupt change in slope.
- Cliff or near-vertical slope.
- Linear topographic feature (includes linear valleys, cliffs, slopes, or combinations of these).

ıne Johnson County landforms map was compiled from interpretations of Skylab color infrared photography (S-190A, Track 5, Pass 10, June 13, 1973, Roll 15, Frames 229-231) and high-altitude color infrared aerial photography (NASA Flights 72-138, August 11, 1972; 73-147, August 30, 1973; no. 239, June 20, 1973; no. 248, August 7, 1973; no. 310, May 7, 1975). The map was first compiled at 1:250,000 by stereo photointerpretation of Skylab photography. This interpretation served to define general land-form classes and mappable units. The Skylab photo interpretation was then field-checked, revised as necessary and recompiled using the field-checked interpretation together with 1:120,000-scale stereo photography. This recompilation served to fill in areas obscured by clouds on the Skylab photography and to improve the accuracy of map-unit boundaries. Areas not covered stereoscopically by high-altitude aerial photography (see reliability index) were transferred directly from the field-checked Skylab map to the final map.



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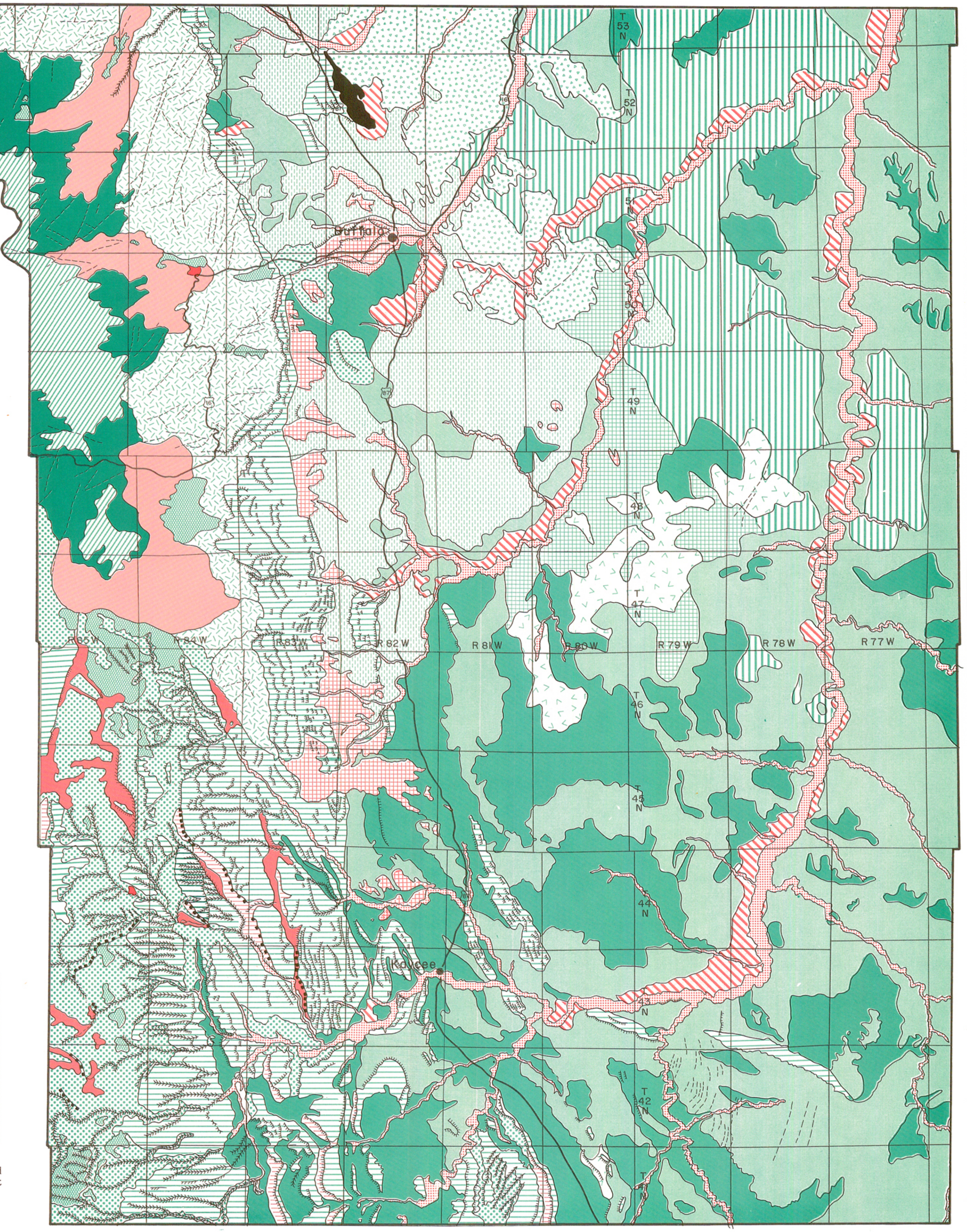

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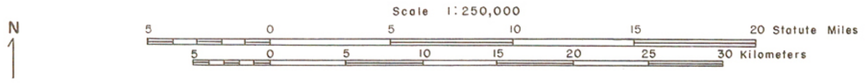

The Geological Survey of Wyoming, 1976

Uranium

Although uranium deposits in southeastern Johnson County were among the nation's first to be commercially mined, the uranium production from the county has, to date, been insignificant. Active mining extended from 1953 to 1964, but only 2400 tons of uranium ore were extracted from 21 different mines. Only one mine, the Antelope, recorded over 1000 tons of ore production.

Virtually all uranium ore produced in Johnson County came from small surface mines in the Pumpkin Buttes Mining District which extends into southeastern Johnson County from neighboring Campbell County. The Pumpkin Buttes District never supplied an important part of the nation's uranium; however, the district was of great historical and technical importance. It was in the Pumpkin Buttes District that commercial grade uranium deposits of the unique Wyoming type were first discovered and exploited.

The Pumpkin Buttes uranium deposits are found in sandstones of the Wasatch Formation, of Eocene age. The Wasatch and the upper part of the underlying Fort Union Formation in this area are mixed sequences of coarse and fine sandstones interlayered with claystones and siltstones. These rocks were deposited in a fluvial (stream valley) environment approximately 40 to 60 million years ago.

The host rocks for uranium ore in the Pumpkin Buttes District are bar and channel sandstones. Studies of the distribution of these ancient bars and channels in the rocks have outlined a complex drainage system with flow from south to north. Water and sediment were carried into the Powder River Basin from the Laramie Range, the Granite Mountains and the Bighorn Mountains (Davis, 1969, p. 136).

The uranium deposits in the Wasatch and Fort Union sandstones are demonstrably younger than the sandstones themselves. That is, the uranium was not deposited with the sand but was carried in and deposited later by moving ground water.

The Pumpkin Buttes uranium deposits are of two general types. The first consists of nodules or pods of black and yellow uranium minerals found within red or pink sandstone (See Type 1). Most of the small surface deposits mined in the district were of this type; most were high grade but of very limited extent. Isolated, high grade deposits of this type are not of economic importance.

A few of the larger deposits in the old Pumpkin Buttes District and most of the deeper deposits which are under consideration for development are of the second type. These ore-bodies are generally lower grade than the first type, but much larger. Their most distinctive characteristic is that they tend to show a crescent or C-shaped cross-section. They occur within sandstone at a contact between red or pink coloration on one side, and gray, tan or cream coloration on the other (See Type 2). Irregularities in this ore contact, where red coloration shows maximum penetration into the drab, are most likely to contain significant uranium deposits.

To the uranium geologist, the localization of uranium predominantly at or near the front of red to pink oxidized zones in the sandstones indicates that uranium was carried down dip in solution in oxidizing ground water until a chemical environment favorable to deposition was encountered. The net result was the formation of a shell of uranium-enriched sandstone around the outer limits of a tongue of red, oxidized sandstone.

The feasibility of solution mining uranium from sandstone-type deposits has been demonstrated. This type of mining is being considered for some smaller, deeply buried orebodies in the northern Pumpkin Buttes District.

Solution mining is not mining in the usually understood sense. Extraction is accomplished by pumping leaching solutions from the surface through the ore body by means of special injection wells. The uranium rich solution is then pumped to the surface from peripheral recovery wells.

If solution mining proves practical in this area, several operations might be anticipated in the Pumpkin Buttes District in the next few years.

Deposits of uranium in Wasatch and Fort Union sandstones, on the west flank of the Powder River Basin near Kaycee, also have this form and are probably of similar origin. An application has been filed with the State by U. S. Energy Company to begin underground mining of some of these deposits. A diagrammatic cross-section showing the relationship of the geology to the ore deposits in the Kaycee area is presented.

A third group of uranium mineral occurrences was found in the Jurassic age Sundance Formation on the east flank of the Bighorn Mountains in the Mayoworth area in the early 1950's. These deposits are low grade, limited in size and do not appear to have commercial potential (Love, 1954).

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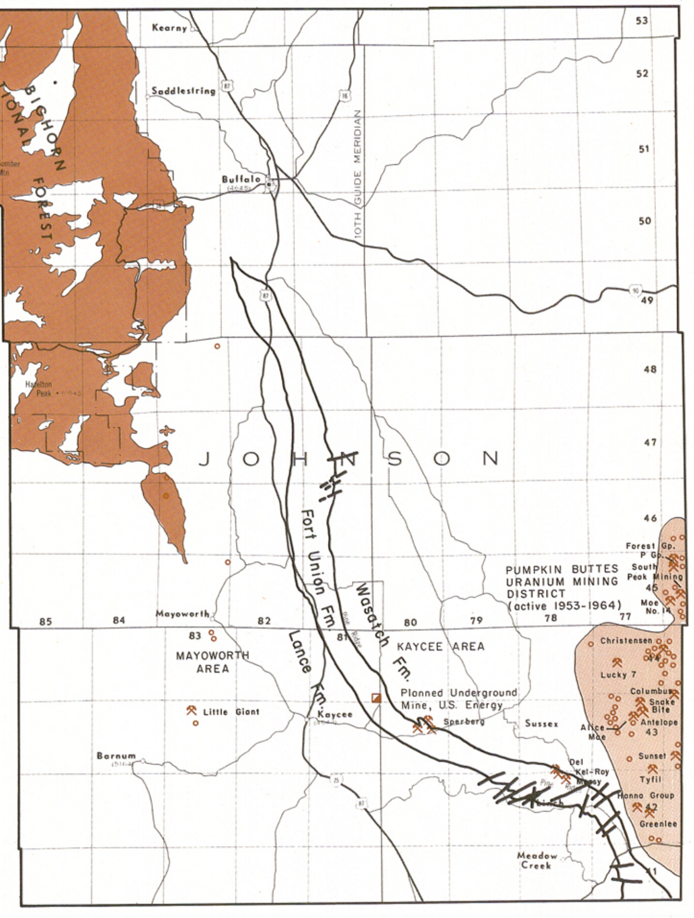
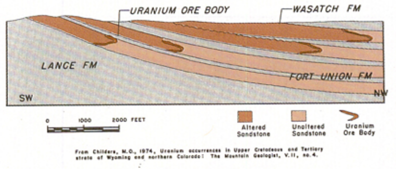
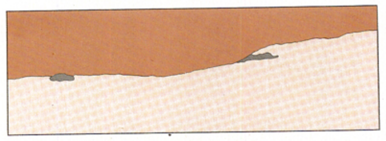


Uranium mineral occurrence, undeveloped
Inactive surface mine, less than 1000 tons of ore produced
Inactive surface mine, more than 1000 tons of ore produced
Proposed underground mine
Area of red, altered sandstone in the Wasatch Formation.
Area of Precambrian igneous and metamorphic rocks.

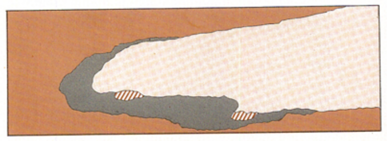
Data from: Sharp, W.N., McKay, E.J., McKeown, F.A., and White, A.M., 1964; and Mrak, V.A., 1968.

DIAGRAMMATIC CROSS-SECTION, URANIUM DEPOSITS OF THE KAYCEE AREA





Type 1. Concretionary Deposits



Type 2. Disseminated Deposits

Uranium Ore · Buff Sandstone · Red Sandstone · Calcite Cemented Sandstone

Modified from Mrak, V.A., 1968.

Construction Materials

The construction materials available in Johnson County are as diverse as their sources, which include a nearly complete section of the rock units present in Wyoming. Crystalline rocks are exposed in the core of the Bighorn Mountains. Steeply dipping Paleozoic and Mesozoic sedimentary rocks flank the uplift and are covered by flat-lying Tertiary sediments which fill the Powder River Basin. Recent weathering and erosion of underlying rocks by wind, water and ice has formed unconsolidated surficial deposits in both the mountain and basin areas.

Demand for construction materials will increase with increased energy production and construction of related facilities in Johnson County and the Bighorn Basin. Some of the counties in the basin lack construction materials in adequate quality and quantities and may seek materials in other counties, like Johnson.

SAND AND GRAVEL

The best sources of high quality construction materials are terrace deposits and some of the unconsolidated pediment conglomerates near the Bighorn Mountains. Most of the terrace deposits are dissected remnants of Quaternary flood plains. They roughly parallel the modern stream valleys. Parts of the Tertiary Kingsbury and Moncrief conglomerates, ancient pediments and alluvial deposits, are too coarse for use and too hard for crushing. Most of these deposits are progressively finer grained away from the Bighorn Mountains and contain mostly fine sand and silt in eastern Johnson County. Only locally are these alluvial deposits suitable for use as sand and gravel.

CRUSHABLE AGGREGATE

Large amounts of rock suitable for crushed aggregate are available in Johnson County. As with many construction material deposits, the proximity to the use area and local demand are the prime economic factors. Excellent crushed rock can be obtained from the Precambrian, Mississippian, Ordovician and lower Jurassic rock units.

Three types of Precambrian rocks are present in Johnson County; granites, metasediments and later igneous intrusives and extrusives. Granite is generally the best suited for crushed rock and is widely distributed in the Bighorn Mountains.

The Madison Limestone (Mississippian) and the Bighorn Dolomite (Ordovician) offer an unlimited source of excellent crushable rock. Many of the marginal units in other formations can be overlooked because of vast quantities of excellent quality material available in these two formations.

Farther from the mountains there are a few Mesozoic sandstones suitable to use as crushed rock. The lower Sundance sands usually form resistant "hogback" ledges and are generally hard enough for crushing. Most of the Cretaceous and Tertiary sandstones are too soft and are associated with shales and clay; however, some local sands may be usable. Specific locations, qualities and quantities of construction materials must be determined by detailed investigations of individual sites.

CLINKER

Large quantities of baked rock, "clinker" or "scoria", are available in Johnson County. The baked rock is a result of coal fires which heat and fuse the overlying rock into a clinker-like form. Like the coal seams, most of the scoria is found in the Wasatch and Fort Union Formations in eastern Johnson County. These deposits have not been widely used as a construction material because they are brittle and have a high absorption rate. However, they have been used successfully for ballast, subsurfacing and surfacing on low traffic roads. Further evaluation and application is needed to assess the worth of clinker as a construction material.

CLAYS

Numerous clays occur in parts of the Cretaceous and Tertiary units of Johnson County. Although none have been recognized to be of particular value, similar clay in adjacent counties has proven economical. Higher quality clays are commonly associated with coal and could be an expected by-product of coal mines, depending on the market demand.

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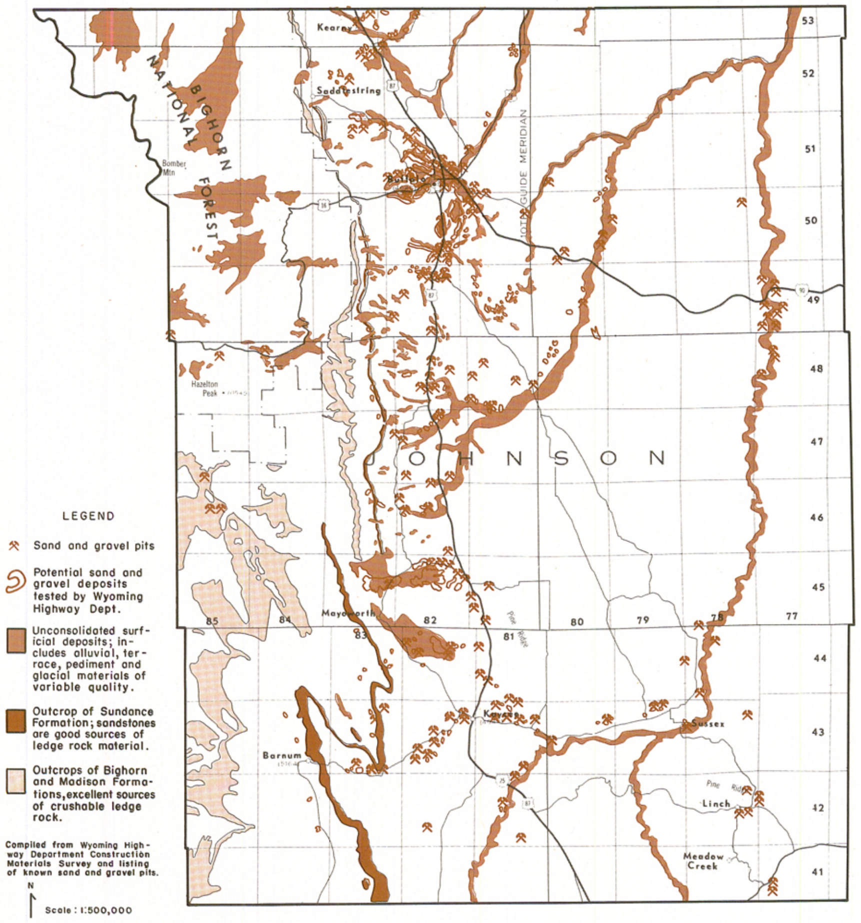


LEGEND

Sand and gravel pits
Potential sand and gravel deposits tested by Wyoming Highway Dept.
Unconsolidated surficial deposits; includes alluvial, terrace, pediment and glacial materials of variable quality.
Outcrop of Sundance Formation; sandstones are good sources of ledge rock material.
Outcrops of Bighorn and Madison Formations, excellent sources of crushable ledge rock.

Compiled from Wyoming Highway Department Construction Materials Survey and listing of known sand and gravel pits.

Scale : 1:500,000

Other Minerals

GOLD

The basal sandstone of the Flathead Formation is known to contain gold at several locations in the Bighorn Mountains. Attempts were made, near the turn of the century, to mine this kind of occurrence at the head of Kelly Creek, southwest of Buffalo, but the venture was unprofitable.

The Powder River Mine in sec. 20, T.47N., R.85W., is a different kind of gold prospect. Mineralization is found in quartz veins which cut through Precambrian metamorphic rocks. A mill was built on this property in 1942 but little production was achieved.

COPPER

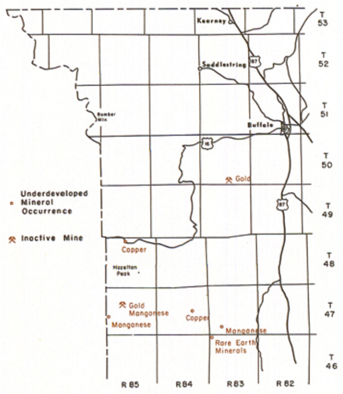
Copper minerals are found in quartz veins which cut Precambrian igneous and metamorphic rocks in T.47N., R.84W. and in sec. 4, T.46N., R.83W., just north of the road at Powder River Pass.

MANGANESE

There are several strong showings of manganese oxides in Paleozoic and Tertiary age sedimentary rocks where they are in close proximity to the Precambrian crystalline rocks. The largest of these deposits is the Beaver Creek deposit in secs. 30 and 32, T.47N., R.83W.

RARE EARTHS

The rare earths are a group of chemical elements which are used in petroleum refining catalysts, iron and steel, ceramics, glasses and in electronic components. Allanite, a rare earth mineral, occurs in a vein in Precambrian granite in sec. 6, T.46N., R.83W. The deposit appears to be sizeable, but rare earths are currently in over-supply on the world market and little incentive exists for development of new deposits.



Industrial Minerals

The industrial minerals form a large and varied group of mineral commodities, principally nonmetallic, which find use in industrial, manufacturing or agricultural applications because of special physical or chemical properties. The only important industrial mineral currently mined in Johnson County is the special type of clay deposit called Wyoming bentonite.

BENTONITE

Wyoming bentonite is a sedimentary rock composed primarily of a sodium-rich variety of the clay mineral montmorillonite. Bentonite layers are found in the Cretaceous Mowry, Thermopolis and Frontier Formations on the eastward dipping flank of the Bighorn uplift. The bentonite was formed by the alteration of volcanic ash which fell into the Cretaceous sea.

The usefulness of Wyoming bentonite is based on its remarkable capacity to absorb water or "swell". When wet, swelling bentonites may increase in volume 15 to 20 times compared to the dry state. This property is especially useful in oil well drilling muds and in reservoir and irrigation ditch sealants. Bentonite is also used as a binder in foundry sands and in the pelletizing of siliceous iron ores for blast furnace feed. The pelletizing process is currently the single greatest use for Wyoming bentonite.

The use of Wyoming bentonite reached a record level in recent years and will continue to increase as (1) siliceous iron ores make up an increasingly greater proportion of the total U. S. iron ore production, (2) oil and gas drilling footage continues to increase as these commodities become more difficult to find and (3) new industrial and waste treatment applications for bentonite come into use.

Production of bentonite in Johnson County comes principally from the operations of the Kaycee Bentonite Company in the south-central part of the county. Because of variability in bentonite quality, mining is very selective and individaul open pit mines are very small. However, the area which includes these many small pits has become very large, extending northwest for about 20 miles from the southern county line to the Kaycee area. Lesser production comes from the Benton Clay Company operations northwest of Kaycee. The bentonite mined by both of these producers is carried by truck to processing plants near Casper.

Johnson County is currently the fourth leading producer of bentonite among the Wyoming counties. Since 1965, about 2,000,000 tons of raw bentonite have been mined in the county. Current production is near the record level of 241,000 tons per year.

HIGH-CALCIUM LIMESTONE

A second industrial mineral present in some quantity in Johnson County and for which a strong local market could develop is high-calcium limestone. High-calcium limestone is already in demand in Wyoming for use in refining sugar from sugar beets.

High-calcium limestone helps to remove sulfur from the stack gases of coal fired power plants through the use of limestone or lime scrubber systems. Some units of the Madison Formation in Johnson County are probably of sufficient quality to be used in this process.

A mine was proposed for the Madison outcrops west of the town of Story in Sheridan County, approximately one mile north of the Johnson County line, last year. State authorities refused approval of this project because of environmental considerations. However, alternative sites for mine development are currently being explored in Johnson County. The limestones at the Story outcrops are high quality, ranging up to 98.7% pure calcium carbonate in the analyses which have been made (Mr. Al Husman, personal communication, 1976).

In the northern half of the county, presumably closer to anticipated electrical-generating developments in the Powder River Basin, the Madison Formation dips steeply to the east. In this geological situation, the only economical way to provide the large amounts of limestone needed for even one scrubber system for an average sized power plant would be through underground mining.

Flatter dips provide a large area of Madison limestone better suited to less expensive surface mining methods in the southwestern part of the county. However, this advantage is probably offset by the much greater transport distances required from this area to the points of use.

In the event of large-scale construction of new electrical generating facilities in the Powder River Basin, it is likely that the high calcium limestones of the Madison Formation will be utilized for scrubbers. As a rough approximation, around 100,000 tons of limestone would have to be mined each year to supply a 1000 MW generating plant. This would vary, of course, with (1) the heat value of the coal burned and (2) the purity of the limestone.

GYPSUM

Very large deposits of gypsum are found in the Goose Egg, Chugwater and Gypsum Spring Formations on the east flank of the Bighorn Mountains, however these deposits have never been commercially mined. The most critical factor affecting the economic feasibility of a gypsum mining-dry wall fabrication complex is the location of the deposit with respect to markets. Wyoming gypsum deposits are well situated with respect to markets in the Pacific Northwest, an area notably deficient in gypsum deposits of its own. Increasing demand from that area and a burgeoning population in the energy-producing areas of Wyoming could certainly create the economic incentives for development of additional gypsum-dry wall manufacturing capacity in Wyoming.

The steep dips which the gypsum-bearing units exhibit in the north half of the county are a definite economic deterrent to mining in that area. The more gentle dips to the south would allow less expensive mining methods to be used. Representative aggregate gypsum bed thicknesses are presented on the accompanying map.

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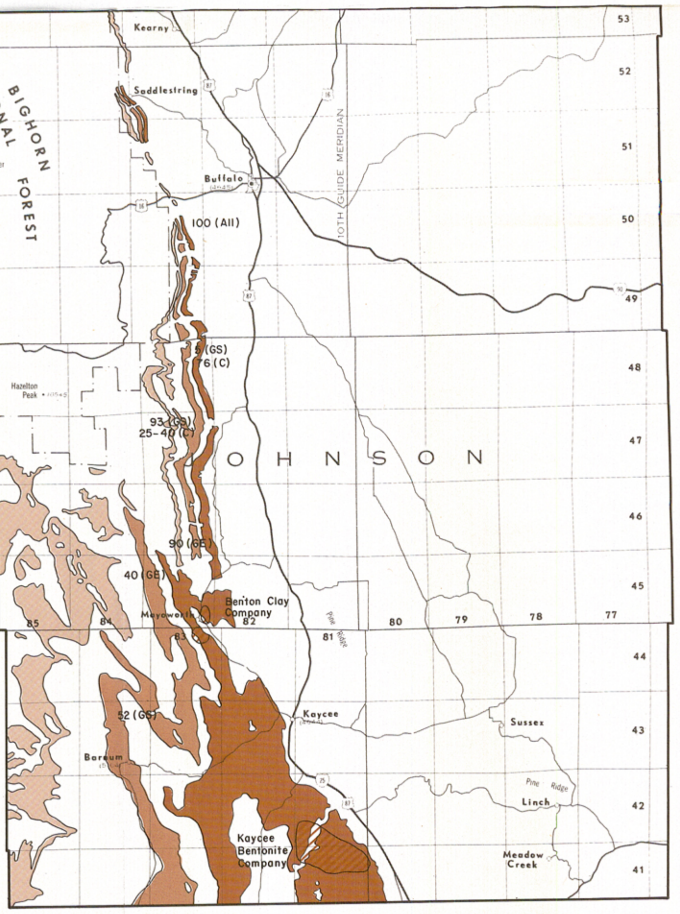
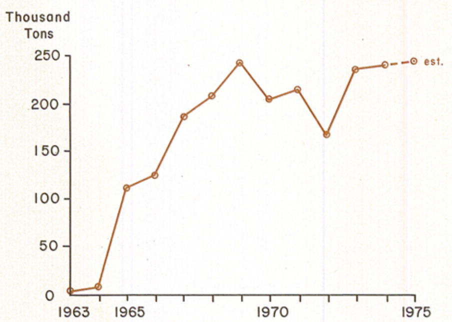


High Calcium Limestone-Bearing Formations
Gypsum-Bearing Formations
Bentonite-Bearing Formations
Area of current Bentonite Mining Activity

Aggregate thickness (ft.) of gypsum layers, gypsum bearing formation indicated in parentheses (GE, Goose Egg; C, Chugwater; GS, Gypsum Spring).

Bentonite Production By Year

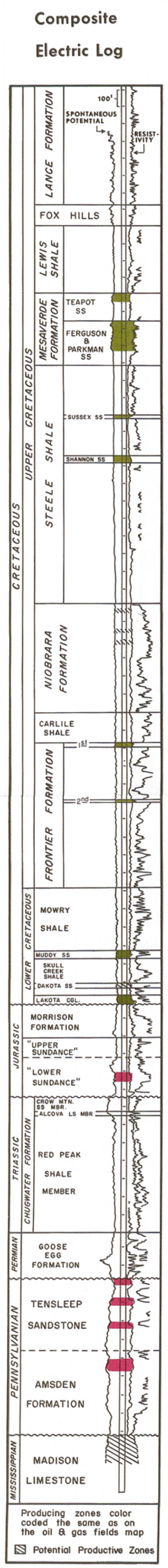


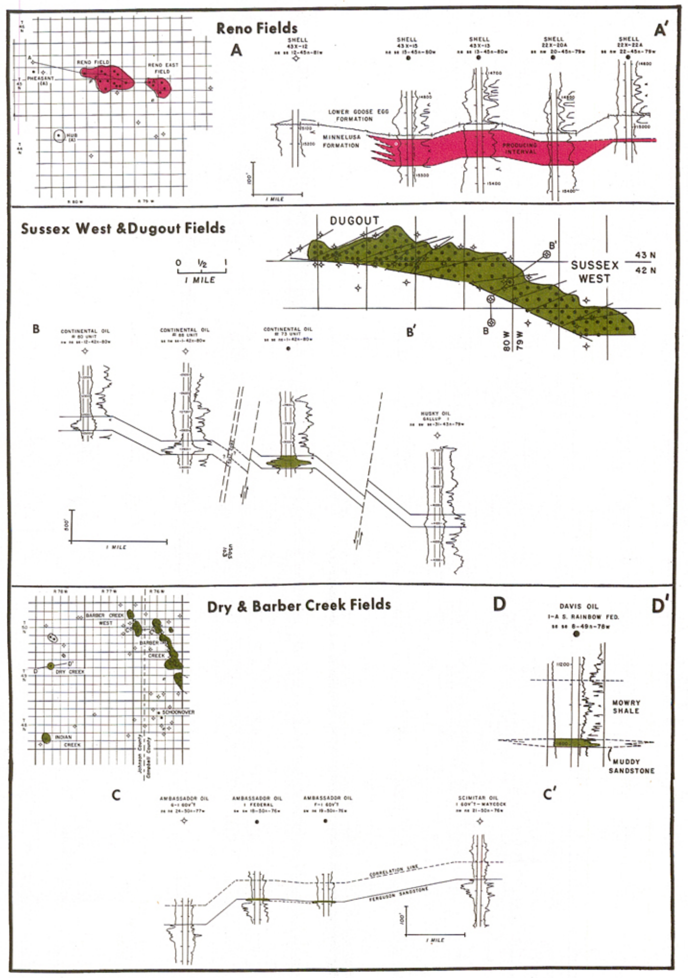
Production Figures From Wyoming Department of Revenue, Ad Valorem Division

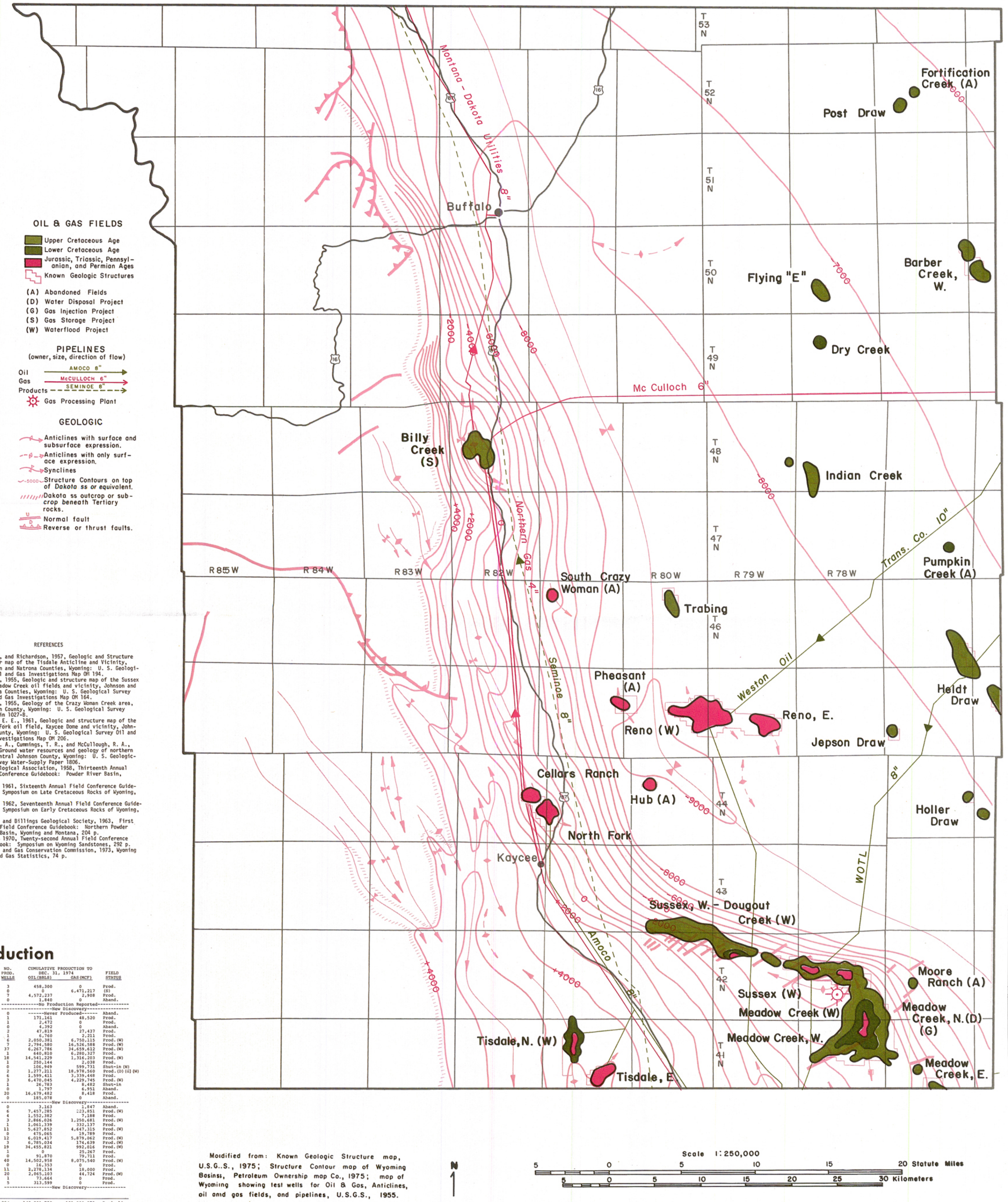
JOHNSON COUNTY CONSTRUCTION MATERIALS SUMMARY

SYSTEM	SERIES	FORMATION	THICKNESS	CHARACTER	CONSTRUCTION MATERIAL POTENTIAL
QUATERNARY	Recent	ALLUVIUM-COLLUVIUM	0-60'	Sand, silt, clay, and gravel; sediments are finer grained away from the Big Horns Mtns; also includes landslide and lake deposits.	Near the mountains gravel can be found in these deposits. In most cases, however, the water table is at or near the ground surface.
QUATERNARY	Recent and Pleistocene	TERRACE DEPOSITS	0-50+'	Clay, silt, sand and gravel. Gravel consists of well-rounded pebbles, cobbles and subrounded boulders of limestone, sandstone, quartzite, chert and igneous rocks. In southern part of county may have 0-5' of silt, sand and clay overburden.	Best source of highway construction material in this county. Gravel is often clean, quite hard and well-graded.
QUATERNARY	Recent and Pleistocene	PEDIMENT DEPOSITS	0-100'	Heterogeneous mixture of Paleozoic and igneous rocks, grading related to distance from mountains.	Not a good source of construction material. Contains large boulders, as well as interstitial clay. An extensive screening and crushing program would be required.
TERTIARY	Pliocene	MONCRIEF CONGL.	10-1200'	Lower one-third interbedded greenish siltstone, silty sandstone, thin beds of conglomerates grading upward to boulder beds.	Conglomerates may be coarse but should yield large quantities of good construction material.
TERTIARY	Oligocene	WHITE RIVER FORMATION	10-300'	Light brown bentonitic claystone interbedded with calcium carbonate and light gray tuffaceous cemented conglomerate.	Could be a source of highway construction material but contains some bentonitic material.
TERTIARY	Eocene	WASATCH	500-2400'	Shale, sandstone, bentonite, and lignite layers having an overall drab brownish-gray appearance in upper part. Some white sandstone and conglomerate in lower part.	This formation generally will not provide any construction material due to interlayering of shales causing high plasticity. Only the scoria beds are recommended for use in highway construction.
TERTIARY	Eocene	KINGSBURY CONGL.	10-600'	Predominantly conglomerate, some sandstone and claystone, consists mainly of hard Paleozoic rocks.	Conglomerates may yield good quality gravel or crushed ledge rock depending on degree of cementation. Sandstone in the conglomerate causes wear grade in the forties. Slopewash overburden may be thick in some areas.
TERTIARY	Paleocene	FORT UNION	2500-4000'	Interbedded clay, shale, sandy shale, and coal in lower and upper parts; middle part consists of massive sandstone beds.	Sandstone beds would yield non-plastic sand and sandstone.
CRETACEOUS		LANCE	1900-3000'	Brownish sandstone, gray shale, and carbonaceous shale; some lignite in upper part. Typically sandstone is a cross-bedded channel deposit.	May have some sand and sandstone, but generally formation is mostly shale and not recommended for use.
CRETACEOUS		FOX HILLS SANDSTONE	100-600'	Salt and pepper sandstone; contains gray shale at top and massive, cliff-forming reddish-brown sandstone at bottom.	A satisfactory source of sand and sandstone, but not hard enough for crushable ledge rock.
CRETACEOUS		BEARPAW SHALE	200	Sandy carbonaceous shale that weathers buff and blue.	No construction materials located within this formation.
CRETACEOUS		MESAVERDE	600-700'	Upper and middle parts consist of carbaneous shale shale and slabby sandstone. Parkman Sandstone Member (lower part) is massive, cross-bedded, and medium grained.	Parkman Sandstone Member could supply unlimited quantities of sand and sandstone, but not hard enough to provide crushed rock.
CRETACEOUS		CODY SHALE	3100-3600'	Medium to dark gray marine shale; contains sandstone lens in upper part.	Although parts of this formation are sandy, the formation should be avoided since interlayered shales tend to cause high plasticity.
CRETACEOUS		FRONTIER SANDSTONE	400-800'	Interbedded sandstone and shale at the top form the Wall Creek Sandstone Member, consisting of three sands; bentonite lies at the base of the formation.	The two top Wall Creek Sandstone Members could provide non-plastic sand and sandstone, but the Lower Wall Creek Member is not recommended, nor is any part of the lower Frontier Formation recommended for any use due to its bentonite content and high plasticity.
CRETACEOUS		MOWRY SHALE	200-350'	Dark brownish gray siliceous shale that weathers to silvery gray; contains thin beds of bentonite.	This formation is hard, brittle, and shatters in plate-like fragments along bedding planes; unconfined, the material tends to slip and is only recommended as "gravel surfacing" of non-paved roads.
CRETACEOUS		THERMOPOLIS SHALE	150-250'	The upper part consists of gray shale and beds of bentonite. Lower part consists of thin-bedded black shale. The Muddy Sandstone Member is a well-indurated drab buff to brown, medium-grained sandstone.	No construction material deposits located within this formation.
CRETACEOUS		CLOVERLY	80-100'	Massive white to light-creme medium-grained sandstone containing lenses of small pebble conglomerate (10-30') with 100' of grayish-black shale.	The sandstone member could provide non-plastic sand and soft sandstone, but is not hard enough to provide crushed rock.
JURASSIC		MORRISON	200-300'	Lenticular beds of fine to medium-grained sandstone and shale; weathers to variegated colors.	No construction material deposits located within this formation.
JURASSIC		SUNDANCE	250-300'	Interbedded greenish-gray glauconitic shale and light-gray and yellow sandstone with 5-10' lenticular limestone layers at top, middle and bottom.	The lenticular limestone is an excellent crushable hard ledge rock. It will have dip slopes exposed with several hundred thousand cubic yards available.
TRIASSIC		CHUGWATER	750-1000'	Bright red, fine to medium-grained sandstone, shale, and siltstone containing gypsum beds as much as 2 feet thick.	No construction material deposits located within this formation.
PERMIAN		GOOSE EGG	200-250'	Soft, reddish-brown, silty clay and siltstone, interbedded gypsum and red siltstone.	No construction material deposits located within this formation.
PENNSYLVANIAN		TENSLEEP SANDSTONE	300-400'	Massive, light-gray, white, yellow, or pinkish-white fine to medium-grained cross-bedded sandstone.	This formation is an unlimited source of non-plastic sand and sandstone, but has only a few lenticular ledges hard enough to provide crushable ledge rock.
PENNSYLVANIAN		AMSDEN	250'	Red sandstone and claystone and tan massive dolomite.	The sandstone and clay are not a source of construction material, but the dolomite layers may provide a crushable hard ledge rock.
MISSISSIPPIAN		MADISON LIMESTONE	500'	Thin-bedded to massive resistant limy dolomite and limestone; unit forms prominent cliffs.	This formation has an unlimited supply of limestone with qualities meeting the most rigid demands of high quality materials specifications.
ORDOVICIAN		BIGHORN DOLOMITE	150-300'	Basal gray to red sandstone overlain by resistant pitted gray dolomite. Top layer is lenticular, slabby dolomite.	The dolomite is recommended as an excellent source of crushable ledge rock. It would be clean and hard and would meet high quality specifications.
CAMBRIAN		GALLATIN LIMESTONE	50'	Greyish-red, slabby, silty limestone, with some flat pebble conglomerate.	This formation is not recommended because it is often obscured by overburden; overlying units have better quality material in open exposures.
CAMBRIAN		GROS VENTRE	500'	Soft non-resistant medium to coarse-grained green to red sandstone overlain by soft grayish-green shale.	This formation is often covered by overburden and vegetation. It is not recommended for use as a construction material.
CAMBRIAN		FLATHEAD SANDSTONE	260'	Tan to brown, medium to coarse-grained quartz sandstone with some conglomerate at base.	Could provide non-plastic sand and sandstone, but no hard ledge rock is available.
PRECAMBRIAN		GRANITE		Pink, pinkish-gray and gray, fine to coarse-grained granite; intrusive rocks of varying composition and metamorphic rocks.	Could provide crushable hard rock as construction material; may also have zones of disintegrated granite which might be used without blasting.

Compiled from Wyoming Highway Department Construction Materials Survey







Modified from: Known Geologic Structure map, U.S.G.S., 1975; Structure Contour map of Wyoming Basins, Petroleum Ownership map Co., 1975; map of Wyoming showing test wells for Oil & Gas, Anticlines, oil and gas fields, and pipelines, U.S.G.S., 1955.

Billy Creek Field, drilled in 1923, was the first oil and gas discovery in Johnson County. Prior to depletion of the field, total cumulative production at Billy Creek was 6.5 billion cubic feet of gas from the Frontier Formation from an average depth of 3,160 feet. Since 1947 Billy Creek Field has been used as a gas storage reservoir.

Exploration activity in the southeast corner of Johnson County was enhanced by the discovery of Sussex Field in 1948. The Sussex Field trends east-west through T.42N., R.78 and 79W. The field lies on the fractured northeast side of a broad structural high. Production comes from rocks of several ages, ranging from the Pennsylvanian Amsden Formation to the Upper Cretaceous Parkman Sandstone. The Meadow Creek Complex and Sussex West-Dugout fields were subsequently discovered in 1950 and 1952 in southeastern Johnson County.

After these discoveries came into full production, oil and gas production declined until 1963 when a large number of new discoveries resulted in a substantial production increase. Barber Creek West, Cellars Ranch, Hub, Reno and Reno East fields were all discovered in the early and middle sixties. Yearly production in the county peaked in 1966 with 8.5 million barrels of oil and 3.5 billion cubic feet of gas.

Since the mid-sixties peak, oil and gas production in Johnson County has steadily decreased. Recent field discoveries include Dry Creek, Flying E, Holler Draw, Indian Creek, Jepson Draw, Moore Ranch, Post Draw , Pumpkin Creek and Trabing fields. However, these new discoveries have thus far had little effect on the overall production decline.

PRODUCTION

Oil and gas production in Johnson County has come from Upper Paleozoic and Mesozoic strata (i.e., Pennsylvanian through Upper Cretaceous). Non-marine strata above the Upper Cretaceous and non-porous strata below the Pennsylvanian have not produced economic oil and gas in the county. Deeper drilling with emphasis on facies analysis and/or deeper testing of producing structures may result in new discoveries in the Lower Paleozoic section.

The majority of the producing fields in the county are anticlines. Anticlines are convex-up folds of continuous strata on which the limbs of the fold dip in opposite directions. Such structures are generally the result of vertical movement of Precambrian "basement" blocks (see geology plate). Hydrocarbons generally accumulate at the crest of such structures within porous and permeable strata.

Anticlinal traps were the chief target in the early days of exploration because they generally have an obvious outcrop expression. Today, the explorationist must look for less obvious clues to hydrocarbon accumulation (e.g., stratigraphic traps).

Cross-sections through four fields in Johnson County are illustrated on this plate. The cross-section through Reno and Reno East Fields demonstrates production from an anticlinal trap. Production is from the Pennsylvanian Minnelusa Formation at a depth of approximately 15,000 feet.

The cross-section through Sussex West-Dugout shows production from another type of structural trap -- one in which faulting produces local highs and barriers to hydrocarbon migration. Production in this field is from the Shannon and "K" Sandstones, with forty wells producing from average depths of 2,860 feet and 4,700 feet, respectively.

The cross-section through Barber Creek West demonstrates a stratigraphic accumulation in the Upper Cretaceous Ferguson Sandstone. This field is at the northwest end of a linear trend of Upper Cretaceous fields running through Campbell and Converse Counties. Three wells in the Parkman Sandstone have produced 458,300 BBLs at an average depth of 6,900 feet.

Cross-section D-D', through the Dry Creek Field, shows a small stratigraphic accumulation in the Muddy Sandstone. Most Muddy fields in the Powder River Basin are stratigraphic traps consisting of thin, discontinuous channel, beach, offshore sands or combinations of these. Offshore bar and beach facies generally trend north-south paralleling the ancient Interior Cretaceous Seaway. Channel sands generally have an irregular pattern subperpendicular to the beach facies.

FUTURE DEVELOPMENTS

Johnson County has a unique geological setting. It overlaps the eastern Bighorn Mountains and western Powder River Basin. The axis of the Powder River Basin trends diagonally NW-SE through the middle of the county. A variety of geologic conditions exist which are favorable for the accumulation of hydrocarbons.

Oil and gas potential may exist along the Powder River Basin axis. However, the cost of deeper drilling and the traditional viewpoint that hydrocarbons do not accumulate in synclines lead explorations to ignore the basin axis. Several discoveries along basin axes throughout the Rocky Mountain region demonstrated that unique conditions of pressure and fracturing exist in synclines. These conditions may be present in the county.

The steep, east-dipping west limb of the Powder River Basin may have oil and gas potential from fault traps. Structural traps, such as the simple model of hydrocarbon accumulation at the up-dip faulted end of a porous stratum might be located with the aid of improved seismic evaluation. Localized traps may occur in faulted and fractured strata due to flexure over the edge of uplifted Precambrian blocks.

Additional oil and gas potential in Johnson County includes stratigraphic accumulations. The northeast corner of the county is a good area for such traps. There is a good possibility that the northwest-southeast Lower Cretaceous sandstone trends located in Campbell County, immediately east, may extend into Johnson County. Although well control is sparse, additional drilling throughout the years will yield more stratigraphic information which may be used for new prospect ideas. There is also potential for stratigraphic accumulations along Lower Paleozoic pinch-out trends in northern Johnson County.

The declining production curve for Johnson County might be reversed with new and integrated exploration concepts ad well as enhanced recovery methods for existing fields. If economic conditions remain favorable for exploration in the Rocky Mountain Region, Johnson County may be expected to yield many new fields.

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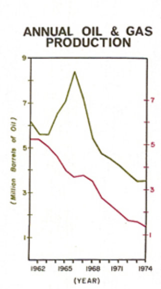


Oil & Gas Production

FIELD NAME AND DISCOVERY DATE		LOCATION	PRODUCING FORMATION(S)	PRODUCING DEPTH(S)	NO. PROD. WELLS	CUMULATIVE PRODUCTION TO DEC. 31, 1974 OIL(BBLS)	GAS(MCF)	FIELD STATUS
Barber Creek, West	1962	50N-76W, 77W	Parkman	6,900	3	458,300	0	Prod.
Billy Creek	1923	48N-82W	Frontier	3,160	0	0	6,471,217	(S)
Cellars Ranch	1960	44N-82W	Tensleep	6,500	7	4,572,237	2,908	Prod.
Crazy Woman, S.	1956	46N-81W	Tensleep	12,210	0	1,840	0	Aband.
Dry Creek	1974	49N-78W	Muddy	11,575	---No Production Reported---			
Flying E	1975	50N-78W	Shannon	8,619	---New Discovery---			
Fortification Creek	1957	52N-77W	Parkman	6,121	0	---Never Produced---		Aband.
Heldt Draw	1973	46N-77W	Shannon	9,348	1	171,161	48,520	Prod.
Holler Draw	1974	44N-76W	Shannon	9,866	1	2,472	0	Prod.
Hub	1966	44N-80W	Minnelusa	15,180	0	4,392	0	Aband.
Indian Creek	1974	48N-78W	Sussex & Shannon	8,935	2	47,819	27,437	Prod.
Jepson Draw	1974	45N-77W	Shannon	9,732	1	6,760	2,211	Prod.
Meadow Creek	1950	41N-78W	Frontier	6,640	6	2,050,381	6,750,115	Prod. (W)
			Lakota	7,600	7	2,794,580	16,526,588	Prod. (W)
			Shannon	4,200	37	6,267,786	34,659,612	Prod. (W)
			Sussex	3,600	1	640,810	6,280,327	Prod.
			Tensleep	8,950	18	14,541,229	1,316,203	Prod. (W)
Meadow Creek East	1951	41N-77W	Shannon	4,301	1	250,144	2,038	Prod.
Meadow Creek, Middle	--	42N-78W	Shannon		0	106,949	599,731	Shut-in (W)
Meadow Creek, North	1949	42N-78W	Frontier	6,367	2	1,277,211	18,978,560	Prod. (D) (G) (W)
			Shannon	4,420	6	1,599,411	3,339,448	Prod.
			Sussex	3,830	3	6,470,045	4,229,745	Prod. (W)
Meadow Creek, West	1950	41N-78W	Shannon	3,550	1	26,783	8,482	Shut-in
Moore Ranch	1971	42N-77W	Frontier	12,552	0	1,797	6,951	Aband.
North Fork	1951	44N-81,82W	Tensleep	6,500	20	16,679,482	8,418	Prod.
Pheasant	1965	45N-81W	Minnelusa	15,035	0	185,078	0	Aband.
Post Draw	1975	52N-77W	Teapot	6,072	---New Discovery---			
Pumpkin Creek	1969	47N-77W	Muddy	11,532	0	3,163	1,847	Aband.
Reno	1965	45N-79,80W	Minnelusa	14,900	6	7,457,285	223,851	Prod. (W)
Reno, East	1966	45N-79W	Minnelusa	14,800	4	1,552,382	7,188	Prod.
Sussex	1948	42N-78,79W	Lakota	7,800	3	2,866,026	1,250,681	Prod. (W)
			Parkman	3,156	1	1,061,339	332,137	Prod.
			Shannon	4,340	11	5,627,852	4,647,315	Prod. (W)
			Sundance	8,000	0	475,065	19,789	Prod.
			Sussex	4,127	12	6,019,417	5,879,062	Prod. (W)
			Tensleep	9,000	3	6,785,034	174,639	Prod. (W)
			Tensleep-Amsden	9,400	19	34,455,821	992,016	Prod. (W)
			Teapot		1	0	25,267	Prod.
			Frontier	6,390	0	91,870	79,711	Prod.
Sussex,W - Dugout Crk.	1951	42,43N-79,80W	Shannon	2,860	40	14,502,958	8,075,540	Prod. (W)
			"K" Sand	4,700	0	16,353	0	Prod.
Tisdale, East	1959	41N-81W	Tensleep	2,150	11	2,278,134	18,000	Prod.
Tisdale, North	1952	41N-81W	Curtis	930	20	2,065,103	44,724	Prod. (W)
			Lakota	200	1	73,664	0	Prod.
			Tensleep	2,110	5	313,599	0	Prod.
Trabing	1975	46N-80W	Frontier	12,538	---New Discovery---			
29 Fields					25[illegible]	143,801,732	121,030,278	Prod. 16

(W) Waterflood project (G) Gas injection project (S) Gas storage (D) Water disposal project

Data sources: Wyoming Oil and Gas Conservation Commission; Wyoming Geological Association; Earth Science Bulletin, June 1973; Petroleum Information

Grassland (bottom)-sagebrush(background)-coniferous site on the Big Horn Mountains (T.47N., R.85W.). Sagebrush communities are frequently found along draws and south facing slopes.

Grassland-riparian site of the Powder River floodplain in July (T.50N., R.77W.). The area is dominated by a variety of perennial and annual grasses, forbs and cottonwoods.

Principal Plants of Johnson County

Symbol	Scientific Name	Common Name
Abl	*Abies lasiocarpa*	alpine fir (subalpine f.)
Acn	*Acer negundo*	boxelder maple
Acl	*Achillea lanulosa*	western yarrow
Agg	*Agoseris glauca*	pale agoseris
AG	*Agropyron* (spp.)	wheatgrass, quackgrass
Agc	*Agropyron cristatum*	crested wheatgrass
Agd	*Agropyron dasystachyum*	thickspike wheatgrass
Agr	*Agropyron repens*	common quackgrass
Agsm	*Agropyron smithii*	western wheatgrass
Agsp	*Agropyron spicatum*	bluebunch wheatgrass
Aga	*Agrostis alba*	redtop bent
Alc	*Allium cernuum*	nodding onion
Ama	*Amelanchier alnifolia (oreophila)*	saskatoon serviceberry
Ang	*Andropogon gerardi*	big bluestem
Ans	*Andropogon scoparius*	little bluestem
Anr	*Antennaria rosea*	rose pussytoes
Arl	*Aristida longiseta*	red threeawn
Arco	*Arnica cordifolia*	heartleaf arnica
Arca	*Artemisia cana*	silver sagebrush
Arfi	*Artemisia filifolia*	sand sagebrush
Arfr	*Artemisia frigida*	fringed sagewort
Arn	*Artemisia nova*	black sagebrush
Arp	*Artemisia pedatifida*	birdfoot sagewort
Ars	*Artemisia spinescens*	bud sagewort
Art	*Artemisia tridentata*	basin big sagebrush
AS	*Astragalus* (spp.)	milkvetch
Atc	*Atriplex confertifolia*	shadscale saltbush
Atn	*Atriplex nuttalli (gardneri)*	nuttall saltbush
Bas	*Balsamorhiza sagittata*	arrowleaf balsamroot
Beo	*Betula occidentalis (fontinalis)*	water birch
BO	*Bouteloua* (spp.)	grama
Boc	*Bouteloua curtipendula*	sideoats grama
Bog	*Bouteloua gracilis*	blue grama
BR	*Bromus* (spp.)	brome
Bri	*Bromus inermis*	smooth brome
Brj	*Bromus japonicus*	japanese brome
Brm	*Bromus marginatus*	mountain brome
Brt	*Bromus tectorum*	cheatgrass brome
Caca	*Calamagrostis canadensis*	bluejoint reedgrass
Cal	*Calamovilfa longifolia*	prairie sandreed
Can	*Calochortus nuttalli*	sego mariposalily
CA	*Carex* (spp.)	sedge
Caf	*Carex filifolia*•	threadleaf sedge
Cag	*Carex geyeri*	elk sedge
Caco	*Castilleja coccinea*	common indianpaintbrush
Cel	*Cercocarpus ledifolius*	curlleaf mountainmahogany
Cem	*Cercocarpus montanus*	true mountainmahogany
Cha	*Chenopodium album*	lambsquarters goosefoot
Chl	*Chrysothamnus lanceolatus*	lanceleaf rabbitbrush
Chn	*Chrysothamnus nauseosus (speciosus)*	rubber rabbitbrush
Cir	*Cirsium arvense*	canada thistle
CR	*Crataegus* (spp.)	hawthorn
Deb	*Delphinium bicolor*	little larkspur
Dis	*Distichlis spicata stricta*	inland saltgrass
Elc	*Elymus condensatus*	giant wildrye
ER	*Eriogonum* (spp.)	wildbuckwheat
Eul	*Eurotia lanata*	common winterfat
Fei	*Festuca idahoensis*	idaho fescue
Grs	*Grindelia squarrosa*	curlycup gumweed
Gus	*Gutierrezia sarothrae*	broom snakeweed
HA	*Halogeton* (spp.)	halogeton
Hob	*Hordeum brachyantherum*	meadow barley
Hoj	*Hordeum jubatum*	foxtail barley
Jub	*Juncus balticus*	baltic rush
Juc	*Juniperus communis*	common juniper
Jus	*Juniperus scopulorum*	rockymountain juniper
Koc	*Koeleria cristata*	prairie junegrass
LE	*Lepidium* (spp.)	pepperweed
LU	*Lupinus* (spp.)	lupine
Meb	*Melica bulbosa*	onion melic
ME	*Melilotus* (spp.)	sweetclover
Mea	*Melilotus alba*	white sweetclover
Mel	*Melilotus officinalis*	yellow sweetclover
Mec	*Mertensia ciliata*	mountain bluebells
Opp	*Opuntia polcantha*	plains pricklypear
Orh	*Oryzopsis hymenoides*	indian ricegrass
PE	*Penstemon* (spp.)	penstemon
Phle	*Phleum* (spp.)	timothy
Pha	*Phleum alpinum*	alpine timothy
PH	*Phlox* (spp.)	phlox
Pie	*Picea engelmanni*	engelmann spruce
Pic	*Pinus contorta*	lodgepole pine
Pif	*Pinus flexilis*	limber pine
Pip	*Pinus ponderosa*	ponderosa pine
PO	*Poa* (spp.)	bluegrass
Pop	*Poa pratensis*	kentucky bluegrass
Pos	*Poa secunda*	sandberg bluegrass
Poa	*Populus angustifolia*	narrowleaf poplar
Pod	*Populus deltoides*	eastern poplar
Pot	*Populus tremuloides*	quaking aspen
Pof	*Potentilla fruticosa*	shrubby cinquefoil
Prv	*Prunus virginiana*	common chokecherry
Psm	*Pseudotsuga menziesii (taxifolia)*	common douglasfir
QU	*Quercus* (spp.)	oak
SA	*Salix* (spp.)	willow
Sat	*Salsola tenuifolia*	tumbleweed russianthistle
Sav	*Sarcobatus vermiculatus*	black greasewood
SE	*Sedum* (spp.)	stonecrop
Shc	*Sheperdia canadensis*	russet buffaloberry
Sih	*Sitanion hystrix*	bottlebrush squirreltail
SO	*Solidago* (spp.)	goldenrod
Soa	*Sorbus americana*	american mountainash
Stc	*Stipa comata*	needleandthread
Stv	*Stipa viridula*	green needlegrass
Sya	*Symphoricarpos albus*	common snowberry
Tao	*Taraxacum officinale*	common dandelion
Ziv	*Zigadenus venenosus*	meadow deathcamus

LEGEND

1 — Grassland and associated herbaceous plants, not under cultivation. Perennial grasses predominate and determine the aspect. Ex.: *Bouteloua gracilis, Agropyron smithii*

2 — Alluvial areas; drainage from nearby highland (erosion usually heavy; sometimes saline.

3 — Areas dominated by grasses rather than sedges. Generally moist, meadow-like areas in open timber or floodplain areas, becoming moderately dry by midsummer. Ex.: *Festuca idahoensis*

4, 5 — Areas characterized principally by sedges, and by very poorly drained and/or partially submerged soils. Ex.: *Carex*

6 — Lakes, reservoirs, and other major water impoundments.

7 — Areas characterized by annual grasses or weeds. Also includes areas in transitory stages and semi-permanent conditions. Ex.: *Bromus tectorum*

8 — Areas where sagebrush predominates.

9 — Areas where the various salt desert shrubs of the *Atriplex* family form the predominant vegetation/aspect. Ex.: *Atriplex nuttalli*

10 — Areas where greasewood (*Sarcobatus*) is the predominant vegetation/aspect. Includes valley floors subject to overflow during flood periods or areas underlain with ground water at shallow depths and having saline soil. Ex.: *Sarcobatus vermiculatus*

11 — Areas where browse, except sagebrush or subtypes, gives the main aspect or is the predominant vegetation. Shrubs occupy the transition zone of lower mountain slopes, foothills, and plateau areas. Ex.: *Cercocarpus ledifolius*

12 — Areas characterized by poplars (cottonwoods), willows, and other vegetation supported by stream water.

13 — Areas characteristic of *Populus* spp. and other deciduous trees not including riparian.

14 — Residential, business, and industrial areas (mines and mills included).

15 — Areas where the land is cultivated for farm-crops, natural haylands, irrigated pastures, and fallow fields.

16 — Areas characterized by coniferous species.

Areas where timber has been logged.

17 — Areas of timberland, brushland or woodland that have been burned over, and a woody vegetation is absent as a result of disturbance. Litter-covered ground is included.

18 — Areas of solid rock or areas of very rocky land are characteristic. Vegetation is essentially absent.

19 — Areas where almost no vegetation exists and which have not been disturbed by man. Ex: Intermittent lakebeds, rockslides, heavily eroded soils.

NOTE:

The vegetation map of Johnson County, Wyoming was compiled from interpretations of Skylab color infrared photography (S-190A, Track 5, Pass 10, June 13, 1973, Roll 15, Frames 229-231) and high-altitude color infrared aerial photography (NASA Flights 72-138, August 11, 1972; 73-147, August 30, 1973; no. 239, June 20, 1973; no. 248, August 7, 1973; no. 310, May 7, 1975). Areas not covered stereoscopically by high-altitude aerial photography (See reliability index) were generalized from 1:24,000-scale U.S. Forest Service, forest-type maps.

Density Classes & Type Designations

DENSITY CLASSES *

Class	Definition	Percent cover
5	continuous	76-100
4	interrupted	51-75
3	parklike	26-50
2	rare	5-25
1	trace/none	<5

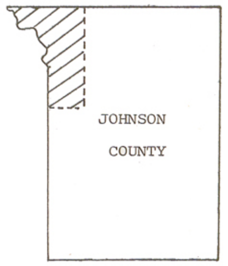
TYPE DESIGNATION

vegetation class - density
principal plant species

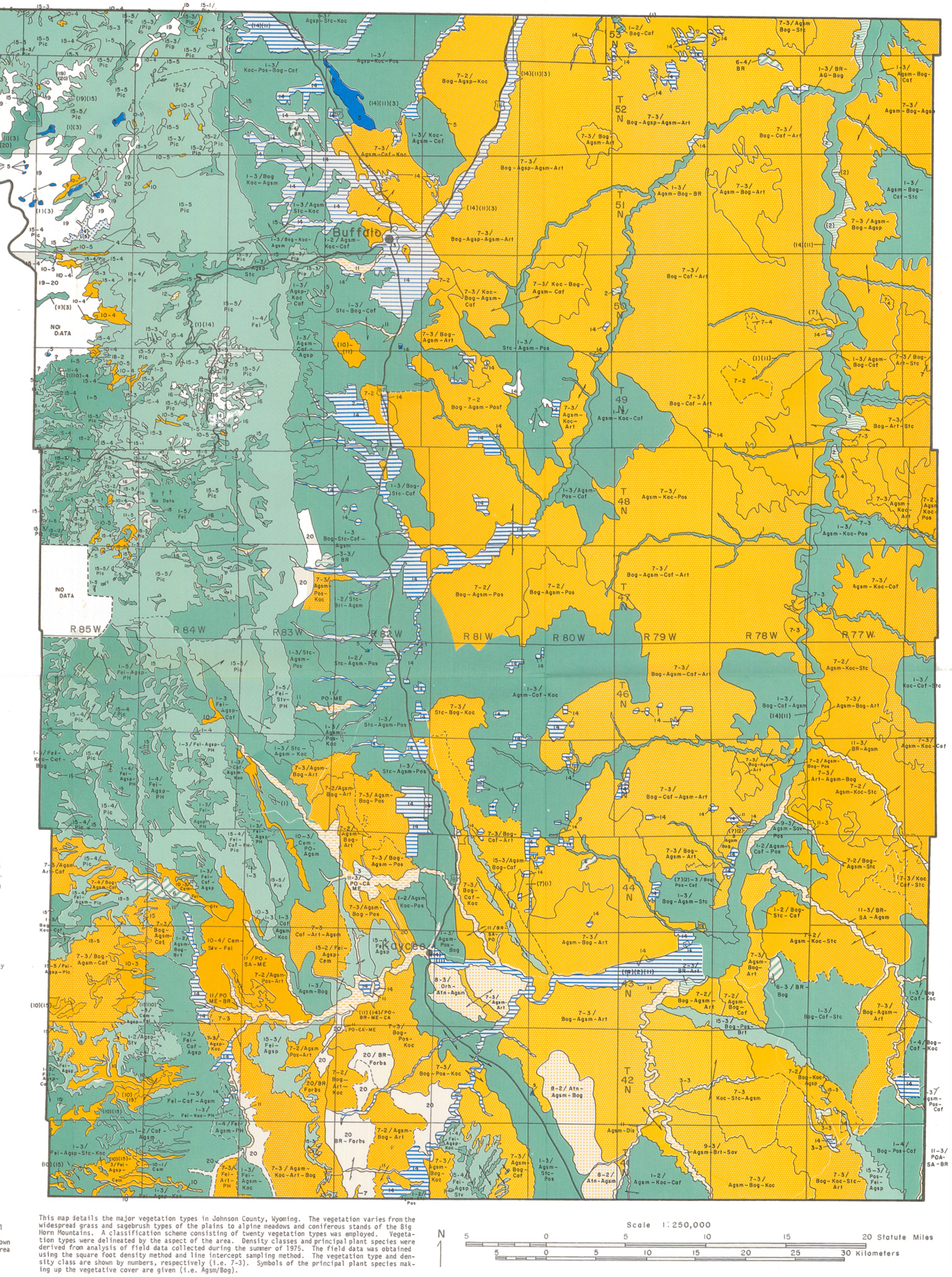
*Density classes refer to the percentage of ground covered by the total vegetation within a vegetation type.

Gently rolling foothill grassland site east of the Big Horn Mountains (T.47N., R.82W.). Principal species include *Koeleria cristata, Stipa comata* and *Agropyron smithii*.

Grassland-sagebrush site comprised of perennial grasses (*Agropyron* spp., *Bouteloua* spp., *Stipa* spp., etc.) and scattered big sagebrush (*Artemisia tridentata*) (T.45N., R.82W.).



Stereoscopic color-infrared aerial photography was not available for that portion of Johnson County shown cross-hatched. Mapping in this area was generalized from U.S. Forest Service forest-type maps, Bighorn National Forest, Wyoming.



This map details the major vegetation types in Johnson County, Wyoming. The vegetation varies from the widespread grass and sagebrush types of the plains to alpine meadows and coniferous stands of the Big Horn Mountains. A classification scheme consisting of twenty vegetation types was employed. Vegetation types were delineated by the aspect of the area. Density classes and principal plant species were derived from analysis of field data collected during the summer of 1975. The field data was obtained using the square foot density method and line intercept sampling method. The vegetation type and density class are shown by numbers, respectively (i.e. 7-3). Symbols of the principal plant species making up the vegetative cover are given (i.e. Agsm/Bog).

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Vegetation map compiled by:
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Department of Range Management
University of Wyoming

Work supported by:
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Environmental Geology Branch
Grant 14-08-0001-G-163

The Geological Survey of Wyoming, 1976

Climate & Precipitation

The climate of Johnson County is influenced strongly by the local topography. As the most prominent topographic feature in the county, the Bighorn Mountains exert the most control over temperature and precipitation. The highest annual totals of precipitation in the county fall on the high crest of the Bighorn Mountains.

A maximum of 24 inches of mean annual precipitation, in the form of both rain and snow, is received in the northwestern tip of the county. The driest part of the county is on the southwest corner, in a belt roughly parallel to the mountain front and extending into the basin to the northeast. In the more arid parts of the county, less than 11 inches of mean annual precipitation may be anticipated.

Most precipitation is received in the spring and summer months. At the Buffalo weather station, more than half the total annual precipitation usually falls in April-July. Buffalo receives about 41 inches of snowfall annually.

Seasonal variations in temperature are greater on the plains than in the mountains. At the Buffalo weather station, the record maximum temperature was 106 F; the record minimum, -40 F. The length of the growing season at Buffalo averages about 119 days, usually extending from the third week of May to mid-September. In the higher mountain areas, frost usually occurs throughout the year.

The few dry-land farms in the county depend on a fortunate distribution of spring and summer rains. Cool, wet springs seem to moderate the severity of grasshopper infestations, which can cause serious crop damage in this area.

The prevailing winds in the county are from the northwest and are strongest in early spring.

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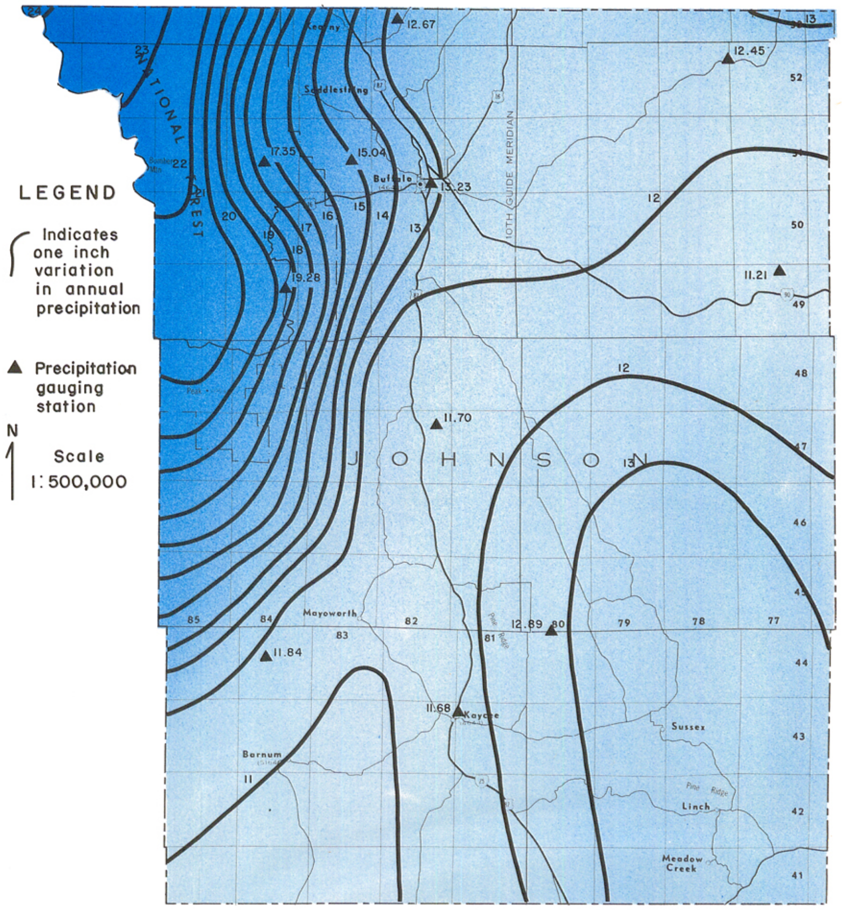
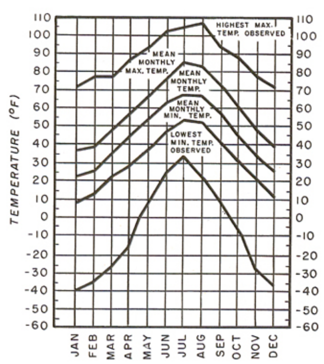


Yearly Temperatures in Buffalo



Surface Water

Johnson County is drained by the Powder River and its tributaries. Most of these streams begin in the Bighorn Mountains where the precipitation is highest. Heavy winter snowpacks and rainfall caused by air rising over the Bighorns provide most of the runoff during the months of April through July.

The flow and character of surface streams depends on geology, topography, vegetation and climate. Non-mountain streams have low flows and high sediment loads. Soil erosion is a problem in the basin area due to sparse cover, easily eroded soils and nonresistant rock units. Reservoir storage projects are confronted with high siltation rates and evaporation losses. Some surface stream flows are apparently lost to groundwater recharge as they cross carbonate rocks in the mountains, but most of the stream flows emerge as springs and seeps in the foothills.

Traditionally the main use of surface water is irrigation along the stream valleys. The municipal supplies of Buffalo and Kaycee also depend on surface water.

Energy development in the Northern Great Plains has resulted in competition for existing water supplies as well as new sources. Transbasin diversions and intensive ground water development have been proposed.

Water appropriation in the Powder River is controlled under the Yellowstone River Compact which provides that no water can be diverted from the basin without consent of all signatory states. A number of reservoir sites in Johnson County have been proposed in order to fully appropriate Wyoming's share of the Powder River water. These proposed sites and permit filings are shown on the map.

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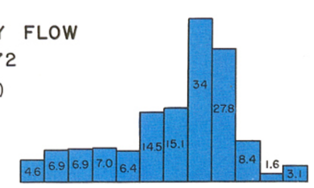
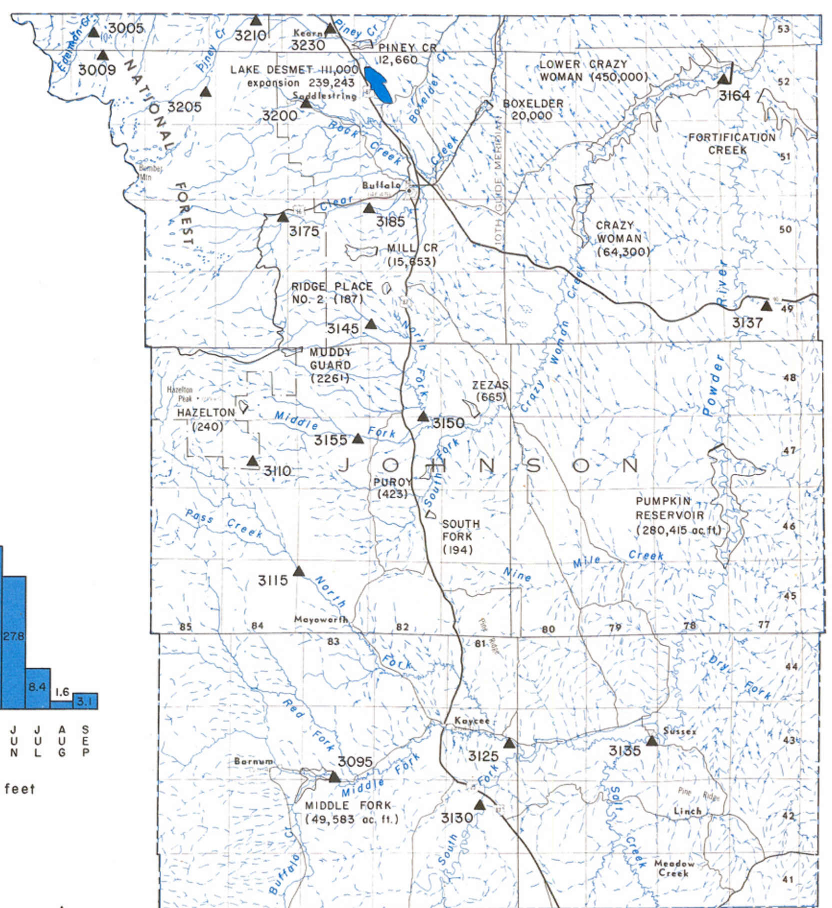
MEAN MONTHLY FLOW 1949 - 1972 (At Sussex)





Legend

▲ Surface guaging station

Proposed reservoir site and storage in acre feet (Existing reservoirs shown in blue)

N

1:500,000

Groundwater

Groundwater in Sheridan County is available from several geologic formations. Aquifer characteristics of the units are generally favorable near the recharge area in the Bighorns but unproven farther eastward. Recharge is from precipitation and infiltration from streams crossing the outcrop, in the narrow belt of steeply dipping sediments along the Bighorns. Some interformational water movement occurs, mainly in areas of secondary permeability from fracturing and solution. Wells in some formations flow at the surface because of artesian pressure. Alluvial deposits along the river valleys are unconfined, or water table aquifers. They receive part of their recharge from irrigation water.

Paleozoic formations with the best groundwater potential are the Madison and Tensleep formations. Other favorable units are the Bighorn Dolomite and Flathead Sandstone.

The most favorable Mesozoic aquifers include the Cloverly, Mesaverde, Fox Hills and Lance formations.

Cenozoic formations are the most common source of groundwater for domestic and stock uses and include the Tertiary Fort Union, Wasatch, Arikaree and White River formations as well as Quaternary alluvium.

Groundwater availability is shown on the adjacent chart. Water well locations and geologic sources, as well as distribution of aquifers, are shown on the map.

SOURCE: Hodson, and others, 1973, Water resources of the Powder River Basin and adjacent areas, Northeastern Wyoming, U.S. Geological Survey Hydrologic Investigations Atlas HA-465.

Geologic Formations & Potential Water Supply

UNIT	LITHOLOGY	GROUNDWATER POSSIBILITIES	WATER QUALITY (dissolved solids in milligrams per liter)
Alluvium & glacial	unconsolidated silt, sand and gravel; underlies floodplains and borders terraces, generally less than 50' thick; till may be up to several hundred feet thick	fine-grained alluvium usually yields a few gal/min, more in coarser deposits	no dominant type; highly variable dissolved solids
Arikaree & White River formations	tuffaceous claystone, siltstone and sandstone with local conglomeratic lenses	limited due to small outcrop area	mostly sodium bicarbonate and calcium bicarbonate
Wasatch Formation	fine- to coarse-grained sandstone with interbedded shale and coal	yields water from lenticular sandstones, coal and clinker beds. Generally 10-15 gal/min, but may produce several hundred	sodium sulfate and bicarbonate are the dominant water types, ranging from 500 to 1500 mg/l
Fort Union Formation	fine-grained sandstone and interbedded carbonaceous shale and coal, about 3000' thick in Campbell County	yields water from fine-grained sandstone, jointed coal and clinker beds; maximum yields 150 gal/min	sodium bicarbonate and sulfate, 500 to 1500 mg/l
Lance Formation	sandstone and interbedded sandy shale and claystone	generally less than 20 gal/min	500 to 1500 mg/l; no dominant type prevalent
Fox Hills Formation	sandstone and sandy shale	yields up to 200 gal/min; several wells near Reno used for water flooding	generally soft, less than 1000 mg/l
Mesaverde Formation	sandstone massive to thin-bedded, with shale and coal	as much as 500 gal/min from sands up to several hundred when fractured	300 to 2000 mg/l, mostly sodium sulfate
Cody, Mowry & Thermopolis shales; Frontier Formation	predominantly shales with only local sandstone lenses	maximum yields minor; most of section not water bearing	greater than 1000 mg/l; mostly sodium sulfate
Cloverly Formation	sandstones, siltstones and interbedded shales	generally yields 20 gal/min, but may produce more in zones of secondary permeability	most water is sodium sulfate type; 300 to 3000 mg/l
Morrison & Sundance formations	claystone and shale with interbedded sandstones	a few sands may yield as much as 10 gal/min	no dominant type; 500 to 2000 mg/l
Gypsum Springs Formation	massive white gypsum, red claystone and gray limestone	only minor quantities from solution cavities	greater than 1000 mg/l. calcium sulfate
Chugwater - Goose Egg & equivalent rocks	shale, gypsum and thin-bedded limestone	small yeilds less than 20 gal/min	calcium sulfate dominant; 500 to 3000 mg/l; locally Goose Egg sodium chloride waters
Tensleep & Amsden formations	cross-bedded sandstone with dolomite beds in lower part	yields of 20 to several hundred gal/min. In areas where fracturing has increased permeability, 1000 gal/min or greater may be possible	dominantly calcium bicarbonate
Madison Limestone	limestone and minor dolomites	yields of more than 1000 gal/min. are possible in areas of fracturing and cavernous weathering, for oilfield waterflooding	mostly calcium bicarbonate; quality varies with depth, sodium suflate in oilfields
Bighorn Dolomite, Gallatin & Gros Ventre formations, Flathead Sandstone	dolomites and slabby limestones, sandstones, shale, siltstones and limestones	yields ranging from 20 gal/min to several hundred but generally 10 gal/min or less	highly variable at these depths
Precambrian	crystalline rocks	as much as 20 gal/min in fractures or joints	usually calcium carbonate, less than 1000 mg/l

MODIFIED FROM: U. S. Geological Survey Hydrologic Atlas 465.

Major Aquifers With Groundwater Potential

Alluvium & Glacial Deposits

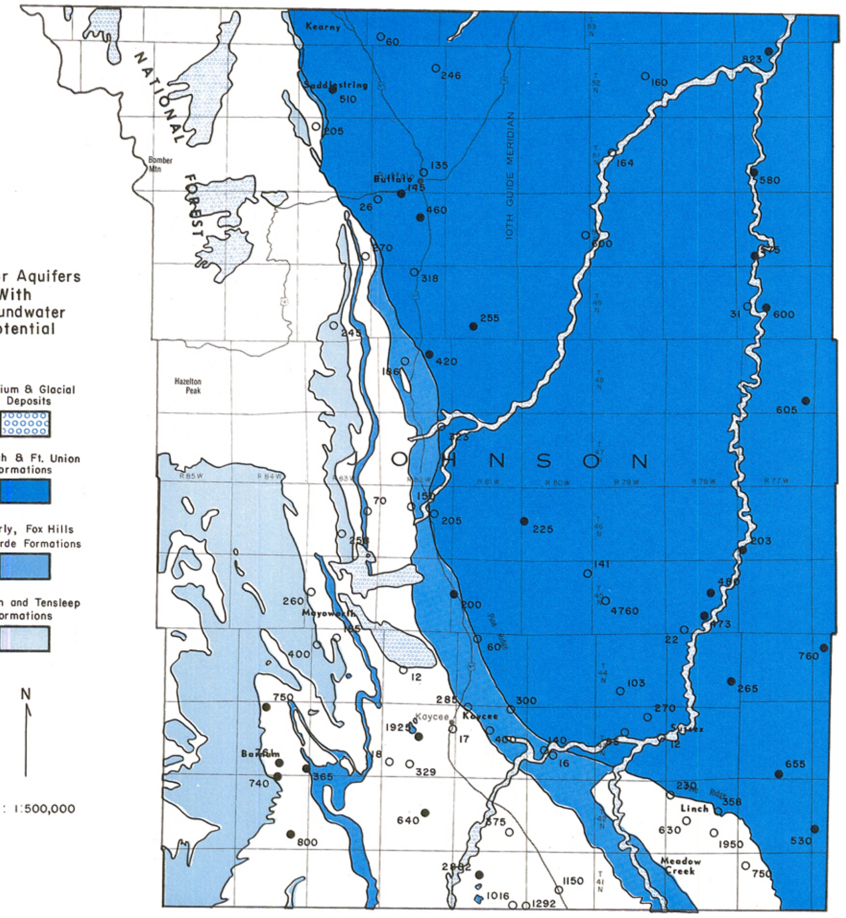
Wasatch & Ft. Union Formations

Cloverly, Fox Hills Mesaverde Formations

Madison and Tensleep Formations

N

Scale : 1:500,000



Water Quality

Quality of the water in a stream system changes with flow and season. The amount and composition of dissolved solids in streams is primarily a function of how long the water is in contact with rock and soil. Usually during high runoff, surface water has a lower mineral content than during periods of low flow.

Water contributed to the surface from the groundwater system, such as in seeps and springs, often has more dissolved solids than surface water. Hexagons on the map illustrate the composition of surface water semi-annually for each station.

GROUNDWATER

Groundwater quality in Johnson County ranges from good to highly mineralized, depending on the aquifer. Both "hard" and "soft" waters occur throughout the county.

The most common water types are sulfate and bicarbonate with calcium and sodium the dominant cations.

Although Precambrian rocks have small water yields, the water usually contains less than 100 mg/L of dissolved solids. Both Paleozoic and Mesozoic rocks contain a variable range of dissolved solids, from less than 100 mg/L to 4000 mg/L. Cenozoic rocks have even more variability, from less than 100 mg/L to 8000 mg/L. Circles on the map show total dissolved solids and major constituents of groundwater at each station (refer to geologic formation chart for formation key).

STANDARDS

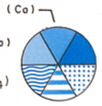
Drinking water standards of the U. S. Public Health Service recommend less than 500 mg/L dissolved solids for human consumption. Stock water could be used up to 5000 mg/L but good stock water is less than 1000 mg/L. Standards for the most common constituents in Johnson County water are:

Constituent	Maximum mg/L for drinking water
Calcium (Ca), Magnesium (Mg), Sodium (Na), Potassium (K)	250 total
Carbonate (CO_3), Bicarbonate (HCO_3)	not determined
Sulfate (SO_4)	250
Chloride (Cl)	250
Total Dissolved Solids (TDS)	500

REFERENCES

Durfor, D. N., and Becker, Edith, 1964, Public water supplies of the 100 largest cities in the United States: U.S. Geological Survey Water Supply Paper 1812, 364 p.
Hodson, W. G., Pearl, R. H., and Druse, S. A., 1974, Water resources of the Powder River Basin and adjacent areas, northeastern Wyoming: U.S. Geological Survey Hydrologic Investigations Atlas HA-465.

CHEMICAL CONSTITUENTS



Tw Geologic source of water (see geologic column in ground water section)

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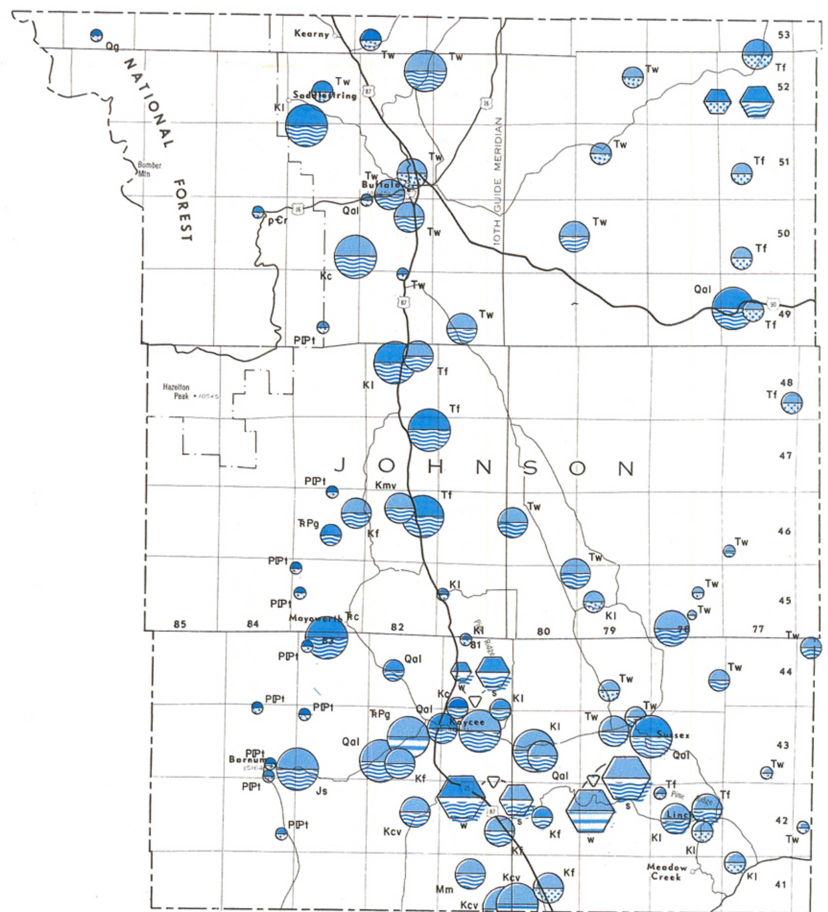

LEGEND

Surface Quality (Milligrams per liter total dissolved solids)

Surface Water Quality Station w-Winter s-Summer

\>2000 | 5000-1000 | 1000-2000 | LESS THAN 500

Groundwater Quality (Milligrams per liter total dissolved solids)

\>2000 | 5000-1000 | 1000-2000 | LESS THAN 500