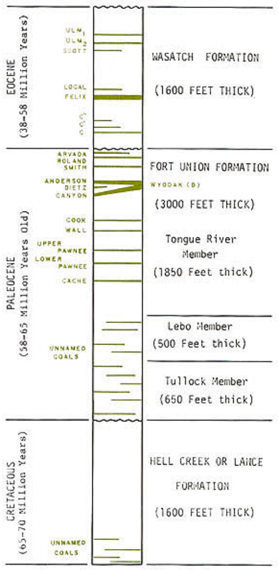


Stratigraphic Column of Coal—Bearing Rocks

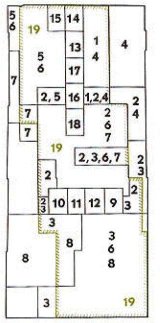
Coal Resources

Between 38 and 70 million years ago, richly vegetated swamps frequently covered what is now Campbell County. Coal seams, which are the fossilized remnants of those swamps, now comprise a high percentage of the stratified rocks formed during those ancient times. Although the Cretaceous Lance Formation contains some of these lignitic to subbituminous coals, persistently thicker coals occur in the Tertiary Fort Union and Wasatch formations. In fact, the upper 1800 feet of the Fort Union Formation (Tongue River Member) is one of the most prolific coal-bearing formations in the state. This member contains 8 to 12 thick subbituminous coals, one of which frequently ranges between 70 to 120 feet thick (Wyodak coal). The lower two members of the Fort Union Formation (Lebo and Tullock members) contain thinner, discontinuous coals. The Wasatch Formation, however, contains as many as 8 persistent coals. The Felix coal is the thickest, locally reaching 50 feet.

Although many coal outcrops have been burned through natural causes, more than 69 billion tons of coal still underlie Campbell County at depths up to 3000 feet. While over 63 billion tons of that coal estimate are under less than 1000 feet of rock, at least 20 billion tons of that resource lies between 0 to 200 feet of the surface. This shallow coal is normally only recoverable by strip mining methods. Meanwhile, recent mapping by the U. S. Geological Survey will soon significantly increase all these resource estimates.

According to published data, 50.4% of Wyoming's remaining coal resources and 84% of its known strippable coals are in Campbell County. Although coal-bearing rocks underlie 99.3% of the county, known strippable deposits only underlie 315 square miles or 201,356 acres (6.6% of Campbell County). Coals are thinnest and least persistent in the northeast quarter. In the southwest corner the gentle westward dip of the rocks carries most of the persistent coals beneath the land surface -- significantly reducing the number of coal outcrops. Noncoal-bearing rocks crop out near Rocky Point in the northeast corner of the county and cap Pumpkin Buttes in the southwest.

Index and List of Pertinent References



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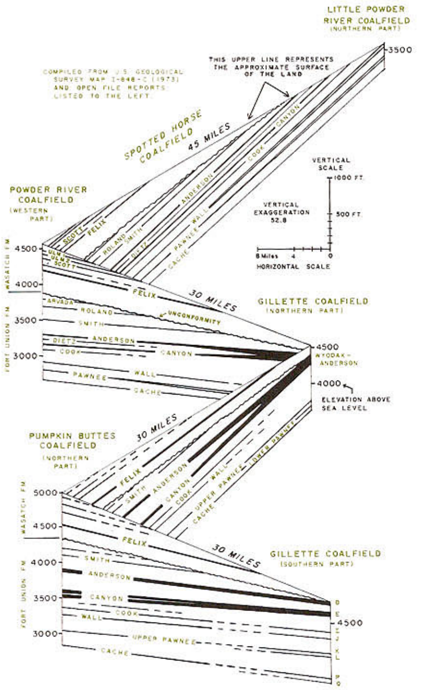


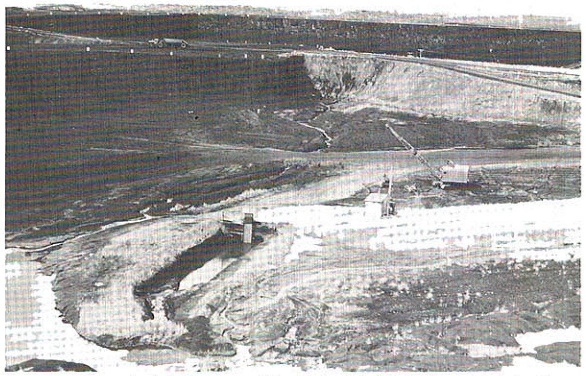
Diagram Showing Correlation and Thickness of Major Coal Seams

History and Forecast for Coal Mining

Although recorded coal mining in Campbell County dates back to 1909, significant production did not begin until 1925. Since then, production has slowly increased from 33,579 tons in 1925 to a record-setting 1.6 million tons in 1973. Unlike the state's more prolific coal-producing counties, most of Campbell County's coal mining has been from strip mines rather than underground mines. In fact, the county's cumulative coal production through 1973 is 15,163,798 tons, of which underground mining accounts for only 30,464 or 0.2% the total. In 1974, two of the county's three active strip mines will nearly triple 1973's tonnage as they mine in excess of 4 million tons.

Demand for the county's low sulfur coal will continue to increase annual production at unparalleled rates. By 1976, Campbell County will undoubtedly be the largest coal-producing county in Wyoming. Production estimates of 62 to 77 million tons per year by 1980 and 84 to 152 million tons per year by 1985 prevail. By 1978, Kerr-McGee, Amax, Atlantic-Richfield, Carter Oil, Sun Oil, and Peabody Coal Company are slated to open 6 to 8 new strip mines on their large federal leaseholds. Each of these new mines will produce 5 to 25 million tons per year. Initially, almost all this coal will be exported to fuel coal-fired power plants in as many as 13 states as far east as Indiana and as far south as Texas and Louisiana. To help ship this coal, a new railroad may connect Gillette with Douglas, 126 miles to the south, by 1976. As many as thirty-two 11,000-ton coal unit trains could travel that new railroad each day by as early as 1980. In other transportation developments, a 1043-mile long coal-slurry pipeline may carry a coal-water mixture from southern Campbell County to Arkansas as early as 1978. An estimated 25 million tons of coal could flow into Arkansas power plants each year through that pipeline.

In related in-state activity, one new coal-fired power plant is already under construction east of Gillette. When completed, this 330-megawatt plant will be the second and the largest air-cooled power plant in the western hemisphere. The other air-cooled plant, the Neil Simpson Station, is located just west of this new plant. Both Panhandle Eastern Pipeline and Exxon have announced plans to build coal conversion plants in Wyoming by 1980. At least one of those plants will probably be built in Campbell County. These plants will convert subbituminous coal into high-Btu synthetic natural gas. Forecasts of other mines, slurry-pipelines, power plants, gasification plants, and liquefaction plants are rumored, but not confirmed.



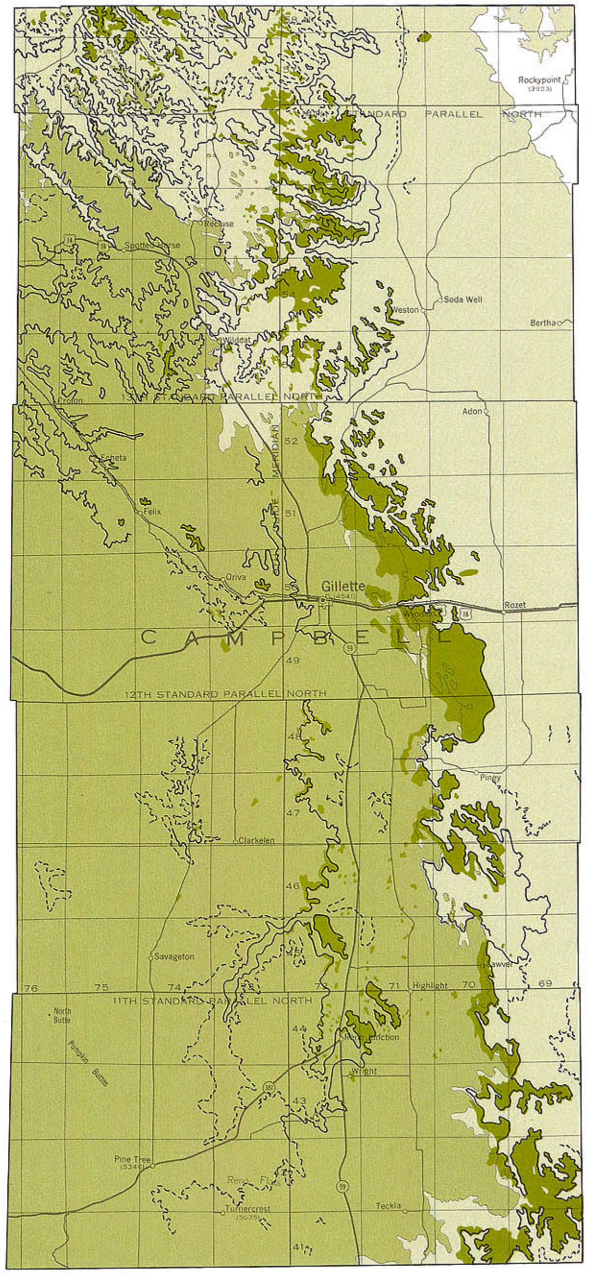
South Wyodak Pit

Wyodak Resources' South Wyodak Pit is located 6.5 miles east of Gillette. This mine is not only the first strip mine opened in Wyoming, but it is also the oldest -- dating back to 1925. Here, the Wyodak coal averages 80 feet thick and thickens to as much as 110 feet. This thick subbituminous coal is mined in two benches each approximately 40 feet thick. Overburden or non-coaly rock and soil that overlies the coal is much thinner than the coal itself. Although production from this mine is now about 600,000 tons per year, it will increase to 2.2 million tons by 1977. This mine is typical of the "area type" strip mines forecast for Campbell County except in size. Most future mines will each strip 5 to 25 million tons annually.

Campbell County Coal Analyses

	As-received	WASATCH FORMATION: ULM2 (3)[1] Range	Average	SCOTT (3) Range	Average	FELIX (42) Range	Average	UNSPECIFIED (6) Range	Average
PROXIMATE	MOISTURE (%)	28.1-29.7	28.9	25.0-32.2	29.1	17.8-33.5	28.0	23.7-29.6	27.6
PROXIMATE	VOLATILE MATTER (%)	31.6-33.2	32.2	29.7-30.9	30.2	29.1-36.4	31.7	26.9-30.9	29.2
PROXIMATE	FIXED CARBON (%)	30.8-33.2	32.4	27.5-29.8	28.8	28.4-39.4	32.5	25.4-33.3	29.9
PROXIMATE	ASH (%)	5.6-7.6	6.5	8.2-15.8	11.9	4.5-14.9	7.8	6.2-23.2	13.3
	SULFUR (%)	0.60-1.24	0.94	0.87-2.22	1.75	0.32-3.26	0.89	1.07-4.16	2.19
	HEAT VALUE (BTU/POUND)	7901-8029	7965	7241-7425	7330	7180-9535	8053	6501-8215	7418
		FORT UNION FORMATION: SMITH (1)		ANDERSON (23)		CANYON (9)		WYODAK (53)	
PROXIMATE	MOISTURE (%)	-	31.8	24.9-34.1	29.5	26.5-31.5	29.6	23.4-36.9	29.8
PROXIMATE	VOLATILE MATTER (%)	-	28.7	26.5-34.5	30.1	28.7-33.3	30.7	26.5-32.7	30.7
PROXIMATE	FIXED CARBON (%)	-	34.8	29.0-38.0	33.9	31.8-38.4	34.6	29.6-41.4	33.5
PROXIMATE	ASH (%)	-	4.7	3.5-12.2	6.5	3.1-7.4	5.1	2.9-12.2	6.0
	SULFUR (%)	-	0.63	0.17-1.13	0.52	0.14-0.92	0.34	0.20-1.20	0.50
	HEAT VALUE (BTU/POUND)	-	7991	7128-8737	7979	7537-8609	8286	7420-9306	8224

[1]Number of samples averaged. (Table compiled from analyses published by the U. S. Geological Survey and the U. S. Bureau of Mines.)



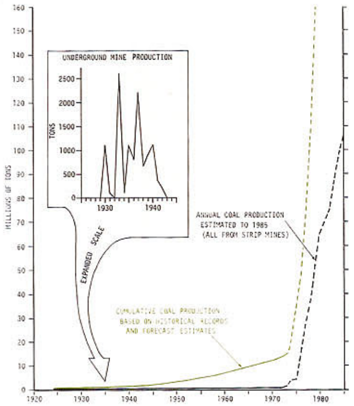
Coal Outcrops, Burned-out Areas

LEGEND
- WASATCH FORMATION
- FORT UNION FORMATION
- CRETACEOUS FORMATIONS
- COAL OUTCROP (GREATER THAN 5 FOOT THICK)
- COAL OUTCROP (LESS THAN 5 FOOT THICK)
- BURNED-OUT AREA (CLINKER OR BAKED ROCK)

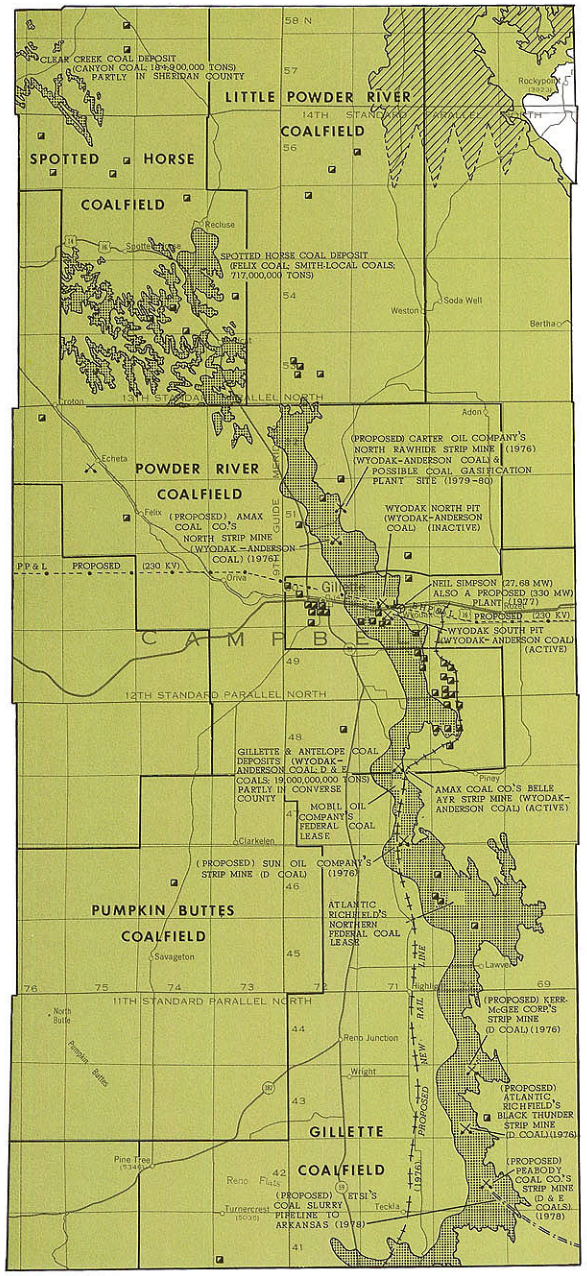
LEGEND
- LIGNITE
- SUBBITUMINOUS COAL
- NO COAL-BEARING ROCKS
- KNOWN STRIPPABLE COAL DEPOSITS
- ABANDONED UNDERGROUND COAL MINE
- ABANDONED STRIP MINE UNLESS OTHERWISE ANNOTATED
- COAL-FIRED POWER PLANT
- TRANSMISSION LINES GREATER THAN 115 KILOVOLTS (KV)

N

SCALE 1:500,000 (0–15 MILES; 0–25 KILOMETERS)

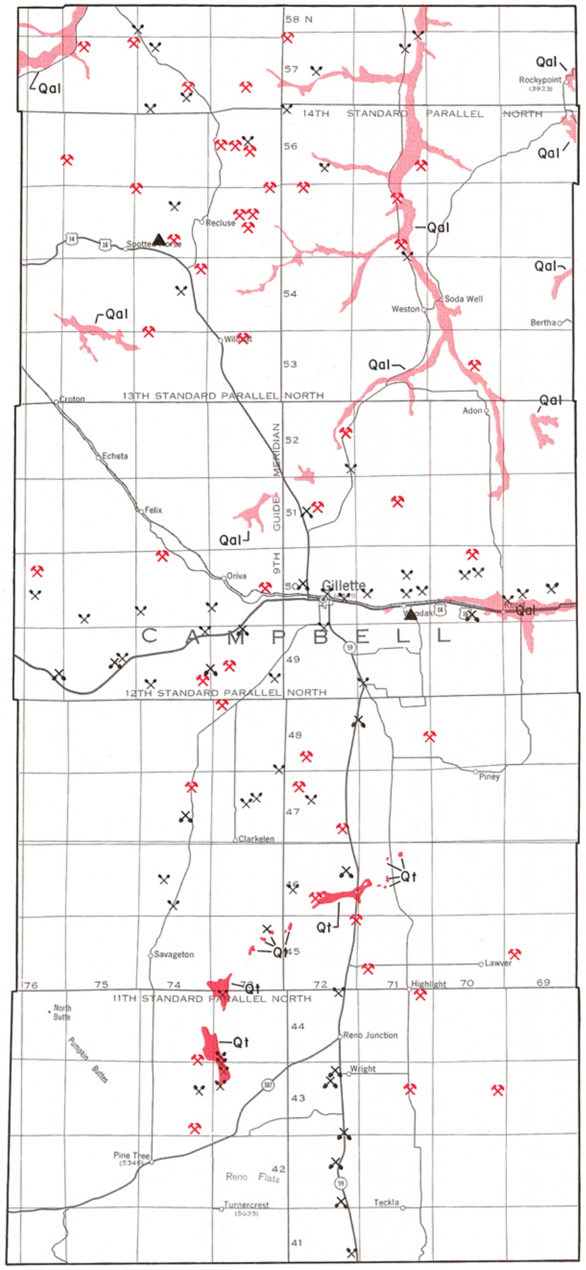


Annual and Cumulative Coal Production with Forecasts to 1985



Coal Mining in Campbell County

Sand, Gravel, Clinker Deposits



Sand pit

Gravel pit

Clay deposit

"Scoria" pit

Qt — Terrace deposits containing good to fair gravel or sand.

Qal — Alluvial deposits with unevaluated construction materials potential.

Compiled from Wyoming Highway Dept. Materials Surveys & lists of permits

Clinker ("Scoria") Pit

Clinker for construction purposes is excavated from numerous small pits in Campbell County such as this one. Most of these pits are located at clinker exposures along the rims of buttes and escarpments.

Construction Materials of Campbell Co.: Extent, Quality, and Uses

Increasing energy resource development in Campbell County and adjacent areas of the Powder River Basin will demand more construction materials for aggregate, highway and railroad construction, and building purposes. Boulders, gravel, sand and even clays and silts are valuable materials used for construction. Campbell County occupies the central Powder River Basin far away from coarser boulders and gravels eroded from mountains to the east and west. However, the county does have extensive clinker deposits in addition to a few sand and gravel deposits.

CLINKER

Clinker or "scoria" beds result from burning coal seams, which ignite on the outcrop from lightning, manmade fires or spontaneous combustion. The reddish clinker beds are formed by melting, partial fusing, and baking of overlying sandstone and shale by heat and gases rising from burning coal beds. Chimneys or pipes may form locally where the heat and gas is vented upward and brecciates and fuses the adjacent rock. The underlying beds usually remain unaltered. Clinker zones may extend underground from the outcrop as much as a mile depending on the oxygen available. Topographically, the clinkered areas are erosion-resistant and cap buttes and escarpments. The baked rock varies greatly in the degree of alteration, some is dense and glassy while some is vesicular and porous.

Much of the clinker is suitable for construction but extensive use must be preceded by testing and a thorough understanding of the variability. The Wyoming Highway Department has run extensive tests on scoria for most road building purposes, and their findings can be applied to many construction situations. Most scoria will admit water due to porosity, thus limiting its quality for construction purposes. For use with asphalt or cement, clinker generally requires twice the normal amount of additive to meet standards. The use of clinker in low traffic roads has been successful in most cases but it is usually used for sub-bases on heavier duty roads rather than surfacing. Many of the new concrete structures in the vicinity of Gillette make use of limestone or gravel aggregate hauled from outside of Campbell County. Railroads in the area have made extensive use of clinker for ballast in roadbeds.

CLAYS

Clays of the Wasatch Formation were mined north of Gillette in the early 1900's for use in the manufacture of brick. The locally manufactured brick was used in the construction of many of the early Gillette buildings. It is likely, though little testing has been done on these materials, that many of the clay beds found in the coal-bearing sequences of the Wasatch Formation would be very suitable for common brick and tile manufacture. The clays which underlie the Arvada and Felix coal beds would probably be best for this purpose. These underclays remain soft and unburned even where the coals above have burned and baked the overlying rocks. The coal beds and brightly colored baked shales make excellent guides in prospecting for the underclays.

A bed of high quality clay 8 feet in thickness has been noted in south ½-section of T55N, R74W. The clay is of moderately high refractive quality and probably suitable for making refractory supplies for foundaries such as ladle brick (Van Sant, J. M., 1961, Refractory-clay deposits of Wyoming: Department of Interior, Bureau of Mines Report of Investigations 5652, p. 26, 27.).

A clay bed which overlies coal in the Wyodak mine 7 miles east of Gillette has been test-fired (Van Sant, p. 27, 28). These tests indicate that the relatively poor grade clay, occurring in a five-foot thick bed, expands or bloats when fired above 2200°F. This kind of expanded clay may be used for lightweight aggregate. These types of clays associated with coal seams could be readily mined as a byproduct where coal stripping is carried on.

SAND AND GRAVEL

Sand and gravel deposits in Campbell County are limited to alluvial and terrace deposits. Well graded sand and gravel is scarce and limited in quality and quantity. Most of the deposits have excessive silt and fine sand fractions. The only sources of gravel are terrace deposits along the major drainages. Deposits of sand are extensive but mostly of poor quality with large percentages of silt. Most of the flood plain deposits do not contain significant construction materials but coarser granular deposits have been noted at the confluence of major tributaries. Aside from clinker deposits no ledgerock of sufficient hardness for construction material has been noted.

REFERENCES

Thurlow, Ernest E., 1974, Western Coal: Mining Engineering, v. 26, no. 5, p. 30-33.

Wyoming Highway Department, 1968, Construction Materials Survey, Federal Aid Primary and State Numbered Highways 59 and 387, Campbell County, Wyoming. 110 p.

Characteristics of and Sieve Tests on Construction Materials

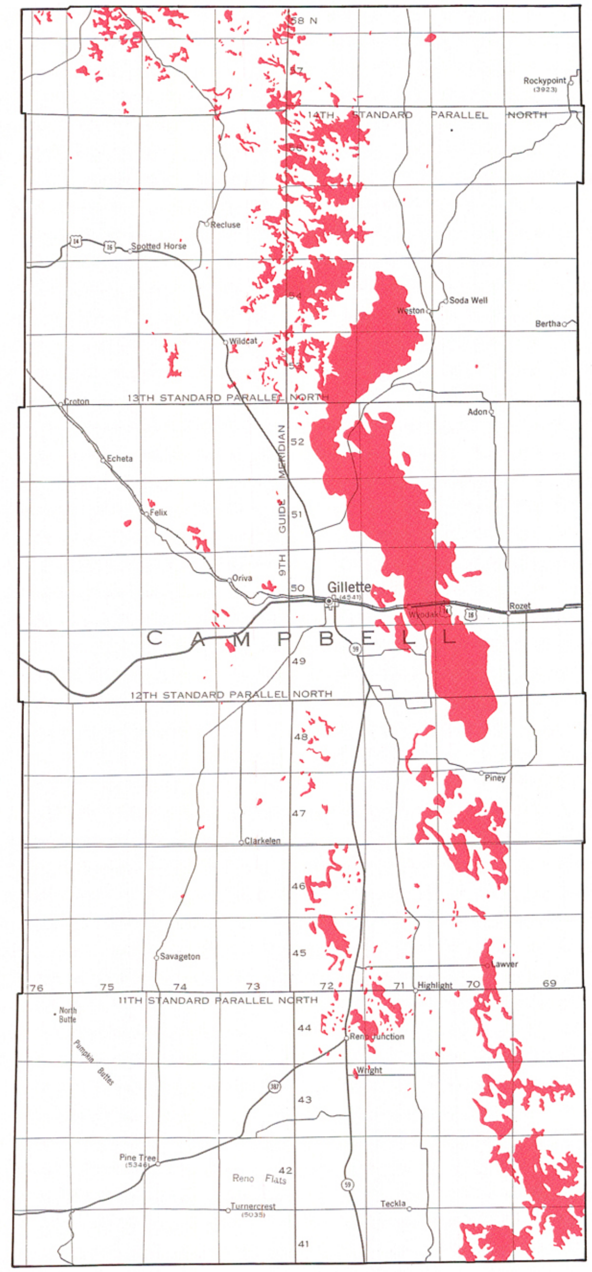
	SAND AND GRAVEL		HEAT ALTERED ROCK
	TERRACE DEPOSITS	ALLUVIUM AND COLLUVIUM	'SCORIA'
Shape of grains	well-rounded to rounded	rounded to angular	angular
Thickness of deposit	3' to 12' known	highly variable	70' + known
Maximum particle size	5'	18"	8"
Swelling - pressure potential of clays	none	moderate to high	none to low
Soft or weak constituents	infrequent clay lenses	clays common	clay lenses
Organic matter	very little	highly variable	none
* Liquid limit	17 (average)	no good averages	25 - 32
* Plasticity index	not applicable	no good averages	not applicable
— SIEVE ANALYSES —			
Number of samples	76		13
Screen Size	average percent of sample by weight passing		
* #4 Medium gravel (4.76 mm)	62		46
* #8 Fine gravel (2.38 mm)	54	no data	not tested
#40 Medium sand (.42 mm)	not tested	available	32
* #200 Very fine sand (.074 mm)	13.9		11.3
QUALITY SUMMARY OF CAMPBELL COUNTY CONSTRUCTION MATERIALS			
* Summary of Liquid limit, Plasticity index & screensize	Good (11)	no data available	Good (10)

Wyoming Highway Department Quality Classification Criteria

	NUMERICAL VALUE	EXCELLENT = 3	GOOD = 2	FAIR = 1
TEST	#4 Screen	50% or less	51 - 67%	68 - 100%
	#8 Screen	42% or less	43 - 50%	51 - 75%
	#200 Screen	12% or less	13 - 18%	19 - 25%
	Liquid Limit	25 or less	26 - 30	31 - 32
	Plasticity Index	4 or less	5 - 7	8 - 12

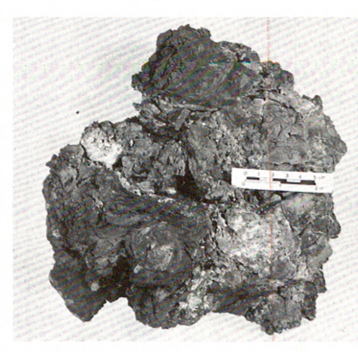
Quality Classification	*Total of Numerical Values (sum of above tests)*
Excellent (crushed base)	*15*
Good (sub-base)	*10-14*
Fair } (select embankment, borrow)	*5-9*
Poor } (select embankment, borrow)	*less than 5*

Clinker Outcrops



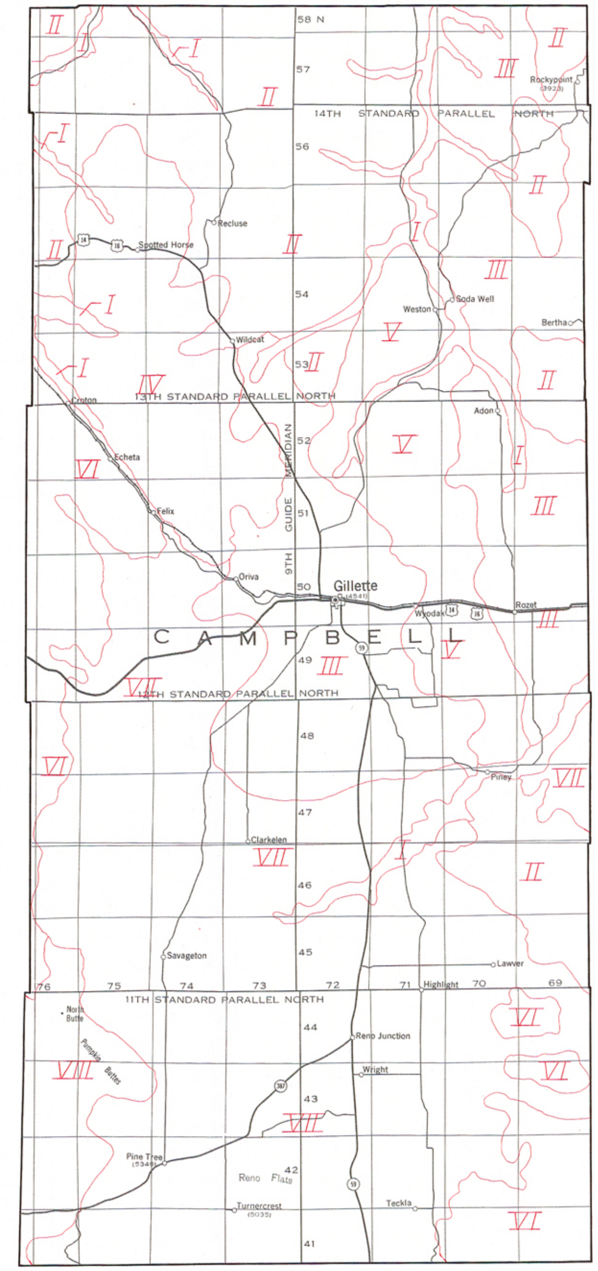
Extent of clinker area.

Compiled from U.S. Geological Survey and Wyoming Highway Dept. data.



Baked Rock

A typical example of baked rock, "clinker", "scoria", or "red dog". This particular sample is glassy and brecciated and illustrates the variability of these deposits. The light-colored areas are coated with sulfur, a byproduct of coal combustion.



Soils

Generalized Soil Types and Characteristics

I	Soils developed on alluvium; moderate depths; high wind erodibility and subject to flooding; generally alkaline	V	Loamy soils derived from heat altered rock (scoria); developed on steeply sloping uplands and broken ground; high erodibility; low productivity
II	Loams derived from sandstones and shales; shallow to moderate depths; moderate to steeply sloping uplands, ridges and sidehills; high erodibility, low agricultural productivity	VI	Moderate to deep soils developed on steeply sloping uplands; ridges and sidehills; high erodibility; generally broken ground, commonly dissected
III	Shallow to deep soils developed on upland areas; gently sloping; high erodibility; moderate productivity	VII	Soils on gently sloping uplands; moderate to high erodibility; moderate productivity
IV	Loamy soils developed on older surfaces (paleosol types); high erodibility; low to moderate productivity; calcareous horizons	VIII	Soils developed on sandstone; uplands, ridges and steep slopes; shallow to moderate depth

Campbell County soils are products of a semi-arid climate, vegetation and organisms acting upon Tertiary sandstones and shales. These soils are characterized by a light gray-brown color and often have a lime-carbonate layer developed at shallow depths. Generally, depth of altered bedrock is not more than 36 inches but the slope areas have a much shallower soil cover and often are dominated by bedrock. Soils developed on the clinker areas are usually limited to grazing as an agricultural use. The soils delineated on this map are generalized from U.S. Soil Conservation Service data based on reconnaissance mapping and only represent large areas of soils with similar gross characteristics.

REFERENCES

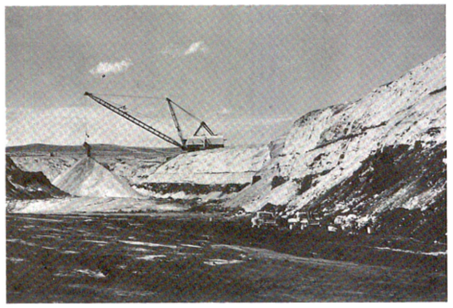
U. S. Soil Conservation Service, 1955, Soil Survey (Reconnaissance) of Campbell County, Wyoming: U. S. Department of Agriculture in cooperation with University of Wyoming Agricultural Experiment Station, 67 p.

Strip Mining for Coal: Five Steps

Over the next few decades, coal strip mining is expected to affect thousands of acres of ranch and farmland in Wyoming, especially Campbell County. Although relatively inexpensive and simple, this mining method creates large surface excavations since all soil and rock that overlie a minable coal seam must be removed. Concern over these excavations prompted passage of the 1973 Wyoming Environmental Quality Act, which requires reclamation of these mine sites to a use of equal or greater value than the mined land's previous use.

REMOVAL OF SOIL

Removal of soil is the first step in the actual mining operation. Power shovels and/or scrapers usually accomplish this step. By law, soil must be segregated and stockpiled for later use in reclamation.

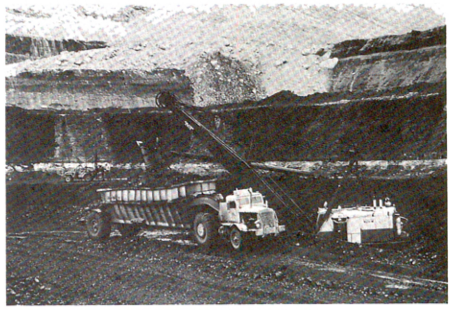


REMOVAL OF OVERBURDEN

Following the removal of the soil, subsoil and bedrock (overburden) must be stripped off the coal. This overburden will range from as little as several feet thick to a common maximum of 200 feet. Thicker overburden is usually blasted with explosives before removal. Then a dragline, shovel or scraper is used to load it. Initially this broken bedrock (spoil) is dumped in piles around the perimeter of the mine. Later when the coal is removed, this spoil is graded back into the open pit. Subsequent spoil is usually cast directly into the older completed portions of the mine as illustrated.

REMOVAL OF COAL

Once the overburden is stripped away, the coal is drilled and shot (blasted) to make it easier to excavate. Large electric or diesel shovels usually load the coal into haulage units that move it to railroad loading facilities (tipples). Although strip mined coal seams in Wyoming average 30-40 feet thick, they often exceed 100 feet in both western Wyoming (Kemmerer area) and northeastern Wyoming (Powder River Basin). Because these coals are often water-bearing units (aquifers), quite frequently this phase of the mining operation also involves pumping ground water from the mine.

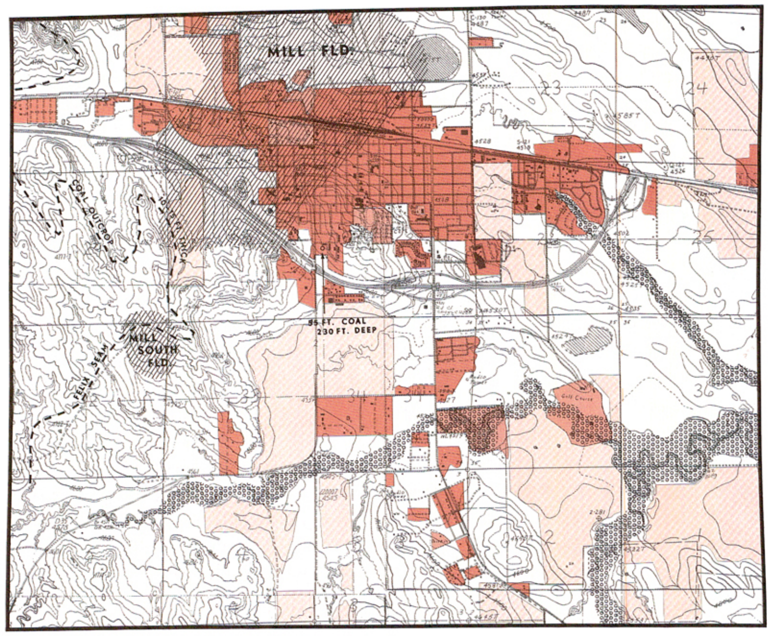


MINE NEAR COMPLETION

Once overburden and coal are removed, the open pit will seldom be less than 100 feet deep and may easily exceed 270 feet in total relief. Reclamation done concurrent with mining should restrict the area of final cut (open pit) to 40-80 acres. Because of the thinness of overburden over much of a mine area and the thickness of the coal seams, it is unlikely that there will be enough spoil available to restore any mined land to its original contour. Some lowering of the original land surface is then expected, and when possible and desirable, some final cuts may have to be converted into water impoundments for lack of spoil.

RECLAMATION

The results of backfilling, recontouring, and revegetation of a strip mine are evident in the right foreground of this photo. In the background an active pit and its ungraded spoil piles are still visible. Eventually the conical spoil piles will be pushed into the open pit (backfilling) and recontoured to blend in with the surrounding topography. Soil will be spread over the area and various grasses planted to effect revegetation. Complicating what sounds like an easy procedure are sites that will lack adequate volumes of spoil for backfilling, that will have little or no soil, and that will receive less than 12 inches of precipitation annually.



Land Use Map of Gillette, Campbell Co.

- Residential and commercial areas
- Recreational lands, parks, outdoor movie etc.
- Croplands and pasture
- Oil field outline, in subsurface
- Extent of modern flood plain

Surface uses mapped from June 1974 aerial photography, courtesy University of Wyoming Remote Sensing Laboratory.

Trace Element Geochemistry of Coal and Related Rocks

Although it has been known for some time that atypical concentrations of various elements in the earth's crust account for naturally derived poisoning in particular areas, we have only recently begun to realize the importance of the chemistry of the earth's rocks. Geochemistry controls the distribution of soil types, vegetation, water quality and air quality as well as some plant and animal diseases. Certain concentrations of many elements are integral to proper health while higher intakes become toxic and even fatal.

Large scale surface coal mining in Campbell County will alter existing rock and soil patterns which will consequently change the geochemical characteristics in those areas. For instance, metals associated with the Wyodak coal seam include: arsenic, beryllium, mercury, copper, lead, uranium, and selenium.[1] Although low concentrations of these metals are known to have severe effects on the health of humans and livestock, exact levels of toxicity have not been firmly established. Moreover, when coal is burned, non-volatile metals are concentrated in the ash and the volatile metals are at least partially released to the air. Disposal and treatment of these coal waste products will alter distribution and concentrations of these elements.

Most of the county's coal seams, including the Wyodak, are important aquifers. Interruption of aquifers during mining will reduce water quality through increased erosion, sedimentation, overtaxed sewage facilities, release of toxic waste to streams and return of production water to streams.[2] Coal mining's regional effect on ground water, however, is not known.

Certain species of plants are known to concentrate the element selenium in quantities damaging to grazing animals. Seleniferous plants grow in the Wasatch soils above the Wyodak coal seam and are most frequent in sandy soils. If redistribution and revegetation of disturbed land is not done carefully, these toxic plants could spread. This would be detrimental to livestock grazing.

1) *Drever, Surdam and Murphy, written communication (ARCO Black Thunder study, Geochemical Sec.), 1974*
2) *Final Environmental Impact Statement, Eastern Powder River Coal Basin of Wyoming, 1974: Bureau Land Management, v. II, p. 1659.*

Coal-Crop Fires

Coal-crop fires in the Powder River Basin have been burning throughout recent geologic time, as evidenced by the widespread clinker (burned rock, or "scoria") outcrops. A few fires have been burning since before recorded history. While some coal-crop fires may smoulder underground for decades or longer, others burn until eventually extinguished by lack of oxygen. An exposed outcrop can be ignited naturally by lightning, prairie fires, and spontaneous combustion, or by man-made causes such as railroad sparks, campfires or mining activity.

Coal-crop fires should concern man, because they 1) deplete the fuel resource and 2) disturb the land surface by subsidence, collapse and heat alteration. Most surface mines at some time have fires in the freshly exposed, rapidly oxidizing coal seam. Numerous Bureau of Mines projects have attempted to extinguish coal-crop fires on federal lands. While most were successful, some of the fires re-ignited. Many of these projects were done in Campbell County between 1940 and 1950 and consisted of three phases: 1) exploratory drilling to determine coal seam thickness and overburden depth and stability, 2) compaction and leveling of the fire area by bulldozing, and 3) smothering the fire by covering with overburden.

Coal-crop fires create areas of distinguishable red "clinkered" bedrock and scattered topographic depressions. The land surface may subside as much as a hundred feet with associated ground cracks and landslides. At present, active coal-crop fires are not widespread in the county, but new fires could have serious local effects.

Data source: U.S. Bureau of Mines, Coal Mine Fire Control Project Reports

Cracking and slumping at edge of subsidence crater formed by coal-crop fire at Little Thunder Basin, Hilight, Campbell County in 1950. This fire, extinguished in 1951, had been burning since before the 1880's. A fire in this vicinity was reported in the Lewis and Clark journals. U.S. Bureau of Mines photo.

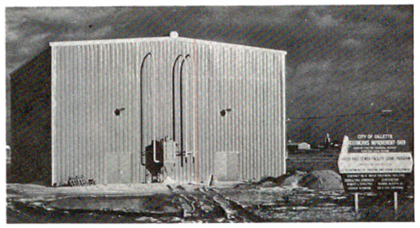
Municipal Water Supplies

The city of Gillette, the county seat of Campbell County, is the center of much of the agricultural, coal, and oil and gas activity in the Powder River Basin. The oil boom in the 1960's and recent coal development have caused the population increase which has made demands on the city water supply. Gillette has lacked both quality and quantity of water ever since the first well was drilled in 1892 by the Burlington Railroad.

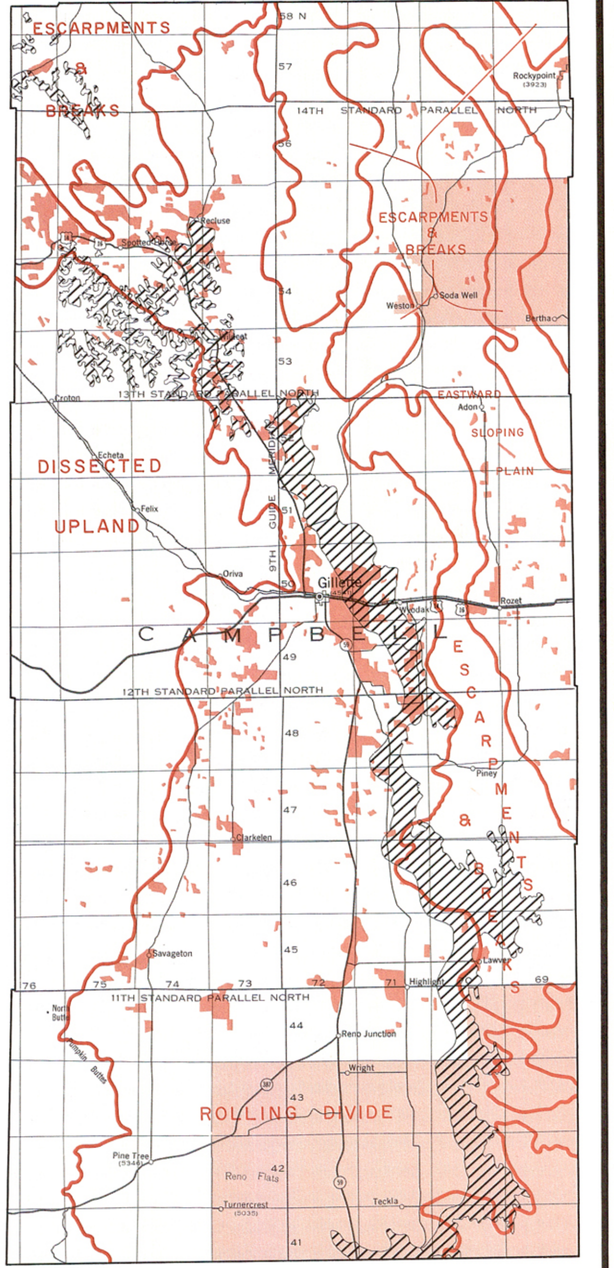
As of December 1972 the city had a total water production capacity of nearly 3.7 million gallons per day from 25 "hard" water and 6 "soft" water wells. The hard water, mostly from the Wasatch Formation, has an average content of 4.4 mg/l iron and 1500 mg/l sulfate with total dissolved solids averaging 2461 mg/l. The soft water, obtained from the Fort Union Formation and Fox Hills Sandstone, has an average hardness of 45 mg/l. Hard water is treated at the new desalinization plant and blended with the soft water at a final cost of about 60 cents per 1000 gallons. Treated water to be delivered to users is not to exceed 0.2 mg/l iron, 550 mg/l sulfate and 1000 mg/l total dissolved solids. Importing ground water and surface water or using deeper local ground water have been considered as alternative sources. Future water needs of the Gillette area will certainly call for expansion.

Small unincorporated towns in the county include Reno Junction, Spotted Horse, Recluse, Rocky Point and Rozet. All obtain small quantities of variable quality water from relatively shallow wells. Continued problems and increasing costs are expected for these municipal water systems.

Data source: Streeter, R. L., 1972, Desalting at Gillette, Wyoming: Cooperative Desalting Studies Conference, Anaheim, California, 10 p.



Desalinization plant at Gillette financed by city and federal funds totalling $995,000 was completed in 1972. The plant consists of two sections: A pretreatment section with aeration, partial softening and filtering systems, and a desalting section which utilizes the electrodialysis method. The overall treatment capacity is 1.75 million gallons per day.



Land Uses in Campbell County

LEGEND

- Farmland, mainly crops and/or pastureland.
- Thunder Basin National Grasslands
- Known strippable coal reserves.

Mapped from aerial photography courtesy Univ. of Wyo. Remote Sensing Laboratory.

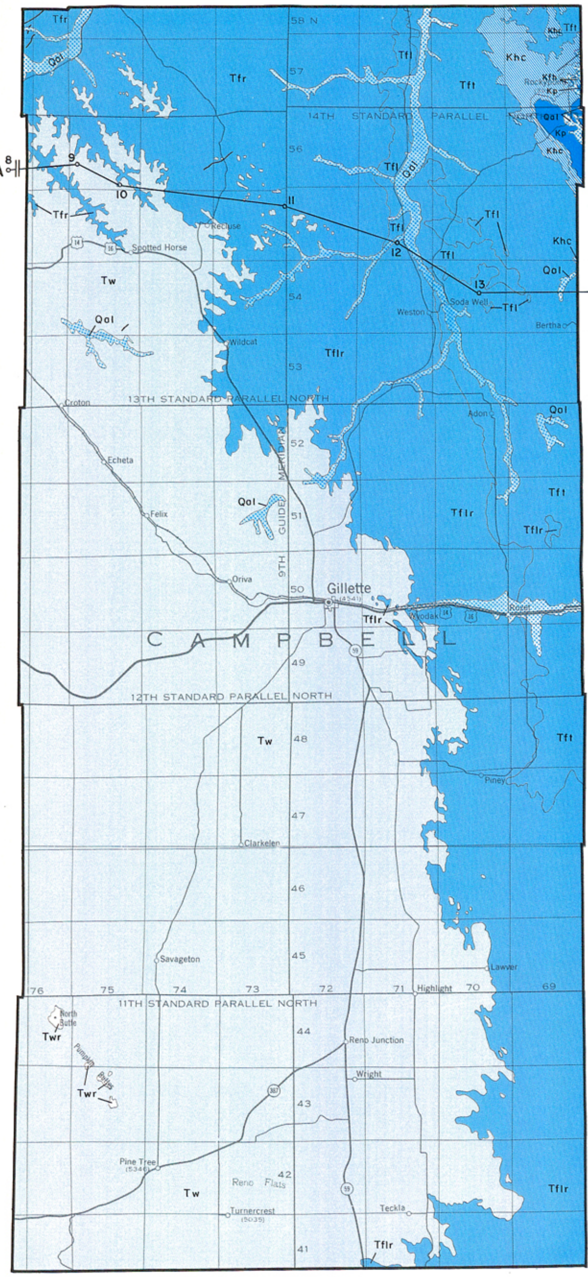
SCALE: 0 – 5 – 10 MILES; 0 – 5 – 10 – 15 KILOMETERS

Traditional land use in Campbell County has been agricultural. After the turn of the century large numbers of cattle were driven from Texas to open range in Campbell County. As settlement gradually increased, grazing was augmented with hay crops for winter feed. Sheep raising has been important since the 1920's. Farming in Campbell County was severely damaged by the 1930-1940 drought. Many homesteads were abandoned and the land reverted to range. The recent trend shows a decrease in number of farms but an increase in acreage. Farmland is mainly situated in two parts of the county: 1) the central rolling divide and, 2) the eastward sloping plain. Principal crops are wheat, oats, barley, and hay grown under dry land farming methods. The dominant agricultural land use is still grazing. Because of the low precipitation and shallow soils most of the county is better suited to cattle and sheep raising than to cultivated crops.

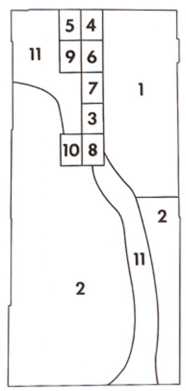
The first commercial oil field discovery in the county was made in 1948, but it wasn't until the 1960's that oil became an important industry. Oil exploration, production, and service workers moved in, and the population of Gillette rose quickly. By 1973, Campbell County led the state in oil production, was second in the production of natural gas, and was the most active county with respect to drilling and new discoveries. Although oil and gas fields dot much of the county, much of the affected land can still be used for grazing.

Ever since the early settlers came to this area, coal was used to heat farm and ranch houses and later to provide electricity for Gillette. For some time the principal commercial market for coal was the Homestake gold mine in South Dakota. In the last few years demand for low sulfur coal has focused interest on the vast deposits that underlie much of the Powder River Basin at shallow depths. Eighty-four percent of Wyoming's known strippable coal resource underlies 201,000 acres of Campbell County. Only small acreages are involved in present mining but planned coal mines and the associated facilities will disturb tens of thousands of acres by the year 2000. Undoubtedly, this coal development will significantly change the traditional land use patterns of Campbell County. Only wise reclamation of these mined areas and foresighted planning in communities can ensure a balanced land use for the future.

Geologic Map of Campbell County, Wyoming



Geologic Map Index and References



Published Reports

1. Mapel, W. J., Robinson, C. S., Theobald, P. K., 1959, Geologic and structure contour map of the northern and western flanks of the Black Hills, Wyoming: U.S. Geological Survey Oil and Gas Investigations Map OM 191, scale 1:96,000.
2. Love, J. D., Weitz, J. L., Hose, R. K., 1955, Geologic map of Wyoming: U.S. Geological Survey Map, scale 1:500,000.

Open File Reports (U.S. Geological Survey)

3. Calf Creek Quadrangle -- McKay, E. J. and Mapel, W. J., 1973
4. Croton 1 NE Quadrangle -- McKay, E. J., 1973
5. Croton 1 NW Quadrangle -- McKay, E. J., 1973
6. Croton 1 SE Quadrangle -- Landis, E. R. and Hayes, P. T., 1973
7. Pitch Draw Quadrangle -- McLaughlin, R. J. and McKay, E. J., 1973
8. Rawhide School Quadrangle -- Mapel, W. J., 1973

Unpublished Maps (U.S. Geological Survey)

9. Croton 1 SW Quadrangle -- Hayes, P. T., 1974
10. Townsend Spring Quadrangle -- McLaughlin, R. J. and Hayes, P. T., 1974
11. Wasatch-Fort Union contact -- Denson, N. M., 1974

Geology of Campbell County, Wyoming

The entire area of Campbell County lies within the Powder River Basin. In Wyoming this structural and topographic basin is bounded by mountains or arches on all sides except the north, where the basin extends into Montana. Most of Campbell County lies east and north of the basin's structural axis. The general strike or trend of the rocks in the county is northwest-southeast. While younger exposed rocks dip almost imperceptably 1-2 degrees westward, older unexposed rocks dip more steeply. Because of its structural asymmetry, the basin is deepest in the extreme southwestern corner of the county.

All of Campbell County's surface bedrock is of sedimentary origin, deposited during the late Cretaceous time or during the Cenozoic era (probably less than 100 million years ago). These exposed rocks consist of sandstones, shales, conglomerates, and coals. The oldest exposed rocks, part of the Pierre Shale, crop out in the northeastern corner of the county. All strata beneath (older than) this are known only from drill hole data or inference from adjacent areas.

The stratigraphic column to the right shows the vertical positions and relative thicknesses of the more significant formations in the county. Because of variations in lithology, thickness, and age of the rock units, different nomenclature is sometimes used for equivalent units on opposite sides of the county. The correlation of these formation names is also represented diagrammatically by the stratigraphic column. As illustrated on the column, the overall thickness of sedimentary rocks beneath Campbell County is between 11,000 and 16,000 feet with the thickest portion located in the southwestern corner.

Quaternary sediments mapped in this county are stream deposits (alluvium). Beneath these recent sediments lie 2,000 to 4,800 feet of Cenozoic rocks, mostly coal-bearing sandstones and shales. The thinner Cenozoic sequence on the eastern side of the county is due to erosion of the Wasatch Formation.

The Mesozoic rocks underlying the Cenozoic strata range from 7,500 feet thick in the east to about 9,000 feet in the western portion of the county. Mesozoic sediments consist of claystone, siltstone, and sandstone of both marine and nonmarine origin as well as some coal-bearing rocks in the Upper Cretaceous.

Paleozoic rocks are the oldest sedimentary rocks in the basin. Approximately 2,500 feet thick, they consist of marine carbonates and sandstones. Beneath these sedimentary rocks are very old crystalline rocks of igneous origin usually referred to as Precambrian "basement".

During the Paleozoic and Mesozoic ages (125-600 million years ago), this portion of Wyoming was a broad relatively stable interior platform that was periodically flooded by shallow seas. Although during most of this time both carbonate and noncarbonate sediments were deposited, there were also periods of erosion or nondeposition (unconformities). By the late Cretaceous and early Cenozoic times (38-125 million years ago), mountains began to rise, bordering what is now known as the Powder River Basin. While these mountains were rising, streams carried sediments off these uplifted areas into the basin. These sediments filled the basin as the mountains rose.

The present topography is a result of recent erosion that has cut into the Cenozoic and older rocks that now crop out across the county. The interested reader is referred to publications indicated on the reference list for further details on the geologic history of Campbell County as well as the county's structural history of folding, faulting, and subsidence.

Unlike many Wyoming counties, Campbell County's geological conditions have resulted in the accumulation of what are now accessible mineral deposits useful to man. The county presently leads the State in oil and gas drilling and is first in oil and second in gas production. Campbell County contains more coal resources than any other county in the State. Although the shallower uranium reserves are nearly depleted, there still remains substantial deeper reserves. Many more years of geological study and drilling will be required before the full potential of Campbell County's mineral resources is realized.

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Wyoming Geological Association, 1958, Thirteenth Annual Field Conference Guidebook -- Powder River Basin: P. O. Box 545, Casper, Wyoming, 341 p.

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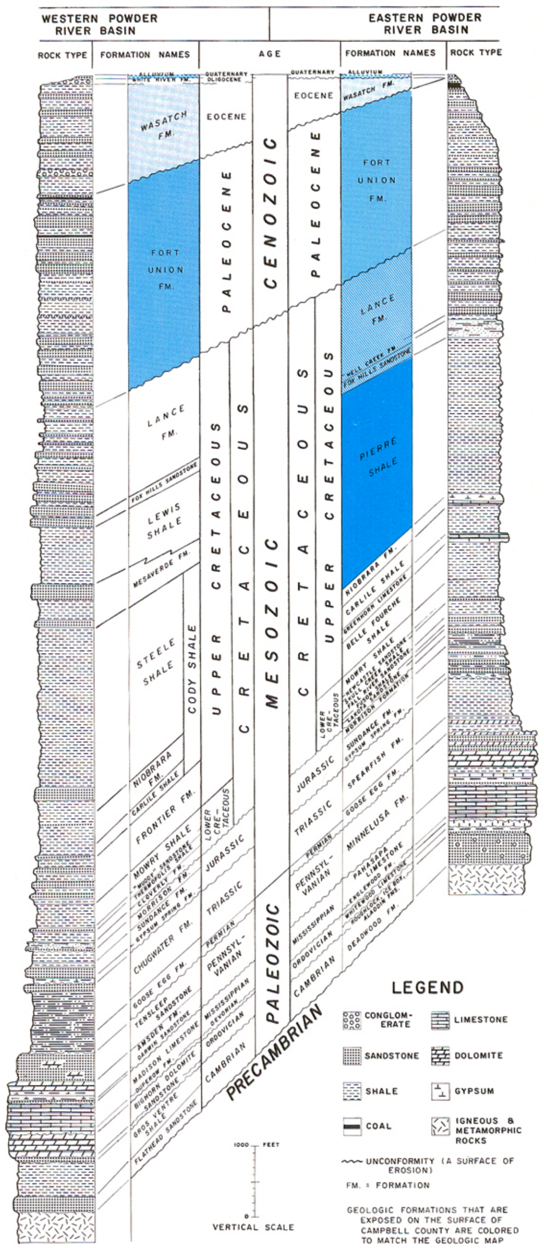
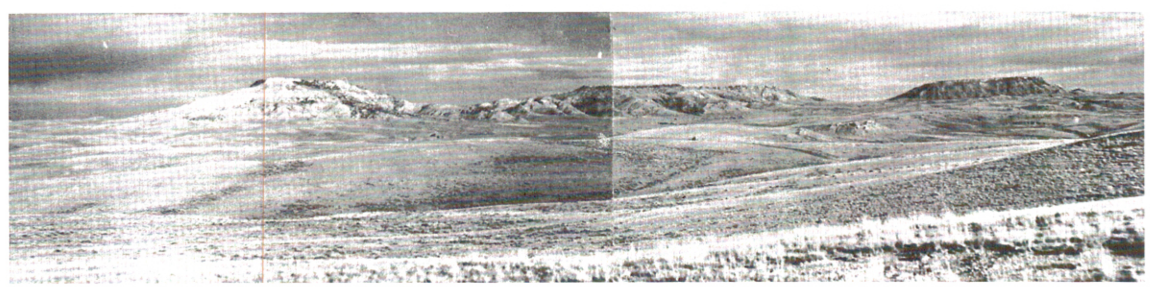
Wyoming Geological Association, 1971, Twenty-third Annual Field Conference Guidebook -- Symposium on Wyoming Tectonics, P. O. Box 545, Casper, Wyoming, 187 p.

Stratigraphic Column

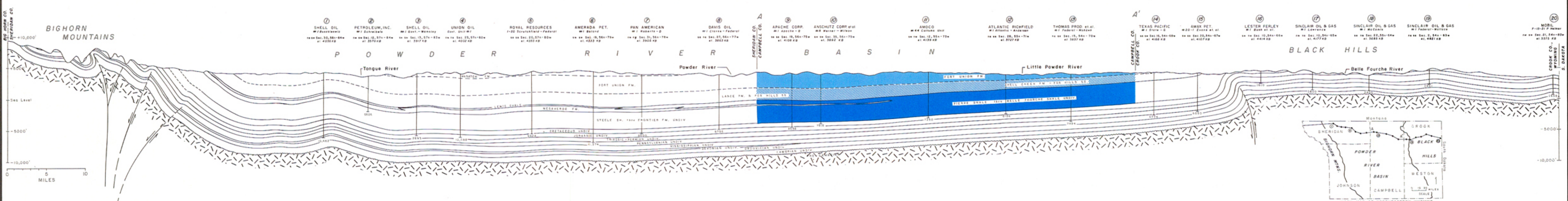
(VERTICAL SEQUENCE OF ROCK FORMATIONS WITHIN CAMPBELL COUNTY)





Pumpkin Buttes

Towering as much as 1,000 feet above the surrounding prairie, Pumpkin Buttes are prominent landmarks in southwestern Campbell County. All of the buttes are capped by hard, resistant conglomeratic sandstone of the Oligocene age White River Formation. This sandstone has protected the underlying softer rocks of the Wasatch Formation, preserving these high buttes from complete erosion. In addition to the Buttes' scenic value, uranium in the Wasatch Formation in this area has been mined in the past and is of current exploration interest. This picture of the Middle and South Pumpkin Buttes was taken from a point four miles west of the buttes. (Photo by J. D. Love, 1951)



East-West Cross-Section of Powder River Basin; Sheridan – Campbell – Crook Counties

Land Ownership in Campbell Co.

Originally the land ownership of Campbell County was all in the public domain, acquired by the United States under the Louisiana Purchase (1803). Since then, much of the land passed into private ownership as a result of the Homestead Act. This passage into private hands, however, was not without incidence, as more than one range war between cattle barons and homesteaders are recorded in the history of the county. Additionally, certain "school lands", usually sections 16 and 36, were conveyed to the State by the federal government at the time of Statehood or acquired in other ways.

Although the land ownership pattern (see map at right) is more or less checkerboarded between federal, state and private lands, private lands comprise 80.7% of the county. Federal lands account for 12.7%; state lands make up the remaining 6.6%. The complexity of private ownership makes it impossible to say anything further about those lands. An interested reader should contact the Campbell County Clerk in Gillette for more information and plat maps. The State lands are administered by the Commissioner of Public Lands in Cheyenne. Federal lands are principally under the jurisdiction of the Department of Interior's Bureau of Land Management (BLM) or the Department of Agriculture's National Forest Service (NFS). The Casper District Office of the BLM manages National Resource Lands or public domain lands in the county. The NFS has jurisdiction over the Thunder Basin National Grasslands, which occupy portions of northeastern and southeastern Campbell County.

The county also contains lands that have been reacquired from private owners by the federal government. These include Land Utilization (L. U.) lands and lands acquired under the Bankhead-Jones Act of the 1930's, which removed them from agricultural production. Either the BLM or the NFS manages these acquired lands depending on where they are located. The Bureau of Reclamation also manages some land in the county.

The predominant surface land use within Campbell County is range for beef cattle and sheep. In addition to the federal lands, the State Board of Equalization reported over 2 million acres were used for grazing in 1972. They reported another 71,000 acres were in dry farm lands. Dryland wheat, oats, and barley are the primary crops although some alfalfa is also grown. Woodland vegetation is typically scrubby ponderosa pine, but juniper, cottonwood and willow grow along the larger streams. About 2,300 acres in the county are assessed as timber lands. Residential, commercial, and industrial or mining sites as well as reservoirs account for most of the additional acreage.

Campbell County Statistics

Land Area: 4,742 square miles
3,034,614 acres

	Surface Ownership	Mineral Ownership (Estimated)
Federal:	384,647 acres (12.7%)	2,564,249 acres (84.5%)
State:	199,759 acres (6.6%)	182,077 acres (6.0%)
Private:	2,450,208 acres (80.7%)	288,288 acres (9.5%)

Population Characteristics:

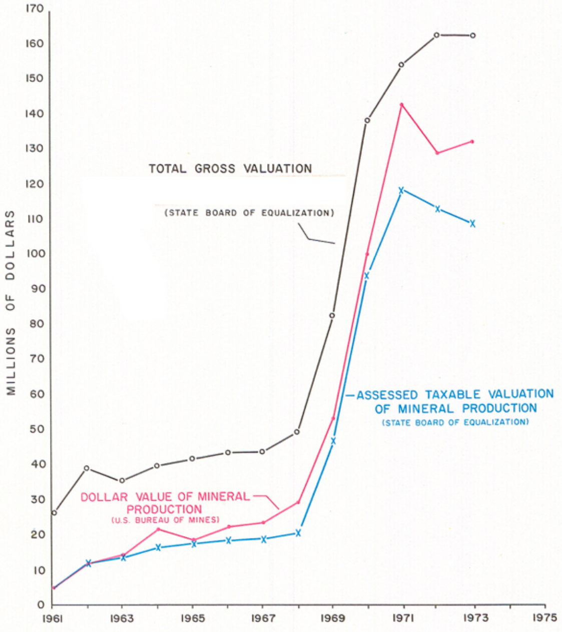
Total population 1960:	5,861	Number of families in 1970:	3,085
Total population 1970:	12,957	Per capita income:	$3,534
Percentage of change 1960-1970:	+ 121.1%	Mean family income:	$12,949
		Median family income:	$11,303

Economic and Government Statistics:

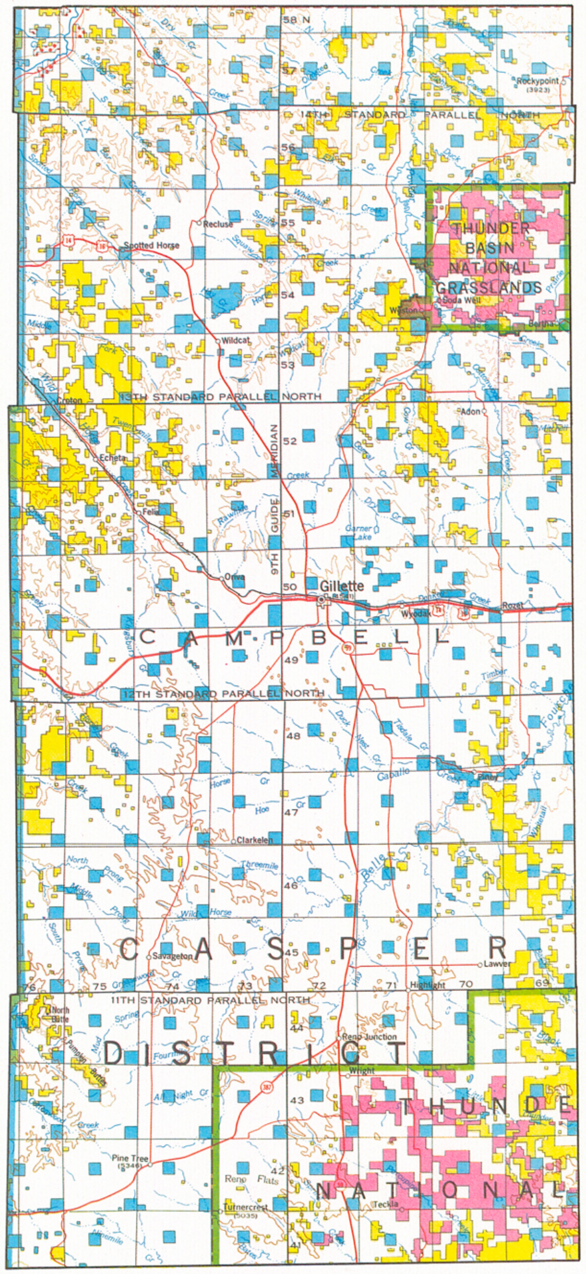
Assessed valuation

	Total		Mineral
1972:	$150,753,201	1972:	$112,143,966
1973:	$162,402,251	1973:	$107,764,145
		Oil:	$97,259,524
		Gas:	$9,843,153
		Coal:	$656,668
		Other:	$4,800

Modified from: Wyoming Data Handbook 1973 published by Dept. of Administration and Fiscal Control, Cheyenne, Wyoming, August, 1973.



Dollar Value and Assessed Taxable Valuation



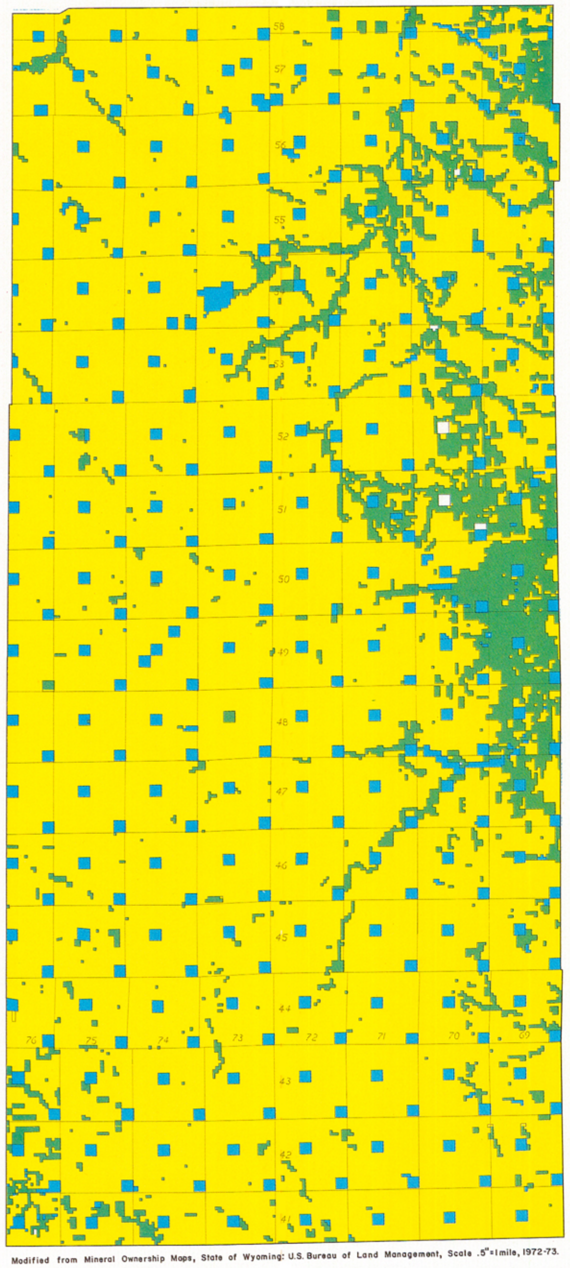
Reproduced from Land Status Map, State of Wyoming, U.S. Bureau of Land Management, 1967.

Land Ownership

LEGEND

- PUBLIC LANDS
- STATE LANDS
- BANKHEAD JONES L.U. LANDS*
- PRIVATE LANDS
- NATIONAL FORESTS**

* Federally owned and administered lands
** Areas containing some private lands not shown



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

Mineral Ownership

LEGEND

- FEDERAL MINERAL RIGHTS*
- STATE MINERAL RIGHTS
- PRIVATE MINERAL RIGHTS

* includes some partially Federal lands

Mineral Ownership and Valuation

An estimate of Campbell County's subsurface mineral ownership shows about 84.5% (over 2.5 million acres) is federally owned, 9.5% is in private (or fee) ownership, and 6% is state owned. These figures clearly illustrate the dominant ownership and, hence, the control of mineral resource development in the county.

Like the surface ownership, private mineral rights can be sold or leased by the owner. While records of private mineral ownership are recorded on plat maps in the Campbell County Clerk's office in Gillette, the State Board of Land Commissioners in Cheyenne is responsible for granting and maintaining records of mineral leases on state lands.

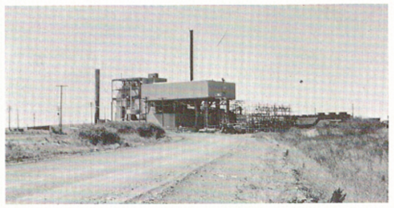
The Mineral Leasing Act and the Mineral Leasing Act for Acquired Lands grant statutory authority for leasing public domain (federal land) mineral rights and minerals on acquired lands, respectively. In the case of acquired lands, the federal agency having administrative jurisdiction over the lands must give its consent before any leasing is permitted. Both laws give the Department of the Interior authority over the mineral leasing program. Within the Department of the Interior, the Bureau of Land Management (BLM) is authorized to issue mineral leases. In addition to managing these federal mineral rights, the BLM also maintains the official federal land status records. The United States Geological Survey administers all operations under the leases.

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 even sand and gravel. 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 1973 at $97,259,524, natural gas was next at $9,843,153, while coal followed at $656,668. Assessed values are determined on the basis of the previous year's production.

Although the 1973 assessed taxable valuation of oil, gas, coal, sand and gravel ($107 million) decreased by more than 4 million dollars from 1972, new highs are expected in the future as the county's coal resources are more fully exploited. Annual lease payments and bonuses paid during exploration, and royalties and taxes paid on oil, gas, and coal production also contribute significantly to the overall economy.

Neil Simpson Station



Located east of Gillette, Black Hills Power and Light Company's Neil Simpson Station is still the only coal-fired power plant in the Western Hemisphere with an air-cooled condenser on a steam turbine. This unique air-cooled unit operates much like a car radiator, discharging waste heat into the atmosphere rather than evaporating steam from open cooling towers. Water consumption for this unit is less than 1/10th that of a conventional plant. Nearby, Black Hills and the Pacific Power and Light Company have begun construction of a 330-megawatt plant, which will be the nation's second air-cooled plant as well as the world's largest such plant. Construction should be completed by 1977.

Potential for Future Mineral Development in Campbell County

Because of its geologic setting in the coal-, oil-, and gas-rich Powder River Basin, Campbell County is especially well endowed with these valuable mineral resources. Oil and gas development can be expected to attract considerable attention for decades to come. In fact, in 1974, exploration activities for new oil and gas fields reached another new high. As new discoveries are made, the incentive to test more remote areas and deeper horizons has increased. Future exploration should result in the discovery of many more oil and gas fields, the extension of existing fields, as well as an increase in producing zones.

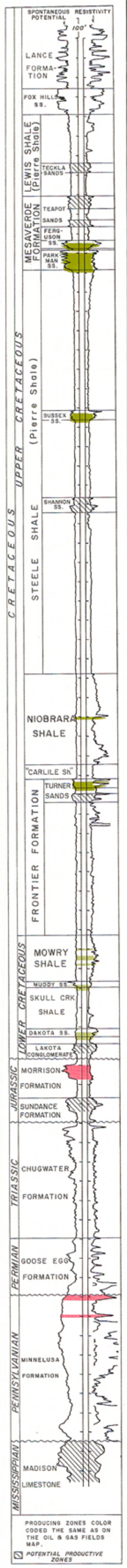
By 1980, approximately six new, large, coal strip mines are expected to open in the eastern half of the county, perhaps twice that many by 1990. Each mine is expected to produce from 5 to 20 million tons of coal annually from the 70-100 foot thick coals that crop out there. By the nation's Centennial year, 1976, Campbell County will lead the state in coal production, producing 12-13 million tons of coal annually. Meanwhile, two of the existing three strip mines in Campbell County will expand their operations also. Carter Oil Company is studying the feasibility of building a coal-to-gas (gasification) plant near Gillette before the 1980's. Several other companies are also evaluating similar plans.

In addition, a coal-slurry pipeline has been proposed. If built, this 1043-mile long pipeline will carry up to 25 million tons of southern Campbell County coal, mixed with water, to destinations in Arkansas. East of Gillette, Pacific Power and Light, and Black Hills Power and Light Companies have started construction of the world's largest air-cooled power plant. This 330-megawatt coal-fired plant should be completed by 1976 or 1977. Other power plants are rumored for the area also.

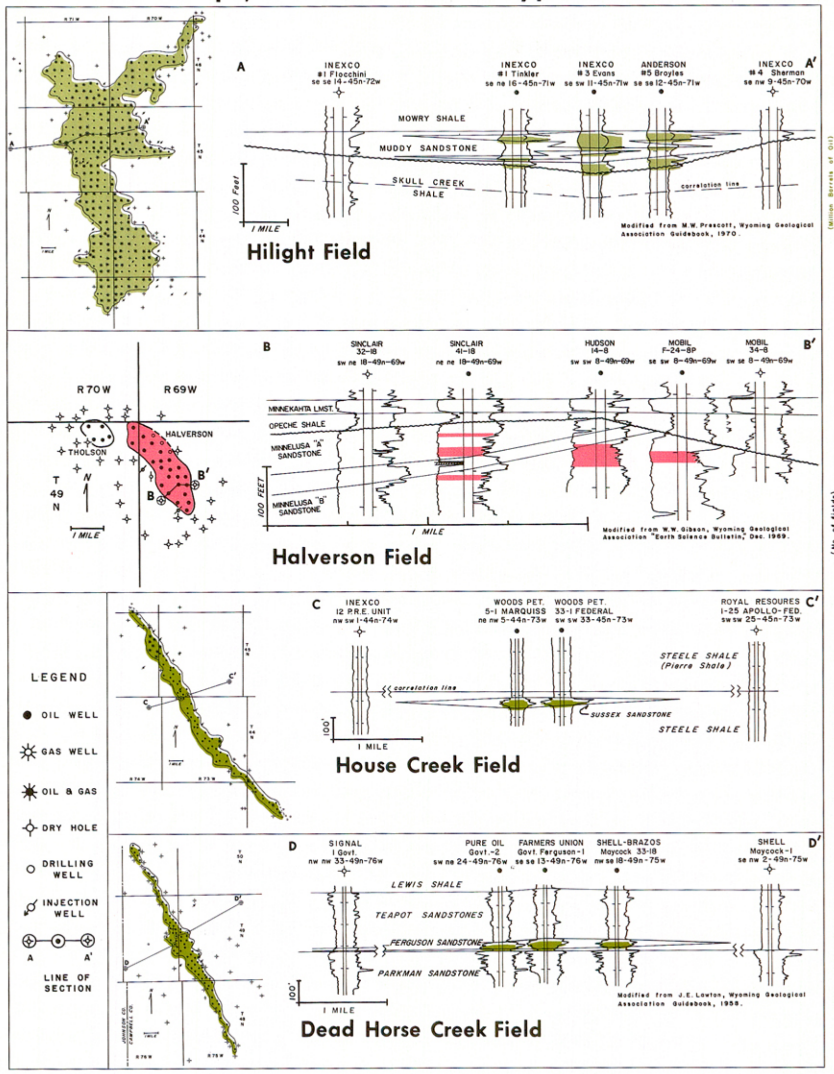
To date, there has been very little uranium production in the county; however, commercial grade uranium ore occurs in the Pumpkin Buttes Uranium District in southwestern Campbell County. Uranium mining operations will probably be established within the next decade.

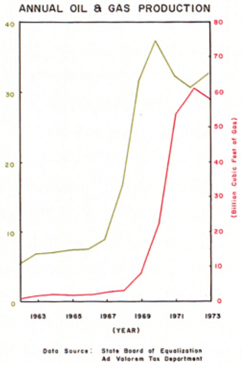
As the population increases in response to these industrial and mining developments, the need for construction materials will grow. Demand for sand, gravel, rock aggregate, and clay will increase. The limited availability of all but perhaps the rock aggregate will critically influence the county's development. Abundant baked and fused rocks (locally called clinker or scoria), which overlie burned out coal seams, should provide ample rock aggregate to meet soaring demands.

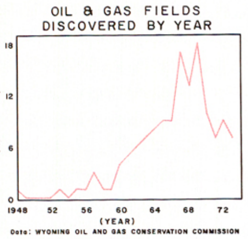
Composite Electric Log



Index Maps, Cross-Sections of Typical Oil Fields







Drilling rigs are a common sight throughout Campbell County (Wyoming Highway Department photo).

History and Future of Oil and Gas in Campbell County

INTRODUCTION The first commercial oil production in Campbell County was from the Minnelusa Formation at Adon Field, a small anticline discovered in 1948. In 1956 the Raven Creek Field, a stratigraphic Minnelusa discovery, was the first significant oil find in the county.

Throughout the 1950's 8 fields were discovered. During this time the major activity in Wyoming was centered farther east and southeast in Weston, Crook, and Niobrara counties.

Beginning in 1960 there was a marked upswing in exploration effort in Campbell County, and since then the county has become the perennial leader statewide for drilling activity and new discoveries. Most of the 1960-67 activity was directed toward the Minnelusa Formation, resulting in 50 new fields. From 1968-71 the principal objective was the Muddy Sandstone -- 39 new fields were discovered. Since 1971 exploration interests and new discoveries have been about equally divided between the Muddy and Minnelusa formations, but increased activity has been directed toward the Upper Cretaceous Sussex Sandstone.

The oil boom in the county reached its peak in 1969 when, according to Petroleum Information, a total of 758 wells were drilled, resulting in 413 producing wells and 18 new field discoveries.

In the early days of exploration the basic prospecting technique was to locate anticlinal structures by surface mapping. By the late 1940's, seismic methods aided in locating subsurface structures that didn't have surface expression, thus focusing attention on areas that had been previously passed over. More geological data became available with increased drilling, and with it more sophisticated exploration techniques and philosophies developed.

PRODUCTION Oil and gas production is lacking from reservoirs in the lower and upper portions of the geologic column. The pre-Mississippian formations are generally dense and contain few source beds, and the post-Fox Hills strata are of non-marine origin and thus far have not yielded commercial oil or gas.

Production in the county comes from the middle portion of the stratigraphic column. The producing units include: the Pennsylvanian-Permian age Minnelusa Formation; Jurassic Morrison Formation; Lower Cretaceous Dakota Sandstone, Muddy Sandstone, and Mowry Shale; and the Upper Cretaceous Turner Sandstone, Niobrara Shale, Sussex, Parkman, and Ferguson sandstones. These stratigraphic units are exhibited on the accompanying composite electric log.

Presently 51% of the oil production in the county comes from the Muddy, 42% from the Minnelusa, and the remaining 7% from the other mentioned zones with the Sussex, Parkman, and Ferguson sandstones producing the largest portion. The Muddy yields 97% of the total gas production with most of the remaining 3% from the Ferguson and Sussex sandstones.

Cross-sections showing the producing horizons in four typical oil fields are pictured above.

Throughout much of Wyoming, anticlines provide the most common trap for oil and gas accumulation; however, in Campbell County and in most of the eastern Powder River Basin stratigraphic traps are prevalent in formations of several ages (see cross-sections above).

Most Muddy fields are stratigraphic traps consisting of thin, discontinuous channel, beach, or offshore bar sands or combinations of these. The complex of offshore bar and beach facies has a general north-south trend and the channel sands have irregular configurations. Hilight Field (section A-A') is a combination of lower channel sands and overlying offshore bar sands.

The Minnelusa play is largely a search for several types of relatively small but prolific stratigraphic traps. A few structural traps occur but most are porosity pinch-outs, facies changes, truncated sandstones, and ancient hills overlain by a shale cap rock. Minnelusa stratigraphic traps have been more completely discussed by Trotter (1963). Halverson Field (section B-B') is a stratigraphic updip truncation of Minnelusa sandstones.

Sussex sandstones occur as a complex of NW-SE trending offshore bars. House Creek Field (section C-C') is the example shown and typically exhibits the NE-SW pinch-out of the sandbars.

The Mesaverde Formation consists of alternating and interfingering deltaic sands, offshore bars, and marine shales. The delta sands pinch out to the east along a NW-SE line which runs approximately through the middle of the county. The Dead Horse Creek Field (section D-D') is a narrow NW-SE trending offshore bar.

Other potentially productive zones are indicated on the composite log. These zones include the Upper Cretaceous Teckla, Teapot, and Shannon sandstones; Lower Cretaceous Lakota Formation; Jurassic Sundance Formation; and Mississippian Madison Limestone.

Two units that presently have only minor production in the eastern portion of the county now appear to have greater potential in the western part. The recent discovery in the Spearhead-Patterson Ranch area, northwestern Converse County, has indicated that the Frontier Sandstone (approximate Turner equivalent) is a better reservoir and has much greater oil and gas potential in southwestern Campbell County. The Dakota Sandstone exhibited significant oil shows in the same discovery, thus enhancing its potential in the southwestern part of the county.

The approximate cost to drill an 8100-foot dry hole to the Sussex Sandstone presently is $72,000, and for a completed well $161,000. Average cost to drill a 9600-foot dry hole (without casing) to the Shannon Sandstone is about $88,000 and for a completed well $137,000. Frontier tests at a depth of 15,000 feet would cost about $870,000 for a dry hole and $1.3 million for a producing well.

CHARACTERISTICS OF CRUDE OILS According to Wenger and Reid, 1958, crude oils of the Powder River Basin are of two major types. In formations younger than Jurassic, oils commonly have API gravities of 34° or higher, low sulfur content (.05 percent and less), are paraffinic, greenish in color and thus referred to as "green oils". Crude oils in formations older than Jurassic generally have API gravities of 34° or lower, higher sulfur content, are asphaltic, much darker in color and are referred to as "black oils". Both types are found in Jurassic formations which seem to form the transition zone between the two general types.

Depth of accumulation affects the properties of crude oils regardless of the source lithology. At shallow depths there appears to be a loss of the lighter oil fractions and paraffin wax, and concentration of sulfur, asphalt, and heavy oil fractions. At depths below 10,000 feet, heavy, high-sulfur oils generally do not occur.

STRUCTURE The present structural form of the Powder River Basin is primarily the result of the Late Cretaceous - Early Tertiary Laramide orogeny. The structural axis of the basin runs through the southwest corner of Campbell County. Deformation was greatest along the basin margins with only very minor flexures developed in the Campbell County area. The subsurface structure as mapped on the Dakota Sandstone exhibits uniform regional southwest dip of 1 to 2 degrees with only a few minor variations (see structure map).

According to Strickland, 1958, isopach maps of the Madison, Minnelusa, and Sundance formations reflect pre-Laramide gentle warpings with northwest trends similar to the present structural grain of the basin.

The Known Geological Structures map by the U.S. Geological Survey includes nearly all the fields in Campbell County. However, since most fields are stratigraphic traps, the U.S.G.S. classification would be better described as "Areas of Known Production". The purpose of the K.G.S. definition is to designate known producing areas so that the public lands immediately adjacent can be put up for competitive bidding.

Oil and Gas Production

Field Name and Discovery Date		Location (Twn.-Rge.)	Producing Formation(s)	Producing Depths	No. Prod. Wells	Total Production to Dec. 31, 1973 Oil (BBLS)	Gas (MCF)	Field Status
Adon	1948	52N-72W	Minnelusa	9,090	0	28,138	0	aband.
Adon Road	1962	52N-72W	Minnelusa	7,800	3	507,802	0	prod.
Adon Road, North	1966	52N-72W	Minnelusa	7,690	1	72,261	2,260	prod.
Am-Kirk	1962	46N-70W	Dakota-Minnelusa	8,704	4	661,893	55,761	prod.
			Muddy	8,400	1	28,221	50,180	prod.
Apostolos	1969	52N-73W	Muddy	8,150	1	73,501	453,045	prod.
Arrow	1966	53N-69W	Minnelusa	7,194	0	21,101	0	aband.
Barber Creek	1957	49,50N-76W	Parkman	6,800	14	2,301,238	137,056	prod.(W)
Basin	1965	47N-70W	Minnelusa	9,970	2	792,214	37,102	prod.(W)
Basin, NW	1965	47N-70W	Minnelusa	9,900	4	882,190	0	prod.(W)
Bertha	1955	54N-69W	Muddy	5,443	0	135,678	31,414	aband.
Bethlehem	1973	48N-73W	Muddy	9,494	1	3,579	157	new disc.
Big Hand	1969	47N-71W	Muddy-Dakota	8,840	5	232,468	278,756	prod.
Bishop Ranch	1963	48N-70W	Minnelusa	9,950	1	290,927	235,611	prod.
Bishop Ranch, South	1968	48N-70W	Minnelusa	9,250	4	815,266	0	prod.(W)
Bone Pile	1972	48N-72W	Minnelusa	10,795	6	847,566	124,314	prod.
Booton	1967	54N-70W	Minnelusa	7,447	1	172,181	133,886	prod.
Border	1969	58N-73W	Muddy	6,880	0	1,838	0	aband.
Bracken	1970	52N-69W	Muddy	5,450	0	9,531	1,253	aband.
Breen	1967	47N-72W	Minnelusa	10,690	3	505,381	0	prod.
			Mowry-Muddy	8,950	2	82,438	0	prod.
Buff	1970	46N-72W	Muddy	10,175	5	232,982	318,585	prod.
Bugher Draw	1972	48N-76W	Ferguson	7,182	1	15,429	14,737	prod.
			Parkman	7,191	1	7,593	9,195	prod.
Bullmarch	1967	53N-69W	Minnelusa	7,420	0	9,925	0	shut-in
C-H	1967	52N-70W	Minnelusa	7,530	5	1,141,808	22,584	prod.(W)
Camp Creek	1962	54N-70,71W	Minnelusa	7,380	8	2,844,795	0	prod.
Cardinal	1966	51N-69W	Minnelusa	7,853	1	45,050	133	prod.
Carson	1969	54N-73W	Muddy	7,675	9	671,975	1,236,490	prod.
Chan	1968	56N-73W	Muddy	7,035	37	2,719,690	3,023,057	prod.
Clabaugh	1964	47N-71W	Minnelusa	9,960	3	98,436	0	prod.
Collums	1969	55N-73W	Muddy	7,120	23	4,386,370	6,350,518	prod.(W)
Cutler	1970	57N-74W	Muddy	6,990	0	29,979	51,050	aband.
Dead Horse Creek	1957	48,49N-75,76W	Ferguson	7,000	19	8,308,393	2,658,378	prod.(W)
Dead Horse Creek, S	1961	47N-75W	Parkman	7,110	5	477,700	449,410	prod.
Dillinger Ranch	1964	47N-69,70W	Minnelusa	9,090	13	7,153,606	0	prod.(W)
Double Shield	1973	51N-70W	Minnelusa	8,330	2	9,678	0	new disc.
Driscoll Creek	1962	56N-68,69W	Minnelusa	5,260	0	41,031	0	aband.
Duck Creek	1967	55N-69W	Muddy	5,035	1	8,710	0	prod.
Duvall Ranch	1964	49N-69W	Minnelusa	8,130	9	4,068,329	0	prod.(W)
*Fence Creek	1968	58N-76W	Muddy	7,710	11	1,091,447	300,559	prod.(W)
Fenton	1972	41N-70W	Muddy	10,087	1	60,135	0	prod.
Flat Draw	1968	54N-74W	Muddy	8,025	0	34,611	2,488	shut-in
Garner Lake	1966	51N-69W	Minnelusa	8,020	0	46,634	0	aband.
Gas Draw	1968	54N-72W	Muddy	7,320	54	12,799,450	9,835,427	prod.(W)
Gibbs	1970	52N-69W	Minnelusa	7,480	4	281,833	0	prod.
Gillette	1962	51N-72W	Muddy	8,010	11	1,305,556	3,449,266	prod.
Grassland	1967	53N-70W	Minnelusa	7,450	1	115,049	0	prod.
Grassland, West	1969	53N-70W	Minnelusa	7,400	1	140,678	9,395	prod.
Gray	1966	50N-69W	Minnelusa	7,915	0	10,616	527	aband.
Halverson	1961	49N-69W	Minnelusa	8,530	11	8,078,949	208,436	prod.(W)
Hamm	1967	51N-69W	Minnelusa	7,955	3	1,993,800	91,479	prod.(W)
Hensley	1968	53N-74W	Muddy	8,390	0	5,815	16,561	aband.
Hensley Draw	1969	53N-73W	Muddy	7,865	2	22,427	71,928	prod.
Hilight	1969	45N-71W	Muddy-Minnelusa	9,400	195	41,029,096	134,590,866	prod.(W)
Hines	1971	50N-73W	Muddy	9,320	4	140,593	293,322	prod.
Hoe Creek	1964	47N-74W	Parkman	7,120	1	45,431	0	prod.
Hoover Gulch	1971	52N-69W	Muddy	7,409	2	31,126	0	prod.
House Creek	1968	44N-73W	Sussex	8,250	66	4,900,621	1,627,000	prod.
House Creek, North	1973	46N-74W	Sussex	8,308	1	5,089	0	new disc.
Hunter Ranch	1968	57N-72W	Muddy	6,330	8	658,955	440,027	prod.
Iberlin	1970	46N-76W	Muddy	11,560	0	3,498	0	shut-in
Interstate	1972	50N-73W	Muddy	9,490	4	59,028	495,554	prod.
Joe Creek	1970	56N-75W	Muddy	7,676	10	1,030,036	2,114,784	prod.
Kane	1966	51N-70W	Minnelusa	8,225	2	246,686	34,378	prod.
Kingsbury Creek	1968	50N-74W	Muddy	9,470	3	229,294	1,291,595	prod.
Kitty	1965	50,51N-73W	Muddy	9,090	129	12,776,094	39,819,595	prod.
Kuehne Ranch	1965	51N-69,70W	Minnelusa	7,970	5	1,068,459	0	prod.(W)
Kuehne Ranch, East	1972	51N-69W	Minnelusa	7,796	0	No Report		prod.
Kuehne Ranch SE	1967	51N-69W	Minnelusa	7,900	1	504,184	37,879	prod.
Lazy B	1969	49N-74W	Muddy	9,610	12	706,548	2,149,396	prod.
Little	1965	55N-70W	Minnelusa	7,298	0	16,255	0	aband.
Little Mitchell Creek	1967	52N-69W	Minnelusa	7,250	6	2,955,363	0	prod.(W)
L-X Bar	1973	56N-75W	Muddy	7,876	6	192,169	370,930	new disc.
*M-D	1967	53N-69W	Minnelusa	7,170	4	3,239,664	0	prod.
Mac	1970	52N-69W	Minnelusa	7,670	1	58,153	959	prod.
May	1967	49N-69W	Minnelusa	8,375	0	42,953	0	aband.
Mill	1969	50N-72W	Muddy	8,185	20	1,137,507	2,665,291	prod.
Mill, South	1970	50N-72W	Muddy	8,760	1	31,208	25,307	prod.
Mitchell Creek	1953	53N-70W	Minnelusa	7,628	0	79,943	0	aband.
Morse	1971	55N-73W	Muddy	7,090	4	348,462	905,998	prod.
O'Connor	1960	52N-69W	Muddy	6,000	4	386,857	242,972	prod.
Oedekoven	1968	55N-73W	Muddy	7,610	8	1,697,462	4,698,792	prod.
Ok	1973	51N-70W	Minnelusa	8,086	1	13,018	0	new disc.
Olmstead	1964	57N-72W	Muddy	6,000	1	30,535	12,106	prod.
Olsen	1965	49N-71W	Minnelusa	9,575	1	189,695	0	shut-in
Paul	1970	55N-73W	Muddy	7,375	3	155,713	241,406	prod.
Payne	1969	43N-70W	Sussex-Muddy-Niobrara	7,255	26	811,122	2,011,965	prod.
Pickrel Ranch	1965	48N-69W	Minnelusa	9,000	3	1,030,264	25,596	prod.(W)
Pinnacle	1969	55N-72W	Muddy	6,800	2	98,719	14,630	prod.
Pleasant Valley	1963	51N-69W	Minnelusa	8,150	1	312,788	0	prod.
Porcupine	1969	42N-70W	Sussex-Turner Muddy	7,400	14	633,422	11,788,668	prod.
Pownall Ranch	1960	53N-70W	Minnelusa	7,470	1	126,534	2,934	prod.
*Prairie Creek	1960	53N-68,69W	Newcastle	5,301	3	804,910	272,552	prod.
Prep	1963	57N-75W	Muddy	7,080	2	258,238	38,428	prod.
Quinn	1971	56N-72W	Muddy	6,780	2	130,807	14,837	prod.
Rainbow Ranch	1960	48N-71W	Minnelusa	9,791	3	1,685,976	56,806	prod.
Rainbow Ranch, N	1973	49N-71W	Newcastle	7,980	5	257,083	4,250	new disc.
Raven Creek	1956	48,49N-69W	Minnelusa	8,400	27	22,055,506	0	prod.(W)
Recluse	1967	56,57N-74,75W	Muddy	5,340	58	19,032,718	57,289,040	prod.(W)
Recluse, SE	1969	55N-73W	Muddy	7,525	4	339,016	426,806	prod.
Reel	1962	49N-68,69W	Minnelusa	8,460	7	2,733,048	30,342	prod.(W)
Rocky Point	1961	56,57N-69W	Muddy-Minnelusa	3,600	23	6,272,040	12,217,173	prod.
Roehrs	1966	53N-70W	Minnelusa	7,460	2	259,598	12,441	prod.
Rourke Gap	1973	48N-71W	Minnelusa	10,270	4	139,017	0	prod.
Rozet	1959	50N-69,70W	Muddy	7,000	26	12,638,628	8,303,472	prod.(W)
			Minnelusa	8,620	1	581,456	82,036	prod.(W)
Rozet, East	1961	50N-69W	Muddy-Minnelusa	6,520	6	807,708	8,370	prod.(W)
Rozet, South	1965	50N-69,70W	Minnelusa	8,490	8	3,349,409	68,649	prod.(W)
Rozet, West	1967	50N-70W	Minnelusa	8,740	8	2,471,357	11,385	prod.(W)
S-Bar	1969	49N-73W	Morrison	9,525	4	243,496	780,276	prod.
Sandbar, E. & W.	1968	57N-73W	Muddy	6,996	22	3,881,511	16,409,089	prod.(W)
Schoonover	1967	48N-76W	Parkman	7,250	1	7,856	0	aband.
Simpson Ranch	1971	51N-69W	Minnelusa	7,880	0	2,946	4,232	aband.
*Slattery	1957	48,49N-68,69W	Muddy-Minnelusa	6,500	14	4,202,692	60,863	prod.
Soda Well	1963	54N-70W	Minnelusa	7,330	2	384,206	0	prod.
Soda Well, East	1964	54N-70W	Muddy-Minnelusa	5,740	4	565,242	0	prod.
Spotted Horse	1972	54N-75W	Muddy	8,066	4	13,403	203,071	prod.
Springen Ranch	1968	51N-71W	Muddy	7,600	30	5,697,608	12,535,691	prod.(W)
			Minnelusa	9,300	1	56,743	0	prod.(W)
Squaw Creek	1972	55N-73W	Muddy	7,350	1	5,068	3,290	prod.
Stewart	1965	50N-69W	Minnelusa	8,000	15	4,695,301	1,138	prod.(W)
Store	1969	55N-74W	Muddy	7,645	4	300,747	477,926	prod.
Tholson	1969	49N-70W	Minnelusa	9,040	5	855,324	0	prod.
Thomas	1969	52N-73W	Muddy	8,250	0	9,440	68,257	aband.
Throne	1971	50N-74W	Muddy	9,467	1	17,929	35,360	prod.
Timber Creek	1958	49N-70W	Muddy	7,612	2	75,060	18,972	prod.
			Minnelusa	9,360	10	9,113,906	9,859	prod.
Timber Creek, NW	1963	49N-71W	Muddy-Minnelusa			Combined with Timber Creek		prod.
Toland	1971	50N-70W	Minnelusa	8,700	1	333,085	0	prod.
2-V Creek	1963	55N-70W	Muddy	5,770	0	9,151	0	aband.
Ute	1967	57N-72W	Muddy	6,410	35	7,496,481	20,181,142	prod.(W)
Wagon Spoke	1972	52N-69W	Minnelusa	7,381	2	361,469	40,290	prod.
Wallace	1966	52N-70W	Minnelusa	7,860	8	1,925,266	6,843	prod.(W)
Wallace, South	1966	51N-70W	Minnelusa	7,860	1	158,118	11,442	prod.
Ward Creek	1961	50,51N-70W	Newcastle	7,220	0	48,504	0	aband.
Ward Creek, SE	1964	50N-70W	Muddy	7,343	1	50,460	0	prod.
Well Creek	1972	50N-69W	Minnelusa	7,908	1	37,078	0	prod.
Whisler	1967	51N-70W	Minnelusa	8,280	2	163,793	6,218	prod.
White	1970	55N-71W	Muddy	5,970	2	49,695	6,973	prod.
Whitetail	1968	56N-72W	Muddy	6,760	18	2,304,791	1,608,170	prod.
Windmill	1967	51N-69W	Muddy	6,450	3	69,759	45,879	prod.
			Minnelusa	8,160	2	1,658,851	0	prod.
Yellow Hammer	1964	47N-70W	Minnelusa	10,050	1	200,419	0	prod.
York	1963	53,54N-69W	Minnelusa	7,240	0	101,012	0	aband.
TOTAL	138 Fields				1230	262,659,360	356,914,516	prod. 115

* Fields partly in Campbell County
(W) water injection projects

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

FUTURE DEVELOPMENTS Regional developments in oil and gas exploration have been dictated by overall market economics, drilling costs, and variations in the subsurface stratigraphy and structure.

For several years the price of crude oil remained fairly stable while drilling costs made substantial increases. This resulted in a downward trend of drilling activity and limited the depths of most exploratory wells; therefore, exploration objectives shifted to younger horizons found at more shallow depths that had previously been located farther into the basin. With the crude oil price increase in the latter part of 1973, the rising costs were offset and activity in 1974 has risen to a rate 34% above a year ago, and deeper drilling is more common.

With the big push for "Project Independence" and if the crude oil prices remain high, then exploration activity in the county and the Powder River Basin can be expected to continue at a high rate for several years.

Future exploration developments will include increased Muddy and Minnelusa activity throughout much of the county, but the greatest emphasis will occur in the southwestern portion where the Mesaverde (Teckla, Teapot, and Parkman), Sussex, Shannon, and Frontier sandstone trends are present. Already these same trends are being developed in northern Converse County where the said units have become very important producers. Only a few fields produce from these Upper Cretaceous sandstones in Campbell County but many more will be discovered in the very near future.

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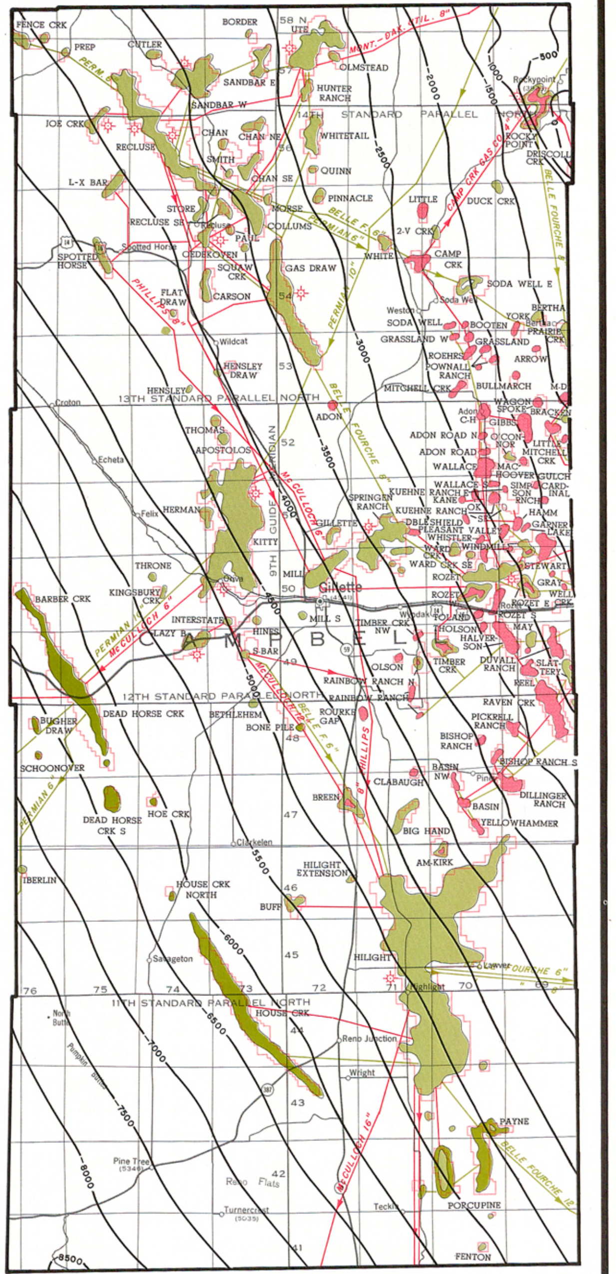
Oil and Gas Fields



LEGEND

OIL AND GAS FIELDS

- UPPER CRETACEOUS AGE
- LOWER CRETACEOUS AGE
- JURASSIC & PENNSYLVANIAN AGE

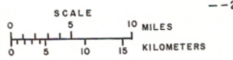
PIPELINES (OWNER, SIZE, DIRECTION OF FLOW)

- OIL — BELLE FOURCHE 6"
- GAS — PHILLIPS 8"

GAS PROCESSING PLANT

KNOWN GEOLOGICAL STRUCTURES

--2000— STRUCTURE CONTOURS TOP DAKOTA SANDSTONE (contour interval 500')



Modified from: Oil and Gas Fields and Pipelines of Wyoming map, Jan. 1974, and Known Geologic Structure map, Apr. 1974, U.S. Geological Survey; Pipelines and Field Map, Powder River Basin, Wyoming Oil and Gas Conservation Commission, 1973; The Petroleum Ownership Map Co. Structure Contour Map of Wyoming Basins, 1969.

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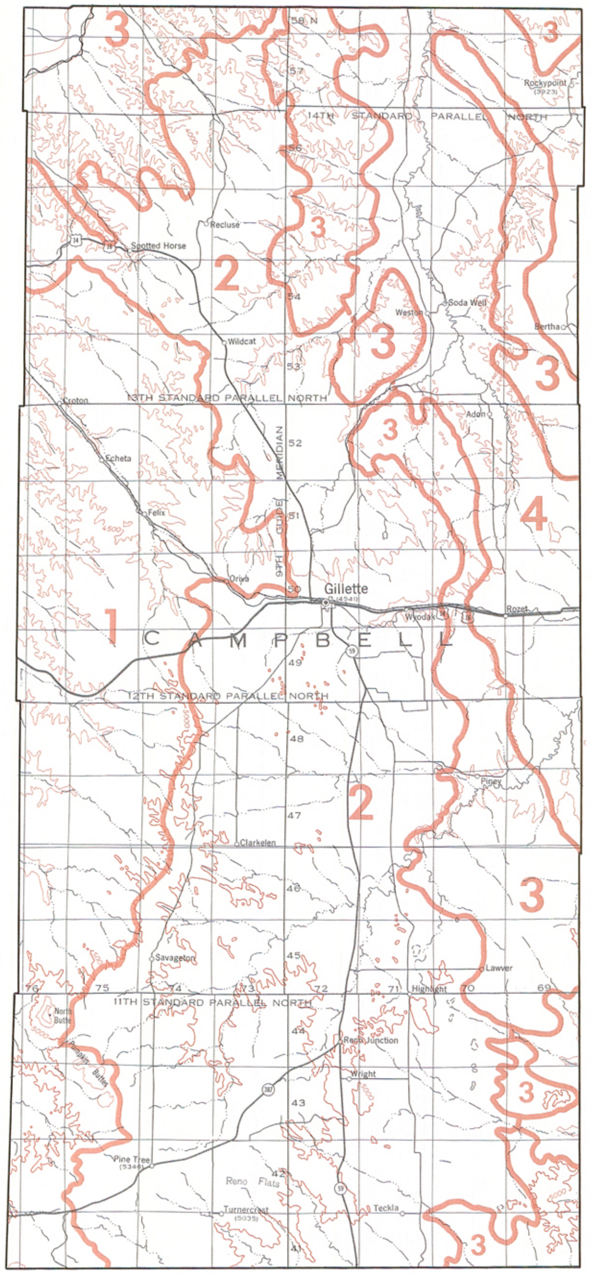
Topography



LEGEND

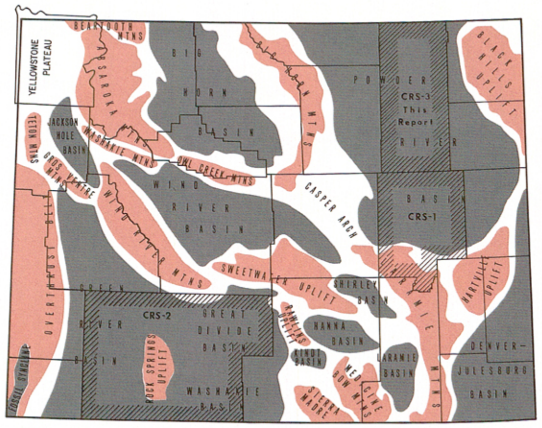
SCALE 1:500,000

0 5 10 MILES / 0 5 10 15 KILOMETERS

1 DISSECTED UPLAND — 2 ROLLING DIVIDE — 3 ESCARPMENTS & BREAKS — 4 EASTWARD-SLOPING PLAIN

TOPOGRAPHIC CONTOUR INTERVAL 500 FEET

From Topographic Map, State of Wyoming, U.S. Geological Survey, 1967.



County Resource Series Index Map

Topographic Features

The deeply buried synclinal structure of the Powder River Basin is not directly reflected in the landscape of Campbell County. The individual topographic features seen here are the result of (1) differences in the erosional characteristics of the flat-lying Tertiary bedrock layers, (2) downward and lateral cutting by streams through rocks of uniform erosional character, and (3) minor subsidence associated with the natural burning of coal seams. The latter phenomenon also has produced many hard, resistant baked rock (scoria) layers and mounds, which have strongly influenced the county's topography.

Four distinct areas differing in average elevation, local relief, and type and style of landforms may be delineated in Campbell County. These areas, outlined on the map to the left are:

1. Dissected Upland. The western one-third of Campbell County is a dissected upland area with extensive badlands and buttes capped by scoria. Prominent topographic features in this area are the Pumpkin Buttes, a line of flat-topped hills capped by the White River Formation.
2. Rolling Divide. The central one-third of the county is characterized by rolling topography, smoother and with less local relief than the areas to the east and west. Numerous red scoria hills ranging in height from 20 to 100 feet are scattered across the divide area.
3. Escarpments. The central divide area is eroded on the east, forming a rough escarpment or "breaks" known locally as the Rochelle Hills. The east-facing escarpment is capped by a layer of erosion-resistant scoria. Escarpment topography is also formed on the Cretaceous age Fox Hills Sandstone which crops out in the northeastern part of the county.
4. Eastward-sloping Plain. The Rochelle Hills escarpment stands 300 to 400 feet above a gently rolling plain. This plain is similar in topographic style to the rolling divide area, but about 400 feet lower in elevation.

Ground elevations in Campbell County range from a low of 3400 feet where the Little Powder River leaves the northern end of the county, to a high of 6060 feet on north Pumpkin Butte.

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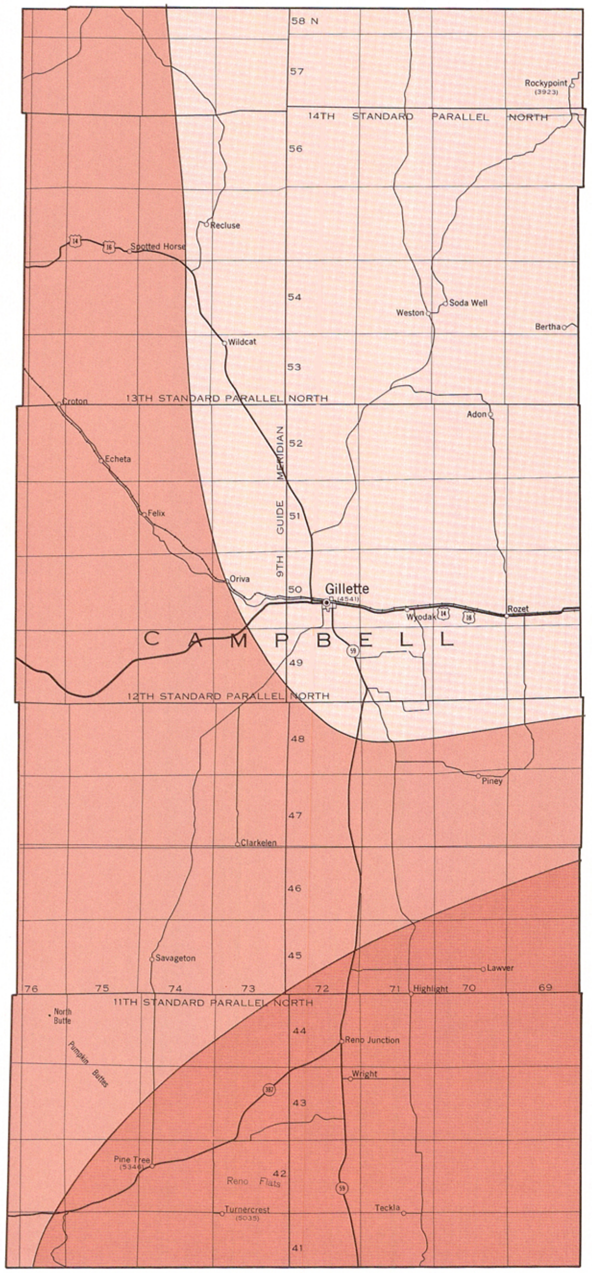
Rolling Divide Much of the county's tillable land is found in a belt of high rolling land in the central part of the county. Hills of red scoria dot this landscape.

Dissected Upland The Pumpkin Buttes, viewed here from the east, form the most prominent topographic features on the dissected upland terrain of western Campbell County.

Rochelle Hills Escarpment and Eastward-sloping Plain
A belt of scrub-forested "breaks", the Rochelle Hills escarpment, separates the rolling divide area on the west from the eastward-sloping plain in the foreground.

Mean Annual Growing Season



LEGEND

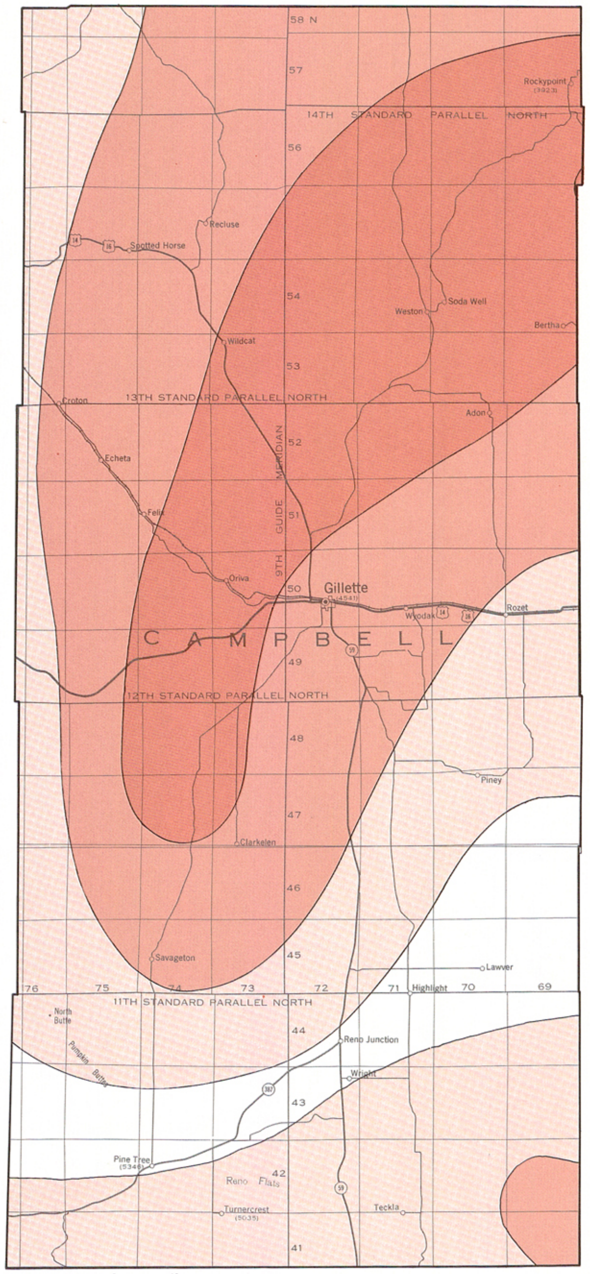
SCALE 1:500,000

0 5 10 MILES / 0 5 10 15 KILOMETERS

100-110 DAYS — 110-120 DAYS — 120-130 DAYS

Taken from map prepared by Wyoming Water Planning Program in cooperation with E.S.S.A. Weather Bureau State Climatologist.

Mean Annual Precipitation



LEGEND

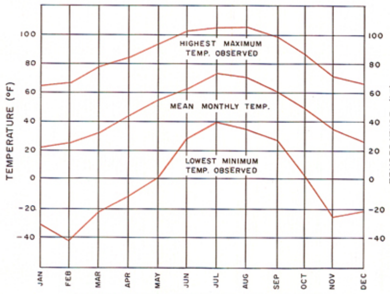
SCALE 1:500,000

0 5 10 MILES / 0 5 10 15 KILOMETERS

Areas which receive 10-12" Total Precipitation Annually. — Areas which receive 12-14" Total Precipitation Annually. — Areas which receive 14-16" Total Precipitation Annually. — Areas which receive 16-18" Total Precipitation Annually.

Taken from map prepared by Water Resources Research Institute, 1974. Base period 1941-1970.

Temperature Observations, Gillette, 1931–1960



Data from Becker, C.F., and Alyea, J.D., 1964, Temperature probabilities in Wyoming: Univ. of Wyo. Ag. Experiment Station Bull. 415.

Climate and Growing Season

Campbell County climate is temperate and semiarid, with wide variations in temperature and precipitation between winter and summer seasons. The county typically has a short growing season, averaging around 120 days between the last spring and first fall freezes. Summer high temperatures range above 90°, but extremely warm temperatures are moderated by cool nights. Coldest winter temperatures occur in January and February.

Average annual precipitation ranges from near 11 inches in the southern part of the county to near 18 inches in the north. More than two-thirds of the annual precipitation falls between March and August of the average year. About one-third of the total annual precipitation comes as snowfall. The average annual snowfall of around 50 inches is well distributed through the winter and spring months, but is heaviest in December.

Prevailing winds in Campbell County are from the northwest, with strongest wind velocities recorded in the spring.

Weather is an important factor in the year to year success of agriculture in Campbell County. Hail storms can cause serious local crop losses in the summer. The extent of insect infestations is partly controlled by the spring weather patterns. Cold, wet springs seem to moderate the severity of grasshopper infestations, which can cause serious crop losses.

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A Brief History of Uranium Mining in Campbell County, Wyoming

The importance of Campbell County to the Wyoming uranium industry does not rest solely in the many small mines operated in the Pumpkin Buttes Mining District between 1953 and 1967. The amount of uranium produced in all these years of production in the District was, in fact, equal only to about one month's output from one of the large uranium mines currently operating elsewhere in the state.

The true importance of Campbell County to the uranium industry of Wyoming lies in the fact that the Pumpkin Buttes deposits were the first of economically minable grade to be located and developed in the state. Also, these deposits, most of which were exposed or very near the surface, provided the kind of close geologic control needed for the development of the geologic models used in exploration and development of the more deeply buried but richer uranium districts discovered later in Wyoming.

The uranium industry of Wyoming began in the Pumpkin Buttes of southwestern Campbell County in October 1951. J. D. Love of the U. S. Geological Survey discovered the ore-grade uranium in the course of a ground check of radioactive areas located earlier by airborne radiometric surveying. By November 1952, U. S. Geological Survey investigators had found over 120 separate localities near the buttes where uranium minerals were visible at the surface. The U. S. Atomic Energy Commission began drilling at some of the larger deposits to determine depth and extent of the ore.

The first commercial production of uranium in Campbell County took place in 1953. The small size and scattered distribution of the high grade, surficial ore bodies in the Pumpkin Buttes District caused a proliferation of small surface mining operations. In all, 55 different mines reported uranium production in Campbell County between the years 1953 and 1967. In those years a total of 36,737 tons of ore containing 208,143 pounds of U_3O_8 were mined.

The average grade of ore mined during the District's history is estimated at .28% U_3O_8. The greatest tonnage of uranium ore was mined in 1960 -- 7,840 tons; however, the greatest amount of U_3O_8 was probably produced in 1957, when even higher grade ores were being mined. The average grade of uranium ore mined in Campbell County decreased from near .50% in the middle 1950's to about .20% in the early 1960's as the higher grade deposits were depleted.

Almost 25% of the total uranium production in Campbell County came from the Blowout-Anomaly 119 ore body in Section 11, T45N R75W. In all, 9,065 tons of uranium ore having an average grade of .32% U_3O_8 were mined from Section 11 between the years 1954 and 1964.

Only the most rudimentary exploration and mining techniques were utilized during the early history of the Pumpkin Buttes Mining District. The many small uranium ore bodies exposed at the surface there were easily located by radiometric surveying, easily delineated, and easily mined.

Drilling was not extensively utilized as an exploration tool, and even when used was carried to very limited depths.

Sophistication in exploration techniques came with better understanding of the geologic processes which produced the ore concentrations. Geologic models which evolved from study of the surficial deposits at Pumpkin Buttes were put to the test by deeper exploratory drilling in the 1960's and proved invaluable as a guide to efficient subsurface uranium exploration both in the Powder River Basin and the other important areas of the state.

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Mrak, V. A., 1968, Uranium deposits in the Eocene sandstones of the Powder River Basin, Wyoming, in Ore Deposits in the United States 1933-1967, American Institute Mining, Metallurgical Engineers, New York, p. 838-848.

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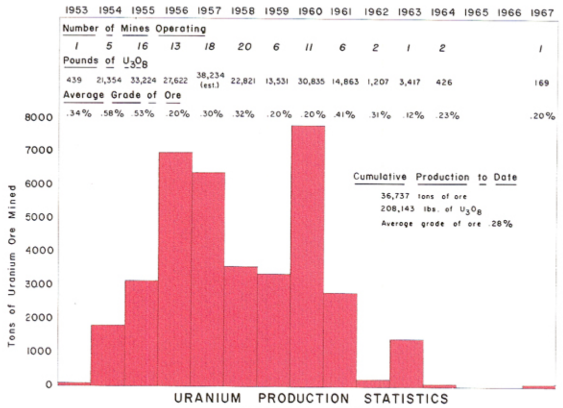
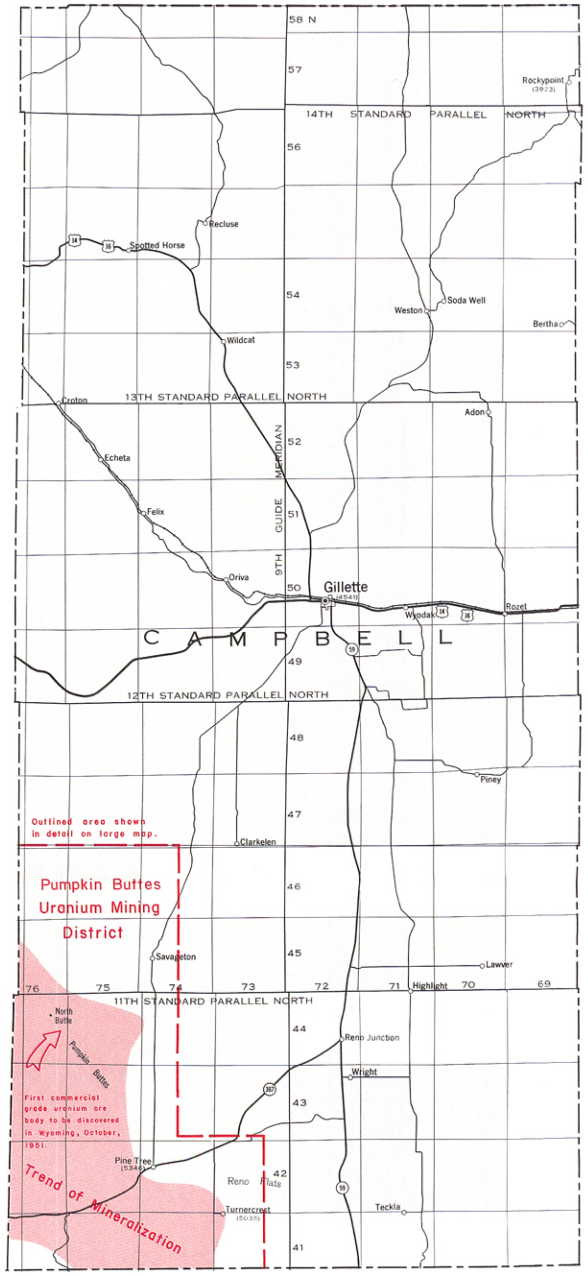
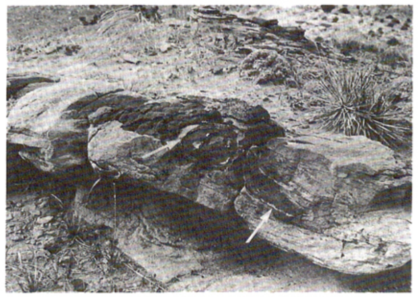


URANIUM PRODUCTION STATISTICS
CAMPBELL COUNTY

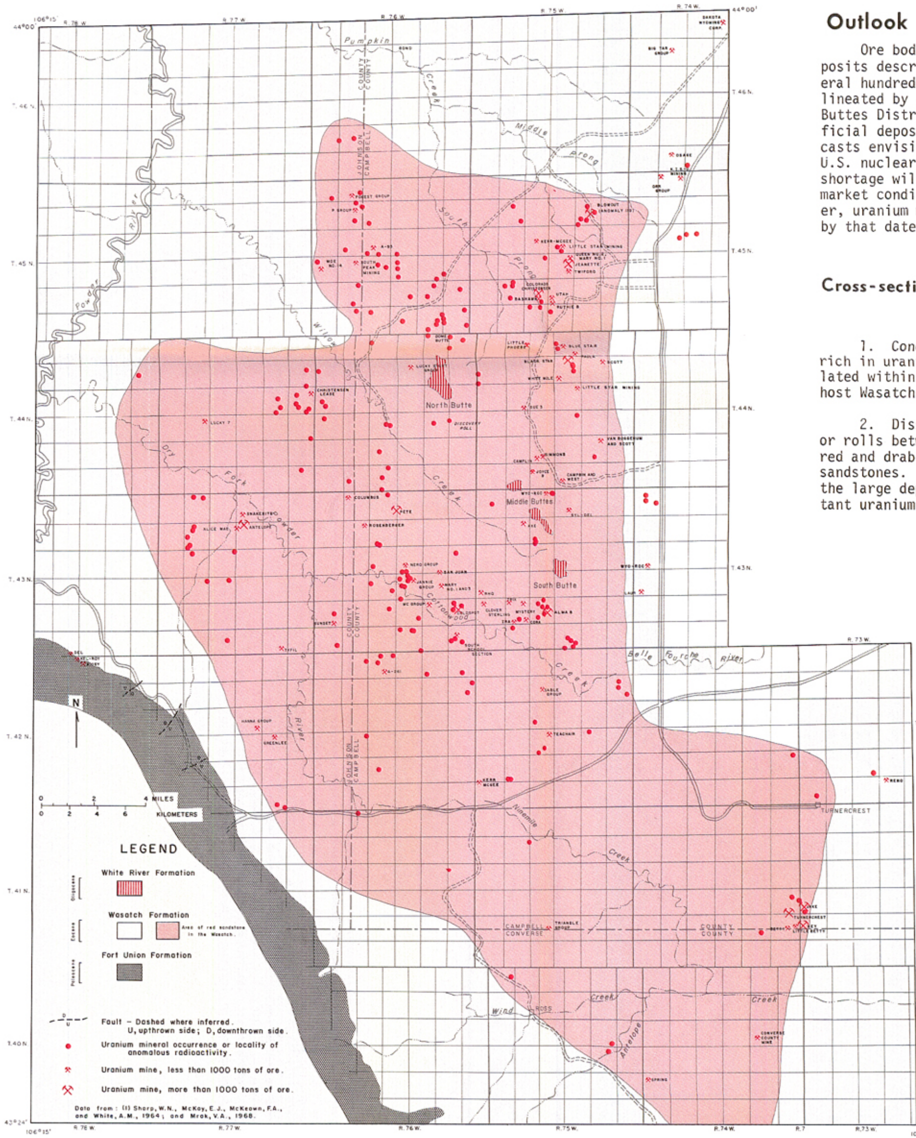


Uranium in Campbell County



Uranium Ore found at Pumpkin Buttes in 1951

The first commercial grade uranium discoveries in Wyoming were made at Pumpkin Buttes in 1951. Arrows point to patches of yellow uranium minerals in the original discovery. Black areas are enriched in manganese as well as uranium minerals. (Photo by J. D. Love, 1951.)



The Pumpkin Buttes Mining District: Campbell, Converse, and Johnson Counties

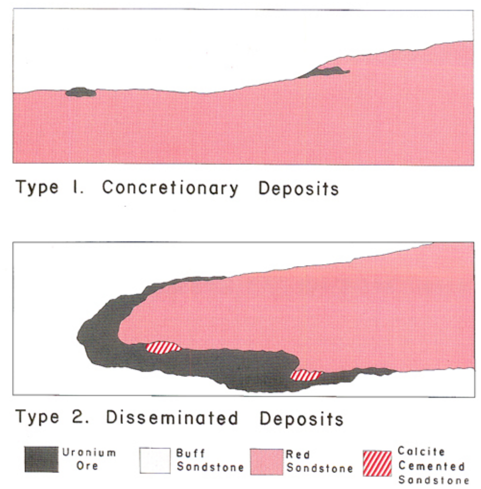
Outlook for Uranium Development

Ore bodies similar to the disseminated deposits described below, but buried beneath several hundred feet of overburden, have been delineated by exploration drilling in the Pumpkin Buttes District since the depletion of the surficial deposits in the 1960's. Current forecasts envision a shortage of fuel for planned U.S. nuclear power plants before 1980. Such a shortage will undoubtedly produce the requisite market conditions for development of new, deeper, uranium mines in the Pumpkin Buttes District by that date.

Cross-sections: Types of Uranium Deposits Found at Pumpkin Buttes

1. Concretionary deposits, small in size, rich in uranium content, generally found isolated within zones of red coloration within the host Wasatch sandstones.

2. Disseminated deposits, found as shells or rolls between interpenetrating tongues of red and drab buff coloration in the host Wasatch sandstones. This type of deposit is similar to the large deposits developed at the other important uranium mining districts in Wyoming.



Modified from Mrak, V.A., 1968.

Characteristics of Pumpkin Buttes Uranium Deposits

The uranium deposits of the Pumpkin Buttes District are found mainly in the sandstones of the Wasatch Formation, which is of Eocene age. The Wasatch Formation in this area is a mixed sequence of coarse and fine sandstones, and interlayered claystones and siltstones, which were deposited in a fluvial (stream valley) environment approximately 40 million years ago. The best host rocks for ore in the Pumpkin Buttes District are bar and channel sandstones. These sandstone bodies outline a complex, ancient drainage system which flowed from south to north, carrying water and sediment from the Laramie Range, the Granite Mountains and the Bighorn Mountains.

The uranium deposits found in the Wasatch sandstones are demonstrably younger than the sandstones themselves. That is, the uranium was not deposited simultaneously with the sand, but was carried in much later in solution (moving ground water). The relationship of the uranium deposits (1) to the geometry of the sandstone bodies in which they are contained, and (2) to zones of oxidation and alteration in the sandstones, have provided the uranium geologist with the evidence needed to formulate a logical theory of origin for the ore bodies.

The uranium deposits of the Pumpkin Buttes District are of two general types. The first type consists of nodules or pods of black and yellow uranium minerals generally found within red or pink sandstones (see cross-section, this page). The deposits observed by Dr. Love in 1951 were of this type, as were the great majority of the deposits designated on the accompanying map of the Pumpkin Buttes District. Most of these small surface deposits were high grade, but of very limited extent. Isolated, high grade pods of this type are not of economic importance, as the tonnages involved will not sustain a large-scale mining and milling operation.

The larger deposits in the Pumpkin Buttes District, such as the Blowout-Anomaly 119 deposit, represent a second distinct type of ore-body. These ore-bodies are generally lower grade than the first type, but are very much larger. Their most important characteristic is that they are located within sandstone at a contact between red or pink coloration on one side and gray, tan, or otherwise drab coloration on the other (see cross-section, this page). Irregularities in this color contact, where the red coloration shows maximum penetration into the drab, are most likely to contain significant uranium deposits.

The disposition of uranium ore bodies at or near the front of the red to pink oxidized zones indicate to the uranium geologist that the metal was carried in solution in oxidizing ground waters downdip through the sandstones to chemically favorable sites of deposition. The uranium ore minerals were emplaced in a shell around the tongue of red sandstone oxidized by the ground water.

The original source of uranium carried by the mineralizing ground water solutions is very much uncertain, but many investigators have concluded that uranium could have been leached in sufficient amount from the tuffaceous White River Formation which once overlay the entire area. Remnants of this blanket of White River Formation are now seen capping the Pumpkin buttes.

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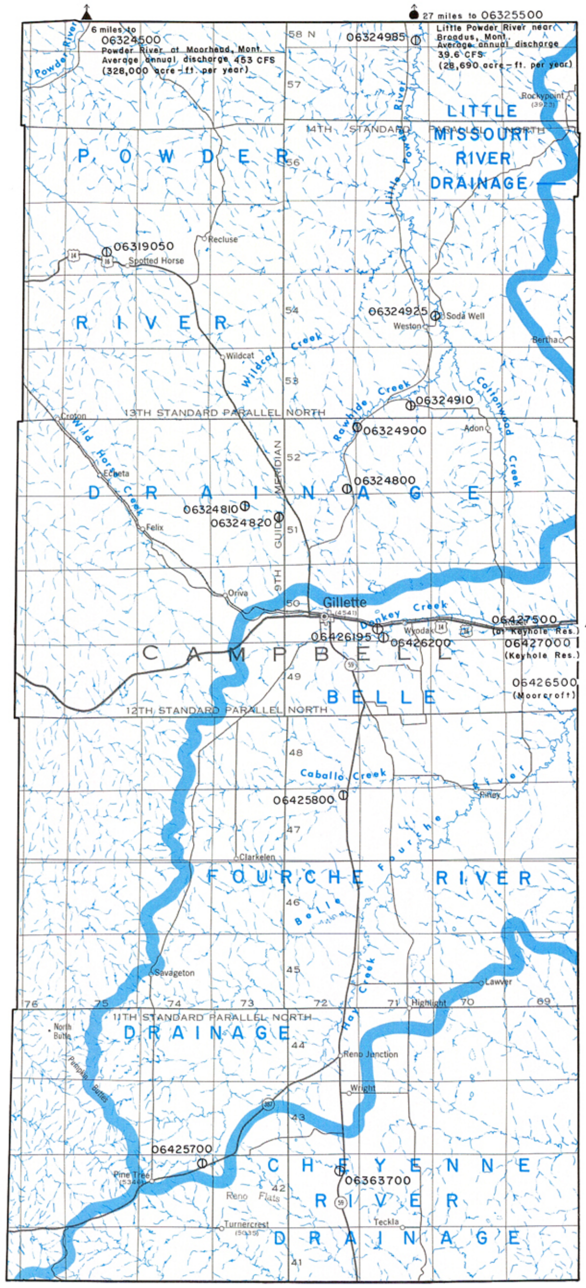


06425700 Station number

Drainage Basin Divide

Chemical quality & stream gaging station (continuous record)

Stream gaging stations (continuous record)

Partial record stations

Miscellaneous site

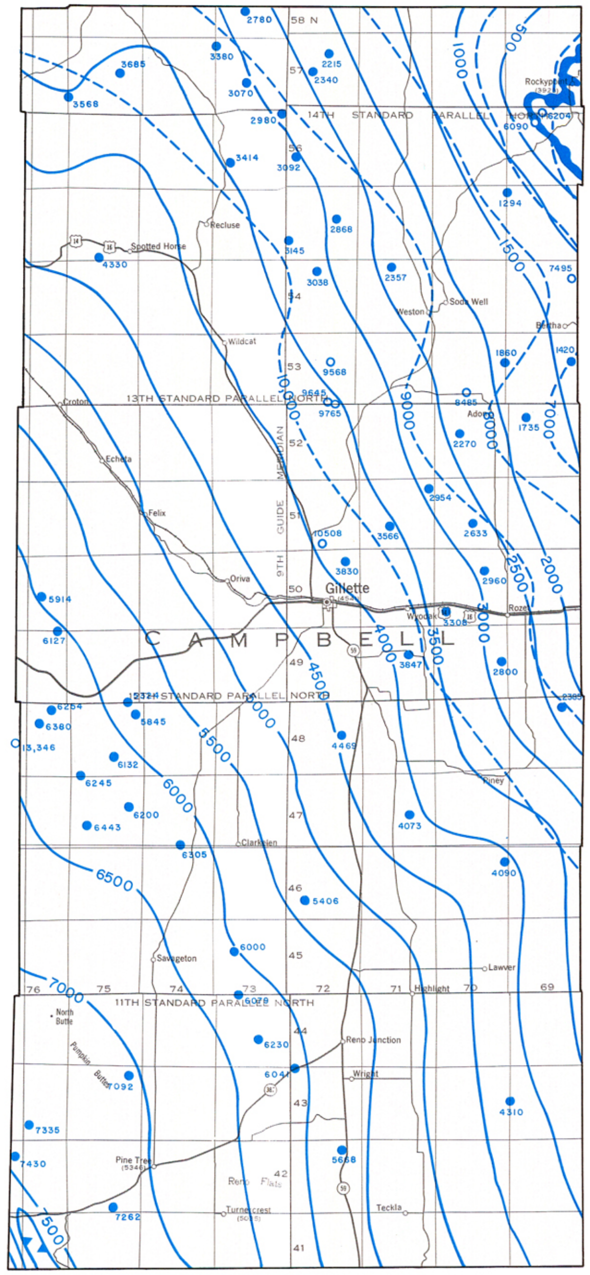
Lake gaging station

Surface Water

Campbell County is located in the central Powder River geologic basin and is drained by the Powder, Little Missouri, Belle Fourche and Cheyenne Rivers, all tributaries of the Missouri River System. Allocation of surface waters in the Belle Fourche and Powder River drainages is controlled by interstate stream compacts while no compact agreements apply to waters of the Cheyenne and Little Missouri drainages.

Campbell County receives an average annual precipitation of 12 to 14 inches which falls mostly as snow or rain during the spring and early summer. Streams originating in the county are mainly ephemeral, flowing only during time of high surface runoff. However, flooding from heavy snowmelt runoff and summer rainstorms has occurred occasionally along most of the major streams. Adequate streamflow data is lacking for most tributaries. Major stream patterns are dendritic and the tributaries have dominantly parallel patterns. Natural chemical quality of the surface waters is related to the mineralogy of the rocks and varies inversely with the discharge.

The dominant use of available surface water is presently agricultural. Numerous small stockwater reservoirs impound water on many of the tributaries. Sparse vegetation and erodable Tertiary rocks result in high suspended stream sediment loads which are a problem in impoundments.



Depth to Madison Limestone - Contour interval 1000 feet

Depth to Fox Hills Formation - Contour interval 500 feet

Outcrop of Fox Hills Formation

Drill Holes: (Depth) Depth to top of Madison Limestone; (Depth) Depth to top of Fox Hills Formation

Ground Water

Groundwater quality and quantity are considered poor in Campbell County. Many of the Powder River Basin aquifers have low permeability and contain unfavorable soluble minerals. Most of the groundwater in Campbell County is produced from sands in the Wasatch, Fort Union, and Fox Hills formations. Other formations are deeply buried in the subsurface and outcrop many miles away on the flanks of the Black Hills Uplift and Bighorn Mountains. Recharge to the aquifers occurs on outcrop from precipitation and surface streams or from subsurface contact with other water-bearing units. Fort Union and Wasatch wells generally produce 10 to 20 gal./min.

Groundwater is predominantly used for livestock and domestic purposes. Very little groundwater is used for irrigation mainly because of the high mineral content. An estimated 8,500 acre feet of formational water was used in 1973 for waterflood in secondary recovery of oilfields in Campbell County. The city of Gillette consumed about 1,000 acre feet of water in 1973 for municipal uses. Energy development in the county has stimulated interest in new water sources. Although the Madison Limestone produces large volumes of water in areas of fracturing and cavernous weathering near the mountains, it is deeply buried in Campbell County and its water productivity characteristics are not well known.

Geologic Formations and Potential Water Supply (major aquifers in blue)

UNIT	LITHOLOGY	GROUNDWATER POSSIBILITIES	WATER QUALITY (dissolved solids in milligrams per liter)
Alluvium	unconsolidated silt, sand, and gravel; underlies flood plains and borders terraces, generally less than 50' thick	fine-grained alluvium usually yields a few gal./min., more in coarser deposits	no dominant type; highly variable dissolved solids
White River Formation	tuffaceous claystone, siltstone with local conglomeratic lenses, isolated remnants on Pumpkin Buttes	very limited due to small outcrop area	mostly sodium bicarbonate
Wasatch Formation	fine- to coarse-grained sandstone with interbedded shale and coal, up to 1575' thick near Pumpkin Buttes	yields water from lenticular sandstones, coal and clinker beds. Generally 10 to 15 gal./min., but may produce several hundred	sodium sulfate and bicarbonate are the dominant water types, ranging from 500 to 1500 mg/1
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/1
Fox Hills Formation	sandstone and sandy shale	yields up to 200 gal./min.; several wells near Rozet used for water flooding	generally soft, less than 1000 mg/1
Lance Formation	sandstone and interbedded sandy shale and claystone	generally less than 20 gal./min.	500 to 1500 mg/1 no dominant type prevalent
Pierre Shale, Niobrara Formation, Carlile Shale, Greenhorn Formation, Belle Fourche Shale, Mowry Shale, Thermopolis Shale	predominantly shales with only local sandstone lenses	maximum yields are minor; most of section not water bearing	greater than 1000 mg/1 mostly sodium sulfate type
Inyan Kara Group	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/1
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/1
Gypsum Springs Formation	massive white gypsum, red claystone and gray limestone	only minor quantities from solution cavities	greater than 1000 mg/1 calcium sulfate
Chugwater - Goose Egg and equivalent rocks	shale, gypsum and thin-bedded limestone	small yields less than 20 gal./min.	calcium sulfate dominant; 500 to 3000 mg/1; locally Goose Egg and Spearfish sodium chloride waters
Minnelusa Formation	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, Guernsey Formation, Pahasapa Limestone	limestone and minor dolomites	yields of more than 1000 gal./min. are possible in areas of fracturing and cavernous weathering	mostly calcium bicarbonates; quality varies with depth
Bighorn and Whitewood Dolomites, Winnipeg, Deadwood, Gallatin, and Gros Ventre Formations and 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	too deeply buried	usually calcium carbonate

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

Major Chemical Constituents of Campbell County Waters

CONSTITUENT	EFFECT UPON USABILITY OF WATER	MAXIMUM mg/1 FOR DRINKING WATER
Calcium (Ca) Magnesium (Mg)	Calcium and magnesium combine with bicarbonate, carbonate, sulfate, and silica to form heat-retarding, pipe-clogging scale in boilers and in other heat-exchange equipment. Calcium and magnesium combine with ions of fatty acid in soaps to form soap suds; the more calcium and magnesium, the more soap required to form suds. A high concentration of magnesium has a laxative effect, especially on new users of the supply.	250 total
Sodium (Na) Potassium (K)	More than 50 mg/1 sodium and potassium in the presence of suspended matter causes foaming, which accelerates scale formation and corrosion in boilers. Sodium and potassium carbonate in recirculating cooling water can cause deterioration of wood in cooling towers.	
Carbonate (CO_3) Bicarbonate (HCO_3)	Upon heating, bicarbonate is changed into steam, carbon dioxide, and carbonate. The carbonate combines with alkaline earths -- principally calcium and magnesium -- to form a crustlike scale of calcium carbonate that retards flow of heat through pipe walls and restricts flow of fluids in pipes. Waters containing large amounts of bicarbonate are alkaline and undesirable in many industries.	not set
Sulfate (SO_4)	Sulfate combines with calcium to form an adherent, heat-retarding scale. More than 250 mg/1 is objectionable in water in some industries. Water containing about 500 mg/1 of sulfate tastes bitter; water containing about 1000 mg/1 may be cathartic.	250
Chloride (Cl)	Chloride in excess of 100 mg/1 imparts a salty taste. Concentrations greatly in excess of 100 mg/1 may cause physiological damage. Some industries desire less than 100 mg/1.	250
Total Dissolved Solids (TDS)	More than 500 mg/1 is undesirable for drinking and many industrial uses. Dissolved solids cause foaming in steam boilers; the maximum permissible content decreases with increases in operating pressure.	500

LIVESTOCK USE

Suitabilities for livestock use depend upon individual constituents, but a general classification has been proposed:

Dissolved solids (mg/1)	Classification
less than 1,000	good
1,000 to 3,000	fair
3,000 to 5,000	poor
5,000 to 7,000	very poor
more than 7,000	not advisable

SOURCES:

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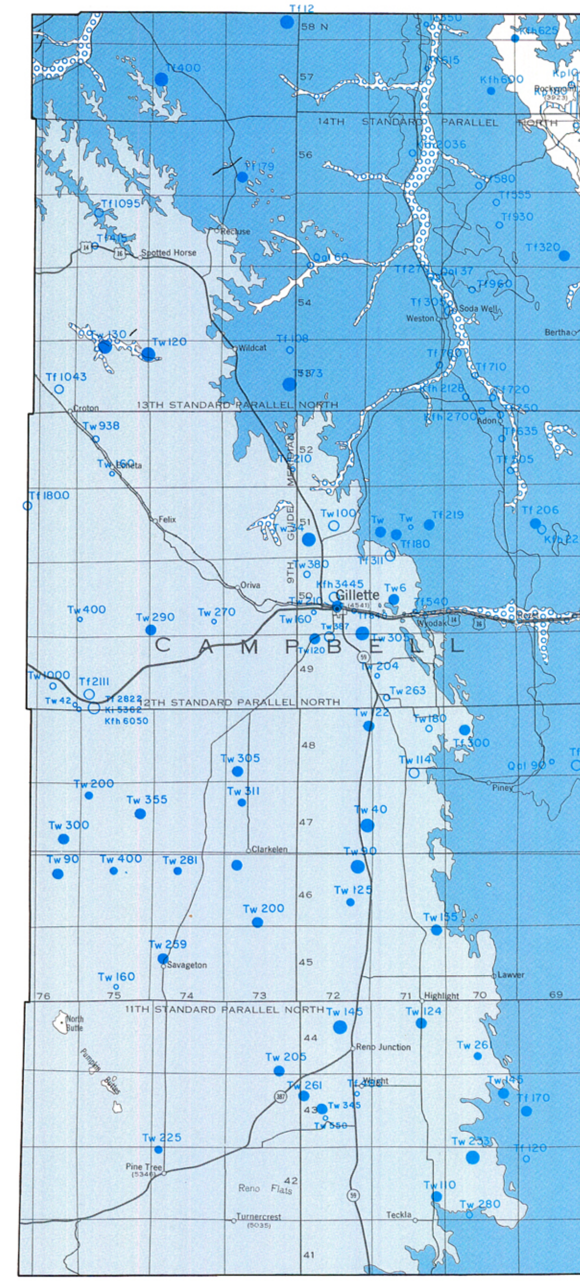

'Soft' water (dominently sodium bicarbonate) · 'Hard' water (dominently calcium sulfate)

Less than 500ppm total dissolved solids

500 - 1000ppm total dissolved solids

1000 - 2000ppm total dissolved solids

Greater than 2000ppm total dissolved solids

Kfh 350 Geologic source of water (see stratigraphic column to left) and depth of well in feet.

Surface Outcrop of Shallow Aquifers

Alluvium · Wasatch Fm. · Fort Union Formation · Fox Hills Formation

Water quality data from U.S. Geological Survey, HA 465.

Water Quality

Few municipal, domestic, agricultural, or industrial uses do not require some restrictions on water quality. Water quality is determined by the rocks which the water contacts. In general, the quality of groundwater deteriorates with lower streamflows. Tertiary and Upper Cretaceous waters are of two types: alkali-carbonate (soft) and alkaline-earth-sulfate (hard). "Soft" waters are generally less toxic and can be treated easier than "hard" waters.

WYOMING GEOLOGICAL SURVEY, 1974