ENVIRONMENTAL / CRS 6, Natrona County, Wyoming

Compiled by R.H. De Bruin and R.L. Oliver

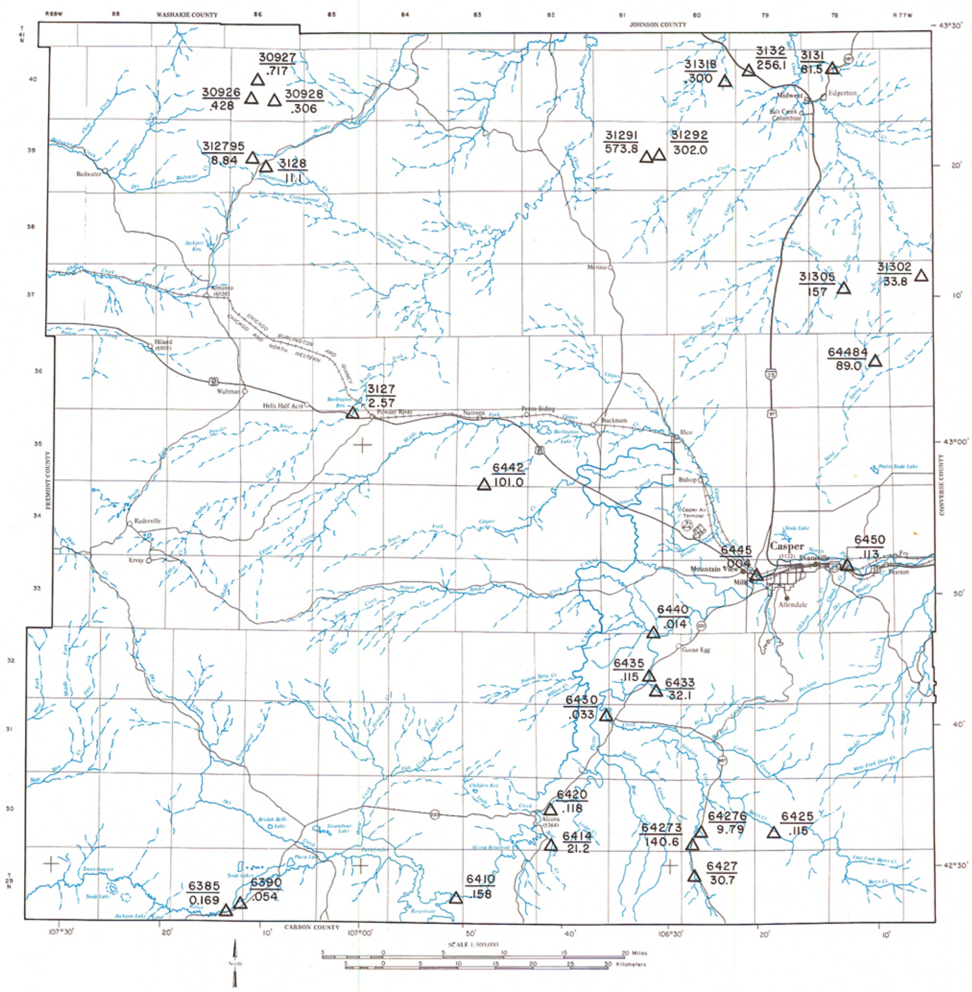
SURFACE WATER

EXPLANATION

△ 3170 / 0.045

Active stream guaging station.

The upper number identifies the station; the lower number is average annual runoff, at the station, expressed in cubic feet per second per square mile of drainage area.



Development of sand areas such as this one northeast of Casper could cause problems for residents. Areas stripped of stabilizing vegetation for excavation purposes could turn into areas similar to the one shown in the lower righthand photo. →

← Most of Casper's water supply is derived directly from the North Platte River or indirectly from alluvial deposits recharged by the river. The North Platte has played a vital part in Casper's growth; however, development projects which utilize the river's flood plain should be undertaken with a great deal of caution.

Sand deposits that have been semi-stabilized may be highly susceptible to erosion when disturbed. →

SURFACE WATER

Parts of three principal drainage basins are included in Natrona County. These basins are the Wind River drainage, the Powder River drainage, and the North Platte River drainage. All three of these drainages are part of the Missouri River drainage. In addition to the three principal drainages, about 3 square miles in the extreme northeastern part of the county are part of the Cheyenne River drainage.

The North Platte River is the main stream in Natrona County and drains nearly all of the south half of the county. Flow in the North Platte is regulated by Pathfinder and Alcova Dams in Natrona County and by Seminoe and Kortes Dams in Carbon County. The major tributary of the North Platte River in Natrona County is the Sweetwater River. Several small creeks, of which Poison Spider Creek, Casper Creek, Bates Creek, and Poison Spring Creek are the main ones, flow into the North Platte River between Alcova Dam and the county line.

The South Fork of the Powder River drains the north-central part of Natrona County. Both Willow Creek and Buffalo Creek drain into the South Fork of the Powder River north of the county line. Salt Creek drains the northeastern part of the county and is perennial north of Salt Creek oil field because water produced in the oil field is discharged into the creek. Salt Creek joins the Powder River north of the county line.

Badwater Creek is the only major stream in Natrona County that belongs to the Wind River drainage. Several other small creeks flow into the Bighorn River. The Wind River and the Bighorn River are the same; the name changes from Wind River to Bighorn River where the stream enters the Bighorn Basin (Crist and Lowry, 1972). Most of the streams and reservoirs described above can be located on the LANDSAT sheet or on the Surface Water Map on this sheet.

CLIMATE AND PRECIPITATION

Natrona County has a temperate, semi-arid climate. Average precipitation varies from less than 7 inches in the west-central portion of the county to almost 32 inches on Casper Mountain. Casper Mountain is an anomalous area since the highest average for any part of the rest of the county is only 14 inches. Precipitation for the county is generally not enough for dry-land farming, and irrigation is necessary for most crops. Usually more than 50 percent of the annual precipitation occurs in the months of April through July.

Mean and Extreme Temperatures (°F)
Casper Airport for the 48 Year Period, 1931-1978

	Mean Daily Maximum Temp.	Mean Daily Minimum Temp.	Monthly Mean Temp.	Record Highest Temp.	Record Lowest Temp.
Jan.	33	14	23	57	–40
Feb.	37	16	27	65	–22
Már.	42	20	31	73	–16
Apr.	55	31	43	81	– 3
May	66	40	53	89	16
Jun.	76	48	62	101	28
Jul.	86	56	71	104	39
Aug.	84	55	70	98	36
Sep.	76	47	62	95	15
Oct.	61	35	48	85	12
Nov.	44	24	34	68	–20
Dec.	36	17	26	65	–18
Year	58	34	46	104	–40

May receives the greatest precipitation and January receives the least.

Winter and summer temperatures vary widely due primarily to high elevation and dry air which permit the passage of warm and cold air masses and rapid incoming and outgoing radiation. The table shows examples of these varying temperatures at the Casper Airport for the 48 year period, 1931-1978.

The growing season in Natrona County varies from 120 to 130 days; however, for many crops, lack of precipitation may be more a limiting factor than length of growing season.

During the winter, air inversions tend to form along the north side of Casper Mountain and the Laramie Range. These inversions result in smog along Casper Mountain; they occur on calm days and usually dissipate when the wind increases in velocity (Coleman, 1979).

Southwest and west-southwest winds are the most common in Natrona County with average windspeed at the Casper Airport of around 13 miles per hour. Wind gusts greater than 50 miles per hour are occasionally recorded; 81 mile-per-hour gusts were reported in March 1956.

GEOLOGIC HAZARDS

With the tremendous growth Casper has experienced in the past few years (1979 population estimated at 75,000), there has been a tendency to develop most land in the vicinity of Casper. Development is now going on in areas with sand dunes as well as in areas with shrinking and swelling soils potential.

Shrinking and Swelling Soils

Volume changes from hydrating and dehydrating clays may cause extensive damage to buildings, patios, driveways, basement floors, highways, and buried utility and service lines.

Much of Casper and the surrounding area is underlain by rocks of Cretaceous age. Many of these units contain beds of bentonite (a clay produced by the alteration of volcanic ash in place, largely composed of smectite clay minerals that are generally highly colloidal and plastic) which cause most of the shrink-swell problem. Sometimes, development in areas that have shrink-swell potential cannot be avoided; in those instances, foundations should be designed and inspected by a registered professional engineer specializing in soil and foundation engineering. Interiors should also be designed to minimize shrink-swell effects. Two other factors which must be considered are proper drainage and landscaping. Water must not be allowed to stand near foundations, watering should not be done closer than 5 feet from the foundation, and all trees should be planted 15 feet from any building to control moisture loss. Large water-loving trees such as cottonwood, willow, and Russian olive should be at least 20 feet away. If construction is planned for an area that is suspected of having shrink-swell potential, it is important that a soils engineer be consulted and that the architect be made aware of any expansive soil problems. When looking at an existing house, a prospective buyer should look for signs of movement such as cracks in floors, driveways, sidewalks, and walls. Some badly damaged homes have been repaired on the outside and paneled on the inside to hide damage. If the prospective buyer suspects anything, a professional engineer or home inspection consultant should be hired before a contract is signed (Holtz and Hart, 1978).

Windblown Sand

Houses, such as the one in the top picture on the right, are being built in the windblown sand area northeast of Casper. The bottom picture on the right shows what can happen once the stabilizing vegetation has been stripped away: the sand is free to be moved by the wind, and in this case is covering the fence and moving onto the road.

Another problem associated with building on windblown sand is that this material may be subject to settlement or hydrocompaction when water is allowed to saturate the deposits. The thickness of windblown material may be variable and bedrock with high swell potential may locally be fairly close to the surface.

Earthquakes

Casper has experienced four tremors in the past 86 years. The first occurred on June 25, 1894 and according to an account in the December 11, 1942 Casper Tribune-Herald, dishes were knocked to the floor and several people were thrown out of bed. The water in the North Platte changed to a reddish hue and became thick with mud. The second and most violent earthquake was on November 14, 1897. The northeast corner of the Grand Central hotel was rent by a crack two to four inches wide, extending from the third to the first floor. The third shock occurred on October 25, 1922. It lasted only about one-half second and caused no damage. The last earthquake to affect Casper was on December 11, 1942. It rattled dishes and pans all over Casper, but did little damage.

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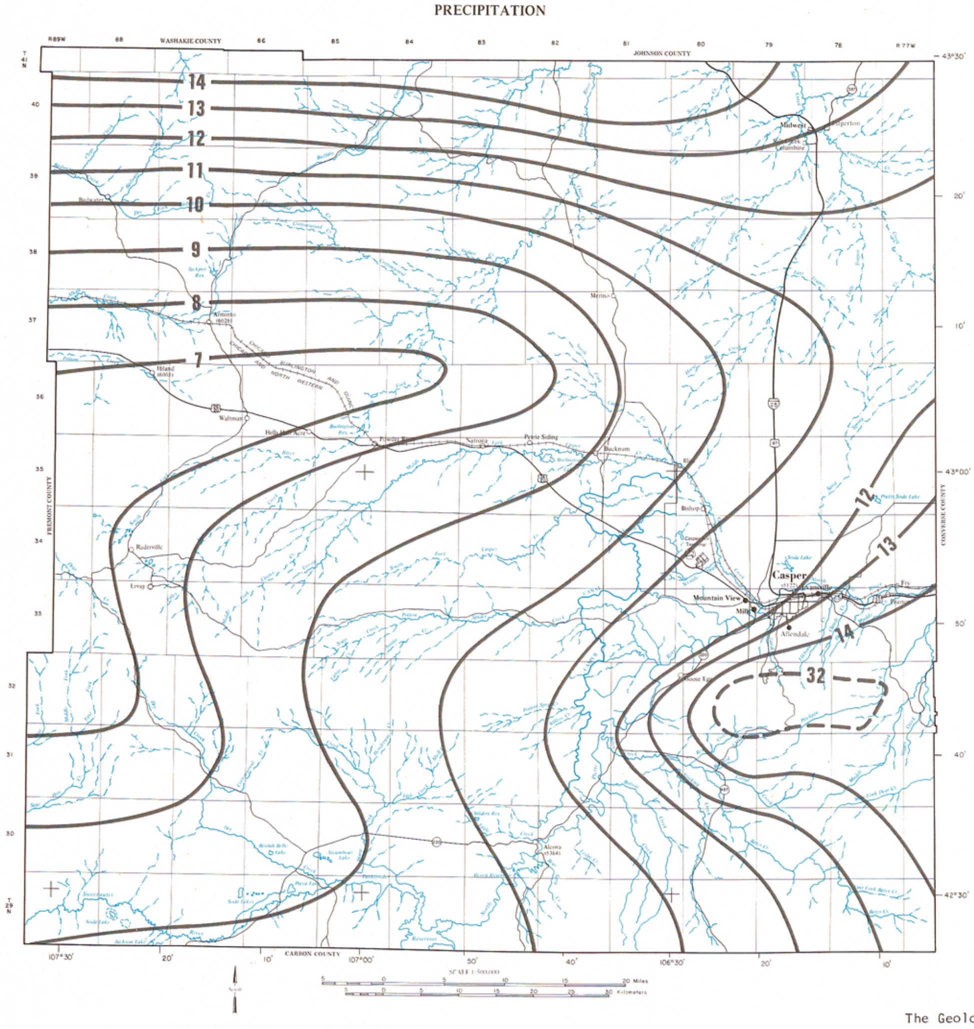
PRECIPITATION



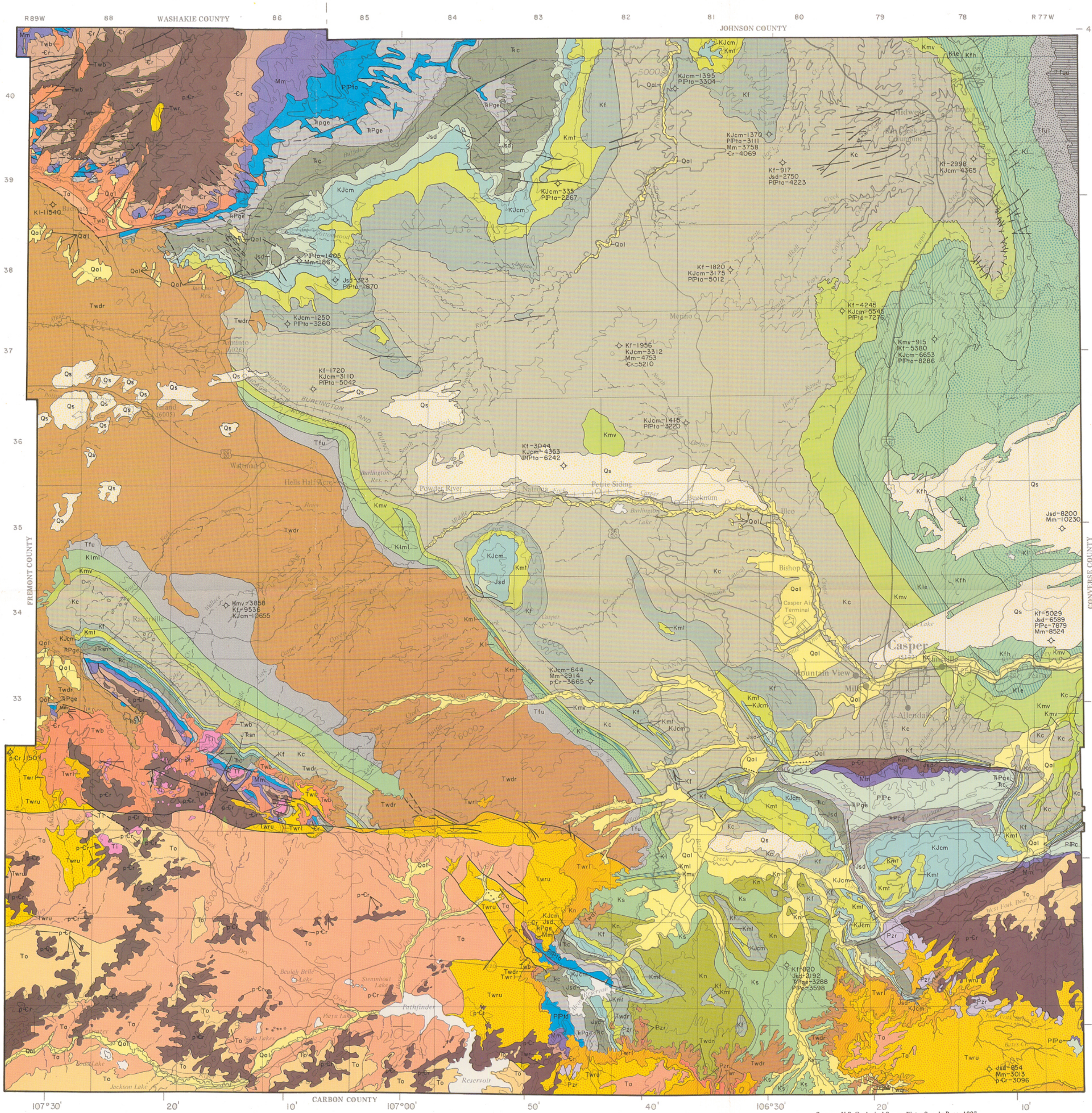
EXPLANATION

Contours represent average precipitation received in one year, in inches. It should be noted that these contours are based on regional trends, and local variations may exist. The contour interval is one inch except for the one large anomaly shown for the Casper Mountain area: the extent of this 32-inch contour is not accurately known; therefore, it is dashed.

The Geological Survey of Wyoming, 1980

GEOLOGY / CRS 6, Natrona County, Wyoming

Sheet compiled by D.R. Lageson



SCALE 1:250,000

5 0 5 10 15 20 Miles

5 0 5 10 15 20 25 30 Kilometers

CONTOUR INTERVAL 500 FEET

North

Source: U.S. Geological Survey Water-Supply Paper 1897.

EXPLANATION

QUATERNARY

Holocene

Qal Alluvial deposits. *Unconsolidated silt, sand, and gravel.*

Qs Windblown deposits. *Unconsolidated sand.*

TERTIARY

Upper Miocene and Pliocene

To Ogallala Formation. *Heterogeneous deposits of silt, sand, and gravel; may be unconsolidated or well cemented. In some areas, may include thin deposits of sand and gravel of Pleistocene age, which on lithologic criteria cannot be separated from the Ogallala Formation.*

Lower Miocene

Ta Arikaree Formation. *Light-gray sandstone, fine- to medium-grained; contains some thin beds of limestone, tuff, and conglomerate.*

Oligocene

Twr (**Twru**, **Twrl**) White River Formation. Twru, *upper member is predominantly sandstone and conglomerate.* Twrl, *lower member is pinkish-gray siltstone containing minor conglomerate lenses.*

Middle and upper Eocene

Twb Wagon Bed Formation. *Bentonitic mudstone, sandstone, and conglomerate.*

Ti Intrusive and extrusive rocks.

Lower Eocene

Twdr Wind River Formation. *Variegated claystone and shale, brown and gray sandstone, and lenticular conglomerate.*

Paleocene

Tfu (**Tfuu**, **Tful**) Fort Union Formation. *Wind River Basin: Shotgun Member consists of very fine-grained sandstone and siltstone; Waltman Shale Member consists of silty and shaly claystone with a few thin beds of sandstone; unnamed lower member consists of fine- to coarse-grained sandstone, very fine-grained sandstone, and siltstone. Powder River Basin:* Tfuu, *upper member consists of sandstone, siltstone, carbonaceous shale, and coal;* Tful, *lower member consists of claystone and siltstone interbedded with sandstone; carbonaceous material less abundant.*

CRETACEOUS

Upper Cretaceous

Kl Lance Formation. *Brown and gray sandstone and shale; thin coal and carbonaceous shale beds.*

Kfh Fox Hills Sandstone. *Light-colored sandstone and gray sandy shale.*

Kle Lewis Shale. *Gray sandy shale and lenticular sandstone.*

Kml Meeteetse Formation and Lewis Shale. *Meeteetse Formation consists of gray carbonaceous shale interbedded with sandstone and thin coal beds.*

Klml Lance, Lewis, and Meeteetse Formations

Kmv Mesaverde Formation. *Gray and brown massive to thin-bedded sandstone, and carbonaceous shale and coal beds; Teapot Sandstone Member at top; unnamed middle member; Parkman Sandstone Member at base.*

Ks Steele Shale. *Gray shale with numerous bentonite beds and thick lenticular sandstones.*

Kn Niobrara Formation. *Light-gray limestone and gray to yellow, speckled limy shale.*

Kc Cody Shale. *Gray soft shale and lenticular sandstone beds; gray limy shale at base; Sussex Sandstone Member about 400 feet above Shannon Sandstone Member; Shannon Sandstone Member about 2,000 feet above base.*

Kf Frontier Formation. *Gray thick sandstone beds in upper part; lower part contains black shale and white bentonite interbedded with sandstone.*

Lower Cretaceous

Kmt Mowry and Thermopolis Shales. *Mowry Shale is black and gray, weathers silvery gray, is hard, contains thin bentonite beds. Thermopolis Shale is black and soft; Muddy Sandstone Member 150-250 feet above base.*

KJcm Cloverly and Morrison Formations. *Cloverly Formation is light-gray sandstone and lenticular conglomerate interbedded with variegated bentonitic claystone; Morrison Formation is variegated claystone and gray silty sandstone lenses.*

JURASSIC

Upper Jurassic

Jsd Sundance Formation. *Olive-gray shale and sandstone; persistent thin-bedded sandstone at base.*

TRIASSIC(?)

Upper Triassic(?)

JTRsn Sundance Formation and Bell Springs Member of Nugget Sandstone. *Triassic(?) Bell Springs Member consists of very fine-grained sandstone and pale red siltstone beds.*

TRIASSIC

TRc Chugwater Group. *Includes: Jelm Formation at top is red sandstone and siltstone; Alcova Limestone in middle is gray laminated limestone; and Red Peak Formation at base is red shale and siltstone.*

PERMIAN

TRPge Goose Egg Formation. *Red shale, gray dolomite and limestone, and anhydrite and gypsum beds.*

TRPcg Chugwater Group and Goose Egg Formation.

PENNSYLVANIAN

PPta Tensleep Sandstone and Amsden Formation. *Massive tan clean sandstone underlain by thin-bedded cherty dolomite and limestone and red shale; red to gray sandstone at base may be the Upper Mississippian Darwin Sandstone Member.*

PPc Casper Formation. *Gray and tan thick-bedded sandstone underlain by interbedded sandstone, pink and gray limestone and dolomite, and red shale; red to gray sandstone at base.*

Pzr Paleozoic rocks. *Casper, Tensleep, Amsden, and Madison Formations, and Cambrian rocks, undivided.*

MISSISSIPPIAN

Mm Madison Limestone. *Gray massive cavernous cherty limestone and dolomite.*

CAMBRIAN

€r Cambrian rocks. *Thin glauconitic shale interbedded with limy shale in upper part; dull pink quartzite and sandstone in lower part.*

PRECAMBRIAN

p€r Precambrian igneous and metamorphic rocks.

Contact
Dashed where approximately located

Fault
Dashed where approximately located; dotted where concealed. U, upthrown side; D, downthrown side

A—A' Location of section

Oil test
Number is depth to top of selected geologic map unit, in feet below land surface. Data from Petroleum Information completion cards

The Geological Survey of Wyoming, 1980

LANDSAT IMAGE / CRS 6, Natrona County, Wyoming

Sheet compiled by R.H. DeBruin and D.R. Lageson

North

SCALE 1:250,000

5 0 5 10 15 20 Miles

5 0 5 10 15 20 25 30 Kilometers

SUMMARY OF NATRONA COUNTY GEOLOGY

The NASA LANDSAT II composite satellite image, taken from an altitude of 565 miles or 900 kilometers on July 4, 1978, shows the major geological and cultural features of Natrona County. This image should be used as a comparative base map with other sheets in this report. Most conspicuous on the image are topographically high areas such as Casper and Muddy Mountains, the reservoirs in the south-central part of Natrona County, and the cultural features associated with Casper.

Parts of six major geological structures of the Wyoming foreland extend into or are contained within Natrona County. These are 1) Granite Mountains, 2) southeast part of the Wind River Basin, 3) southern Bighorn Mountains, 4) Casper Arch, 5) Powder River Basin, and 6) northern Laramie Range. Each structural terrane has unique physiographic and geologic characteristics; combined, they make Natrona County one of the most interesting areas of the State.

The Granite Mountains extend into the southwest corner of Natrona County. Precambrian rocks of the Granite Mountains include Archean intrusive granites (2600-2500 million years old), metasedimentary, and metavolcanic rocks (Karlstrom, 1979). Late Precambrian mafic dikes cross-cut the older Precambrian rocks and form conspicuous blank bands, many of which may be seen near Pathfinder Reservoir. The Precambrian rocks are discomformably overlain in the central part of the Granite Mountains by the Miocene Split Rock Formation (silty and clayey sandstone) and the Pliocene Moonstone Formation (tuffaceous clastics of lacustrine origin). The Granite Mountains are unique in Wyoming because they remain partly covered by Cenozoic sedimentary rocks, whereas other ranges have been almost entirely exhumed (Love, 1970). The Granite Mountains thus possess a late Tertiary (Pliocene) aspect to their topography and appearance. This is possible because the entire central part of the Granite Mountains was down-dropped more than 2,000 feet during Pliocene time along the north and south Granite Mountains fault system (Love, 1970). Other features of interest in the Granite Mountains include the Rattlesnake Hills and associated volcanic field (middle and late Eocene peraluminous alkaline and calcalkaline volcanic rock suite; Pekarek, 1978), and the Gas Hills uranium district.

The southeast part of the Wind River Basin projects into western Natrona County. The Wind River Basin formed approximately 50 to 60 million years ago as a result of differential crustal motion during the mountain and basin-building episode called the Laramide orogeny. The lighter shades of the lower Eocene Wind River Formation are clearly visible on the LANDSAT image. This part of the basin is flanked on the southwest by the Rattlesnake Hills and on the northeast by the Casper Arch. Oil saturated sandstones in the Mesaverde Formation and oil seeps associated with the Muddy Formation along the southwest flank of the Wind River Basin are famous; the oil seeps were exploited during the 1800's for lubrication of wagon axles. Of special interest in western Natrona County are Hell's Half Acre, where badlands are carved out of the Lysite Member of the Wind River Formation, and the Waltman oil and gas field, where deep production in excess of 20,000 feet has recently been developed from the Muddy, Lakota, Morrison, and Sundance Formations (Petroleum Information, 1979).

The southern Bighorn Mountains lie in the northwest corner of Natrona County. The bedrock consists largely of Archean orthogneiss and paragneiss (Karlstrom, 1979). As shown on the geology plate, strata ranging in age from Cambrian through Cretaceous dip southeast off the east and southeast flanks of the Bighorn uplift, while the south and southwest flanks are characterized by complex faulting. The direction of upthrusting or asymmetry for this part of the Bighorn Range is toward the northwest, as evidenced by a large reverse fault extending north of Natrona County into Washakie County.

The Casper Arch is a large asymmetric anticline which structurally connects the northern Laramie Range with the southern Bighorn Mountains. The arch is flanked to the southwest by the Wind River Basin and to the northeast by the Powder River Basin. The darker shades of the Cretaceous Cody Formation are evident on the LANDSAT image over a large part of the arch. Oil fields that prominently show on the LANDSAT image include Pine Mountain, Tisdale Dome, Salt Creek, and Teapot Dome. Pine Mountain is a relatively small field with only six producing wells. The producing part of Tisdale Dome lies in Johnson County and is discussed in CRS-4 (1976) of the Geological Survey of Wyoming. The greater Salt Creek oil field has produced in excess of 583,000,000 bbls of oil and 71,900,000 Mcf of gas since its discovery in 1889. The greater Teapot Dome field, famous for the political scandal of the early 1920's, has produced in excess of 12,236,000 bbls of oil and 1,250,000 Mcf of gas since 1922 (Wyoming Oil and Gas Conservation Commission, 1978; current to December, 1978).

The City of Casper lies at the south end of the Casper Arch. As seen on the LANDSAT image, the city and outlying areas have developed largely along the North Platte River and Casper Creek. The city and adjacent suburbs are built on alluvial sediment along the North Platte River and on the Cretaceous Cody Shale. The various geologic hazards associated with the Casper area are discussed on the environmental geology sheet in this report.

A very small part of the Powder River Basin covers the northeast and east parts of Natrona County. The Powder River Basin is similar to the Wind River Basin in that it formed by differential crustal movements 50 to 60 million years ago. The Powder River Basin covers most of northeast Wyoming and contains immense quantities of oil and gas, coal, and uranium. The reader is referred to CRS-3, 4, and 5 of the Geological Survey of Wyoming for information on the mineral resources of the Powder River Basin.

The Laramie Range and adjacent Bates Hole are in the southeast corner of Natrona County. The Laramie Range is the northern extension of the Colorado Front Range; its northern terminus is Casper Mountain. The Laramie Range may be divided into two terranes of differing Precambrian rock type. South of Sybille Creek and Morton's Pass (in Albany County), the range is composed of a large anorthosite intrusive complex, volcanogenic gneiss (1900-1600 million years old), and intrusive granites (1800-1400 million years old; Karlstrom, 1979). The Laramie Range north of Sybille Creek, including Casper Mountain, is composed of Archean orthogneiss and paragneiss (3200-2600 million years old), intrusive granites (2600-2500) million years old), and metasedimentary and metavolcanic rocks (Karlstrom, 1979). Mining operations on Casper Mountain have extracted copper, feldspar, beryl, and asbestos. Bentonite has been mined from Cretaceous shales at various localities around Casper Mountain. The reader is referred to the mineral & uranium sheets in this report for information on the history and development of mineral commodities on Casper Mountain and Natrona County in general.

Bates Hole is a topographic depression at the north end of the Shirley Basin that has been carved from Tertiary and Cretaceous strata by Stinking Creek. The stratigraphic succession, in descending order from the Shirley Rim to the floor of Bates Hole, includes the Miocene Arikaree Formation, Oligocene White River Formation, Eocene Wind River Formation, and the Cretaceous Steele Shale. The badlands along the Shirley Rim, a characteristic erosional feature of Tertiary strata, are clearly visible on the LANDSAT image. Bates Hole will undoubtedly enlarge with geological time as headward stream erosion carves into the Shirley Rim.

Use the LANDSAT image on this sheet for side-by-side comparison with other sheets in this report.

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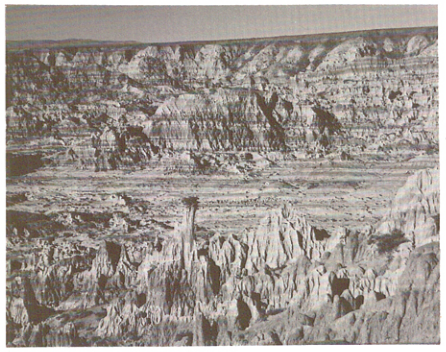


Hells Half Acre, Natrona County. This unusual area of badlands is the result of differential erosion of the Lysite Member of the Wind River Formation (Eocene). The Lysite Member is dipping or tilting about 20° west, which has aided the erosional development of the area.

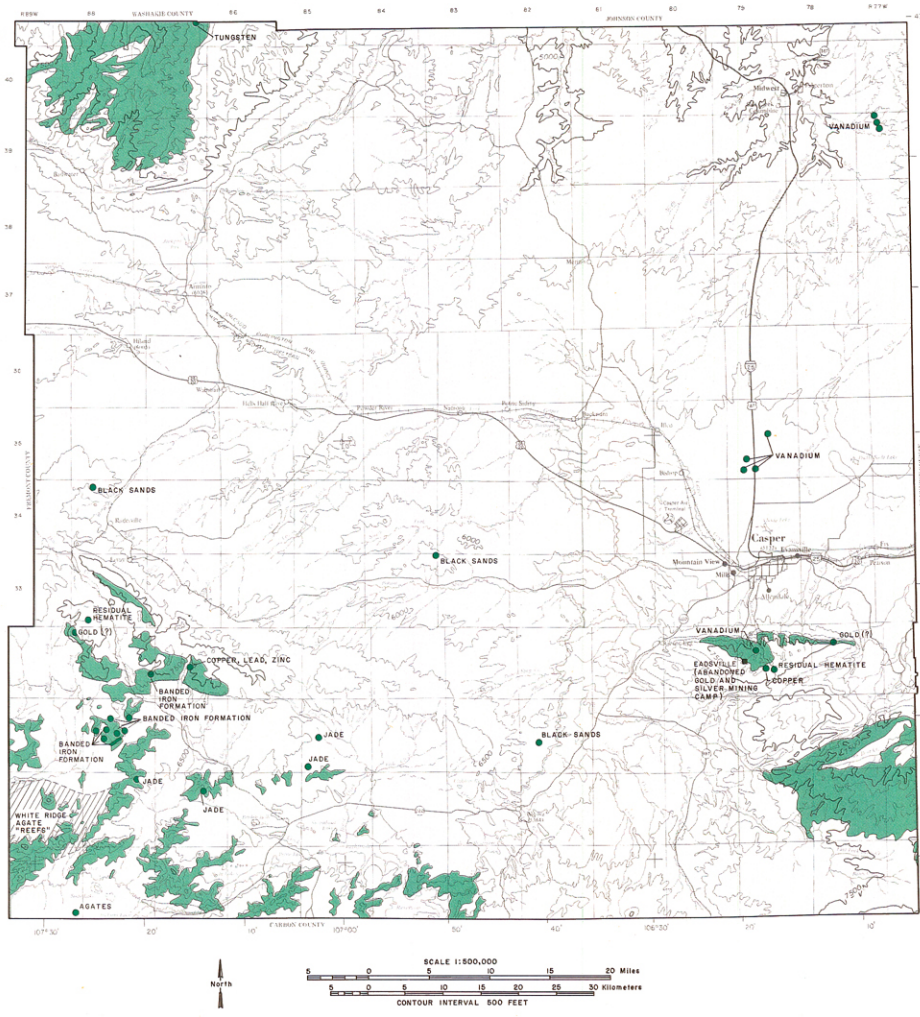
North side of Garfield Peak (elevation 8,210 feet), Rattlesnake Hills. The peak and adjacent hills compose a quartz latite intrusive center with multiple vents, dikes, and laccoliths (Pekarek, 1978).

The Geological Survey of Wyoming, 1980

MINERALS & COAL / CRS 6, Natrona County, Wyoming

Sheet compiled by W.D. Hausel and G.B. Glass

BASE METAL, PRECIOUS METAL, METALLIC OXIDE, LAPIDARY STONE, AND GEMSTONE OCCURRENCES OF NATRONA COUNTY



Explanation

White Ridge agate "reefs" area — Precambrian rocks — Mineral occurrence

BASE METAL, PRECIOUS METAL, SOME COMMON METALLIC OXIDE, LAPIDARY STONE, AND GEMSTONE OCCURRENCES OF NATRONA COUNTY

Known resources of base and precious metals are limited to a few minor occurrences in Natrona County. Probably the most important metallic deposits are banded iron formations in the Granite Mountains and uranium-associated vanadium deposits north of Casper. The iron formations are not presently of commercial value; however, only cursory studies have been made of these deposits, and they merit further investigation of their extent, volume, and iron concentration. Very little is known about the vanadium deposits north of Casper, other than that some ore was produced commercially with uranium in 1956 and 1957.

Other reported metals in the county include disseminated Phanerozoic sedimentary iron deposits, low-grade copper mineralization from the Casper Mountain and Rattlesnake Hills districts, and reported occurrences of gold and silver mineralization on Casper Mountain.

Although metals are significantly lacking, the county has several popular collecting localities for lapidary stones and semiprecious gemstones in the Granite Mountains region of southwestern Natrona County. Agates occur in Tertiary sediments and in Quaternary lag gravels; the most popular collecting localities are along Sage Hen Creek, where the Sweetwater moss agate is commonly collected. In the same general vicinity, jade is found in lode deposits in the Precambrian crystalline rocks and in placer occurrences in Tertiary sediments and Quaternary lag gravels.

IRON

Iron deposits of Natrona County can be separated into two categories distinct in age and origin. These are the Phanerozoic sedimentary deposits, of little significance as potential iron resources, and the Precambrian banded iron formation deposits, of possible future economic importance.

The Phanerozoic sedimentary iron deposits occur as heavy mineral concentrates of magnetite and ilmenite in the Upper Cretaceous Mesaverde Formation and Lewis Shale, and as residual hematite deposits restricted to late Paleozoic rocks.

Heavy mineral concentrates from the titanium-bearing black sandstone deposits are rich in magnetite (iron oxide), ilmenite (iron-titanium oxide), and other nonferrous heavy minerals (see the uranium plate, and industrial minerals discussion, this plate). These heavy mineral deposits are fossil beach placers formed at the shoreline of a Cretaceous sea. Three such deposits are identified in Natrona County in T.34N., R.88W. (Coalbank Hills); T.31N., R.82W. (Clarkson Hill); and T.33-34N., R.84W. (Poison Spider deposit) (Houston and Murphy, 1962). Although the black sand deposits may provide an economic source of titanium, their low iron content and tonnage prevent their consideration as an important iron resource.

Paleozoic sediments at several localities in the county contain nodular hematite and rich hematite layers. Particularly pervasive layers occur near the bases of Amsden and Casper sandstones (Harrer, 1966). The available iron is too finely disseminated for economic consideration.

Precambrian banded iron formation deposits are the most significant deposits in the county in terms of potential iron resources. These deposits were formed as chemical precipitates in a Precambrian sea. Similar banded iron formation deposits are presently exploited in Fremont and Platte counties at the rate of nearly 5.5 million tons per year. Available information on the Natrona County Precambrian iron formations is limited, but it is apparent that the deposits do not contain enough high-grade iron to mine feasibly under present economic conditions. Two chemical analyses of the Natrona County iron formations show 25.3% and 49.0% iron as Fe_2O_3. No tonnage estimates are available; however, the iron formation in T.32N., R.88W. reaches 75 feet thick, in places (Pekarek, 1977).

COPPER

Although no significant quantity of copper ore has ever been mined in Natrona County, early prospecting activity, which began in the late 1800's, disclosed copper mineralization both at Casper Mountain and in the Rattlesnake Hills region.

The Casper Mountain deposit (T.32N., R.79W.), initially prospected in 1892 and later in 1906, reported copper shipments to the Denver Deadwood smelter in 1906. A 100-foot shaft was developed on the property, in the hope of exposing rich ore at depth; however, after economic mineralization was not located, the operations ceased. The tonnage shipped to the Denver smelter is not known, but undoubtedly was very small in that the mine operations terminated after the first ore shipment (Mokler, 1923). The copper mineralization occurs as fracture fillings and replacements in the Cambrian Flathead (?) arkosic conglomerate and the Madison Limestone, on the southern flank of Casper Mountain.

The Rattlesnake Hills were first prospected for copper and precious metals at about the same time as the Casper Mountain area. A few prospects were developed, ranging from a possible gold mine (King Solomon Gold Mine) near the Black Mountain spodumene prospect (T.32N., R.89W.) (Hanley et al., 1950), to a few copper prospects in T.32N., R.87W. Low-grade copper mineralization is exposed in mine dump tailings and along a fault scarp in T.32N., R.87W. Cuprite, malachite, pyrite, covellite, and bornite are found as fissure fillings in fractured hornblende schist host rock. A selected sample assayed 1.5% copper, 800 ppm lead, 170 ppm Zn, with a trace of nickel and silver (Pekarek, 1977).

GOLD AND SILVER

In every established prospecting and mining camp near the turn of the century, rumors of fabulous riches of gold and silver filled the mine ventures with excitement. The Casper Mountain District was no exception. Eadsville, a mining camp long since abandoned, was established in the late 1800's by prospectors in search of gold (Kinttel, 1978). Silver was reputed to assay as high as $66.00 per ton (1890 prices) in rich veins (Mokler, 1923), but such reports can not be verified in that no record of silver production from the Casper Mountain district is known to exist.

Free milling gold in a quartz vein near the northeast slope of Casper Mountain was located in 1897. The vein, found between the heads of Goose and Hat Six creeks (probably in T.32N., R.78W.), pan-tested $3 to $4 (1897 prices) in gold. The vein was prospected in Goose Creek Canyon with unfavorable results (Mokler, 1923).

A diabase dike in the Casper Mountain granite carried gold and silver values (T.32N., R.79W. ?). No assay reports are available (Osterwald et al., 1966).

TUNGSTEN

Massive quartz veins in the northwestern county corner (T.41N., R.87W.) contain disseminated scheelite (calcium tungstate). The extent of the mineralization appears to be very restricted and no production has been reported (Osterwald et al., 1966).

VANADIUM

Vanadium has been recovered from uranium ore in the northeastern portion of the county in the Dry Lake - Nine Mile Lake and Pine Ridge areas (see uranium plate). Vanadium is also reported on Casper Mountain in T.32N., R.79W. (Osterwald et al., 1966).

JADE

No records are available to account for the number of jade samples that have been collected in the Granite Mountains region of southwest Natrona County. The jade found in Wyoming is a variety of amphibole known as nephrite, as opposed to jadeite (a pyroxene), the more valuable form of jade. The Wyoming jade varies in color from a poor quality black jade with quartz inclusions to the high quality emerald-green jade. Evidence suggests that jade is derived from hydrothermal alteration.

In Natrona County, jade occurs in lode deposits in Precambrian rocks, in some Tertiary sediments, and as float in Quaternary lag gravels in the southwestern corner of the county. Some of the highest quality jade found in Wyoming has been collected from lag gravels in T.31N., R.85W. This jade is believed to have originated from Precambrian rocks south of the Rattlesnake Hills (Love, 1970).

AGATES

Agate is a form of banded microcrystalline quartz (chalcedony) commonly found as replacements or cavity fillings. Lapidary groups have long recognized that agates can be cut and polished into excellent ornamental stones of fair value.

One popular agate indigenous to Wyoming is Sweetwater moss agate, a gray-blue agate with black dendrites. Collecting localities for Sweetwater agate extend along Sage Hen Creek in extreme southwestern Natrona County and into Fremont County (Root, 1977).

A pale-greenish-gray translucent agate known as Angel agate is found in the Split Rock Formation and nearby surrounding drainage areas of the Split Rock Formation in T.29N., R.89W.

In the White Ridge area, agate "reefs" of the Moonstone Formation are extensively exposed in the southwestern portion of the county. These agates have not been as extensively exploited as other agates in this region (Love, 1970).

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INDUSTRIAL MINERALS AND CONSTRUCTION MATERIALS OF NATRONA COUNTY

Only a few of Natrona County's industrial minerals and construction materials are found in large enough tonnages to be considered economic or as potential resources. The foremost of these are bentonite and sand and gravel.

Bentonite has been produced within the county since 1950, and presently is mined on the south flank of Casper Mountain and to the west of both Salt Creek and Midwest. Sand and gravel deposits are abundant along the North Platte River in the Casper area, but are absent elsewhere, or found only in relatively small deposits.

In the past, small tonnages of asbestos, feldspar, and vermiculite were mined. However, these commodities never contributed significantly to the total State industrial minerals production.

ASBESTOS, CHROMITE

In 1891, the Casper Mountain asbestos deposit was proclaimed to contain asbestos of as good quality as that produced from the famous Canadian mines (Molker, 1923). Several mining ventures were created to develop the deposit, and mills were constructed on both Casper and Muddy mountains, but no record is available to show how much material was extracted.

Asbestos is found at three localities within the county – Casper Mountain (sec. 16 and 17, T.32N., R.79W.), Smith Creek (sec. 19, T.31N., R.78W.), and Green Hill (sec. 23, T.31N., R.78W.). The asbestos in these deposits occurs as cross-fiber chrysotile veins and veinlets averaging 1/8 to 1/4 inch wide, separated by massive serpentine layers (Beckwith, 1939).

The chromite on Casper Mountain forms massive to disseminated bands in a chromite schist. Chemical analyses of the schist range between 3.6% Cr_2O_3 in the disseminated layers to 46.6% Cr_2O_3 in the massive layers. No chromite has been produced from Casper Mountain.

BENTONITE

Bentonite is a commercial term for clays containing not less than 75% montmorillonite. Two bentonite varieties, separated on the basis of their predominant exchangeable ion, are recognized in Natrona County.

Some bentonites have sodium as the predominant exchangeable ion. Due to absorption, these bentonites commonly expand up to 10 to 15 times their original volume in water. This unique property is valuable in several industrial uses – especially in the petroleum industry for drilling muds and in the iron industry for the pelletization of taconite ore. These sodium-rich bentonites, found almost exclusively in Wyoming and adjacent states, represent one bentonite variety.

Calcium bentonites, the second variety, lack the swelling and colloidal properties commonly found in sodium bentonites. However, these bentonites are suitable for a number of industrial applications, including decolorizing and foundry uses (Gillson, 1960).

The Cretaceous section of Natrona County contains several bentonitic beds, ranging from a few inches to a few feet in thickness. The commercially important bentonites in the Cretaceous section are found in the Mowry, Frontier, Cody, and Steele formations.

Since 1950, Natrona County has produced more than one million tons of bentonite. In 1978, 75,000 tons were mined and nearly 300,000 tons milled within the county. (State Ad Valorem Tax Division report, 1979). Both Benton Clay Company and the Kaycee Bentonite Partnership operate active strip mines and bentonite mills in Natrona County.

FELDSPAR, BERYL, SPODUMENE

Pegmatite is an exceptionally coarse-grained granitic rock, commonly rich in minerals found only in trace amounts in most granites. The concentration of a number of industrial minerals makes pegmatite a valuable exploration target if sufficient tonnage is available. Pegmatites are reported on Casper Mountain and in the Granite Mountains. Pegmatite on Casper Mountain is of two types – a simple, pink granitic to granodioritic rock, and a simple white granitic pegmatite (Burford et al., 1979). One pegmatite of the latter variety yielded a total of 12,400 tons of feldspar beginning in 1953, with sporadic production recorded up to 1977 (State Ad Valorem Tax Division reports).

This pegmatite is feldspar-rich and contains quartz, biotite, and muscovite gangue, with a minor percentage of doubly terminated beryl. The feldspar (plagioclase and microcline) is a source for potash and abrasives, with some high quality material useful in the manufacture of false teeth. Some of the feldspar produced on Casper Mountain was high-graded for dental uses (State Mine Inspector Annual Reports).

Two tons of beryl (an important source of beryllium metal) were produced in 1956 (State Mine Inspector Annual Reports). The mined beryl crystals were commonly several inches in diameter.

The Black Mountain pegmatite (T.32N., R.89W.) in the Granite Mountains area contains up to 50 percent spodumene and progressively decreases to 10 percent spodumene near the footwall of the prospect (Hanley et al., 1950). Spodumene is an important source of lithium. Industrial uses of lithium range from electrical battery storage cells to neutron moderators in nuclear reactors.

GYPSUM

Gypsum deposits of any significance in Wyoming are found in Permian, Triassic, and Jurassic red bed strata (Goose Egg, Chugwater, Gypsum Springs formations). In Natrona County, these strata are exposed along the northwestern flank of Casper Mountain; near Alcova; along the northeastern flank of the Rattlesnake Hills; and along the southern flank of the Bighorn Mountains. The gypsum in Wyoming is remarkably pure, but no gypsum has been mined in Natrona County (Osterwald et al., 1966).

SAND AND GRAVEL, LEDGE ROCK

Sand and gravel deposits are relatively scarce in Natrona County. The southeastern portion of the county has the most abundant resources, and these are found along the North Platte River valley in floodplain and terrace deposits. Some dirty and predominately thin gravel deposits form gently sloping surfaces along the Casper Mountain front but these are of little value. North of Casper, dune deposits are sources of relatively pure sand.

In the north and central portions of the county, sand and gravel are found in floodplain deposits and as thin cappings on local terrace remnants and upland surfaces. But, for the most part, these deposits are too small to be commercially exploited.

Precambrian rocks in Natrona County are a potential resource for ledge rock (crushable material). In addition, both the Alcova Limestone Member of the Chugwater Formation and the Madison Limestone in the Casper Mountain vicinity are potential ledge rock resources (State Highway Department, 1966; 1968).

LIMESTONE-DOLOMITE

The late Paleozoic section in Natrona County is predominately limestone bearing. Rock units of potential interest include the Alcova, Minnekahta, Madison, and Casper limestones. However, no limestone is mined in Natrona County.

Reported chemical analyses of limestone and dolomite in Natrona County are as follows:

FORMATION OR MEMBER	LOCATION	ANALYSES (percent)			
		CaO	MgO	SiO_2	Al_2O_3
Alcova (12 feet thick)	T.32N., R.80W.	47.7	1.0	9.2	2.55-R_2O_3
		49.0	0.94	7.6	1.9
		46.3	0.87	11.4	2.7
Minnekahta (11 feet thick)	T.32N., R.80W.	42.9	5.8	8.2	2.2-R_2O_3
Casper	T.32N., R.80W.	33.2	19.2	1.6	0.65-R_2O_3
		32.1	20.2	1.6	—
		34.3	18.2	1.6	—
Madison (30 feet thick)	T.32N., R.80W.	41.5	12.3	1.2	0.9-R_2O_3
Casper	T.32N., R.79W.	53.1	1.6	1.6	—
Casper	T.32N., R.79W.	34.2	13.0	8.3	—
Casper	T.32N., R.78W.	55.5	0.7	0.9	—

(After, Harrer, 1966)

MANGANESE

Manganese is reported to occur as patches and pockets in a prospect pit in the Casper Limestone (T.32N., R.79W.). Manganite is also reported in the Arminto area (Osterwald et al., 1966).

PUMICITE

Pumicite, a finely divided volcanic ash, consists primarily of shards and small pumice fragments. In Natrona County, pumicite deposits are located in the Granite Mountains area – (1) in beds commonly less than four feet thick in the White River Formation, and (2) in two units of the Split Rock Formation that are five to ten feet thick (T.29N., R.89W.). The two pumicite beds in the Split Rock Formation have a combined estimated tonnage of at least 15 million tons of pumicite per square mile (Love, 1970). Although no pumicite is mined in Natrona County, these pumicite deposits represent a resource for abrasives and light-weight aggregate.

RARE EARTH ELEMENTS

Rare earth elements and thorium are chemically and physically similar, and are therefore commonly found together. Their mode of occurrence is as accessory minerals in granites, pegmatites, and alkalic igneous rocks. Commercial rare earth deposits are rare, but do occur as placer deposits and as rare earth-rich pegmatites.

In the county, rare earths are associated with allanite-bearing pegmatites in the southern Bighorn Mountains (T.39N., R.88 and 87W.) (Osterwald et al., 1966). Additional rare earths occur in fossil black sand placers (see iron and titanium) in late Cretaceous sandstones (Houston and Murphy, 1962), and are also reported in T.33N., R.83W. The mode of occurrence of this last deposit is not known, but it is probably a placer occurrence.

SODIUM SULFATE

Saline deposits commonly occur in undrained depressions where the water evaporation rate is nearly equal to the water flow rate into the depression. Saline deposits in Natrona County contain two dominant salts – sodium sulfate and sodium carbonate. Some important deposits are listed in the following table of chemical analyses taken from Osterwald et al., (1966):

NAME	LOCATION	ANALYSES (percent)			
		Na_2SO_4	NaCl	Na_2CO_3	$NaHCO_3$
Berthaton Lake	NE¼T.30N., R.86W.	17.26	11.69	55.50	—
		37.36	6.30	50.26	6.08
Yale Lake	NE¼T.30N., R.86W.	34.27	6.16	59.57	—
		20.44	13.84	65.72	—
New York and Philadelphia Claims	Sec. 12, T.29N., R.87W.	78.86	8.20	12.94	—
		70.66	11.62	17.72	—
		95.58	1.80	2.62	—
Omaha Deposit	Sec. 34,35,T.30N., R.86W.	9.49	4.84	85.67	—
		65.08	0.32	16.70	—
Wilmington and Wilkesbarre Deposits	Sec. 2,3,10,11, T.29N., R.86W.	55.14	7.47	37.42	—
		95.80	0.60	3.60	—
		24.40	17.71	57.89	—

Explanation

GRAVEL	Includes some Recent to Pleistocene gravels
LEDGE ROCK	Includes Precambrian rocks, Alcova Limestone Member of Triassic Chugwater Formation, and Pennsylvanian Casper Formation
BENTONITE-BEARING STRATA	Includes Cretaceous Mowry, Thermopolis, Frontier, Steele, and Cody formations.
COAL-BEARING STRATA	Includes Upper Cretaceous Mesaverde and Lance Formations and Tertiary Fort Union and Wasatch formations
GYPSUM-BEARING STRATA	Includes Triassic to Permian undivided, Triassic Chugwater Formation, Jurassic Gypsum Springs Formation, and Jurassic undivided.
LIMESTONE-BEARING STRATA	Includes Mississippian Madison, Pennsylvanian Casper, and Cretaceous Niobrara formations and Alcova Limestone Member of Triassic Chugwater Formation.
PRECAMBRIAN ROCKS	

Bentonite mill (capacity in tons per day)
Area of extensive mining
Mine permit boundary
Abandoned underground coal mine
Abandoned bentonite strip mine
Gravel pit
Sodium sulfate mine
Abandoned mine or prospect pit
Industrial materials occurrence as identified (Na_2SO_4 = sodium sulfate, Na_2CO_3 = sodium carbonate)
115 KV Transmission lines (voltage in kilovolts)
Hydroelectric power plant (plant name, capacity in megawatts

Love (1970) reports the following analyses for Turkey Track soda lake (sec. 20, T.29N., R.88W.): Na_2O = 14.6 to 15.6%; K_2O = 0.31 to 3.04%; CaO = <0.01 to 0.40%; MgO = <0.01 to 0.04%; Cl = 0.43 to 0.98%; and SO_4 = 4.1 to 24.0%.

A small tonnage of sodium sulfate is produced from a lake located north of Natrona. In 1978, nearly 3,000 tons of the salt were produced by the Pratt Sodium Sulfate Company. The predominant salt occurs as the mineral mirabilite or Glauber's salt, which is marketed as a mineral and feed additive for livestock (Hausel and Holden, 1978).

TITANIUM

Reported titanium deposits in Natrona County occur as rutile (titanium oxide) and as ilmenite (iron-titanium oxide) in titaniferous black sandstone deposits of late Cretaceous age (Houston and Murphy, 1962; see also Hausel, 1980; and discussion on iron, this plate).

VERMICULITE

Vermiculite is a soft, pliable micaceous mineral that expands or exfoliates into long worm-like shapes when heated or acid tested. This unusual property makes vermiculite useful for insulation, as a filler, and as a concrete aggregate (Osterwald et al., 1966).

Vermiculite occurs in bands and lenses at a granite-hornblende schist contact in two prospects in the Sweetwater rocks (Granite Mountains). Kaolinite and sericite are alteration products of vermiculite and biotite in these prospects. Approximately 225 tons of vermiculite were produced from the prospect in T.30N., R.87W. in 1941; and in 1942, 70 tons were extracted from the prospect in T.31N., R.86W. (Hagner, 1944). No additional vermiculite has been produced in the county.

ZEOLITES

Zeolites are hydrated aluminosilicates that are used commercially as water softeners. In the future, zeolites may have widespread use in the purification of industrial, municipal, and atomic wastes. Zeolites in Wyoming are found in Cenozoic lake bed deposits where the alkaline lake solutions altered large volumes of air-fall volcanic ash. Zeolites are found in Natrona County in a tuff of the Pleistocene Bug Formation northwest of Independence Rock; in a tuff in the Pliocene Moonstone Formation near Moonstone Peak; and in a tuff in the Miocene Split Rock Formation near Split Rock (Surdam, 1972). No zeolite has been produced to date in Wyoming; however, in 1973, the Double Eagle Mining Company of Casper located reserves of high purity zeolites in neighboring Fremont County (Diedrich, 1976).

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COAL

Coal-bearing areas of Natrona County include some relatively unexplored portions of the Wind River and Powder River coal basins. In the Wind River Basin portion of the county, minable coals occur in the Upper Cretaceous Mesaverde Formation. These coals are reportedly up to 9.8 feet thick, but average closer to 4 feet thick. A large portion of the coal-bearing rocks in this area, however, is deeply buried beneath rocks barren of coal.

Mesaverde coals also crop out in the Powder River Basin in eastern Natrona County, but they are reportedly less than 3 feet thick in that area. Thicker coals in this eastern part of the county are found in the Upper Cretaceous Lance Formation, where some coals up to six feet thick have been mined.

All the coals in Natrona County are reportedly of subbituminous rank with as-received heat values commonly between 8,000 and 8,600 Btu/pound. The few published coal analyses from Natrona County suggest that ash content is quite variable, that sulfur content averages less than one percent, and that moisture content is usually in the low 20's on an as-received basis.

Natrona County is underlain by at least 192 million tons of coal (Berryhill et al., 1950). This estimate, however, is extremely conservative since resources were not even estimated for half the county's coal-bearing area. Of the estimated resources, 157 million tons are defined on coals less than 5 feet thick and greater than 1,000 feet deep. Only the remaining 35 million tons of shallower, thicker coal resources are regarded as reserve base or potentially minable coal. Records show that less than 30,000 tons of coal were ever mined in the county and that all that tonnage came from small underground mines. Since the closure of the Swigart Mine in 1945, there has been no coal mining in Natrona County. At the present time, resumption of coal mining is not expected.

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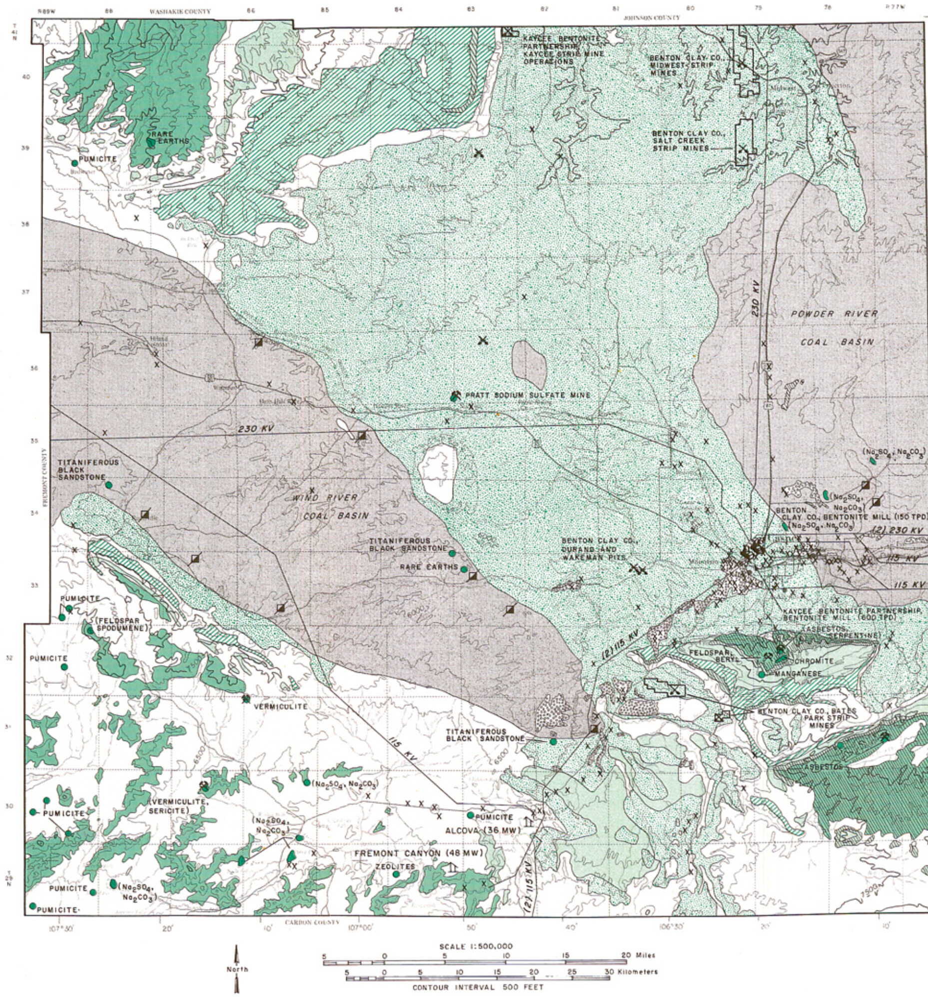
INDUSTRIAL MINERALS, CONSTRUCTION MATERIALS AND COAL RESOURCES OF NATRONA COUNTY



CONSTRUCTION MATERIALS SUMMARY

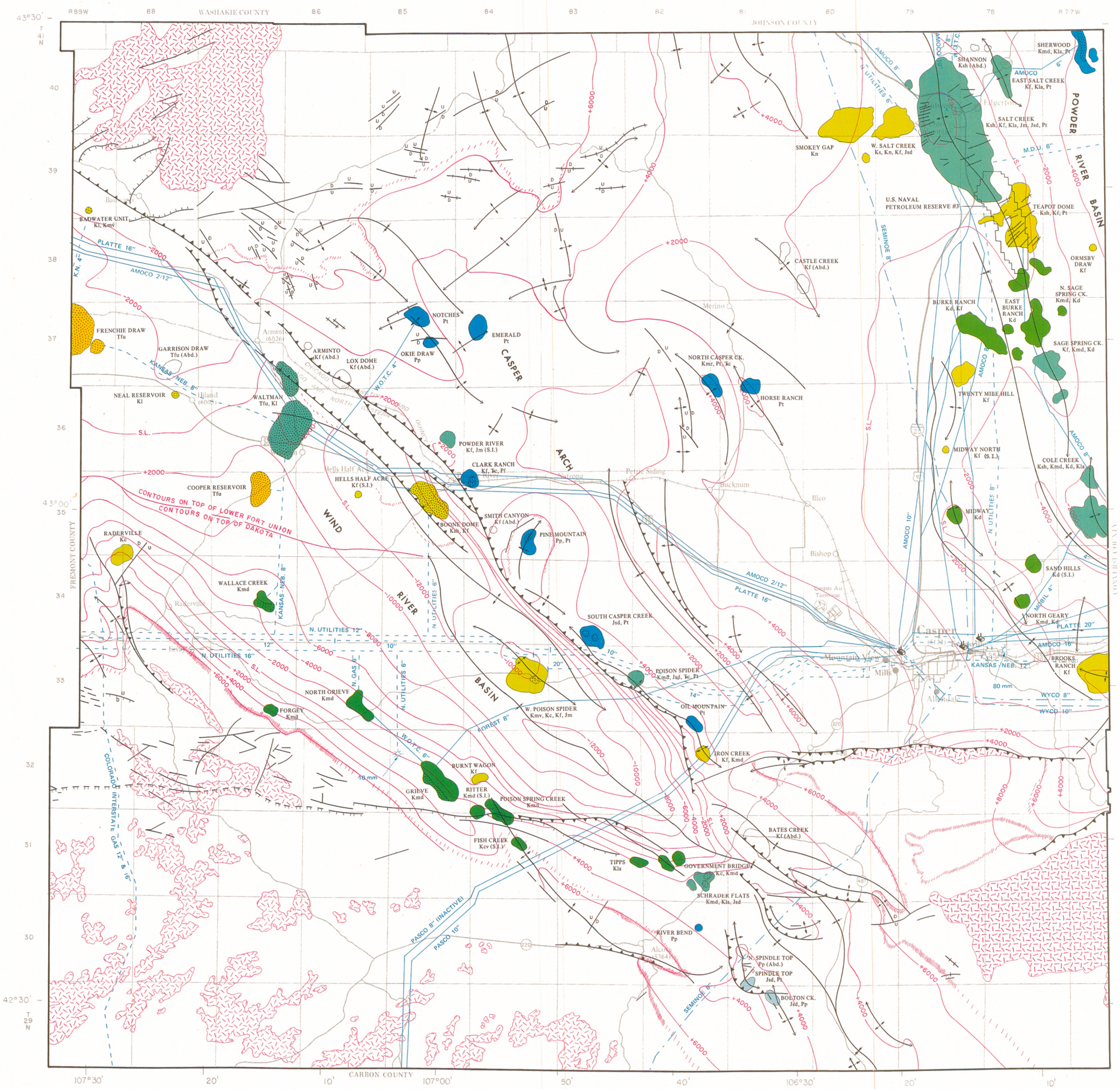
AGE		FORMATION	THICKNESS	CHARACTER	CONSTRUCTION MATERIAL POTENTIAL
QUATERNARY	RECENT	alluvium	0-60'	Flood plain, alluvial fan, and landslide deposits consisting of clay, silt, sand, gravel, and boulders.	Potential source of sand and gravel along North Platte River and Deer Creek.
		wind blown sand	0-150'	Fine- to medium-grained sand.	Sand
		slopewash	0-50'	Heterogeneous mixture of clay, silt, sand, gravel, and boulders.	Poor source of sand and gravel.
	RECENT & PLEISTOCENE	terrace deposits	0-50'	Poorly to well-graded, unconsolidated to poorly-consolidated clay, silt, sand, gravel, and boulders.	Good source of construction material along North Platte River and Bates Creek. Generally clean, well graded, hard gravel.
TERTIARY	OLIGOCENE	White River	10-300'	White, pink, brown, and green tuffaceous claystone and siltstone; thin beds of pumicite and limestone; lenticular conglomerate near base.	Locally, a source of usable construction material.
	EOCENE	Wind River	200-500'	Lenticular deposits of poorly-sorted yellowish gray to orange sandstone, poorly-sorted pebble and boulder conglomerate, red-banded mudstone, and local layers of carbonaceous shale and coal beds.	Gravel from conglomerate beds.
		Wasatch	500-2500'	Shale, bentonite, lignite and sandstone layers having an overall drab brownish-gray appearance in upper part. Some white sandstone and conglomerate in lower part. Scoria associated with lignite beds.	Scoria
	PALEOCENE	Fort Union	2200-4000'	Interbedded clay, shale, sandy shale, sandstone, and coal. Some scoria (clinker) associated with coal beds.	Scoria and some sandstone.
CRETACEOUS	UPPER CRETACEOUS	Lance	1900-3000'	Brownish sandstone, with gray to black shale and carbonaceous shale. Some coal and bentonite units.	Sand and sandstone; sandstone in lower part of formation may supply some crushable rock.
		Fox Hills	100-700'	Light gray to white, fine- to medium-grained, poorly-cemented, argillaceous sandstone.	Source of sand and sandstone.
		Lewis Shale	200±'	Brown and gray marine shale with sandy shale zones and thin lenses of dirty-gray, fine-grained calcareous sandstone.	No useable construction material.
		Mesaverde	600-700'	White medium-grained sandstone and marine shale, with massive to thin-bedded marine and continental sandstone, coals, and carbonaceous shales.	Sand and sandstone.
		Cody Shale: Steele Shale	2200-2600'	Dark gray shale with some interbedded sandstone, sandy shale, and bentonite.	Sand and sandstone.
		Cody Shale: Niobrara	770±'	Light colored limy sandstones and shales; gray to yellow speckled limy shales.	No useable construction material.
		Frontier	600-1000'	Interbedded sandstone, siltstones and shales; bentonite and coal in lower part.	Sand and sandstones.
	LOWER CRETACEOUS	Mowry Shale	200-350'	Gray siliceous shale with numerous bentonites and some thin sandstone.	No useable construction material.
		Thermopolis Shale	110-900'	Black fissile shale with numerous silty and sandy interbeds; thin beds of siltstone and sandy limestone; thin bentonite beds.	Poor source of sand and sandstone from upper member (Muddy Sandstone).
		Cloverly	75-275'	Chert pebble conglomerate; gray to brown fine- to coarse-grained massive sandstone with lensitic coal beds; and black to gray variegated shales with thin interbeds of gray and yellowish sandstone.	Sand, sandstone, and fine gravel from basal Lakota Conglomerate Member.
JURASSIC		Morrison	100-250'	Non-marine variegated green, gray, and maroon sandy shale with sandstone; thin lenses of shaly limestone.	No useable construction material.
		Sundance	225-400'	Gray to greenish-gray, glauconitic, calcareous sandy shales with some interbedded sandstone and thin oolitic limestones.	Poor source of sand and sandstone
TRIASSIC		Chugwater	350-590'	Red shale, siltstone, limestone, and intercalated anhydrite and gypsum.	Crushable material (ledge rock) from the Alcova Limestone Member. Sand and sandstone.
		Dinwoody	50-80'	Tan to olive drab, hard, slabby fine-grained dolomitic siltstone and sandstone. Grades eastward into the upper part of Goose Egg Formation.	Crushable material from dolomitic and limestone beds.
PERMIAN		Goose Egg	200-385'	Red to ocher shale and siltstone, thin limestone, dolomite, and gypsum beds.	No usable construction material.
PENNSYLVANIAN		Casper	300-1100'	Red and white sandstone, gray hard persistent limestone, and red shale and siltstone. Cross-bedded sandstone predominates in upper part; limestone predominates in lower part.	Sand, sandstone, and limestone ledge rock.
MISSISSIPPIAN		Madison Limestone	100-400'	Blue-gray massive to thin-bedded cherty limestone and hard calcareous sandstone.	Ledge rock.
CAMBRIAN		Flathead Sandstone	90±'	Tan to brown, medium- to coarse-grained sandstone with some conglomerate.	Sand and sandstone.
PRECAMBRIAN		granite and metamorphic rocks	---	Granite, intrusive dikes, irregular pegmatites, and metamorphic crystalline rocks.	Ledge rock.

After Wyoming State Highway Dept. Material Inventory Rpts. (1966; 1968).

The Geological Survey of Wyoming, 1980

PETROLEUM I / CRS 6, Natrona County, Wyoming

Sheet compiled by A.J. VerPloeg and T.R. Stephenson



SCALE 1:250,000

5 0 5 10 15 20 Miles

5 0 5 10 15 20 25 30 Kilometers

North

MAP MODIFIED FROM: Color Geological Structure Map of Wyoming, Petroleum Ownership Map Company, 1978; Energy Resources Map of Wyoming, Wyoming Geological Survey, 1975; Map of Oil and Gas Fields and Pipelines of Wyoming, U.S.G.S., 1979; and 1979 Natural Gas Pipeline System Map, Western Oil Reporter, 1979.

NATRONA COUNTY OIL AND GAS PRODUCTION

Field Name and Discovery Date	Location	Producing Formation(s) (Current and Abandoned)	Approximate Producing Depth(s) (feet)	Current Number of Producing Wells	Total Production to Dec. 31, 1978 Oil (Bbls)	Gas (Mcf)	Field Status
Arminto (1924)	37N - 86W	Frontier	2,000	0	–	–	Abd.
Badwater (1957)	39N - 89W	Lance		0	–	793,777	Prod.
		Mesaverde	15,200	1			
Bates Creek (1954)	31N - 81W	Frontier	1,200	0	56,602	–	Abd.
Bolton Creek (1920)	29N - 81W	Sundance	1,100	2	56,677	–	Prod.
		Phosphoria	2,100	0			
Boone Dome (1923)	35N - 85W	Shannon	1,600	2	414,268	28,937,271	Prod.
		Frontier	6,500	4			
*Brooks Ranch (1957)	33N - 77W	2nd Frontier	4,200	20	2,501,120	–	Prod. (W)
Burke Ranch (1953)	37N - 78,79W	Dakota	6,700	15	6,105,629	175,399	Prod. (W)
Burke Ranch, E. (1971)	37N - 78W	Dakota	7,300	1	64,134	9,640	Prod.
Burnt Wagon (1976)	32N - 84W	Frontier	7,600	4	128,564	197,184	Prod.
Casper Creek, N. (1925)	36,37N - 82W	Mowry	1,000	0	511,180	7,290	Prod.
		Chugwater	2,000	0			
		Tensleep	3,200	6			
Casper Creek, S. (1919)	33,34N - 83W	Sundance	1,500	0	9,968,747	–	Prod. (H)
		Tensleep	2,500	38			
Castle Creek (1948)	38N - 80,81W	3rd Frontier	2,300	0	25,548	1,400	Abd.
Clark Ranch (1955)	35N - 84,85W	Frontier	900	0	1,320,063	166,076	Prod.
		Chugwater	3,200	0			
		Tensleep	4,700	5			
*Cole Creek (1938)	35N - 77W	Shannon	4,500	2	16,911,181	500,509	Prod. (W)
		Muddy	8,400	0			
		Dakota - Lakota	8,000	8			
Cooper Reservoir (1959)	35N - 87W	Fort Union	3,700	1	–	10,687,804	Prod.
Emerald (1975)	37N - 84W	Tensleep	4,000	12	601,209	–	Prod.
Fish Creek (1951)	31N - 84W	Cloverly	1,400	0	426	–	Shut In
Forgey (1969)	33N - 87W	Muddy	2,500	2	63,677	62,193	Prod.
*Frenchie Draw (1961)	37N - 89W	Fort Union	8,500	11	973,759	36,033,566	Prod.
Garrison Draw (1971)	37N - 88W	Fort Union	8,900	0	–	–	Abd.
Geary, N. (1968)	34N - 78W	Muddy	6,500	0	34,321	2,697	Prod.
		Dakota	6,600	1			
Government Bridge (1956)	31N - 82W	Cody (Stray Sand)	2,200	0	1,328,424	7,679	Prod.
		Muddy	2,500	2			
Grieve (1954)	32N - 85W	Muddy	6,700	5	29,567,694	56,962,777	Prod. (W)(G)(D)
Grieve N. (1974)	33N - 86W	Muddy	9,700	4	1,729,589	3,322,993	Prod. (G)
Hell's Half Acre (1976)	35N - 86W	Frontier	18,500	0	–	–	Shut In
Horse Ranch (1955)	36N - 81W	Tensleep	5,100	5	117,487	–	Prod.
Iron Creek (1917)	32N - 82W	Frontier	200	11	159,693	–	Prod.
		Muddy	800	0			
Lox (1921)	37N - 86W	Frontier	2,000	0	–	–	Abd.
Midway (1931)	35N - 79W	Dakota	5,500	2	368,503	–	Prod.
Midway, N. (1978)	36N - 79W	3rd Frontier	6,500	0	–	–	Shut In
Neal Reservoir (1978)	36N - 88W	Lance	16,000	1	219	3,975	Prod.
Notches (1923)	37N - 85W	Tensleep	2,800	11	6,833,119	19,972	Prod.
Oil Mountain (1945)	33N - 82W	Tensleep	2,600	1	76,753	11,251	Prod.
Okie Draw (1953)	37N - 85W	Phosphoria	2,800	1	46,560	–	Prod.
Ormsby Draw (1975)	38N - 77W	Frontier	8,000	1	405	42	Shut In
Pine Mountain (1914)	35N - 84W	Phosphoria	1,500	0	66,997	233,645	Shut In
		Tensleep	1,800	6			
Poison Spider (1917)	33N - 82,83W	Muddy	600	1	3,328,929	65,000	Prod. (W)
		Sundance	1,400	13			
		Chugwater	1,300	17			
		Tensleep	2,400	3			
Poison Spider W. (1948)	33N - 84W	Mesaverde	9,200	13	7,715,356	19,838,051	Prod. (G)
		Cody (Stray Sand)	10,400	10			
		1st Frontier	14,200	1			
		Morrison	15,900	0			
Poison Spring Cr. (1958)	31N - 84W	Muddy	6,000	2	216,352	9,243	Prod.
Powder River (1930)	36N - 85W	Frontier	900	0	–	–	Shut In
		Morrison	2,300	0			
Raderville (1955)	35N - 89W	Cody (Stray Sand)	2,000	3	103,423	–	Prod.
Ritter (1956)	31,32N - 84W	Muddy	6,200	0	133,402	7,153	Shut In
River Bend (1965)	30N - 82W	Phosphoria	3,300	1	7,225	–	Prod.
Sage Spring Cr. (1949)	36,37N - 77W	Frontier	4,000	3	10,265,363	3,230,851	Prod. (w)
	37,38N - 78W	Muddy	5,000	0			
		Dakota	5,600	22			
Salt Creek (1889)	39,40N - 78,79W	Shannon	700 - 1,000	13	569,678,776	711,185,987	Prod. (W)(G)(T)
		1st Wall Creek	900 - 1,500	252			
		2nd Wall Creek	1,300 - 2,100	595			
		3rd Wall Creek	2,100 - 2,400	8			
		Lakota	2,100 - 2,400	6			
		Morrison	2,600	0			
		Sundance	2,800 - 3,000	29			
		Tensleep	3,800	22			
Salt Creek, E. (1951)	40N - 78W	2nd Wall Creek	5,000	5	11,598,761	774,756	Prod. (W)
		Lakota	6,000	0			
		Tensleep	7,500	5			
Salt Creek, W. (1917)	39,40N - 79W	Steele (Fishtooth)	700	0	1,740,845	4,003	Prod. (W)
		Niobrara	1,900	0			
		2nd Wall Creek	2,700	6			
		Sundance	2,700	0			
		3rd Sundance	3,000	0			
Sand Hills (1977)	34N - 78W	Dakota	7,700	0	1,199	–	Shut In
Schrader Flats (1961)	31N - 82W	Muddy	2,500	0	1,886,103	15,759	Prod.
		Lakota	2,700	2			
		Sundance	3,300	2			
Shannon (1889)	40,41N - 78,79W	Shannon	900	0	7,124	–	Abd.
*Sherwood (1954)	40,41N - 77W	Muddy	10,700	0	1,482,321	23,367,065	Prod.
		Lakota	11,000	0			
		Tensleep	12,500	1			
Smith Canyon (1966)	35N - 84W	Frontier	200	0	–	–	Abd.
Smokey Gap (1956)	40N - 80W	Niobrara	800	24	530,947	–	Prod.
Spindle Top (1922)	29,30N - 81W	Sundance	1,000	7	171,046	–	Prod.
		Tensleep	2,300	0			
Spindle Top, N. (1959)	30N - 81W	Phosphoria	3,000	0	1,299	–	Abd.
Teapot (1922)	38,39N - 78W	Shannon	300 - 1,100 }	324	8,242,501	1,251,435	Prod.
		Frontier	2,800 }				
		Tensleep	5,400	0			
Teapot, E. (1927)	38,39N - 78W	Shannon	2,500	54	3,994,330	–	Prod.
Teapot, W. (1970)	38N - 78W	Niobrara	2,000	0	–	490	Abd.
Tipps (1963)	31N - 83W	Lakota	5,400	2	319,894	–	Prod.
Twenty Mile Hill (1960)	36,37N - 78,79W	3rd Frontier	5,700	5	1,276,516	124,978	Prod. (w)
Wallace Creek (1960)	34N - 87W	Muddy	10,300	4	295,922	4,640,280	Prod.
Waltman (1959)	36,37N - 86,87W	Fort Union	4,400	4	110,631	38,914,606	Prod.
		Lance	5,700	1			
TOTAL 62 Fields				1645	703,140,813	941,566,797	45 Prod.

*Field partly in Natrona County
Abd. - Abandoned Fields
Prod. - Producing Fields

(W) - Water Injection Projects
(H) - Hydrothermal Injection Projects
(G) - Gas Injection Projects
(D) - Water Disposal Project
(T) - Tertiary Recovery Project

Data Sources: Wyoming Oil and Gas Conservation Commission, Wyoming Geological Association and Petroleum Information Corporation

OIL AND GAS FIELD SYMBOLS

GRIEVE — Field name
Kmd — Past and present producing formations

No pattern denotes oil production

Stippled pattern denotes gas production

Note: Color coded to age of production; abandoned fields not colored.

REFINERY

GAS PROCESSING PLANT (Capacity in million cubic feet per day)

AGE OF PRODUCTION

- Tertiary Production
- Upper Cretaceous Production
- Lower Cretaceous Production
- Jurassic and Triassic Production
- Paleozoic Production
- Production from more than one age

PIPELINE SYMBOLS
(Showing Ownership and Size)

Oil	Gas	Products
Amoco 12"	N. Util. 16"	Seminoe 8"

GEOLOGIC SYMBOLS

- +4000 Structure contours on top of Dakota Sandstone and lower Fort Union
- Anticline
- Syncline
- Faults
- Normal faults, hachures on downthrown block
- Reverse Faults
- Surface faults and folds of unknown subsurface extent
- Outcrop of Dakota Sandstone
- Subcrop of Dakota Sandstone
- Outcrop of lower Fort Union
- Outcrop of Precambrian Crystalline Rocks

FORMATION SYMBOLS

TERTIARY
- Fort Union Formation – Tfu

UPPER CRETACEOUS
- Lance Formation – Kl
- Mesaverde Formation – Kmv
- Cody Shale – Kc
- Shannon Sandstone – Ksh
- Steele Shale – Ks
- Niobrara Shale – Kn
- Frontier Formation – Kf

LOWER CRETACEOUS
- Mowry Shale – Kmr
- Muddy Sandstone – Kmd
- Cloverly Sandstone – Kcv
- Dakota Sandstone – Kd
- Lakota Sandstone – Kla

JURASSIC
- Morrison Formation – Jm
- Sundance Formation – Jsd

TRIASSIC
- Chugwater Group – Ꞓc

PERMIAN
- Phosphoria Formation – Pp

PENNSYLVANIAN
- Tensleep Sandstone – Pt

The Geological Survey of Wyoming, 1980

PETROLEUM II / CRS 6, Natrona County, Wyoming

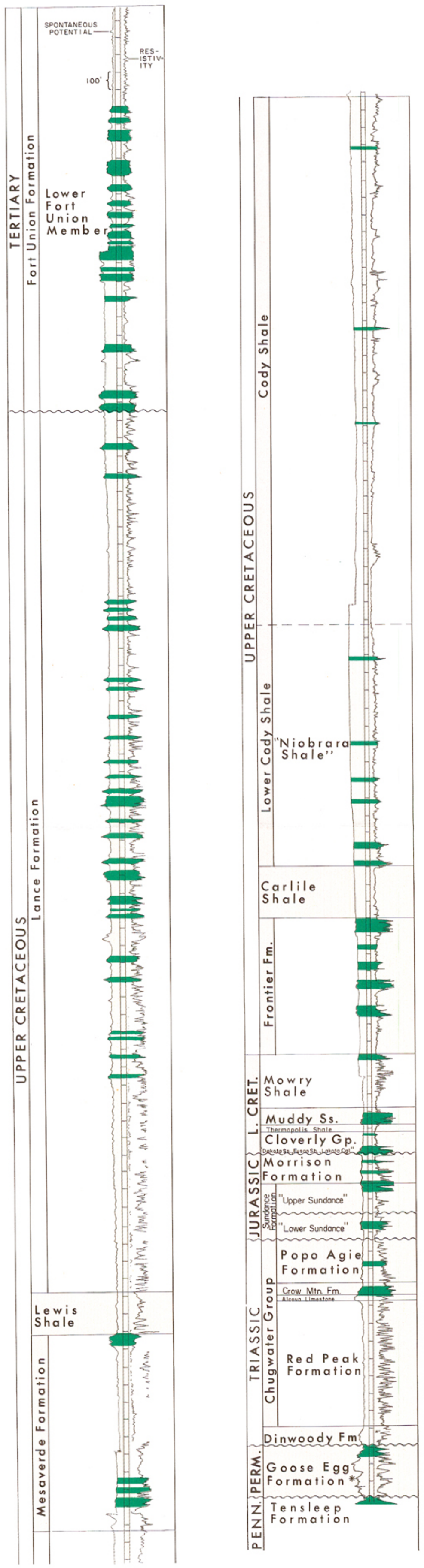
Sheet compiled by A.J. VerPloeg

ANNOTATED ELECTRIC LOG

UNION OIL OF CALIFORNIA

1-K-11 Hells Half Acre Unit III

ne sw 11-35N-86W



Past, Existing and Potential Producing Zones

* Often referred to as Phosphoria Formation in field statistics

PETROLEUM IN NATRONA COUNTY

Introduction and History

Natrona County has historically played an important role in Wyoming's oil and gas development. In 1851, the county's long and often colorful petroleum related history was initiated with the first commercial marketing of oil in Wyoming. Records indicate that a group including Jim Bridger, Kit Carson, and Cy Iba extracted quantities of oil from an oil seep on Poison Spider Creek, west of present-day Casper. They mixed the oil with flour and sold it for a dollar per jar to emigrants on the Oregon Trail for use as axle grease.

However, it wasn't until 1889 that M.P. Shannon and his associates from Pennsylvania drilled the first successful oil well in the county, immediately north of present-day Salt Creek Field in the now abandoned Shannon Field. Production was rather insignificant, ranging between 10 and 15 barrels per day from the Shannon Sandstone at a depth of about 700 feet. Between 1889 and 1908, Belgian and French companies explored the area, with little success. Finally, in 1908, H.E. Stock drilled the first commercial well on the Salt Creek anticline producing from the upper Frontier Formation, or the First Wall Creek Sandstone as it is locally referred to, at a depth of 1050 feet. Major production did not begin, however, until the Second Wall Creek Sandstone (Frontier) discovery by the E.T. Williams Oil Company in 1917. Later, various oil companies discovered producing zones ranging from the Cody Shale at 400 feet to the Tensleep Sandstone at 3800 feet. In the early years, there was very little demand for Salt Creek oil or any Wyoming oil. The producing and refining of oil was a very young technology and was limited to the more populous areas in the East. Kerosene and lubricant for machinery were the most important petroleum products, with gasoline representing a useless by-product. In 1895, the Pennsylvania Oil and Gas Company, a company formed by Shannon and his associates, erected the first Wyoming refinery in Casper, having a capacity of 100 barrels per day. Freight wagons pulled by horses or mules, hauled oil from Shannon Field to the refinery in Casper, a distance of nearly sixty miles. A group of men from Colorado formed the Midwest Oil Company in 1910, and another refinery with a 2000-barrel-per-day capacity was constructed in Casper. With the installation of a pipeline from Salt Creek Field to Casper in 1911, the colorful days of oil transportation by freight ended. Construction of another pipeline in 1912 accelerated production from Salt Creek Field, and by 1923 yearly production peaked at 35,301,608 barrels, 5% of the total U.S. production for that year. During 1921 and 1922, gasoline from Salt Creek was transported as far as Europe, during a time when the U.S. was actually exporting petroleum products. Salt Creek Field is considered a classic example of anticlinal oil entrapment and ranks as one of the Rocky Mountain region's largest fields in terms of ultimate oil production. Ultimate production from the field is estimated at 712,095,006 barrels of oil and 898,942,000 Mcf of gas. Total production through the end of 1978 was 569,678,776 barrels of oil and 711,185,987 Mcf of gas, ranking Salt Creek Field as Wyoming's number one field in terms of cumulative production.

U.S. Naval Petroleum Reserve Number 3, or Teapot Dome, as it is more commonly known, represents another colorful chapter in the history of oil and gas development in Natrona County. In 1915, President Woodrow Wilson set aside what now composes the western two-thirds of Teapot Dome as the nation's third petroleum reserve. Initially, the reserve was supervised by the Navy; however, in 1921 President Warren Harding transferred supervision responsibility to the Department of Interior. In order to prevent drainage of Teapot Dome as a result of production from the structurally higher Salt Creek Field immediately to the north, Secretary of Interior Albert Fall decided to lease Teapot Dome for production. In 1922, Fall issued an oil lease to Mammoth Oil Company, an oil company organized by Harry Sinclair. Interest was keen in the lease, and several companies accused the Secretary of Interior of issuing the lease to Mammoth Oil without benefit of competitive bidding. Controversy continued, and finally, in 1927, the U.S. Supreme Court voided Mammoth's lease and the field's 62 producing wells were shut in, with supervision being returned to the Navy. Fall and Sinclair were tried and found guilty of bribery and conspiracy, thus ending the series of events known as the "Teapot Dome Scandal." Eventual development of the field showed it to be less prolific than the famous Salt Creek Field, although flow measurements from one of the early wells indicated initial flows of up to 28,000 barrels per day from a fractured shale zone directly above the Frontier Formation. Ultimately, production was obtained from the Shannon Sandstone at 400-1000 feet, the Second Wall Creek Sandstone (Frontier Formation) at 2500-3000 feet, and the Tensleep Sandstone at 5500 feet. The Second Wall Creek has been the source of most of the field's production. Through December 1978, Teapot Dome produced 8,242,501 barrels of oil from an estimated ultimate recovery of 49,534,000 barrels. The field remained shut in from 1927 until 1964 when production resumed. In 1976, the Naval Reserve Production Act brought the field to full development, including the initiation of a 500-well drilling program. However, recently, controversy has again entered the Teapot Dome picture. The Act requires that the oil from the reserve be sold at a price equal to an oil company's bid plus the highest posted price for "stripper" oil, a category of oil production not subject to price control (wells producing less than 10 barrels per day). The Department of Energy, which now administers the reserve, opened a portion of the reserve's crude for competitive bidding in early January of 1980 and the high bid came in at $43.52 per barrel, a price which is among the highest in the world "spot" market. By comparison, similar oil from the privately operated Salt Creek Field is limited by federal price controls to $6.50 per barrel; a situation which, to say the least, appears quite inconsistent to private companies operating in the area.

Spurred by the success at Salt Creek and Teapot Dome, exploration spread throughout Natrona County. Important discoveries included North and South Casper Creek Fields (1925 and 1919), Cole Creek Field (1938), Grieve Field (1954), Waltman Field (1959) and Frenchie Draw (1961). These and other discoveries brought the county's total to 62 fields by the end of 1978, 45 of which are currently producing oil or gas or both.

Production

Oil and gas production in Natrona County is distributed throughout most of the sedimentary section. Fields produce or have produced from reservoirs ranging in age from Pennsylvanian (Tensleep Sandstone) to Tertiary (Fort Union Formation). In terms of volume, the most important producers of oil include the Frontier Formation, Muddy Sandstone, Dakota Sandstone, and Tensleep Sandstone; and of gas include the Frontier Formation, Fort Union Formation, Mesaverde Formation, and Muddy Sandstone. Reservoir rock is commonly sandstone and siltstone, although some carbonate reservoirs do produce in the county. Also, some early production in Salt Creek and Teapot Dome fields came from a fractured shale reservoir.

Two major types of petroleum traps exist within the county, structural traps related to the deformed margins of the Powder River and Wind River basins and the Casper Arch; and stratigraphic traps located mainly in the more stable interior portion of the Wind River Basin. However, many of the stratigraphic traps, especially those nearer the margin of the Wind River basin, are actually combinations of the two types of traps.

The structural or anticlinal trap is illustrated below by Emerald Field. Cross-section A - A' portrays the mildly folded or upwarped Tensleep Sandstone which forms the trap. Industry located the structure as a result of a detailed seismic program, an exploration technique greatly different from the techniques used in the early days to locate the classic structural traps like Salt Creek and Teapot Dome. Early exploration efforts centered around the search for surface expression of anticlinal structures, usually by surface mapping. Often, however, the presence of oil seeps in an area was all that was necessary to convince the early "wildcatter" to drill. Today, new, sophisticated seismic techniques are the industry's most important tool in locating the subtle, buried structural traps remaining to be found.

Parker Drilling Rig #112 contracted by Colorado Interstate Gas Company to drill the 1-6-36-86 Bullfrog Unit well in western Natrona County. This well was drilled to a depth of 20,850 feet in Waltman Field and completed in October 1979 in the Muddy, Dakota, Morrison, and Sundance, producing at the rate of 1,764,000 cubic feet of gas per day. (Photograph by compiler.)

Grieve Field, shown below, is used to illustrate one of the most common types of stratigraphic or structural/stratigraphic trap present in the county. As shown in cross-section B - B', the field is actually a combined structural/stratigraphic trap best described as an updip stratigraphic pinchout of the Lower Cretaceous Muddy Sandstone. Structure comes into play in the form of folding or tilting of the unit basinward. Recent interpretations suggest that this sand unit was deposited in the estuarine mouth of a large stream system which flowed westerly across the present day Casper Arch. This same stream system appears to be related to several similar traps which produce from the same Muddy Sandstone in the area, namely, North Grieve, Forgey, Wallace Creek, Ritter, Fish Creek, Poison Spring Creek, Tipps, and Government Bridge Fields. The stratigraphic traps and structural/stratigraphic traps found in the interior portion of the Wind River Basin differ from the Grieve-type traps in that they produce from a series of lenticular Tertiary (Fort Union Formation) channel sandstones which are quite discontinuous. Waltman, Frenchie Draw, and Cooper Reservoir are good examples, representing the types of traps that will probably be the target of much of the future exploration efforts in Natrona County.

Of total production, most to date has come from structural traps and most of that can be credited to Salt Creek Field. As mentioned before, early exploration efforts were directed toward the search for anticlines expressed on the surface and, as a result, structural traps were found almost exclusively until the 1950's when new techniques, notably seismic methods, allowed for subsurface exploration for stratigraphic traps and buried anticlinal traps. Therefore, most of the more recent discoveries have been stratigraphic or structural/stratigraphic traps, a trend which is not unique to Natrona County.

Future Development

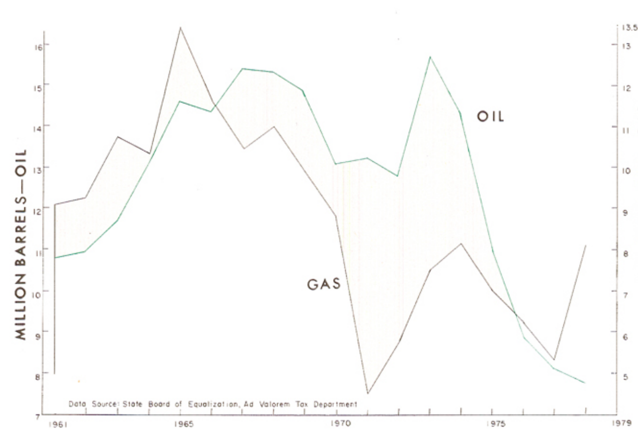
Obviously, it can be said that in terms of oil production, as Salt Creek goes, so goes Natrona County. Unfortunately, Salt Creek has been declining steadily in oil production over the last several years. The field produced 13.4 million barrels in 1974, 9.8 million in 1975, 7.5 million in 1976, 6.8 million in 1977, and 6.3 million in 1978, considerably less than the 35 million barrels produced in its peak year, 1923. This decline is strikingly reflected on the oil production curve in the accompanying production graph for Natrona County. Although secondary and tertiary recovery techniques (water flooding, stream or gas injection, and injection of detergents or solvents to "wash" or dissolve oil from the reservoir rock) might slow the decline in many of the older fields, the overall decline in oil production will continue.

In terms of gas production, once again, Salt Creek Field historically carried the county's production. However, in recent years, more and more of the field's gas was re-injected in an effort to improve oil production, and by 1974 Salt Creek's gas production ceased. The resurgence in the county's gas production indicated for 1973, 1974, and 1975 on the accompanying graph resulted from new and increased production from West Poison Spider, Waltman, and Frenchie Draw fields. Production from these fields dropped in 1976 and 1977; however, increased production, especially from Waltman Field, in 1978, points toward another upswing. Deeper drilling in Waltman Field in late 1979 has expanded gas production to the Muddy Sandstone, Lakota Conglomerate, Morrison Formation, and Sundance Formation. This, along with the Hell's Half Acre deep discovery in 1976, is indicative of the deep drilling effort which will be necessary to Natrona County's future gas production. Gas production will begin a definite long-term upswing and could eventually overtake oil production in terms of importance to the county.

In summary, future exploration efforts will include extensive seismic surveys and very costly deep drilling. Most of this activity will be restricted to the portion of the Wind River Basin in the western half of the county, especially the deeper interior portion of the basin along the structural axis. Also, deeper tests in established fields can be expected in an attempt to locate deeper pay zones. At those depths, new discoveries of this type will most likely be gas. Additional relatively shallow gas deposits could exist in Tertiary sands of the interior Wind River Basin. In terms of oil production, it should be remembered that Natrona County has been explored for oil in particular since the late 1800's and, in all probability, the large oil traps have been found. Any new oil discoveries will be a result of seismic prospecting and will be found at much greater depths and in smaller quantities than in the past. Emerald Field, discussed previously, is probably indicative of the size and type of deposits which might remain.

Natrona County has had a long and colorful history in relation to its oil and gas production. Petroleum should retain its role of importance in the county with, possibly, an eventual change in production emphasis from oil to gas.

NATRONA COUNTY Annual Taxable Oil and Gas Production



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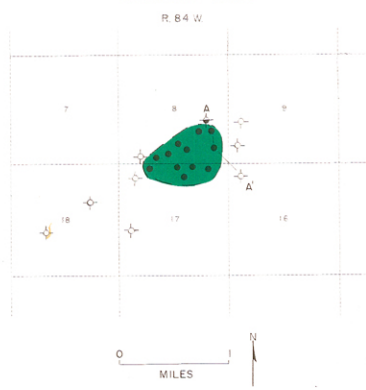
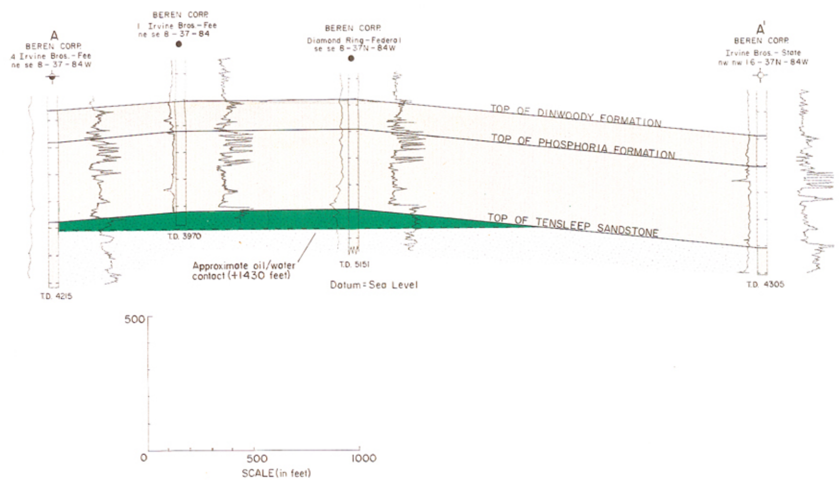
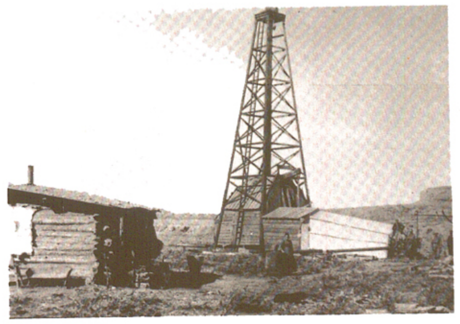
EMERALD FIELD

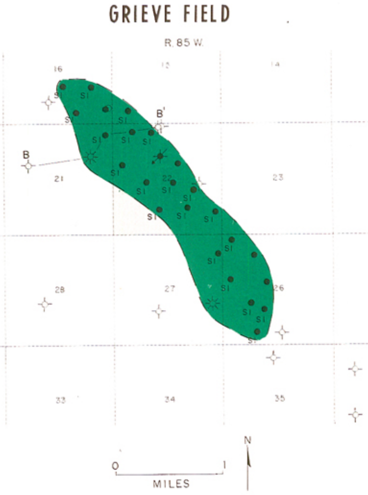


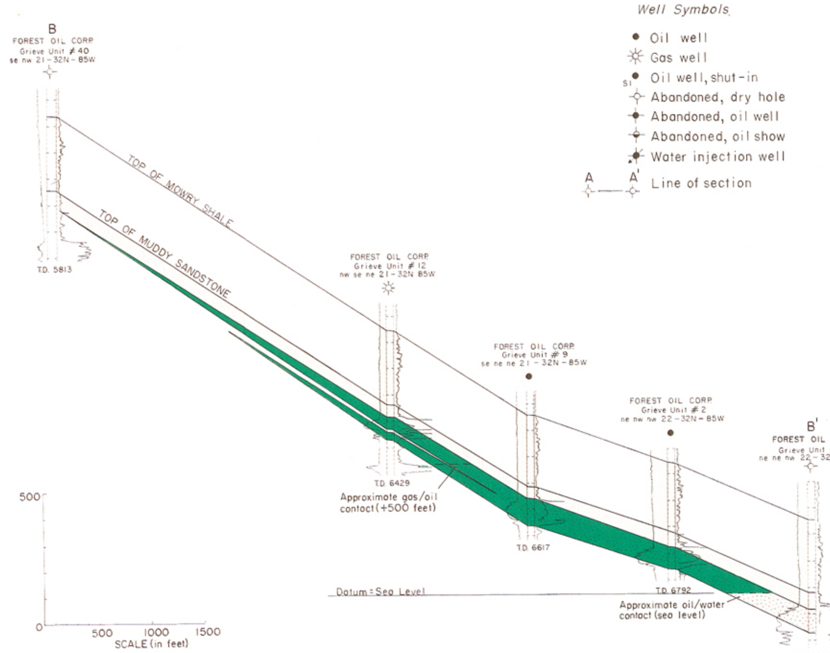




The Shannon Field discovery well, drilled by H.P. Shannon in 1889 and representing the first commercial oil well drilled in Natrona County. Oil flowed at the rate of 10 barrels per day from the Shannon Sandstone at 1000 feet. Soon after this discovery, Shannon and his associates formed the Pennsylvania Oil and Gas Company. (Photo from University of Wyoming Petroleum History Center)

GRIEVE FIELD





Well Symbols

- Oil well
- Gas well
- Oil well, shut-in
- Abandoned, dry hole
- Abandoned, oil well
- Abandoned, oil show
- Water injection well
- A—A' Line of section

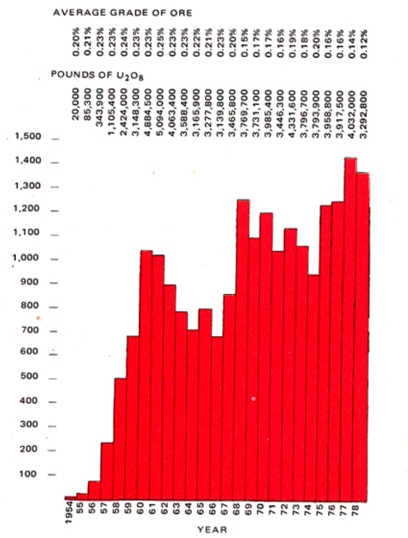
Shannon completed construction of this, the first refinery in Wyoming, in Casper in 1895. The refinery was quite small by today's standards, having a capacity of 100 barrels per day. Kerosene and lubricants were its first products, as there was no real use for gasoline at this time. (Photo from University of Wyoming Petroleum History Center)

Oil was transported by wagon from Shannon Field to the refinery in Casper until the completion of a pipeline in 1911. A normal complement of wagons was pulled by 12 to 18 horses. Supplies and equipment were transported to the fields on the return trip. The trip was 60 miles one way and usually took at least two or three days. (Photo from University of Wyoming Petroleum History Center)

URANIUM / CRS 6, Natrona County, Wyoming

Sheet compiled by W.D. Hausel

Gas Hills Uranium Production, Natrona-Fremont Counties



Since mining in the district began in 1954, the Gas Hills uranium d.strict has been a significant contributor to the total uranium production, not only of Wyoming, but of the United States. Until recently (1978), the Gas Hills uranium district out-produced all other uranium districts in Wyoming. In 1978, production from the Box Creek District in the southern Powder River Basin exceeded production from the Gas Hills area by nearly 300,000 tons of ore. The total uranium production from the Gas Hills district, to date, is 21,400,000 tons of ore containing nearly 80,000,000 pounds of uranium oxide. (Snow, 1978; State of Wyoming Ad Valorem Tax Division Annual Reports, 1977-1979.)

RADIOACTIVE MINERAL OCCURRENCES AND PRODUCTION IN NATRONA COUNTY

The economically significant uranium deposits of Natrona County are in the Gas Hills mining district; only minor uranium production has been reported outside this region. Production outside of the Gas Hills district has been reported from the Hiland, Dry Lake – Nine Mile Lake, and Pine Ridge areas and totals less than 1500 tons of uranium ore.

Areas of anomalously high radioactivity due to uranium mineralization include the Clarkson Hill and Poison Spring Creek areas. Radioactivity is also associated with Precambrian allanite-bearing pegmatites in the Bridger Mountain area and with Late Cretaceous titaniferous black sandstone deposits found in the Coalbank Hill, Clarkson Hill, and Poison Spider areas.

These black sand deposits are fossil beach placers formed by the concentration of heavy mineral constituents by wave action along beaches of a prehistoric sea. The associated radioactivity results from several opaque heavy minerals containing small concentrations of uranium, thorium, and rare earths. Opaque heavy minerals of potential economic value in the black sands are titanium-oxide-bearing and iron-oxide-bearing minerals. Radioactive heavy minerals of interest include zircon, monazite, and a radioactive mineral containing niobium.

HILAND AREA. Uranium mineralization in the Hiland area is found in a lenticular arkosic sandstone channel of the Wind River Formation. The uranium is restricted to a 10 foot wide, 1 to 5 foot thick, 2000 foot long zone within the lens. Uranium concentrations are reported to range between 0.001 and 3.3 percent.

In 1955, Highland Uranium Incorporated produced 9 tons of ore containing 0.04 percent U_3O_8 from the Bridger Trail prospect in T.37N., R.88W. One hundred tons of uranium ore were later reported stockpiled near the Hope Mine in the same section. More recently, Uranex, Inc. and Great Basin Petroleum Company identified uranium reserves on the property of between 175,000 and 200,000 tons of ore.

DRY LAKE – NINE MILE LAKE AREA. In 1955, production from the Dry Lake – Nine Mile Lake area, T.35N., R.79W., north of Casper totalled only 87 tons of ore containing 0.32 percent U_3O_8 and 596 pounds of associated vanadium oxide. No additional production is reported from the Dry Lake prospects.

Rocky Mountain Energy Company is presently conducting feasibility studies for a possible in situ solution mine in the Nine Mile Lake region. In situ solution mines extract ore from the host rock "in place" by the use of chemical leachates. The leachate, pumped into the ground, oxidizes the uranium ore and carries the oxidized ore in solution to a recovery well where it is extracted. The advantages of this type of mine are that it requires only minor environmental disturbances and can be used to extract ore that would not be recoverable by conventional mining methods. The uranium in the Dry Lake area is found in the Mesaverde Formation.

PINE RIDGE AREA. In the Pine Ridge area, T.39N., R.77W., 1261 tons of rock containing 0.18 percent U_3O_8 and 3130 pounds of vanadium oxide were mined from the Baker pits in 1957 and 1958. The uranium mineralization occurs in a pink to red sandstone of the Lance(?) Formation.

CLARKSON HILL AREA. Several radioactivity anomalies occur in a conglomerate sandstone in the Wind River Formation in the vicinity of Clarkson Hill, T.31N., R.82W. The radioactivity is localized in lenses of carbonaceous siltstone within the conglomeratic sandstone. Uranium content varies from 0.02 to 0.12 percent.

In the same general area, a titanium-bearing black sandstone deposit (sec. 20, T.31N., R.82W.) occurs in the Parkman Sandstone Member of the Mesaverde Formation. Analysis shows 0.001 percent U_3O_8.

POISON SPRING CREEK. Anomalously high radioactivity is present in a carbonaceous siltstone lens in the upper coarse-grained sandstone facies of the Wind River Formation in T.32N., R.84W. and T.32N., R.83W. Selected samples are reported to contain uranium concentrations as high as 0.017 percent.

In sec. 4, T.31N., R.82W., uranium is reported in a carbonaceous siltstone lens of the lower part of the White River Formation. Maximum uranium concentration is 0.044 percent.

BRIDGER MOUNTAIN AREA. A group of claims in T.39N., R.88W. and in T.39N., R.87W. contain total indicated reserves of 4,700,000 tons of allanite-bearing rock. Allanite is a mineral that commonly contains thorium, uranium, and rare earth elements in variable amounts. No production has been reported from these claims.

COALBANK HILLS. The radioactive occurrences in the Coalbank Hills deposit are associated with a titanium-bearing black sandstone lens of the Mesaverde Formation. No chemical analyses of this deposit are available.

POISON SPIDER AREA. The Poison Spider deposit occurs in T.33N., R.84W. and in T.34N., R.84W., in the Lewis Shale. The average chemical uranium content of this deposit is reported as 0.0008 percent. The uranium is associated with opaque heavy minerals. In addition, the deposit contains monazite, a rare-earth-thorium-bearing phosphate mineral.

SUMMARY. Although uranium production in Natrona County has been minimal, production additional to Union Carbide's eastern Gas Hills mine operations will undoubtedly come from the Nine Mile Lake area. If successful, the Nine Mile Lake operation could open the door for extended production using similar in situ technology in this same region. A recent Mesozoic uranium discovery near Boot Heel in northwestern Albany County, near the Natrona County line, will require a reexamination of Mesozoic sediments in Natrona County for uranium mineralization, and could lead to the identification of additional uranium reserves for the county.

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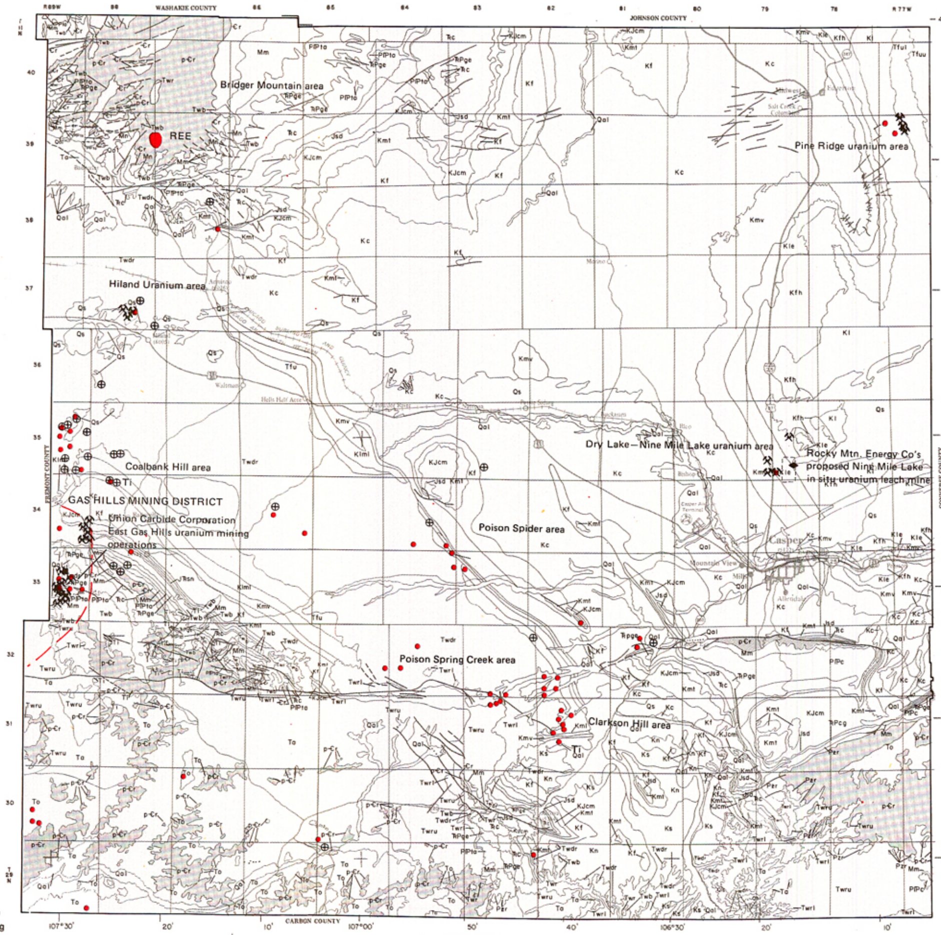

EXPLANATION

- Active mine operation
- Uranium mill
- Area of past production
- Area of extensive mining
- Uranium occurrence
- In situ solution mine
- Radioactivity anomaly
- REE Radioactive occurrence caused by the presence of rare earth elements
- Ti Titaniferous black sandstone deposit containing radioactive mineral occurences
- Precambrian crystalline rocks

THE GAS HILLS MINING DISTRICT, FREMONT-NATRONA COUNTIES

INTRODUCTION. The important commercial uranium deposits of Natrona County are found within the Gas Hills mining district on the west-central edge of the county. The district extends 3 miles east into Natrona County and nearly 12 miles west into neighboring Fremont County and includes about 150 square miles of land. Since uranium was discovered in the Gas Hills area in 1953, the district has ranked as Wyoming's number one uranium producer – until 1978, when the Gas Hills ranked second in production to the Box Creek district in the southern Powder River Basin by nearly 300,000 tons.

HISTORY. Uranium mineralization in the Gas Hills area was discovered on September 13, 1953, by Neil and Maxine McNeice near the present site of Pathfinder Mines' Lucky Mc uranium mining operations, sec. 21, T.33N., R.90W. McNeice and associates formed the Lucky Mc Uranium Corporation (renamed Pathfinder Mines in 1978) which mined more than 750,000 tons of ore from its Gas Hills operations in 1978. After the news spread of the McNeices' discovery, a uranium rush began in which thousands of mining claims were staked by prospectors and speculators.

Early mining in the Gas Hills district was of surface to near-surface ore deposits. For the most part, these deposits contained small tonnages of oxidized and out-of-equilibrium ore. The disequilibrium had resulted from the leaching of the ore by acidic (oxidizing) supergene solutions over eons of time. This resulted in the removal of much of the valuable uranium mineralization while leaving behind the less soluable gamma-emitting daughter products (e.g. bismuth 214, lead 210). These oxidized ores were an enigma to the early miners in that geiger counters used in ore-grade control commonly registered much higher counts of uranium than the subeconomic ore received at the mill. This problem was corrected by chemically analyzing the ore for uranium at the mine and recalibrating the radiometric readings to correct for the discrepancy. As mining and exploration technology advanced, much larger ore depostis in the form of "roll fronts" were discovered at depth.

URANIUM DEPOSITS. The Uranium deposits in the Gas Hills area are restricted to the upper part of the Wind River Formation known as the Puddle Springs Member. The Puddle Springs Member varies in thickness from 300 to 800 feet near the mine sites and consists predominantly of coarse-grained arkosic sandstones and conglomerates with layers of interbedded mudstone, carbonaceous shale, and siltstone. The significant ore deposits in the district are associated with the fluvial (stream deposited) sandstones and conglomerates.

Four distinct types of ore deposits are found in the district. Near-surface oxidized uranium mineralization similar to the McNeices' discovery is one type. These deposits are high gamma radiation emitters, which led to their rapid detection during the early uranium rush.

Stratigraphically below the near-surface oxidized deposits are the transitional bedded deposits. These occurrences were formed by downward (supergene) leaching solutions which enriched the underlying fine-grained rock units.

Lignites and carbonaceous shales containing uranium mineralization are termed residual remnant deposits. These deposits are formed by oxidizing, uranium-rich ground water coming into contact with reducing carbonaceous material and precipitating uranium in and around the organic debris.

These three types of uranium deposits are insignificant compared to roll fronts or solution fronts which form more than 90 percent of the uranium reserves of the district. Roll fronts commonly occur as crescent-shaped deposits of primary uranium minerals (uraninite and coffinite) at the contact between altered rock on the concave side and unaltered rock on the convex side of the roll front.

Evidence suggests that the roll fronts were formed by oxidizing, uranium-rich ground water solutions which migrated through permeable sediments, altering the rock. The oxidized uranium apparently precipitated out of solution where the ground water flow rate slowed or the uranium-bearing solutions were influenced by reducing agents (such as organic debris, hydrogen sulfide) over a relatively long period of time. In some places, the roll fronts were restricted by permeability – when layers of impermeable rock stopped the progression of the fluids, secondary enrichment resulted. Today, the location of altered-unaltered contacts in fluvial sandstones and conglomerates acts as an excellent ore guide in exploration.

The ore front orientations suggest that the mineralizing fluids migrated northwest from the southern edge of the district and formed three trends: the West, Central, and East Gas Hills trends. These trends may continue under younger rocks on the southern end of the district.

MINING. Nearly all of the ore produced from the Gas Hills district is mined from open pit operations. A few small deposits are high enough grade and deep enough to be mined underground, but the small tonnages associated with these deposits limit the lifetime of the mines.

Uranium was first mined in the district in 1954. Production continued to increase to a peak of 1,040,000 tons of 0.23% uranium in 1960. After 1960, less tonnage was mined due to a somewhat depressed uranium market which affected other districts more drastically – for example, production in the Powder River Basin came to a virtual standstill. By 1968, the uranium market began to pick up, and the higher price for a pound of uranium oxide led to the present uranium boom.

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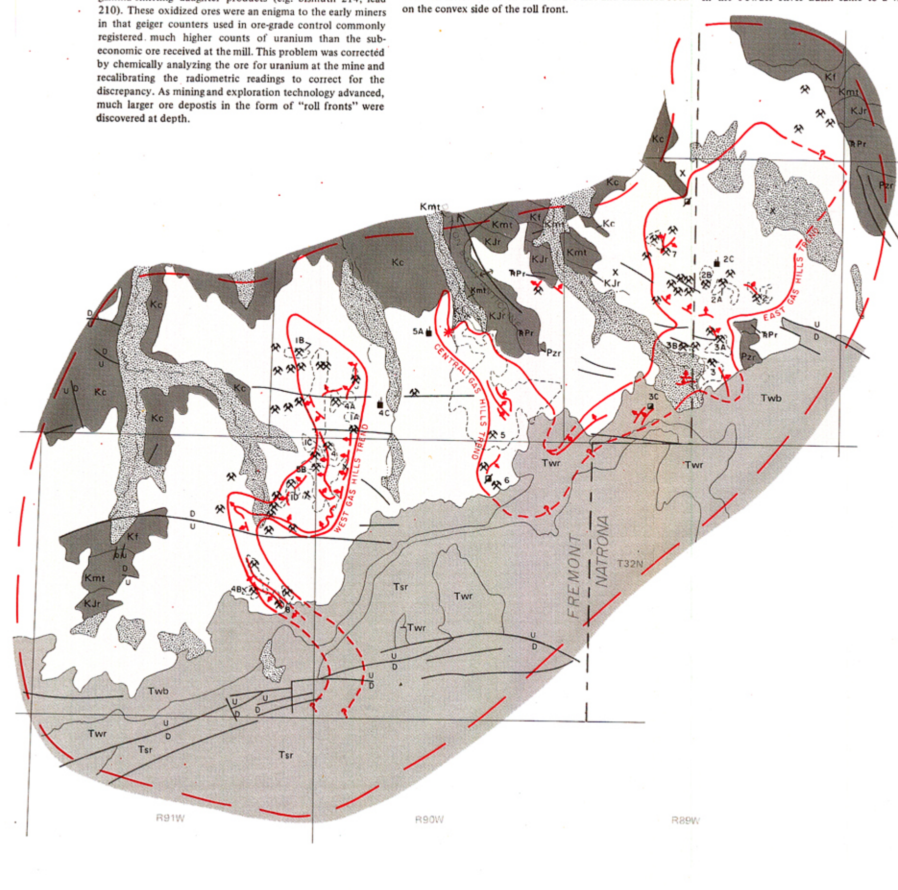
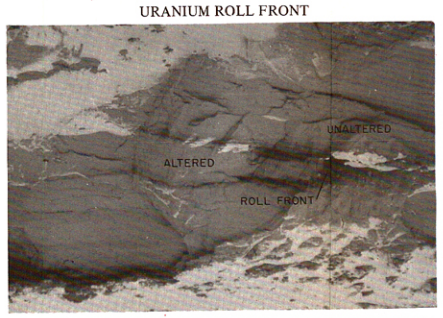


URANIUM ROLL FRONT



A typical crescent-shaped roll front in the wall of an open-pit uranium mine. The ore forms a contact between altered (left) and unaltered rock (right).

EXPLANATION

- ALLUVIAL DEPOSITS
- POST-WIND RIVER: Includes; Split Rock (Tsr), White River (Twr), and Wagon Bed (Twb) formations.
- WIND RIVER FORMATION
- PRE-WIND RIVER: Includes; Cody Shale (Kc), Frontier Formation (Kf), Mowry & Thermopolis Shales (Kmt), Cretaceous & Jurassic rocks (KJr), Triassic & Permian rocks (TrPr), and Paleozoic rocks (Pzr).
- Uranium ore trend
- Uranium roll front within Wind River Formation (arrow towards unaltered rock)
- McNeices's discovery location
- Active or proposed open pit mine
- Abandoned open pit mine
- Active underground mine
- Abandoned underground mine
- Uranium mill
- X Prospect
- Area of extensive mining
- Fault showing upthrown and downthrown sides
- Geologic contact
- Anticline with direction of plunge

MINES & MILLS

Union Carbide Corporation, West Gas Hills Mine Operations

1	D-pits
1A	K-pits
1B	G-pits
1C	E-pits
1D	P-pits

Union Carbide Corporation, East Gas Hills Mine Operations

2	B-pits
2A	A-pits
2B	C-pits
2C	Uranium mill (1375 tpd capacity)

Federal-American Partners, East Gas Hills Mine Operations

3	Buss-Russ pits
3A	Cap pits
3B	Two states pit
3C	U.P.Z. shaft

Federal-American Partners, West Gas Hills Mine Operations

4	Sunset pits
4A	Sagebrush-Tablestakes pits
4B	Clyde-Bret pits
4C	Uranium mill (950 tpd capacity – 4000 tpd proposed)

Pathfinder Mines Corporation, Gas Hills Mine Sites

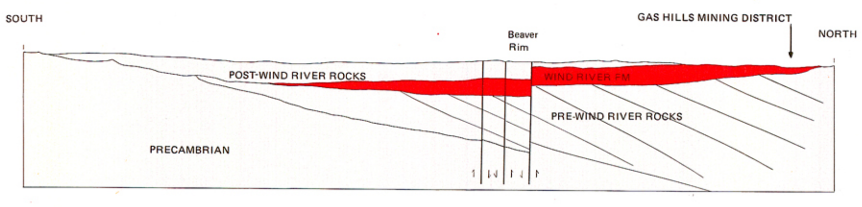
5	Lucky Mc mine site
5A	Uranium mill (1800 tpd capacity)
5B	Green River mine sites

PROPOSED MINES

6	American Nuclear Corporation, Cotter Ferguson mine
7	Adobe Oil & Gas Company, Rock Hill mine
8	Centurion Nuclear Incorporated, Day Loma project

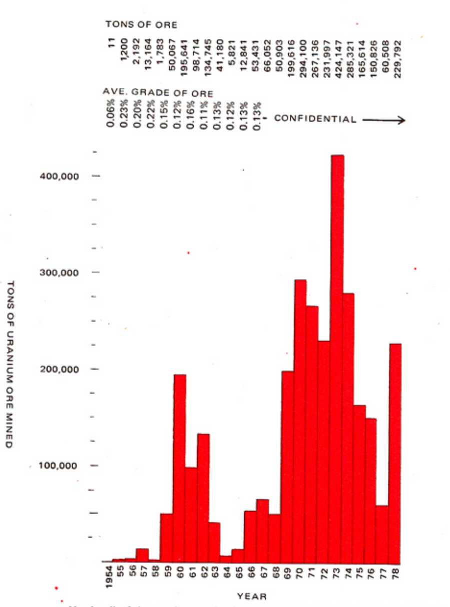
PATHFINDER MINES CORPORATION'S LUCKY MC URANIUM MINE

Pathfinder Mines' Lucky Mc uranium mine in the Gas Hills District of Fremont and Natrona Counties. Nearly all of the mining in the district is by conventional open pit operations.



Generalized cross-section through the Gas Hills mining district showing relationship of the Wind River Formation (host of uranium ore) to the post Wind River rocks to the south. Uranium deposits may continue under the Beaver Rim area under the overburden to the south. (After, Armstrong, 1970)

Natrona County Uranium Production



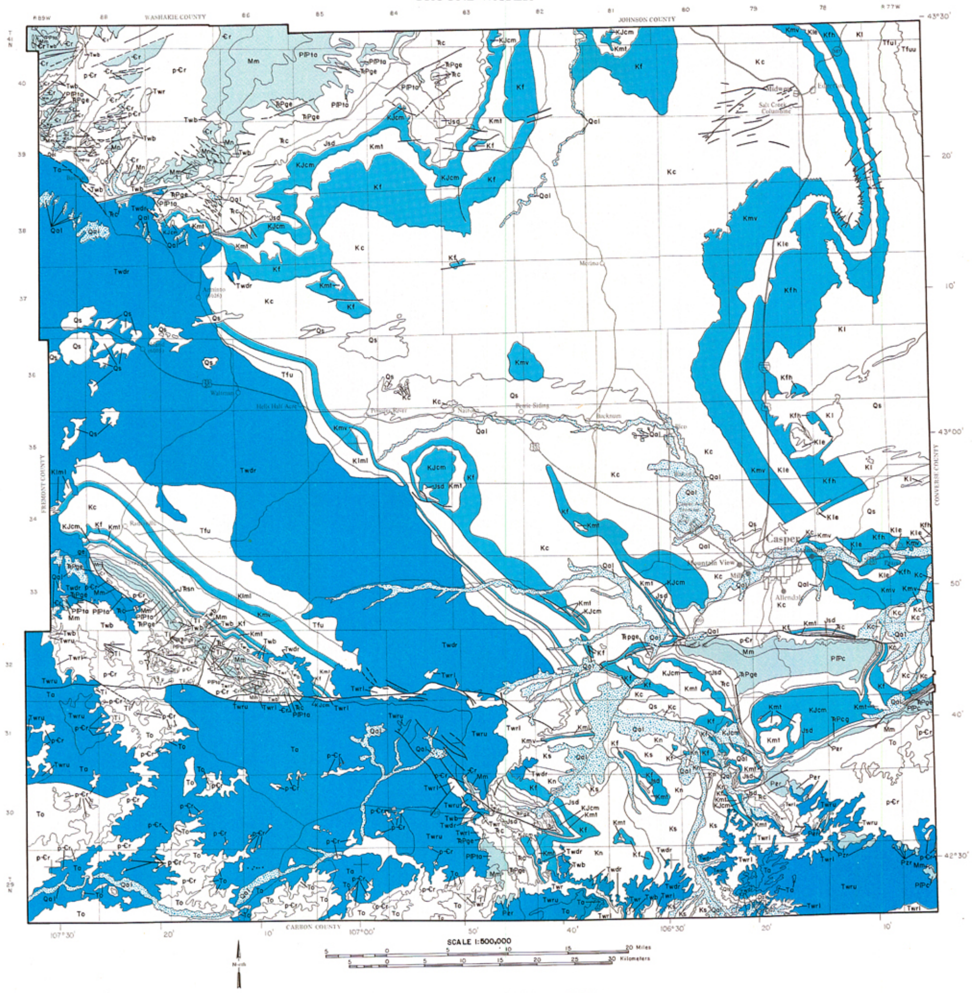
Nearly all of the uranium production reported from Natrona County has been mined from the eastern Gas Hills region. A total of less than 1,500 tons of uranium ore was mined outside this area during the years 1955, 1957, and 1958. All of the most recent production of uranium ore in Natrona County has been from Union Carbide's East Gas Hills mine operation. (U.S Atomic Energy Commission Production Reports, 1954-1967; State of Wyoming Ad Valorem Tax Division Annual Reports, 1967-1979.)

The Geological Survey of Wyoming, 1980

WATER / CRS 6, Natrona County, Wyoming

Sheet compiled by R.H. DeBruin

GROUND WATER



Major Aquifers with Ground Water Potential

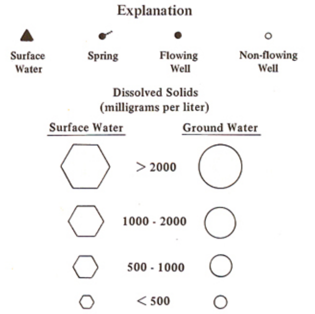
SURFICIAL DEPOSITS
Common shallow and inexpensive sources

TERTIARY SANDSTONES AND CONGLOMERATES
Major sources, of moderate yield, for domestic and agricultural uses

MESOZOIC SANDSTONES
Variable potential

PALEOZOIC SANDSTONES AND CONGLOMERATES
Largely unevaluated aquifers with great potential and large development costs

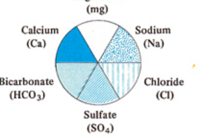
Explanation



The chemical type of the water is shown by segments of a colored circle (for ground water) or hexagon (for surface water), the size of which denotes the range in total disolved solids. Segment divisions are diagrammatic, with the major cation relation shown in the top half and the major anion relation shown in the bottom half. The following procedure is used to designate water type:

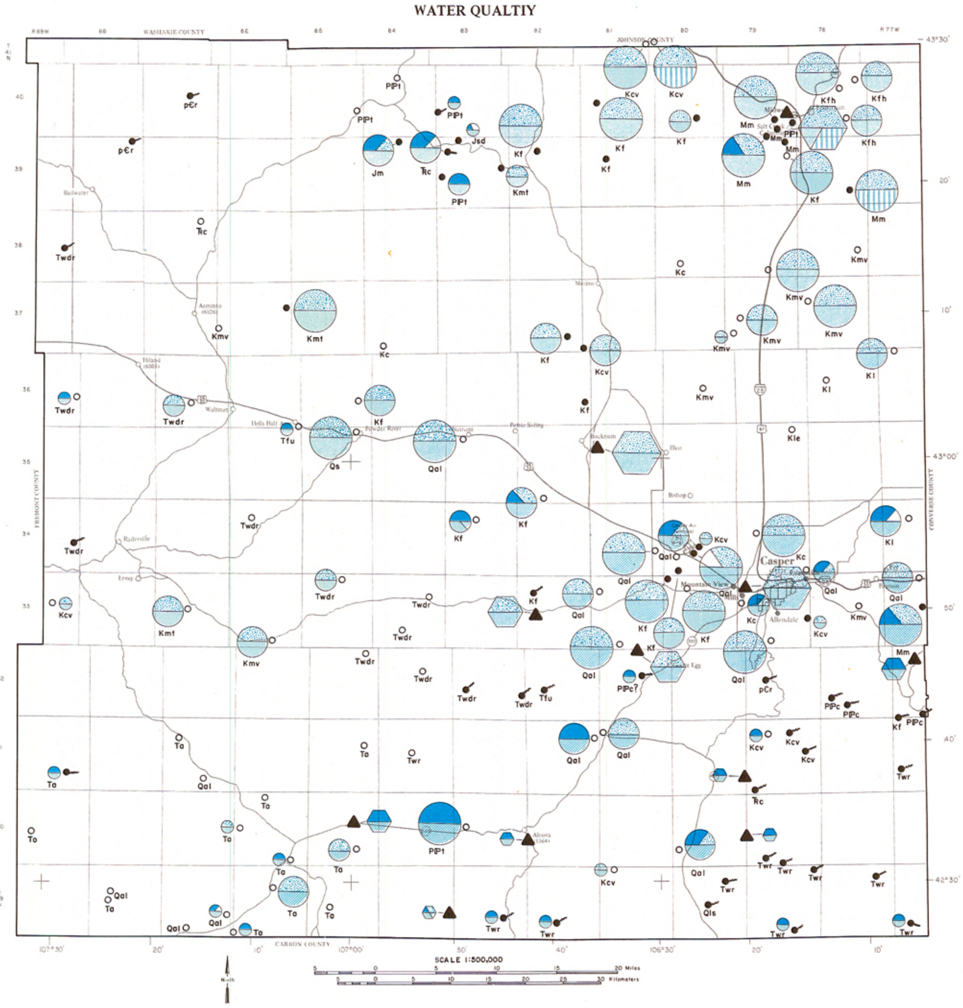
1. The content of the major cations – calcium, magnesium, and sodium (or sodium plus potassium) – in milliequivalents per liter is normalized to 100 percent; similarly, the content of the major anions – bicarbonate (or bicarbonate plus carbonate), sulfate, and chloride – is normalized to 100 percent.
2. If one cation constitutes 50 percent or more of the total cations and one anion constitutes 50 percent or more of the total anions, that cation and that anion designate the water type. For example, if sodium is 60 percent of the total cations and sulfate is 75 percent of the total anions, the water is classified as a sodium sulfate water.
3. If no cation constitutes as much as 50 percent of the total cations, the cation with the highest percentage is given two thirds of the upper half and is named first, and the ion with the second highest percentage follows as a subsidiary term. For example, if magnesium is 45 percent of all cations and calcium 35 percent (and sulfate is 75 percent of the anions), the water is classified as a magnesium calcium sulfate water. Likewise, a sodium water with 45 percent of the total anions bicarbonate and 35 percent sulfate is classified as a sodium bicarbonate sulfate water. Rarely are all three cations, or anions, nearly equal in percentage.

Chemical Quality



Refer to the Geologic Formations and Potential Water Supply Table to identify the geologic formation indicated by the symbol beside each circle.

WATER QUALTIY



GROUND WATER

Ground water levels fluctuate in response to recharge to and discharge from the aquifer. Precipitation is the main source of recharge to the consolidated aquifers in Natrona County. Water levels in unconsolidated aquifers such as alluvium and terrace deposits can rise considerably due to recharge from stream flow and irrigation seepage. Aquifers discharge through wells and springs and through evaporation.

Twenty-eight aquifers, ranging in age from Precambrian to Holocene, yield water to wells and springs in Natrona County (Crist and Lowry, 1972). The units shown in various shades of blue on the Ground Water Map and Geologic Formations and Potential Water Supply Table are those with the best ground water potential. However, an aquifer not shown in blue may be locally important. In some parts of Natrona County, low-yield aquifers may be the only feasible source of water supply. Water quality and the purpose for which the water is intended may determine the aquifer from which water is to be withdrawn. Logs and records of specific wells are available for inspection at the Wyoming State Engineer's Office, Barrett Building, Cheyenne, Wyoming 82001.

Precambrian and Tertiary Crystalline Rocks

Igneous and metamorphic crystalline rocks make up less than ten percent of the total rock outcrop in Natrona County. Most are of Precambrian age; however, igneous rocks of Tertiary age occur in the vicinity of the Rattlesnake Hills. Although ground water can be produced from these rocks, yields are generally less than 5 gallons per minute (gpm). Openings or fractures in which water occurs in these rocks are almost always near the surface. As a rule, water wells should be drilled no deeper than 100 feet into crystalline rocks in Natrona County.

Paleozoic Rocks

Paleozoic rocks in Natrona County yield the largest amounts of water through single wells and springs of any aquifer. Of all the Paleozoic units, the Madison Limestone has the potential for the greatest yield, one well yielding about 9,000 gpm. There are three wells in the Tensleep Sandstone with flows of over 400 gpm. Goose Egg Spring (sec. 15, T.32N., R.81W.), considered the largest in the county, flows 7,630 gpm from the Casper Formation.

The best areas for drilling a large capacity well in Paleozoic aquifers are near structures where there is a likelihood for development of secondary permeability. Such areas include the south side and west end of Casper Mountain, the north slope of the Rattlesnake Hills, and the east flank of the Bighorn Mountains (Crist and Lowry, 1972).

Mesozoic Rocks

Mesozoic rocks are not a good source of water in Natrona County. The rocks of the Goose Egg Formation up through the Bell Springs Member of the Nugget Sandstone (see the Geologic Formations and Potential Water Supply Table) have almost no aquifers of any consequence. Sandstone units in the Sundance, Morrison, and Cloverly Formations have some potential but probably would not yield more than 20 gpm; but conglomeratic beds in the Cloverly Formation may yield 100 gpm or more.

Of all the formations in the Mesozoic succession, the principal aquifers are the Frontier and Mesaverde Formations and the Fox Hills Sandstone. Because of low permeability, yields through wells completed in sandstone within these formations are usually less than 50 gpm. The Frontier Formation is the most used aquifer underlying the Cody Shale in northern and central Natrona County. Yields range from 1 to 10 gpm. Wells in the Mesaverde Formation usually yield 10-20 gpm and the water is mostly used for livestock. Fox Hills Sandstone wells commonly yield 10-25 gpm.

Tertiary Rocks

The Wind River Formation is present in the western part of Natrona County within the Wind River Basin, but is absent in most of the rest of the county. Water yields usually do not exceed 25 gpm from this formation, and nearly all the wells are for stock or domestic use. The White River and Arikaree Formations are considered the main aquifers in the Tertiary succession because they have the greatest areal extent and thicknesses. Local supplies can also be developed from saturated conglomerate in the Ogallala and Wagon Bed Formations.

Quaternary Deposits

Of all the Quaternary deposits, alluvium, especially where it is derived from resistant rocks such as igneous and metamorphic rocks, is the most reliable water supplier. Yields of 1,000 gpm or more are common. Wind-blown deposits are reservoirs for ground water in some areas, but yields are usually small. Landslide deposits drain ground water quickly, but may trap some precipitation. Springs and seeps are common near the base of these deposits. Areas with the best potential for water development from alluvium are along Bates Creek, Poison Spider Creek, and the North Platte River (Crist and Lowry, 1972).

WATER QUALITY

The chemical quality of water is usually expressed in parts per million (ppm) or in milligrams per liter (mg/l) of dissolved anions and cations and of total dissolved solids and trace elements. Water quality is often more important than quantity for domestic, agricultural, and industrial uses. The inorganic quality of water is primarily determined by the rocks and soil units over and through which it flows. The organic quality of water is often affected by man's activities.

Standards

The U.S. Public Health Service has recommended the following standards for water used for drinking and cooking.

Constituents	Recommended Maximum Concentration (ppm)
Iron (Fe)	.3
Manganese (Mn)	.05
Sulfate (SO_4)	250
Chloride (Cl)	250
Fluoride (F)	.8-1.7
Selenium (Se)	.01
Total Dissolved Solids	500

Although the recommended maximum concentration for total dissolved solids is 500 ppm, there are several instances where water containing more than 1,000 ppm is being used for drinking without apparent adverse effects.

Hardness in water is caused principally by calcium and magnesium cations in solution; it is classified as follows:

$Ca^{2+} + Mg^{2+}$	Classification
60 ppm or less	Soft
61-120 ppm	Moderately hard
121-180 ppm	Hard
More than 180 ppm	Very hard

Studies at the Wyoming Agricultural Experiment Stations yield the following classification of water for stock.

Dissolved Solids (ppm)	Classification
< 1,000	Good
1,000-3,000	Fair
3,000-5,000	Poor
5,000-7,000	Very poor (questionable)
> 7,000	Not advisable

The most significant properties that affect the suitability of water for irrigation are the dissolved solids, percent sodium, and sodium concentration relative to calcium and magnesium concentrations. In general, when dissolved solids approach 1,000 ppm and the concentration of sodium is appreciably greater than 50 percent of the total cations, the water is of limited suitability for irrigation.

Surface Water Quality

The quality of surface water usually varies with seasonal flow. During high surface runoff, streams have lower mineral content than during periods of low surface runoff. Chemical composition of surface water in Natrona County is shown by colors and patterns within the hexagons on the Water Quality Map. The range of total dissolved solids is shown by the size of the hexagons. It should be noted that selenium in concentrations of .94 mg/l has been detected in the Oregon Trail Drain, which empties into the North Platte River just upstream from Casper. Selenium is toxic to humans and livestock, and effects of selenium poisoning may be permanent. The recommended limit of selenium for drinking water is .01 mg/l.

Ground Water Quality

The chemical composition of ground water in major aquifers is shown on the Water Quality Map by colors and patterns within the circles. Total dissolved solids is shown by the size of the circles. The quality of water from the confined aquifers is often best near the outcrop area. This is because the water that recharges the aquifer has not had time to react with the various constituents of the aquifer. Ground water in the Quaternary deposits is unconfined and interacts with surface water, and therefore is variable in water quality. Selenium concentrations in water sampled from the alluvial terraces west of Casper range from .03 to 1.1 mg/l. Ground water from these terraces discharges into drainages which empty into the North Platte River, causing the selenium concentration to rise in the North Platte as well as in other alluvial deposits downstream that are recharged by water from the North Platte (Crist and Lowry, 1972).

GEOLOGIC FORMATIONS AND POTENTIAL WATER SUPPLY

MAP SYMBOL	UNIT/MAP SYMBOL/ THICKNESS IN FEET	LITHOLOGY	GROUND-WATER POSSIBILITIES	WATER QUALITY (Dissolved solids & water type)
	Alluvium, Qal, 0-190	Unconsolidated silt, sand, and gravel underlies floodplains and terraces; landslides include loose blocks and fine matrix; windblown deposits are unconsolidated sand.	Alluvium yield up to 1,300 gpm. Landslide small yield to springs and seeps; poor well site. Windblown will yield a maximum 5-10 gpm.	Sulfate dominant anion with 246-8,240 mg/l in alluvium and 500-2,500 mg/l in windblown
	Landslide, Qls, 50±			
	Windblown, Qs, 0-40+			
	Ogallala Fm., To, 0-800	Deposits of silt, sand, and gravel; may be unconsolidated or well cemented.	Yield more than 200 gpm from conglomerate and secondary permeability zones as well as Arikaree nearly everywhere, with smaller yields in areas underlain by these rocks.	Primarily calcium bicarbonate type with generally less than 500 mg/l.
	Arikaree Fm., Ta, 0-1000	Light gray sandstone, fine- to medium-grained; some thin beds limestone, tuff, and conglomerate.		
	White River Fm. Twr: Upper, Twru, 0-600	Upper member is mostly sandstone and conglomerate.		
	White River Fm. Twr: Lower, Twrl, 0-865	Lower member is pinkish gray siltstone with conglomerate lenses.		
	Wagon Bed Fm., Twb, 0-1000; Intrusive and Extrusive, Ti	Wagon Bed is made up of bentonitic mudstone, sandstone, and conglomerate.	Yields generally less than 5 gpm.	
	Wind River Fm., Twdr, 0-7000	Variegated claystone and shale, brown and gray sandstone, and lenticular conglomerate.	Yields mostly less than 10 gpm. Higher yields possible from conglomerate or large saturated thicknesses.	Sulfate with sodium, calcium, and magnesium. Range: 276-1,830 mg/l.
	Fort Union Fm. (Wind River Basin) Tfu, 0-8000; Ft. Union Fm. (Powder River Basin) Upper, Tfuu and Lower, Tful, 0-3000	Wind River Basin: Shotgun Member consists of fine-grained sandstone and siltstone; Waltman Shale Member is silty and shaly claystone; unnamed lower member is sandstone and siltstone. Powder River Basin: Upper Member consists of sandstone, siltstone, carbonaceous shale and coal; lower member consists of claystone and siltstone interbedded with sandstone.		
	Lance Fm., Kl, 0-5000	Brown and gray sandstone and shale; thin coal and carbonaceous shale beds.		
	Fox Hills Sandstone, Kfh, 0-700	Light colored sandstone and gray sandy shale.	Yields to 50 gpm.	Sodium sulfate with an excess of 1,000 mg/l.
Kml	Meeteetse Fm., Km., 430-630; Lewis Shale, Kle, 0-500	Meeteetse consists of gray carbonaceous shale interbedded with sandstone and thin coal beds. Lewis consists of gray sandy shale and lenticular sandstone.	Yields mostly less than 10 gpm. Higher yields possible from conglomerate or large saturated thicknesses.	Sulfate with sodium, calcium and magnesium. Range: 276-1,830 mg/l.
	Mesaverde Fm., Kmv: Teapot Sandstone Member, 50-115; Unnamed middle member, 260-750; Parkman Sandstone Member, 50-500	Gray and brown massive to thin-bedded sandstone, carbonaceous shale, and coal beds.	Yields up to 50 gpm in the Mesaverde and Frontier Formations, sandstones in other formations will yield much less.	Sodium sulfate is the dominant type with an excess of 1,000 mg/l.
	Steele Shale, Ks; Niobrara Fm., Kn; Cody Shale, Kc, 3000-5000	Steele is gray shale with bentonite beds and thick lenticular sandstone; Niobrara is light-gray limestone and speckled limy shale; Cody is soft shale and lenticular sandstone beds; gray limy shale at base.		
	Wall Creek Sandstone Member; Frontier Fm., Kf, 650-900	Thick gray sandstone beds in upper part; black shale and bentonite interbedded with sandstone in lower part.		
Kmt	Mowry Shale, 200-300	Black and gray, hard shale with thin bentonite beds.		
	Muddy Sandstone Member; Thermopolis Shale, 200	Thermopolis is soft, black shale; Muddy sandstone is 150-250 feet above base.		
KJcm	Cloverly Fm., 150-300	Light gray sandstone and lenticular conglomerate interbedded with bentonitic claystone.	Generally yields 5-20 gpm but may yield as much as 250 gpm.	Sodium bicarbonate type with 70-1,780 mg/l.
	Morrison Fm., 150	Variegated claystone and gray silty sandstone lenses.	Only small yields in most areas.	Sundance variable with 416-1800 mg/l. Morrison predominantly sodium bicarbonate.
JꞦsn	Sundance Fm., Jsd, 300	Olive-gray shale and sandstone; thin-bedded sandstone at base.		
	Bell Springs Member of Nugget Sandstone, 0-90	Very fine grained sandstone and pale red siltstone beds.		
ꞦPcg	Chugwater Gp., Ꞧc: Jelm Fm., 25-85; Alcova Limestone, 10-20; Red Peak Fm., 600-700	Jelm is red sandstone and siltstone; Alcova is gray laminated limestone; Red Peak is red shale and siltstone.	Yields only small supplies.	Chugwater group variable with 300-1,330 mg/l. Goose Egg calcium sulfate type with 1,300-1,500 mg/l.
	Goose Egg Fm., ꞦPge, 150-380	Red shale, gray dolomite and limestone, and anhydrite and gypsum beds.		
Pzr	PⱣta: Tensleep Sandstone, 0-500; Amsden Fm., 0-200; Casper Fm., PⱣc	Tensleep and Amsden are massive sandstone underlain by thin-bedded dolomite, limestone and red shale. Casper is gray and tan thick bedded sandstone underlain by interbedded sandstone, pink and gray limestone and dolomite, and red shale.	Yields may exceed 4000 gpm in secondary permeable sandstone and limestone beds. Otherwise, 50 gpm in sandstone nearly everywhere.	Variable types. Less than 500 mg/l near outcrop but quality deteriorates with increased distance from recharge area.
	Madison Limestone, Mm., 200-400	Gray, massive, cavernous cherty limestone and dolomite.		
	Cambrian rocks undivided, Ꞓr, 0-900	Thin glauconitic shale interbedded with limy shale in upper part; dull pink quartzite and sandstone in lower part.		
	Precambrian rocks, pꞒr	Igneous and metamorphic rocks.	Yields generally less than 5 gpm.	Usually a calcium bicarbonate type. Less than 500 mg/l.

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