GEOLOGIC FORMATIONS AND POTENTIAL WATER SUPPLY

ERA	SYSTEM	SERIES	GEOLOGIC UNIT: WEST SIDE OF BASIN	GEOLOGIC UNIT: EAST SIDE OF BASIN	LITHOLOGY, THICKNESS, AND DISTRIBUTION	AVAILABILITY AND CHEMICAL QUALITY OF GROUND WATER
CENOZOIC	QUATERNARY	Pleistocene and Holocene	Alluvium		Silt, sand, and gravel, unconsolidated; underlies flood plains and bordering terraces. Thickness mostly less than 50 feet, but may be as much as 100 feet in some valleys near mountains. Coarser alluvial deposits occur in valleys of the North Platte, Belle Fourche, Cheyenne, Powder, and Little Powder Rivers, and Lance, Crazy Woman, and Clear Creeks. Alluvium overlying formations of Tertiary age in central part of basin is mostly fine to medium grained.	Yields range from a few gallons per minute to more than 1,000 gpm (gallons per minute). Yields depend on saturated thickness, grain assortment, well construction and development. Ground-water possibilities generally good in coarse-grained deposits but poor in fine-grained deposits. Potential source for irrigation, municipal, and industrial supplies in valleys where more than 40 feet of saturated well sorted sand and gravel are present. Chemical analyses of water show dissolved solids range from about 100 to more than 4,000 mg/l (milligrams per liter), but commonly range between 500 and 1,500 mg/l. Water in alluvium near Bighorn Mountains and in Black Hills is better quality than water in alluvium in central part of basin. Water in alluvium in southwest part of basin and in Powder River valley is generally poorer quality than water in alluvium elsewhere in basin. No dominant water type is prevalent.
			Landslide deposits		Rock debris near base of steep slopes; most extensive in northern part of Bighorn Mountains.	Not considered an aquifer, but may yield water locally to springs.
			Windblown sand		Sand and silt, unconsolidated. Thickness mostly less than 50 feet. Present locally in southwest part of basin as both active and inactive sand dunes.	Generally too thin to yield much water, but, locally, may yield adequate water for domestic or stock needs. Probably aids recharge to underlying rocks in some places.
		Pleistocene	Glacial deposits		Sand, gravel, and boulders in high elevations of Bighorn Mountains, mostly above 9,000 feet. Occurs chiefly as terminal moraines across valleys, as lateral moraines along valley sides for considerable distances above terminal moraines, and as ground moraines inside boundaries of lateral and terminal moraines. Maximum thicknesses occur in terminal moraines and are mostly less than 500 feet.	Ground-water possibilities not well known, but, except where drained, the deposits should yield water of good quality. Yields of 50 gpm or more possible locally, but much of the deposits would yield lesser amounts. Spring 53-86-27cd, Johnson County, had a reported flow of about 400 gpm; dissolved solids were 82 mg/l.
	TERTIARY	Miocene	Arikaree Formation		Sandstone, fine-grained, tuffaceous; contains hard beds of locally derived limy conglomerate (Denson and Botinelly, 1949, sheet 2). Locally fractured and jointed (Whitcomb, 1965, p. 31). Thickness about 600 feet near Whitman (Babcock and Keech, 1969, pl. 1). Present chiefly in extreme southeast part of basin, but also present as remnants in the Bighorn Mountains (Love and others, 1955).	Yields of as much as several hundred gallons per minute possible in areas of greater saturated thickness in extreme southeast part of basin (Tps. 33 and 34, Niobrara County). North of this area, the formation becomes progressively more eroded leaving mesas and buttes that are largely drained of ground water. Water generally contains less than 500 mg/l dissolved solids and is dominantly calcium bicarbonate type.
		Oligocene	White River Formation		Claystone and siltstone, tuffaceous, bentonitic; contains lenses of locally derived conglomerate (Denson and Botinelly, 1949, sheet 2). Thickness about 560 feet near Whitman in southeast part of basin (Babcock and Keech, 1969, pl. 1). Present chiefly in extreme southeast part of basin, but also present as isolated remnants in southwest Campbell County (Pumpkin Buttes), and as small remnants on a few high divides in the Black Hills and Bighorn Mountains (Love and others, 1955).	Yields ranging from 5 to 20 gpm possible in extreme southeast part of basin, but, locally, larger yields may be possible where permeability has been increased significantly by fractures and joints. Dissolved solids generally range from 300 to 500 mg/l in Niobrara County and from 500 to more than 1,000 mg/l in Converse County. Water type is mostly sodium bicarbonate, and to a lesser extent sodium sulfate.
		Eocene	Wasatch Formation		Lenticular sandstone, fine- to coarse-grained, and interbedded shale and coal. Coarse-grained rocks proportionately greater toward south part of basin (Davidson, 1953, p. 9). Thickness about 1,575 feet in Pumpkin Buttes area (Sharp and others, 1964, pl. 13), becoming generally thinner toward basin margins. Forms surface of most of central part of basin. In northwest part of basin near the Bighorn Mountains, the Wasatch is divided into two conglomeratic members --the Kingsbury and overlying Moncrief--which consist of as much as 2,000 feet of siltstone, sandstone, cobbles, and boulders, and which grade imperceptibly into the fine-grained facies of the Wasatch within a few miles of the mountains (Hose, 1955, p. 67; Lowry and Cummings, 1966, p. 37).	Yields water from lenticular sandstone, and to a lesser extent from jointed coal and clinker beds. Yields can be expected to range from 10 to 50 gpm in north part of basin becoming generally greater southward with 500 gpm or more possible in south part of basin. Well 50-72-35dd near Gillette had a specific capacity of about 4 gpm per foot of drawdown. Seven wells on the Buffalo Ranch (T. 44N., R. 72 W.) had specific capacities, as reported on drillers' logs, ranging from 5 to 14 gpm per foot of drawdown. Yields of 200 gpm or more may be possible locally from Moncrief and Kingsbury Conglomerate Members in northwest part of basin, but these rocks characteristically abut against the mountain flanks, are moderately dissected, and are probably largely drained. Dissolved solids range from less than 200 to more than 8,000 mg/l, but commonly range between 500 and 1,500 mg/l. No relation of dissolved solids to depth is discernible, but water mineralization decreases in general southward. Sodium sulfate and sodium bicarbonate are the dominant water types.
		Paleocene	Fort Union Formation		Sandstone, fine-grained, and interbedded shale, carbonaceous shale and coal. Thickness about 2,270 feet in east part of basin (Dobbin, Kramer, and Horn, 1957), about 2,900 feet in southwest part (Horn, 1955), and about 3,450 feet in northwest part (Hose, 1955, pl. 8). Outcrop of Fort Union encircles most of basin; the beds dip basinward into the subsurface.	Yields water from fine-grained sandstone, jointed coal, and clinker beds. Maximum yields are about 150 gpm. Average specific capacity of four wells in southwest Crook County was 0.3 gpm per foot of drawdown, and for four wells at Wyodak coal mine in Campbell County was 0.9 gpm per foot of drawdown (Whitcomb and Morris, 1964, table 1 and p. 40). Well 50-72-22cac near Gillette had a specific capacity of 0.7 gpm per foot of drawdown (Littleton, 1950, p. 14). Average specific capacity for 85 wells in Sheridan County computed from yield-drawdown data from drillers logs was 0.42 gpm per foot of drawdown (Lowry and Cummings, 1966, p. 21). Dissolved solids range from about 200 to more than 3,000 mg/l, but commonly range between 500 and 1,500 mg/l. Water type is mostly sodium bicarbonate, and to a lesser extent sodium sulfate.
		Paleocene(?)	Intrusive rocks		Monzonite and syenite porphyry, phonolite, bostonite, nepheline syenite, and pseudoleucite porphyry (Love and others, 1955). Present in the Black Hills as laccoliths and plugs, such as Bear Lodge Mountains, Inyan Kara Mountain, Sundance Mountain, Missouri Buttes, Black Buttes, and Devils Tower, and as sills and dikes.	Yields water to springs locally in outcrop areas from fractured and weathered zones. Yields are generally less than 5 gpm, and dissolved solids less than 100 mg/l.
MESOZOIC	CRETACEOUS	Upper Cretaceous	Lance Formation		Sandstone, fine- to medium-grained, and interbedded sandy shale and claystone. Thickness increases southward on east side of basin from about 500 feet in northeast Campbell County to about 1,600 feet in northern Weston County (Robinson and others, 1964, p. 98), and from about 2,500 feet in Niobrara County (Whitcomb, 1965, p. 23) to as much as 3,000 feet in southern Converse County (Rapp, 1953, table 1). On west side of basin, thickness increases southward from about 600 feet in southern Montana (Thom and others, 1935, p. 61) to about 2,000 feet near Buffalo (Mapel, 1959, p. 60) and to about 2,400 feet in southern Johnson County (Horn, 1955).	Generally yields less than 20 gpm, but yields of several hundred gallons per minute may be possible from the complete section of the formation. Most wells have been drilled in outcrops of the Lance for domestic and stock purposes and tap only a small part of the formation. The specific capacity of three wells in Crook County ranged from 0.4 to 1.7 gpm per foot of drawdown (Whitcomb and Morris, 1964, p. 15). Dissolved solids range from about 200 to more than 2,000 mg/l, but commonly range between 500 and 1,500 mg/l. No dominant water type is prevalent.
				Fox Hills Sandstone	Predominantly sandstone, fine- to medium-grained, containing thin beds of sandy shale; thickness ranges from about 125 to 200 feet in Crook and Weston Counties (Robinson and others, 1964, p. 95), and from about 400 to 500 feet in Niobrara County (Whitcomb, 1965, p. 19). Thickness is about 700 feet in southwest part of basin (Horn, 1955), but has not been differentiated, if present, from the overlying Lance Formation in west and northwest parts of basin (Hose, 1955, p. 65; Mapel, 1959, p. 59).	Yields of as much as 200 gpm are available from sandstone beds in east part of basin. Several wells south of Rozet produce about 200 gpm from the Fox Hills for water flooding. Well 56-71-15dd, Campbell County, flows 75 gpm from a depth of about 2,000 feet, and has a shut-in pressure of 54 psi (pounds per square inch) at the surface. Maximum yields in west part of basin will probably be less than 100 gpm. Well 40-78-15abb, Natrona County, had a specific capacity of only 0.37 gpm per foot of drawdown (Crist and Lowry, 1972, p. 61). Dissolved solids are mostly less than 1,000 mg/l in east part of basin, but generally range between 1,000 and 2,000 mg/l in west part. No dominant water type is prevalent.
			Lewis Shale	Pierre Shale	Lewis Shale--Mostly shale; contains sandy shale zones and lenses of fine-grained sandstone (Dunlap, 1958, p. 109; Hose, 1955, p. 64). Thickness about 200 feet in northwest part of basin (Mapel, 1959, p. 59) and about 470 feet in southwest part (Horn, 1955). Pierre Shale--Shale, some sandy shale and sandstone, and many beds of bentonite (Robinson and others, 1964, p.77). Contains Groat Sandstone Bed of the Gammon Ferruginous Member in Crook and Weston Counties that Gill and Cobban (1961, p. D190) report becomes thicker and coarser grained toward west. Formation thickens southward from about 2,100 feet in northernmost Crook County to about 2,900 feet in central Weston County (Robinson and others, 1964, fig. 5), and to as much as 3,100 feet in Niobrara County (Whitcomb, 1965, table 3). Present on east side of basin; grades westward in subsurface into Lewis Shale, Mesaverde Formation, and upper part of Cody Shale on west side of basin.	Lewis Shale--Sandy zones may yield as much as 10 gpm, but most of the formation does not yield water. Pierre Shale, Niobrara Formation, Carlile Shale, Greenhorn Formation, and Belle Fourche Shale--Sequence of rocks is predominantly shale with only local lenses of sand from which small amounts of water can be expected. The Groat Sandstone Bed might be an exception, but yields of 10 to 20 gpm would probably be maximum.
			Mesaverde Formation		Mesaverde Formation--Sandstone, massive to thin bedded, shale, sandy shale, and coal beds. Thickness about 700 feet in northwest part of basin (Hose, 1955, p. 64; Mapel, 1959, p. 57), and about 900 feet in southwest part where it is divided into three members: Parkman Sandstone Member at base, about 470 feet thick; unnamed middle shale member, about 320 feet thick; and Teapot Sandstone Member at top, about 110 feet thick (Downs, 1949, p. 49).	Mesaverde Formation--Yields of as much as 50 gpm are possible from sandstone beds, and as much as 200 gpm where fracturing has increased the permeability, generally near geologic structures. Well 37-78-7dcd, Natrona County, yields about 120 gpm. Dissolved solids can be expected to range from about 300 mg/l to more than 2,000 mg/l. Most water will be sodium sulfate type.
			Cody Shale	Niobrara Formation	Cody Shale--Shale, calcareous lower part; contains siltstone and sandstone beds; thickness about 3,600 feet in northwest part of basin and about 3,000 feet in southwest part; Shannon Sandstone Member, a fine-grained sandstone about 200 feet thick, occurs 2,000 to 2,500 feet above the base (Hose, 1955, pl. 8; Mapel, 1959, p. 49; Horn, 1955). In southwest part of basin, Sussex Sandstone Member occurs about 400 feet above the Shannon (Crist and Lowry, 1972, pl. 2; Horn, 1955). Niobrara Formation--Calcareous shale and marl with some noncalcareous shale near base; contains many thin beds of bentonite; thickness ranges from 150 to 225 feet (Robinson and others, 1964, p.74).	Cody Shale--Yields of as much as 20 gpm possible from sandstone beds, but other rocks in formation would yield little or no water. Shannon and Sussex Sandstone Members contribute most water from formation. Dissolved solids are generally more than 1,000 mg/l and may be much higher near oil-field areas. Sodium sulfate is the dominant water type.
				Carlile Shale	Carlile Shale--Shale, sandy in middle part; thickness ranges from about 450 feet near Newcastle to about 600 feet in northwest Crook County (Robinson and others, 1964, p. 66). Contains Turner Sandy Member in Crook and Weston Counties which is about 185 feet thick near Upton (Mapel and Pillmore, 1964, p. J25).	
			Frontier Formation	Greenhorn Formation	Frontier Formation--Sandstone and interbedded shale; conglomeratic sandstone at top (Hose, 1955, p. 59; Mapel, 1959, p. 43). Becomes more sandy toward south (Faulkner, 1956, p. 4); contains Wall Creek Sandstone Member at top in southwest part of basin. Thickness increases southward from about 500 feet near Buffalo (Mapel, 1959, p. 43) to about 830 feet in southeast Johnson County (Horn, 1955). In Buffalo area, Frontier is equivalent to Belle Fourche Shale and lower part of Greenhorn Formation of Black Hills area (Mapel, 1959, p. 46). In southwest part of basin, Frontier is equivalent to Belle Fourche Shale, Greenhorn Formation, and Carlile Shale (Hose, 1955, p. 61; Haun, 1958, p. 84; Beikman, 1962, p. 44). Greenhorn Formation--Shale, limestone, and marl. Thickness variable: 125 to 370 feet in northern Crook County (Knechtel and Patterson, 1955, sheet 2); 70 to 80 feet in southwest Crook County (Bergendahl and others, 1961, p. 653); and about 270 feet in Newcastle-Osage area (Brobst and Epstein, 1963, p. 353).	Frontier Formation--Yields of as much as 50 gpm are available from sandstone beds. Formation is principal aquifer in areas underlain by Cody Shale in southwest part of basin, and many flowing stock wells at depths of about 1,000 feet have yields ranging from about 1 gpm to 10 gpm. Dissolved solids can be expected to range from about 300 mg/l to more than 3,000 mg/l. Most water is sodium bicarbonate or sodium sulfate type.
				Belle Fourche Shale	Belle Fourche Shale--Shale, dark-gray to bluish-black; contains numerous concretions and a few thin beds of bentonite (Bergendahl and others, 1961, p. 652). Thickness about 370 feet in Newcastle-Osage area, about 450 feet in northeast Crook County, and as much as 850 feet in northwest Crook County (Robinson and others, 1964, p. 53).	
		Lower Cretaceous	Mowry Shale		Hard siliceous shale upper part, soft slightly siliceous shale lower part; contains a few silty and sandy beds (Robinson and others, 1964, p. 49; Hose, 1955, p. 59). Thickness increases northward on east side of basin from about 180 feet at Newcastle (Robinson and others, 1964, p. 49) to about 250 feet in northern Crook County (Knechtel and Patterson, 1962, p. 911), and on west side of basin from about 230 feet in southeast Johnson County (Horn, 1955) to as much as 525 feet in the Buffalo-Lake De Smet area (Mapel, 1959, p. 41).	Some of these rocks may yield as much as 10 gpm, but most of the formation does not yield water. Formation is mostly brittle thin-bedded shale, and greater secondary permeability is more possible than in other more plastic shale formations of Cretaceous age.
			Thermopolis Shale	Newcastle Sandstone	Thermopolis Shale--Soft black shale; contains thin beds of ferruginous sandstone and bentonite partings; thickness about 200 feet (Mapel, 1959, pl. 3; Horn, 1955). Contains Muddy Sandstone Member near top, a medium-grained sandstone and interbedded shale, which extends eastward in subsurface to the Black Hills where it is called Newcastle Sandstone (Eicher, 1958, p. 81). Thickness of Muddy ranges from about 40 feet in northern Johnson County (Mapel, 1959, pl. 3) to 6 feet or less in northeast Natrona County (Thom and Spieker, 1931, p. 15). Newcastle Sandstone--Lithology varied; mostly fine- to medium-grained lenticular sandstone, with lesser amounts of siltstone and shale; thickness at most places ranges from 20 to 60 feet (Robinson and others, 1964, p. 44), but is as much as 100 feet in Newcastle area (Dobbin and Horn, 1949). Called Muddy Sandstone Member of Thermopolis Shale in parts of basin.	Thermopolis Shale, Newcastle Sandstone, and Skull Creek Shale--Ground-water possibilities not known, but probably poor. Sandstone beds may yield as much as 10 gpm locally, but other rocks are not considered aquifers.
				Skull Creek Shale	Skull Creek Shale--Shale, dark-gray to black; contains a few thin beds of sandstone and siltstone; thickness about 200 feet in Osage-Newcastle area, and between 240 and 270 feet in northern Crook County (Robinson and others, 1964, p. 42).	

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ERA	SYSTEM	SERIES	GEOLOGIC UNIT: WEST SIDE OF BASIN	GEOLOGIC UNIT: EAST SIDE OF BASIN	LITHOLOGY, THICKNESS, AND DISTRIBUTION	AVAILABILITY AND CHEMICAL QUALITY OF GROUND WATER
MESOZOIC	CRETACEOUS	Lower Cretaceous	Cloverly Formation	Inyan Kara Group: Fall River Formation	Cloverly Formation--Shale and interbedded siltstone upper and middle parts; persistent medium- to coarse-grained crossbedded sandstone lower part; thickness about 150 feet in northwest part of basin and about 140 feet in southwest part (Mapel, 1959, p. 36; Hose, 1955, p. 56; Horn, 1955). Fall River Formation--Sandstone, fine- to medium-grained, and interbedded shale and siltstone, thickness generally 120 to 150 feet (Robinson and others, 1964, p. 27; Knechtel and Patterson, 1962, p. 907).	Cloverly, Fall River, and Lakota Formations--Most yields range from 5 to 20 gpm, but yields of 100 gpm or more possible from the complete section of rocks, and as much as several hundred gallons per minute from zones of secondary permeability. Well 33-79-24acc, Natrona County, flows about 40 gpm from the Cloverly and is pumped at about 250 gpm. Well 56-62-1ca, Crook County, flowed 70 gpm from the Lakota, and well 54-67-22da had a reported flow of more than 150 gpm from both the Lakota and Fall River (Whitcomb and Morris, 1964, table 11). Well 35-65-35ab, Niobrara County, flowed 140 gpm from the Lakota and Fall River when drilled (Whitcomb, 1965, table 9). Dissolved solids generally range between 300 and 3,000 mg/l; most water is sodium sulfate type.
				Inyan Kara Group: Lakota Formation	Lakota Formation--Sandstone, conglomeratic sandstone, and shale; lenticular, with rapid composition changes both laterally and vertically; thickness mostly ranges from about 100 to 300 feet (Robinson and others, 1964, p. 23). Mapel and Pillmore (1963a, p. M18) report a thickness range of 50 to 240 feet north of Osage, and Cuppels (1963, p. 289) reports as much as 370 feet southeast of Newcastle.	
	JURASSIC	Upper Jurassic	Morrison Formation		Mostly varicolored claystone; contains interbedded fine-grained sandstone lower part; on east side of basin, thickness generally between 80 and 120 feet but, locally, 20 to 30 feet or absent in places; thickness about 150 feet in southeast part of basin, between 130 and 220 feet in southwest part, and about 180 feet in northwest part (Robinson and others, 1964, p. 19; Mapel, 1959, p. 34; Cuppels, 1963, p. 286; Denson and Botinelly, 1949, sheet 2; Horn, 1955). In an area north of Newcastle and east of Osage, the Morrison consists locally in part or all of fine-grained sandstone resembling the Unkpapa Sandstone (Mapel and Pillmore, 1963a, p. M16; and 1963b, p. N16) which locally replaces the Morrison at the south end of the Black Hills (Darton and Paige, 1925, p. 11).	Sandy zones may yield as much as 10 gpm, but most of the formation does not yield water.
			Sundance Formation		Shale, greenish-gray, and interbedded yellowish-gray fine-grained sandstone; thickness generally between 370 and 400 feet in east part of basin, about 280 feet in northwest part, and about 350 feet in southwest part (Robinson and others, 1964, p. 14; Hose, 1955, p. 54; Mapel, 1959, p. 32; Horn, 1955). Formation contains five members in the Black Hills, which, in ascending order, are the Canyon Springs Sandstone, Stockade Beaver Shale, Hulett Sandstone, Lak, and Redwater Shale.	Yields of as much as 50 gpm should be possible from the Hulett Sandstone Member in the Black Hills; sandstone beds in other parts of the formation will probably yield no more than 20 gpm. Dissolved solids may be expected to range from about 500 to more than 2,000 mg/l. No water type is dominant.
		Middle Jurassic	Gypsum Spring Formation		Massive white gypsum, red claystone, and gray limestone on east side of basin; thickness about 125 feet in northern Crook County (Robinson and others, 1964, p. 10), but thins southward and is not present in southern Weston County (Mapel and Pillmore, 1963b, p. N11). Mostly red shale and claystone on west side of basin; contains thin-bedded limestone; thickness 145 to 185 feet in northern Johnson County (Mapel, 1959, p. 28) but thins southward and is not present in southern Johnson County (Hose, 1955, p. 52).	Yields a few gallons per minute locally for stock purposes from solution cavities in or near outcrop areas. Dissolved solids are generally more than 1,000 mg/l; water is dominantly calcium sulfate type.
	TRIASSIC		Chugwater Formation	Spearfish Formation	Chugwater Formation--Mostly dark-red siltstone, sandstone, and shale; topmost part consists of fine- to medium-grained sandstone; thickness about 800 feet in northwest part of basin (Hose, 1955, p. 51; Mapel, 1959, p. 26) and about 700 feet in southwest part (Horn, 1955). Spearfish Formation--Red shale, siltstone, sandstone, and white gypsum; contains thick beds of gypsum lower part; thickness ranges from about 450 feet in Newcastle area to as much as 825 feet in northwest Crook County (Robinson and others, 1964, p. 9). Locally in Newcastle area, lower part contains discontinuous beds of halite (Mapel and Pillmore, 1963b, p. N10).	Chugwater Formation, Goose Egg Formation and equivalent rocks, Spearfish Formation, Minnekahta Limestone, and Opeche Shale--Rocks consist mostly of shale, gypsum, and thin-bedded limestone with sand a minor constituent and, consequently, yields will be small. The Chugwater Formation will probably yield as much as 20 gpm, and the Spearfish Formation, Minnekahta Limestone, and Opeche Shale as much as 10 gpm. The Goose Egg Formation and equivalent rocks will yield little or no water from most of the rocks. Dissolved solids generally range from about 500 to more than 3,000 mg/l. Calcium sulfate is dominant type, but, locally, water from the Goose Egg and Spearfish Formations is sodium chloride type such as water from spring 46-61-9bd which has dissolved solids of more than 30,000 mg/l and issues from the Spearfish along Salt Creek.
PALEOZOIC	PERMIAN		Goose Egg Formation (Includes equivalent rocks in northwest part of basin)	Minnekahta Limestone	Goose Egg Formation and equivalent rocks--Interbedded red shale, gypsum, and thin-bedded limestone (Crist and Lowry, 1972, p.52; Hose, 1955, pl. 8). Includes red shale and gypsum sequence of Hose (1955) and Mapel (1959) in northwest part of basin. Thickness is about 350 feet in southwest part of basin (Burk and Thomas, 1956, fig. 1; Horn, 1955), about 250 feet in central Johnson County (Hose, 1955, p. 50), and about 180 feet in Buffalo-Lake De Smet area (Mapel, 1959, p. 24). Minnekahta Limestone--Thin-bedded limestone and dolomitic limestone; thickness about 40 feet in the Black Hills (Mapel and Pillmore, 1963a, p. M10), and from 20 to 40 feet in southeast part of basin (Denson and Botinelly, 1949, sheet 2).	
				Opeche Shale	Opeche Shale--Shale, fine-grained sandstone and gypsum; thickness ranges from about 70 to 120 feet in the Black Hills (Brobst and Epstein, 1963, table 1), and from about 25 to 75 feet in southeast part of basin (Denson and Botinelly, 1949, sheet 2).	
	PENNSYLVANIAN		Tensleep Sandstone	Hartville Formation; Minnelusa Formation	Tensleep Sandstone--Dominantly crossbedded sandstone, fine- to medium-grained; dolomite beds common in lower part, but are thinner and less common in upper part (Hose, 1955, p. 50). Thickness increases southward from about 50 feet in northern Sheridan County to about 250 feet at the Sheridan-Johnson County line (Lowry and Cummings, 1966, p. 27), and from about 275 feet in the Lake De Smet area (Mapel, 1959, p. 23), to about 350 feet in central Johnson County (Hose, 1955, p. 50). Crist and Lowry (1972, p. 46) report as much as 500 feet in Natrona County. Hartville Formation--Limestone, dolomite, shale, and sandstone; contains about 100-foot bed of fine- to medium-grained sandstone at top locally called "Converse sand," and about 100-foot bed of sandstone at base; total thickness of formation ranges from about 850 to 1,300 feet (Denson and Botinelly, 1949, sheet 2; Love and others, 1953, sheets 1 and 2). Present in southeast part of basin. Minnelusa Formation--Interbedded sandstone, sandy dolomite and limestone, some shale and siltstone, and local beds of gypsum and anhydrite; thickness ranges from about 700 to 900 feet (Mapel and Pillmore, 1963a, p. M8; Brobst and Epstein, 1963, p. 326). Present in the Black Hills. Correlates with the Hartville Formation in southeast part of basin (Foster, 1958, fig. 1).	Tensleep Sandstone, Amsden, Hartville, and Minnelusa Formations--Except for the Amsden Formation, yields ranging from 20 gpm to as much as several hundred gallons per minute are possible from these rocks, and where fracturing has increased the permeability, yields greater than 1,000 gpm may be possible. The rocks range from densely cemented to fractured and faulted, and the ability of the rocks to yield water will range accordingly. The Tensleep Sandstone should be the most favorable for larger yields, but the rocks dip steeply basinward, and are deeply buried except along the west edge of the basin. The Minnelusa Formation dips much more gently toward the basin than the Tensleep, but the lithology of the Minnelusa is more variable and, in general, the rocks more densely cemented. Well 46-83-22ddb, Johnson County, yields 600 gpm from the Tensleep. Wells 40-79-25caa and 40-84-9aba, Natrona County, have flows of about 500 gpm and 1,200 gpm, respectively, from the Tensleep. Well 45-61-28abl, Weston County, had a reported flow of 300 gpm from the Minnelusa when drilled. City wells at Hulett had reported flows ranging from 250 to 480 gpm from the Minnelusa when drilled. Dissolved solids commonly range from 200 to 500 mg/l and are generally less than 1,000 mg/l, but locally may be more than 2,000 mg/l. Water from the Tensleep is mostly calcium bicarbonate type, and from the Minnelusa mostly calcium bicarbonate or calcium sulfate type.
			Amsden Formation		Amsden Formation--Sandstone, shale, dolomite, and limestone; Darwin Sandstone Member commonly found at base; formation 250 to 300 feet thick in northwest part of basin (Hose, 1955, p. 49; Mapel, 1959, p. 20), becoming thinner southward and is not present near south edge of basin (Faulkner, 1956, p. 36; Crist and Lowry, 1972, p. 46).	
	MISSISSIPPIAN	Upper Mississippian	?	?		
		Lower Mississippian	Madison Limestone	Guernsey Formation; Pahasapa Limestone	Madison Limestone--Dolomite and limestone, massive to thin bedded, cavernous in upper part; thickness about 670 feet in northern Johnson County and about 550 feet in central Johnson County (Hose, 1955, p. 48; Mapel, 1959, p. 17). Formation thins southward from about 1,000 feet near State line to about 200 feet in south part of basin (Andrichuk, 1955, fig. 5; Faulkner, 1956, p. 36). Rocks dip steeply into subsurface and underlie most of basin at great depths. A dark shale unit of Late Devonian and Early Mississippian age at the base of the Madison in northwest Wyoming was named the Cottonwood Canyon Member of the Madison Limestone by Sandberg and Klapper (1967, p. B14). About 5 feet of the member may be present locally in the extreme northwest part of the project area. Guernsey Formation--Cherty limestone and interbedded chalky dolomite; thickness as much as 300 feet (Denson and Botinelly, 1949, sheet 2; Love and others, 1953, sheet 1). Present in southeast part of basin; mostly equivalent in age to Pahasapa Limestone and Englewood Formation in the Black Hills (Jenkins and McCoy, 1958, p. 33). Pahasapa Limestone--Massive dolomitic limestone, highly cavernous (Gries and Crooks, 1968, p. 209). Thickness ranges from more than 900 feet in northern Black Hills to about 300 feet near Weston-Niobrara County line (Jenkins and McCoy, 1958, fig. 3; Andrichuk, 1955, fig. 5).	Madison Limestone, Guernsey Formation, Pahasapa Limestone, and Englewood Formation--Yields of more than 1,000 gpm are available from the Madison and Pahasapa Limestones where cavernous and fractured zones are present. Ground-water possibilities of the Guernsey and Englewood Formations are unknown, but yields of 100 gpm or more may be possible from the Guernsey. The Englewood would probably yield little or no water. Wells 40-79-26caa, 40-79-35acb, and 39-79-11aad, Natrona County, have flows from the Madison at depths of about 5,000 feet each of 3,900 gpm with 150 psi flowing pressure at the surface, 7,000 gpm with 179 psi flowing pressure at the surface, and 4,750 gpm with unknown flowing pressure, respectively. Several wells in the Newcastle area had initial flows of more than 1,000 gpm from the Pahasapa at depths of about 3,000 feet. Well 46-63-10dca at Osage had an initial flow of about 800 gpm from the Pahasapa. Municipal wells at Upton that tap the Pahasapa do not flow but are pumped at about 200 gpm. Dissolved solids determined by 15 analyses of water from the Pahasapa ranged from 248 to 588 mg/l; most depths of sampled wells ranged from 2,600 feet to more than 4,500 feet; water type was calcium bicarbonate. Dissolved solids ranged from 1,560 to 3,240 mg/l in five waters from the Madison at depths ranging from about 2,900 feet to more than 7,600 feet; water type was sodium sulfate. The Madison waters were from areas near oil fields in southwest part of basin between 30 and 50 miles from the outcrop. Water from the Madison nearer the outcrop may be expected to be of better quality; quality of water in these rocks in the deeper parts of the basin is unknown.
				Englewood Formation	Englewood Formation--Limestone, moderately thin bedded; thickness about 50 feet (Mapel and Pillmore, 1963a, table 1).	
	DEVONIAN	Upper Devonian				
	ORDOVICIAN	Upper Ordovician	Bighorn Dolomite	Whitewood Dolomite	Bighorn Dolomite--Basal fine- to coarse-grained sandstone overlain by massive to thin-bedded dolomite (Hose, 1955, p. 45; Mapel, 1959, p. 13). Formation thins southward from about 430 feet in northern Sheridan County to about 150 feet in central Johnson County (Richards and Nieschmidt, 1961, sheet 2) and is missing in southernmost Johnson County and southward (Darton, 1906, p. 27; Hose, 1955, p. 47). Whitewood Dolomite--Massive-bedded dolomite; thickness about 50 feet (Robinson and others, 1964, p. 8). Formation thins southward and probably absent south of Crook County (Peterson, 1956, p. 43; Mapel and Pillmore, 1964, table 1).	Bighorn and Whitewood Dolomites, Winnipeg, Deadwood, Gallatin, and Gros Ventre Formations, and Flathead Sandstone--Yields ranging from 20 gpm to several hundred gallons per minute should be available from solution cavities and fractures in the Bighorn Dolomite in and near outcrops. Yields of 20 gpm are probably available from the Flathead Sandstone and Deadwood Formation. Other formations would probably yield less than 10 gpm.
		Middle Ordovician		Winnipeg Formation	Winnipeg Formation--Siltstone and shale; thickness about 50 feet (Mapel and Pillmore, 1963a, table 1). Formation thins southward and probably absent south of Crook County (Peterson, 1956, p. 43; Mapel and Pillmore, 1964, table 1).	
		Lower Ordovician				
	CAMBRIAN	Upper Cambrian	Gallatin Formation	Deadwood Formation	Gallatin and Gros Ventre Formations, undifferentiated--Slabby limestone and thin beds of flat-pebble conglomerate upper part; shale and interbedded thin beds of limestone, sandstone, and flat-pebble conglomerate middle part; medium- to coarse-grained sandstone lower part; total thickness about 600 feet in northern Johnson County (Hose, 1955, p. 44; Mapel, 1959, p. 10). Strata thin southward and are missing near south edge of basin (Faulkner, 1956, p. 35; McCoy, 1958, p. 21). Deadwood Formation--Sandstone, shale, siltstone, and limestone; thins southward from about 500 feet in northern Crook County to about 200 feet in the Newcastle area and is probably absent in southeast part of basin (Robinson and others, 1964, p. 8; Mapel and Pillmore, 1963b, table 1; McCoy, 1958, p. 21; Jenkins and McCoy, 1958, p. 31).	
			Gros Ventre Formation			
		Middle Cambrian	Flathead Sandstone		Flathead Sandstone--Fine- to coarse-grained sandstone; thickness about 260 to 340 feet in northern Johnson County (Hose, 1955, p. 44; Mapel, 1959, p. 10). Formation thins southward and is about 90 feet thick near south edge of basin (McCoy, 1958, p. 21).	
PRECAMBRIAN			Igneous and metamorphic rocks		Chiefly granite, gneiss, and schist complex of igneous and metamorphic basement rocks (Love and Weitz, 1951) that underlie sedimentary strata in the basin and form core of Bighorn Mountains. Rocks of Precambrian age also found associated with intrusive rocks of Tertiary age in the Black Hills such as Bear Lodge Mountains and Mineral Hill.	Yields of as much as 20 gpm may be possible locally from fractures, joints, and weathered zones in areas of outcrop, but rocks may not yield any water at many locations. The number of fractures and size of openings may be expected to decrease with depth; thus, the chances of obtaining water will decrease with increasing depth. Dissolved solids are generally less than 100 mg/l; water is usually calcium bicarbonate type.

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