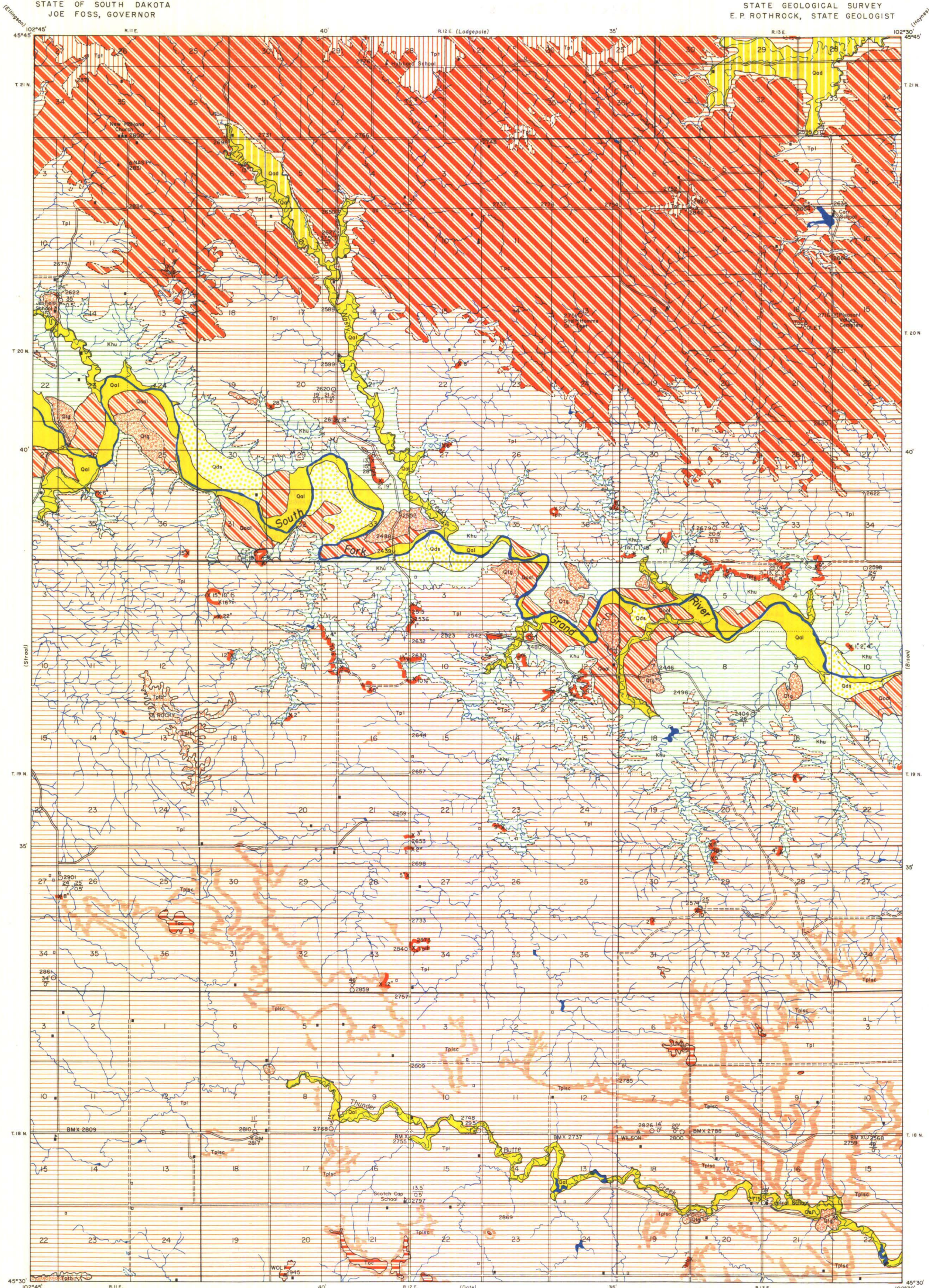


# AREAL GEOLOGY OF THE CASH QUADRANGLE

STATE OF SOUTH DAKOTA  
JOE FOSS, GOVERNOR

STATE GEOLOGICAL SURVEY  
E. P. ROTHROCK, STATE GEOLOGIST



**EXPLANATION**

**SEDIMENTARY ROCKS**

**QUATERNARY**

- Qal**  
Alluvium  
(Valley-bottom deposits of clay, silt, sand, and gravel in North Fork of Grand River and larger tributaries)
- Qad**  
Alluvial Deposits  
(Low terrace and floodplain deposits of gravel, silt, and clay, locally derived)
- Qds**  
Dune Sand  
(Rounded, graded dunes with "blowouts" and composed of fine to medium-grained angular micaceous, chloritic quartz sand)
- Qol**  
Older Alluvium  
(Older alluvial deposits above North Fork of Grand River floodplain)
- Qtg**  
Terrace Gravel  
(Terrace deposits of sand and gravel 5'-2' thick with less-silt cover)

**PLEISTOCENE**

- Tac**  
Chadron Formation  
(A 1/2'-1' thick light tan to light gray buff-capping dense, microparticulate fresh-water limestone. Interbeds of gray-buff bentonitic clays, fine to coarse-grained, angular to rounded quartz sand, minor shales, chert pebbles, and multicolored clays, silts, sands near base. About 60' thick)

**OLIGOCENE**

- Tpb**  
Tongue River Boulders  
(Rounded light gray, weathered brown, orthoquartzite boulders, exhibiting high degree of wind polish and vesicular impressions of roots and branches)

**TERTIARY**

- Tpl**  
Tongue River Formation  
(Buff-yellow, fine to medium-grained sand and micaceous, calcareous and quartzose sandstone, orthoquartzite boulders, and bentonitic clays. About 80' thick)

**PALEOCENE**

- Tpc**  
Cannonball Formation  
(Buff to gray clay, silt, and sand with pebbled-bearing sandstones and dark gray fossiliferous limestone "cannon balls" interbeds with Ludlow formation. About 50-80' thick)

**UPPER CRETACEOUS**

- Tplsc**  
Ludlow Formation  
(Yellow to gray interbedded clay, silt, sand, and sandstone. "Scotch Cap sandstone, 5'-36" thick. Tpe-Hiwan facies. 2' coal beds up to 36" thick with "backpack", peat-logs, and Rhynchonella zones. 10'-25' thick Tpe-Shadehill facies. 1/4" coal beds up to 28" thick with "backpack", peat-logs, and Rhynchonella. 13'-14' thick peat-logs with Cannonball formation. Formation about 200' thick)
- Khu**  
Upper Hell Creek  
("Sonder" beds of lenticular bentonitic clays, silt, sand, peat-logs, and "backpack" beds. Coluform or silt-weak in bottom-slope areas. Locally parallel arenaceous concretionary layers. About 100' thick)

**DRAINAGE**

- Intermittent Streams
- Intermittent Lakes

**CULTURE**

- Roads, Trails, and Buildings  
(Houses, church, and school)

**Bench Marks and Altitudes**

- (Monuments marking points of known altitude and altitudes in feet above sea level)

**Triangulation Stations**

- (U.S. Coast & Geodetic and/or U.S. Geological Survey monuments marking points of exact geographic location)

**Coal mines and Gravel pits**

- (x 36")

**Coal Thickness**

- (325' Top Hole)
- (3' Overburden)
- (2' Thickness)

**Drill Holes**

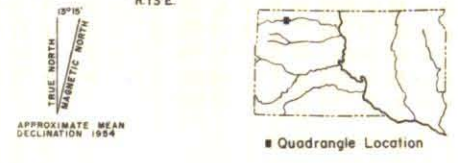
- (Shell Of Ca)
- (Home No. 1)

**Oil-test Borings**

Geology by R. E. Curtiss  
Assisted by M. F. Nielsen, E. E. Lutzen, D. Vetter, W. L. Foley  
Surveyed in 1954. Drafted by P. Rist.  
Coal-Test Holes Drilled in 1954 and 1955.

Scale = 62500  
0 1 2 3 4 MILES

Vermillion, South Dakota  
1955





# AREAL GEOLOGY OF THE CASH QUADRANGLE

By  
Robert E. Curtiss

## INTRODUCTION

THE QUADRANGLE WAS MAPPED IN JULY, 1954, AS A PART OF THE STATE GEOLOGICAL SURVEY'S COAL APPRAISAL PROGRAM. EXPLORATORY DRILLING FOR SUB-SURFACE COAL WAS DONE IN AUGUST, 1954, AND JUNE, 1955.

## LOCATION

THE QUADRANGLE IS SITUATED IN PERKINS COUNTY AND IS LOCATED ABOUT 20 AIRLINE MILES SOUTHWEST OF LEMMON, 103 MILES NORTHEAST OF RAPID CITY, AND APPROXIMATELY 134 MILES NORTHWEST OF PIERRE BETWEEN PARALLELS 45°30' AND 45°45' NORTH LATITUDE AND MERIDIANS 102°30' AND 102°45' WEST LONGITUDE AND CONSTITUTES AN AREA OF ABOUT 210 SQUARE MILES.

## TOPOGRAPHY AND DRAINAGE

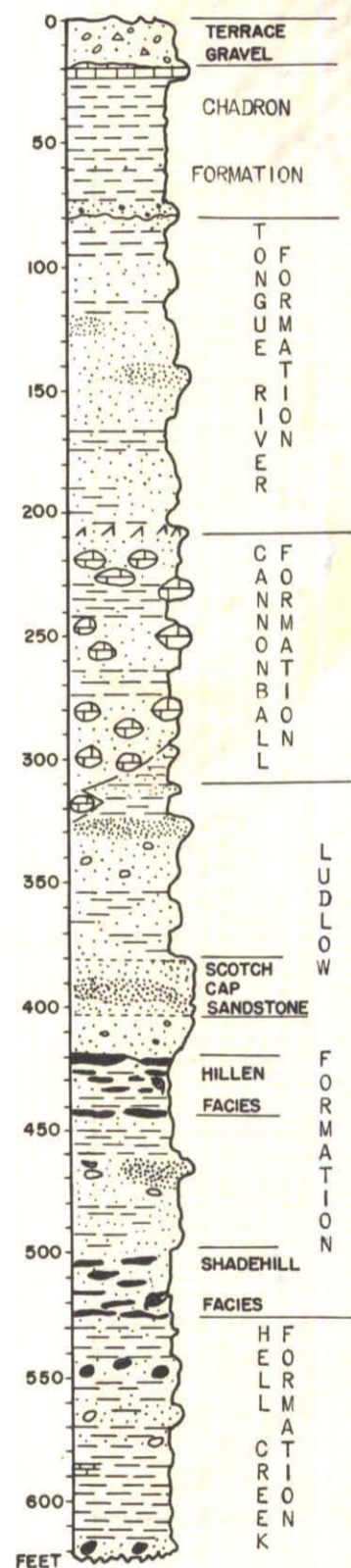
TOPOGRAPHICALLY, THE SOUTH FORK OF GRAND RIVER, WHICH IS OF PARAMOUNT IMPORTANCE, FLOWS FROM THE WEST TO THE EAST ACROSS THE CENTRAL PORTION OF THE AREA. THE VALLEY IS A CONSPICUOUS TRENCH THAT DISPLAYS SHARP, STEEP WALLS, RANGING UP TO 150 FEET ON THE NORTHSIDE OF THE RIVER, GRAVEL TERRACES, ALLUVIAL TERRACES, ABANDONED MEANDERS, ROUNDED SAND DUNES, AND A SIZABLE FLOODPLAIN THAT VARIES IN WIDTH BETWEEN ONE-FOURTH AND THREE-FOURTHS OF A MILE. THE RIVER IS GENERALLY AFFLUENT THROUGHOUT THE YEAR AND IS THE MASTER STREAM WHICH RECEIVES MOST OF THE RUNOFF WATER FROM THE QUADRANGLE.

THUNDER BUTTE CREEK IS THE SECOND LARGEST STREAM AND ROUGHLY PARALLELS STATE HIGHWAY 8. THE CREEK RECEIVES SURFACE WATER FROM THE SOUTHERN PART OF THE QUADRANGLE AND CONVEYS IT SOUTHEASTERLY TO THE MOREAU RIVER.

THE NORTHERN ONE-THIRD OF THE AREA COMPRISES A PART OF THE NORTH AND SOUTH FORKS OF GRAND RIVER INTERSTREAM DIVIDE. THIS LOCALE IS DISSECTED BY DENDRITIC DRAINAGE. TO THE SOUTH, THE SOUTH FORK OF GRAND RIVER-THUNDER BUTTE INTERSTREAM DIVIDE IS VIVIDLY MARKED BY MANY PICTURESQUE BUTTES, LEDGES, AND SHARPLY-CUT INTERMITTENT STREAMS THAT ERODE THE DIVIDE SLOPES.

THE RELIEF IN THE QUADRANGLE APPROXIMATES 625 FEET. THE MAXIMUM ALTITUDE IS ABOUT 3,000 FEET ABOVE SEA LEVEL ON A HILL OF TONGUE RIVER STRATA IN SEC. 27, T. 21 N., R. 11 E. THE MINIMUM ALTITUDE IS ROUGHLY 2,375 FEET ABOVE SEA LEVEL AT THE WATER LEVEL OF THE SOUTH FORK OF GRAND RIVER IN SEC. 10, T. 19 N., R. 13 E. THE AVERAGE ALTITUDE OF THE QUADRANGLE IS ABOUT 2,687 FEET ABOVE SEA LEVEL.

## GENERALIZED COLUMNAR SECTION



## STRATIGRAPHY

CHRONOSTRATIGRAPHICALLY, THE SURFACE FORMATIONS RANGE IN AGE FROM UPPER CRETACEOUS TO RECENT. A COMPLETE SECTION OF CANNONBALL IS FOUND NORTH OF THE SOUTH FORK OF GRAND RIVER. THE HELL CREEK (UPPER CRETACEOUS AGE)-LUDLOW (PALEOCENE), LUDLOW-CANNONBALL (PALEOCENE AGE), AND THE CANNONBALL, TONGUE RIVER (PALEOCENE AGE) FORMATIONAL BOUNDARIES ARE CONFORMABLE, REPRESENTING CONTINUOUS DEPOSITION. ON EROSIONAL UNCONFORMITY EXISTS BETWEEN THE CHADRON FORMATION (OLIGOCENE AGE) AND THE UNDERLYING LUDLOW AND CANNONBALL FORMATIONS. RESIDUAL TONGUE RIVER ORTHOQUARTZ BOULDERS AND SILICIFIED WOOD, PLEISTOCENE TERRACE GRAVELS, PLEISTOCENE-RECENT OLDER ALLUVIUM, AND RECENT ALLUVIUM AND SAND DUNES CONSTITUTE THE REST OF THE OUTCROPPING SEDIMENTS IN THE AREA.

UPPER HELL CREEK, HELL CREEK FORMATION (BROWN 1907). THIS ROCK UNIT ATTAINS A THICKNESS OF ABOUT 100 FEET. LENTICULAR, "SOMBER BEDS" CONSIST LITHOLOGICALLY OF BUFF TO BROWN FINE-GRAINED SANDS, LOESSIL SILTS, AND DRAB GRAY BENTONITIC CLAYS, THIN BLACK COAL-SEAMS, NEAR THE TOP OF THE FORMATION, BROWN PEAT-CLAYS, BLACK CARBONACEOUS CLAY OR "BLACKJACK" BEDS, DISCONTINUOUS ORANGE-BROWN LIMONITIC CONCRETIONS AND NODULES, AND MINOR AMOUNTS OF PURPLE-BLACK MANGANESE-IRON CONCRETIONS. EXPOSURES ARE CONFINED TO THE SOUTH FORK OF GRAND RIVER VALLEY AND MAIN TRIBUTARIES.

LUDLOW FORMATION (LLOYD AND HARES 1915). THE FORMATION IS ABOUT 200 FEET THICK. IT FORMS THE MAJOR PORTION OF THE BEDROCK IN THE QUADRANGLE AND CONSISTS OF LENTICULAR, INTERBEDDED PASTEL SHADES OF BUFF AND CREAM-COLORED SANDS AND SILTS AND VARIATED CLAYS, LOCALLY ABUNDANT PINK CALCAREOUS NODULES, BROWN RIPPLE-MARKED, CROSS-LAMINATED CALCAREOUS SANDSTONE, BROWN PEAT-CLAY AND BLACK CARBONACEOUS, CLAY BEDS, ORANGE-BROWN LIMONITIC CONCRETIONARY LAYERS, YELLOW JAROSITE AND/OR MELANITERITE, AND GYPSUM LAYERS.

THE BASAL SHADEHILL BIOFACIES, PLUS TEXTURAL AND COLOR CHANGES MARK THE CONTACT WITH THE UNDERLYING HELL CREEK FORMATION. THE HELL CREEK-LUDLOW CONTACT WAS PLACED AT THE BASE OF THE LOWEST COAL IN THE SHADEHILL BIOFACIES ABOVE THE TYPICAL "SOMBER" BEDS OF THE HELL CREEK. WHERE THE SHADEHILL INTERVAL IS MISSING OR COVERED, THE CONTACT WAS DRAWN ON THE BASES OF COLOR AND TEXTURE CHANGES OR TOPOGRAPHY. THE SHADEHILL COAL, ZERO TO 28 INCHES THICK, CONSISTS OF FROM ONE TO SIX LIGNITE BEDS, CONTAINING JAROSITE NODULES AND STAIN, GYPSUM, AND FOSSIL RESIN PELLETS, BROWN PEAT-CLAY BEDS, AND "BLACKJACK" BEDS, AND INTERBEDDED CLAYS, SILTS, AND SANDS. THE COALS MAY GRADE LATERALLY INTO PEAT-CLAYS AND/OR "BLACKJACK" BEDS. THE BIOFACIES VARIES IN THICKNESS BETWEEN 25 AND 40 FEET.

YELLOWISH BROWN CROSS-BEDDED, FINE-GRAINED SAND AND LOCAL, THIN COALS EXIST BETWEEN THE SHADEHILL AND HILLEN BIOFACIES.

THE HILLEN COAL FACIES, WHICH LIES ABOUT 100 FEET ABOVE THE SHADEHILL, INCLUDES TWO BLACK, BLOCKY COAL BEDS, WHICH RANGE IN THICKNESS BETWEEN ZERO AND 36 INCHES THICK, ASSOCIATED PEAT-CLAYS, "BLACKJACKS", SELENITE GYPSUM, LOCALLY PERSISTENT FOUR TO SIX-INCH THICK HEMATITE-STAINED ASH, AND FLORASTROME (FOSSIL PLANTS) ZONES. THE FLORA IS EXCELLENTLY PRESERVED AND DISPLAYS PERFECT LEAVES AND SEEDS. THE BIOFACIES IS ABOUT 10 TO 25 FEET THICK, AND IT ALSO INCLUDES ADMIXTURES OF BUFF TO GRAY CLAYS, SILTS, AND SANDS.

THE SCOTCH CAP SANDSTONE UNIT, WHICH VARIES BETWEEN 5 AND 36 FEET IN THICKNESS, IS COMPOSED OF DRAB BROWN LICHEN-SPOTTED, LEDGE-MAKING, FRIABLE TO INDURATED, CROSS-BEDDED, RIPPLE-MARKED, FINE-TO MEDIUM-GRAINED SANDSTONE. THE TYPE SECTION IS LOCATED AT SCOTCH CAP BUTTE IN SEC. 23, T. 18 N., R. 12 E. NUMEROUS BUTTES AND RIDGES ARE CAPPED WITH SCOTCH CAP ALONG STATE HIGHWAY 8.

THE UPPER PORTION OF THE LUDLOW FORMATION, WHICH APPROXIMATES 50 FEET IN THICKNESS, EXHIBITS BUFF-COLORED CLAYS, SILTS, SANDS, AND LOCAL LEDGE-FORMING SLABBY, CROSS-LAMINATED, CALCAREOUS SANDSTONES AND LIMONITE NODULES.

THE TERRESTRIAL OR CONTINENTAL LUDLOW INTERFINGERS WITH THE MARINE CANNONBALL FORMATION IN THE NORTHERN SECTOR OF THE QUADRANGLE WHERE THE HILLEN BIOFACIES CLOSELY UNDERLIES THE CANNONBALL.

CANNONBALL FORMATION (LLOYD 1914). THIS FORMATION VARIES IN THICKNESS BETWEEN 50 AND 180 FEET. MUCH OF THE FORMATION IS GRASSSED OVER. IT CONSISTS PRIMARILY OF BUFF-GRAY CLAYEY SILTY QUARTZ SANDS, SILTS AND CLAYS, ABUNDANT DIAGNOSTIC, TYPICAL "CANNONBALLS" COMPOSED OF DARK BLuish GRAY, DENSE LIMESTONE WITH GOLDEN CALCITE GEODES AND DRUSES THAT INTERMITTENTLY CONTAIN GASTROPODS AND PELECYPODS, AND BROWN IRON-CEMENTED PELECYPOD-BEARING SANDSTONES. THE CANNONBALL IS FOUND SOUTH OF THE SOUTH FORK OF GRAND RIVER ONLY IN SEC. 14, T. 19 N., R. 12 E.

THE LUDLOW-CANNONBALL CONTACT WAS DRAWN BIOSTRATIGRAPHICALLY ON THE LOWEST FOSSILIFEROUS "CANNONBALLS" AS THE TWO LITHOLOGIES CLOSELY RESEMBLE ONE ANOTHER IN MANY INSTANCES.

TONGUE RIVER FORMATION (TAFF 1909). THE FORMATION, WHICH MAY BE 125 FEET THICK, IS RESTRICTED TO THE NORTHERN PART OF THE AREA. ITS LITHOLOGY IS PREDOMINANTLY BUFF-YELLOW, FINE-GRAINED, MICACEOUS, CALCAREOUS SANDSTONES ("CEMENTATIONS"), QUARTZOSE SANDSTONE, BENTONITIC CLAYS, AND ORTHOQUARTZITE BOULDERS. MUCH OF THE TONGUE RIVER IS GRASS-COVERED, ALTHOUGH SEVERAL ISOLATED OUTCROPS SUGGESTED THAT A PORTION OF THE FORMATION IS THE "REINCARNATION OF THE HELL CREEK."

TONGUE RIVER BOULDERS, TONGUE RIVER FORMATION. THICK CONCENTRATIONS OF RESIDUAL ORTHOQUARTZITE BOULDERS BLANKET THE LUDLOW FORMATION IN SEC. 12, 13, 14, T. 19 N., R. 11 E., SECS. 7, 18, 19, T. 19 N., R. 12 E., AND SECS. 22, 23, 26, 27, T. 18 N., R. 11 E. THE BOULDERS (VENTIFACTS) ARE LIGHT GRAY AND POSSESS A HIGH DEGREE OF WIND POLISH AND VESICULAR IMPRESSIONS OF ROOTS AND BRANCHES. SOME OF THE BOULDERS ARE 10 FEET IN LENGTH. ONE SILICIFIED PETRIFIED LOG, WHICH IS FOUND IN SEC. 13, T. 19 N., R. 11 E., IS 72½ FEET IN LENGTH AND 7½ FEET IN DIAMETER.

CHADRON FORMATION (DARTON 1899), WHITE RIVER GROUP (MEEK AND HAYDEN 1858). THE CHADRON FORMATION, WHICH IS 60 FEET THICK, IS THE OLDEST FORMATION IN THE WHITE RIVER GROUP OF SEDIMENTS, AND IT IS PRESENT AS REMNANTS, CAPPING HILLS AND BUTTES. THE MOST PROMINENT CHADRON DEPOSIT CAPS COLET BUTTE IN SEC. 16, T. 20 N., R. 13 E. THE FORMATION IS COMPOSED OF INTERBEDDED GRAY-BUFF BENTONITIC CLAYS, FINE TO COARSE-GRAINED, ANGULAR TO ROUNDED SAND, VOLCANIC SHARDS, MILKY GRAY CHERT PEBBLES, AND LIGHT PASTEL SHADES OF TAN, YELLOW, AND PINK CLAYS, AND SANDS NEAR THE BASE. A SIX-INCH TO ONE-FOOT THICK LIGHT TAN TO LIGHT GRAY MICROCRYSTALLINE FRESH-WATER LIMESTONE CAPS MANY OF THE CHADRON HILLS AND BUTTES. THE CHADRON WEATHERS TO A PUSTULAR, DESICCATED, OR "POPCORN" SURFACE--INHERENT TO BENTONITIC CLAYS.

TERRACE GRAVELS. SEVERAL LARGE GRAVEL TERRACES EXIST ALONG THE SOUTH FORK OF GRAND RIVER. THEY CONSIST PRIMARILY OF LIMONITE, TONGUE RIVER ORTHOQUARTZITE, CHERT, CHALCEDONY, QUARTZ, SANDSTONE, LIMESTONE, AND SILICIFIED WOOD. PORTIONS OF SOME DEPOSITS DISPLAY GOOD SORTING.

OLDER ALLUVIUM. OLDER ALLUVIAL DEPOSITS OCCUR ABOVE THE PRESENT FLOODPLAIN OF THE SOUTH FORK OF GRAND RIVER. THESE DEPOSITS ARE COMPOSED OF CLAY, SILT, SAND, AND GRAVEL.

DUNE SAND. ROUNDED, GRASSSED-OVER DUNES, WHICH REACH 40 FEET IN HEIGHT, CONSTITUTE CONSIDERABLE AREAS ALONG THE SOUTH FORK OF GRAND RIVER.

ALLUVIAL DEPOSITS. LOW TERRACE AND FLOODPLAIN DEPOSITS ARE UNDIFFERENTIATED AND COMPOSED OF HETEROGENEOUS MATERIALS.

ALLUVIUM. THIS IS A VALLEY-FILL DEPOSIT WHICH OCCURS IN THE SOUTH FORK OF GRAND RIVER VALLEY AND SEVERAL TRIBUTARY VALLEYS.

## STRUCTURE

THERE IS A 15 TO 20 FEET REGIONAL DIP TO THE NORTH-NORTHEAST TOWARD THE AXIS OF THE DAKOTA (WILLISTON) BASIN. NORMAL FAULTS OF SMALL MAGNITUDE AND POSSIBLY SMALL GENTLE FLEXURES EXIST IN THE AREA. LENTICULARITY, PRIMARY SEDIMENTATIONAL DIPS, AND SLUMPING, PREVALENT IN THE HELL CREEK, TEND TO COMPLICATE THE DETERMINATION OF SURFACE STRUCTURE.

## ECONOMIC GEOLOGY

A VARIETY OF MINERAL RESOURCES IS CONTAINED IN THE QUADRANGLE. COAL, GRAVEL, QUARTZITE, SANDSTONE AND CLAY ARE POTENTIALLY IMPORTANT. IN ADDITION, THE SHELL-HOMME NUMBER 1 OIL-TEST WELL REVEALED GAS AND OIL SHOWS. CONSEQUENTLY, GAS AND/OR OIL MAY BE PRESENT IN COMMERCIAL QUANTITIES IN THE SUBSURFACE ROCKS IN THIS AREA.

## COAL

AREAL EXTENT. THE APPROXIMATE BOUNDARIES OF THE HELL CREEK AND LUDLOW COALS ARE DEPICTED ON THE MAP BY THICK ORANGE COAL LINES. THE BOUNDARIES WERE DETERMINED BY NATURAL OUTCROPS, PROSPECT PITS, AND 19 STATE GEOLOGICAL SURVEY COAL-TEST HOLES.

THICKNESS. THE HELL CREEK COAL BEDS ARE THIN AND NONCOMMERCIAL. IN THE LUDLOW FORMATION, THE SHADEHILL COAL ATTAINS A MAXIMUM THICKNESS OF 28 INCHES, AND THE HILLEN COAL MEASURED THREE FEET IN THICKNESS.

PHYSICAL CHARACTER. GENERALLY, THE HELL CREEK AND LUDLOW COALS ARE BROWNISH BLACK (5YR2/1) IN COLOR AND STREAK, SMOOTH, HARD, BLOCKY (HELL CREEK AND LUDLOW) TO FISSILE (LUDLOW) WITH OCCASIONAL AMBER-COLORED RESIN PELLETS, PSEUDOSCORIA, CLINKER, ASH, PEAT-CLAY AND "BLACKJACK" BEDS, AND THE ASSOCIATED MINERALS LIMONITE, SELENITE GYPSUM, MELANITERITE AND/OR JAROSITE. THE SPECIFIC GRAVITY IS ABOUT 1.25.

CHEMICAL CHARACTER. CHEMICAL ANALYSES PROVIDE AN EXCELLENT BASIS FOR COMPARING COALS AND FOR DETERMINING THE RANK AND GRADE OF COAL AND COMMERCIAL QUALITIES. THE PROXIMATE ANALYSIS FURNISHES NECESSARY DATA CONCERNING THE QUALITY AND COMBUSTION PROPERTIES OF THE COAL (MOISTURE, VOLATILE MATTER, FIXED CARBON OR THE PRINCIPAL HEAT-PRODUCING CONSTITUENT, ASH, AND SULPHUR).

TABLE 1 SHOWS ONE SHADEHILL COAL SAMPLE (SAMPLE NUMBER 1) 24-INCHES THICK, SEC. 28, T. 20 N., R. 12 E., AND ONE HILLEN COAL (SAMPLE NUMBER 2) 12-INCHES THICK, SEC. 33, T. 19 N., R. 12 E., WERE ANALYZED AS RECEIVED MEANING THE SAMPLES REPRESENT THE COAL AS MINED. THE PROXIMATE ANALYSES FOLLOW:

SAMPLE	MOISTURE	VOLATILE MATTER	FIXED CARBON	ASH	SULPHUR	B.T.U.	DRY B.T.U.
1	38.70%	40.19%	11.31%	9.00%	0.86%	4,994	8,147
2	42.10%	43.46%	1.39%	13.05%	1.41%	6,743	8,705

ECONOMICALLY, IF THE COAL IS AIR-DRIED PRIOR TO DOMESTIC OR COMMERCIAL CONSUMPTION, THE HEATING VALUE WILL BE INCREASED ABOUT 3,000 B.T.U.'S.

CHARACTER OF OVERBURDEN. THE CHARACTER OF THE OVERBURDEN IMPOSES NO PARTICULAR STRIPPING PROBLEM AS EARTH-MOVING EQUIPMENT READILY EXCAVATE LENTICULAR CLAY, SILTS, SANDS, AND SOFTLY INDURATED SANDSTONES AND SILT-STONES THAT OVERLIE THE SHADEHILL COAL. IF THE HILLEN COAL IS EXPLOITED, THE SCOTCH CAP SANDSTONE WOULD PRESENT A MINING PROBLEM AS THE SANDSTONE IS MODERATELY THICK AND EXCEPTIONALLY HARD IN PLACES. OVERBURDEN THICKNESSES PENETRATED IN THE SURVEY DRILL HOLES ARE SHOWN ON THE MAP.

ESTIMATED COAL RESERVES. THE ESTIMATED COAL TONNAGE FOR THE QUADRANGLE IS ABOUT 382,500 TONS. THIS ESTIMATION IS BASED ON THICKNESSES MEASURED ON OUTCROPS, PROSPECT PITS, AND DRILL-HOLE DATA, AND THE TONNAGE IS COMPUTED ON THE BASIS OF A MINIMUM THICKNESS OF 2½ FEET, A SPECIFIC GRAVITY OF 1.25, AND 1,700 TONS PER ACRE-FOOT. TONNAGE IS FURTHER RESOLVED INTO THREE CATEGORIES; MEASURED (COAL RESERVES LOCATED WITHIN 0.5 MILES FROM OUTCROPS, MINES, OR DRILL HOLES), NO TONS; INDICATED (COAL RESERVES LOCATED BETWEEN 0.5 AND 1.5 MILES FROM OUTCROPS, MINES, OR DRILL HOLES), NO TONS; AND, INFERRED (COAL RESERVES LOCATED MORE THAN 1.5 MILES FROM OUTCROPS, STRIP MINES, OR DRILL HOLES), 382,500 TONS.

POTENTIAL MINING AREAS. DATA FROM 19 STATE GEOLOGICAL SURVEY COAL-TEST HOLES INDICATE A POTENTIAL STRIPPING AREA IN SECS. 8, 9, 16, 17, T. 18 N., R. 12 E., WHERE ONE DRILL HOLE PENETRATED THREE FEET OF HARD COAL AT 27 FEET. SYSTEMATIC DETAILED DRILLING IS WARRANTED TO DETERMINE THE AREAL EXTENT OF COAL, COMMERCIAL THICKNESS, AND CHARACTER OF OVERBURDEN.

## SAND AND GRAVEL

SAND AND GRAVEL TERRACE DEPOSITS CONTAINS APPROXIMATELY 9,000,000 CUBIC YARDS. THE LARGEST DEPOSITS ARE LOCATED ALONG THE NORTH FORK OF GRAND RIVER. MUCH OF THE MATERIAL IS ADEQUATE FOR ROAD METAL.

THE ESTIMATED VOLUMES OF TERRACES THAT CONTAIN IN EXCESS OF 500,000 CUBIC YARDS ARE AS FOLLOWS:

SECTION	LOCATION TWP.N.	RGE.E.	ACRES	AVERAGE THICKNESS	CUBIC YARDS
33,34	20	12	159	8'	2,048,288
1,12	19	12			
7	19	13	52	15'	1,263,140
9,16	19	13	69	10'	1,109,973
7	19	13	62	10'	1,003,493
23,24,25,26	20	11	152	3'	735,690
21,22	18	13	44	10'	716,320

## CLAY

PART OF THE UPPER HELL CREEK UNIT IS COMPOSED OF IMPERVIOUS BENTONITIC CLAY THAT CAN BE USED TO LINE AND SEAL STOCK DAMS, PREVENTING WATER LEAKAGE.

## ORTHOQUARTZITE AND SANDSTONE

MANY ORTHOQUARTZITE BOULDERS MAY BE FOUND IN THE NORTHWESTERN CORNER OF THE QUADRANGLE. THESE BOULDERS MAY BE USED FOR BUILDING-STONE.

THE SCOTCH CAP SANDSTONE WOULD PROVIDE AN EXCELLENT SOURCE FOR BLOCK OR BUILDING-STONE AND RIPRAP FOR DAMS.