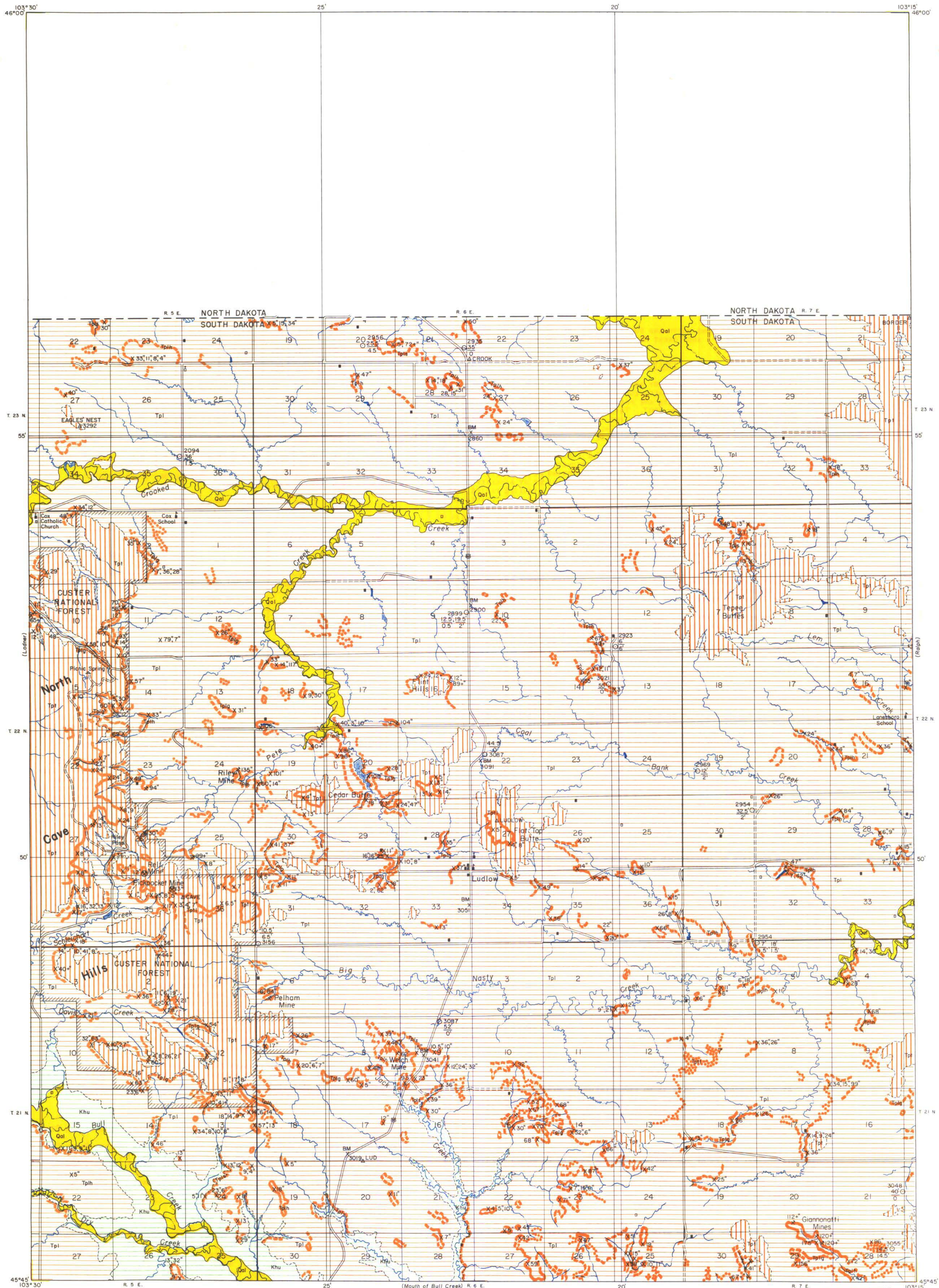
AREAL GEOLOGY

OF THE

LUDLOW QUADRANGLE

STATE OF SOUTH DAKOTA
JOE FOSS, GOVERNOR

STATE GEOLOGICAL SURVEY
E. P. ROTHROCK, STATE GEOLOGIST



EXPLANATION

SEDIMENTARY ROCKS

RECENT — QUATERNARY

Qal — Alluvium

(Floodplain deposits of silt, sand and gravel. Includes low terrace deposits.)

PALEOCENE — TERTIARY

Tpl — Tongue River Formation

(Two massive white to light gray subgraywacke, cross-bedded sandstones with interbedded subgraywacke sand, silt, and clay-shale, locally bentonitic. Tpll Lodgepole facies-interbedded sand, silt clay and peat-clay with 1-3 seams 1" to 27" thick of uraniferous low grade lignite.)

Tpl, Tpll, Tplh — Ludlow Formation

(Dominantly cross-bedded white to buff, fine to medium grained subgraywacke sands with numerous large calcareous cementations. Interbedded somber and gray silts and clays locally slightly bentonitic. Tpls Shadehill facies-interbedded white to gray sands, silts and clays, brown peat-clay and 4 to seams of black blocky lignite 1" to 77" thick. Tpih Hillen facies-gray clay and brown peat-clay with 3 to 5 seams of black blocky lignite 6" to 123" thick. Tplg Giannonatti facies-1 to 5 black blocky lignite seams 1" to 174" thick and associated beds of clay and peat-clay.)

UPPER CRETACEOUS — Hell Creek Formation — CRETACEOUS

Khu — Upper Member

(Gray to dark gray bentonitic clays and subgraywacke sands.)

DRAINAGE

intermittent Streams and Springs

Lakes

CULTURE

Buildings
(House, church, and school)

Roads and Trails

× B.M. 1706
Bench Marks
(Monuments marking points of known altitude.)

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

Operating Uranium Abandoned
Lignite mines and Uranium prospects

× 36"
Lignite Thickness
(Exposed)

2323 Top Hole Altitude
36' Overburden Thickness
2' Lignite Thickness
Drill Holes

Geology by R. E. Stevenson.
Assisted by S. G. Collins.
Surveyed in 1955. Drafted by P. Rist.
Coal-test Holes Drilled in 1955.

Base Map by South Dakota State Geological Survey.

Scale = 1/62500

1 0 1/2 1 2 3 4 MILES

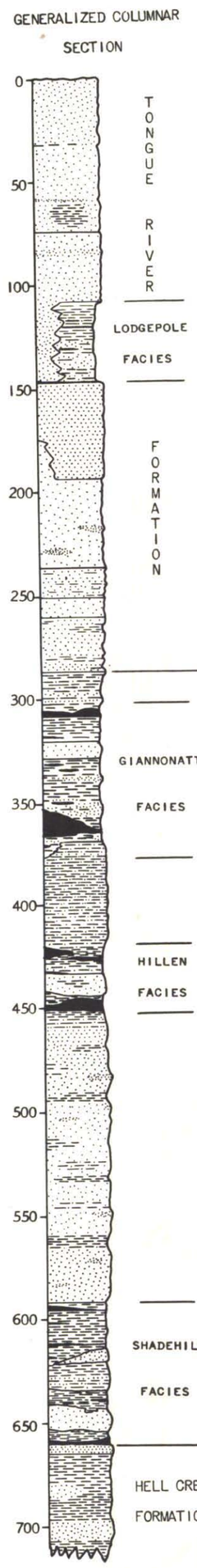
Vermillion, South Dakota
1956

APPROXIMATE MEAN DECLINATION 1955

■ Quadrangle Location

AREAL GEOLOGY OF THE LUDLOW QUADRANGLE

By
Robert E. Stevenson



INTRODUCTION

The mapping of this quadrangle was done in 1955 as a part of the State Geological Survey's coal resources program. Exploratory drilling for coal was done concurrently with the mapping. The writer was assisted by Sam G. Collins and the drilling was done by Robert A. Schoon and Orin Rosenbaum.

LOCATION

This quadrangle lies in the north central part of Harding County along the North Dakota-South Dakota line. The area lies approximately 180 miles northwest of Pierre and 120 miles north of Rapid City.

GEOGRAPHY

The dominant topographic features of this area are the North Cave Hills, a group of mesas, ridges, and buttes topped with ponderosa pine and edged with cliffs; they rise 350 to 500 feet above the surrounding plains along the western edge of the quadrangle. There are several sandstone capped buttes in the vicinity of Ludlow, in the central part of the quadrangle. Small scattered patches of badlands are found to the south, along the Bull Creek drainage; elsewhere, there is rolling grass-covered prairie with scattered mesas and buttes. Three major streams, characterized by wide flat valleys, flow eastward across the mapped area. Of these, Big Nasty Creek heads in the North Cave Hills, and Bull Creek lies south and Crooked Creek to the north of the Hills. There are a number of springs near the base of the cliffs bordering the North Cave Hills and adjacent buttes. The only permanent water bodies are numerous stock lakes.

This is an agricultural area, mostly stock grazing, but with some areas in small grain. The climate is semi-arid with an average rainfall of 10-14 inches. The area has about one family per 5 square miles. There is a small settlement at Ludlow. Most of the North Cave Hills lie in the Custer National Forest.

U. S. Highway 85 runs north and south through the center of the mapped area. County, township, and Forest Service roads make the area fairly accessible.

STRATIGRAPHY

Late Cretaceous, early Tertiary and Quaternary rocks crop out in the Ludlow quadrangle, but only the Paleocene Ludlow formation is exposed in its entirety. Only continental strata are present in this quadrangle.

Hell Creek Formation Brown 1907. This formation is poorly exposed in Bull Creek valley and its tributaries in the southwest corner of the mapped area. Only the upper 45 feet is present. The dominant lithology seems to be gray and dark gray bentonitic clays which lense and interbed with gray to buff subgraywacke sands.

Ludlow Formation Lloyd and Hares 1915. The formation was named for the good exposures in the vicinity of Ludlow. Scattered exposures of the Ludlow formation are present in most of the quadrangle excepting along the west edge and in the northeast corner. The formation is characterized by a series of lensing and interfingering sandy sediments and associated lignitic facies, and is dominantly cross-bedded, white to buff, fine- to medium-grained, clayey or silty, subgraywacke sands. Locally these sands are ripple-marked with both oscillation (Index = 10) and current (Index = 7) ripples. There are numerous calcareous cementations. Interlensing with the sands are somber (brown, tan, or gray) slightly bentonitic silty clays; light gray partly fissile silts, clays, and silty clays; and buff slightly bentonitic sandy clay. Scattered throughout the sediments are horizons of hard orange red limonitic concretions.

Marking the base of the formation is the Shadehill facies: a series of interbedded white to gray, slightly bentonitic to bentonitic fine graywacke sands, silts, and clays; brown peat-clay; layers of hard orange-red to black limonitic concretions; and 4 to 9 seams of black blocky to fissile lignite (1 inch to 77 inches thick). The Shadehill ranges in thickness between 25 and 65 feet.

One hundred and forty feet above the Shadehill is another lignite facies, the Hillen. It is approximately 35 feet of interbedded gray slightly bentonitic clay and sandy clay, brown peat-clay, black lignitic peat-clay, and 3 to 5 seams (6 inches to 123 inches thick) of black blocky to fissile lignite. This facies includes the Widow Clark seam of Winchester (1916) and Searight (1930).

Lying about 50 feet above the Hillen, is the third Ludlow lignitic facies, the Giannonatti. It is a series of interbedded buff to gray sandy clay and clay, brown to tan fissile silty clay with plant fragments, buff fine grained subgraywacke, brown peat-clay, and 1 to 5 seams (1 inch to 174 inches in thickness) of black blocky and fissile lignite. The facies, which is about 60 feet thick, may be the correlative of the Bison facies 50 miles farther east (Bolin 1955), and the T-cross seam just to the north in North Dakota (Kepferle and Culbertson, 1955). The U. S. Geological Survey's "B", "C", and "D" seams (King, 1955) are equivalent to this facies.

The Shadehill, Hillen, and Giannonatti facies are characterized by the presence of jarosite, melanterite, and selenite.

Tongue River (Taff 1909) The North Cave Hills and Eagles Nest Butte on the west; Cedar Butte, Flat Top Butte, and Flint Hills in the center; Tepee Buttes in the northeast; and several small buttes in the southeast are capped by the massive sandstones of the Tongue River formation.

With the exception of the Lodgepole lignitic facies, the formation is dominantly sandy, characterized by two massive sandstones; a lower, white to light gray, coarse- to medium-grained, calcareous subgraywacke, cross-bedded with local horizons of angular fine white sandstone pebbles; and an upper, buff white to gray, fine- to medium- grained, calcareous subgraywacke, cross-bedded streaked with limonitic stains, and locally unconsolidated. The rest of the formation consists of interbedded buff, fine- to medium-grained, calcareous subgraywacke and subgraywacke sand; gray-brown and buff fine clayey sand and clay-shale with clay streaks, limonitic streaks, and limonitic concretions, buff to white clayey silt, and gray to tan bentonitic clay.

About 140 feet above the base of the formation is the Lodgepole lignitic facies. It is a series of interbedded buff subgraywacke sand and sandy clay, slightly bentonitic light gray clay and clay-shale, black carbonaceous clay, brown peat-clay and one to three thin seams (1 inch to 27 inches thick) of friable uraniferous low-grade lignite.

The Lodgepole facies includes the "E" and "F" beds of King (1955) and is possibly the equivalent of the Harmon lignite to the north in North Dakota (Kepferle and Culbertson 1955).

Recent Deposits Mapped as alluvium are the recent accumulations of silt, sand, and gravel in the valleys of the major streams.

STRUCTURE

The Ludlow quadrangle lies on the southwest flank of the Dakota (Williston) Basin. The regional dip into the basin is about 22 feet per mile. Minor faults and shallow folds (amplitude and displacement less than 20 feet) are present, but have no persistent strike. In the SW¼ Sec. 9, T. 21 N., R. 6 E., there is an area of a persistent dip of 3° to the southeast.

ECONOMIC GEOLOGY

At the present time there is no exploitation of mineral resources, but in the early 1900's considerable mining of lignite was done, primarily for local consumption. Additional lignite mining on a local scale was done during the 1930's. In recent years, there has been considerable uranium prospecting but no production. Baked clay and clinker have been quarried sporadically for local road topping.

COAL: There are four lignitic horizons in this area, the Shadehill, Hillen, and Giannonatti facies of the Ludlow formation and the Lodgepole facies of the Tongue River formation. The three Ludlow coal facies contain minable seams, in the Pelham area in the southwest part of the quadrangle, the Riley area in the west-central part, the Giannonatti area in the southeast part, the Tepee Butte area in the northeastern part, and the State line area in the northwest part of the quadrangle (see Index Map).

Shadehill facies: Minable seams range from 30 to 46 inches in thickness. The lignite is black in color with a brownish-black streak, brittle, banded, fissile and locally blocky. It is non-coking and slacks upon drying. A proximate analysis is shown in Table 1. Tonnage estimates of Shadehill lignites from the Pelham and State line areas are shown in Table 3. Roof rock is either clay, sand, or soft sandstone, and the floor is clay or peat-clay. Stripping methods of mining could be used as the overburden is mostly unconsolidated rocks.

Hillen facies: The commercial seams range in thickness from 30 inches to 123 inches. The lignites are black in color, brownish-black in streak, brittle, blocky locally fissile and contains small quantities of melanterite or jarosite, and marcasite. This non-coking lignite slacks upon drying, which increases its B.T.U. value. A proximate analysis is given in Table 1. Table 3 gives the tonnage estimates for the Hillen lignites in the Ludlow quadrangle. Roof rock is usually clay or sand (locally sandstone) and the floor is peat-clay. The overburden is mostly sand suitable for strip mining.

Giannonatti facies: There are two major seams (locally very thick) and several minor ones. Thickness of minable seams ranges from 30 inches to 174 inches (14½ feet). The Giannonatti lignites have the same general physical characteristics as the Hillen lignites (see above). The lignite proximate analyses are given in Table 1, and the ultimate analyses in Table 2. Tonnage estimates for the Giannonatti lignites in the Ludlow quadrangle are given in Table 3. The floor is usually peat-clay and the roof rock is sandstone, sand, or clay. In two areas, Pelham and Riley, there is a thick (150 feet) overburden of massive sandstone which makes underground mining necessary. Locally in these two areas and elsewhere in the quadrangle, the overburden is thin enough to make strip mining feasible.

TABLE 1 Proximate Analyses of Lignite

Coal	Sec.	Tps.	Rge.	Moisture	Volatile Matter	Fixed Carbon	Ash	Sulpur	B.T.u.
Lodgepole*	27	21N.	7E.	48.2	18.7	5.6	27.5	0.1	1,853
Giannonatti**	20	21N.	7E.	44.4	24.0	19.7	11.9	0.7	4,440
Giannonatti**	20	21N.	7E.	46.5	20.6	25.0	7.9	0.7	5,460
Giannonatti**	6	21N.	6E.	38.0	24.4	25.5	12.1	1.0	5,520
Giannonatti*	9	21N.	6E.	44.9	29.8	20.4	4.9	0.9	4,939
Hillen*	24	22N.	5E.	45.5	25.2	14.8	14.6	0.3	3,917
Shadehill*	30	21N.	6E.	53.8	21.7	4.6	19.9	0.4	1,926

TABLE 2 ULTIMATE ANALYSES OF LIGNITE

Coal	Sec.	Tps.	Rge.	Carbon	Hydrogen	Oxygen	Nitrogen	Ash	Sulfur
Giannonatti	20	21N.	7E.	28.5	6.7	51.8	0.4	11.9	0.7
Giannonatti	20	21N.	7E.	33.0	7.2	50.7	0.5	7.9	0.7
Giannonatti	6	21N.	6E.	34.6	6.3	45.5	0.5	12.1	1.0

* Analyses by State Chemical Laboratory, Vermillion, South Dakota.
** Analyses from Cooper, et. al. (1948).

TABLE 3 LIGNITE TONNAGE ESTIMATES*

Estimates in Short Tons

DISTRICT	Giannonatti Lignites	Hillen Lignites	Shadehill Lignites	Total
State Line			935,000	935,000
Tepee Butte	1,035,000	5,661,000		6,696,000
Riley	18,266,000	10,530,000		28,796,000
Pelham	8,288,000	2,427,000	4,969,300	15,684,000
Giannonatti	28,149,000	6,824,000		34,973,000
Totals	55,738,000	25,442,000	5,904,000	87,084,000

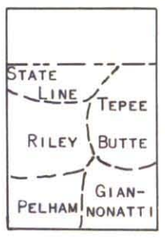


Fig. 1-Index Map for Lignite Tonnage Estimates

* These are classified as measured reserves (less than a half mile from an outcrop). The addition of inferred and indicated reserves (less than 3 miles from an outcrop) would more than double the tonnage estimate. Based on a minimum thickness of 30 inches.

Lodgepole Lignite: These lignites contain so much ash (see Table 1) and are all below the minimum commercial thickness of 30 inches. Therefore, they are not considered as an exploitable mineral fuel.

URANIUM: Although there are many uranium prospects and several mines in the Tongue River and upper Ludlow sediments, no ore has been shipped from this quadrangle. At the present time private prospecting with core drills has outlined the larger deposits and there has been some stockpiling at the Pickpocket and Relf mines. The principal ore horizons are the lignites, especially those of the Lodgepole facies ("E" and "F" beds of King, 1955) but uranium also occurs in the lower sandstones of the Tongue River formation. The uranium is present as disseminated "organo-uranium complex" and autunite in the lignite. Typical assays of the Lodgepole lignites are shown in Table 4.

The principal commercial deposit in the North Cave Hills (Secs. 22, 26, 27, 35, T. 22 N., R. 5 E.) is in the vicinity of Riley Pass. An area of about 440 acres is underlain by about 16 inches of uraniferous lignite that contains 0.76% uranium (Gill, 1954).

TABLE 4 URANIUM ASSAYS

Sec.	Tps.	Rge.	% Uranium	Reference
SE¼SW¼26	22N.	5E.	0.19	Gill (1954)
SW¼ 22	22N.	5E.	1.12	Gill (1954)

OIL AND GAS: The western edge of the quadrangle is only 6½ miles east of the South Cave Hills (Buffalo) oil field. The field probably lies on the east flank of the southeast trending Cedar Creek anticline (Stevenson, 1956).

The flanks of this anticlinal structure may extend under part of the Ludlow quadrangle and other buried structures may be present. The producing horizon in the South Cave Hills field is the Ordovician Red River formation (which lies at depths of about 9100 feet in the Ludlow quadrangle). Another possible oil horizon is the Mississippian Mission Canyon formation (at depths of about 7300 feet in this area), which produces in North Dakota.

ROAD MATERIAL: Baked clay and clinker from the scattered lignite burns are used locally for road material, but whereas the clay tends to powder rapidly, the clinker holds up well under normal farm to market traffic. The clinker does not occur in large enough deposits to be commercially exploitable.

REFERENCES CITED

Bolin, E. J. (1955) Areal Geology of the Bison Quadrangle; South Dakota Geol. Survey, Geologic Quadrangle Series, 1 pp.

Cooper, H. M., et. al. (1948) Analyses of Michigan, North Dakota, South Dakota, and Texas coals; U. S. Bureau of Mines, Tech. Paper 700, pp. 27-31.

Gill, J. R. (1954) Uranium in Carbonaceous, Lignite Investigations, Northwestern South Dakota, southwestern North Dakota, and eastern Montana; U. S. Geol. Survey, Trace Elements Invest. Rept. 540, pp. 153-155.

Kepferle, R. C. and Culbertson, W. C. (1955) Strippable Lignite Deposits, Slope and Bowman Counties, North Dakota; U. S. Geological Survey, Bull. 1015-E, 182 pp.

King, J. W. (1955) Uranium in the Black Hills and Northwestern South Dakota; North Dakota Geol. Soc. Guidebook Black Hills Field Conf., pp. 82-86.

Searight, W. V. (1930) A Preliminary Report of the Coal Resources of South Dakota; So. Dak. Geol. Survey, Rept. Invest. 3, pp. 46.

Stevenson, R. E. (1956) Preliminary Report on the Major Structural Features of South Dakota; Proc. So. Dak. Acad. Sci., vol. 34.

Winchester, D. F., et. al. (1916) The Lignite Field of Northwestern South Dakota; U. S. Geol. Survey, Bull. 627, 165 pp.