GEOLOGY OF THE WEST END
of the
TENSLEEP FAULT, WYOMING

May 1 9 4 7 — Master's Thesis
University of Michigan — Donald F. Notley

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Abstract.--The region described in this report includes about 30 square miles on the eastern margin of the Big Horn Basin, in the north-central part of Washakie County, Wyoming. The region lies in the eastern anticlinal belt of the Big Horn Basin, which borders the western slopes of the Big Horn Mountains. Big Horn River is the principal stream of the region; Nowood Creek is its chief affluent in the area mapped.

The climate is that of a cool temperate desert, with an average rainfall of about 6 inches and a mean annual temperature of about 44° F. The natural vegetation is mainly the desert brush type. Irrigated agricultural soils support stands of grains and feed crops. The usual vegetables and fruits common to the North Temperate Zone are produced.

Several rock formations that underlie the region at various depths crop out in Tensleep Canyon 5 to 10 miles east of the area mapped. They include the Deadwood, Bighorn, Amsden, Tensleep, and Embar formations of the Paleozoic age.

The oldest exposed sedimentary rock in the region mapped is the red Chugwater formation of Triassic age. This thick series of sandstones and shales is overlain by the massive gypsum, reddish siltstones, and thin limestones of the Gypsum Spring formation, of Middle Jurassic age. The Sundance formation, of Upper Jurassic age, overlies the Gypsum Spring and consists of marine glauconitic greenish-gray sandstone, limestone, and shale. Marine fossils are abundant in its upper members. The overlying Morrison formation, of Upper Jurassic age and continental origin, includes several variegated claystones, shales, and sandstone members. A white granule conglomerate bed is prominent in the top third of the formation.

The Cloverly formation, the basal unit of the Cretaceous sequence, overlies the Morrison and includes numerous brown sandstones and "rusty beds." The overlying Thermopolis shale is a black fissile shale with one impure sandstone bed known locally as the Muddy sand. Overlying the Thermopolis shale are the siliceous gray shales, siltstones, and bentonite beds of the Mowry formation. The Frontier formation overlies the Mowry shale, and consists of light- to dark-gray sandstone, dark-gray gypsiferous shale and minor amounts of gypsum. Overlying the Frontier are the thick gray shales and massive sandstone of the Cody formation. The marine Upper Cretaceous series closes with the Mesaverde formation, largely a succession of massive light- and dark-gray sandy shale. The overlying non-marine Meeteetse is the youngest Cretaceous formation exposed in the area mapped, and consists of gray and yellow poorly cemented sandstones and lignitic shale.

The gravel-capped terraces along Big Horn River and Nowood Creek are probably Pleistocene in age. Minor amounts of alluvium of Recent age are found associated with the lower terraces and occur along the larger tributaries.

The area mapped includes the western end of the Tensleep fault, a major transcurrent fracture of the middle Big Horn Mountain structures. The fault is a normal one with the south block downthrown; however, in the local region mapped the sediments of the south block are upthrown into a reverse fault. This local anomalous movement is postulated to have been caused by gypsum flowage at shallow depths in the plane of the fault, resulting in the elevation of the overlying sediments.

INTRODUCTION

Location and extent of area.--The area covered by the present report lies in Washakie County, in the eastern part of the Big Horn Basin of northwestern Wyoming. The region mapped is a rectangular area of about 30 square miles, the eastern border of which lies approximately at the village limits of Tensleep, Wyoming.

Previous investigations and publications.--The general geologic features of the Big Horn Basin and its encircling mountains have been known for many years. Dr. F. V. Hayden first described the region in his report on the explorations of the northwest, and a more descriptive and suprisingly accurate report was published by Eldridge[1] in 1894. A report on the geology and water resources of the Big Horn Basin by Fisher,[2] published in 1906, includes numerous observations on the region west of Tensleep. Also published in 1906 was N. H. Darton's[3] comprehensive report on the geology of the Big Horn Mountains, in which he gives considerable information on

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1. Eldridge, G. H., A geological reconnaissance in northwest Wyo.: U. S. Geol. Survey Bull. 119, 72 pp., 1894.
2. Fisher, C.A., Geology and water resources of the Bighorn Basin, Wyo.: U. S. Geol. Survey Prof. Paper 53, 72 pp., 1906.
3. Darton, N. H., Geology of the Bighorn Mountains: U. S. Geol. Survey Prof. Paper 51, 129 pp., 1906.

the geology of the Big Horn Basin. A report by Hewett and Lupton,[4] published in 1917, on the anticlines in the Big Horn Basin, describes the lithology of many of the formations included in the present report. Mackin,[5] in 1937, gives an excellent description of recent geologic events in the basin in his report on the erosional history of the Big Horn Basin; and Wilson,[6] in 1938, describes the Tensleep fault, which lies, in part, in the area mapped.

Other general papers relating to the regional phases of the geology and stratigraphy of the area west of Tensleep and neighboring features are cited at appropriate places in this report.

Present investigation and acknowledgments.--The field work for this report was done in the summer season of 1946 and in April of 1947. The geologic map is prepared largely from published sources with additions and modifications by the author from field notes. The source for the regional geology is the Geologic Map of the United States: U. S. Geological Survey, 1932.

The author wishes to acknowledge the assistance of Mr. Carl P. Rogers, Jr. of the U. S. Geological Survey for making part of the field work possible and rendering valuable criticism of the report. Professors A. J. Eardley and K. K. Landes of the Geology Department of the University of Michigan gave additional helpful advice on the preparation of the manuscript.

4. Hewett, D. F. and Lupton, C. T., Anticlines in the southern part of the Big Horn Basin, Wyo.: U. S. Geol. Survey Bull. 656, 192 pp., 1917.
5. Mackin, J. H., Erosional history of the Big Horn Basin, Wyo.: Geol. Soc. Amer. Bull., vol. 48, pp. 813-894, 1937.
6. Wilson, C. W., Jr., The Tensleep fault, Johnson and Washakie Counties, Wyo.: Jour. Geol., vol. 46, pp. 868-881, 1938.

Mr. Rufus A. Waldo of Tensleep, Wyoming made the aerial views especially for this paper; all other photographs are by the author.

GEOGRAPHY

Topography.--The local region west of Tensleep presents a diversity of topographic forms. Most of the area is characterized by low hills developed on soft Cretaceous and Tertiary sediments. The dominant colors of yellow-brown and gray of the beds are relieved in places by streaks of red and purple. Sharp valleys and irregular ridges carved by tributaries of the Big Horn River may be found in many localities. Badland topography is a common feature at the headwaters of a few tributary streams. The Big Horn River and its larger tributaries are flanked by a series of gravel-capped terraces.

The area lies, for the most part, in the eastern anticlinal belt that parallels the western slopes of the Big Horn Mountains. The strata dip moderately and are breached in places by intermittent tributaries. The area mapped includes the west end of Tensleep fault, in which a thick sedimentary sequence has been upended and downthrown on the south. In addition, the fracture has produced a local east-west alignment of ridges and beds that parallel the fault.

Drainage and water supply.--The principal stream of the region is the Big Horn River. This broad, north-flowing, silt-laden stream drains the entire Big Horn Basin before joining the Yellowstone River in Montana.

At the gaging station on the Big Horn River at Manderson,[1] which is about 5 miles north of the area described, the records for

1. Surface water supply of the United States, 1944, part 6, Missouri River Basin: U. S. Geol. Survey Water-Supply Paper 1006, p. 131, 1946.

the water year 1943-44 show a mean discharge of 9,404 second-feet during June, 4,567 second-feet during May, and 3,776 second-feet during July, the mean dropping abruptly to 358 second-feet in August, the low figure for the year. The records of this station, which includes those for the years 1941 to 1944, show a maximum of 160 second-feet on December 11, 12, 1943 and August 21, 1944.

The most important tributary of the Big Horn River in the Worland Tensleep region is Nowood Creek, so named by the early travelers who were hard pressed to find wood along its banks. Following a northwesterly meandering course independent of structure, it joins the Big Horn River two miles north of Manderson. Nowood is fed by flowing tributaries that rise in mountain springs east of the area here described. On August 21, 1897 a discharge measurement of Nowood Creek at a point four miles above its mouth showed a flow of 109 second-feet.[2] The two most important affluents of this creek are Paintrock and Tensleep creeks. Sand Creek is an additional north-flowing tributary of Nowood Creek that contributes water only during storm periods.

Other tributaries of the Big Horn River in the region are intermittent in character, and add their loads of silt and flood waters only during the infrequent storms. Among these lesser tributaries are Alamo Creek, followed upstream by Five, Six, Ten and Fifteen mile creeks, in the order named.

Fifteen Mile Creek is the largest intermittent stream in the central part of the Big Horn Basin. Rising in the foothills of the Absaroka Mountains near Meeteetse, it drains a watershed of over 400 square miles before joining the Big Horn at Worland. This stream

2. Fisher, C.A., Geology and water resources of the Big Horn Basin: U. S. Geol. Survey Prof. Paper 53, p. 7, 1906.

has its source on the west side of the basin, where the relatively larger rainfall contributes materially to its load of water.

Irrigation is a universal practice among the ranchers of the region, with little attempt being made to grow crops on land above a natural irrigation level. Water for irrigation purposes comes chiefly from the Big Horn River and its tributaries; natural artesian water and pumped water contribute minor amounts. The Big Horn River valley north of Worland is supplied with irrigation water by large ditches on either side of the river, which in turn are fed by diversion waters from the Big Horn River at a point upstream (south) of Worland.

Ranchers living in the valley of Nowood Creek are similarly dependent on diversion water from the creek. During the low water period of late summer, brush and trees are utilized in constructing temporary dams in an effort to maintain normal water supplies in the irrigation ditches. These makeshift dams are breached or entirely washed away during the high water month of May and June of the following year.

Water for domestic use in the towns of Worland and Tensleep is obtained from wells that tap pure water aquafers in Cretaceous and Paleozoic strata. The high initial expense of drilling to the pure water horizons has forced most of the valley bottom ranchers to depend on river water for domestic purposes.

Climate and vegetation.--The climate in northern Wyoming is arid to semi-arid; the precipitation varies greatly, both as to the amount and seasonal distribution, and between the basins and elevated land. The Big Horn Mountains are favored with the most rainfall, amounting to about 26 inches at an elevation of 8,821 feet. Approximately 21 inches of this precipitation is from melted snow that in turn furnishes a supply of good water to irrigate several projects in the eastern portion of the region under consideration.

A compilation of the records of United States Weather Bureau stations in the Worland-Tensleep area is given in the following table.[3]

Rainfall and Temperature Data,
Worland-Tensleep Region

Monthly averages in inches and degrees, Fahr.

	Worland, Washakie County; Elev. 4061'		Hyattville Big Horn Co. Elev. 4623'		Basin, Big Horn, Co. Elev. 3837'	
	Precipitation, 1907-30	Temp., 20 yr. period	Precipitation 1899-1923	Temp., 24 yr. period	Precipitation 1898-1930	Temp., 27 yr. period
Jan.	.36	12.2	.36	22.8	.45	15.4
Feb.	.25	21.2	.20	25.1	.41	21.6
March	.41	33.2	.46	35.0	.58	34.1
April	.89	45.0	.57	45.4	.76	46.7
May	1.24	54.2	.50	54.1	1.08	56.4
June	1.15	64.8	.64	63.8	.85	66.4
July	.68	71.3	.16	70.2	.46	74.0
August	.67	68.2	.36	68.2	.41	71.5
Sept.	.99	57.4	.37	58.4	.68	59.6
Oct.	.71	45.2	.46	47.1	.61	46.6
Nov.	.31	30.8	.27	35.6	.34	32.4
Dec.	.23	17.7	.35	24.8	.40	17.8
Annual	7.89 (total)	43.4 (average)	4.70 (total)	45.9 (average)	7.03 (total)	45.2 (average)

3. All data on climate is taken from Climatic Summary of the United States: U. S. Weather Bureau, 1893-1930, inclusive.

The major portion of the Worland-Tensleep region supports a desert brush vegetation composed chiefly of black sage, matchweed, rabbit brush, shadscale, salt brush, and a small growth of grass and weeds. However, vegetation is almost entirely absent on some zonal soils that have developed on shales of Cretaceous age and now exhibit black alkali soil characteristics. Vegetation is similarly lacking on other zonal soils that are merely immature and incapable of supporting plant growth in arid climate. Typical badland topography can be found in several localities at the head of intermittent stream tributaries, and plant life is almost completely absent in these areas.

The precipitation increases eastward near the mountains, and the grasses are much more abundant on the broad benches. The principal varieties are wheat bunch grass, gramma grass, western wheat grass, blue grass, mountain timothy, and rye grass.

Associated with the grass vegetation are larkapur, lupine, loco weed, balsam root, and yellow dock. Cedar and pinon are found on many of the higher ridges along the eastern margin of the area. The mountains east of the region furnish the district with yellow pine, scrub fir, lodge pole pine, Engleman spruce, Douglas fir and balsam. Aspen and cottonwood are abundant along the permanent streams and most of their intermittent tributaries.[4]

Soils and land use.--The Worland-Tensleep region receives less than 10 inches of rainfall annually, and since evaporation far exceeds precipitation, irrigation is practiced wherever crop raising is attempted. The most important crop grown is alfalfa hay, which is used as feed for cattle and sheep. The important cash crops are sugar beets, dry beans,

4. Information on vegetation taken from Aldrous, A. E. and Deeds, J. F., Land Classification of the Northern Great Plains, Montana, North Dakota, South Dakota, and Wyoming: U. S. Geol Survey, pp. 31, 120-22, 1929, mimeographed manuscript.

potatoes, and grains. Local markets are afforded by the small towns of the region, and most of the cash crops are shipped by rail to larger markets north, south, and east of the area. Large shipments of cattle, lambs, and wool are made, and the raising and shipping of turkeys has become an important industry. Several flour mills are located in the area, and a sugar mill at Worland handles the beet crop.[5]

Most of the agricultural soils occupy the alluvial terraces and fans of the river and creek valleys. The most important agricultural soils of the area are those of the Ralston and Billing series. The Ralston soils are underlain by gravel and occupy the river terraces, and the soils of the Billings series lie on alluvial fans. Soils of the Meeteetse series are equal in value to those of the Billings series but are much less extensive. The value of the soils of the Shoshone series, which occupy the first bottoms of the rivers and creeks, is limited because of the danger of alkali accumulation. Soils of the Chipeta, Greybull, and Pierre series, which are derived from shales and sandstone, are of low value because they are too shallow to allow the downward percolation of water.

Under natural conditions the regional surface drainage of practically the whole area is good. However, it is necessary to drain nearly all the land when it is put under irrigation, because underdrainage is not sufficiently good to take care of the large amounts of irrigation water used. The waste water collects in the small natural depressions of the river terraces, raises the water table of the whole terrace, and in a comparatively short time evaporation of the excess capillary water causes an accumulation of alkali at the surface. The soils with gravelly substrata, which theoretically should be free from this

5. Data on crops and soils is taken from Soil Survey of the Basin Area, Wyoming: U. S. Dept of Agriculture, pp. 47-48, Series 1928, No. 27.

difficulty, are in fact most subject to it. This is because they lie in a flat position and because many reefs of uneroded sandstone and shale rocks underlie the gravel, checking the underground movement of water and causing it to approach the surface. The soils lying on the rolling uplands and alluvial fans are less subject to the ponding of waters and hence are in less need of drainage. However, on the broad, gently sloping alluvial fans it is necessary to construct drainage ditches to keep the water table low enough to prevent interference with the growing of crops. The Big Horn River, Nowood Creek, and their tributaries remove all the run-off from the region.

STRATIGRAPHY

General Features.--The sedimentary rocks exposed in the Worland-Tensleep region range in age from Triassic to Recent and have an aggregate thickness of about 9,000 feet. Older sedimentary rocks underlie much or all of the area described, and crop out in majestic exposures in Tensleep Canyon, 2-10 miles east of Tensleep. Carboniferous, Devonian, Ordovician, and Cambrian strata form the steep canyon walls; granites of pre-Cambrian age are also exposed.

The general lithologic character and distribution of the formations exposed in the region are shown on Plate 4 .

Except for a hiatus or unconformity between the oldest exposed formation, the Chugwater of Triassic age, and the overlying Gypsum Spring formation of Jurassic age, the remaining sequence of younger beds is conformable up to the Fort Union formation of Tertiary age. The thin sequence of beds assigned to the basal part of the Fort Union formation apparently is conformable with the underlying Lance formation of Upper Cretaceous age, but Hewett[1] has noted a local erosional

1. Hewett, D. F., Geology and oil and coal resources of the Oregon Basin, Meeteetse, and Grass Creek Basin quadrangles, Wyo.: U. S. Geol. Survey, Prof. Paper, 145, p. 36, 1926.

unconformity at the base of the Fort Union formation in T. 50 N., R. 100 W., about 20 miles northwest of the area described in the present report.

The major structural features of this region were formed after the deposition of the Fort Union formation. As a consequence of early Laramide deformation the Willwood (Wasatch) formation was locally deposited on the upturned and beveled strata of late Cretaceous and Paleocene age. Later phases of the Laramide orogeny locally arched the Willwood formation.

The formations below the Cody shale are exposed only in the belt of eroded anticlines and synclines along the eastern margin of the area. The thick Cody shale and overlying Upper Cretaceous sediments form low hills over the central part of the region; and the Fort Union and Willwood deposits of Tertiary age have weathered to badlands in the western region. Alluvium and gravelled terraces are preserved along the major drainage channels.

Rocks not exposed.--Rocks older than the Chugwater formation of Triassic age are not exposed in the Worland-Terrace region. However, several Paleozoic formations that underlie the region at depths crop out in Tensleep Canyon just east of the area described.

Fisher[2] notes a thickness of 900 feet for the Deadwood formation of Cambrian age. The Deadwood consists of sandstone, shale, conglomerate, and limestone. The overlying Bighorn dolomite of Ordovician age is about 300 feet thick. A prominent cliff-former in Tensleep Canyon is the massive Madison limestone of Mississippian age. According to Fisher,[3] it has a total thickness varying from 600 to 1,000 feet, and consists mainly of massive gray limestone. In the Tensleep region Fisher[4] notes that the Madison consists of two members: the lower one

2. Fisher, C. A., op. cit., Plate 5.
3. Fisher, C. A., op. cit., p. 13
4. Fisher, C. A., op. cit., p. 14.

a somewhat massively bedded limestone in part a dark gray color, and the upper about 200 feet thick of softer, purer, and more massive rocks which weather into the characteristic pinnacled forms. The contact between the Madison limestone and the Bighorn dolomite is not distinct and, although there is a hiatus present representing Silurian and Devonian times, no unconformity is noticeable.

Overlying the Madison limestone are the red shales, limestones, sandstones, and cherts of the Amsden formation. This Mississippian and Pennsylvanian representative has a thickness of about 200 feet and is unconformable on the underlying Madison limestone. Red shales are prominent in the lower portion of the Amsden, and the upper portion consists of thin-bedded sandy limestone and chert.

The Tensleep sandstone of Pennsylvanian age consists of white to buff sandstone in thick, massive beds. Crossbedding and weathering into irregular features are prominent characteristics of the formation. The thickness of the Tensleep formation in the Tensleep area is about 100 feet. See plate 6.

A series of limestones, dark red sandstones and cherty beds overlie the Tensleep sandstone. Darton originally named these red and white beds the Embar formation; however, the name Embar was abandoned in 1934 by the U. S. Geological Survey[5] because the rocks previously so designated were found to constitute two formations: the Permian Phosphoria formation and the Triassic Dinwoody formation. More recent work has made it seem inadvisable to use the term Phosphoria in the Big Horn Basin, because the rocks differ decidedly in lithology from the Phosphoria of the typical area. The term Embar is so well established

5. Pierce, W. G. and Andrews, D. A., op. cit., p. 110.

in local usage by the petroleum geologists that it will be continued here. The 200 feet of sediments, approximately, of Embar formation that crop out in the vicinity of the area mapped have been included as a part of the lower Chugwater formation in this report, pending more definitive work on the problem. See plate 6 .

Rocks exposed

Triassic system.--The oldest formation exposed in the area mapped is the Chugwater. The name for this formation was proposed by Darton for the series of red beds extending along the foot of the Big Horn Mountains and southward through Wyoming and Colorado. The name Chugwater is derived from Chugwater Creek in the Laramie Range, along which an extensive series of red beds crop out in the vicinity of Iron Mountain, Wyoming. Darton's original definition of the Chugwater included all the red beds between the Tensleep and Sundance formations. The scarcity of diagnostic fossils make the age of the formation difficult to determine; however, its age is delimited by the marine Sundance of Jurassic age above and the marine Embar of Permian age below.

The Chugwater formation crops out in a dolomite-capped cliff in the center of sec. 24 of T. 49 N., R. 89 W., (see plate 7) and strikes slightly west of north. The deposits of the Chugwater consist of a series of red sandy siltstones and soft red sandstones with some gypsum members. Various characteristics indicate marine origin for the major part of the red beds and subaerial origin for other parts.[6] Since land form fossils are found in one member of the Chugwater, and marine origin is assumed for the greater part of the beds, it is difficult to explain the absence of marine fossils in the other members.

6. Branson, E. B., Triassic-Jurassic "Red Beds" of the Rocky Mountain region: Jour. Geol., vol. 35, p. 607, 1927.

Branson[7] suggests that high salinity killed off most of the plants and animals, thereby also accounting for the persistence of the red color. Abundant life, according to Branson, would act as a reducing agent and destroy the red colors.

No measurement was made of the thickness of the Chugwater formation, but estimates average about 750 feet.

Jurassic system.--The oldest formation definitely assigned to the Jurassic in the Tensleep area is the Gypsum Spring. The formation was first named and defined by Love[8] as the topmost 180 feet or so of the gypsum and limestone bearing member of the Chugwater formation. The name is derived from the gypsum spring on Red Creek at the western end of the Owl Creek Mountains. Love originally assigned the Gypsum Spring to the Triassic, but suggested that the Chugwater of Northwestern Wyoming might be, in part, of Jurassic age.[9]

In his investigation of the Gypsum Spring, Imlay has found marine fossils from the limestones and dolomites of the upper beds that are Middle Jurassic in age.[10] The sequence of gypsiferous beds, occupying the same stratigraphic position as the Gypsum Spring formation, has been identified on the surface[11] as far north as Indian Creek in the Madison Range and Belt Creek in the Little Belt Range,[12] as far east as the northeast end of the Bighorn Mountains, and as far north as the Judith and Maccasin Mountain.

7. Branson, E. B., op. cit., p. 625.
8. Love, J. D., Geology along the southern margin of the Absaroka Range, Wyo.: Geol. Soc. America Spec. Paper 20, p. 45, 1939.
9. Love, J. D., op. cit., p. 48.
10. Imlay, R. W., Marine Jurassic of Black Hills area, South Dakota and Wyo.: Bull. Amer. Assoc. Petrol. Geol. vol. 31, p. 236, 1947.
11. Gardner, L. S., Hendricks, T.A., Hadley, H. D., and Rogers, C. P., Jr. Mesozoic and Paleozoic formation in south-central Mont.: U. S. Geol. Survey Prelim. Chart 18, Oil and Gas Investig. Ser., 1945.
Hadley, H. D., Gardner, L. S., and Rogers, C. P., Jr., Sub-surface Stratigraphy of Lower Mesozoic and Upper Paleozoic formations in the basin area of south-central Mont.: U. S. Geol. Survey Prelim. Chart 19, 1945.
12. Cobban, W. A., Marine Jurassic formations of Sweetgrass Arch. Mont.: Bull. Amer. Assoc. Petrol. Geol., vol 29, pp. 1275, 1298, 1945.

In the local area of this report the Gypsum Spring formation consists of a series of thin-bedded gray to white limestone, massive gypsum and reddish-brown siltstones. It rests with a sharp lithologic break on the underlying red sandstone of the Chugwater formation. At the base of the formation in the area mapped is a hard, gray dolomite that grades laterally to the northeast into a red siltstone.

Although no fossils were found in the formation, the presence of massive gypsum strongly supports the marine origin theory, as suggested by Imlay's Jurassic marine fauna. A measurement of the formation by the author about 4 miles northwest of Tensleep showed a thickness of about 275 feet.

Section of Gypsum Spring formation measured about 4 miles northwest of Tensleep, Wyo., 200 yds, west of Tensleep-Bonanza road. By P. W. Richards and D. F. Notley.

	Ft.
Sundance formation	
Sandstone, light brown to greenish, calcareous, thinly bedded, ledge-forming.	8
Gypsum Spring formation	
Sandstone, light brown, calcareous, non-resistant. . .	10
Claystone, light gray, slightly calcereous, non-resistant.	8
Siltstones, red and gray, calcareous, non-resistant .	20
Limestone, light gray, thin-bedded, platy; forms small ledges.	15
Sandstone, red, non-resistant, probably contains much claystone.	32
Limestone, light gray, thin-bedded, platy; forms small ledges.	6
Siltstone and claystone, red, non-resistant.	36
Gypsum, white, pure, massive, ledge-forming, some thin layers of red sandstone.	53
Sandstone, red, Medium-grained, massive in fresh exposures; weathers to non-resistant red sand.	90

Dolomite, gray to white, medium bedded, resistant;
forms ledges and caps buttes. 5

275

Chugwater formation
Sandstone, red, medium grained, non-resistant. . . . ?

Overlying the white limestones and red siltstones of the Gypsum Spring formation are the characteristic green sandy shales and sandstones of the Sundance. This widespread upper Jurassic formation has been recognized throughout most of Wyoming (except southwestern portion), southwestern South Dakota, central Southern Montana, northwestern Nebraska, and central northern Colorado. The formation was named and defined by Darton[13] for the green shales and thin-bedded sandstones of Jurassic age that extend continuously around the Black Hills uplift.

The sandy shales of the Sundance formation crop out in a broad band of gently dipping beds along and roughly parallel to the Tensleep-Bonanza road in sec. 3 of T. 47 N., R. 89 W. Other excellent exposures may be found along the Tensleep fault in secs. 23 and 24 of the same township.

Some characteristic fossils of the Sundance are Gryphaea calceola var. nebrascensis, very abundant in the upper part of a basal green shale member; Beleminites densus is relatively abundant in the lower part of the same shale member. Other fossils commonly found at this same horizon are Camptonectes bellestriatus and various species of Trigonia and Cardioceras.[14]

The uppermost unit of the Sundance formation is a gray-green consolidated sandstone. The characteristic green is probably due

13. Darton, N. H., Jurassic formations of the Black Hills of South Dakota: Geol. Soc. Amer. Bull., vol. 10, p. 387, 1899.
14. Pierce, W. G., and Andrews, D.A., Geology and oil and coal resources of the region south of Cody, Park County, Wyo.: U.S. Geol. Survey Bull. 921, p. 112, 1941.

to glauconite;[15] weathering produces a gray-green color. A few calcareous layers in this topmost unit are almost entirely made up of the shells of <u>Ostrea strigilecula</u>; <u>Rhychonella myrina</u> is also abundant. The relation between the topmost, highly fossilferous, gray-green sandstone of the Sundance and the overlying gray-green, non-fossiliferous sandstone of the Morrison is gradational, and the contact has been drawn to restrict all marine beds to the Sundance and include all non-marine beds in the overlying Morrison formation.

The Morrison formation was first named and defined by Cross[16] from the exposures near the town of Morrison, Colorado. The formation has also been recognized in northern New Mexico and northeastern Arizona, eastern Utah, Wyoming, western South Dakota, central southern Montana, western Oklahoma, and possibly in western Kansas.

The Morrison has been assigned by various authors to the Jurassic, Jurassic (?), Cretaceous (?), Lower Cretaceous, and even Upper Cretaceous; it is now placed by the U. S. Geological Survey in the Upper Jurassic.[17]

The formation is well developed in secs. 10,15, and 22 of T. 47 N., R. 89 W. The contact between the Morrison and the overlying Cloverly formation is abrupt, the lithology changing from the non-resistant, variegated claystones or shales of the Morrison to the resistant, brown sandstone of the Cloverly.

The lower units of the Morrison formation consist of calcareous light gray-green sandstone, red and gray siltstones and white sandstones.

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15. Hewett, D. F., The Shoshone River section, Wyo.: U. S. Geol. Survey Bull. 541, p. 92, 1914.
16. Cross, W., Pikes Peak, Colorado, quadrangle: U. S. Geol. Survey, Atlas, Folio no. 7, 1894.
17. Baker, A. A., Dane, C. H., and Reeside, J. B., Jr., Correlation of the Jurassic formations of parts of Utah, New Mexico, and Colo.: U. S. Geol. Survey Prof. Paper 183, pp. 59-63, 1936.

Rapid lateral variation in lithology is a prominent feature of most of the thinner units of the formation. Slightly above the middle of the formation is a characteristic medium to coarse grained sandstone containing thick lenses of granule conglomerate. Few pebbles in the conglomerate exceed 4 mm. in diameter, and most of them are somewhat smaller in size. The conglomerate forms distinct ridges in a few places (see Pl. 3) and is sufficiently distinct in all exposures of upper Morrison to be useful as a horizon marker in detailed mapping.

The members of the Morrison formation overlying the conglomerate units are mostly non-resistant shales and claystones. The colors of these upper members are a distinctive feature of the formation. In no other local formation is there found such a profusion of pastel colors. Lighter shades of red and purple predominate as weathered evidence of darker colored parent material. Gray, brown, and lighter tints of color up to a glistening white are also present.

Highly polished, well-rounded stones or "gastroliths" are found here and there among the upper units of the Morrison. Under favorable conditions, at the base of weathered slopes, they are sometimes found in abundance.[18]

Measurements made of the thickness of the Morrison formation over short lateral distances show a considerable variation in thickness. The section described in this report gives the maximum thickness recorded; a more accurate estimate of the average thickness in the

18. For comment on the origin of "gastroliths," see Stokes, W. L., Some field observations bearing on the origin of Morrison "gastroliths,": Science, n. S., vol 95, no. 2453, p. 18-19, 1942.

mapped area would be about 375 feet.

Section of Morrison formation measured by F. W. Richards and D. F. Notley; units down to conglomerate measured on east flank of Nowood anticline, south of Nowood Creek; conglomerate and lower units measured on Paintrock anticline, east of water well at south end of anticline:

	Ft.
Cloverly formation	
Sandstone, medium grained, clean, thick to massive, poorly bedded.	6
Morrison formation	
Claystones and siltstones, red and gray, non-resistant	75
Shale, dark brown.	34
Sandstone, white, very fine grained.	6
Sandstone, gray to white, medium to coarse grained, conglomeratic lenses.	50
Shale, dark brown, clayey.	40
Sandstone, light green, medium grained, non-resistant	41
Sandstone, white, fine grained.	8
Siltstones, red and gray, interbedded.	40
Sandstone, white, fine grained.	40
Siltstone, red and gray, interbedded.	154
Sandstone, light gray-green, very fine to fine grained, non-resistant.	20
	508
Sundance formation	
Sandstone, light gray-green, highly fossilferous . .	?

Lower Cretaceous.--The lowest formation in the Cretaceous system found in the Worland-Tensleep area is the Cloverly. This formation was named by Darton[19] for the coarse grained, crossbedded

19. Darton, N. H., Comparison of the stratigraphy of the Black Hills, Big Horn Mountains, and Rocky Mountain Front Range: Geol. Soc. Amer. Bull., vol. 15, p. 398, 1904.

buff or dirty gray sandstone that overlies the Morrison. The name "Cloverly" is derived from a former post office on the east side of the Big Horn Basin. Darton as first correlated the Cloverly with the Lakota sandstone and Fusion formations of the Black Hills; [20] however, in a later paper he extended the Black Hills equivalents to include the Dakota sandstone.[21]

The Cloverly formation in the mapped area consists mostly of brown to gray sandstones and thin beds of shale and mudstone. The topmost and lowermost sandstone beds are the most resistant to weathering, and are free from mud and silt inclusions. Black shales of the overlying Thermopolis formation and green, sandy shales of the Morrison formation effectively delimit the formation. The middle sandy units of the Cloverly formation have been termed "rusty beds" by Washburne,[22] because of their brown coatings of limonite. Most of the sandstone units of the formation are not continuous for any great distance laterally; the usual gradation is into a brown, sandy shale. As a consequence, the thickness and lithologic description of neighboring sections are subject to marked variation.

A measurement of the Cloverly formation on Paintrock anticline a few miles north of the mapped area showed a thickness of about 120 feet.

Upper Cretaceous.--The thick series of black shales which overlie the Cloverly formation has been named the Thermopolis

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20. Darton, N. H., op. cit., p. 398.
21. Darton, N. H., Geology of the Big Horn Mountains: U. S. Geol. Survey Prof. Paper 51, p. 53, 1906.
22. Washburne, C. W., Gas fields of the Big Horn Basin, W yo.: U. S. Geol. Survey Bull. 340, p. 350, 1905.

formation from the town of Thermopolis in Hot Springs County, near which it is well exposed.[23] The formation is well developed in the Worland-Tensleep area in sec. 22, T. 49 N., R. 89 W.

The Thermopolis is predominantly a brown to black shale that is fissile in its upper member. The uppermost shale unit contains some admixed bentonite in small quantities. Locally there is a fairly sharp contact between the black, fissile shale of the Thermopolis and the overlying gray, siliceous shale of the Mowry formation.

A fairly persistent bed of gray-brown sandstone occurs about 225 feet above the base of the formation. This semi-resistant sandstone is termed the "Muddy sand" by the drillers, and yields considerable gas in the Grass Creek field of the western part of the Big Horn Basin. The Thermopolis formation in the region studied is about 405 feet thick.

The Mowry shale is best exposed along the highway west of Tensleep, in secs. 21-24 of T. 49 N., R. 89. W. The name is derived from Mowry Basin on the east side of the Big Horn Mountains. Darton's original spelling of "Mowrie" was changed to "Mowry" in 1906. The formation has been recognized over a broad area from the west side of the Big Horn Basin to the Black Hills and from northern Montana to the Uinta Basin, Utah.

The Mowry is composed almost entirely of brown and gray shale. The shale is largely hard, fissile and siliceous. Rubey[24] suggests

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23. Lupton, C.T., Oil and gas near Basin, Big Horn County, Wyo.: U. S. Geol. Survey Bull. 621-L, p. 168, 1916.
24. Rubey, W. W., Origin of the siliceous Mowry shale of the Black Hills region: U. S. Geol. Survey Prof. Paper 154, p. 153, 1929.

that the silica in the Mowry shale was derived from highly siliceous volcanic ash, probably through decomposition by sea water and later precipitation by decaying organic matter. Fish scales are abundant in a few units of the shale and many beds of bentonite of varying thickness and purity are present.

A distinctive unit of the Mowry shale is a gray sandstone that occurs about 40 feet from the top of the formation. The sand contains siliceous siltstone and shale in stringers and thin lenses that do not follow the bedding planes.[25]

A measurement of the Mowry at a location 2.3 miles west of Tensleep showed a thickness of about 340 feet.

The prominent sandstone which caps the relatively non-resistant Mowry shale is the basal unit of the Frontier formation. The Frontier was formerly called the Fox Hills formation; however, the new name was proposed by Knight[26] after he was unable to find a Fox Hills fauna in the Wyoming exposures attributed to the Frontier. The formation is well developed at the town of Frontier in Uinta County, Wyoming, and has been described in western Wyoming and southern Montana.

The Frontier formation crops out in narrow exposures in secs. 22-23, 26-27 of T. 49 N., R. 89 W. The southern segment of the Tensleep fault is downthrown in this locality and the upended sediments of the Frontier are easily examined. West of sec. 22 the strike

25. Compare with Pierce, W. G., and Andrews, D. A., op. cit., p. 122.
26. Knight, W. C., Geol. Soc. Amer. Bull., vol. 13, pp. 542-544, 1903.

of the Frontier beds changes abruptly from an east-west direction to a northwest-southeast direction, reflecting the west end of the Tensleep fault.

The Frontier consists of gray and brown sandstones in thick beds near the top and base of the formation and a thick, median series of dark gray gypsiferous shales. Some bentonite beds are also present. The more prominent sandstones at the top and base of the formation are known as the Torchlight and Peay sandstones, respectively. The Torchlight member is a light gray to white sacchroidal sandstone, often strongly cross-bedded. It is usually easily recognized in the field by its capping layer of gray and black chert pebbles which weather out of the poorly cemented sand. Chert pebbles may also be found in lesser quantities in the immediate lower beds. The Peay sandstone, on the other hand, is a light gray, highly resistant member of the formation. Hintze[27] describes it as having large sandy concretions in its central part and a conglomeratic layer at the top, but lacking interbedded conglomerates.

The thickness of the Frontier formation in the mapped area is about 555 feet.

The thick shales of the Cody formation overlie the Frontier, and crop out in broad exposures on both sides of U. S. Highway 16 at a distance of four to ten miles west of Tensleep. The gently dipping strata are concealed in part by a mantle of soil and vegetation.

The Cody shale was named by Lupton[28] for the town of Cody which rests on an outcrop of the shale. The formation is conformable with both the underlying Frontier and overlying Mesaverde formations. The

27. Hintze, F. F., Jr., Wyo. State Geol. Bull. 10, p. 21, 1915.
28. Lupton, C. T., op. cit., p. 171.

Cody shale in the Worland-Tensleep region is largely a light to dark gray marine, sandy shale. Sandstone concretions occur in the top third of the section. The lower shale units of the Cody are neither sandy nor carbonaceous and the contact is easily discernable from the topmost chart pebble sandstones of the Frontier. The top unit of the Cody is gradational into the overlying Mesaverde formation, and the contact is placed between the topmost sandy shale of the Cody and the lowermost massive sandstone of the Mesaverde formation.

A measurement of the Cody shale made a few miles west of Tensleep showed a thickness of about 3,400 feet.

The Mesaverde formation is best exposed in sec. 32 T. 47 N., R. 89 W. of the area mapped. The formation was named by Holmes and described as composed of a massive sandstone at the base, called the "Lower Escarpment," a middle coal-bearing group, and a massive sandstone at the top, called the "Upper Escarpment."[29]

The Mesaverde in the region here described differs somewhat from the exposures in the typical area. Locally it consists of a series of massive, light to dark gray sandstones and sandy shale. A member in the upper third of the formation is a sandy shale containing a stringer of aragonite three inches thick. This member also contains a zone of calcareous concretions, up to one foot thick, 71 feet from its top. A fossil tooth (unidentified) was found near the base of the same member.

The contact between the Mesaverde and the overlying Meeteetse

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29. Holmes, W. H.: U. S. Geol. and Geog. Surv. Terr. 9th Ann. Report, for 1875, pp. 245, 248, 1877.

formation is drawn where the topmost yellowish sand of the Mesaverde grades into the basal gray and white sandstone of the Meeteetse.

A rough measurement of the Mesaverde taken about 5 miles west of Tensleep showed a thickness of 476 feet. Probably a more accurate estimate of the thickness in the local region would be nearer 650 feet.

The Meeteetse formation was named by Hewett[30] from the exposures at the town of Meeteetse on the western side of the Big Horn Basin. It has been recognized until lately only in the Big Horn Basin, but recent work has proved that this formation includes equivalents of the Bearpaw shale and the upper part of the Judith River formations of Montana.

In the area here mapped the Meeteetse is exposed only in sec. 32 of T. 47 N., R. 89 W. The gently dipping beds of the formation are poorly exposed and can only be examined in the few placed where the soil and vegetation mantle has been stripped off by erosion.

The many members of the Meeteetse formation are, in a large part, thin beds of gray and yellow sandstones of varying resistance to weathering, but the majority are poorly cemented. Dark bands in the formation are carbonaceous material, mostly carbonaceous shales. The textural units of the formation are not continuous laterally, but pinch out or grade into other beds.

The top of the Meeteetse is placed at the upper limit of the highest group of sandy, yellow-brown shales. Immediately overlying the formation are the basal white sandstones of the Lance formation.

No measurement was made of the thickness of the Meeteetse; however, estimates made locally average about 650 feet.

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30. Hewett, D. F., The Shoshone River section, Wyo.: U. S. Geol. Survey Bull. 541, p. 91, 102, 1914.

Terrace gravels.--During the Quaternary period the Big Horn Basin was being subjected to a cycle of marked erosion, which had its beginnings in late Miocene or Pliocene. Most of the sediments have been carried away, but some residual remnants remain, derived chiefly from the high mountains along the western border of the basin.

Gravel-capped terraces are conspicuously developed along the Big Horn River and to a lesser degree along Nowood Creek. The terraces are called "benches," a term used locally to describe a nearly flat gravelly deposit occuring on shales and sandstone beds which have been beveled without respect to hardness.

The terrace gravels of the higher divides of Nowood Creek are restricted in extent, and consist mostly of quartzitic pebbles which range in size up to about 60 mm. Sand and smaller grains have been washed out of the perched deposits. Although the higher residual gravels represent remnants of much larger deposits of unknown age, the lower, more extensive gravelly terraces along Nowood Creek are tentatively correlated with the Pleistocene terraces mapped by Pierce and Andrews along Meeteetse Creek.[31]

The terraces along Nowood Creek locally blend together, particularly where downcutting has been retarded by more resistant strata, however, several surfaces are distinct. Correlation of terrace levels between adjacent streams is practically impossible, due to differential downcutting of the sediments exposed in neighboring valleys.

The terraces are preserved for long periods with essentially their original slopes because their gravelly surfaces effectively resist erosion and allow water to percolate downward with a minimum of slopewash.

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31. Pierce, W. G. and Andrews, D. A., op. cit., plate 11.

Alluvium of Recent age occurs in mappable amounts along the Big Horn River, Nowood Creek, and the larger tributaries of these streams. Along the Big Horn River the alluvium is, for the most part, within 35 feet of stream level, and occupies a broad band about two miles wide that is extensively used for agriculture. Similar zones of alluvium along Nowood Creek are turned to crop use.

The alluvium consists chiefly of silts, sands, and clays that, in aggregate, make up a diversity of soil series. Minor amounts of gravel are also present.

The river terraces and alluvium deposits of the local area received only incidental study in the presence of more pressing stratigraphic and structural work.

STRUCTURAL GEOLOGY

General and regional relations.--The Big Horn Basin, as the name suggests, is a large topographic and structural basin almost surrounded by mountain units. On the east is the Big Horn-Pryor uplift; on the south are the folded rocks of the Owl Creek Range; and on the west are the high volcanic of the Absarokas. Some of the larger mountain units are divisible into smaller units or segments, each of which has been deformed in a characteristic manner.

The Big Horn Basin is rimmed, in a large part, by anticlinal foothill belts which constitute sympathetic structural expressions of the larger mountain ranges. The anticlines and synclines parallel the ranges and diminish basinward in the intensity of folding. The region here described is a part of the eastern anticlinal belt of the basin. The general strike of the beds and trend of the folding is northwest.

A prominent structural features of the mapped area is the western end of the Tensleep fault. This fault lies for the most part within the Big Horn Mountains, however, the western terminus extends into the Big Horn Basin, and provides some interesting problems in the interpretation of block movements.

The structure contour map of the west end of the Tensleep fault is shown on plate 5 . Contours are drawn on the top of the Chugwater formation at intervals of 200 feet with a datum plane of mean sea level. The map is not to be considered more than a generalization of the subsurface structure, as no well has been drilled in the area of study and accurate vertical control was not available for the western portion of the map.

The Tensleep fault.--The Tensleep fault is a major transverse tectonic feature of the central Big Horn Range. The fault separates the central and southern structural segments of the mountains.[1] The strike of the fault is approximately east-west throughout its extent, and in the western end of the region considered it passes into a monoclinal flexure. The eastern end of the fault lies near the east front of the Big Horn Mountains, where, according to Wilson,[2] it changes direction and continues southeastward for about 10 miles as the Horn fault.

The Tensleep fault has had a marked effect on the structure and geomorphology of the region mapped. Linear ridges resulting from differential erosion are a characteristic feature of the upturned

1. For a discussion of structural features of the Big Horn Mountains, see--Demorest, M. H., Critical features of the Bighorn Mountains, Wyo.: Geol. Soc. Amer. Bull., vol. 52, pp. 162-176, 1942.
2. Wilson, C. W., Jr., personal communication.

beds of the south block near the place of the fault (see plate 1).
A dendritic drainage pattern can be seen developing on a small scale between the more resistant upturned beds, in contrast to the typical dendritic drainage of the more gently dipping strata not affected by the faulting.

The best exposures of the fault in the region mapped are in secs. 23 and 24 of T. 47 N., R. 89 W. In this locality the drag is up on the south block, but the upended beds have also been locally elevated so as to bring a crescent-shaped outcrop of middle upper Chugwater in contact with the Gypsum Spring formation. The apparently anomolous arrangement may possibly be the result of secondary motion of the south block in a direction normal to the fault trace, producing locally a reverse fault. This local elevation of the south wall is explained on cross section B-B' of the geologic map as due to a lens or lenses of gypsum in the lower members of the Chugwater, which under the stress of diastrophic movement, have flowed and elevated the overlying sediments at the fault. Aside from the local area of study, the south side is down,[3] and the fault as a whole is thought to be a normal one.

The displacement of the pre-Cambrian surface of the Tensleep fault is estimated to be 400 feet;[4] however, differential movement and perhaps compaction has dampened the displacement in the Carboniferous sediments to 25 feet or less. The displacement along the local reverse fault varies from a few feet to an estimated 150 feet.

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3. Wilson, C. W., Jr., op. cit., see map, p. 870.
4. Wilson, C.W., Jr., op. cit., p. 874.

The regional relation and geologic history of the Tensleep fault have been summarized by Wilson as follows:

> During the (pre-Laramide) stages of uplift and tilting of the (Big Horn) crustal blocks, and before they were strongly crowded together by compressive stresses, the Tensleep fault probably acted as a normal or tension fault. It has inherited features of this first stage of development such as the usual direction of drag being down on the upthrown (north) side and up on the downthrown (south) side. Also, the movement was down on the hanging wall, or south side. Later, during the operation of maximum compressive stresses in the Laramide revolution the southern and central segments of the Bighorn Mountains were crowded together and definite indication of their compressive stage along the intervening (Tensleep) fault are superimposed upon the evidence of earlier normal faulting.[5]

Although Wilson describes compressive and overthrust relations along the Tensleep fault within the Big Horn Range, no such structures are thought to occur at the west end in the area of this report.

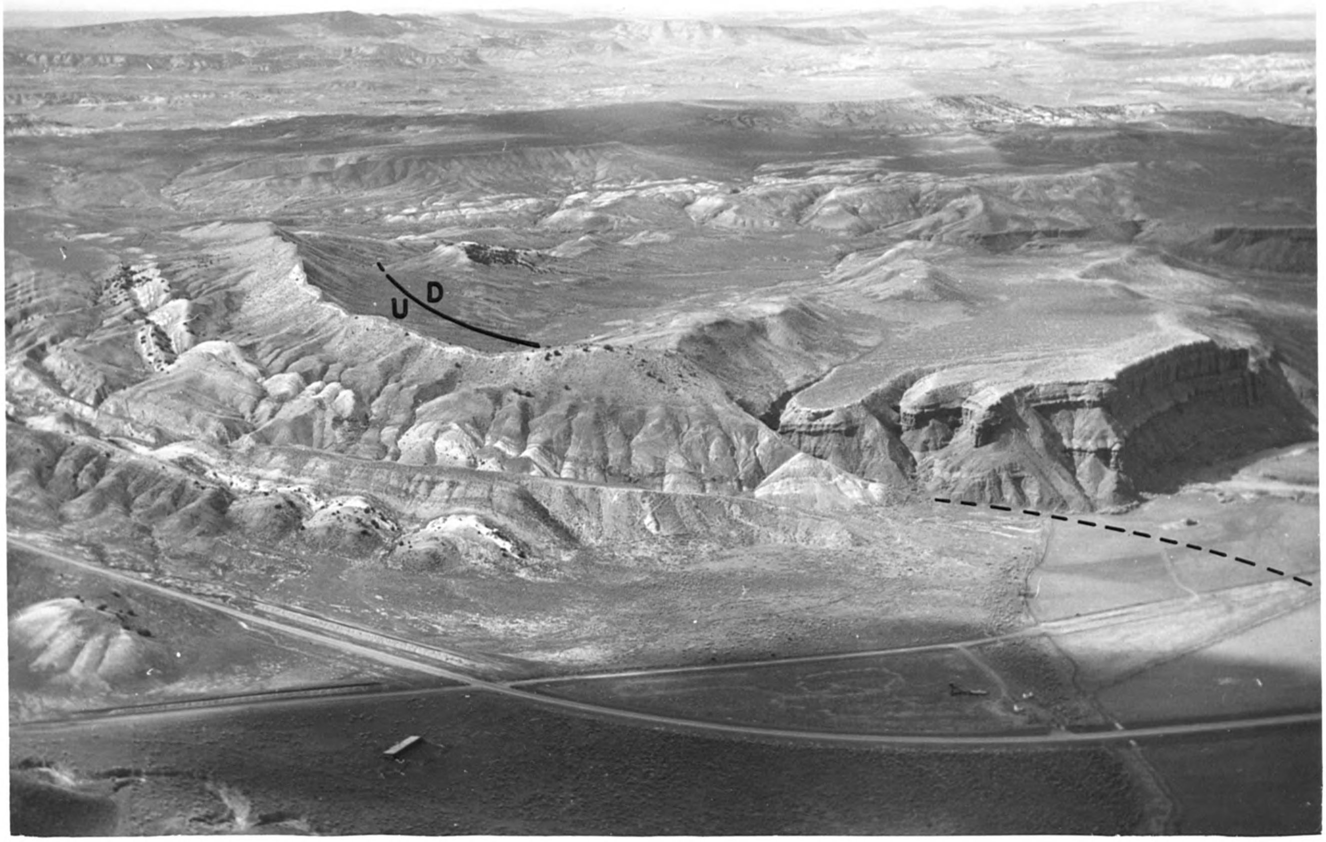
5. Wilson, C. W., Jr., op. cit., p. 880-881.

Explanation of Plate 1

Aerial view of west end of Tensleep fault, looking northwest into secs. 23 and 24 of T. 47 N., R. 89 W. A thick section of upper Chugwater formation (Triassic), capped with Gypsum Spring formation (Jurassic), is in right central foreground. The left-center of the photograph shows the upended and weathered outcrops of Gypsum Spring, Sundance, Cloverly, and Morrison formations (all Jurassic), and Thermopolis formation (Cretaceous).

Close-up view looking west into the plane of Tensleep fault in sec. 24 of T. 47 N., R. 89 W. Note secondary faulting in Gypsum Spring formation on north block (center of photo).

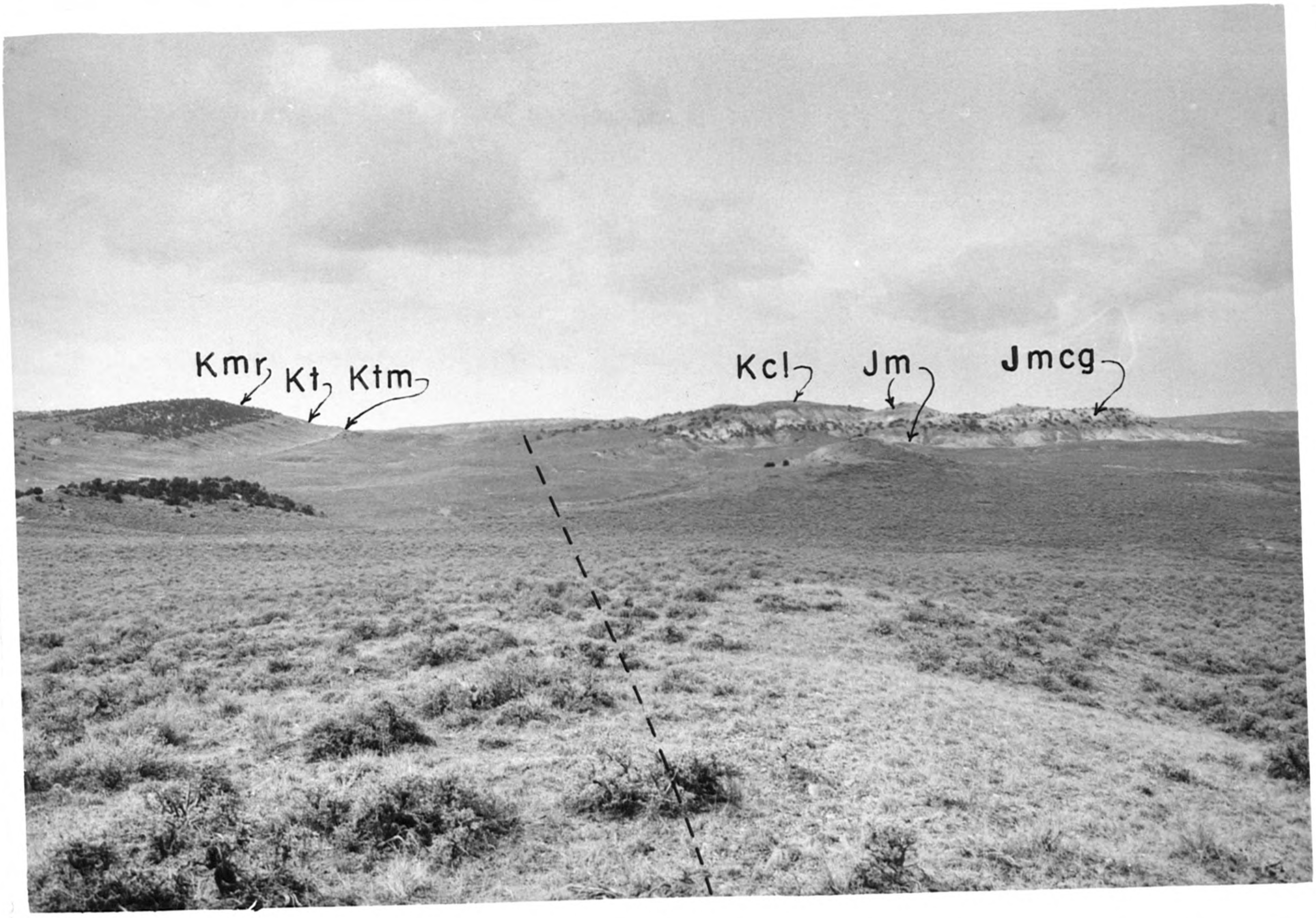
Plate 1



Explanation of Plate 2

View looking west in plane of Tensleep fault in sec. 22, T. 47 N., R. 89 W. Note monoclinal flexure of beds as shown by flat-lying Morrison conglomerate in right-center (white band with juniper bushes) and Mowry formation (Heavily wooded) dipping to the south in the left-center of picture.

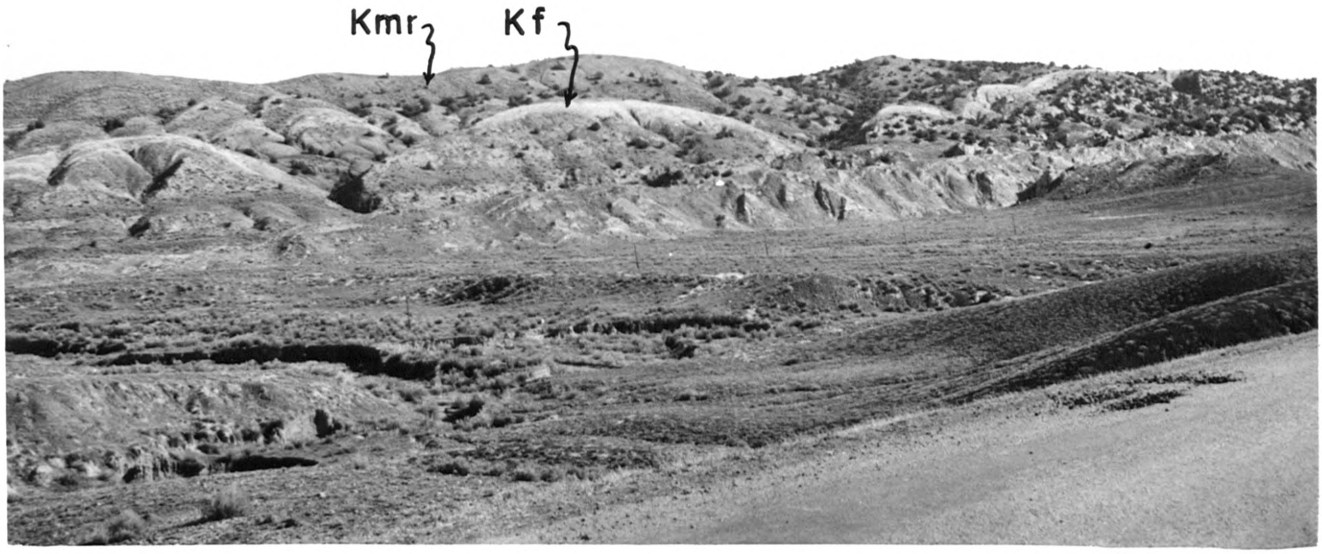
View looking east into Big Horn Mountains, showing trace of Tensleep fault projected east of area mapped.


Kmr
Kt
Ktm
Kcl
Jm
Jmcg

Explanation of Plate 3

View looking northeast in sec. 22, T. 47 N., R. 89 W. Note characteristic arcuate weathering of upended Mowry and Frontier formations (both Cretaceous).

View of characteristic weathering of granule conglomerate member of Morrison formation (Jurassic):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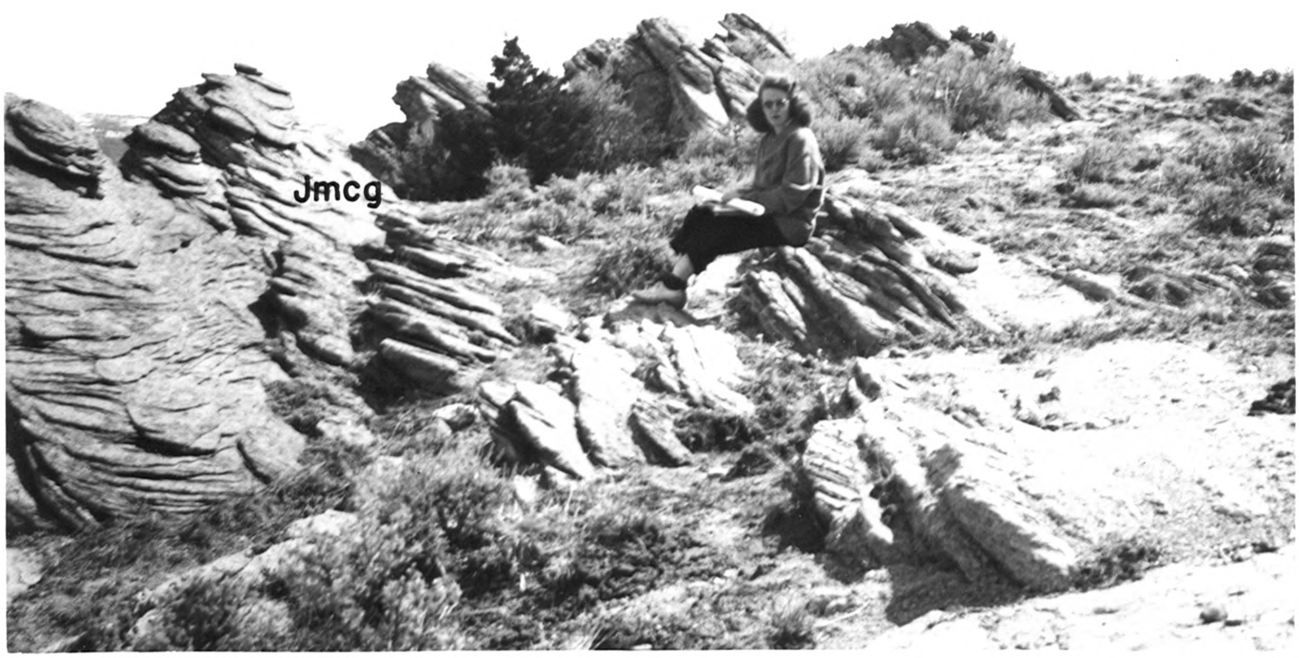
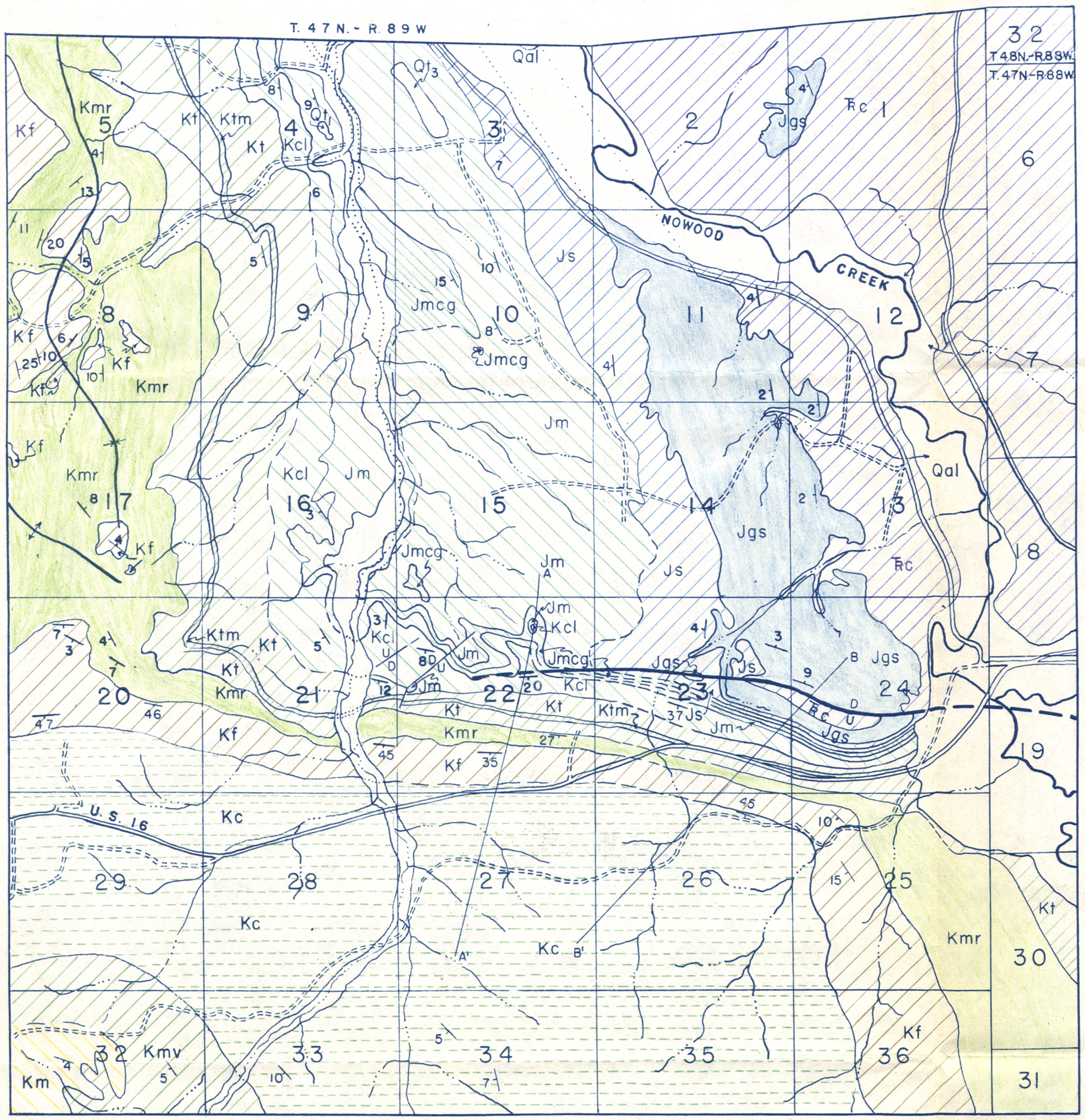

Jmcg

View of Tensleep Sandstone (Pennsylvanian) outcrop at mouth of Tensleep Canyon, 3 miles east of Tensleep. Note prominent cross-bedding.

View of Embar formation (Permian) near Tensleep. White bloom on redbeds is limestone. Big Horn Mountains are in the background.

Cliff of upper Chugwater Sandstones (Triassic) with caprock of Gypsum Spring dolomite (Jurassic); same locality as pl. 1.

View of pedistal weathering of Upper Cretaceous sandstones; 5 miles southwest of Tensleep.



EXPLANATION FOR GEOLOGIC MAP

QUATERNARY

Qal — ALLUVIUM
Includes some low terraces and slope wash.

Qt_1 — TERRACE DEPOSITS
Gravel, sand, and silt. Numbers increase with elevation.

unconformity

CRETACEOUS

Km — MEETEETSE FORMATION
Gray and yellow poorly cemented sandstone and lignitic shale.

Kmv — MESAVERDE FORMATION
Massive light gray and buff sandstone; dark gray sandy shale.

Kc — CODY SHALE
Light- to dark-gray shale with massive sandstone in upper part.

Kf — FRONTIER FORMATION
Light- to dark gray sandstone and dark gray gypsiferous shale.

Kmr — MOWRY SHALE
Siliceous gray shale and siltstone.

CRETACEOUS

Ktm / Kt — THERMOPOLIS SHALE
Black fissile shale with thin sandstone and ironstone beds. Muddy sandstone, Ktm, near middle part.

Kcl / Jmcg / Jm — CLOVERLY AND MORRISON FORMATIONS UNDIFFERENTIATED
Gray thin-bedded sandstone, shale, and ironstone; underlain by variegated claystone, sandstone and conglomerate. One bed, Jmcg, varies laterally from conglomerate to sandstone.

JURASSIC

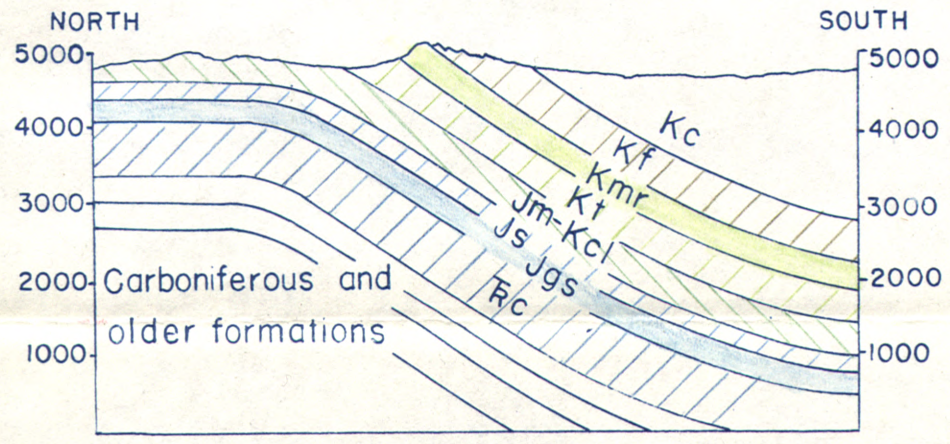
Js — SUNDANCE FORMATION
Glauconitic greenish-gray sandstone, limestone, shale. Marine fossils present, especially near top.

Jgs — GYPSUM SPRING FORMATION
Reddish-brown and gray siltstone and claystone; thin-bedded gray limestone and massive gypsum.

unconformity

PERMIAN AND TRIASSIC

Ꞧc — CHUGWATER FORMATION
(Lower part equivalent to Embar fm.) Red siltstone and sandstone with thin limestone beds and gypsum in lower part.



Cross Section along A-A'

SYMBOLS

Strike and dip of beds

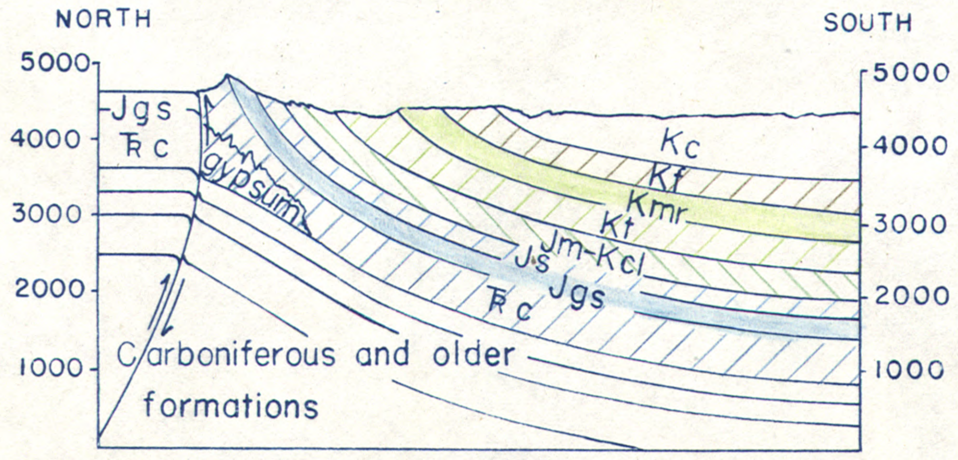
Axis of syncline

Axis of anticline

Formation boundary, dashed where inferred, dotted where concealed by overlying formation.

Fault-U, upthrown side
D, downthrown side

Fault with vertical displacement.



Cross Section along B-B'

GEOLOGIC MAP OF THE

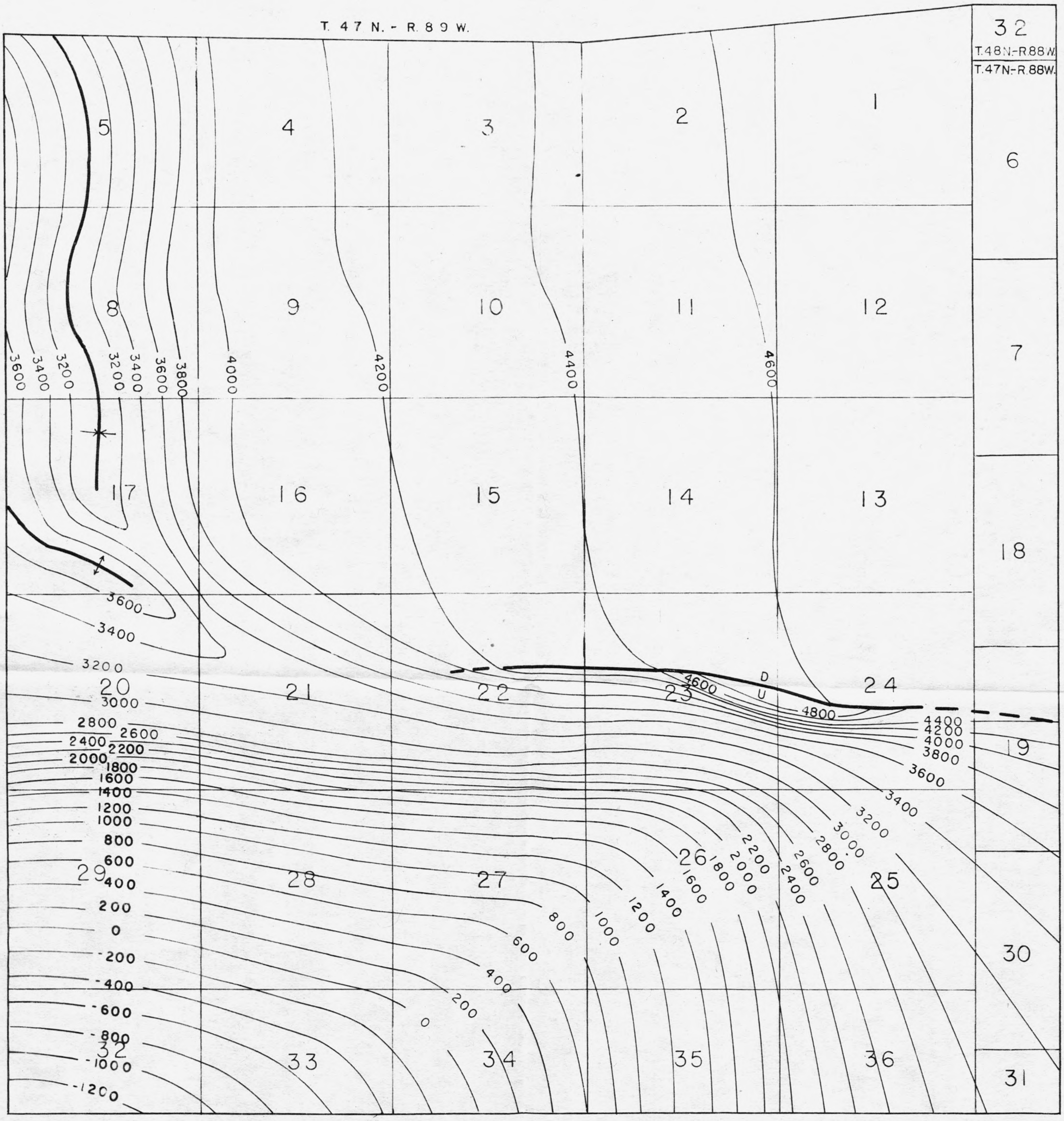
WEST END OF THE TENSLEEP FAULT

WASHAKIE COUNTY, WYOMING

Geology by D.F. Notley
Mapped in 1946

SCALE 1:31680

0 — 1 — 2 miles



STRUCTURE MAP OF TENSLEEP FAULT AREA

Washakie County, Wyoming

CONTOURED ON TOP OF CHUGWATER FORMATION

CONTOUR INTERVAL 200 FT. - DATUM - SEA LEVEL

D.F. Notley

SCALE