GEOLOGY AND OIL AND GAS POSSIBILITIES OF THE BELL SPRINGS DISTRICT, CARBON COUNTY, WYOMING

By C. E. Dobbin, H. W. Hoots, and C. H. Dane

INTRODUCTION

Gas in commercial quantities was discovered in 1924 on Separation Flats, 16 miles northwest of Rawlins, Wyo., by the Kasoming Oil Co., and the area was examined in detail by the United States Geological Survey in 1925, to obtain data that would permit the proper classification of the public land in accordance with the leasing Act of February, 1920. The investigation consisted of detailed areal mapping in Separation Flats and vicinity and a painstaking study of the Paleozoic and Mesozoic formations that are so well exposed in the Rawlins uplift near Bell Springs.

Previous geologic investigations.—The western part of the Bell Springs district falls within the limits of an area examined to obtain data for coal-land classification in 1907.[1] The outcrop of the Mesaverde formation, the lowest coal-bearing formation in the region, served as the eastern limit of the area examined at that time, and forms the western border of the area described in this report.

Investigations carried out in the Lost Soldier-Ferris district by Fath and Moulton[2] in 1920 extended southward, with reduced detail, to include the Bell Springs district. A generalized map and a description of the rocks in the Rawlins uplift were also included in the Geological Survey's guidebook for the Overland Route.[3]

Field work and acknowledgments.—The writers are especially indebted to Mr. E. W. Krampert, of the Prairie Oil & Gas Co., for logs of wells and other pertinent data regarding the area covered by this report.

The field work on which the report is based was done during parts of July and August, 1925. Horizontal control points for mapping

[1] Smith, E. E., The eastern part of the Great Divide Basin coal field, Wyo.: U. S. Geol. Survey Bull. 341, pp. 220–242, 1909.

[2] Fath, A. E., and Moulton, G. F., Oil and gas fields of the Lost Soldier-Ferris district, Wyo.: U. S. Geol. Survey Bull. 756, 1924.

[3] Lee, W. T., and others, Guidebook of the western United States, Part B, The Overland Route: U. S. Geol. Survey Bull. 612, pp. 60–70, 1916.

40615°—28——12

were located from the ends of a base line laid out along the Bairoil Road across Separation Flats, and vertical control was established by reference to several United States Geological Survey bench marks. Most of the detailed mapping was done by Messrs. Hoots and Dane. Mr. Dobbin did detailed stratigraphic work in the area and exercised a general oversight of the work in progress. Mr. Hoots also contributed a large share in the preparation of the report.

The dip readings shown on the map are all based upon exposures which were in the writers' opinion sufficiently large to represent the true structure of the rocks. Care in making such determinations was necessary, for except along the south line of secs. 7 and 8, T. 23 N., R. 88 W., and farther south near Buck Springs, all observations were taken in soft shale, which is inclined to slump or creep. Where no large exposures could be found shallow holes were dug and observations taken upon clean bedding planes. Most of the dip records shown on the map are supported by several readings taken at different points at the same locality.

The structure contours shown on the map are based upon altitude of the top of the Cloverly formation in wells on and near the Separation Flats anticline and upon dip observations where they could be obtained. In wells that did not reach the Cloverly formation but which penetrated the sandstones in the Frontier formation the altitude of the Cloverly was calculated, 1,170 feet being used as the stratigraphic interval between the tops of the two formations.

GEOGRAPHY

Location and accessibility.—The Bell Springs district lies in south-central Wyoming near the western edge of Carbon County. (See fig. 11.) It is 15 miles northwest of Rawlins, on the Union Pacific Railroad, its most accessible supply point, and 25 miles southeast of the Lost Soldier oil field. The main highway from Rawlins to the Lost Soldier district, Lander, and Casper crosses the area, and secondary roads lead from it to ranches and oil fields near the Ferris and Seminoe Mountains.

Topography and water supply.—The most prominent topographic features in the Bell Springs district are the series of ridges that rise about 800 feet above Separation Flats on the eastern or upthrown side of the Rawlins-Bell Springs fault, extending thence southeastward. (See pl. 23, *A*.) These ridges are formed by hard Paleozoic and early Mesozoic rocks which have withstood the agencies of erosion much better than the soft Mesozoic rocks that underlie Separation Flats on the western or downthrown side of the fault. As shown in the photographs, each ridge crest is formed by a hard sandstone, limestone, or conglomerate, and the softer beds crop out in the steep slopes.

Separation Flats present an expanse of alluvium and wind-blown sand which cover an eroded surface of soft Upper Cretaceous shale. This expanse is bordered on the west by an eastward-facing escarpment of the Mesaverde formation and on the south, except for the creek valley shown on the map, by low northward-facing bluffs less than 1 mile south of the Bairoil Road. Beyond these bluffs are low hills of shale on which are superimposed remnants of ancient gravel terraces.

Springs having a steady flow issue at numerous points in the bluffs east of Separation Flats and supply water for ranches and for drill-

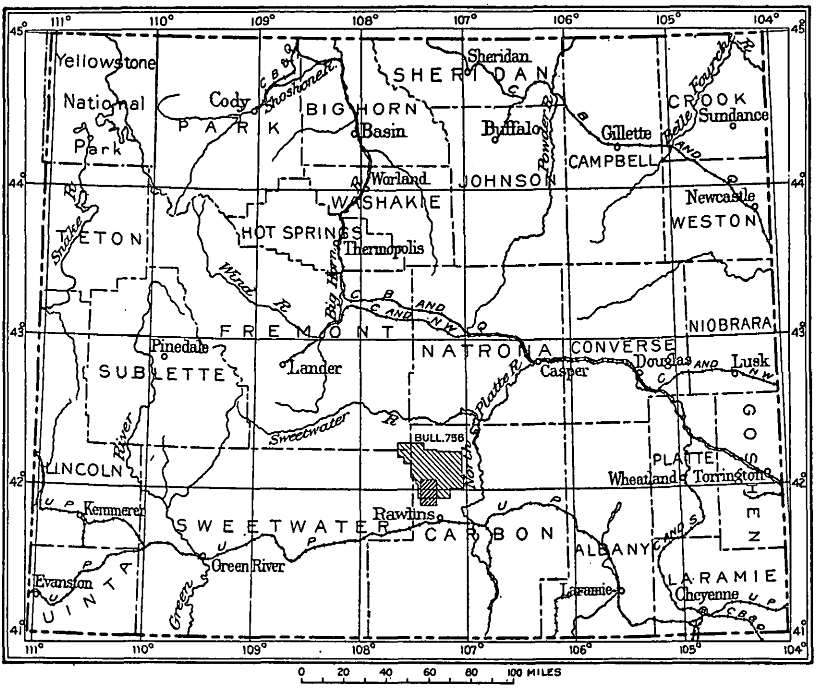


FIGURE 11.—Index map of Wyoming showing location of Bell Springs (heavy shading) and Lost Soldier-Ferris (light shading) districts

ing wells. The greater number of these occur near Bell Springs and serve as a boon to livestock as well as travelers across this dry region.

No perennial streams occur in the district, though pools of muddy water are usually present in the few channels that traverse the swales until they disappear in sand-covered areas.

STRATIGRAPHY

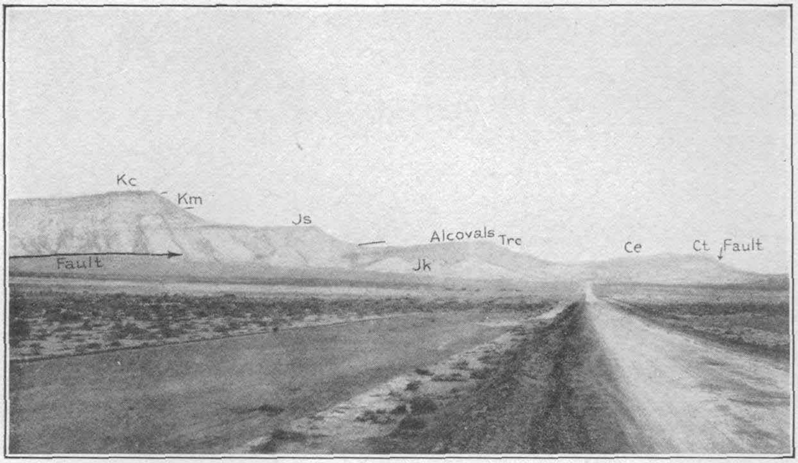
GENERAL SECTION

Rocks that range in age from pre-Cambrian to Middle Upper Cretaceous crop out in normal succession in the series of escarpments that border Separation Flats on the east and extend southward to Rawlins. In a single straight-line traverse extending northeastward from Bell Springs for about 4 miles the observer may examine in detail the rocks from the Tensleep sandstone to the Frontier formation, inclusive, and rocks older than the Tensleep sandstone may be studied from 3 to 10 miles south of Bell Springs. There is no evidence that the normal thickness of these rocks has been materially changed by abrupt upturning or compression along the Rawlins-Bell Springs fault, for the fault is a clean fracture which has permitted only regional eastward tilting of the upthrown block at comparatively gentle angles commonly between 8° and 12°.

Variations in the lithology and color of the rocks and the presence of massive resistant beds, which stand out in ridges several hundred feet high, are characteristic features that aid materially in a study and description of the geologic section.

Geologic formations in the Bell Springs district, Wyoming

Age	Formation	Character	Thickness (feet)
Quaternary.	Alluvium and dune sand.	Sandy clay and fine gravel derived from near-by Paleozoic and Mesozoic rocks; dune sand derived from Tertiary formations that crop out farther west.	+0-70
	Pleistocene (?) terrace gravel.	Angular to subangular pebbles and boulders from 1 inch to 4 feet across, consisting, in order of abundance, of granite, sandstone, basalt, limestone, and chert.	±0-50
Cretaceous.	Lewis shale.	Dark-gray shale with several thin yellowish-brown sandstones. Marine.	680
	Mesaverde formation.	An upper division consisting of thick beds of white and brown sandstone intercalated with beds of shale and coal. Teapot sandstone member at top is about 100 feet thick. A middle division of dark-gray shale and sandy shale containing beds of brown and gray sandstone. A lower division which resembles the upper division and contains at its base a prominent grayish-white sandstone 50 feet thick capped by an oyster-shell bed 3 feet thick.	1,800
	Steele shale. Niobrara shale. Carlile shale.	Soft gray to black shale, sandy shale, and thin slabby sandstone; gray limestone concretions and hard slabby, light-gray calcareous shale carrying *Ostrea congesta* and large thick-shelled *Inoceramus;* upper part of Steele shale transitional into the overlying Mesaverde formation. Formations inseparable in Bell Springs area.	±6,100
	Frontier formation.	Consists of four light-gray to brown resistant sandstones separated by black shale and sandy shale. Wall Creek sand of drillers at top.	774
	Mowry shale.	Hard and fissile black shale which weathers steel-gray and contains abundant fish scales.	122
	Thermopolis shale.	Soft dark-gray to black shale containing in its middle a thin-bedded brown sandstone 17 feet thick.	272
	Cloverly formation.	Conglomerate grading upward into quartzitic sandstone.	100

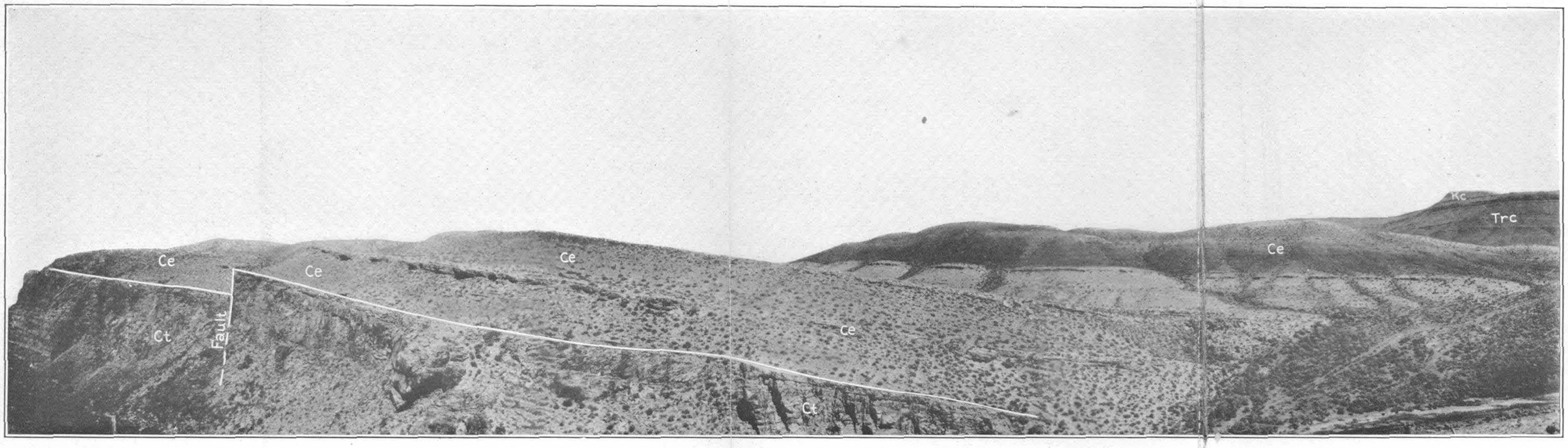


A. CONTRASTED TYPES OF TOPOGRAPHY ON OPPOSITE SIDES OF THE RAWLINS-BELL SPRINGS FAULT NEAR BELL SPRINGS, WYO.

Arrow shows position of fault, Separation Flats in foreground. Kc, Cloverly formation; Km, Morrison formation; Js, Sundance formation; Trc, Chugwater formation; Ce, Embar (?) formation; Ct, Tensleep sandstone; Jk, Sundance to Frontier formations, much disturbed

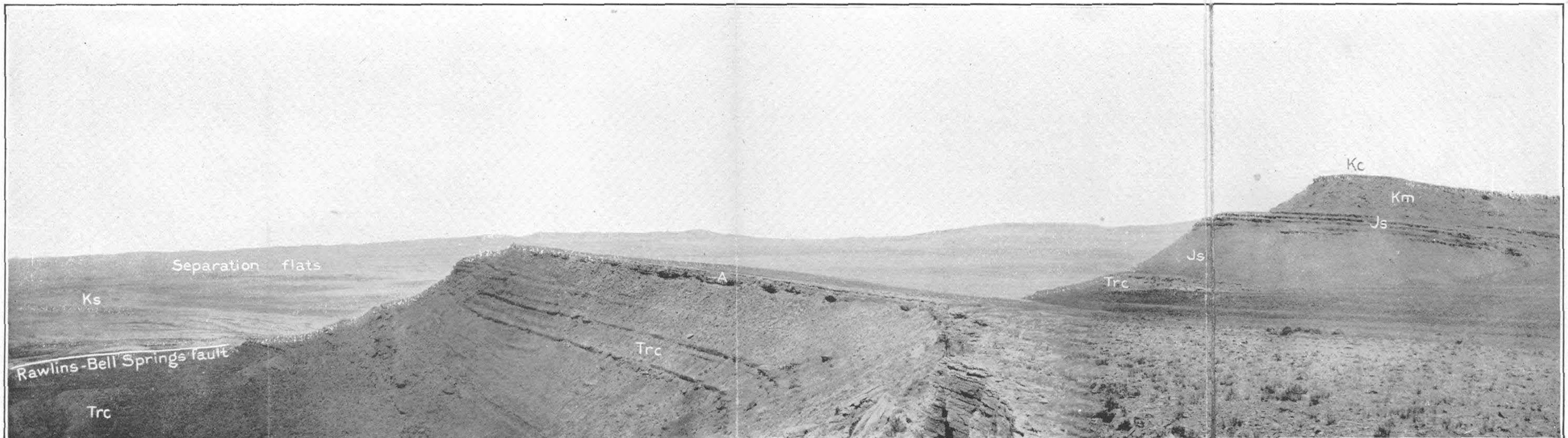
B. CAMBRIAN QUARTZITE ABOUT 1 MILE NORTH OF RAWLINS, WYO.

Quartzite is in foreground



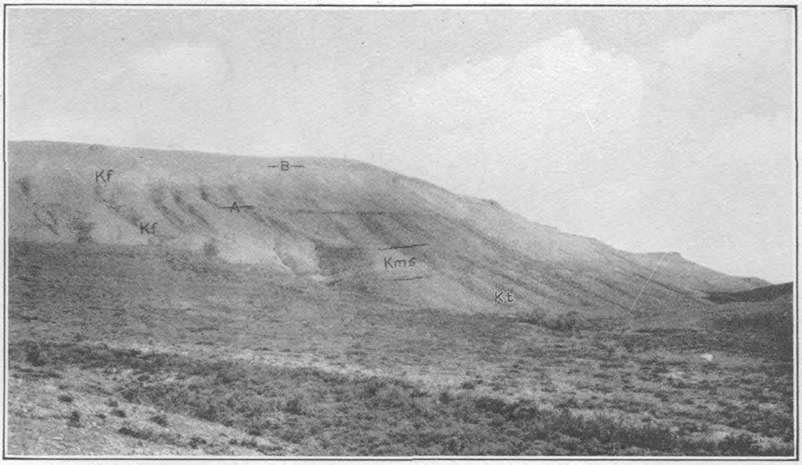
A. TENSLEEP SANDSTONE AND OVERLYING FORMATIONS AT BELL SPRINGS, WYO.

Ct, Tensleep sandstone; Ce, Embar (?) formation; Trc, Chugwater formation; Kc, Cloverly formation



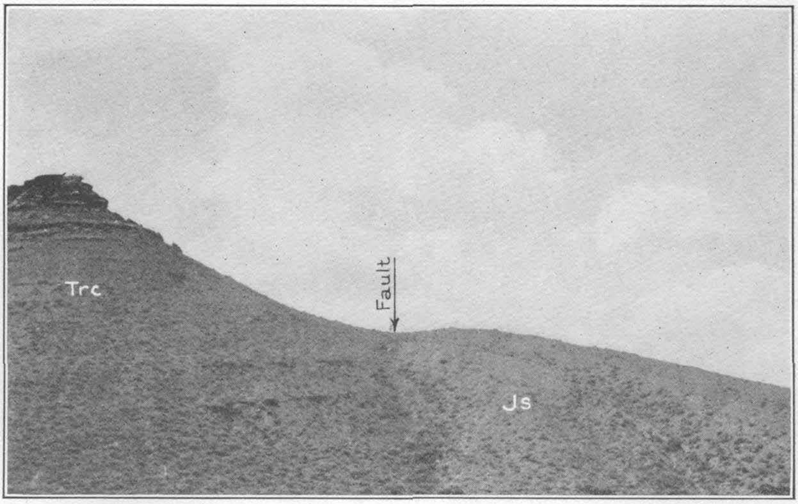
B. CHUGWATER AND OVERLYING FORMATION ABOUT 1 MILE NORTHEAST OF BELL SPRINGS, WYO.

View from top of Alcova limestone escarpment. Trc, Chugwater formation; A, Alcova limestone member; Js, Sundance formation; Km, Morrison formation; Kc, Cloverly formation



A. THERMOPOLIS, MOWRY, AND FRONTIER FORMATIONS IN SEC. 3, T. 23 N., R. 88 W., WYO.

Kf, Frontier formation, including sandstone (A) and sandy shale (B) (see section in text); Kms, Mowry shale; Kt, Thermopolis shale



B. RAWLINS-BELL SPRINGS FAULT IN THE SW. ¼ SEC. 9, T. 23 N., R. 88 W., WYO.

Looking southwest. Chugwater red beds (Trc) occupy the upthrown side, and Sundance sandstones (Js), dipping steeply away from the fault, occur on the downthrown side

Geologic formations in the Bell Springs district, Wyoming—Continued

Age	Formation	Character	Thickness (feet)
Cretaceous (?).	Morrison formation.	Green, purple, and red shale with several thin beds of greenish sandstone.	234
Jurassic.	Sundance formation.	Soft cream-colored to gray sandstone alternating with beds of green, gray, and red shale and sandy shale. Marine.	711
Triassic.	Chugwater formation.	Red shale, sandy shale, and sandstone containing Alcova limestone member near the top.	985
Permian.	Embar (?) formation.	Gray cherty limestone intercalated with gray, green, red, and purple shale and sandy shale and minor sandstones.	265
Pennsylvanian.	Tensleep sandstone.	Light-gray massive to cross-bedded quartzitic sandstone.	±300
	Amsden formation.	Fossiliferous gray limestone; gray quartzitic sandstone and red to gray sandy shale.	183
Mississippian.	Madison limestone.	Blue limestone intercalated with white sandstone, salmon-colored quartzite, and gray shale.	298
Age unknown. May be Mississippian, Devonian, Silurian, Ordovician, or Cambrian.	(?)	Reddish-brown shale and soft sandstone.	0–35
Cambrian.	Quartzite.	Quartzitic conglomerate grading upward into light-gray, brown, and purple, massive to thin-bedded quartzite.	412

CAMBRIAN ROCKS

The Cambrian period is represented in the Rawlins uplift by gray, brown, and purple quartzite, which is coarsely conglomeratic at the base. The quartzite is unusually well bedded, and its outcrop of alternating hard and soft strata presents a striking appearance. (See pl. 23, *B*.) The pebbles in the basal portion are generally well rounded and consist of quartz and red feldspar. The abundance of the red feldspar, which, together with the associated quartz, was derived by erosion from the underlying granite, is characteristic of the lower part of the unit.

In places the Cambrian quartzite is overlain by 35 feet of reddish-brown shale and soft sandstone which may be of Cambrian, Ordovician, Silurian, Devonian, or Mississippian age. These red beds are well exposed about 1½ miles northeast of Rawlins on the Rawlins-Casper highway, where they have been mined for use in paint. Farther north, near Buck Springs, no red beds separate the quartzite from the overlying Madison limestone.

Section of Cambrian quartzite about 5 miles northwest of Rawlins

	Feet
Madison limestone.	
Quartzite, gray and purple, hard, cross-bedded, alternately massive and thin bedded, medium to coarse grained. Some beds 2 to 4 feet thick are not quartzitic	112
Quartzite, light gray, very hard; gritty and finely conglomeratic throughout, especially in lower 100 feet. Fresh surface is white and shows scattered grains of partly oxidized ferromagnesian minerals and completely silicified red feldspar. Alternately massive and thin bedded, cross-bedded throughout	265
Quartzite, weathers brown and light gray; conglomeratic; contains rounded pebbles of quartz and red feldspar 2 inches or more in diameter. Red feldspar constitutes 20 per cent or more of some beds, which are thin and exhibit cross-bedding	35
Granite.	412

MISSISSIPPIAN ROCKS

Madison limestone.—The Madison limestone was examined near the southwest corner of sec. 28, T. 23 N., R. 88 W., where it is underlain by Cambrian quartzite and is faulted against Cretaceous shale, probably belonging to the Niobrara formation. The formation consists almost entirely of hard, well-bedded blue and bluish-gray limestone but includes also a bed of hard white sandstone 6 feet thick, a bed of pink or salmon-colored quartzite 22 feet thick, and probably some thin beds of shale. The limestone beds are characteristically cherty and would be difficult to penetrate in wells. The formation is 298 feet thick.

Fossils collected by W. T. Lee at the top of the Madison limestone in this area have been identified by G. H. Girty, who considers them indicative of lower Mississippian age.

Section of Madison limestone near the southwest corner of sec. 28, T. 23 N., R. 88 W.

	Feet
Amsden formation.	
Limestone, blue, hard, well bedded, very cherty	52
Concealed, probably occupied by thin beds of limestone and shale	54
Sandstone, white, hard, fine grained	6
Concealed, probably thin beds of shale and limestone	11
Quartzite, salmon colored, weathers reddish brown, well bedded, slabby in places	22
Concealed, but probably blue limestone	22
Limestone, bluish gray, pink at top, cherty, hard, fairly well bedded	35
Largely concealed by talus; several ledges 1 to 10 feet thick are hard blue limestone	96
Cambrian quartzite.	298

PENNSYLVANIAN ROCKS

Amsden formation.—The Amsden formation consists for the most part of red shale but also contains beds of sandstone and sandy limestone at its top. The formation is 183 feet thick in the SW. ¼ sec. 28, T. 23 N., R. 80 W., and contains diagnostic early Pennsylvanian fossils in its upper part.

Section of Amsden formation in the SW. ¼ sec. 28, T. 23 N., R. 80 W.

	Feet
Tensleep sandstone.	
Limestone, gray, very sandy, jointed, fossiliferous	12
Sandstone, gray, quartzitic	10
Concealed; shows patches of red shale in grass-covered slopes, becoming gray toward top	70
Shale, red, probably containing thin sandstones	91
Madison limestone.	
	183

Tensleep sandstone.—The Tensleep sandstone is, with the possible exception of the Cloverly formation, the most massive formation in the Bell Springs section. It is about 300 feet thick and consists of light-gray quartzitic sandstone, much of the lower part of which is extensively cross-bedded. Its upper 260 feet was measured in the vertical cliff just west of Bell Springs. (See pl. 24, *A*.) Its basal portion, about 40 feet thick, was measured in the southwest corner of sec. 28, T. 23 N., R. 88 W.

Section of Tensleep sandstone at Bell Springs

	Feet
Embar formation.	
Sandstone, light gray, hard, quartzitic, fine grained, well bedded	40
Sandstone, light gray, fine grained, quartzitic; cross-bedded in lower portions but becomes very massive upward	260
Amsden formation.	
	300

PERMIAN ROCKS

Embar (?) formation.—The rocks herein called Embar (?) formation include beds of limestone, green and red shale, and gray sandstone, which overlie the massive Tensleep sandstone and underlie the Chugwater red beds. Some of the limestones are cherty, but most of them, unlike the underlying Madison limestone, contain little or no chert. One bed of limestone 8 feet thick, about 60 feet above the base of the formation, has an unusually strong odor of petroleum when freshly broken. The top of the formation has been placed at the top of the lavender-colored limestone which occurs beneath the typical red beds referred to the Chugwater. This limestone is being quarried extensively for road-surfacing material at Bell Springs.

No fossils, so far as known, have been obtained from the Embar (?) formation near Bell Springs. It is undetermined whether the formation at this place includes equivalents of both the Phosphoria and the Dinwoody formations or only of the Phosphoria.

Section of Embar (?) formation at Bell Springs

[See pl. 24, *A*]

	Feet
Chugwater formation.	
Limestone, light gray in lower part and lavender in upper part	15
Shale, red	18
Limestone, cherty, intercalated with red and purple shale	10
Shale, sandy shale, and soft sandstone, olive-colored	51
Limestone, dark gray, slabby, cherty; weathers light gray	13
Shale, sandy shale, and soft sandstone, olive-colored	51
Limestone, gray, massive to slabby, and light greenish-gray sandy shale	11
Limestone, blue; gives strong odor of petroleum when freshly broken	8
Sandstone, thin bedded, quartzitic, alternating with gray shale	30
Limestone, gray, very cherty	12
Shale, gray	2
Limestone, blue	2
Limestone, sandstone, and shale forming dip slope	15
Tensleep sandstone.	
	265

TRIASSIC RED BEDS

Chugwater formation.—The Chugwater formation is about 1,000 feet thick at Bell Springs, and with two exceptions is made up of red shale, sandy shale, and sandstone. The most prominent exception, one which is in striking contrast to the general lithology of the formation, is the bed of dark bluish-gray limestone, 12 feet thick, which occurs about 75 feet below the top of the formation. This limestone, which is very resistant and caps a prominent escarpment (see pl. 24, *B*), has a peculiar wavy lamination, and in places gives a strong odor of petroleum when freshly broken. At 14 feet above this limestone is a cream-colored sandstone 3 feet thick. This sandstone is the only one in the formation which is not red.

The limestone bed described above has been correlated by Lee [4] with a limestone which occupies a similar stratigraphic position near Alcova and in other parts of south-central Wyoming and which he has named the Alcova limestone member of the Chugwater forma-

[4] Lee, W. T., Correlation of geologic formations between east-central Colorado, central Wyoming, and southern Montana: U. S. Geol. Survey Prof. Paper 149, p. 14, 1927.

tion. The limestone is marine, for Lee has collected *Natica lelia?* and *Naiadites?* sp. from it at Bell Springs and has reported other marine forms from it in the Owl Creek Mountains.

Section of Chugwater formation measured at Bell Springs

	Feet
Sundance formation.	
Sandstone, red, massive to slabby, cross-bedded, and red shale	57
Sandstone, cream colored, soft, fine grained	3
Shale, red	14
Limestone (Alcova), dark bluish gray; shows very irregular lamination and has strong petroliferous odor; forms prominent escarpment and dip slope	12
Sandstone and shale, red, alternating	34
Sandstone, dark brick-red, massive	34
Shale, red	2
Sandstone, red	2
Shale, red	13
Sandstone, dark brick-red, fine graineed, micaceous	4
Shale and sandy shale, brick red	60
Sandstone, brick-red, slabby, cross-bedded	17
Shale, red	10
Sandstone, red	2
Shale, red	110
Sandstone, red, slabby, well bedded, micaceous	32
Shale, red, and sandy shale	62
Sandstone, red, slabby, very micaceous; forms prominent bench	17
Shale, red, containing very few thin red sandstones and beds of limestone 1 inch thick	500
Embar (?) formation.	
	985

JURASSIC ROCKS

Sundance formation.—A prominent group of cream-colored, gray, and green sandstones, with some green and gray shale in its upper part and a 5-foot bed of fossiliferous dark-gray limestone at its top, makes up the upper part of the Sundance formation near Bell Springs. Approximately the lower two-fifths of the formation is red shale which has a bed of fine grayish-white sandstone 62 feet thick at its base.

As shown in Plate 24, *B*, the sandstone in the middle part of the Sundance formation makes cliffs at the top of an escarpment 400 feet high. Hard and soft beds alternate within the sandstones, and most of them are fine grained and show considerable cross-bedding.

At the base of the Sundance escarpment shown in Plate 24, *B*, occurs a bed of grayish-white sandstone 62 feet thick, the basal member of the formation, which underlies a succession of red shale and shaly sandstone 221 feet thick. Both the red shale and the basal sandstone, according to Reeside and Lee,[5] are widespread over much of Wyoming. The basal sandstone has yielded marine fossils at several localities in central Wyoming and is believed to be correlative with a part of the Nugget sandstone of southwestern Wyoming.

Green shale in the upper part of the formation is separated from similar shale in the overlying Morrison formation by at least two dark-gray limestones that contain marine fossils, mostly *Camptonectes* sp.

Section of Sundance formation 1½ miles north of Bell Springs

	Feet
Morrison formation.	
Limestone, dark gray, sandy in part and very fossiliferous; *Camptonectes* sp. is most abundant fossil	5
Sandstone, green, soft	6
Limestone, gray, dense, very fossiliferous	1
Sandstone, green, soft	5
Shale, green and gray	80
Sandstone, grayish cream-colored, soft, and gray shale; upper part cross-bedded, fine grained, and makes a poorly defined ledge	35
Sandstone, light yellow or cream-colored, very soft, alternating with similar but harder sandstone ledges	80
Sandstone, gray, soft, and greenish sandy shale	12
Sandstone, gray, hard	4
Sandy shale, green, and several thin beds of fine-grained grayish sandstone	19
Sandstone, reddish, green and gray, cross-bedded, mud cracked, and thin bedded, with some intercalated sandy shale	78
Sandstone, greenish gray, jointed, well bedded	15
Sandy shale, green	3
Sandstone, gray, quartzitic	11
Sandy shale, red	12
Sandstone, light gray, very fine grained, well bedded, ripple marked	62
Shale, red, and soft red fine shaly sandstones	221
Sandstone, grayish white, soft, poorly cemented, fine grained, cross-bedded, massive to poorly bedded	62
Chugwater formation.	
	711

CRETACEOUS (?) ROCKS

Morrison formation.—The Morrison formation at Bell Springs is 234 feet thick and consists largely of shale and sandy shale with two thin sandstones at its base and several others intercalated throughout. The predominant color of the formation is green, al-

[5] Oral communication.

though gray, brown, and red beds occur in its upper portion. Many of the details of the Morrison section are concealed by débris from the overlying Cloverly formation.

Section of Morrison formation 1½ miles north of Bell Springs

	Feet
Cloverly formation.	
Shale, green, with lenses of hard green sandstone and some red shale; gray and light-brown shale in upper part and a 15-foot bed of light-green sandstone near the middle; forms steep slope below conglomerate at base of Cloverly formation	215
Sandstone, green, hard, fine, well jointed	3
Sandstone and sandy shale, green, soft	16
Sundance formation.	
	234

CRETACEOUS ROCKS

Cloverly formation.—The Cloverly formation, where examined along the crest of the high escarpment about 1½ miles northeast of Bell Springs, consists of a hard, quartzitic, unusually massive conglomerate 75 feet thick which grades upward into hard, clean, but more thinly bedded sandstone about 25 feet thick. The conglomerate is the only part of the formation that is easily measurable on the outcrop; the upper sandstone crops out on a dip slope back of the conglomerate escarpment, and, because of the character of the erosion to which it has been subjected its base and top are not sharply defined. No shale interval was found within the formation, although such an interval exists locally in this area, for it is recorded in two of the three well logs shown on Plate 26, and at a near-by locality a 10-foot bed of shale separates the conglomerate from the upper sandstone of the formation.[6] Pebbles and boulders in the conglomerate attain a maximum size of 4 inches or more and are, as a rule, well rounded. The sandstone beds and matrix are strikingly free from clayey material, and mineral grains other than quartz and feldspar are rare.

It seems likely that the basal conglomerate of the Cloverly was deposited unconformably on the Morrison formation and that it thickens and thins throughout the region at the expense of the Morrison. The Producers & Refiners well in sec. 1, T. 23 N., R. 89 W., penetrated 175 feet of sandstone referable to the Cloverly formation, a thickening of 75 per cent over the section measured near by, and only 17 feet of shale separated the sandstone from an underlying limestone that may represent the top of the Sundance formation.

Thermopolis shale.—The Thermopolis shale in the Bell Springs area consists of two divisions of black shale, each about 125

[6] Lee, W. T., oral communication.

feet thick, separated by a zone of soft thin-bedded ridge-forming sandstone and sandy shale about 17 feet thick. The lower shale division contains an abundance of gray to brown ironstone concretions, which are commonly recorded as "shells" in well logs of this district. The middle sandy zone and the black shale below it were included in the Cloverly formation by Fath and Moulton.[7]

Mowry shale.—Here, as elsewhere in this general region, the Mowry shale consists of moderately hard grayish-black fissile shale which weathers to a steel-gray color and contains great numbers of fossil fish scales. In this particular area the Mowry shale crops out at the base of a prominent escarpment of the Frontier formation rather than in a pine-clad ridge, as usual. (See pl. 25, *A*.)

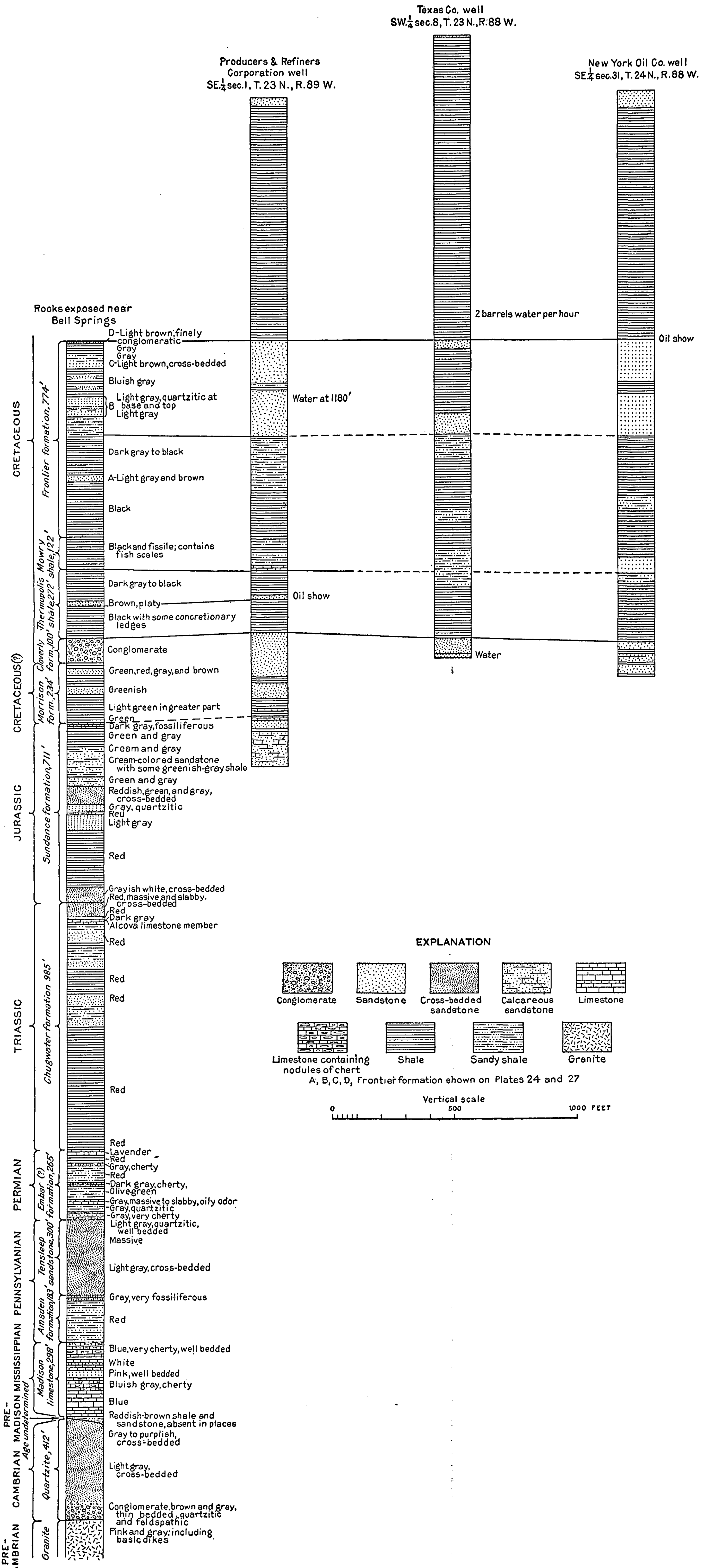
Section of Mowry and Thermopolis shales and Cloverly formation 2 miles northeast of Bell Springs

	Feet
Frontier formation.	
Mowry shale: Shale, black, hard, platy; contains fossil fish scales	122
Thermopolis shale:	
Shale, dark gray to black, soft	125
Sandstone, brown, platy and papery, and intercalated sandy shale; makes a low but distinct ridge	17
Shale, black, soft, with numerous thin beds of hard dark-gray and reddish-brown ironstone	130
Cloverly formation:	
Sandstone, light gray, quartzitic	25
Conglomerate; contains rounded pebbles of quartz and basic igneous rocks	75
Morrison formation.	
	494

Frontier formation.—The Frontier formation is 774 feet thick in the bluffs about 3 miles northeast of Bell Springs and consists of four sandstones, or groups of sandstones, intercalated with thicker beds of gray to black shale and sandy shale. The three uppermost sandstones lie in the upper two-fifths of the formation and make the cap rocks on prominent escarpments and dip slopes; the lowest one occurs in the middle of a shale series 450 feet thick which crops out in the face of an escarpment. The lower part of the formation, therefore, is predominantly dark gray to black shale, and its upper part gray and light-brown sandstone and sandy shale.

The uppermost sandstone of the Frontier formation is called the Wall Creek sand by the drillers and is the highest sand from which commercial quantities of oil or gas may be obtained in the Bell Springs district. In the Lost Soldier dome the Frontier sand-

[7] Fath, A. E., and Moulton, G. F., Oil and gas fields of the Lost Soldier-Ferris district, Wyo.: U. S. Geol. Survey Bull. 756, pp. 17–18, 1924.



COLUMNAR SECTION OF ROCKS EXPOSED IN THE RAWLINS UPLIFT NEAR BELL SPRINGS, WYO., AND LOGS OF WELLS DRILLED ON SEPARATION FLATS stones contain oil in paying quantities, and in the Mahoney and O'Brien Springs fields they have yielded initial flows of gas ranging from 1,000,000 to 7,000,000 cubic feet a day. Several wells drilled upon and near the Separation Flats anticline have encountered good shows of oil or gas, or both in the sandstones of the Frontier formation.

Section of Frontier formation 3 miles northeast of Bell Springs

	Feet
Carlile shale.	
Sandstone, brown, coarse, and slightly conglomeratic; forms a ridge (bed D)	10
Shale, gray, sandy	42
Sandstone, dark gray, hard, medium grained	1
Shale, gray, sandy	4
Sandstone, light gray, hard, fine grained	1
Sandstone and sandy shale, gray, soft	13
Sandstone, light brown, fine grained, well bedded, concretionary at top, cross-bedded in part (bed C)	40
Shale, bluish gray, containing lenses of concretionary sandstone; sandy in upper portion	110
Sandstone, light gray, fine to coarse grained, quartzitic at top and bottom; forms top of prominent escarpment	40
Shale, gray, sandy	1
Sandstone, light gray, quartzitic	1
Sandy shale, dark gray; weathers blue (bed B)	10
Sandstone, light gray, massive, quartzitic in greater part; with thin beds of black shale near middle	22
Sandstone, light gray, quartzitic; and soft gray shale intercalated in thin layers	4
Shale, gray, sandy	6
Shale, grayish black, sandy, soft	220
Sandstone and sandy shale, greenish brown, soft, concretionary	14
Sandstone, light gray, jointed, fine grained, cross-bedded in part; outcrop forms distinct bench in bluff (bed A)	11
Shale, black, soft	224
Mowry shale.	
	774

Carlile, Niobrara, and Steele shales.—In the Bell Springs area the Carlile, Niobrara, and Steele shales can not be readily separated because of lack of exposures, scarcity of diagnostic fossils, and similarity in lithology. Their combined thickness is about 6,100 feet. South of the point where the main Casper-Rawlins highway crosses the Bell Springs fault black shale containing in places numerous dark-gray limestone concretions is underlain by hard platy gray shale which contains *Ostrea congesta* in abundance. Several other exposures of shale containing *Ostrea congesta* were observed along the Bell Springs fault northeast of the Casper-Rawlins highway, but as this fossil, long supposed to be confined to the Niobrara shale, is now known to occur also in the Steele and Carlile shales it is not considered wise to differentiate these formations without the evidence of more strictly diagnostic fossils. The shale that crops out in the low northward-facing bluffs near the south line of secs. 7 and 8, T. 23 N., R. 88 W., contains several beds of brown limestone from 2 to 6 inches thick, which have been arbitrarily adopted by some as the top of the Niobrara shale.

Erosion of the soft Carlile, Niobrara, and Steele shales has produced the broad alluvium-covered valley which extends from a point south of Buck Springs northward and northwestward to the Lost Soldier-Ferris and other districts. The south end of this valley, in the drainage basin of Separation Creek, is known as Separation Flats.

Scattered exposures of shale and thin, slabby, nonpersistent sandstones occur in the Steele shale in Separation Flats. In its upper 1,500 feet the Steele shale becomes sandy and contains several brown sandstones, one of which is about 30 feet thick and makes a prominent ridge paralleling the higher ones in the Mesaverde formation.

Mesaverde formation.—The Mesaverde formation crops out in the eastward-facing bluffs west of Separation Flats and is characteristically separable into three divisions—a lower and an upper division of sandstone and a middle division of shale. Either brackish-water or fresh-water fossils occur throughout the formation in this area.

The base of the Mesaverde formation was drawn at the base of a grayish-white massive sandstone about 50 feet thick, which has at its top an oyster-shell bed about 3 feet thick. Above the oyster bed are massive beds of brown and gray sandstone alternating with more abundant but thinner and less massive beds of sandstone and sandy shale.

The middle division of the Mesaverde formation is made up of a group of comparatively soft dark-gray shales and sandy shales which crop out in a pronounced strike valley. Thin beds of brown and gray sandstone are intercalated with the shale, and coal occurs near its base.

The upper sandstone division is much like the lower division in general appearance, except that the white sandstones are commonly more abundant. Coal beds occur near the top and base of this division. The Teapot sandstone member at the top is about 100 feet thick.

Lewis shale.—According to Fath and Moulton[8] the Lewis shale in this general region is 680 feet thick and consists principally of

[8] Op. cit., p. 10.

dark-gray thinly laminated shale containing several beds of yellowish-brown sandstone of variable thickness. The formation is marine and crops out in areas of subdued relief between hogbacks of the Mesaverde and Lance formations.

PLEISTOCENE (?) TERRACE GRAVEL

Remnants of once extensive gravel and boulder deposits occur at two distinct levels west of the Bell Springs fault in this area and represent two different stages of valley filling. Both of these aggraded surfaces slope westward from the fault toward the present valley at an angle of about 1°. The lower level, represented by Qt_2 on the map, slopes at a slightly steeper angle than the higher one, Qt_1, for eastward toward the fault scarp these surfaces merge into one, whereas near the middle of the valley Qt_2 is about 70 feet below Qt_1. The extension of the Qt_2 surface in sec. 17, T. 23 N., R. 22 W., is 125 feet above the level of the present valley floor, but in the southwest corner of sec. 6 this interval is reduced to about 20 feet.

The individual pebbles and boulders of this deposit range in diameter from less than 1 inch to at least 4 feet. Their shapes commonly range from angular in the smallest ones to subangular in the largest. The largest boulders are commonly light-gray granite, and the smallest ones platy limestone and flint derived from the Madison and Embar (?) formations.

ALLUVIUM AND DUNE SAND

Deposits of alluvium and wind-blown sand occur extensively in the low featureless valley traversed by Separation Creek in this and neighboring areas. The alluvium is generally a sandy clay eroded from the Paleozoic and Mesozoic formations near by; the dune sand is probably derived from the softer Tertiary formations that crop out a few miles farther west. Characteristic sand-dune topography occurs in the central part of T. 24 N., R. 88 W., as well as over much broader areas to the north and northeast.

COMPARISON OF THE SURFACE AND SUBSURFACE SECTIONS AT BELL SPRINGS

Strata that form striking topographic features in the surface section at Bell Springs are, as a rule, readily recognized in records of deep wells drilled in this district. This is illustrated by the graphic logs of three wells, all within a radius of 10 miles from Bell Springs, shown on Plate 26 opposite the measured surface section which has already been described. Although it is probable that none of the wells are so located that the drill holes are at right angles to the bedding planes of the rocks, it is practically certain that in none does the dip of the rocks penetrated exceed 10°, an angle which does not cause material divergence between the true and recorded thicknesses.

The interval between the top of the Frontier formation, marked by the Wall Creek sand of the drillers, and the top of the Cloverly formation in the surface section is 1,165 feet. In the New York Oil Co.'s well in sec. 21, T. 24 N., R. 88 W., the interval is 1,190 feet; in the Texas Co.'s well in sec. 8, T. 23 N., R. 88 W., 2 miles farther south, it is 1,170 feet; and in the Producers & Refiners Corporation well in sec. 1, T. 23 N., R. 89 W., it is 1,150 feet.

Although the measurements given above were made in an area whose diameter is only about 5 miles, they show that on the crest of the Separation Creek anticline the interval between the top of the Frontier formation and the top of the Cloverly formation, an important interval for every operator in the district, can be confidently expected to be between 1,150 and 1,200 feet. Wells located farther from the axis of the anticline, especially to the west, where the dip of the rocks becomes progressively steeper, would find this interval to be greater in proportion to the degree of dip.

The thickness of the upper part of the Frontier formation, as identified by the drillers, is the same in the three graphic well logs shown on Plate 26. The base of the sandstones in the upper part of the formation as recorded in the logs does not, however, correspond in position with the one in the surface section. This discrepancy is due either to poor exposures below these sandstones in the surface section or to lack of differentiation between sandstone and sandy shale by the drillers.

The Mowry shale, which is black and hard in the surface section, was recorded at the proper depth in two of the wells as either "lime" or "hard gray sandstone" and in the Texas Co.'s well as "light sandy shale." The record of the beds between the Mowry shale and the top of the Cloverly formation in the log of the Producers & Refiners Corporation well is nearly identical with the surface section.

The Thermopolis shale, consisting of soft black shale and hard concretionary beds, was recorded in two of the logs as "shells" and in the third as "dark shale containing a bed of very hard gray lime 15 feet thick." The so-called Muddy sand, occurring near the middle of the Thermopolis shale and consisting of soft, slabby sandstone and shaly sandstone, was recorded in only one well, that of the Producers & Refiners Corporation, where it contained a show of oil.

In the high escarpment northeast of Bell Springs the Cloverly formation consists of a basal conglomerate 75 feet thick overlain by a quartzitic sandstone 25 feet thick. Near this locality Lee[9] found 10 feet of shale separating the conglomerate from the uppermost sandstone.

COMPARISON OF THE FRONTIER-CLOVERLY INTERVAL IN THE BELL SPRINGS AND LOST SOLDIER-FERRIS DISTRICTS

On the Mahoney dome the No. 1 well of the Kasoming Oil Co., in the NE. ¼ sec. 34, T. 26 N., R. 88 W., penetrated 1,330 feet of strata between the top of the Frontier formation and the top of a thin sandstone believed to be at the top of the Cloverly formation. The corresponding interval was 1,346 feet in a well drilled by the Producers & Refiners Corporation on the Ferris dome, 8 miles east of the Mahoney dome, in sec. 25, T. 26 N., R. 87 W. On the Wertz dome, 10 miles northwest of the Mahoney dome, a well drilled by the Producers & Refiners Corporation in sec. 7, T. 26 N., R. 89 W., found what is believed to be the top of the Cloverly formation 1,260 feet below the top of the Frontier formation.

The interval between the top of the Frontier formation and the top of the Cloverly formation appears, therefore, to be from 100 to 200 feet thicker in the Lost Soldier-Ferris district than in the Bell Springs district, about 20 miles farther south.

STRUCTURE

PRINCIPAL FEATURES

The dominant structural features of the Bell Springs district consist of the elevated block of the Rawlins uplift, the less elevated and slightly domed crustal segment underlying Separation Flats, and the profound Rawlins-Bell Springs fault, which separates the two crustal blocks referred to.

The Rawlins uplift is the highest part of the structural rim of which the Lost Soldier dome is a part. It separates the Great Divide Basin on the west from the Hanna Basin on the east. (See fig. 12.) East of the town of Rawlins the uplift trends about due west; near Rawlins, however, it swings abruptly and trends in a northerly direction to a point about 10 miles northeast of Bell Springs, where it blends with folds that are more properly related to the Ferris and Seminoe uplifts. Distortion of the uplifted block has been the greatest near the abrupt bend, from 2 to 8 miles northwest of Rawlins, and decreases more or less regularly thence to the northeast. The uplift is bounded on the south, west, and northwest by the Rawlins-Bell Springs fault, which marks, in a general way, the line of maximum uplift from a point 4 miles east of Rawlins west and north to Bell

[9] Oral communication.

Springs, where it swings to the northeast, parallel to the Separation Flats anticline. The southwest end and structurally high point of this anticline is opposite the northeastward bend in the fault.

The geologic map and structure section (pl. 27) clearly show the distribution of the geologic formations on opposite sides of the

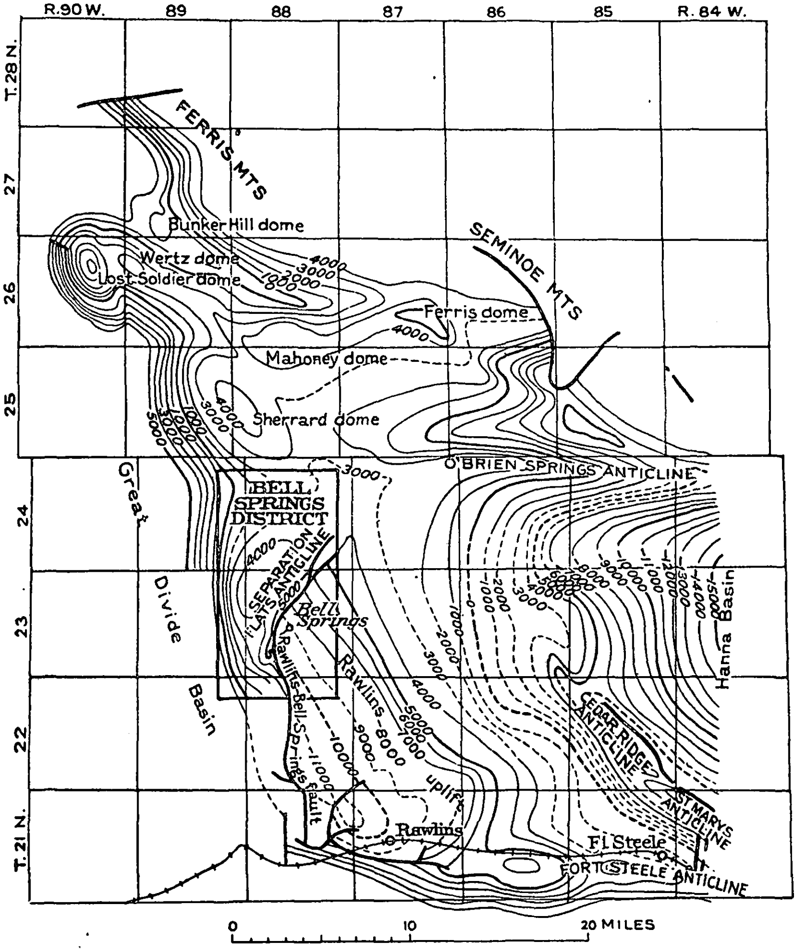


FIGURE 12.—Sketch map of the Bell Springs and adjacent districts, Wyoming, showing the position of the top of the Cloverly formation with respect to sea level. From compilation by W. T. Thom, jr.

Rawlins-Bell Springs fault in the vicinity of Bell Springs. In the southern part of the area shown by Plate 27, Cambrian quartzite, exposed at the base of a high escarpment east of the fault, is faulted against Upper Cretaceous shale, probably belonging to the Niobrara formation, which crops out along the eastern edge of a broad valley largely occupied by alluvial and gravel deposits. Farther south, toward Rawlins, pre-Cambrian granite is exposed east of the fault in contact with Upper Cretaceous rocks, which are largely concealed by terrace gravel.

Displacement along the Rawlins-Bell Springs fault becomes progressively less northward and northeastward; at Bell Springs massive Tensleep (Pennsylvanian) sandstone abuts against Niobrara shale, here concealed by gravel and alluvium; 1 mile farther north, Chugwater (Triassic) red beds east of the fault are in contact with Sundance (Jurassic) sandstones which, together with still younger beds, have been dragged up sharply along the fault; where last observed, about 3 miles northeast of Bell Springs, the fault has developed several branches, the main branch swinging to the west and separating much distorted Niobrara shale on the northwest from beds of the Frontier formation; branch faults that swing to the east have produced stratigraphic displacements of several hundred feet in the Frontier beds.

RELATION OF THE RAWLINS-BELL SPRINGS FAULT TO THE RAWLINS UPLIFT

The Rawlins-Bell Springs fault is a steeply dipping fracture, the plane of which is not far from vertical. The fault plane was not observed at any place, but the eroded contact of the faulted beds affords a suggestion of the angle of the fault plane near the southwest corner of sec. 9, T. 23 N., R. 88 W., 1 mile north of Bell Springs. (See pl. 25, *B*.)

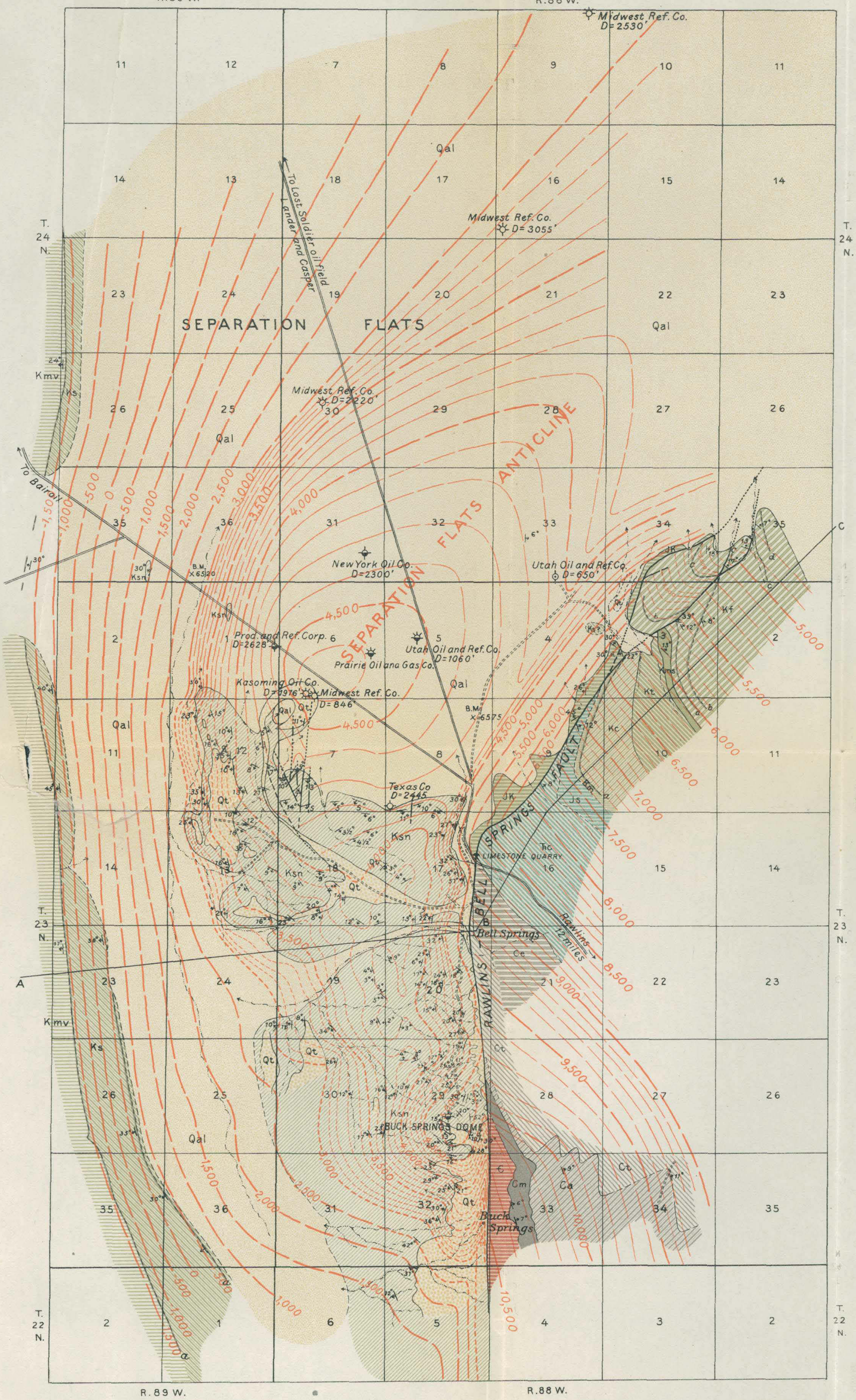
From a point east of Rawlins westward and northward to Bell Springs the fault follows the axis of major elevation of the Rawlins uplift. The writers will not attempt here to account for the primary origin and nature of the stresses that have produced this uplift, but the conclusion that it has resulted directly from fracturing of the deep-seated granite basement, one block of which has moved upward and is now exposed at the surface, seems inevitable. In fact, it seems altogether probable that the structure as shown in the structure section on Plate 27 has resulted from compound fracturing, which has developed at least two parallel north-south faults, the western one of which, having a relatively smaller displacement, is concealed under the alluvium-covered valley near the steep western flank of the uplift, and, like the exposed fault on the east, has its downthrown block on the west. Eight miles south of Bell Springs the block between these faults is narrower and instead of being elevated relative to the western block, as at Bell Springs, has been dropped, for here a notable graben exists between a steep western wall of Cambrian quartzite and a similar eastern wall of granite.

It is assumed that the displacement along these faults was gradual. Early movements probably resulted in gentle folding of the overlying sedimentary beds high in the stratigraphic column in accommodating themselves to the attitude of the lower beds, which were tilted, stretched, and compressed by displacement of the underlying granite blocks. As block movements increased in magnitude the faults extended higher into the overlying strata, ultimately producing a stratigraphic displacement in Upper Cretaceous rocks of at least 5,000 feet. What appears to be the broken remnant of a comparatively small dome superimposed upon the major prefault fold of the Rawlins uplift occurs in the southern part of the area, near Buck Springs. Here the eastern portion of a dome occurring in Paleozoic rocks east of the fault lies somewhat south of a similar but sharper and more complete dome in Upper Cretaceous rocks west of the fault. If these are parts of a dome which existed before faulting took place, as seems probable, they afford evidence that movement along the Rawlins-Bell Springs fault was not altogether parallel to the dip of the fault plane but consisted in part of relatively southward movement of the eastern or upthrown block.

The fact that the Separation Flats anticline parallels the northeast end of the Rawlins-Bell Springs fault suggests that genetically they are very closely related—that they have been formed at about the same time by the same stresses or stresses acting in parallel directions, or that they have originated at different times and that the trend of the younger structural feature paralleled that of the older one because of a predetermined direction of deformation.

There appears to be no evidence from the attitude of the rocks north of Bell Springs and southeast of the Rawlins-Bell Springs fault that the Separation Flats anticline existed prior to the major faulting. Instead of being so flexed as to suggest a prefault fold, these rocks strike at right angles to those which now occupy the southeastern limb of the anticline and conform to the attitude of rocks 2 or 3 miles farther south that were probably folded before being faulted.

It seems logical to assume that a fold shaped like the Separation Flats anticline and similarly located would have resulted from extensive displacement along the abruptly curving Rawlins-Bell Springs fault, providing that fault movement was accompanied by squeezing of the north ends of the two fault blocks by pressure exerted from the southeast. A fold, then, having the position of the Separation Flats anticline could have been formed by direct transmission of stresses to the downthrown block by pressure from the southeast; the most pronounced folding, under these conditions, would have been produced at a place due northwest of the curve in the fault near Bell Springs, for it is at this curve that transmitted stresses from the southeast would be concentrated.



EXPLANATION

SEDIMENTARY ROCKS

QUATERNARY
- *Recent* — Qal: Alluvium and dune sand
- *Pleistocene?* — Qt: Terrace gravel

CRETACEOUS

Upper Cretaceous
- Kmv: Mesaverde formation with sandstone ledge (a)
- Ks: Steele shale with sandstone ledge (a)
- Ksn: Steele, Niobrara, and Carlile shales
- Kf: Frontier formation with sandstone ledges (a to d)
- Kms: Mowry shale
- Kt: Thermopolis shale

Lower Cretaceous
- Kc: Cloverly formation with ledge (a)

CRETACEOUS (?)
- Km: Morrison formation

JURASSIC
- Js: Sundance formation

- JK: Undifferentiated Sundance formation to Niobrara shale

TRIASSIC
- Tr̄c: Chugwater formation

CARBONIFEROUS
- *Permian* — Ce: Embar (?) formation
- *Pennsylvanian* — Ct: Tensleep sandstone; Ca: Amsden formation
- *Mississippian* — Cm: Madison limestone

CAMBRIAN
- Ꞓ: Quartzite

Faults

Strike and dip of strata

Structure contours on top of Cloverly formation. Interval, 100 feet. Datum, sea level

Location essentially correct. Based on data from well logs and surface exposures

Location approximately correct. Based on data from well logs and surface exposures

Location uncertain, controlled by dips in soft shale, which may not have the same attitude as the Cloverly formation

Gas well

Dry hole

Dry hole with show of gas

Dry hole with show of oil

Dry hole with show of oil and gas

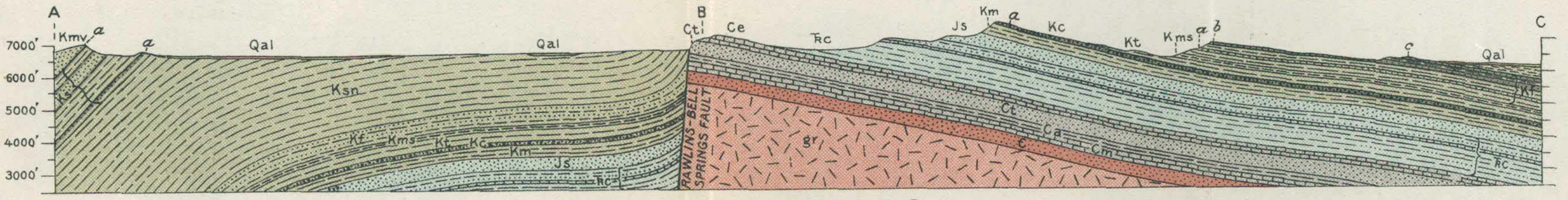
Drilling well

Idle well

GEOLOGIC MAP AND SECTION OF THE BELL SPRINGS DISTRICT, WYOMING

Scale 1:63,360

0 1 2 3 MILES



Section along line A–B–C

FOLDS

Separation Flats anticline.—The Separation Flats anticline lies in a broad valley largely covered by alluvium and trends northeastward parallel to the northeast end of the Rawlins-Bell Springs fault. At its southwest end the anticline terminates abruptly in a dome which lies opposite the bend in the Rawlins-Bell Springs fault near Bell Springs. The axial portion of the anticline is inclosed by dips of 5° or less, and its western and northwestern flanks have dips ranging between 15° and 45°, beginning 1 mile from the top of the dome. Dips to the south, east, and north average 5° or less.

Sharp upturning of the rocks along the southeastern edge of the downthrown side of the Rawlins-Bell Springs fault has produced a sharp syncline between the fault and the Separation Flats anticline. This syncline limits the closure of the anticline to about 300 feet, although it may possibly be as much as 400 feet. The structure contours on the geologic map show the closed area to be about 4 miles square and to include secs. 5 and 6 and parts of secs. 7 and 8, T. 23 N., R. 88 W. It also includes small areas in townships adjoining on the north and west.

The form of the axial part of the Separation Flats anticline, as shown on the map, has been deduced from altitudes of the top of the Cloverly formation in five wells drilled in this vicinity. Farther to the northeast, where no outcrops occur and no wells have been drilled, the contouring is tentative only. The structure of the southern part of the dome on the Separation Flats anticline can be determined in detail from observations on thin beds of limestone in the Niobrara and Steele shales, which crop out in the low northward-facing bluffs in secs. 17 and 18, T. 23 N., R. 88 W., and along the base of mesalike hills farther south.

Buck Springs dome.—Four miles south of the dome on the Separation Flats anticline, and adjoining the Rawlins-Bell Springs fault on the west, is a small, narrow fold commonly known as the Buck Springs dome. Although the dome has its surface expression in the soft Niobrara and Steele shales, ample exposures reveal the surface structure. The eastern and southern extensions of the dome are largely concealed beneath gravel deposits derived from the adjacent fault scarp.

The structure in the vicinity of the Buck Springs dome as shown on the map is based entirely upon surface dips taken in soft incompetent shale and on thin beds of limestone. No subsurface data on the configuration of the Cloverly formation are available, for only one well has been drilled to test this dome, and its log suggests that the normal position of the subsurface strata has been disturbed by faulting. Although the Buck Springs dome may have been a part of a fold which existed before the Rawlins-Bell Springs fault was formed, it is the opinion of the writers that the present form of this fold is due largely to the jamming and squeezing of incompetent shale beds along the fault. The axial part of the dome is well exposed in one locality, where dips of 30° or more on opposite limbs of the fold are less than 100 feet apart. It is evident that there is no flattened area along the axial part of the fold and that the sharp flexing has not been produced by vertical uplift in underlying rocks.

Minor folds.—Several small folds occur in the soft shale a mile or so west of the Rawlins-Bell Springs fault. One such fold occurs along the west line of sec. 20, T. 23 N., R. 88 W., 1 mile northwest of the Buck Springs dome, where reverse dips of 2° to 9° reveal the presence of a small anticline trending northward parallel to the fault. Such small folds probably have been produced by fault movement against incompetent beds, although the small fold described above may represent incompetent folding produced by the wrinkling of deeper competent strata.

Irregularities in the direction and amount of the dip of the rocks suggest that small folds exist throughout the area. However, inasmuch as many of the dips were taken in isolated exposures of soft shale, the attitude of which may have been altered locally by almost any number of conditions, they are not of much reliability, especially if they are abnormal in proving the existence of small folds.

FAULTS

It is impossible to be certain of the relative amounts and directions of displacement along most of the individual faults in this area, owing largely to the fact that the faults have offset several limestone beds that are identical in appearance and are closely grouped stratigraphically, some of which are not exposed at critical points. However, aside from the surface altitudes of the limestone outcrops shown on the geologic map, which may be considered approximately the same on opposite sides of the faults, it is obvious from the distribution of these beds that the faulting has resulted in the relative upward displacement of beds to the east and the southward displacement, by erosion, of beds on the upthrown side. Well-defined slickensides on slabs of calcite still in place along fault planes show that the displacement has been vertical.

Individual faults probably extend for greater distances than shown on the map, but lack of exposure prevents their being traced. The faults appear to be arranged roughly in two sets; the trend of one set is in general radial to the outline of the dome on the Separation Flats anticline, and that of the second set, represented by two faults, is roughly concentric with the dome. These faults have resulted, apparently, from the stretching or tension to which the rocks have been subjected during the formation of the dome.

Other faults of smaller displacement and calcite veins that may or may not mark actual fault planes occur farther south in secs. 20 and 29, T. 23 N., R. 88 W. These fractures appear also to be grouped, in a general way, into the two sets mentioned above.

ECONOMIC GEOLOGY

SEPARATION FLATS ANTICLINE

HISTORY OF DRILLING

The first wells drilled to test the oil and gas possibilities of the Bell Springs district were those of the Midwest Refining Co., put down in 1919 and 1920 in the NE. 1/4 sec. 9, and the NW. 1/4 sec. 16, T. 24 N., R. 88 W. The well in section 9 encountered a little gas at a depth of 1,370 feet, probably in the lower part of the Steele shale, but was abandoned as a dry hole at 2,530 feet without reaching the Frontier formation. Some gas was also found in the well in section 16 at about the same horizon. This well was abandoned, however, at a depth of 3,055 feet in rocks recorded as "dry sand" and "sandy shale," which occur at about the proper depth for the Mowry shale, though, owing to possible steep dips, they may belong to the lower part of the Frontier formation. There seems to be no doubt that these wells are northwest of the axis of the Separation Flats anticline, and it is probable that the one in section 9 was drilled to test another fold believed to exist beneath the alluvium.

In 1919 and 1920 the Texas Co. drilled an unsuccessful well in the SW. 1/4 sec. 8, T. 23 N., R. 88 W. This well, which dips obtained near by show to be on the south limb of the Separation Flats anticline, was abandoned at a depth of 2,445 feet after penetrating the Frontier and Cloverly formations without encountering any important shows of oil or gas.

In 1920 and 1921 the Midwest Refining Co. drilled a well near the center of sec. 30, T. 24 N., R. 88 W., to a depth of 2,220 feet. A sand in the lower part of the Steele shale, as in the Midwest wells to the northeast, yielded a small amount of gas. Drilling was continued nearly to the middle of the Frontier formation, where the well was abandoned after encountering some gas 25 feet from the bottom of the hole.

In the early part of 1921 the New York Oil Co. completed a dry hole, 2,300 feet deep, in the SE. 1/4 sec. 31, T. 24 N., R. 88 W. This well, which was only about a mile from the axis of the Separation

Flats anticline, obtained about 10 quarts of light-green oil from the top of the Frontier formation at a depth of 975 to 1,125 feet. Water was obtained in the Cloverly formation, near the base of which the well was abandoned.

The first well to encounter more encouraging results in the area was that of the Producers & Refiners Corporation near the eastern edge of sec. 1, T. 23 N., R. 89 W. This well was drilled in 1923 and 1924 and encountered oil in the sand in the middle of the Thermopolis shale at a depth of 1,953 to 1,972 feet. About 1,500 feet of fluid, part of which was oil, filled the hole. The well was later drilled to a depth of 3,120 feet, nearly to the base of the Sundance formation, and then abandoned.

The Utah Oil Refining Co. in 1924 drilled a shallow well in the W. ½ sec. 5, T. 23 N., R. 88 W., which penetrated only to the middle of the Frontier formation. Oil and gas shows were encountered in the sandstone at the top of the Frontier and in a thin sand in either the Niobrara or Carlile shale. No attempt was made to test the Cloverly formation.

In August, 1924, the first large flow of gas in the district was obtained by the Kasoming Oil Co. in a well near the south line of the SW. ¼ sec. 6, T. 23 N., R. 88 W. The gas sand was encountered at a depth of 1,924 feet in the top of the Cloverly formation, and yielded dry gas at a rate of 11,000,000 cubic feet a day. Upon drilling 30 feet deeper the flow was increased to 15,000,000 cubic feet a day, with a pressure of 860 pounds to the square inch. Drilling was continued to a depth of 1,979 feet, but upon finding water the well was plugged back to a depth of 1,959 feet, where an unsuccessful attempt was made to shut off the water.

A shallow well previously drilled by the Midwest Refining Co. a few hundred feet east of the Kasoming gas well obtained a show of gas at a depth of 846 feet in the top of the Frontier formation. The well was then abandoned.

A well being drilled by the Utah Oil Refining Co. near the south line of sec. 33, T. 24 N., R. 88 W., is shut down at a depth of 650 feet, with the bottom of the hole in "black shale" probably belonging to the Niobrara formation.

A well drilled by the Prairie Oil & Gas Co. in the E. ½ sec. 6, T. 23 N., R. 88 W., gave a show of oil and gas in the first sandstone of the Frontier formation, but yielded water in the Cloverly and Sundance formations.

OIL AND GAS POSSIBILITIES

Four wells have been drilled within half a mile of the highest structural point on the Separation Flats anticline. Three of these have penetrated the Cloverly formation and have encountered therein good shows of either gas or oil, or both. One well, drilled by the Kasoming Oil Co., encountered gas in commercial amount, and would probably have been a more successful producer had not serious water trouble been encountered. Gas from this well has served as fuel for the Prairie Oil & Gas Co. in drilling its well in the E. 1/2 sec. 6, T. 23 N., R. 88 W. Drilling records seem to indicate that the shows of oil and gas in the Prairie well were not as promising as the oil shows encountered in the well drilled by the Producers & Refiners Corporation 1 mile farther west. The reverse should be true if the relative structural positions of these wells are the only important factors influencing the accumulation of oil and gas. At present (1926) the SW. 1/4 sec. 6 looks better for commercial production than the SE. 1/4.

It is suggested that normal accumulation of oil and gas in this fold may have been prevented by a northward extension of one or more of the northward trending faults in the SW. 1/4 sec. 7. Such an extension may cut entirely across the high part of the anticline and, as suggested on the geologic map, may lie only a few hundred feet east of the Kasoming well. In view of the amounts of gas encountered in this well and the good showings of oil in the Producers & Refiners well, the writers believe that another well should be drilled in the SW. 1/4 sec. 6, T. 23 N., R. 88 W., and suggest that it be located 1,600 feet north and 1,300 feet east from the southwest corner. A well so located will give an additional test to that part of the anticline which thus far has yielded commercial quantities of gas and the most promising showings of oil.

It is believed that, in order to obtain definite information regarding the productivity of deeper sands in this district, one well should be drilled to the Tensleep sandstone. The top of the Tensleep should be encountered at a depth of about 4,250 feet by a well drilled in the S. 1/2 sec. 6, T. 23 N., R. 88 W.

Attention has already been called to the possible presence of a small closed fold in or near sec. 28, T. 24 N., R. 88 W. No well should be drilled here until good evidence for the actual existence of such a fold has been obtained. (See p. 197.)

BUCK SPRINGS DOME

HISTORY OF DRILLING

One well, that of the Producers & Refiners Corporation, has been drilled to test the Buck Springs dome. Because of the close proximity of the top of the dome to the Rawlins-Bell Springs fault the well was located about 500 feet west of the axis of the fold. Drilling began in April, 1925, in black shale near the base of the Niobrara formation. Two shows of oil were obtained in sands of the Frontier (?) formation between depths of 200 and 550 feet, one of which was accompanied by a large flow of water. Shows of gas were encountered in dark shale and "hard black shell" at depths of 592 and 800 feet and in "red shell" at 1,140 feet.

The rocks penetrated by this well are much disturbed by faulting or thinning out due to squeezing, as "red shell" and "hard red shale" were found at depths at which dark-gray or black shale of the Thermopolis shale would be expected. Records of numerous flows of water occur throughout the log of this well. It seems likely that subsurface faulting, associated with major displacement along the Rawlins-Bell Springs fault, has caused the sandstone and red shale of the Sundance formation to lie directly beneath the Frontier formation.

OIL AND GAS POSSIBILITIES

It is doubtful if the Buck Springs dome deserves further testing. The Producers & Refiners well encountered numerous oil and gas shows but no indications that commercial quantities of either oil or gas exist at any one horizon. It is entirely possible that no closed structure occurs in the subsurface sands that might be expected to be productive, and in that event it would be necessary to depend upon the Rawlins-Bell Springs fault and associated faults to have prevented the escape of oil or gas migrating into this dome. The failure of the well drilled suggests that if commercial quantities of oil or gas have entered the dome from the west, they have escaped along one of the faults that adjoin or cut the dome, in spite of the fact that beds of soft yielding shale occupy much of the stratigraphic section which has been faulted.

OIL AND GAS POSSIBILITIES OF OTHER LOCALITIES ADJOINING THE RAWLINS-BELL SPRINGS FAULT

Except the Separation Flats anticline, described above, there is no locality along the Rawlins-Bell Springs fault that is obviously worthy of a test well, to judge from existing data. The fold that occurs along the west line of sec. 20, T. 23 N., R. 88 W., is small, has slight structural relief and may not represent the structure in the deeper Frontier and Cloverly formations. There is also no evidence of definite closure on the east, a lack of which would probably permit oil and gas to migrate eastward to the fault, where it might either spread north and south to more favorable sites of accumulation or escape to the surface. It is possible that oil and gas producing tracts may exist in the alluvium and gravel covered areas along the fault, but the data at hand do not lend much encouragement to that idea.

The probability that the dome on the Separation Flats anticline is genetically related to the bend in the large fault near Bell Springs, as discussed on pages 190–191, suggests the question whether another dome may not be similarly situated with respect to the sharp bend in the main branch of this same fault 3 miles farther to the northeast, in the southern part of sec. 34, T. 24 N., R. 88 W. It seems that if such a dome is present it should lie near or in some part of sec. 28, about 2 miles northwest of the bend. The only surface expression of structure in this vicinity was obtained from shallow excavations in soft shale in the western part of sec. 33. The dips at this locality are eastward and do not suggest the presence of a dome in or near sec. 28, 1 mile to the north. It is suggested, however, that pits be dug in secs. 33 and 28 and, if advisable, in neighboring sections, in order to determine more accurately the structural conditions in this area. This bend in the Rawlins-Bell Springs fault is not so sharp as the one near Bell Springs and occurs where fault displacement has materially decreased; it may, therefore, not be accompanied by material folding on the downthrown block.

INDEX