OIL AND GAS PROSPECTS IN AND NEAR THE CROW INDIAN RESERVATION, MONTANA.

By W. T. Thom, Jr.

INTRODUCTION.

Examinations of the region.—The mineral resources of the Crow Indian Reservation, in Big Horn and Yellowstone counties, Mont., were examined some time ago by field parties directed by Carroll H. Wegemann and Ralph W. Howell, of the United States Geological Survey, and the results of the examination were reported to the United States Office of Indian Affairs, for which it was made, but were not published. A more detailed examination of some of the structural features in the reservation was made in the summer of 1921 by the writer, who was assisted by Gail F. Moulton and N. W. Bass. These two examinations and information collected from several sources now make it possible to determine the prospect of obtaining oil and gas in the greater part of the Crow Reservation and in small areas just northwest of it. The extreme western part of the reservation was not examined.

In the area studied no other structural uplift appears to be nearly so favorable for the accumulation of oil or gas as the Soap Creek Dome, on which the Soap Creek oil field is being developed. Considerable areas in the reservation or next to it on the northwest may yield oil or gas in commercial quantities, but tests of these areas for oil may involve many disappointments.

Although the structure in the parts of the Crow Reservation that have not been drilled does not warrant enthusiasm, the reservation nevertheless affords a much better chance to the wildcatter than many other areas in Montana, especially those whose surface rocks belong to the Fort Union formation or the upper part of the Lance formation.

Regional structure.—The structural features of the Crow Reservation that are believed to warrant a search for oil or gas lie just east and north of the Big Horn-Pryor Mountain uplift, within an area of about 3,000 square miles, and most of them are in the drainage basins of Big Horn and Little Horn rivers. The dominant

structural features of this area are (1) the great northwestward-trending anticline of the Big Horn Mountains; (2) the Pryor Mountains, which form an offset continuation of the Big Horn Mountains and differ from them in being more sharply folded and in having a more northerly trend; and (3) the Lake Basin-Huntley belt of faults, which passes eastward just south of Huntley and seems to terminate in T. 1 N., R. 34 E. In addition to the dominant northwestward-trending folds of the Big Horn-Pryor Mountain system there are apparently series of minor folds in the reservation, which trend north, northeast, and east and which produce at their intersections a complex system of structural domes and terraces.

Accessibility and operating conditions.—The Chicago, Burlington & Quincy Railroad extends along the valley of Little Horn River northward from Sheridan, Wyo., across the Crow Reservation. It turns northwestward at the confluence of the Little Horn with the Big Horn and runs by way of Toluca to Huntley, its point of junction with the Northern Pacific Railway, and thence to Billings. Hardin, the county seat of Big Horn County and the principal point of supply for oil companies operating in the Crow Reservation, is on the Chicago, Burlington & Quincy Railroad just west of Big Horn River. Practically all parts of the reservation that are of interest to the oil and gas operator are either already accessible by road or trail or can be made so without great cost, and ample water for drilling can be obtained in the foothill belt close to the mountains or along the larger streams. The surface relief, even in the parts of the reservation outside of the mountains, is considerable. Its character and extent are shown on the Huntley, Fort Custer, St. Xavier, and Rosebud topographic maps published by the United States Geological Survey, which cover more than half of the reservation.

ROCK FORMATIONS.

The rock formations in the reservation that may be of interest to the driller comprise 8,500 feet of sedimentary beds, which range in age from Eocene to Mississippian and have been divided into the formations described below. Most of the formations above and including the Morrison are probably somewhat thicker in the eastern and southern parts of the reservation than in the western and northern parts.

Fort Union formation.—The Fort Union formation consists principally of yellowish and grayish soft shale and sandstone and persistent beds of lignite, whose outcrops are commonly marked by beds of bright-red clinker produced by the burning of the lignite. The formation occurs along the higher divides in the eastern part of the reservation, where its thickness may be as much as 800 feet.

Lance formation.—The Lance formation, of Tertiary (?) age, consists of an upper member, 300 feet thick, composed of yellowish sandy shale containing carbonaceous layers, and a lower member, about 800 feet thick, consisting of dark clay, irregular beds of lignite, and massive beds of sandstone exposed along the west slopes of the Wolf and Rosebud mountains east of Little Horn River and in Pine Ridge northwest of Hardin.

Bearpaw shale.—In the northern part of the Crow Reservation the Bearpaw shale (the top formation of the Montana group, of Upper Cretaceous age) consists of dark marine shale, but between Reno Creek and the Montana-Wyoming line it consists principally of sandstone and sandy shale that closely resemble those of the Lance formation. A prominent white bed of bentonite marks approximately the base of the formation north of the Crow Agency, and a coal bed prospected at Lodge Grass is about 350 feet above the base there and 435 feet above it at Parkman, Wyo. This coal bed probably corresponds to one present near the base of the Lennep sandstone in the Lake Basin field.

Parkman sandstone.—The Parkman sandstone, which is familiar to oil operators in Wyoming, is typically exposed near Parkman, a station on the Chicago, Burlington & Quincy Railroad about 12 miles south of Wyola, and is closely equivalent to the Judith River formation as that formation was mapped in the Huntley field. At Parkman the formation consists in ascending order of a cliff-forming basal sandstone 70 feet thick, 120 feet of shale, 10 feet of white fine-grained sandstone, 75 feet of shale, and 5 feet of white sandstone, having thus an aggregate thickness of 280 feet. The basal sandstone of the Parkman is continuously exposed between Parkman and Wyola and appears in isolated outcrops in the hills west of Little Horn River between Wyola and Bear Creek and in Tps. 3 and 4 S., R. 34 E. It is exposed on the east side of the Little Horn at the mouth of Reno Creek and in the river bank just below Crow Agency, whence its outcrop extends north and then west, reaching the bank of the Big Horn just south of Ninemile Point. West of the Big Horn it is much obscured by terrace gravel, but it appears at intervals and stands out boldly in the southwest point of Pine Ridge. Between this point and Corinth the basal sandstone, though broken by several faults, is well exposed and is seen to be the stratum which for convenience was mapped by Hancock in the Huntley field as the basal sandstone of the Judith River formation. The sandy shale and thin beds of sandstone that form the upper three-fourths of the Parkman at its type locality are therefore equivalent to all except perhaps the uppermost part of the Judith River formation as that formation was for convenience mapped in the Huntley and Lake Basin fields.

Claggett formation.—West of Toluca the Claggett formation is 400 to 500 feet thick and consists of dark marine shale with some sandy shale and soft sandstone at its top and a 15-foot sandstone 140 feet above its base. This bed is probably the stratigraphic equivalent of a thin zone of conglomerate containing shark teeth exposed in the east-central part of T. 4 S., R. 34 E.

Eagle sandstone.—Along the Chicago, Burlington & Quincy Railroad right of way near Pryor Creek the top of the Eagle formation is marked by a buff massive standstone 40 feet thick, which is underlain successively by 55 feet of shale, 10 to 30 feet of massive sandstone, 50 feet of shale, and 50 feet of massive sandstone (Virgelle sandstone member). The three thick beds of sandstone form a cliff on the divide between East Fork and Telegraph Creek and are conspicuously exposed in the valley of East Fork south of the old railroad grade. The middle sandstone dies out rapidly toward the east, but the other two are traceable as far as Spring Creek, northwest of Toluca, north of which they disappear, probably as a result of faulting. Near Hardin the Eagle formation consists of a thick mass of sandy shale and a few thin beds of sandstone, which form the yellow hills just east of the river, and it extends southward as a rather indefinite unit along the Rotten Grass and Little Horn divide. South of the Little Horn in T. 9 S., R. 35 E., a massive sandstone that is believed to represent approximately the horizon of the Shannon sandstone of the Salt Creek field reappears in the formation.

Telegraph Creek formation.—The Telegraph Creek formation is typically developed at the head of Telegraph Creek, in T. 2 S., Rs. 28 and 29 E., and consists of 320 feet of yellow sandy shale parted in the middle by a thin bed of concretionary sandstone, which caps an escarpment. Less prominent layers of concretionary sandstone occur in the upper half of the formation. The fossils in the formation are predominantly of Montana types. They include a number of species found in the Eagle sandstone, with which are mingled forms usually found in the Niobrara shale of latest Colorado age.

Niobrara shale.—The Niobrara shale, the top formation of the Colorado group, of Upper Cretaceous age, is about 400 feet thick in the Crow Reservation. It is exposed in a broad belt south and west of the outcrop of the Eagle sandstone. The top part of the Niobrara is composed of blue limy shale, which weathers yellowish, and contains fragments of crinoids and *Ostrea congesta.* The lower part of the formation also consists of blue shale, and at the base there is a zone of large yellow concretions, which is exposed near the top of the hills in secs. 18, 23, and 32, T. 2 S., R. 32 E., and sec. 36, T. 6 S., R. 32 E.

Carlile shale.—The Carlile shale, which underlies the Niobrara, has a thickness of about 425 feet in the Crow Reservation. Beneath

the yellow concretions that mark the Niobrara-Carlile contact there is about 60 feet of black shale which contains many whitish concretions and, at its base, another zone of yellow concretions. About 35 feet lower in the column is a zone of easily recognized thin, hard rust-red concretions, which apparently corresponds to the red concretion and ironstone zone of the Cat Creek area. These red concretions were seen in sec. 34, T. 3 S., R. 29 E.; in the southeastern part of T. 2 S., R. 32 E.; at a number of points a short distance east of the Big Horn ditch; along the east side of the Soap Creek and Rotten Grass Creek fold; and in the south bank of Rotten Grass Creek in sec. 3, T. 8 S., R. 33 E.

At 250 feet above the base of the Carlile is the top of a zone containing two streaks of bluish limy shale which at many places along hillsides weather into whitish streaks that are readily distinguishable from beds of bentonite. These limy streaks, which are regarded by some geologists as the equivalent of the Greenhorn limestone of the Black Hills district, have been observed east and northeast of the Soap Creek dome and in sec. 18, T. 3 S., R. 32 E. The basal part of the Carlile, which consists of dark marine shale with interbedded layers of bentonite, is similar lithologically to the underlying Frontier formation.

Frontier formation.—The rocks composing the Carlile and Frontier formations are so nearly alike that the line separating them has been drawn somewhat arbitrarily at the top of a thick bed of bentonite exposed east of the Soap Creek dome. The Frontier formation at Soap Creek is about 410 feet thick and consists principally of dark shale but in the top 100 feet includes thin layers of coarse sandstone, which seem to thicken rather abruptly toward the west. Beds of sandstone probably belonging to this zone were observed near the northwest corner of sec. 35, T. 4 S., R. 31 E., and are reported to be exposed in sec. 28, T. 3 S., R. 31 E.

Mowry shale.—The Mowry shale, because of its hardness, is one of the most conspicuous formations in the Crow Reservation. It consists of several layers of hard light-colored more or less sandy shale containing fish scales, interbedded with somewhat thicker layers of hard dark shale. The top and bottom of the formation as mapped were placed at the highest and lowest layers of fish-scale shale, which gives the formation a thickness ranging from 200 to 300 feet.

Thermopolis shale.—The Thermopolis shale is believed to be the lowest formation of the Colorado group. It is well exposed east and north of the Soap Creek dome, where it consists of a basal unit of dark marine shale, a middle unit of dark beds of ferruginous clay and bentonite, and an upper unit of dark marine shale containing variable streaks and lenses of light-colored thin-bedded sandstone. The

aggregate thickness of the formation is about 550 feet at Soap Creek and about 800 feet at Beauvais Creek.

Cloverly formation.—The Cloverly formation, of Lower Cretaceous age, occupies approximately the position of the Kootenai formation of central Montana and is believed to be of fresh-water origin throughout. It normally consists of an upper zone of yellow sandy shale, thin-bedded rusty sandstone, or coarse massive yellow sandstone; a middle zone of bright variegated clay, which east of Soap Creek changes to dark fissile, rather carbonaceous shale ("rusty beds"); and a basal zone of coarse sandstone or conglomerate (correlated with the Lakota sandstone of the Black Hills area), which is one of the most conspicuous beds in the Crow Reservation. The thickness of the formation seems to range from 320 feet at Soap Creek to 425 feet at Beauvais Creek.

Morrison formation.—The Morrison formation is of fresh-water origin and is of Lower Cretaceous or late Jurassic age. It consists chiefly of bright variegated clay like that of the middle Cloverly, which is likely to cave badly when penetrated by the drill. At some points along its outcrop the Morrison seems to be only a few feet thick, but it is apparently 250 feet thick where penetrated by wells at Soap Creek and 345 feet thick in the well at Black Gulch.

Sundance formation.—The Sundance, a marine formation of late Jurassic age, underlies the Morrison, probably with slight unconformity, and is in part equivalent to the Ellis formation of central Montana. It consists of beds of gray and greenish sandstone and white or pink limestone and thicker beds of shale, dark gray or greenish in the upper part of the formation and pink or red in the lower part. The top of the Sundance is commonly marked by a fossiliferous coarse soft sandstone, from which a number of springs issue. The outcrops of the beds of the upper two-thirds of the formation are commonly marked by great numbers of the thick curved shells of *Gryphaea calceola.* Wells penetrating this formation will probably strike two or three water-bearing sandstones, and the first conspicuous pink or red beds may be found as high as 140 feet above the base of the formation. The formation is 425 feet thick just north of the mouth of Big Horn Canyon, and its thickness seems to increase away from the mountains, reaching 650 to 680 feet in wells at Soap Creek.

Chugwater formation.—The Chugwater formation consists mainly of conspicuous dark-red sandstone and shale but includes thick local beds of gypsum near its top and base and usually a thin reddish limestone in its upper part. The formation is 590 to 655 feet thick at Soap Creek and seems to grow thinner toward the north and northwest. Near Little Horn River thick beds of the Chugwater sandstone show a greenish tint instead of the normal red color, and a hand

specimen taken from one of these greenish beds was considerably impregnated with oil.

Although the Embar formation is not found in its normal character north or northeast of the Big Horn Mountains, the beds of gypsum that occur in the basal 100 feet of red strata here described as Chugwater may perhaps be of the same age as the Park City formation or the lowest part of the Embar. The thin limestone at the base of the Chugwater in the Soap Creek field may also be of Park City age, and if so, the rocks of that age may in places have a thickness of 125 feet. The Embar yields oil in several fields in Wyoming, but the rocks that are possibly equivalent to it have not yet proved productive in the Crow Reservation.

Tensleep sandstone.—The Tensleep sandstone, of Pennsylvanian age, is a coarse yellowish sandstone 45 to 75 feet thick, which contains in its upper part nodules of black chert. The Tensleep stands out strongly where it rises beneath the Chugwater red beds, sweeps up over the steep northeast slope of the Big Horn Mountains near Big Horn Canyon, and is well exposed where East Pryor Creek cuts through the Shively Hill dome, in sec. 26, T. 5 S., R. 27 E. The outcrops of the Tensleep on Little Horn River and on Lodge Grass Creek are more or less tarry. The formation commonly yields shows of oil when penetrated by wells and has yielded some noninflammable gas at Soap Creek.

Amsden formation.—The Amsden formation underlies the Tensleep without apparent break and is chiefly or perhaps wholly of Pennsylvanian age. At most places along its outcrop it consists of 155 to 365 feet of red shale, thin beds of white and red limestone, and quartzitic sandstone. The base of the formation is placed below a bed of red shale 15 feet or more thick, which seems to be invariably present at the contact between the Amsden and the Madison limestone. Most of the oil produced at Soap Creek has been obtained from a sand 80 feet below the top of the formation, and lower sands in the Amsden have also yielded some oil.

The Amsden may be equivalent to a part of the Quadrant formation of the Lewistown district, but the uncertainty as to the true age of beds classed as Quadrant in that district makes a definite statement impossible.

Madison limestone.—The Madison limestone, of early Mississippian age, underlies the Amsden and is separated from it by an unconformity that may possibly represent a considerable time interval, as is perhaps indicated by variations in the thickness of the Amsden and by folding that had affected the Madison prior to the deposition of the Amsden and that is shown by exposures on East Pryor Creek east of the Shively dome. The Madison consists of several hundred to 1,000 feet of massive light-colored limestone. At the canyon of

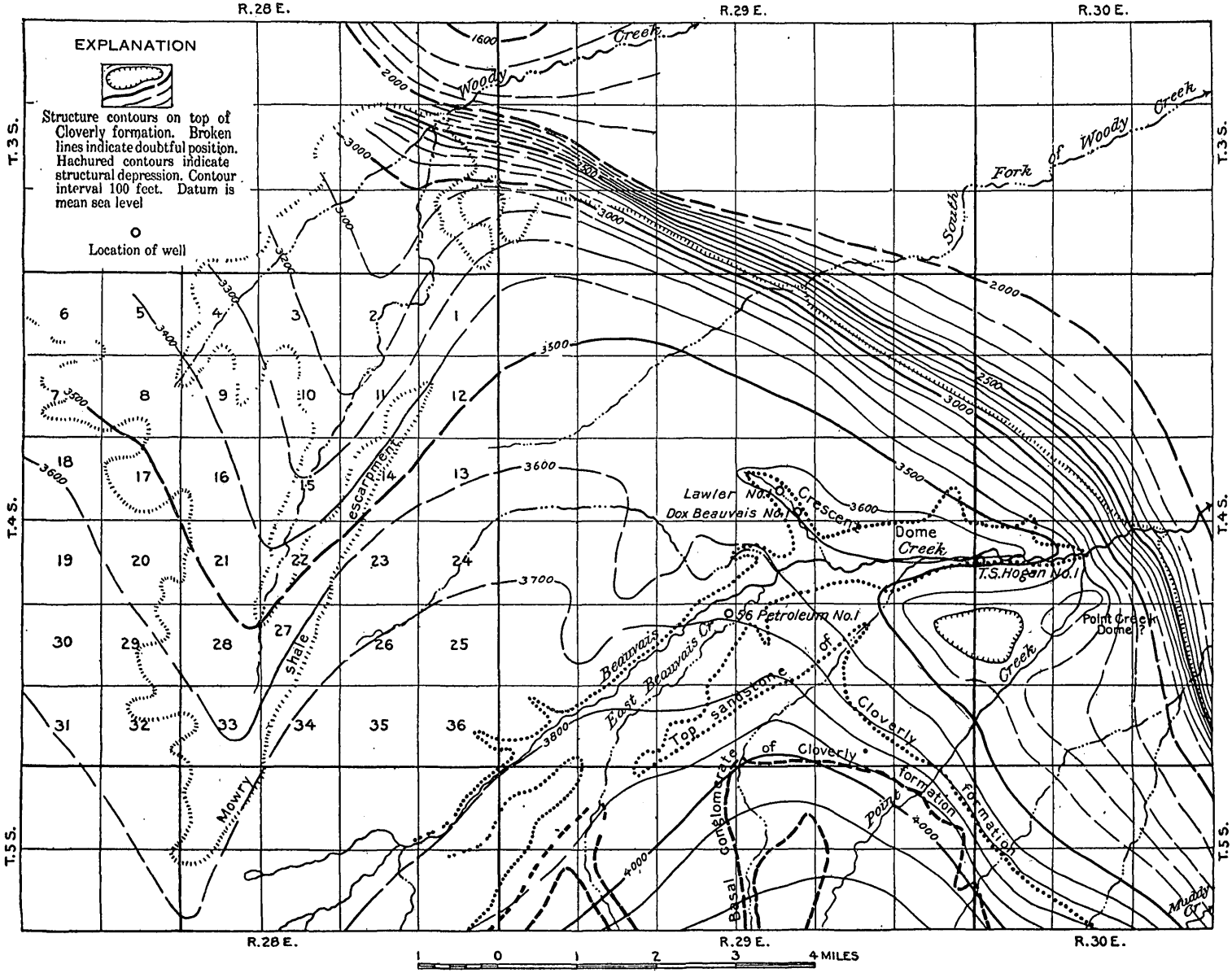
Big Horn River it is apparent that solution cavities were developed along the joints and bedding planes in the upper part of the Madison prior to the deposition of the Amsden, and that these cavities were in places filled with infiltered mud that is now represented by layers of red shale, in part very limy.

The upper part of the Madison has yielded some oil at Soap Creek, and hand specimens taken from the upper part of the formation at exposures on the Little Horn yield an odor of gasoline when struck with a hammer, especially the samples taken near the irrigation head gate at Big Horn Canyon. Analyses of samples of the Madison limestone taken at Big Horn Canyon by K. C. Heald, of the United States Geological Survey, showed practically 100 per cent calcium carbonate and therefore indicate that the rock is pure enough to be eminently suitable for use in sugar refining.

STRUCTURAL UPLIFTS IN OR NEAR THE CROW RESERVATION.

The Soap Creek dome, on which the Soap Creek oil field has been developed, and the Rotten Grass, Reed, and supposed South Soap Creek domes have been described in a press notice issued in December, 1921, by the United States Geological Survey. More or less fragmentary additional data have since been collected concerning the geologic structure and the possibility of obtaining oil and gas in the greater part of the Crow Reservation and in small areas northwest of the reservation.

Beauvais Creek uplift.—The accompanying sketch map (Pl. VII) illustrates the structural conditions that exist within the indefinite boundaries of the Beauvais Creek uplift. This uplift is generally considered to embrace the area along Beauvais Creek south of and within the crescent-shaped ridge formed by the Mowry shale where that formation swings around the plunging north end of the main Big Horn Mountain anticline. This Mowry ridge passes the southeast corner of sec. 33 and the northeast corner of sec. 20, T. 4 S., R. 30 E.; the northeast corners of secs. 11 and 4, T. 4 S., R. 29 E.; and the northeast corner of sec. 1 and the southeast corner of sec. 33, T. 4 S., R. 28 E. The greater part of the area so outlined is structurally unclosed, being open on the south side, although the upward slope of the beds is rather gradual for 3 or 4 miles south of Beauvais Creek. The Crescent dome, which has a closure of 60 to 70 feet, includes the southern edge of secs. 13 and 14, the southeastern and central parts of sec. 15, and the northern parts of secs. 23 and 24, T. 4 S., R. 29 E., and most of the S. ½ NW. ¼ sec. 19, T. 4 S., R. 30 E. Another very small uplift on Point Creek, in the northwest corner of sec. 29 and the extreme southern part of sec. 20, T. 4 S., R. 30 E., also probably has a small closure, and it is believed that a small uplift of slight



MAP SHOWING STRUCTURE IN A PART OF THE CROW INDIAN RESERVATION, MONT.

closure may be present near the southwest corner of sec. 9, T. 4 S., R. 29 E.

No development work had been begun when the field was examined, but according to recent reports in the trade journals the 56 Petroleum Co. has begun a well in the NE. ¼ NE. ¼ sec. 28, T. 4 S., R. 29 E., and locations have been made by the Dox-Beauvais Oil Co. in the SE. ¼ sec. 15, T. 4. S., R. 29 E.; by T. S. Hogan on the Hackney & King lease, in the SW. ¼ NW. ¼ sec. 19, T. 4 S., R. 30 E.; and by Hughes & DeBolt in sec. 15, T. 4 S., R. 29 E.

The Beauvais Creek uplift appears to merit a test for oil, although so far as can be judged from surface indications it is much less promising than the Soap Creek dome, because of the small size and lowness of its closed areas. As a consequence of this slight closure and the proximity of the mountain uplift, artesian waters passing outward from the Big Horn Mountains may have flushed the closed areas and dispersed any oil that may once have been present. Areas northeast of the crests of the Crescent dome and the supposed Point Creek dome are least likely to have been adversely affected by artesian water, but areas south of these domes would have been the first to be flushed. Lenticularity of the Amsden sands, which would cause the sands to thin out toward the mountains, might possibly have caused oil to accumulate and at the same time have prevented flushing, but it is not yet definitely known that the Amsden includes oil-bearing sands at Beauvais Creek. The top of the Madison limestone will probably be reached by wells on the Crescent dome at depths of 1,800 to 2,000 feet, and as oil may possibly be obtained from the Madison, wells that have failed of production in higher formations should be carried into the Madison until flows of water indicate that there is no further chance for the discovery of petroleum.

The Beauvais Creek district is about 50 miles by road from both Hardin and Billings, but because of better grades Hardin is the principal supply point for the field. The surface relief in the vicinity of the Crescent dome is relatively small, and water for drilling can be obtained from Beauvais Creek, which is a perennial stream. To provide a fuel supply coal can be brought in on the railroad and hauled to the district, or wood can be obtained from the mountains, or oil can be hauled by tank truck from Soap Creek to Big Horn River, piped across, and hauled to Beauvais Creek.

Woody Creek dome.—The axis of the Woody Creek dome, which is probably continuous southward to the Soap Creek fold, was located by C. H. Wegemann in 1916, but no map of it was made. However, Mr. F. W. Rohwer has very courteously given to the United States Geological Survey a copy of a report made by him for the Maxwell Syndicate, of Billings, which indicates that this dome

has a closure of about 300 feet. According to this report the apex of the dome lies in the NE. ¼ SW. ¼ sec. 28, T. 3 S., R. 31 E., and the closed area is apparently outlined approximately by points 2½ miles north of the apex and 1½ miles east, south, and west of it.

A thin sandstone believed by Mr. Rohwer to be a member of the Frontier formation crops out just east of the apex, in sec. 28, so that, according to estimates of thickness made by the Geological Survey, it would appear that a well sunk at the apex of the dome would reach the upper Cloverly sand (the approximate starting point of wells on the Crescent dome at Beauvais Creek) at a depth of about 1,400 feet and that the probable depth to the Madison limestone would therefore be from 3,200 to 3,400 feet.

The Woody Creek dome is about 30 miles from Hardin. It lies near the road from Hardin to Beauvais Creek, and only a small amount of road building would be required to make it accessible. The surface relief of the dome, which is not great, is shown on the Fort Custer topographic map, on which the words "Woody Creek" appear immediately to the north of the point reported to mark the apex of the dome. Water for use in drilling would have to be obtained either by constructing local reservoirs or by pumping water from Beauvais Creek, 3 miles away.

Grapevine dome.—The Grapevine dome centers in secs. 36 and 25, T. 5 S., R. 29 E., and is a large dome whose crest has been so deeply eroded as to make expenditure for a test well on it appear at present unwarranted. Because of its apparently unfavorable character, the dome was examined only very hastily by members of the United States Geological Survey, but it was seen that the top of the Madison limestone is either actually exposed or very close to the surface near the center of the uplift. However, if subsequent tests elsewhere should indicate the existence of an important productive bed some distance below the top of the Madison, a test of the Grapevine dome might be a justifiable wildcat venture.

Shively Hill dome.—The Shively Hill uplift is a very conspicuous eroded dome whose center falls near the northwest corner of sec. 35, T. 5. S., R. 32 E. The Tensleep sandstone arches over the crest of the uplift, and the Amsden formation and upper part of the Madison limestone appear on its east side in the canyon walls of East Pryor Creek. This dome, therefore, like the Grapevine, does not at present seem to hold out sufficient hope for oil production to warrant the drilling of a test well. A section measured in the East Pryor Canyon northeast of the dome gives the following local thicknesses: Cloverly formation, 400 feet; Morrison, 73 feet; Sundance, 627 feet; Chugwater, 570 feet; Tensleep, 44 feet; Amsden, 156 feet. These exposures apparently show that the Madison was somewhat folded and eroded before the deposition of the Amsden.

Mifflin anticline.—The Mifflin anticline, which lies just south of the former station of Mifflin, on the abandoned line of the Chicago, Burlington & Quincy Railroad, is on the same general line of uplift as the Woody Creek dome and the uplift reported to exist on Bitter Creek. It extends from a point near the southeast corner of sec. 4, T. 2 S., R. 28 E., past the southeast corner of sec. 12 of the same township, and fades out toward the center of T. 2 S., R. 29 E. The axis of the anticline lies between East Fork and the old railroad right of way and plunges sharply toward the northwest for the greater part of its length but seems to have a slight closure, whose highest point is in the west-central part of sec. 17, T. 2 S., R. 29 E. The fold is unsymmetrical, having dips of 1° to 5° on its northeast side and apparently much steeper dips on its southwest side. The yellow sandy shale of the lower part of the Telegraph Creek formation makes a fairly distinct scarp around the west and east ends of the anticline and extends across its crest just east of its highest point. The interval from the lowest stratum exposed at the point marking the apex of the structural closure to the top of the Cloverly (which corresponds approximately to the Kootenai) is estimated to be about 2,150 feet, which would apparently place the top of the Madison somewhat more than 4,000 feet below the surface at this point.

Some gas may be obtained from the Frontier sandstone beds or the Mowry shale beneath this anticline, and there is a slight possibility that oil or gas may be obtained from the Cloverly, Sundance, or Chugwater, and a trifle better chance for production from the Tensleep, Amsden, or Madison. However, this anticline should not be drilled unless the projected tests in the Bitter Creek area, 15 miles farther west, are successful, as nearly all the sands underlying the Mifflin anticline are there present at very much shallower depths. The surface relief of the Mifflin anticline is not great; it is easily accessible by road from Billings, 15 to 20 miles away; and water for use in drilling is obtainable from East Fork Creek at no great distance.

Bitter Creek area.—A steep hogback with a northward dip, presumably formed by the Mowry shale, lies a short distance south of the road between Billings and the former station of Coburn, on Pryor Creek. This hogback, which is shown on the Huntley topographic map, apparently crosses the southwest corner of sec. 32, T. 1 S., R. 27 E., and the south-central part of sec. 25, T. 1 S., R. 26 E., and curves thence toward the southwest. A reconnaissance geologic examination along the valley of Pryor Creek south of Coburn points suggestively, though not conclusively, to the existence of some structural closure south of the Mowry (?) hogback described above. It is reported in trade journals that a shallow test well drilled in the SE. ¼ NE. ¼ sec. 2, T. 2 S., R. 26 E., by C. B. MacMenamin, of Bil-

lings, obtained a showing of gas at 150 feet and yielded 100,000 cubic feet of wet gas at a depth of 350 feet. This hole stopped at 470 feet, but according to reports it is to be deepened to 800 feet, and a second and deeper test well is to be drilled a short distance farther south. The Cloverly formation should be reached on the higher part of this supposed uplift at depths of less than 1,000 feet, and the Madison limestone probably lies 1,800 to 2,000 feet lower. The present test well is about 10 miles south of Billings by road. The surface relief in the immediate vicinity of the Mowry (?) hogback amounts to several hundred feet, but the dissection is not extreme, as is shown by the Huntley topographic map. It seems probable that water for use in drilling in this vicinity will have to be obtained either from a distance or from artificial reservoirs, although enough artesian water for drilling requirements may be obtained in the course of projected development work.

Telegraph Creek plunging anticline.—No study of the area supposed to be included in the Telegraph Creek fold was made by the United States Geological Survey parties in the Crow Reservation, but from observations made by these parties along the northern reservation line and from field notes made by E. T. Hancock in his examination of the Huntley field it is apparent that a low plunging anticline passes a little east of the northwest corner of T. 2 S., R. 29 E., and extends thence toward the northwest corner of T. 1 S., R. 29 E. The outline of this anticlinal nose is irregular, and it is possible that a minor cross flexure may produce a small area of structural closure in T. 1 S., R. 29 E. The surface rocks over the area of the supposed Telegraph Creek fold belong to the upper part of the Eagle sandstone and the lower part of the Claggett, so that the local depth to the Cloverly is 2,600 to 2,800 feet. Terraced uplands and steep escarpments are prominent features of this locality, as is shown by the Huntley topographic map, and in the absence of reliable local water supplies reservoirs should probably be constructed before any drilling is begun. In view of the depth of the test hole required and the minor and uncertain character of this uplift, it is believed that a test of it should not be undertaken until the Mifflin anticline has been drilled and found to contain commercial quantities of oil or gas.

Tenmile plunging anticline.—A small plunging anticline just west of Corinth and south of Tenmile Creek is shown on the map accompanying Hancock's report on the Huntley field.[1] The Judith River formation and basal Bearpaw are exposed at the surface of this fold, indicating a local depth to the Cloverly of about 3,300 feet. Because of the apparent lack of structural closure on this fold and

[1] Hancock, E. T., Geology and oil and gas prospects of the Huntley field, Mont.: U. S. Geol. Survey Bull. 711, pl. 14, 1920.

because of the great depths required for a test, it now seems that a well on this anticline would not find paying quantities of oil or gas.

Toluca uplift.—The Toluca uplift, near the center of T. 1 N., R. 31 E., is known to be very severely and complexly faulted, although no detailed examination of it has been made by the United States Geological Survey. The Claggett formation and the lower part of the Parkman are exposed on the crest of this uplift, which lies just southwest of the south end of Pine Ridge, and the depth to the Cloverly is therefore probably about 3,000 feet. Some road building would be required to make the uplift accessible from the Hardin-Billings road at Fly Creek. The local surface relief amounts to several hundred feet, as is shown by the Fort Custer topographic map, and the lack of an adequate water supply would necessitate the construction of reservoirs for flood-water storage. The Toluca uplift has some possibility of yielding oil or gas, but it now appears rather improbable that enough oil or gas can be obtained from this uplift to be commercially profitable.

Pine Ridge area.—The so-called Pine Ridge field is about 10 miles northwest of Hardin, in T. 1 N., R. 32 E. A well was begun in sec. 15 of this township but was abandoned at a relatively shallow depth. A large part of the township is mantled by terrace deposits, but apparently a slight anticline extends southwestward from the northeast corner. More detailed investigation, however, may prove this to be primarily a fault feature rather than an anticline, as it lies within the Lake Basin-Huntley belt of faulting. The depth from the surface to the top of the Cloverly in this area is about 3,200 feet. This large depth and the relatively small likelihood that important quantities of oil or gas lie beneath the surface here make it improbable that the "field" can be profitably developed. The locality has a comparatively level surface, as is shown by the Fort Custer topographic map, and it can easily be reached by road from Hardin. Reservoirs would probably have to be built for water storage.

Two Legging uplift.—Slight dips in shale indicate the presence of a very low anticlinal crest extending northeastward through the center of sec. 34, T. 1 S., R. 31 E. North of this point the axis plunges toward the northeast for a short distance and becomes obscure. Southwest of this point it seem to rise gradually and may continue to rise as far as Beauvais Creek. It is, however, rather more likely that some slight structural closure exists along the crest of the fold in the west-central part of T. 2 S., R. 31 E., although this inference is highly speculative. The Niobrara shale and topmost part of the Carlile shale cover the known (northern) portion of this uplift, and it is estimated that the top of the Cloverly and the Madi-

son limestone would lie, respectively, about 2,000 and 4,000 feet below the surface of the higher part of the fold. It is quite possible that some gas might be obtained in this area from the Frontier sandstone beds or the Mowry shale, which lie at comparatively shallow depths, and there is a slight chance that oil and gas might be found in the deeper sands, although no attempt at development on the Two Legging uplift should be made until the Woody Creek dome has been tested successfully. The Two Legging area is about 14 miles from Toluca by road and about 22 miles from Hardin. The relatively slight surface relief of the area is indicated by the Fort Custer topographic map. The Two Legging fold passes about three-quarters of a mile east of the 3,500-foot hill on the divide between Two Legging Creek and Williams Coulee and extends thence southwestward along the headwaters of Two Legging Creek.

Reservoirs would have to be constructed for water storage if drilling operations should be attempted during the dry season in late summer and fall.

Ninemile and Dry Creek areas.—The Ninemile "field" lies near the center of the south line of T. 1 N., R. 34 E., and the Dry Creek "field" is supposed to lie north of the point where Dry Creek crosses the east line of T. 1 S., R. 34 E. No detailed structural study of these two areas has been made by the United States Geological Survey, but enough work has been done to show that they lie upon the crest of the broad, low anticlinal nose whose axis passes some little distance south of Hardin and extends thence northeastward and makes a marked northeast plunge near the east line of T. 1 N., R. 34 E. It is reported that slight faults extending across this arch produce small areas of structural closure in the Ninemile and Dry Creek "fields," and the reports may be true, as the Lake Basin-Huntley zone of faults seems to terminate near the heads of Ninemile and Dry creeks, east of the area under discussion. The Superior Oil & Coal Co. is now drilling on Ninemile Creek in the SE. ¼ sec. 33, T. 1 N., R. 34 E., and, according to unconfirmed trade-journal reports, has so far obtained about 1,000,000 cubic feet of gas at 750 feet, a good showing of gas at 1,950 feet, and a small flow of water at 2,350 feet. It is not known at what geologic horizon this well starts, although most probably it begins near the top of the Eagle, and the reported water flow at 2,350 feet would presumably come from the top of the Cloverly. The Ninemile and Dry Creek areas are about 8 miles from Hardin by road. Neither area has a natural water supply adequate for drilling.

East Tullock Creek dome.—A low dome in the southeastern part of T. 1 S., R. 37 E., and the southwestern part of T. 1 S., R. 38 E., near East Tullock Creek, has a northwesterly elongation, is parallel to a large fault that bounds it on the southwest, and has a structural closure of probably 150 to 200 feet. Its apex lies near the southwest

corner of sec. 24, T. 1 S., R. 37 E., and the fault has been traced from a point near the northwest corner of sec. 4, T. 1 S., R. 36 E., to its termination near the southeast corner of T. 1 S., R. 37 E. The beds exposed in the vicinity of the dome belong to the topmost part of the Lance and the basal part of the Fort Union, so that the local depth to the Parkman sandstone is apparently about 2,700 feet and to the top of the Cloverly about 5,900 feet. In consequence of the great depths to the sands, it would seem highly inadvisable to drill a test well on this dome unless the well now in progress near Sarpy obtains oil or gas in commercial quantity.

Hardin area.—Several years ago natural gas was struck in a well drilled about 2 miles northwest of Hardin, on the property of C. M. Bair, now owned by the Great Western Sugar Co. When visited in September, 1921, this well showed a closed pressure of 120 pounds to the square inch and was reported to have shown a maximum pressure of 160 pounds. During the winter the gas is used as domestic fuel by about 30 families, and it is said that by spring the pressure is sometimes as low as 5 pounds to the square inch. No log of this well is available, but it is stated that the gas comes from a 15-foot sand, variously reported to lie from 800 to 1,100 feet below the surface, and also that red shale, presumably of the Cloverly formation, was reached at 2,300 feet. The well apparently starts at about the top of the Niobrara shale, a horizon which would suggest that the gas comes from the Mowry shale, but in the absence of more reliable data than are now available such a speculation is of little value.

A well that was being drilled for water on the Bowman ranch, about 1½ miles northeast of Hardin, yielded a little gas from shale at a depth of 135 feet. A third well near the railroad track at the southwest edge of Hardin is reported to have been drilled to a depth of 2,200 feet without having yielded oil or gas. From these three wells and from what is known of the structural geology of the country between Hardin and the Crow Agency it would seem quite possible that the Bair well is on the upthrown northwest side of a northeasterly fault, or more probably that a fault approximately parallel to that southwest of the East Tullock Creek dome passes between the gas well northwest of Hardin and the dry hole southwest of the town, and it may be that the presence of gas northeast of this assumed fault indicates the presence of a small area of structural closure extending northwestward parallel to the fault. At least it would seem quite reasonable to suppose that a well a mile or two about due southeast of the Bair well should obtain small flows of gas from the same sand at about the same depth (800 to 1,000 feet) as the Bair well. If gas should be found in a well so located it would probably be possible to extend the productive area somewhat to the northeast, southwest, and southeast. If this well should find no gas, it might

be worth while to drill one more well due northeast of the Bair well, on the chance that a northeast-southwest fault caused the local accumulation.

The aggregate yield of gas that might under the most favorable conditions be expected from the Hardin area would be relatively small, and arrangements should therefore be made to conserve for domestic use any supply that may be obtained.

Sport Creek anticline.—The Sport Creek anticline, on which a test hole has been drilled without success by the Mid-Northern Oil Co., is a small, sharp fold imposed on the flank of the main Big Horn uplift. It extends from the south-central part of sec. 4, T. 9 S., R. 33 E., to the central part of sec. 30, T. 9 S., R. 34 E. This anticline has a closure of about 400 feet, and its highest point lies in the SE. ¼ sec. 14, T. 9 S., R. 33 E. The Chugwater red beds cover the crest of the fold, and Little Horn River has cut into its south end until the Tensleep sandstone is now exposed in the river bank. The Tensleep is strongly impregnated with oil residues at this exposure, and hand specimens of a light-colored sandstone which occurs here in the upper part of the Chugwater and is conspicuous because of its contrast in color with the normal dark red of the formation showed oil stains. The west limb of the Sport Creek anticline dips about 50° opposite the high point of the fold, and the anticline is clearly defined throughout the greater part of its length. The test well of the Mid-Northern Co., in sec. 14, was abandoned at a depth of 487 feet, after having penetrated 39 feet into the Madison limestone. A sand that apparently represents the productive sand of the discovery well at Soap Creek was penetrated between 320 and 326 feet, or 159 feet below the base of the Chugwater red beds, and the base of the Amsden at Sport Creek was marked by beds interpreted by the driller as red quartz sand (390–402 feet), red sandy shale (402–445 feet), and quartz sand (445–448 feet). The aggregate thickness of the Tensleep and Amsden at Sport Creek is therefore apparently 287 feet, compared with 325 feet at Soap Creek.

Willow Creek dome.—The Willow Creek or Big Rim dome is a local uplift in secs. 30 and 19, T. 8 S., R. 33 E., imposed upon the continuation of the Sport Creek anticlinal axis, which in its northern extension also passes through the Reed dome. The Willow Creek uplift has a structural closure of about 250 feet, and the basal part of the Sundance formation and the upper part of the Chugwater red beds are exposed in its crest. A test well was drilled on this dome in the northern part of sec. 30 by the Mid-Northern Oil Co. and was abandoned at a depth of about 576 feet. The exact horizon reached by this well is not known, as the record for the lower 100 feet is reported to have been lost, but from a study of the portion of

the log available it would appear that the top part of the Madison and the lower 50 feet of the Amsden were not tested by this well.

Black Gulch dome.—The Black Gulch dome is an uplift defined by sharp dips, about 4 miles northeast of the steep slope of the Big Horn Mountains and about 3 miles south of Little Horn River, with its highest point in the SE. ¼ sec. 24, T. 9 S., R. 34 E. The dome lies on the downthrown south side of a fault having a maximum throw of about 1,000 feet and marks the point where the Sport Creek anticline, which has been offset by the fault, intersects a prominent cross fold that is noticeable in the main mountain mass to the west. The Producers & Refiners Corporation drilled a well on the Black Gulch dome in the NE. ¼ SW. ¼ sec. 24, T. 9 S., R. 34 E., at a point on the surface axis of the dome about 1,000 feet northwest of the apex and about 100 feet structurally below it. The depths to the tops of the several formations penetrated by this well are as follows: Cloverly, 495 feet; Morrison, 890 feet; Sundance, 1,235 feet; Chugwater, 1,810 feet; Tensleep, 2,535 feet; Amsden, 2,655 feet. No showings of oil or gas were reported from this well, and both the basal sandstone of the Cloverly, which was penetrated between 845 and 890 feet, and the Tensleep sandstone carried water. According to the log the well stopped in a thick sandy red shale, such as usually marks the base of the Amsden formation, and the bottom of the well was therefore probably just a few feet above the top of the Madison limestone. It is consequently apparent that although the well makes it appear somewhat improbable that the dome will yield oil or gas, it did not test the possibilities of the uplift completely, as it was not drilled at the highest point of the dome and did not penetrate the upper members of the Madison, which yield some oil at Soap Creek and are somewhat petroliferous at their outcrops in Big Horn and Little Horn canyons, as proved by the odor of petroleum emitted from freshly broken surfaces of the limestone.

The Black Gulch dome is about 14 miles from the railroad town of Wyola and is on top of the high flat-topped hill between Little Horn River and West Pass Creek, 6 miles west of Aberdeen. The irrigation ditches south of the Little Horn and West Pass Creek, both about 1½ miles from the dome, are the nearest sources of water supply, and the altitude of well sites on the dome makes the water problem rather difficult.

Other areas that might possibly yield oil or gas.—In addition to the more pronounced or better-known uplifts already described there are several areas within the Crow Indian Reservation in which there is at least a slight possibility of obtaining oil or gas in commercial quantities. According to a report from Mr. F. W. Rohwer a low anticlinal flexure crosses Pryor Creek near the mouth of Wet Creek, in the southern part of T. 2 S., R. 27 E., and extends thence

in the general direction of the Crescent dome at Beauvais Creek. From the meager data at hand as the result of a hasty reconnaissance by members of the United States Geological Survey in parts of the Pryor Creek valley, Mr. Rohwer's interpretation seems a probable one, and it is belived that a further examination might demonstrate the presence of a structurally closed area near the northeastern part of T. 3 S., R. 27 E., or in the western part of T. 3 S., R. 28 E., where the supposed Wet Creek fold would intersect the structural line running north from the Shively Hill dome.

The report from Mr. Rohwer also mentions two small domes outlined in the Chugwater red beds about 4 and 7 miles east-southeast of the Shively Hill dome. The western one of these reported uplifts is apparently the object of the test well which trade journals report is being drilled by the Beauvais Creek Syndicate on the Lock ranch, in sec. 33, T. 5 S., R. 28 E.

From information at hand its seems that there is an extensive structural terrace east of Little Horn River between Crow Agency and Reno Creek, or perhaps more probably that a low dome, bounded on the southwest side by a fault, is present in this area, and that both dome and fault present a general parallel in shape and direction to the East Tullock Creek dome and fault, already described. The Parkman sandstone underlies this area, and the depth to the top of the Cloverly would therefore be about 3,300 feet, more or less, the exact depth depending on the geologic structure of the area. The Mowry shale, the probable gas-bearing stratum of the Bair well, northwest of Hardin, would be about 1,000 feet nearer the surface. Some gas might also occur in the Eagle, or even in the Parkman if a structural closure is present in the area. It would probably be possible to work out the geologic structure of this area in much greater detail than has yet been done, and it is strongly recommended that no drilling for gas be done in the area until a careful geologic study of it has been made.

Another area that may eventually warrant more detailed geologic examination lies along Sunday Creek in the northeast quarter of T. 6 S., R. 34 E. The Claggett shale, which underlies the Parkman, is the surface bedrock formation over most of this area but is largely concealed by soil and terrace gravels. It is probable, however, that enough exposures can be found to prove or disprove the suspected presence of a slight structural closure in this area.

Another small uplift, which might have slight possibilities as a source of gas, is suggested but by no means certainly present at the northwest corner of T. 8 S., R. 34 E., where the axis of the Soap Creek and Rotten Grass fold seems to intersect the slight anticline that appears to extend from north to south through the western parts of Tps. 6 and 7 S., R. 34 E. Reliable data are hard to procure in this

area, especially in the southern part, and it may not be possible to obtain conclusive evidence even by a very detailed study, which would seemingly be warranted only if success attends tests of the Rotten Grass dome. The base of the Niobrara shale is exposed along Lodge Grass Creek somewhere in the northwestern part of T. 8 S., R. 34 E., and beds of sandy shale and thin sandstone representative of the Eagle are present along the divide east of Rotten Grass Creek.

In conclusion, attention should be called to the probability that the southeasterly dips observable in the hills southeast of St. Xavier, taken in conjunction with observations made in Tps. 2 and 3 S., R. 32 E., indicate that the Soap Creek anticline forks at the north end of the Soap Creek dome, and that the eastern fork continues northward as a broad, low arch that approximately follows the valley of the Big Horn to the vicinity of Hardin. If the Woody Creek dome should ever yield commercial quantities of oil or gas it would seem worth while to make a careful examination of the west bank of the Big Horn at low water, and also to attempt to locate definitely the position of the east-west axis of the Woody Creek dome in the hills east of St. Xavier, as it might be possible in this way to predict the probable position of the small dome which theoretically should mark the point of intersection of these two axes of uplift. Attempts at exploitation at the present time do not, however, appear to be warranted in the area along the Big Horn between Soap Creek and Hardin.

Success in the exploitation of the Woody Creek dome would also warrant a careful study of the shale-covered area northeast of the Beauvais Creek district between the Woody Creek dome and the Mifflin anticline, as it is possible that small low uplifts may be present in that area.