POSSIBILITY OF FINDING OIL IN LACCOLITHIC DOMES SOUTH OF THE LITTLE ROCKY MOUNTAINS, MONTANA.

By A. J. Collier and S. H. Cathcart.

South of the Little Rocky Mountains, Mont., the beds of rock at a number of places have been arched upward into small domes by the heaving or bulging force exerted by masses of molten rock (laccoliths) beneath the strata. Some of these domes may contain oil. The chances of finding oil in them are undoubtedly small, but nevertheless they may present the most favorable conditions to be found within the general region where they occur. The following description of the geology of these domes is the result of a hurried examination during the summer of 1921. (See fig. 9.)

The Little Rocky Mountains, which are just north of these domes, form a prominent landmark, rising about 2,000 feet above the surrounding plains. They are 40 miles south of the Great Northern Railway at Harlem, in Blaine County. The nearest wells yielding oil or gas in commercial quantities are those that supply gas at Havre, 70 miles to the northwest, and those of the Cat Creek field, 70 miles to the southeast. Showings of oil and gas have been reported from nearer localities.

The rocks exposed in and around the Little Rocky Mountains are described in the following table:

Geologic formations exposed in the Little Rocky Mountain region, Mont.

Geologic age.	Group, formation, and member.	Thickness (feet).	Character.	Oil and gas in near-by fields.
Pleistocene.	Glacial drift.		Boulder clay containing granite and limestone boulders from Hudson Bay and Lake Winnipeg, shonkinite boulders from Snake Butte, quartzite and other pebbles from the Flaxville gravel and from the Cypress Hills of Canada.	
	Glacial silt.		Stratified clay deposited in lakes and ponds along the ice front.	
Tertiary (probably).	Pleistocene gravel and Flaxville (?) gravel.		Thin veneer of gravel on terraces sloping away from the Little Rocky Mountains.	
	Unconformity			

Geologic formations exposed in the Little Rocky Mountain region, Mont.—Continued.

Geologic age.	Group, formation, and member.			Thickness (feet).	Character.	Oil and gas in near-by fields.
Upper Cretaceous.	Montana group.	Bearpaw shale.		1,000±	Dark-gray shale of marine origin. Contains *Baculites*, ammonites, *Inoceramus*, and other fossils.	
	Montana group.	Judith River formation.		400±	Sandstone, shale, and thin beds of coal deposited in fresh and brackish water. Fossils, dinosaurs and many forms of fresh and brackish water invertebrates.	Yields gas in the Baker anticline.
	Montana group.	Claggett shale.		600±	Shale closely resembling the Bearpaw.	
	Montana group.	Eagle sandstone.		40–100	Light-yellow sandstone and gray shale of marine origin.	Yields gas at Havre and oil and gas in Lake Basin.
	Colorado group.	Warm Creek shale.[a]		775	Dark bluish-black shale of marine origin. *Baculites*, *Inoceramus*, etc.	
	Colorado group.	Warm Creek shale.[a]	Mosby sandstone member.	5	A rather thin calcareous sandstone containing many periwinkle-like fossils.	Possibly contains oil.
	Colorado group.	Warm Creek shale.[a]		360	Dark-blue marine shale. Very few fossils.	
	Colorado group.	Mowry shale.		50	Marine shale appearing on outcrop like broken porcelain. Abundant fish scales.	Contains traces of disseminated oil.
	Colorado group.	Thermopolis shale.		430	Dark-blue shale with lenses of sandstone, of marine origin. Few fossils.	
Lower Cretaceous.	Kootenai formation.			700	Sandy shale and lenses of sandstone. A lens of feldspathic sandstone (the Cat Creek (?) sand) near the top, a persistent feldspathic sandstone 60 feet more or less thick 100 feet above the base, maroon shale between these sandstones, and varicolored shale at the base. Probably wholly a fresh-water formation. Worm tracks near the middle; unios near the base.	Yields oil in the Cat Creek field. The most promising formation for oil production south of the Little Rocky Mountains.
Jurassic.	Ellis formation.			210	Greenish-yellow to brown limestone, shale, and sandstone of marine origin. Distinctive fossils, *Belemnites* and *Gryphaea*. Nearly equivalent to the Sundance formation of the Black Hills, S. Dak.	Reported to yield oil at Kevin.
	-Unconformity-					

[a] Named for exposures along Big Warm and Little Warm creeks, in the Little Rocky Mountain region.

Geologic formations exposed in the Little Rocky Mountain region, Mont.—Continued.

Geologic age.	Group, formation, and member.		Thickness (feet).	Character.	Oil and gas in near-by fields.
Mississippian.	Madison group.[b]	Mission Canyon limestone.	500	A massive white limestone of marine origin. Not so fossiliferous as the Lodgepole limestone.	Yields oil in the Soap Creek field.
		Lodgepole limestone.	800	Thin-bedded limestone and shale. Contains many fossils.	Contains albertite near Landusky.
Devonian.	Jefferson limestone.		350	Upper 250 feet massive dark limestone, lower 100 feet thin-bedded limestone. A few brachiopods, corals, and Stromatopora.	Fetid odor indicates the presence of disseminated oil. The Athabaska tar sand derives its oil from the Devonian.
Ordovician.	Big Horn limestone.		350	Light-colored massive sandy limestone. Fossils principally corals.	Fetid odor indicates presence of disseminated oil.
Cambrian.	Deadwood formation.		800±	Thin-bedded limestone, shale, sandstone, and intraformational conglomerate. Conglomerate or quartzite at base. Fragments of trilobites and a small brachiopod.	May be oil-bearing in favorable localities.
	-Unconformity				
Pre-Cambrian.	Schist.			Mica, hornblende, and feldspar schists.	No possibility of oil.

[b] In this part of Montana the Madison limestone becomes a group, divisible into two distinct formations, here named Mission Canyon limestone and Lodgepole limestone. The Mission Canyon limestone is so named because of its exposure in Mission Canyon, and the Lodgepole limestone because of its exposure in Lodgepole Canyon.

The older formations from the schist up to and including the Mission Canyon limestone of the Madison group are exposed principally within the mountains; the younger ones, from the Ellis to the recent formations, encircle the mountains. The rocks of the Judith River formation are exposed in many places—in fact, the Judith River is the prevalent formation of the plains in this vicinity. Sloping away from the mountains are terraces at different elevations, which are covered with gravel derived from mountains. This gravel, which conceals the underlying rocks in many places, is probably of Tertiary age and is thought to be, at least in part, equivalent to the Flaxville gravel. The Little Rocky Mountains are due to intrusions of porphyry, which raised the sedimentary rocks in great domes. In the center of the mountains the sedimentary rocks have been eroded from the domes, leaving large dome-shaped "buttes" of porphyry as the highest points. Around these are lower hills in which erosion has not progressed so far and the domes are still capped with sedi-

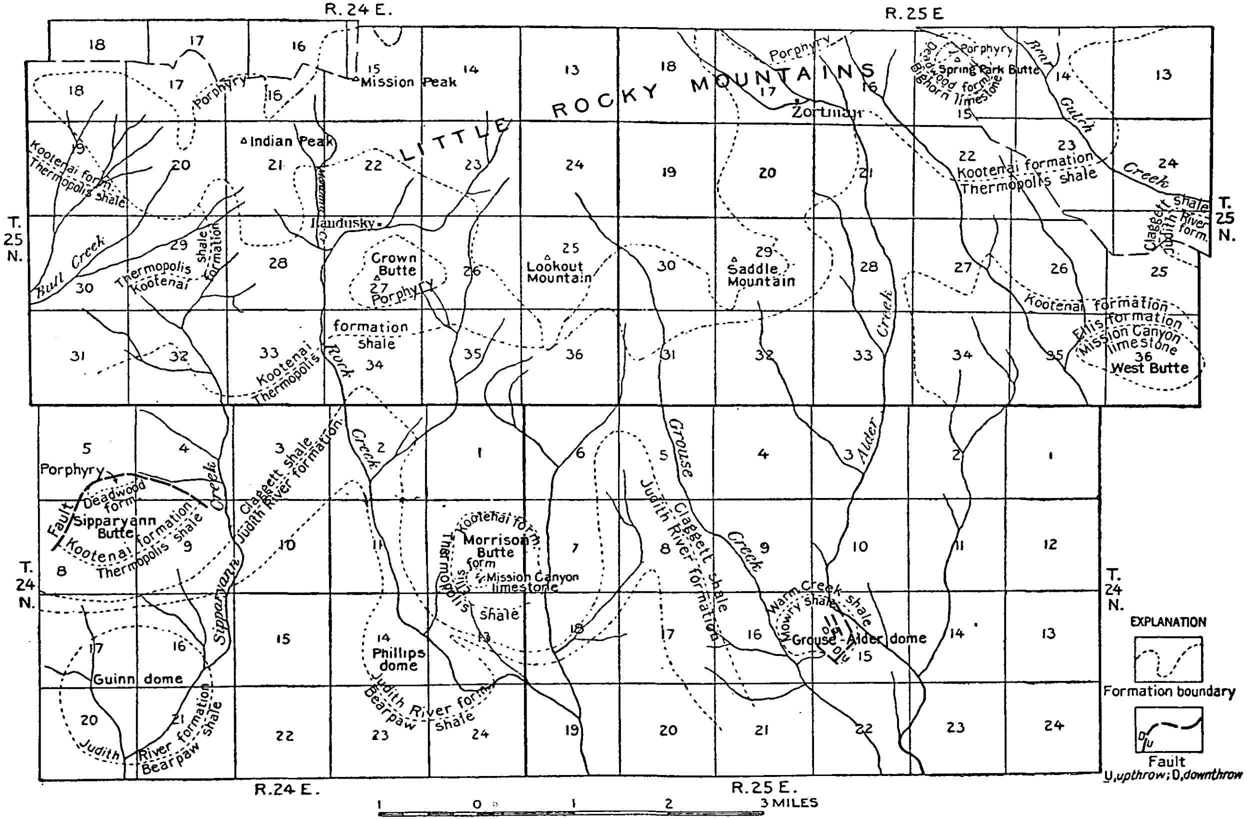

FIGURE 9.—Map of area south of the Little Rocky Mountains, Mont., showing location of laccolithic domes.

mentary rocks. Intrusions of this character are called laccoliths. In a laccolith the igneous magma, instead of flowing out on the surface through dikes or volcanoes, stopped rising at one or more horizons in the sedimentary rocks and spread laterally along the bedding planes, raising the rocks above it in domes. An ideal section of a laccolith is shown in figure 10. So far as has been determined, the laccoliths of the Little Rocky Mountains lie near the contact of the Deadwood formation and the underlying schist. The overlying beds were domed or lifted by the intrusion of the igneous mass, and the height of the schist in many places in the mountains indicates that there may also be large bodies of igneous rock that are deeply buried beneath the schist. Although the igneous porphyry invaded the pre-Cambrian schist and spread out in the Cambrian formation

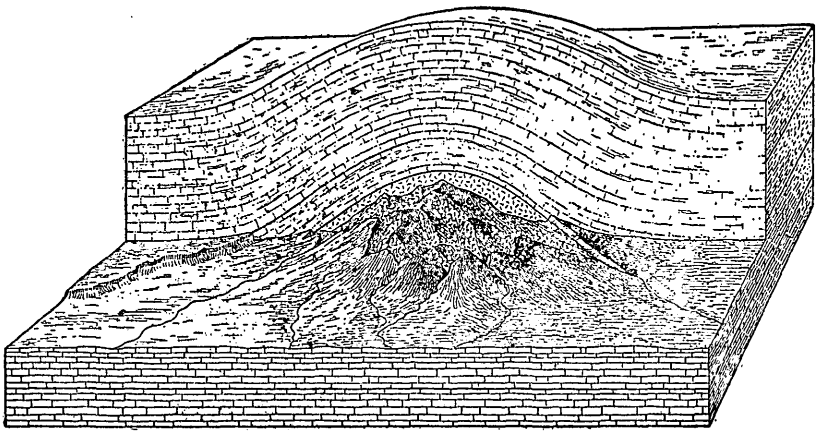

FIGURE 10.—Sketch and ideal section of a laccolith. The block at the rear shows the former position of the sedimentary beds after they were forced upward by the intrusion of the lava.

as laccoliths, it must not be inferred that the porphyry is nowhere in contact with the formations overlying the Cambrian, for as some of the sedimentary rocks are more or less rigid, in the process of intrusion they were doubtless broken and sheared rather than stretched by elongating and thinning. In places one or more of the formations are crushed and completely squeezed out of the section, and the overlying sedimentary rocks are thus brought into contact with the porphyry. In one place the igneous rocks cut across the overlying sediments as high as the Kootenai formation. In a few places the formations are faulted, and the porphyry is in contact with the dome of the Cambrian rocks on one side of the fault and with some higher formation which is not domed on the other.

The accompanying map (fig. 9) shows the larger area of porphyry in the central portion of the mountains. The higher points, such as Mission Peak, Indian Peak, and Lookout Mountain, probably indicate approximately the position of some of the vents through which the porphyry flowed upward. Saddle Mountain is a laccolith on which the overlying sedimentary beds are partly removed by erosion. Spring Park Butte is a laccolith in which erosion has proceeded just far enough to expose a little of the porphyry surrounded by Cambrian rocks. Sipparyann Butte shows a laccolith in which the overlying rocks on the south side have been faulted and raised, whereas on the north side the Warm Creek shale is undisturbed and is in contact with the porphyry. These facts indicate that West and Morrison buttes are laccolithic domes that have been eroded down to the Madison group; and that laccoliths underlie the dome surrounding the southwest corner of sec. 16, T. 24 N., R. 24 E., which is here called the Guinn dome; the dome on which the Phillips ranch house stands, in sec. 14 of the same township; and the Grouse-Alder dome, in secs. 15 and 16, T. 24 N., R. 25 E.

The Guinn dome is nearly circular and exposes the Judith River formation, the upper beds of which lie about three-quarters of a mile from the southwest corner of sec. 16, T. 24 N., R. 24 E., and in places form an escarpment surrounding the summit of the dome. The dips away from the crest are practically the same in all directions and are about 12° on the outer margin of the Judith River formation. A well drilled on the crest of the dome should reach the Eagle sand at a depth of about 800 feet, the Mosby sand at about 1,600 feet, the Mowry scale at about 2,000 feet, the Cat Creek (?) sand at about 2,500 feet, and the lower sandstone of the Kootenai at about 3,000 feet.

The Phillips dome, in secs. 13, 14, 23, and 24, T. 24 N., R. 24 E., exposes a small area of Judith River sandstone and is not so nearly circular as the Guinn dome, being flattened on the northeast side. The absence of exposures of bedrock on the northwest side renders that part of the mapping uncertain, but it is thought that the dome is fairly complete, having a good closure on all sides. The depths of the sands that are most likely to yield oil are about the same as in the Guinn dome.

The Grouse-Alder dome, in secs. 15 and 16, T. 24 N., R. 25 E., exposes the Mowry shale in an area of about half a section. The dips away from the summit are about 25°, but the shale is faulted so that its outcrops are repeated several times, and the whole outcrop covers a larger area than it would if not faulted. The faults are all small, having a displacement of less than 100 feet, and they probably have not permitted the escape of oil from the Kootenai sands. A well to test this dome properly should be drilled in the NE. ¼ sec. 16, where the Mowry shale lies nearly flat. Such a well would reach the Cat Creek (?) sand at a depth of about 500 feet and the large persistent sandstone of the Kootenai at about 1,000 feet.

The reports of other observers and meager observations of the writers indicate the probable presence of other domes more or less concealed by the gravel that covers the terraces south of the mountains, but the time available did not permit a detailed examination. No domes as promising as the southern domes were found on the north side of the mountains.

In most places where the bases of the laccoliths of the Little Rocky Mountains are exposed the igneous rock invaded the Cambrian formation along horizons near its base; in relatively few places did it invade higher beds. It is probable, therefore, that the laccoliths underlying the Guinn, Phillips, and Grouse-Alder domes do not extend above the Cambrian formation. Their depth below the Kootenai is therefore about 2,800 feet, and it is probable that the heat transmitted through so great a distance was not sufficient to drive off any oil that may have accumulated in the Kootenai and overlying formations. Even though oil may have been expelled from the sands by the heat of the intrusion, the domes are structurally suitable to gather any oil that may migrate up the slope of the rock beds from formations outside the area affected by the intrusion.

Thin beds of coal occur in the Kootenai formation. Two samples, one taken in sec. 22, T. 25 N., R. 25 E., 2 miles east of Zortman, and the other in sec. 34, T. 25 N., R. 25 E., 3 miles southeast of Zortman, were analyzed by the Pittsburgh laboratory of the Bureau of Mines and show the fixed carbon in pure coal (water and ash free) to be 55.8 and 56.7 per cent, respectively. As the carbon ratio that would preclude the presence of oil is more than 60 per cent, the Kootenai formation in the vicinity of these coals has evidently not been metamorphosed sufficiently to drive off any oil that may have accumulated in it.

As the rocks dip away from the mountains and as the Bearpaw shale is exposed in the Missouri River canyon 15 miles south of the mountains, the domes probably have a large collecting area for oil. The most promising sands in the domes can be tested with rather light drilling rigs. All the possible oil sands of the Kootenai formation can be reached within 1,000 feet by drilling in the Grouse-Alder dome, in secs. 15 and 16, T. 24 N., R. 25 E. The possibility of finding oil in the Eagle sandstone, Mosby sandstone, and Mowry shale can be tested by drilling in the Guinn dome, in secs. 16, 17, 20, and 21, T. 24 N., R. 24 E., where the Eagle sand lies at a depth of about 800 feet and the Mosby sand at a depth of about 1,600 feet.

The only formation in this region in which an oil residue was actually seen is the Lodgepole limestone near Landusky, where albertite occurs in a fissure. A test of this formation in the Grouse-Alder dome would require drilling to a depth of about 2,700 feet, but owing to the close proximity of the igneous rock below this limestone such a test is probably inadvisable.