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GEOLOGY OF SOUTHERN JACKSON COUNTY AND VICINITY

by

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GEOLOGY OF SOUTHERN JACKSON COUNTY AND VICINITY

A short field season in the summer of 1952 was spent in the search for possible upwarps favorable for oil prospecting in Jackson County. Owing to the Pierre clay being the only outcropping formation in the Bad River drainage basin of the north half as well as in a strip 10 miles wide in the east of the county, effort was confined to the remainder. Favorable structure found is noted at the end of this account. Work on development of the plains surface supplements that formerly done in Gregory and Lyman counties, resulting in a comprehensive view of the Pleistocene history of Dakota plains.

SURFACE OUTCROPPING FORMATIONS

Pierre Clay - The greatest thickness of outcrop of the Pierre is near the eastern county line where 350 feet is exposed. The water well at Kadoka penetrated about 1500 feet of Pierre which may be its full thickness. The formation is a structureless, massive, blue grey clay, largely composed of bentonite, which by expansion when wetted causes slaking upon exposure, first disintegration into cracked or joint clay, next into thin flakes and finally into dust particles easily removed by wind or water. It is easily undermined in meander bends of water courses, forming landslides, and where thoroughly lubricated by moisture forms earth flows down the slopes. Where longest exposed, in the eastern part of the county, it produces a characteristic hummocky or dimpled surface. Because of its relative impermeability and content of alkali, the eroded slopes support only a sparse vegetation of grass, the steeper slopes being bare, since there the clay is constantly in motion either downwards under influence of gravity and water in motion, or else being removed by the wind. Since the topography is generally mainly sloping (in the mature stage), little or no real soil, in this region mainly a wind deposit, can accumulate.

The single bed of exposed clay shows little difference from top to base. There are thin layers of silt, as on the bluff on the north side of White River just above the bridge on Highway 73 south of Kadoka. There and elsewhere are thin limy layers. At the top around Kadoka and farther west, there are concretions cemented by dark, rusty, yellow-brown hydrous iron oxide. In places lower in the clay are blue grey clay ironstone concretions cemented by iron carbonate, and veined with honey-yellow calcite. Fossils are rare, probably because the original volcanic dust forming the formation was rapidly deposited; they are ammonites (Acanthoscaphites), uncoiled ammonites (Baculites), and large fibrous-shelled clams (Inoceramus).

At the time the formation of the overlying White River Oligocene began, the Pierre virtually non-resistent to removal agencies, had been stripped down to a flat surface, known as a peneplain. This was deeply weathered under a climate different from that of the present and likely sufficiently warm and moist to be subtropical or tropical like that producing the reddish residual soil known as laterite. The ancient subsoil is tan, yellowish or yellowish-brown while the surface soil is dull, dark maroon or purplish red.

Fox Hills (?): The Bad-White River divide at Kadoka and vicinity is covered largely with wind-deposited loess, but some artificial excavations reveal thin platy grey sandstones interbedded with grey clay. No fossils were found in the scanty exposures which may belong to Fox Hills. One of the best exposures is the south wall of the excavation for the reservoir near the northwest corner of Sec. 20, T. 3 S., R. 22 E., one and one-half miles north of Kadoka Junction.

White River Oligocene: The uppermost Cretaceous, the Paleocene, and the Eocene rocks are missing in this area, in which up to about 400 feet thickness of Oligocene rocks rest upon Pierre clay. The Oligocene deposits, named for White River, and famous for a century because of their fossils of fur-bearing animals, have been described in another publication by the writer*, and only a summary account will be given here.

At the base in many places is a pebble or boulder bed, ranging in thickness from perhaps a foot down to merely a thin line of pebbles. The materials are largely angular pieces of

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*How the South Dakota Badlands Formation was Made, Proceedings of South Dakota Academy of Science, Vol. XXX, 1951 silicified wood, or larger worn and battered fragments of logs up to larger than a foot in size, which contain uranium and are apparently derived from Fort Union Paleocene deposits, once existent in the territory, quartz, chert, feldspar, limestone and dolomite, some of which are highly polished either by wind or water. In places these pebbles cover the surface, forming a "desert pavement", the overlying, easily removed, fine, unconsolidated material often having been stripped back long distances along the Pierre-White River contact. Paleozoic fossils, likely from Black Hills rocks, occur in some of the chert, limestone, and dolomite pebbles. Above the pebble bed is a gleaming white, fine, angular sand, generally only a few feet thick, above which the strata are largely bentonite, derived by hydration and leaching from original volcanic dust settling out of the air. The highest part of the Oligocene is unaltered volcanic dust, such as occurs in the uppermost exposures at Cedar Pass, but most is bentonite. Many of the bentonite zones have a surface wooly or shaggy appearance, owing to disintegration to powder upon drying; these are greasy or soapy and slippery when wetted. Other interbeds, which are apt to have steeper surfaces, have hardening on the outside, because of efflorescence and deposition near the surface of limy and alkaline salts brought to the exterior by capillarity. At a short distance beneath the surface, practically all White River except the lower sand, becomes hard and tough but moisture penetrates and softens - largely by increase of volume causing slaking - the surface zone, which powders when dry. Blocks falling or rolling down steep slopes into bottoms of ravines become fused with the ravine walls, the rain water flowing beneath, hence "natural bridges" are common. Prevalent colors are ashy grey and buff though broad color bands of dull rose pink are often regular enough to enable one to determine the dip. Also, especially south of White River, south of Kadoka, certain layers in the lower part, sandier than the intervening, are cemented harder by lime, giving rise to a terrace or stairstep profile. In this eastern part of the outcrops true stream channel deposits are quite rare and it appears that nearly the whole is composed of material brought in by winds and settling out of the air.

The upper part of the White River Oligocene is unaltered volcanic dust or "ash". This is the only part of the formation permeable enough to absorb moisture and hence juniper trees (so-called "cedars") grow on it; in the underlying bentonite about the only plant is the gumbo lily.

Rosebud Miocene: W. D. Matthew and J. W. Gidley in 1904 named the Rosebud beds, stating they are especially well developed along the South Fork or Little White River in the vicinity of the Rosebud Indian Agency. They are equivalent in age to a part of the Arickaree formation though it is not certain that the latter term is synonymous, therefore, Rosebud is preferable beacause more definite.

The Rosebud appears to be nearly without bedding planes and weathers on the surfaces to large and small nodules. The prevailing color is cream to buff. In composition it is a sandy, volcanic ash, containing numerous shards (splinters and flakes) of volcanic glass. Both sand and volcanic dust have been deposited both by wind or water though the massiveness (lack of bedding plains and channel deposits) indicates that the wind was the main transporting and depositing agent. However, there are a few granules and small pebbles probably transported and deposited by running water. Garnet, feldspar, zircon, magnetite, apatite, chert, chalcedony, and bentonite occur, all but the last three in sand or silt size grains. Cement is either lime or chalcedonic silics. Mammalian fossils show the age to be lower and middle Miocene. Since the Rosebud is not so bentonitic as the White River it weathers into sharper, more angular forms, vertical joints being cemented harder with chalcedony and producing buttresses. For the same reason, it is more permeable to rain and melting snow water than the White River, western juniper and jack pine growing upon it.

Little of the Rosebud remains in Jackson County - only the caps of some of the pinnacles in the vicinity of Cedar Pass north and northwest of Interior. Owing to a south dip, its outcrop is mainly south of White River, especially in the basin of Craven Creek, where there exist the roughest and wildest badlands. Another good exposure is along the upper part of the grade where Highway 23 climbs the south rim of the basin of Pass Creek, south of Kadoka.

Pleistocene and Recent Water and Wind Deposits: These may be divided into two: (1) the water transported and deposited terrace and flood plain sediments, mainly of White River, and (2) the wind transported and deposited silty to fine sandy loess covering the flatter surfaces.

the southeast corner of Sec. 18, T. 2 S., R. 21 E. They have been reconcentrated in successively lower terraces deposited as White River has cut its course deeper.

The other class of alluvium is that covering the flattish rock pediments sloping in the direction of White River from the foot of steep badland slopes eroded in the White River formation. The most extensive and lowest of these pediments are north of White River, sloping southwards for long distances from the south base of the wall of the badlands, but remnants of higher ones are widely distributed. Owing to the bentonitic content of the White River formation, which supplies the debris, the water-transported material is crumbly and also generally pebbly, being mud balls bound together by the plastic bentonite.

The loess, of the texture of silt to fine sand, covers all flattish surfaces, such as the flood plain of White River, the stream terraces, the pediment slopes and the upper part of the White-Bad river divide. It covers much of the bedrock of the riverine divide north and west of Kadoka and the north faces, or steps, of the terraces, which are mainly south of White River. It is still being brought in by the winds, especially the northerly and northwesterly ones, and lodges wherever trapped by the grass cover. There are places where it is as much as fifteen feet thick. Its color is tawny, buff or light yellowish-brown. It produces the only real soil in the region.

SUBSURFACE GEOLOGY

The rock section, all of Cretaceous age, penetrated in the Kadoka water well, from surface downwards, is as follows:

Pierre:	Blue grey bentonitic clay with 180 feet of Sharon Springs black, bituminous shale at base	1550 feet
Niobrara:	Blue grey chalk-spotted marl (limy clay)	140 "
Carlile:	Blue grey clay shale	365 "
Greenhorn:	Shell-breccia limestone, light grey	35 "
Graneros:	Blue grey shale	257 "
Dakota:	Water-bearing light grey fine-grained sandstone	100 "
Fuson:	Bentonitic, vari-colored clay	110 "
Lakota:	Water-bearing, light grey, fine-grained sandstone	115 "
	Shale, blue grey	185 "
	Sandstone, as those above, water-bearing	100 "

Probably some Paleozoic, more likely Minnelusa Pennsylvanian and Madison Mississippian rocks, with perhaps some older formations, will be encountered on deeper drilling.

DEVELOPMENT OF THE PRESENT SURFACE

Presumably the entire surface of Jackson County has been eroded beneath the level of the former early Pleistocene depositional plain. An old age erosion surface occurs near the head of northward-flowing tributaries of Bad River, being well represented along the highway between Kadoka and Cedar Pass. Below this level come two widespread terraces of White River, one 160 feet above the river channel and the second, or higher 160 feet above the first. The surfaces of both have the same amount of fall downstream as the present river namely, 8.9 feet per mile. These two terraces are much better preserved to the south of the river than to the north. However, the higher, somewhat eroded, is the White-Bad river divide at Belvidere, extending from about two miles west to three miles east of the town. Remnants of the lower terrace occur in Sections 1 and 11, T. 3 S., R. 24 E., and Sec. 13, T. 3 S., R. 22 E., and more abundantly, near White River west of the east line of R. 20 E., all in southern Jackson County. The older and higher terrace is pre-glacial, being the highest terrace at the junction of White and Missouri Rivers.

East of the west line of Range 21 East, the White-Bad river divide lies close to White River; in fact it is within a mile of the river around the northeast corner of Sec. 29, T. 2 S., R. "5 E. Connected with this is the remarkable fact that the north-flowing tributaries entering White River from the south are several times as long as its south-flowing tributaries entering from the north,the latter being true throughout White River drainage basin.

The northern tributaries of the North Platte River in Nebraska are likewise much longer than that river's southern tributaries. Another significant fact bearing on our problem is that the Arkansas River in eastern Colorado flows at a higher level than that of the country farther north and south.

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East of the west line of Range 21 East, the White-Bad river divide lies close to White River; in fact it is within a mile of the river around the northeast corner of Sec. 29, T. 2 S., R. 25 E. Connected with this is the remarkable fact that the north-flowing tributaries entering White River from the south are several times as long as its south-flowing tributaries entering from the north, the latter being true throughout White River drainage basin.

The northern tributaries of the North Platte River in Nebraska are likewise much longer than that river's southern tributaries. Another significant fact bearing on our problem is that the Arkansas River in eastern Colorado flows at a higher level than that of the country farther north and south. Also, at the present day, the land surface along the White-Niobrara river divide, near the Nebraska-South Dakota boundary, is higher than that of South Dakota farther north to the east of the outer hogbacks of the Black Hills, and that this higher (strictly speaking, High Plains) surface continues southwards from the White-Niobrara river divide to the southeast end of the Staked Plains of Texas, all the High Plains being a depositional surface. The eastward extension of what may be called the High Plains depositional surface (distinguished from the lower eroded plains surface), situated both south and east of the Black Hills, is directly east of the eastward offset of the Rocky Mountains from the south end of the Wind River Mountains in west-central Wyoming to the northeast end of the Laramie Mountains in central-southeast Wyoming. Another pertinent fact is that the depositional high plain forms the White-Niobrara river divide in Gregory County, South Dakota, its deposits occurring at least one place east of the Missouri River, namely northeast of Pickstown in Charles Mix County. Its intermixed cross-bedded stream-laid sands and fine gravels contain an early Pleistocene fauna older than the appearance of true elephants (mammoths), bison and musk oxen, and true or equine horses.

What, therefore, apparently happened is that an early Pleistocene river system, more or less corresponding with the present upper North Platte to as far east as Douglas, Wyoming, deposited a compound alluvial fan or land delta between the present White and Lower North Platte rivers. A network of stream distributaries, shifting here and there to lower places as former channels were built up, exactly as are found today beyond the west base of the Sierra Nevada in the great interior valley of California, derived the deposits they made from erosion of the recently upraised Rocky Mountains of Wyoming. Deposition ended with both North Platte and White Rivers occupying the south and north lower margins of the depositional surface. Thereupon, apparently the middle North Platte, favored by greater rate of fall to the Missouri than the ancestral White, extended its course headwards and captured the Wyoming part of the lower Pleistocene river. Or, perhaps more correctly, the White and Niobrara began as distributaries of the North Platte.

Aside from decrease in amount of fall and loss by evaporation, the cause of deposition of the sand and gravel fan was seepage of water into the pervious deposits. The imbibing of the surface water prevents formation of surface valleys in the sand and gravel area except where streams, eroding less permeable underlying material, have extended headwards their courses into the old fan area. There operates in this area, aside from water in motion, another potent agency removing the sand. This is the wind. The strongest eroding winds blew here from the north-northwest, as shown by the direction of the southern tributaries of White River and other secondary streams throughout western South Dakota as well as by the longer direction of wind-scooped or grooved hollows on the lower

White River terrace, which action becomes more intense going westwards until it becomes very important in the vicinity of Imlay section house on the Milwaukee Railroad, but is already quite noticeable on the terrace surface south of the river south of T. 4 S., R. 19 E. A third proof of the efficacy of the wind as an eroding agent is the great sandhill belt of western Nebraska, the northern edge of which reaches a few miles into South Dakota to the south of Jackson County. The Nebraska sand hills have their steeper sides facing south, proof that the sand is moving southwards, driven by the prevalent wind. Much of the sand evidently must have been derived from southern South Dakota where, once removed from the surface, the drainage lines or valleys rapidly extended themselves southwards and headwards through the less permeable formations. Thus have grown longer the southern White River tributaries.

White River itself has shifted its channel northwards in its northward bend east of Range 19 E. to as far as south of Murdo, Jones County, as shown by its course being close to the White-Bad river divide and likewise by the much greater development and preservation of the two terraces south of the river. Also, the valleys of all important south side tributaries become constricted into bottle necks across the lower terrace, just as streams extend their courses in valleys, younger than higher up, where they cross a recently uplifted coastal plain. So notable are the constrictions that the interstream areas are triangular, the triangles having their bases on White River and their apices to the south, the edges of the triangles being bounded by the steep slopes of rejuvination of present drainage lines, below the lower terrace level. Part of the lower course constrictions is attributable to the permeable loess above, and sand and gravel below composing the terraces, seepage of rain and snow water into which is unfavorable for the growth of side gullies.

However, the main cause of northward shifting of the river valley apparently is something else than the above, being really the almost total lack of resistence to denudation of the bentonitic and impervious Pierre clay, thicker north of the river than south, the general dip of the formations being southwards. As a consequence of the swelling, heaving, spalling, and caving of the Pierre, becoming sticky but viscous when wet but disintegrating to powder when dry, and the fact that it does not readily absorb water beyond the very thin surface film, all rainfall and meltwater from snow is concentrated in rapid runoff favoring rapid deepening of drainage courses all the way from rill to river. The more rapid denudation north of the river, forming a mature topography on the Pierre east of Range 19 E., has led to a northward shifting of the White's channel until it is now encroaching on the Bad River drainage basin.

There is a possibility that at a former time White River may have occupied the present eastward-draining course of Cottonwood Creek in the middle of the west half of Mellette County, the present northward bend along the eastern Jackson and western Jones county boundaries having been cut subsequently.

There is close similarity between the recession of Pierre slopes and pediment formation in exposures of the Oligocene White River formation. A pediment is a flat produced by denudation adjacent to highlands rising abruptly above the pediment surface, the latter having a gentle slope in the direction of drainage flow, the rate or angle of slope decreasing with the distance from the highland base. One of the best pediments of this entire region, floored with Pierre overlain by detritus from Oligocene badlands, in turn mantled with loess, extends southwards nine miles along the road from the south foot of the badland wall southeast of the Pinnacles to about a mile south of Conata railroad siding. Where uneroded near Conata the southward slope, here lowest, is about 20 feet per mile, or about twice the average rate of fall of White River channel in the vicinity. The longest pediment in Jackson County extends southwards from the south foot of the wall of the badlands at Chamberlain Pass (Sec. 35, T. 2 S., R. 20 E.) 6½ miles to NE¼, Sec. 1, T. 4 S., R. 20 E., the average rate of southward slope being about 25 feet per mile, though in the first mile southward from the foot of the wall the slope is 50 feet. Rising abruptly out of the pediment flat are a number of long, narrow bedrock ridges, most of the slopes of which are too steep and slippery to climb. However, the area exhibits other pediments ranging downwards to less than an acre in area and situated at widely varying altitudes.

One can note from a viewpoint on top a narrow badland ridge that many of the drainage ways lie at the very bases of the steep bedrock slopes, or else that those bases are swept bare of vegetation. From these facts it can be deduced that erosive action of water flowing down rills and gullies is greatest where it reaches its maximum velocity which is at the bases of the steep bare slopes at junctions with the lower and flatter bases. Along this line of junction, therefore, the steep slopes recede and so the pediment flats are constantly widening and lengthening. In this region also, all fine loose material upon drying is carried away by wind, leaving water courses without soil and consequently bare of vegetation. Pediment flats are grassed and they are destroyed and diminished mainly by cloudbursts affording enough water to fall over their edges which, where concentrated in rills and rivulets, cutting first through the grass cover by headward undermining, rapidly increase the length of gullies. White River, so long as it has notable volume and current, has a grey milky color from its suspended load of bentonite, the color of the water having given the name to the river. In times of flood it carries a very heavy load of mixed sand, silt and clay which explains its notably meandering course, due to heavy sediment load. The width of the river flood plain averages perhaps a mile. At present the river appears to be straightening its course, leaving abandoned oxbows which have more extensive loopings. This might be attributed to a decrease in sediment load, but perhaps more likely is caused by an increase in the rate of fall of the channel. This in turn may be caused by the master river, the Missouri, cutting its bed to a lower level. Also, runoff, increasing water supply, may be due to grazing since the establishment of ranching denuding the basin by destruction of the grass cover, increasing volume (intensity) of flood stages, another possible factor, hard to evaluate because rain and snowfall statistics available are for far too short a time, is a dry cycle in which precipitation (rain and snow) is concentrated in fewer intervals of greater intensity. At least there has arisen the impression that floods throughout the West are becoming greater in volume.

STRUCTURE

The construction, largely by mechanical process, of large scale accurate topographic maps with 10 foot contour interval in the valley of White River has made it possible to determine fairly rapidly the structure of the contact between Pierre and White River formations. Apparently structural determinations with these topographic maps is about as accurate as by the older and slower method by plane table using telescopic alidade and stadia rod, since sapping, or underminining by flowing, landsliding and slumping, in the Pierre gives a margin or error regardless of what method is used to determine structure.

Since the very poorly resistent Pierre has a surface long eroded by the beginning of White River time, the probabilities are great that it was very nearly flat, or in other words, peneplaned. Quite certainly it was not so hilly, in such broad ridges and valleys, as the present altitudes. Where not covered, the contact can be followed quite readily because the highly colored reddish and yellowish surface weathered zone of the Pierre contrasts with the fine whitish basal White River sand even where the pebble to boulder zone of the latter is lacking. Mapping shows the existence of closed basin downwarps (synclines) and not valleys.

The evidence shows a regional dip to the south into a basin or downwarp somewhere south of the area mapped. In the vicinity of Belvidere the rate of southward dip is about 25 feet per mile on the average, which is slightly greater - nearly 30 feet per mile - west of Kadoka on the line between Ranges 20 and 21 East. There is a cross downwarp about half way between Belvidere and Kadoka almost directly south of which, south of White River, there is evidence of the south half of a broad dome (upwarp).

Better data are available farther west where the Pierre-White River contact approaches the channel of White River. As can be seen on the structural contour map included with this report, the major structure is a large syncline 100 feet deep and more than 10 miles long, extending in east-southeast direction from Weta railroad siding, the eastern half lying south of White River. This is followed to the southwest by a narrow anticline four or five miles long with dips on either flank of about 50 feet per mile. The dips on either flank of the axis are especially prominent south of the river in Sec. 17, T. 43 N., R. 36 W., on the east side of Fifteen Creek valley and near the middle of the south half of Sec. 24, T. 43 N. R. 37 W., on the east side of Long Creek valley. Continuing the axis of the upwarp (or anticline) NNW, is an outlier of Pierre clay entirely surrounded by White River formation in Secs. 35 and 36, T. 3 S., R. 19 E., and the north parts of Secs. 1 and 2, T. 4 S., R. 19 E., where, because of regional updip to north the domical upwarp of the Pierre-White River contact reaches an altitude of about 2400 feet; there is a dip of 4 degrees southeast near the NE corner of Sec. 1, and a southward dip of the same amount in NE$\frac{1}{4}$ NW$\frac{1}{4}$ Sec. 2.

West of the upwarp just mentioned, is a broad downfold two townships wide which carries the White River-Pierre contact beneath river from Sec. 7, T. 4 S., R. 20 E., upstream to the Pennington-Jackson county line near NW corner Sec. 7, T. 4 S., R. 18 E; very likely this is the major downwarp of the region into which, in general, the strata of southern Jackson County dip from the north southwards.

CONCLUSIONS

The best situation for test borings for petroleum are: (1) near the middle of the line between Secs. 35 and 36, T. 3 S., R. 19 E., and (2) in SW$\frac{1}{4}$ Sec. 12, T. 4 S., R. 20 E. Success will depend upon two contingencies: (a) whether underlying rocks contain or will yield oil or gas in paying quantities, and (b) whether proper methods of drilling and adequate testing are used. The nearest deep test well being 40 miles away, it is inadvisable to predict, before drilling, what rocks may underlie the Cretaceous known in the Kadoka water well. It is the writer's judgement that methods of rotary drilling with heavy circulating mud are not conducive to adequate testing for oil. One reason for this is that Cretaceous sands are fine-grained and if Paleozoic or Jurassic rocks are encountered lower down, they may be prevailingly "tight", that is, have usually poor permeability, hence the hole should be empty of fluid in order to permit oil to show up in it. Apparently, geophysical methods to date are not sufficiently precise to locate the low structures of the Dakota plains.