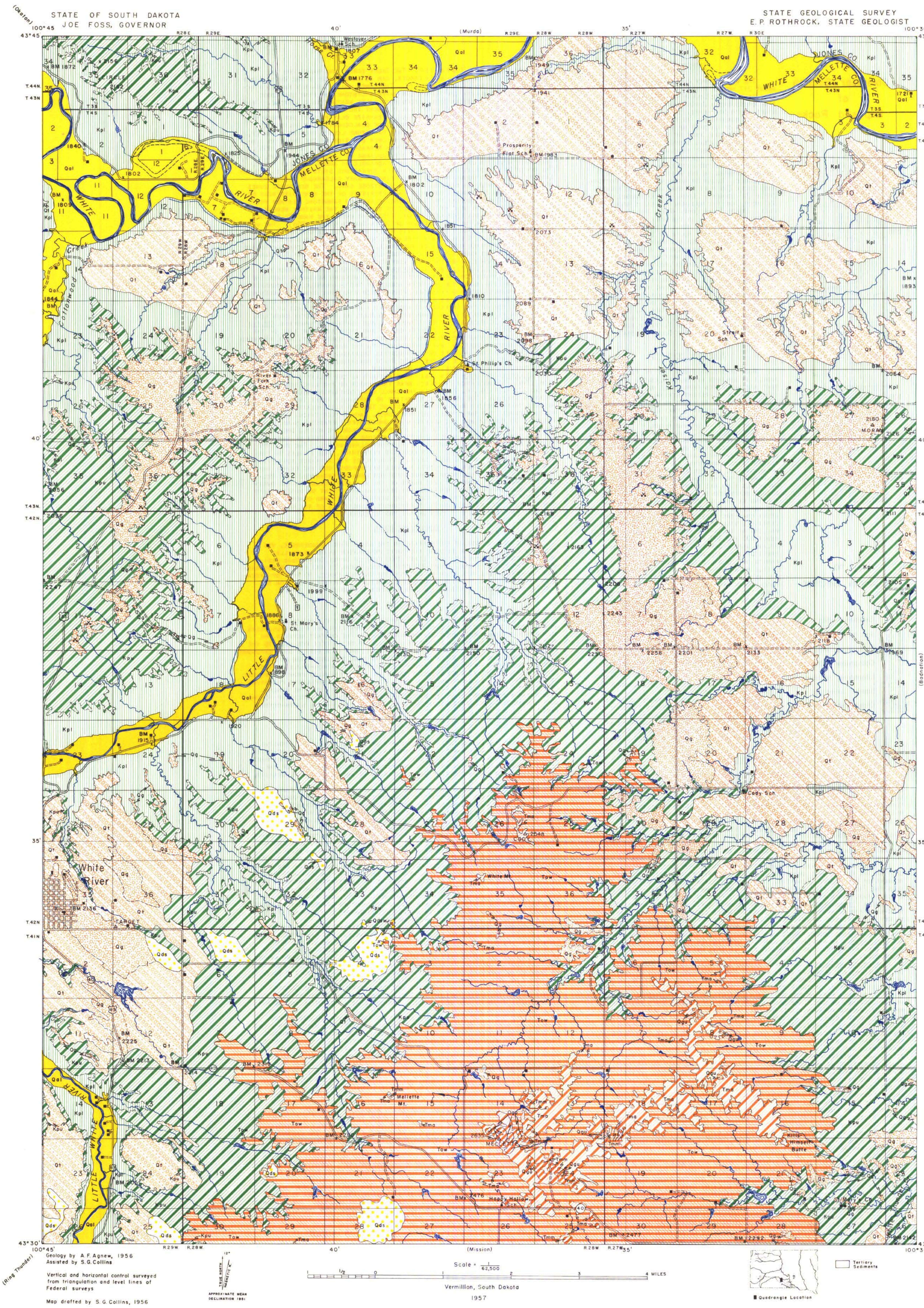
AREAL GEOLOGY
OF THE
WHITE RIVER QUADRANGLE

STATE OF SOUTH DAKOTA
JOE FOSS, GOVERNOR

STATE GEOLOGICAL SURVEY
E. P. ROTHROCK, STATE GEOLOGIST



Geology by A. F. Agnew, 1956
Assisted by S. G. Collins

Vertical and horizontal control surveyed from triangulation and level lines of Federal surveys

Map drafted by S. G. Collins, 1956

Vermillion, South Dakota
1957

EXPLANATION

QUATERNARY

RECENT

Qal — Alluvium
(Floodplain deposits of silt, sand, and gravel, with local low terraces and sand dunes; in valleys of major streams)

Qds — Dune Sand
(Eolian deposits of sand, mainly clear quartz with some darker minerals; forms dunes on uplands with local blowouts)

?

PLEISTOCENE

Qt — Terrace Deposits
(Fluvial deposits of silt, sand, and gravel; about 200 and 300 ft. above present valleys of major streams)

Qg — Middle Gravel
(Fluvial deposits of gravel and sand, mainly quartz and greenish feldspar but with some darker minerals and fragments of rocks derived both locally and from Black Hills; caps middle elevations)

Qgu — Upland Gravel
(Fluvial deposits of gravel and sand similar to Qg but with little locally-derived material; caps buttes)

? ?

TERTIARY

MIOCENE

Tmm — Mellette Formation
(Tuffaceous silt, mainly reddish but some olive-gray; ledges of flesh-colored fine-grained dense limestone 2-7 ft. thick, at 16, 55, and 78 ft. above base; limestones weather in relief; middle and upper limstones contain small gastropods; thickness of formation 78 ft.)

Tma — Arikaree Formation
(Basal reddish cross-bedded sandstone, partly conglomeratic, 5-7 ft. thick; olive blocky shale, with pinkish thin finely granular tuffaceous limestone and gray tuffaceous siltstone at base, 75-77 ft. thick, with vertebrate fossils; thickness of formation about 82 ft.)

UNCONFORMITY ?

OLIGOCENE

Tow — White River Group (Undifferentiated)
(Chadron formation, below.-- Olive bentonitic clay with basal gravel mainly of clear quartz; 20-40 ft. thick; unconformity at base. Brule formation.-- Lower unit: interbedded pale pink and gray silty tuff, tuffaceous silt, and bentonite; weathers to stairstep profile; 110 ft. thick. Upper unit: greenish and pinkish bentonite at base, pink and greenish tuffaceous siltstone in middle, and pinkish bentonite at top, respectively 25, 20, and 32 ft. thick. Brule thickness 187 ft. Thickness of White River group 207-227 ft.)

UNCONFORMITY

CRETACEOUS

UPPER CRETACEOUS

Kpu — Pierre Shale; Upper Unit
(Lower part-probably Mobridge member: dark gray marine shale, very calcareous, marly, blocky, white specked; 80 ft. thick. Upper part-probably Elk Butte member: yellowish gray marine shale, blocky, limonitic; weathers yellowish-brown; gypsum and limonite along veins, bedding planes, and thin bentonite layers; septarian concretions with cone-in-cone at top; 130-150 ft. thick. Thickness of unit 210-230 ft.)

Kpl — Pierre Shale, Lower Unit
(Lower part: gray to dark-gray marine shale, blocky to platy, partly covered and slumped; at least 195 ft. thick. Upper part: gray to dark-gray marine shale; gray limestone nodules, many with fossil nuclei, in upper 25 ft.; upper 90 ft. calcareous. Thickness of unit at least 285 ft.)

Contact
(dashed where approximately located)

Gravel Pit

x BM 2139
Bench Mark
(monument showing exact altitude above sea level)

x 2635
Spot Altitude

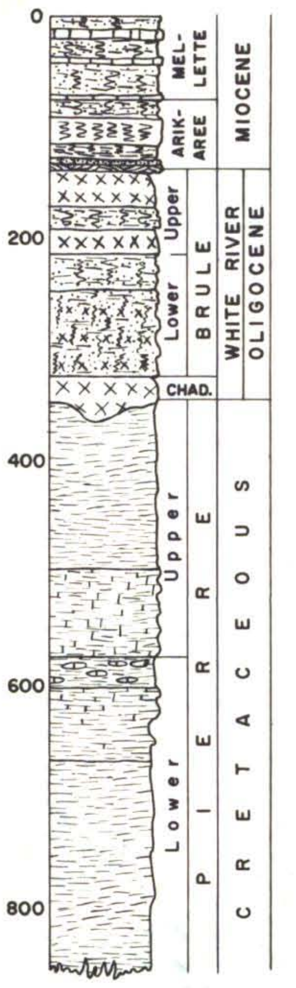
△ Mellette
Triangulation Station
(monument marking exact geographic location)

GEOLOGY OF THE WHITE RIVER QUADRANGLE

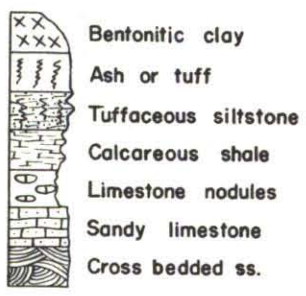
By

Allen F. Agnew

Columnar Section of Exposed Rocks



Key to Columnar Section



INTRODUCTION

The White River quadrangle includes about 217 square miles in the north-central part of Mellette County and the adjoining part of southern Jones County, and is 45-60 miles south of Pierre.

The quadrangle, in the relatively little-known area of outcrop of Tertiary rocks in the south-central part of the State, is in the Missouri Plateau section of the Great Plains physiographic province. The White River crosses the northern part of the area; it is joined by the Little White River, which flows northward in the western part of the quadrangle. Major tributaries include Cottonwood Creek (NW part of map) and White Thunder Creek (SE corner). Local relief ranges up to 350 feet, and the maximum relief is about 900 feet. White River (pop. 465), the county seat of Mellette County, is the only settlement of this rather sparsely populated region. U. S. Highway 83 and State Route 40 cross respectively the western and southern parts of the quadrangle. A well-developed network of unsurfaced roads serves most of the region; those underlain by shales are impassable when wet. The climate is characterized by a wide temperature range, an average rainfall of 19 inches per year, and by strong winds.

The geology was mapped during the summer of 1956 under the supervision of Dr. E. P. Rothrock, State Geologist. Drs. A. L. Lugn, J. R. Macdonald, and C. B. Schultz generously shared their knowledge of Tertiary stratigraphy and paleontology of South Dakota and Nebraska.

SURFICIAL DEPOSITS

Much of the northern half of the quadrangle is covered by unconsolidated deposits that are separated into three main groups: (1) alluvium in present stream valleys, (2) terrace deposits adjacent to these valleys, and (3) gravel deposits that represent old stream channels. A fourth type, wind-blown dune sand, lies on upland areas.

Stream deposits. Alluvium (Qal) consists of quartz silt, sand, and gravel, which resulted from reworking of bedrock and older surficial deposits, and is confined to present stream valleys. It is mostly of local origin, derived from Tertiary beds and from rocks of the Black Hills. Terrace materials (Qt) are quartz silt, sand, and gravel deposited by Pleistocene streams, whose ponding by the ice front to the east caused the material to be laid down over larger areas than the present streams affect. Two terrace levels are present along the present valleys of the White and Little White Rivers, about 200 and 300 feet above their floors. Upland gravel deposits are present in most parts of the quadrangle; they appear on ranges of low hills (Qg) that seem to bear little relationship to present stream courses, and as caps (Qgu) on the highest upland surface. Away from the higher elevations the gravel is mainly chalcedony, quartz, and silicate rocks from the Black Hills and neighboring uplifted areas; the gravel is very coarse, cobbles 4-6 inches or larger being common. Near the higher elevations the lower gravels have a large percentage of locally-derived material that is not as well rounded as the rest of the gravel. Fossil vertebrate bones from these deposits have been identified as Pliocene (J. R. Macdonald), but some show evidence of stream action which appears to indicate that the age of the deposit is post-Pliocene. These deposits are all assigned to a probable Pleistocene age.

Wind deposits. Fine to coarse dune sand is present mainly in the southern third of the quadrangle and seems to be related to Tertiary sediments. In addition to the dune sand at higher elevations, dunes are present locally in the alluvium of the valley of the Little White River.

EXPOSED SEDIMENTARY ROCKS

Pierre shale, a marine deposit of Cretaceous age, occurs throughout the quadrangle, but is overlain in the southern third by Tertiary fluviatile and lacustrine sediments of Oligocene and Miocene age. In contrast to the shale lithology of the Pierre, the Oligocene White River strata are silty tuffaceous claystone, sandstone, and bentonite; the Miocene Arikaree is mainly sandstone with some ash, and the Miocene Mellette formation consists of limestone and silty tuffaceous claystone and siltstone.

Cretaceous System. Pierre shale (Meek & Hayden, 1862). The Pierre shale, named from exposures near Ft. Pierre (50 miles north of the quadrangle), crops out along the major drainage in the quadrangle and, where not overlain by Quaternary deposits, constitutes the bedrock of the uplands in the northern two-thirds of the mapped area. Most natural exposures of the Pierre are badly slumped. In the area of south-central South Dakota, including the White River quadrangle, it is impossible to distinguish the members of the Pierre (Searight, 1937) recognizable along the Missouri River; thus the Pierre is here divided into two conformable lithologic units, for which formal names are not proposed as yet, pending further studies.

Lower Pierre unit. The lower Pierre unit (Kpl) is mainly gray to dark-gray partly bentonitic shale that weathers light-gray. It is generally blocky but weathers to thin flakes, and becomes a plastic structureless mass when wet. In its upper part the shale contains layers of dark-gray argillaceous limestone concretions, many of which have as cores the long cephalopod Baculites. In the shales, however, megafossils are generally sparse and poorly preserved. At least 285 feet of this unit is exposed in the quadrangle.

Upper Pierre unit. The upper Pierre unit (Kpu) is gray calcareous shale (below) and brownish silty shale. These two subdivisions of the upper Pierre unit correspond generally with the Mobridge and Elk Butte members, respectively, of the Pierre formation along the Missouri River. The lower (Mobridge) part of the unit is a dark-gray blocky calcareous shale; broken surfaces of the shale show minute white calcareous spots which are probably crushed foraminiferal shells. The shale generally weathers light-gray, although locally it alters brownish, like its weathered counterpart along the Missouri River. This part of the upper Pierre unit is fossiliferous, but the megafossils are poorly preserved. The upper (Elk Butte) part of the upper Pierre unit is brownish to olive shale that ranges from blocky near the base to thin-bedded and platy near the top. It is generally silty, and contains fine sand in the upper part. Gypsum and iron sulfate minerals fill veins and bedding planes throughout this part of the unit. Near the top are large yellowish-brown iron-bearing calcareous septarian concretions with cone-in-cone structure. A placer of thin limonitic plates covers slopes that are developed on the Elk Butte part of the upper Pierre unit. Fossils are sparse and very poorly preserved in this part of the unit. The sandiness near the top, and the septarian concretions are characteristic of the lower part of the Cretaceous Fox Hills sandstone elsewhere in the State, but the more massive character of the Fox Hills is not present here. The upper Pierre unit is 210-230 feet thick, the variation being due to an unconformity at the top. This unconformity is marked by a 30-40 foot weathered zone (Interior formation of Ward, 1922) of yellowish-brown to reddish-brown bentonitic shale that is olive and yellowish-brown platy shale when fresh.

Tertiary System. Oligocene Series. White River group Meek & Hayden 1858. The White River group, exposed in the uplands of the southern third of the quadrangle, comprises the Chadron (below) and the Brule formations. The White River group is overlain unconformably by Arikaree sediments of Miocene age, and by gravels of probable Pleistocene age. The White River group forms badlands.

Chadron formation Darton 1899. The Chadron formation, named from exposures near Chadron, Nebr. (120 miles SW of the White River quadrangle), is mainly light-greenish and olive-gray silty very bentonitic clay. It contains near the base a poorly cemented conglomerate of rounded quartz and feldspar pebbles up to 3 or 4 inches across, although most are about 1 inch in diameter. The top of the Chadron is marked locally by a lenticular yellowish-gray "algal" silty limestone that is commonly silicified; it pinches out from 3 feet thick within 40 feet horizontally. Where the limestone is absent, the silty bentonitic clays at the Chadron-Brule contact are distinguished mainly by the slight change in color from light greenish-gray (below) to light pinkish-gray. The Chadron is very bentonitic and weathers into characteristically rounded humps or "haystacks", in contrast to the tread-and-riser profile of the weathered Brule above, and to the relatively smooth cutbanks in the Pierre below. When wet the Chadron is an impassable mass of sticky gumbo. The Chadron is only 20-40 feet thick in the White River quadrangle. For this reason and because the upper contact is difficult to locate accurately, the two formations are mapped together (Tow).

Brule formation Darton 1899. The Brule formation, named for the Brule Indians in southern South Dakota, can be subdivided in the White River quadrangle into two lithologic units. The lower unit is mainly banded pinkish and grayish clayey tuffaceous laminated siltstone and fine quartzose poorly cemented sandstone interbedded with silty bentonitic claystone. Iron oxide and calcium carbonate irregularly cement the sandstone ledges, which weather to a somewhat wormy appearance. Pea-size clay pellets are present in some zones, as are local thin veinlets of chalcedony. The siltstones weather into vertical faces and the thin sandstone ledges project slightly, thus giving a stair-step profile. This lower division of the Brule is similar to the Orella member of northwestern Nebraska (Schultz, Stout, 1955), which has been called Scenic in the Big Badlands of South Dakota (Bump, 1956). The lower division of the Brule in the quadrangle is about 110 feet thick. The upper Brule consists of pink and green tuffaceous siltstone that is overlain by pinkish to brownish bentonite, pinkish waxy calcareous clay, and brown and pink nodular fine calcareous quartzose sand. The bentonite zones tend to weather to rounded surfaces characteristic of the bentonite beds of the Chadron below, whereas the siltstone, clay, and sandstone weather vertically. This upper unit of the Brule is similar to the Whitney member of northwestern Nebraska (Schultz, Stout, 1955), to which the name Poleslide has been applied in the Big Badlands of South Dakota (Bump, 1956). The upper division of the Brule in the White River quadrangle ranges up to 77 feet thick. These White River strata appear to be relatively unfossiliferous (except for the upper division of the Brule, which contains a few vertebrate bones); this is in contrast to their fossiliferous nature in the Big Badlands, where channel sandstones are very fossiliferous.

Miocene Series. Arikaree formation Darton 1899. The Arikaree formation (Tma), named for the Arikaree Indians of western Nebraska, caps the higher elevations along the southern border of the quadrangle. It consists in the quadrangle of reddish-brown cross-bedded quartzose channel sandstone that is overlain by gray and pinkish unconsolidated tuffaceous quartzose sands. The top of the Arikaree is arbitrarily marked by the base of the lowest pink fine-grained limestone bed. Locally, as at Mellette Mountain, remnants of a 20-foot bed of white volcanic ash containing spherical Celtis seeds cap pre-Miocene hills of upper Brule, and there form the base of the Miocene. The cross-bedded Miocene sandstone in the quadrangle, here referred to the Arikaree formation, may correspond with the basal, or Gering channel deposits of the Arikaree of northwestern Nebraska. The Arikaree ranges up to about 82 feet thick in the White River quadrangle. Vertebrate fossils are present in the Arikaree in the quadrangle.

Mellette formation. The unit here defined as the Mellette formation (Tmm) is named from exposures near the center of the line between secs. 14 and 23, T. 41 N., R. 28 W., in the small mesa containing Mellette triangulation station. The Mellette formation is typically three zones of fine-grained thin-bedded pinkish dense limestone that is white-weathering and fossiliferous; the two lower limestone zones, each 2 feet thick, are separated by 38 feet of red and grayish-pink uncemented tuffaceous sand, whereas the upper limestone, 7 feet thick, is separated from the middle one by 19 feet of similar sand. Above the upper limestone several feet of similar sand is exposed beneath a cap of Pleistocene upland gravel. The Mellette formation in the quadrangle is at least 78 feet thick, and 9 miles to the south it is more than 150 feet thick. It overlies the Arikaree formation conformably. The limestones contain small gastropods, but the faunal characteristics of the interbedded sands have not been ascertained. The Mellette formation is somewhat like parts of the Arikaree formation and overlying Hemingford group of northwestern Nebraska in content of reddish sand and sandy tuffaceous clay, but lacks the cemented zones and concretionary character of the Nebraska units; furthermore, limestones of the Mellette type are not reported in either of the two Nebraska units.

SUBSURFACE ROCKS

Rocks not exposed at the surface in the White River quadrangle, yet probably present therein because they were penetrated in wells drilled near the borders, constitute at least 1600 feet of Upper Cretaceous sediments. The Pierre shale, about 900 feet thick, overlies 100 feet of Niobrara marl, which is followed below by 600 feet of Carlile shale, 90 feet of Greenhorn limestone, and 340 feet of Graneros shale. The Graneros lies on the Dakota-Fuson-Lakota sandstone and shale, several hundred feet thick.

STRUCTURE

The sedimentary rocks in the quadrangle are nearly flat-lying, as it is apparently on the structural saddle that separates the Williston Basin to the north from the Kennedy Basin in Nebraska. The contact between the two units of the Pierre shale shows a general dip of 15 feet per mile to the north and west. (The Pierre shale slumps badly, and as a result only exposures a mile or more away from major drainage and at some distance from present topographic slopes were used.) The structure at the Chadron-Brule contact dips northward and eastward slightly (about 12 feet per mile) from the south-central part of the quadrangle, and the limestones in the Mellette formation dip slightly (less than 15 feet per mile) to the north. Thus the general structural picture of the White River quadrangle is one of gentle dip to the north, with the added possibility of a slight reversal in the south-central part.

ECONOMIC GEOLOGY

Ground water is available in all parts of the quadrangle. Extensive resources of sand and gravel are present in the terrace and gravel deposits; ledges of limestone cap the buttes and small mesas in the southernmost part of the quadrangle, and bentonite is present in the southern third of the mapped area. Other potentially economic products are oil and gas, uranium, clay, and ash.

Ground Water. Ground water adequate in amount for domestic farm supplies is available throughout the quadrangle. Water of good quality can be obtained from shallow wells that penetrate the Tertiary sediments, from the Pleistocene gravel deposits, and from the Quaternary alluvium and terrace deposits. Water from the Pierre shale usually contains excessive alkali; it is generally unsuitable for human consumption, and should be given to livestock only with caution. Wells drilled into the Quaternary alluvium near the borders of the valleys in the Pierre shale, and into thin terrace deposits that overlie the Pierre, also penetrate water high in alkali.

Sand and Gravel. Sand and gravel suitable for road material and possibly for bituminous or concrete aggregate is available in the upland gravel and terrace deposits. The gravels near the badlands in the southern part of the quadrangle contain a higher percentage of undesirable carbonate and argillaceous material, whereas the better gravels consist mainly of chalcedony, quartz, feldspar, and igneous and metamorphic rock fragments. The Chadron formation contains near its base a well-sorted gravel that is mainly several varieties of quartz, with a conspicuous amount of feldspar; it is mostly well-sized, about 1 inch in diameter.

Limestone. Three thin limestone zones are present in the Mellette formation near the southern border of the quadrangle. The limestones range from 2 to 7 feet thick and are fine-grained, dense, and relatively pure. Only the cap limestone of a mesa could be recovered economically, because of the intervening 19-38 feet of sands that would need to be removed before the next lower limestone is reached. These limestone caps are the same rock as that being quarried currently for road aggregate 15 miles to the south, and could be used similarly in the White River quadrangle.

Bentonite. Bentonitic sediments are characteristic of the Chadron formation and the upper part of the Brule formation, which are present in the southern third of the quadrangle. Bentonite is a potential source for sealing or bonding material.

Oil and Gas. Gas has been produced from the Dakota sandstone near Pierre, and deep oil tests to the west and south of Pierre have given shows of gas in the Dakota. In the White River quadrangle the Dakota sandstone lies at depths estimated to range from about 1400 feet at Westover School (N border) to 2200 feet at Mellette triangulation station. The gentle structural high in the south-central part of the quadrangle (SE¼ of T. 42 N., R. 28 W.) appears to have 50 feet or more of closure at the top of the Pierre, and therefore might possibly be a favorable structure for prospecting. Potentially productive deeper zones, the Whitewood (Red River) dolomite and Winnipeg sandstone and possibly the Pahasapa (Lodgepole-Mission Canyon) limestone, are perhaps present in the subsurface, at depths up to 1000 feet or more below the top of the Dakota.

Uranium. Uranium and other rare-earth minerals are present in small amounts in the Pierre shale, and in the Chadron formation. The oxidized zone at the top of the upper unit of the Pierre shale has a higher concentration of radioactive minerals than does the rest of the Pierre. The Chadron formation probably contains significant amounts of uranium minerals in the pinkish bentonitic zone near the top. The origin of the uranium seems to have been the Tertiary volcanic ash. Thus the Miocene Arikaree formation (especially the white ash bed at its base) and Mellette formation, and the tuffaceous silts of the Oligocene Brule member may also be regarded as potential sources of uranium minerals.

Other, potentially economic, resources. The Brule silt, when mixed with sand in proper proportions, is said (Reagan, 1905, p. 234) to make a hard mortar that was formerly used by the Indians as plaster. The bentonitic clays of the Chadron formation in the Black Hills have been investigated from the standpoint of fuller's earth, because of their bleaching qualities. An excellent, though limited exposure of the basal Miocene white ash, 20 feet thick, caps Mellette Mountain; it could be used as an abrasive, as it is relatively pure.

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