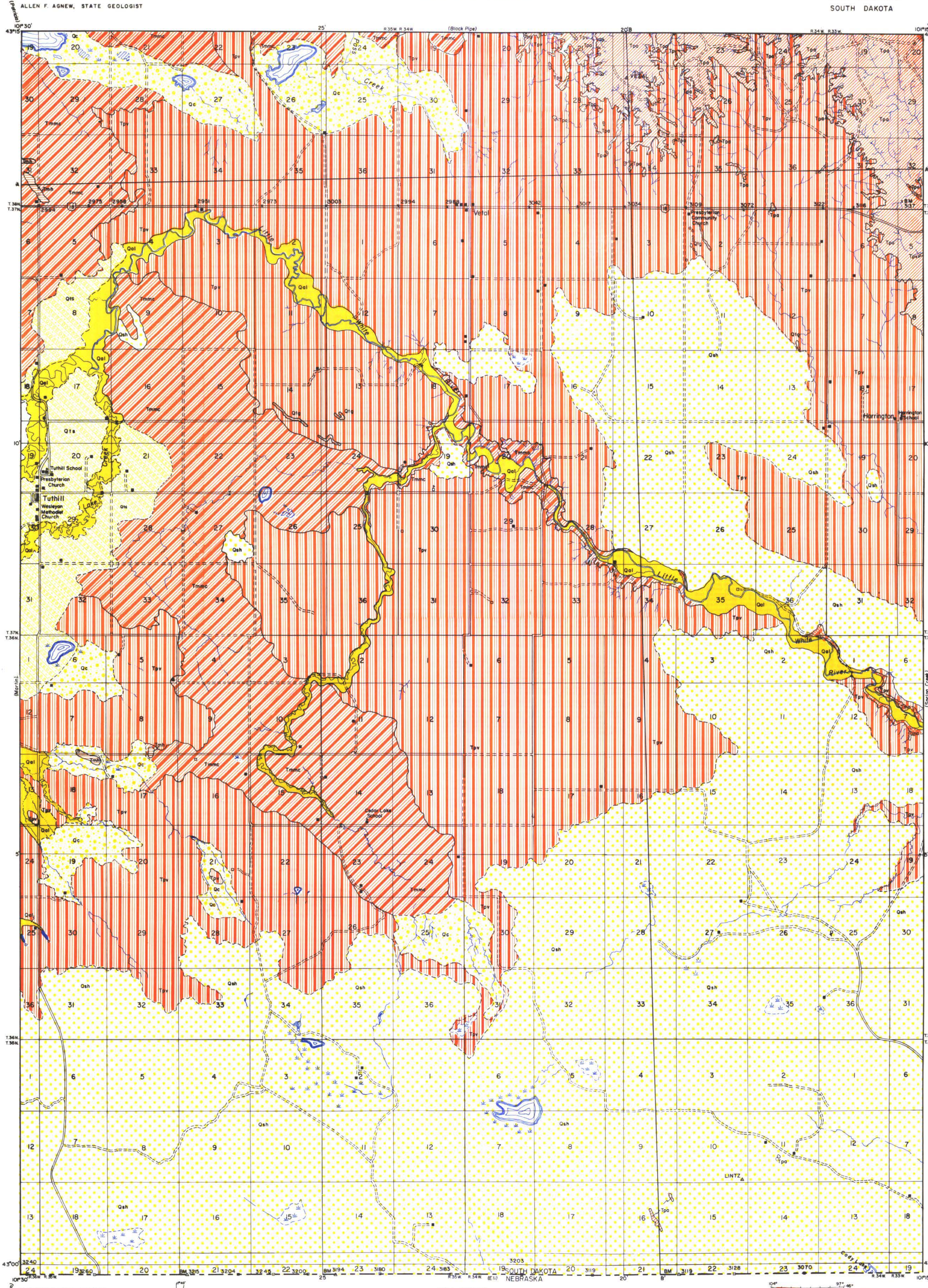
SOUTH DAKOTA GEOLOGICAL SURVEY
ALLEN F. AGNEW, STATE GEOLOGIST

STATE OF SOUTH DAKOTA
ARCHIE GUBBRUD, GOVERNOR

GEOLOGY of the VETAL QUADRANGLE SOUTH DAKOTA



EXPLANATION

QUATERNARY

RECENT

Qal — Alluvium
(Floodplain deposits of silt, sand, and gravel; in valleys of present streams.)

Qc — Colluvium
(Loose, incoherent sand, silt, and clay; results from gravity and stream mixing of sediments of the Valentine and Monroe Creek Formations.)

Qts — Terrace Deposits
(Stream terrace deposits of fine- to coarse-grained feldspathic quartzose sand and gravel; up to 35 feet thick.)

?

PLEISTOCENE

Qtg — High Level Terrace Gravels
(High level gravels of siltstone, sandstone, and limestone pebbles derived from the Ash Hollow Formation; 3 to 12 feet thick; 50 to 100 feet above present stream levels.)

Qsh — Sand Hills Formation
(Fine- to medium-grained unconsolidated wind-blown feldspathic quartzose sand characterized by dunes and blowouts; as much as 200 feet thick.)

TERTIARY

PLIOCENE

Tpa — Ash Hollow Formation
(Light-tan to light-gray calcareous massive feldspathic quartzose sandstone; abundant caliche and local box-work structure; limestone and diatomaceous earth in lower part; volcanic ash in upper part; as much as 150 feet thick.)

Tpv — Valentine Formation
(Greenish-gray to tan unconsolidated feldspathic quartzose sand; local zones of cementation in lower part; as much as 200 feet thick.)

UNCONFORMITY

MIOCENE

Tma / Tmh / Tmmc — Arikaree Group
(Undifferentiated: pinkish-brown massive well-compacted silt; weathers very light-pinkish to very light-buff; 40 feet exposed.)
(Harrison Formation: (Tmh) Light-gray partly calcareous poorly cemented very fine sand and silt; thin discontinuous horizontal zone of white calcareous concretions in lower part; 15 feet thick.)
(Monroe Creek Formation: (Tmmc) Pinkish-brown to pinkish-buff well-compacted to moderately consolidated massive silt; some clay and very fine-grained sand; weathers very light pinkish to very light buff; forms gently rolling hills; as much as 90 feet thick.)

Geologic Contact
(dashed where approximately located)

X BM 3137
Bench Mark
(monument showing exact altitude above sea level)

x 3003
Spot Altitude

▲ VETAL
Triangulation Station
(monument marking exact geographic location)

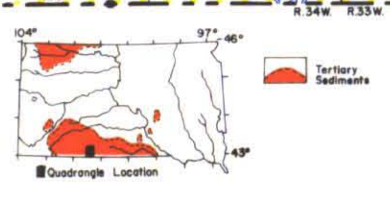
House, School, and Church

Geology by William D. Sevon, 1960
Assisted by Lamont Sorenson
Vertical and horizontal control surveyed from triangulation and level lines of Federal surveys
Drafted by Bruno C. Petsch, 1960

TRUE NORTH
MAGNETIC NORTH
APPROXIMATE MEAN DECLINATION, 1960

Scale 1:62 500
1 ½ 0 1 2 3 4 Miles

Vermillion South Dakota
1961



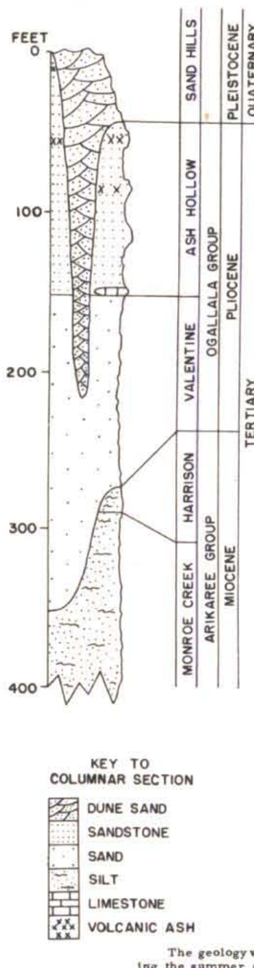
VETAL QUADRANGLE

GEOLOGY OF THE VETAL QUADRANGLE

by

W. D. Sevon

COLUMNAR SECTION OF EXPOSED ROCKS



INTRODUCTION

The Vetal quadrangle includes about 218 square miles in the southeastern part of Bennett County. The quadrangle, in the region of outcropping Tertiary continental deposits in the south-central part of the State, is in the Missouri Plateau and the High Plains sections of the Great Plains Physiographic Province.

The topography of the quadrangle is varied: the southern third of the area is characterized by sand dune topography; the extreme northeastern portion, by a dissected high plains remnant; the west-central part, by alluvial and colluvial flats; and the remainder, by rolling plains punctuated by small isolated areas of sand dunes. Maximum topographic relief in the quadrangle is about 505 feet, altitudes ranging from 3295 feet at Vetal triangulation station (NW¼ sec. 27, T. 38 N., R. 34 W.) to about 2790 feet at water level where the Little White River flows out of the area (Sec. 7, T. 36 N., R. 33 W.). Local relief is greatest in the northeastern part of the quadrangle, where ground elevations differ more than 250 feet within a mile. Local relief of 75 to 150 feet within half a mile is characteristic in the sand hills of the southern third of the quadrangle.

The Little White River enters the quadrangle near Tuthill (west-central part of map) and flows northeastward to a point near U. S. Highway 18 where it turns sharply and flows southeastward across the remainder of the quadrangle. The Little White River is joined by Lake Creek (NE of Tuthill) and an unnamed northward-flowing creek (central part of map). Pass Creek has its headwaters in the north-central part of the area and flows northward out of the quadrangle, and a small intermittent creek originates in the dissected High Plains remnant (NE part of map) and flows southeastward out of the area. The remainder of the quadrangle has a poorly developed system of surface drainage. Several natural lakes are present in the quadrangle. Three small lakes occupy the lowest parts of depressions in colluvial material in the northwestern part of the quadrangle, and several small lakes and marshy areas, resulting from the intersection of the ground water table with the surface, are present in sand blowouts in the southern third of the quadrangle.

The area is sparsely populated, about one family per three square miles. Vetal, in the north-central part of the quadrangle (pop. 20), Tuthill (pop. 50), and Harrington, at the center of the east edge (pop. 5) are the only settlements in the area. Ranching and farming are the principal occupations, with wheat being the principal farm crop. Some of the farm access roads are graded and improved, but much of the area can be traversed only on unimproved trails. U. S. Highway 18, the only hard-surfaced road in the area, crosses the northern part of the quadrangle from east to west. The only graveled road in the area runs south through Tuthill from U. S. Highway 18 to the Nebraska State line.

The climate of the Vetal quadrangle area is characterized by low humidity, hot summers, cold winters, and a wide temperature range. Sudden changes in the weather are common. Summer storms usually are intensive thunder-showers of local extent, and are often accompanied by hail. The average annual precipitation of 16 inches, according to records of the U. S. Weather Bureau station at Martin, is received mainly in the spring and summer. Strong winds are common, prevailing from the northwest in winter and from the south in summer.

The geology was mapped with the assistance of LaMont Sorenson during the summer of 1960, under the supervision of Dr. Allen F. Agnew, State Geologist, as a part of the State Geological Survey's program of mapping the economic geology of south-central South Dakota. Thanks are extended to Warren Johnson of the U. S. Soil Conservation Service for the information that he furnished.

EXPOSED ROCKS

The Arikaree Group, a series of fluviatile silts of Miocene age, underlies the entire quadrangle. It is divided into the Monroe Creek (lower) and Harrison Formations in the west and central parts of the quadrangle, but is mapped as Arikaree Group, undifferentiated in the east-central part of the quadrangle. The Arikaree Group is overlain in most of the quadrangle by the fluviatile and lacustrine deposits of the Pliocene Ogallala Group. The Ogallala Group is represented by sands and sandstones of the Valentine Formation (lower), and by sandstones, limestone, and volcanic ashes of the Ash Hollow Formation. The Ogallala Group is overlain in the southern third and parts of the northeastern quarter of the quadrangle by the sand dunes of the Pleistocene Sand Hills Formation.

Miocene Series. Arikaree Group, Darton, 1899.

The Arikaree Group, named for the Arikaree Indians who inhabited western Nebraska, underlies the entire quadrangle, and is divided into the Monroe Creek (lower) and Harrison Formations in the west and central parts of the quadrangle, but has been mapped as Arikaree Group, undifferentiated in the eastern part of the area.

Arikaree Group, Darton, 1899

Sediments of the Arikaree Group, undifferentiated (Tma) occur along the valley walls of the Little White River in the east-central part of the quadrangle. These sediments are mapped as Arikaree Group, undifferentiated because: (1) they cannot be traced by continuous exposures into known sediments of the Monroe Creek or Harrison Formations of the Arikaree Group, which crop out in the western and central parts of the quadrangle, and (2) because these sediments are traced by continuous exposures into sediments farther east (in the Spring Creek quadrangle), which have been mapped as Arikaree Group, undifferentiated by Sevon (1960b). Sevon (1959, 1960a, and 1960b) was not able to differentiate the Arikaree Group into subdivisions in the Spring Creek, Ring Thunder, and Okreek quadrangles to the east, and Collins (1960) questioned the practicality of differentiating the Arikaree Group east of the Martin (Collins, 1959) and Patricia (Collins, 1960) quadrangles. On a regional scale, the lower Arikaree Sharps Formation of Harksen (1960), the Monroe Creek, and the upper Arikaree Harrison Formations become less distinct as separate units eastward from their source area, and the writer agrees with Collins (1960) that subdivision of the Arikaree east of eastern Bennett County is impractical.

In the Vetal quadrangle, the Arikaree Group, undifferentiated consists of light pinkish-brown noncalcareous silt which contains a small amount of sand and clay. The unit is well compacted to moderately consolidated, massive, blocky, and weathers very light pinkish to a very light buff. Weathered slopes are steep and smooth, and have the appearance of being composed of thin flaky sheets which conform to the contour of the surface. About 40 feet of this unit is exposed in the Vetal quadrangle. It is overlain unconformably by either the Valentine Formation or the Sand Hills Formation.

Monroe Creek Formation, Hatcher, 1902.

The Monroe Creek Formation (Tmmc), named from exposures along Monroe Creek canyon near Harrison, Nebraska, about 140 miles southwest of Vetal, crops out in rolling farm lands of the western part of the quadrangle, and along the valley walls of the Little White River in the central part of the area. It is noteable that, for the most part, only those soils developed on the Monroe Creek and the overlying Harrison Formation are cultivated in the Vetal quadrangle. The unit consists of pinkish-brown to pinkish-buff noncalcareous silt which contains a small amount of clay and very fine-grained quartzose sand. The unit is well compacted to moderately consolidated, massive, blocky, and weathers very light pinkish to very light buff. The Monroe Creek develops a very gently rolling topography, and, where it is not protected by soil cover, is characterized by smoothly rounded surfaces which have the appearance of being composed of thin, flaky sheets which conform to the contour of the surface. Wet surfaces of the unit are slippery. About 90 feet of the unit is exposed in the Vetal quadrangle. The Monroe Creek Formation is conformably overlain by the Harrison Formation in four localities described below, and unconformably overlain by the Valentine Formation in most of the remainder of the quadrangle.

Harrison Formation, Hatcher, 1902.

The Harrison Formation (Tmh) was named from outcrops at the general level of the high plains in the vicinity of Harrison, Nebraska, about 140 miles southwest of Vetal. In the Vetal quadrangle sediments of the Harrison Formation cap small hills in Secs. 31 and 32, T. 38 N., R. 35 W., and Secs. 7, 8, 17, and 18, T. 36 N., R. 35 W. The unit consists of light-gray partly calcareous poorly cemented silt which contains some very fine-grained sand. The base of the unit is arbitrarily placed at a thin discontinuous horizontal zone of calcareous concretions. This concretionary zone varies from a thin zone of small irregular nodules ½ to 1 inch in diameter to a discontinuous zone of thinly laminated calcareous siltstone 1 to 8 inches in thickness. The concretionary material is grayish-white, and weathers to a brilliant white which shows up plainly on cultivated fields. The maximum thickness of the Harrison Formation in the Vetal quadrangle is 15 feet.

Pliocene Series. Ogallala Group, Darton, 1899.

The Ogallala Group, named from exposures in western Nebraska near Ogallala Station, about 150 miles south of Vetal, includes the Valentine (below) and Ash Hollow Formations.

Valentine Formation, Barbour and Cook, 1917.

The Valentine Formation (Tpv), named for exposures near Valentine, Nebraska, about 50 miles southeast of Vetal, outcrops in a large part of the northern two-thirds of the Vetal quadrangle. The Valentine Formation is mainly unconsolidated very fine- to medium-grained greenish-gray to tan feldspathic quartzose sand. The sand is generally poorly to medium-well sorted, sub-angular to well-rounded, and contains many somewhat frosted grains. Local zones of calcareous cement are common, but not laterally persistent. A light-green bentonitic clay is locally present near the base of the unit. Randomly scattered pebbles of feldspar and quartz, ranging from 1/4- to 3/4-inch in diameter, are present locally near the base of the unit in exposures along the Little White River in the northwestern part of the quadrangle. A hard light-gray calcareous-cemented zone occurs at the base of the Valentine in Sec. 7, T. 36 N., R. 33 W., and Secs. 1 and 12, T. 36 N., R. 34 W. This zone of cementation ranges from 1 to 3 feet in thickness, and locally contains intermixed volcanic ash. The upper part of the Valentine locally contains a light greenish-gray noncalcareous massive well compacted silty sand which contains abundant short, white, siliceous tubules generally less than ¼-inch in diameter and seldom more than 2 inches in length. The Valentine Formation has a maximum thickness of 200 feet in the Vetal quadrangle. The unit is conformably overlain by the Ash Hollow Formation, and is unconformably overlain by the Sand Hills Formation. No identifiable fossils were found in the Valentine in the Vetal quadrangle, but bone chips and fragments are locally present at all levels in the formation.

The contact of the Monroe Creek and Valentine Formations in Sec. 33, T. 38 N., R. 35 W., is about 75 feet lower than the top of the Harrison-capped hill in the NE¼ sec. 31, T. 38 N., R. 35 W., and about 200 feet lower in Sec. 7, T. 36 N., R. 33 W. This difference in elevation of the contacts indicates a post-Arikaree pre-Ogallala erosional surface which had a relief of at least 200 feet in the Vetal quadrangle, and an apparent slope to the southeast.

Ash Hollow Formation, Engelmann, 1876.

The Ash Hollow Formation (Tpa), named for exposures in Ash Hollow Canyon, near Lewellen, Nebraska, about 140 miles south of Vetal, crops out in the highly dissected High Plains remnant in the northeastern part of the quadrangle, and in three isolated areas in the southeastern part (Secs. 11 and 16, T. 35 N., R. 34 W.). The unit consists of light-tan to light-gray calcareous massive feldspathic quartzose sandstones which vary considerably in degree of cementation. This variation causes numerous covered slopes, recesses, and ledges. White silicified and calcified remains of plant roots and stems are abundant, and locally form a random criss-cross network in the sandstone. These plant remains are more resistant to weathering than the rest of the rock, and locally cause a "boxwork" structure on weathered surfaces of ledges. Weathered surfaces of the harder sandstones usually are covered with gray, black, green, and orange lichens, and at a distance appear dark gray to gray in color.

Thin deposits of volcanic ash occur locally in the upper part of the formation, and a deposit at least 11 feet thick occurs near the top of the unit about a mile to the northeast of the northeastern corner of the quadrangle in NE¼SE¼ sec. 17, T. 38 N., R. 33 W. A creamy white thin-bedded limestone locally occurs in the lower part of the Ash Hollow. The limestone is hard, contains small black dendritic structures, weathers brilliant white, and ranges from 6 inches to 1½ feet in thickness. Skeletons of small fish are locally present in this unit. A 1-2 foot zone of diatomaceous earth is locally associated with the limestone, occuring either directly above or below the limestone. In some localities the diatomaceous earth occurs without the limestone. The diatomaceous earth is soft, flaky, grayish-white, noncalcareous to calcareous, and weathers brilliant white. Sevon (1960b) referred to this unit in the Spring Creek quadrangle as a calcareous silt, but later examination revealed the presence of abundant diatoms (microscopic algae which secrete siliceous shells). The limestone and the diatomaceous earth have been used arbitrarily to mark the base of the Ash Hollow Formation. Degree of cementation is the gross lithologic difference between the Ash Hollow Formation and the underlying Valentine Formation, and the limestone-diatomaceous earth zone seems to occur at the base of the cemented material in the Vetal and Spring Creek quadrangles. No identifiable vertebrate fossils were found in the Ash Hollow Formation in the Vetal quadrangle, but bone fragments are common throughout the unit. Fossil seeds of the hackberry, Celtis willistoni, occur locally throughout the unit. The Ash Hollow Formation has a maximum thickness of 150 feet in the Vetal quadrangle.

Pleistocene Series. Sand Hills Formations, Lugn, 1934.

The Sand Hills Formation (Qsh) covers most of the southern third, part of the northeast quarter, and small isolated areas in the remainder of the Vetal quadrangle. The unit consists of unconsolidated fine- to medium-grained rounded to well-rounded frosted feldspathic quartzose sand. The sand occurs in a great succession of dunes, and, because of its great similarity to the unconsolidated sand of the Valentine Formation, has been mapped only where dune topography is well developed. The dune topography is characterized by small hills up to 150 feet in height above their base, and by undrained depressions. Good grass cover and yucca plants are the vegetation characteristic of the Sand Hills Formation. The unconsolidated sand is very permeable; consequently, all the rainfall not lost by transpiration and evaporation permeates downward, and no surface drainage is developed. The ground water table in the Sand Hills Formation is generally less than 25 feet below the surface, and some deep blowout depressions have intersected the ground water table giving rise to small ponds or marshy areas. The Sand Hills Formation is composed of sand derived from weathered Ogallala sediments and reworked by wind action during the Pleistocene Epoch. Increased moisture in more recent times has led to the development of a good grass cover which has stabilized the sand movement. The Sand Hills Formation has a maximum thickness of at least 200 feet in the Vetal quadrangle.

SURFICIAL DEPOSITS

Unconsolidated deposits associated with present drainage are present throughout the quadrangle, and are divided into four main groups: (1) alluvium in present stream valleys, (2) terrace deposits adjacent to these valleys, (3) high-level gravel deposits that represent old stream channels, and (4) colluvium.

Alluvium (Qal) consists of feldspathic quartzose silt, sand, and gravel which resulted from reworking of bedrock and older surficial deposits, and is confined to present stream valleys. The alluvium is generally less than 10 feet thick, but some exposures in the Little White River valley in the eastern part of the quadrangle show up to 50 feet of alluvium. At least two terrace levels are present along the Little White River in the eastern half of the quadrangle, but they have been mapped as alluvium because (1) they are too small in areal extent to be mapped, and (2) because they tend to grade into each other as a result of gravity movement and slope wash.

An extensive sand terrace (Qts) is present in the western part of the quadrangle along the valleys of the Little White River and Lake Creek. The terrace material is fine- to coarse-grained feldspathic quartzose sand and gravel that is poorly to moderately sorted, and for the most part, poorly rounded. About 90 percent of this material is quartz, feldspar, and other minerals derived from igneous rocks, whereas the remainder consists of locally derived sandstone, limestone, and siltstone pebbles. Fragments of vertebrate bones are locally present. The upper 4 feet of the terrace material usually contains a large amount of silt and clay in contrast to the almost pure sand of the lower part. The exact thickness of the terrace deposit is not known, but 35 feet of sand is exposed along the valley of Lake Creek east of Tuthill, and the deposit is probably thicker.

Several small gravel capped hills are present in Secs. 2 and 12, T. 37 N., R. 34 W., and Secs. 13, 14, 23, and 24, T. 37 N., R. 35 W. These deposits have been mapped as high-level terrace gravels (Qtg). The deposits consist of sandstone and limestone pebbles derived from the Ash Hollow Formation. The pebbles range from ½ to 2 inches in diameter, and average about 1 inch in diameter. Boulders up to 2 feet in diameter are locally present, but are not abundant. The gravel is mixed with fine- to medium-grained sand. The deposits range from 3 to 12 feet in thickness. These deposits are generally aligned with present drainage channels, but are 50 to 100 feet above the present stream levels. The gravel deposits in Sec. 2, T. 37 N., R. 34 W., occur at two levels, the upper gravel being 33 feet higher than the lower.

Colluvium (Qc) is loose, incoherent, sand, silt, and clay which has resulted from gravity and stream-reworking and mixing of sediments of the Valentine and Monroe Creek Formations. The colluvium occurs in low, poorly drained areas in which marshes and small ponds are common.

DRAINAGE HISTORY

Sevon (1960b) suggested that Spring Creek had at one time flowed southeastward into the Minnechadusa River, and that it was subsequently captured by a tributary of the Little White River. This idea was proposed to explain the anomalous change in the direction of flow of Spring Creek in Sec. 6, T. 35 N., R. 31 W. of the quadrangle, and to explain the broad abandoned valley which exists between Spring Creek and the Minnechadusa River. The writer now feels, as a result of more extensive field work, that the drainage history is much more complex.

An examination of the Martin, South Dakota, Topographic Map (NK 14-1, U. S. Army Map Service, scale 1:250,000) revealed several facts pertaining to the problem, and this investigation was followed up in the field. Bennett and Todd Counties are crossed by a more or less east-west topographic high (fig. 1 and 2), which acts as a drainage divide except in three localities. This drainage divide continues to the east through Tripp and Gregory Counties, and to the west into Shannon County. North of this topographic high the drainage is northward into the White River; to the south it is southeastward into the Niobrara River, except for the Little White River and Bear in the Lodge Creek. The topography north of the drainage divide is generally rough and deeply dissected; south of the drainage divide, it is generally gently rolling and lacks deep dissection. This difference in topographic development, despite the fact that the sediments north of the divide, (consolidated silts and clays of the White River and Arikaree Groups) are more resistant to erosion than those of south of the divide (consolidated and unconsolidated sands of the Ogallala Group), suggests that the opposite sides of the divide have been carved by drainages of different erosional vigor.

The divide is cut by three north-flowing streams (fig. 1): the Little White River, Pass Creek, and Bear in the Lodge Creek. Pass Creek has no anomalous features but, by the process of headward erosion, is nearing a point where it could capture the headwaters of the Little White River. Five miles northeast of Martin the east-flowing Bear in the Lodge Creek makes an abrupt turn to the northwest and flows through the drainage divide to the White River. Between Harrington and St. Francis, the southeast-flowing Little White River makes an abrupt turn and flows northeastward through the drainage divide to the White River.

Because of the anomalous changes in the direction of stream flow, the cuts through the drainage divide, the general differences in topography on opposite sides of the divide, and the broad valley in the vicinity of Spring Creek and the Minnechadusa River, the writer proposes the following explanation of the geologic history of the drainage development: at one time the present east-flowing part of Bear in the Lodge Creek, here named the ancient North Fork Vetal River, joined the present southeast-flowing part of the Little White River, here named the ancient Vetal River (fig. 2), and flowed southeastward through the broad northwest-southeast valley of the present Spring Creek and Minnechadusa River into the Niobrara River. The ancient Vetal River was joined northeast of Tuthill by the present northeast-flowing part of the Little White River, here named the ancient South Fork Vetal River, and by Spring Creek, and the Minnechadusa River in southwestern Todd County. The northeast-flowing Little White River and the northwest-flowing Bear in the Lodge Creek eventually cut through the drainage divide, probably during Late Pleistocene time, and captured parts of the ancient Vetal River and North Fork Vetal River, respectively, giving rise to the present drainage pattern (fig. 1).

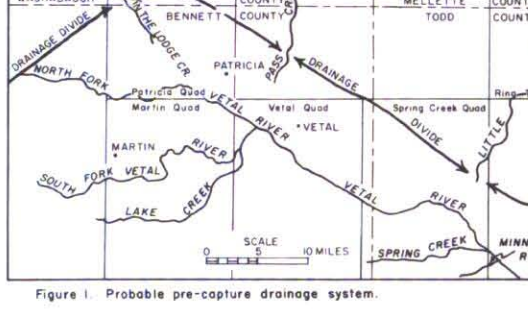


Figure 1. Probable pre-capture drainage system.

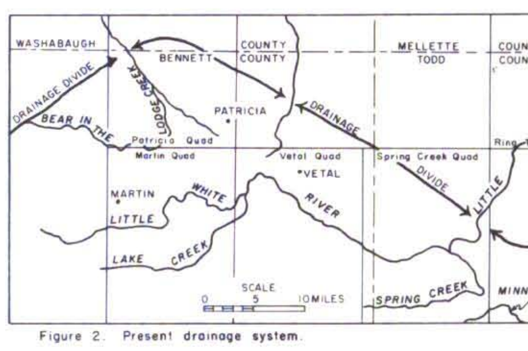


Figure 2. Present drainage system.

Table 1.--Water analyses of samples from wells in the Vetal quadrangle

Location of Sample	Source	Total Solids (parts per million)	SO_4	Cl	Mg	Ca	Alkalinity*	Hardness	Na	Fl	Fe	Mn	Nitrate	Volatiles
NW¼NW¼NW¼ sec. 11, T. 35 N., R. 35 W.	Qsh	168	7	1	1	21	0 57	56	3	0	0	0	2	58
SW¼NW¼SE¼ sec. 3, T. 35 N., R. 35 W.	Qsh	218	10	2	1	37	0 103	95	3	0.4	0	0	0	0
SE¼SE¼NW¼ sec. 11, T. 36 N., R. 35 W.	Tmmc	300	16	6	9	48	0 175	157	12	0.2	0	0	0.3	0
SE¼SE¼SE¼ sec. 31, T. 38 N., R. 35 W.	Tmmc	412	37	15	11	64	0 218	206	25	0.2	0	0	3.3	0
SE¼SE¼SE¼ sec. 31, T. 38 N., R. 35 W.	Tmmc	340	26	7	13	50	0 206	172	30	0.2	T	0	0.1	0
SE¼SE¼SW¼ sec. 6, T. 37 N., R. 33 W.	Tpv	196	6	4	3	37	0 116	103	4	0	0	0	0.3	0
NE¼NE¼NE¼ sec. 5, T. 37 N., R. 34 W.	Tpv	228	11	6	4	39	0 114	115	4	0	0	0	3.9	0
Maximum concentrations allowable in water for domestic use **		500	250	250	125					1.5	0.3			

* Alkalinity expressed as: Phenolphthalein
Methyl Orange

** U. S. Public Health Service, 1946

Analyses by State Chemical Laboratory, Vermillion, 1961.

SUBSURFACE ROCKS

(after Collins, 1959)

Information on the subsurface rocks of the Vetal quadrangle is from well log data of the English #1 Kocer oil test in Sec. 30, T. 37 N., R. 36 W. (about 15 miles southwest of Vetal). The well, drilled from a surface elevation of 3,079 feet to a total depth of 3,370 feet, penetrated the following rock units:

Age	Name	Lithology	Depth in feet
Tertiary	Arikaree and White River	silts, sands, and clays	0-1208
Cretaceous	Pierre	shale	-1855
	Niobrara	marl	-2060
	Carlile	shale	-2382
	Greenhorn	limestone	-2440
	Belle Fourche-Mowry	shales	-2715
Cretaceous (?)-Jurassic (?)	Newcastle (?)-Morrison (?)	siltstone, sandstone	-2902
		shale	-2940
		sandstone	-3110
Permian (?)	Opeche (?)	shale	-3165
Permo-Pennsylvanian (?)	Minnelusa (?)	sandstone, shale	-3315
		shale, sandstone	-3370

The sandstones from 2940-3110, 3165-3205, and 3240-3315 feet are well developed and permeable.

STRUCTURAL GEOLOGY

(after Collins, 1959)

The Vetal quadrangle lies on the northeastern slope of the Chadron Arch and is at the northern edge of the Kennedy Basin of northern Nebraska. No reliable structural datum is exposed at the surface in the Vetal quadrangle. Subsurface measurements on the Greenhorn limestone and Newcastle sandstone show easterly dips of 50 and 40 feet per mile, respectively. Two structural datum surfaces below, and the Precambrian surface, show dips of the same magnitude to the southeast and south.

ECONOMIC GEOLOGY

Sand, gravel, volcanic ash, diatomaceous earth, and ground water are the only known potentially economic resources in the Vetal quadrangle. Oil and gas may be potentially economic in the area.

Ground Water

Ground water of sufficient quantity and quality for domestic and stock use is available in most parts of the quadrangle. Eight analyses of water from various sources in the area (table 1) show the water to be within the U. S. Public Health Service standards for good drinking water, but generally somewhat hard. Wells drilled into the Monroe Creek Formation generally are deeper (100 feet) than those drilled into the Valentine Formation (75 feet). Wells drilled in the Sand Hills Formation are generally shallow (25 feet deep).

The Valentine Formation and the Sand Hills Formation serve as good reservoir sands because of their moderate to high permeability, and because of the presence of relatively impermeable Arikaree sediments below. Wells drilled into the Valentine and Sand Hills Formations recharge quickly during pumping, and seldom go dry. Wells in the less permeable Monroe Creek Formation do not recharge as rapidly, and may go dry during extended periods of little rainfall. The Ash Hollow Formation is not a good reservoir rock because of the low permeability of most of the unit, and the tendency for the water to seep into the underlying Valentine Formation.

Sand and Gravel

Sand is abundantly available from the Valentine and Sand Hills Formations, and to some extent from terrace deposits near Tuthill. Although these sands are too fine for concrete work, similar sands from the Valentine and Sand Hills Formations have been used with some success for bituminous highway mat in Nebraska.

Gravel deposits in the Vetal quadrangle are limited in size and poor in quality, owing to the high content of carbonate material.

Volcanic Ash

Volcanic ash deposits are present in the upper part of the Ash Hollow Formation. For the most part these deposits are thin and limited in lateral extent, but a deposit just northeast of the northeastern corner of the quadrangle (NE¼SE¼ sec. 17, T. 38 N., R. 33 W.) is at least 11 feet thick, relatively pure, and apparently of considerable lateral extent. Volcanic ash is used as an abrasive.

Diatomaceous Earth

Small deposits of diatomaceous earth occur locally in the lower portion of the Ash Hollow Formation. These deposits are generally thin and of limited lateral extent; however, more detailed investigation might reveal larger deposits. A deposit of diatomaceous earth in the Spring Creek quadrangle (Sec. 21, T. 37 N., R. 32 W.), about 7 miles east of Harrington, ranges from 1 to 6 feet thick, and crops out along the valley walls in that vicinity for at least half a mile. Diatomaceous earth is used as a filter, and a filler in paints.

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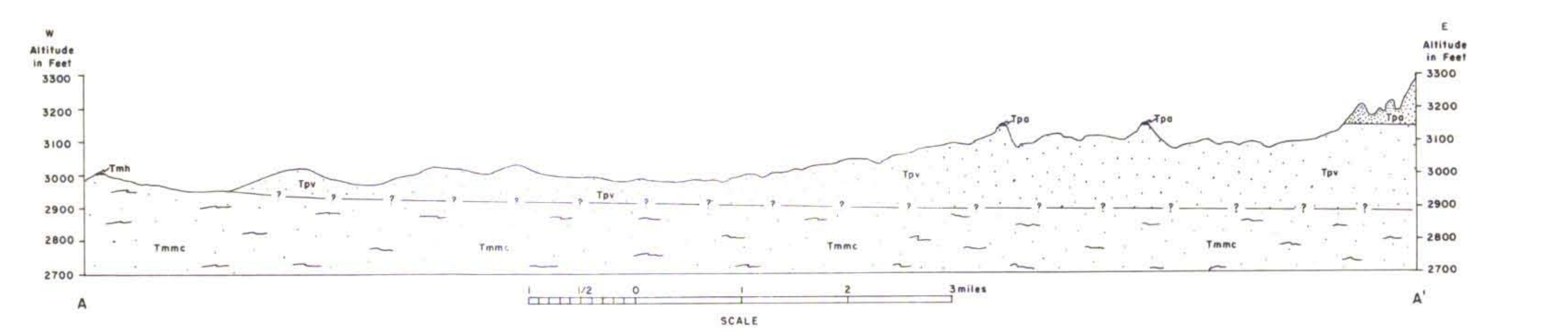
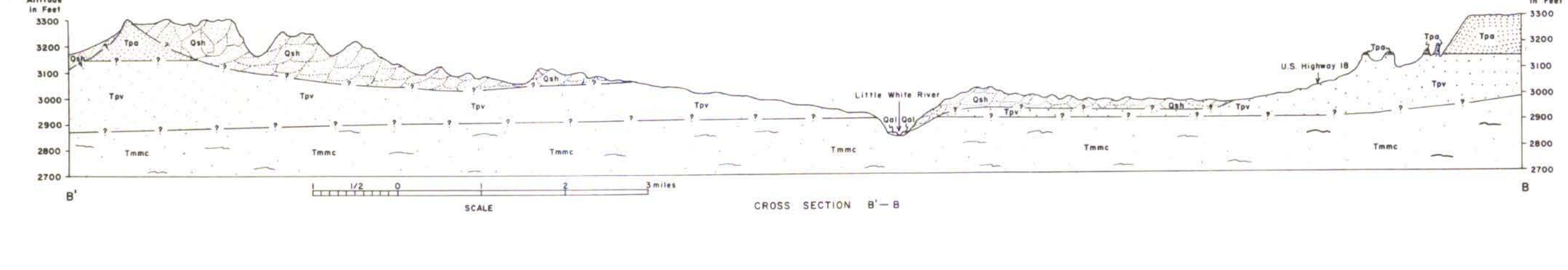


CROSS SECTION A—A'



CROSS SECTION B'—B