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Areal Geology

Preliminary Report on the Geology of the Zahl No. 3 Quadrangle North Dakota

by

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This report is submitted to supply preliminary information to the Interior Department agencies and others concerned in planning the Missouri Basin Development Program. It is not for publication. The report accompanies a geologic map.

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INTRODUCTION

The geology of the Zahl No. 3 quadrangle was surveyed in the summer of 1946. The area is included in the Missouri-Souris unit of the Missouri Basin Development Program.

GEOGRAPHY AND GENERAL GEOLOGY

The Zahl No. 3 quadrangle and surrounding area are partially covered by deposits of glacial drift laid down during the Pleistocene period. The drift consists mainly of late Wisconsin (Mankato?) terminal moraine deposits, the Altamont (4 pp., 388-393), in the northern two-thirds of the quadrangle, and of earlier Wisconsin ground moraine in the southern third (2, p. 127). The Altamont moraine is composed of thick till deposits having a highly irregular, poorly drained surface of high relief. The ground moraine has a relatively smooth surface with rather well-integrated drainage patterns.

The Tongue River member of the Fort Union formation of Paleocene age underlies the glacial deposits in the Zahl No. 3 quadrangle at depths of as much as 200 feet. Local surface exposures in the vicinity of Hanks consist of gray to buff clay, sandstone and silt and one workable lignite bed.

Outwash gravels of Altamont age have been deposited in a broad sag trending northeast through the northern third of the quadrangle, and also west of Grenora. Gravel terraces occur along Cottonwood Creek in the southern part of this area.

All streams in this area are intermittent and carry little water except after rains and thaws. The drainage is about equally divided between Little Muddy Creek to the east and Big Muddy Creek to the west.

STRATIGRAPHY

Sub-surface deposits.- Formations older than Tongue River are not exposed in this region, and no deep wells have been drilled within the quadrangle. However, one deep well, theCalifornia Company's Kamp No. 1, has been drilled to a depth of 10,281 feet in Williams County, 40 miles southeast of the area. The following systems and thicknesses were encountered: Tertiary- 800 feet, Cretaceous- 3,820 feet, Jurassic- 900 feet, Triassic- 970 feet, Mississippian- 3,160 feet and Devonian- 631 feet (6,pp. 13-14).

Surface deposits.- The Tongue River member is exposed in the vicinity of Hanks along the steep banks of Scoria Valley in T. 159 N., R. 102 W. along the banks of the coulee in Section 8, T. 158 N., R. 101 W., and along the banks of Cottonwood Creek in T. 159 N., R. 102 W.

The Tongue River is essentially a clay, silt and sand unit and in this area consists chiefly of blue-gray to buff clay and silt and gray to buff sandstones. There is a gradational interfingering of clay, sandy clay, silt, fine sand and coarse sand facies throughout the section. Most of the sandstones have a calcareous cement and become friable on weathering, yielding sand near the surface in many places. Concretionary masses and lenses of silt and sand and thin bands of limonite are common in the shales. Several lignite beds of varying purity are in the Tongue River in this area and range in thickness from a few inches to one 8-foot bed.

The Tongue River weathers and erodes readily except where the sands have been cemented locally to sandstones. Where the sands are not cemented the beds break down even more rapidly than the clays and silts and form gentle slopes. In this area the Tongue River has a thickness of 800 feet or more (6, p. 13). The partial section in Table 1, measured near Anderson Bros. (Erkie) Mine, SW$\frac{1}{4}$ of NW$\frac{1}{4}$, Sec. 20, T. 159 N., R. 101 W., is typical of the formation in this area. Few other outcrops show the completeness of this section. A rather persistent six to eight-foot coal bed is exposed in the vicinity of Hanks, and in many places it is overlain by 10 to 15 feet of blue-gray clay and 10 to 20 feet of highly cross-bedded, friable, yellow sandstone. At this locality a thinly bedded, light gray to dark, rusty brown sandy limestone crops out along the valley rim. It has a minimum thickness of 6 feet and weathers to form steep bluffs. Sand content varies considerably, and its more sandy phases are cross-bedded and platy. The limy phases weather to massive blocks.

Few fossils have been observed in the Tongue River in this area, Pelecypod fragments, which disintegrate quickly on exposure, are found south of Hanks along Scoria Valley and numerous pieces of silicified wood are found at the base of the Hanks coal bed. Remains of fresh water fish and invertebrates, turtles, mammalian teeth and alligators from areas outside the limits of this quadrangle have been described (7, p. 3).

Table 1

Tongue River section at Erkie Mine

Top of Exposure			Description
From	To	Thickness	
0 ft.	5 ft.	5 ft.	Till, weathered
5	15	10	Covered
15	38	23	Clay, dark gray
38	40.5	2.5	Sand, dark gray
40.5	46	5.5	Clay, buff to gray
46	60	14	Clay, gray, limonite concretions; weathers to a radial fibrous pattern, polygonal cracks on surface ½ inch to 1 inch.
60	66	6	Shale, gray, platy, well bedded, limonite-stained siltstone.
66	73	7	Lignite, est. 7 feet thick (burned and covered).
73	84	11	Covered
84	94.5	10.5	Clay, dark gray, case-hardened on surface; 1½ inch - 2½ inches polygonal fractures, homogeneous structure, no bedding.
94.5	100	5.5	Clay, blue-gray, ¼ inch - 1 inch polygonal fractures, iron streaks and small concretions.
100	105.5	5.5	Clay, buff, sandy, 1 inch - 2½ inches polygonal fractures.
105.5	106	.5	Lignite, interbedded with dark, brown shale.
106	110.5	4.5	Clay, gray to buff, fine laminations, semi-plastic.
110.5	116	5.5	Clay and silt, gray, semi-plastic; 1 inch of litnite.
116	118	2	Sand, very fine, argillaceous, cream to gray; weathers gray, contains gypsum.
		118.0 feet	

Bottom of Exposure

Clinker or "scoria" beds.- Conspicuous in the Tongue River formation are masses of baked and fused clinker or "scoria". Where lignite beds, ignited by spontaneous combustion, lightning or prairie fires, have burned at the outcrop, the overlying shales and sandstones have been oxidized to various shades of red, brown and orange, and in places have been completely fused to slag-like masses. Clinker caps many of the buttes in the vicinity of Hanks, protecting them from erosion by its relatively superior hardness. Exposures in this area range in thickness from 5 to 20 feet, depending apparently upon the original thickness of the underlying burned-out coal beds. This phenomenon is well illustrated in a road-cut $1\frac{1}{2}$ miles south of Hanks in the SW$\frac{1}{4}$ SW$\frac{1}{4}$ of Sec. 19, T. 159 N., R. 101 W., where a six-foot lignite bed overlain by blue-gray shales grades to a 1.5-foot bed of white ash, overlain by 15 to 20 feet of brick-red clinker. The overlying shale beds have slumped at the coal-ash contact, forming a sharp synclinal fold.

Flaxville gravel.- The youngest pre-Pleistocene sediments within the general area but not within the limits of this quadrangle are the gravels of the Flaxville plain. The Flaxville gravel at the type locality consists of well-rounded, brown quartzite and chert fragments, which, on the basis of paleontological evidence, has been regarded as Miocene or early Pliocene in age (5). Just north of the quadrangle boundary in NE$\frac{1}{4}$ NE$\frac{1}{4}$ SW$\frac{1}{4}$, Sec. 24, T. 161 N., R. 102 W., Fort Union sediments overlain by brown, well-worn, quartzite and chert gravels crop out near the morainal crest. The gravels in this exposure may represent a Flaxville plain remnant over which glacial material has later been deposited. The numerous concentrations of "Flaxville" type gravel within the glacial deposits were either derived from Flaxville plain remnants similar to that represented by the above exposure or were incorporated into the advancing ice which was moving over a surface rich in Flaxville gravel reworked at lower levels.

PLEISTOCENE GLACIAL DEPOSITS

With the melting and retreat of the Pleistocene glaciers, great quantities of debris, both sorted and unsorted, were left behind by the ice. These deposits are reported to be as much as 200 feet or more in thickness in the Zahl No. 3 quadrangle.

Morainal deposits

Pre-late Wisconsin drift.- Previous studies by several workers indicate two or more advances of ice into this region prior to the late Wisconsin glaciation. Alden (2, Pl. 1) has mapped a broad belt of pre-Altamont Wisconsin ground moraine stretching southward from the Altamont moraine to an east-west-trending boundary six to eight miles south of the quadrangle, where there are areas of end moraine topography. He further mapped as Illinoian or Iowan a sheet of drift extending southward from this line to a maximum of 35 to 40 miles southwest of the Missouri River, where only occasional patches of till and scattered boulders give evidence of glaciation.

Leonard (7, p. 532) earlier considered pre-Altamont Wisconsin drift to stretch from the southern boundary of the Altamont moraine to the present course of the Missouri River.

The pre-Altamont Wisconsin ground moraine of Alden is reflected topographically by rather well-integrated drainage and subdued relief. Kettles are numerous but closure in most does not exceed a few feet, and many are joined by minor intermittent stream channels. No lithologic basis has been found for distinguishing the till from that of the Altamont.

No contacts between any of the above-mentioned drifts have been identified in this area, and the boundary here mapped is therefore tentative and approximate. The distinction is made largely on topographic evidence. Direct evidence of any pre-Illinoian or Iowan glacial advance into the region is lacking. Whether either Nebraskan or Kansan drift is present and is buried beneath younger deposits, whether the drift has been largely incorporated into younger deposits, or whether it ever was deposited, is not yet known.

<u>The Altamont moraine</u>.- The Altamont terminal moraine here represents the southwestern terminus of the Dakota lobe of the late Wisconsin (Mankato?) glaciation. Proper use of the term Altamont terminal moraine is disputed by Leverett (9, p. 67) who points out that at the type locality, Altamont, South Dakota, another moraine, the Bemis, lies outside it. Whether the moraine here identified as Altamont is actually the correlative of the Altamont, South Dakota, moraine is therefore open to question, but for convenience of nomenclature, usage of the term is continued here.

The moraine consists chiefly of poorly compacted, calcareous, blue-gray till, oxidized near the surface to grayish-brown, and containing numerous lenses and local deposits of sand and gravel and scattered tracts of boulders and cobbles. Much of the finer fraction has been derived from the underlying Tongue River sediments, but the coarse material is largely foreign to the region. Gray and red granite, pegmatite, and gneiss are the most abundant boulder size rock types. Light gray and pink, fossiliferous dolomite and limestone are very common, and "Flaxville" type quartzites, lignite and basic igneous and metamorphic rocks are present. Boulders as much as 4 or 5 feet in diameter are common, and much larger ones can be found. All gradations from rude angular fragments to well faceted, polished and striated stones occur.

The knob and kettle topography of the moraine is very youthful and is marked by hummocky, ungraded profiles, and many large undrained depressions, kettles, marshes, alkali lakes, gravel knobs and till hills. Closure on many individual kettles is 50 feet or more, and overall relief exceeds 300 feet. The great prominence of the Altamont moraine, however, probably is due in part to the underlying bedrock surface. Beyond the limits of the quadrangle to the north, exposures of Fort Union overlain by "Flaxville" type gravel in several localities within the moraine are indicative that the Altamont has been deposited upon a dissected preglacial plateau.

The southernmost extremity of the Altamont ice formed an irregular line with large lobate protrusions extending down the major valleys. Lobate masses of ice extended beyond the main ice front down the Little Muddy valley on the east side of the quadrangle and down the broad sag toward Medicine Lake in Montana on the west side. The boundary drawn here, to include within the Altamont prominent morainal areas northeast and southwest of the town of Grenora, has been placed several miles south of that originally mapped by Alden (2, Pl. 1). A belt of morainal ridges lies just north of Cottonwood Creek and trends roughly parallel to it extending westward beyond the quadrangle boundary. Gullies draining into Cottonwood Creek from the north are short, steep and widely spaced, whereas those draining from the south are relatively long, have gentle gradients, and branch into numerous tributaries. This indicates that the drainage on the north side of Cottonwood Creek may have been interrupted by the Altamont ice and that it has not yet had time enough to become regraded to the same degree that it was before interruption. In the light of these facts, therefore, the Altamont has been extended to Cottonwood Creek.

Other facts support the idea that the till south of Grenora is of Altamont age. A long chain of large kettles, marked by the alkali lakes northwest of Grenora, lies in a topographic low trending northeastward outside and along the west edge of the quadrangle. This kettle chain intersects the outwash surface reaching west from Grenora, and it joins the large gravel outwash train known as the Stady Channel crossing the northern third of the quadrangle. This relationship indicates that both outwash bodies are of the same age, and since the Stady Channel (described below under fluvioglacial deposits) is undoubtedly Altamont, the Grenora outwash body probably is, also. The irregular Grenora outwash surface has a mean altitude of about 2050 feet, whereas much of the morainal area to the south is at least 20 to 30 feet lower. It seems unlikely that this moraine would have escaped burial under outwash if it were not ice-covered during outwash deposition.

Fluvioglacial deposits.

The Stady Channel.- The Stady Channel is a broad train of outwash lying in the bottom of a wide topographic sag which crosses the northern third of the quadrangle in a west-southwesterly direction. The average width of the channel is about one-half mile. It narrows along its course to about one-fourth mile and widens in places to a mile or more. In sections 2 and 3, T. 160 N., R. 102 W., the northern edge of the channel is marked by a prominent, well-preserved ice contact face. Kettles are not numerous, but in places the outwash surface is higher than the adjoining till. The ice contact face, the presence of outwash gravels deposited topographically higher than the till, and the presence of kettles indicate that Altamont ice was present during deposition of the outwash. The outwash is composed of fine to coarse sands, gravels up to 2 inches in diameter, and some silts.

Sorting and bedding are developed to fair degree and cross-bedding is common. Limestones and dolomite are the most abundant rock fragments in the gravels. Granite and gneiss are numerous. Chert, quartzite rhyolite and related rocks, and basic igneous and metamorphic rocks are present in about the same proportion as in the till, and lignite slack is sometimes present. Quartz is the predominant mineral in the sands, and feldspar is common. There is no appreciable apparent difference in size or composition of outwash constituents along the length of the channel within the quadrangle.

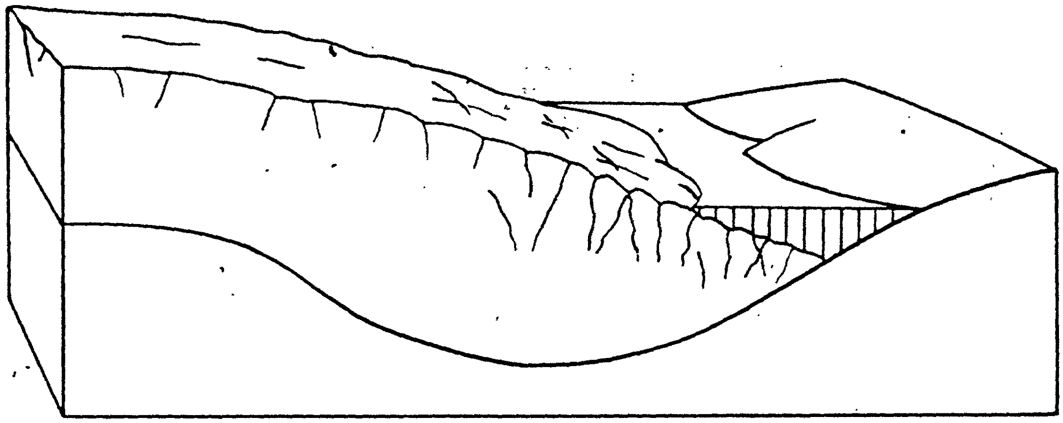
The Grenora outwash body.- The outwash body west of Grenora is similar in character and composition to the Stady Channel, which it joins west of the quadrangle boundary. However, because the meltwater source was nearer than that of the Stady Channel, much coarser material, including 5-inch cobbles, has been deposited.

Two eskers are within the outwash body and extend westward beyond the quadrangle boundary. These apparently were deposited while ice still covered the area. Ice blocks must have remained during later deposition of the surrounding outwash, however, because the outwash surface is hummocky and is pitted with numerous kettles. Till is found lying on gravel in some exposures along road-cuts about one-half mile southwest of Grenora.

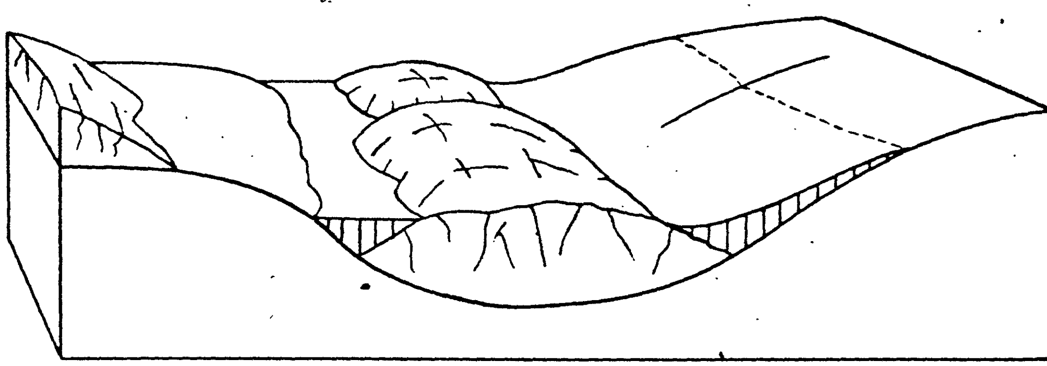
The Cottonwood Valley terraces.- Terraces of sand and gravel are along both sides of the lower half of Cottonwood Valley, but are wider, higher, and more extensive along the south side than along the north side. These are interpreted (Figure 1) as kame terraces formed while the ice front stood at Cottonwood Valley. Near the southeast corner of SW$\frac{1}{4}$ of Sec. 1, T. 158 N., R. 103 W., a sand pit has been opened which shows evidence of ice contact origin. The bedding of the sand is highly disturbed, dips steeply toward the valley at angles up to 70 degrees, and contains large blocks of compact, clayey till. Dips in other exposures are also valleyward, although such steep angles have not been observed. There is no general accordance of the terrace surface along the length of the valley as would be expected of graded alluvial terraces, and in most instances the surface slopes irregularly toward the valley.

The north side terrace probably was deposited adjacent to and upon ice blocks left in the valley after the main ice front had retreated northward from the immediate vicinity.

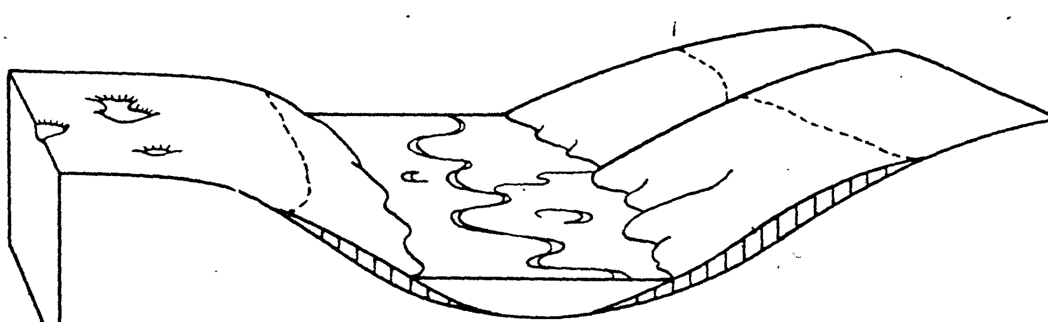
Other fluvioglacial deposits.- Near the northwest corner of the quadrangle is an extensive tract of fluvioglacial sand and gravel. Its knobby surface and irregular boundary suggest deposition in, on and under ice. Locally it is overlain by till, and in some knobs that have been opened for gravel the bedding dips parallel to the surface slope away from the crest, suggesting slumping after removal of the supporting ice.



1. Ice front against south wall; deposition of southside terrace.



2. Thinning and stagnation of ice front; ice blocks left in valley; deposition of northside terrace.



3. Final disappearance of ice; alluviation of valley bottom.

FIG. 1. STAGES IN DEVELOPMENT OF COTTONWOOD VALLEY KAME-TERRACES.

Other smaller, irregular ice contact deposits, too small to be mapped, are scattered throughout the quadrangle, and many have been exploited for local gravel needs. Several pits have been opened in gravel lenses in a morainal area about 1 mile southeast of Grenora in the $S\frac{1}{2}$ of Sec. 7., T. 159 N., R. 102 W.

ALLUVIUM

Recent alluvium makes up the floodplain of Cottonwood Creek, mantles the floor of Scoria Valley and covers the bottoms of most of the larger kettles and closed depressions. It consists mostly of reworked glacial sands, silts and clays, but some has been derived directly from the Fort Union formation. Alluviation of Scoria Valley has been accomplished largely by side wash and rill action.

GEOLOGIC STRUCTURE

Well borings into the Dakota sandstone indicate that western North Dakota is structurally a large, gently sloping trough to which the name Dakota (Williston) basin has been given (3, p. 1568). The Zahl No. 3 quadrangle lies on the northern flank of the basin. The Tongue River member of the Fort Union formation underlying the glacial drift in this area has been only slightly, if at all, disturbed since deposition, the beds being essentially horizontal with a slight southeastward dip to the Dakota basin. Limited information gained from local wells and from the few outcrops in the area indicates dips of less than one degree. No evidence of faulting has been observed in the area, and the few joints in the Tongue River member do not have any definite pattern.

GEOLOGIC HISTORY

Fort Union time.- Warm, continental, conditions persisted throughout Fort Union time, and extensive forests probably covered much of North Dakota. The Tongue River member contains numerous remains of terrestrial and fresh water plants and animals. Previous workers (8, p. 3) have identified a large assemblage of conifers and deciduous trees, all occurring chiefly in the lignite. In addition various turtles and alligators as well as invertebrates have been described.

Swampy, humid conditions must have occurred repeatedly and persistently for long periods of time, as indicated by the presence of lignite beds within the area. The Tongue River member consists predominantly of well stratified clay and silt, and stable quiet conditions must have attended their deposition. The presence of sands, however, often strongly cross-bedded, indicates transporting currents of considerable velocity. For the most part, conditions of deposition must have fluctuated, causing interfingering of the sediments which successively filled and buried the coal swamps and shallow lakes.

The Glacial period.- Miocene or Pliocene gravels of the Flaxville plain possibly covered this part of North Dakota during late Tertiary time. If the plain did extend this far east, streams later dissected the surface and the Pleistocene ice sheets finally obliterated its remnants. According to Alden (2, Pl. 1) the preglacial Yellowstone River flowed northward in the valley of the present Little Muddy Creek east of the quadrangle, and the preglacial Missouri River flowed northeastward in the adjoining quadrangle to the west. The broad sag now occupied by the Stady outwash may represent a portion of the old Missouri channel. At any rate, all northward-flowing or northeastward-flowing drainage must have been blocked by the advance of the first ice sheet into the area, and presumably the Yellowstone and Missouri Rivers were diverted into courses approximating their present-day channels. Scoria Valley may represent a temporary channel carved by the Missouri River during its southward diversion.

An Illinoian or Iowan ice sheet (2, Pl. 1) advanced far beyond the southern limits of the quadrangle and deposited drift in the Missouri channel. The river re-occupied this channel when the ice withdrew. An early Wisconsin ice sheet then advanced approximately six to eight miles beyond the southern boundary of the quadrangle and remained long enough to build a fairly large end moraine which erosion has since reduced to isolated patches of morainal topography. The final advance of the ice into the region in late Wisconsin time produced the great Altamont moraine.

North of Scoria Valley are several "ghost" channels or filled valleys. Most of these are bottomed with closed depressions, but some extend westward into valleys containing consequent drainage. These are interpreted as ice marginal channels carved either by diverted drainage or by meltwaters escaping from the ice sheet. Dating of these channels has not yet been established, but since most are blanketed with till, and since some are closed at both ends, they must antedate the recession of the youngest ice.

Cottonwood Valley may have had a similar origin. The valley is steep-sided and continuous from the west boundary of the quadrangle to its intersection with Scoria Valley, but in the SE$\frac{1}{4}$ SW$\frac{1}{4}$, Sec. 25, T. 159 N., R. 102 W., is a low divide from which Cottonwood Creek flows westward, and a short tributary of Scoria Creek flows eastward. This condition suggests original entrenchment earlier than the present erosion cycle. The Scoria Valley tributary appears to have captured the headwaters of Cottonwood Creek, and may have done so while the lower part of Cottonwood Valley was blocked with ice from the north.

Recent erosion.- Fairly well integrated drainage has developed in the older pre-Altamont part of the quadrangle, but dissection there is by no means complete, and shallow kettles are still numerous. The Altamont moraine is essentially as the ice sheet left it, although rill action has carved small gullies into the steeper slopes, and consequent drainage has produced local integration, especially in certain ice marginal channels.

ECONOMIC GEOLOGY

The Hanks lignite district.- The lignite deposits of the Hanks district have been described by Dove and Eaton (8, pp. 157-159). All coal mined in the area is taken from the Tongue River member of the Fort Union formation, and only one bed, the Hanks, has been mined commercially. Mining has been in progress intermittently for many years in the Hanks district, but production is largely for local use and has never been great. The Hanks bed averages 7 to 8 feet in thickness and outcrops about 70 feet above the floor of Scoria Valley at the town of Hanks. The bed is solid and tough when fresh, but slacks readily on exposure to air and sunlight, checking first to small fragments and finally to powder. Most of the mining, therefore, is done in the autumn and winter when storage of the coal is not required because of immediate consumption. Most of the coal contains small quantities of pyrite or marcasite and gypsum, especially along joints and fractures, and clay partings are common but not persistent. The plants from which the coal is formed were chiefly coniferous, and occasional specimens are remarkably well preserved. The unweathered lignite is dark brown to black, has a dense, woody texture, and is laminated and jointed.

Recoverable reserves of the Hanks bed are estimated by Dove and Eaton (8, p. 159) to be about 377,000,000 tons. Approximate analyses made by the U. S. Bureau of Mines (unpublished report) of samples from the Hanks bed shows the fresh coal to average about 40-45 per cent moisture, 25 per cent volatile matter, 25 per cent fixed carbon, and 5 per cent ash, with a B. T. U. rating of 6,000 ±. Air drying reduces the moisture content to about 12-15 per cent and raises the B. T. U. rating to about 9,000.

Sand and gravel.- The Stady and Grenora outwash bodies are the most extensive sand and gravel deposits in the quadrangle and offer almost unlimited quantities of usable construction material. These and smaller deposits, including the Cottonwood Valley terraces, have provided material for local needs for many years. Material for secondary road metal usually is taken directly from the pits, and with preliminary screening and washing it can be used for general construction work. Materials considered deleterious for use in concrete aggregate are present to some degree in most deposits. These include ironstone concretions, lignite slack, and certain substances such as chert, chalcedony and acidic volcanic rocks, that are reactive with high alkali cements. Also, caliche or secondary lime coats most deposits to a depth of a foot or two. As deleterious materials vary widely from place to place, individual samples should be examined prior to exploitation of a deposit.

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