Geology of the Lower Marias River Area Chouteau, Hill, and Liberty Counties Montana

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CONTRIBUTIONS TO GENERAL GEOLOGY

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GEOLOGY OF THE LOWER MARIAS RIVER AREA, CHOUTEAU, HILL, AND LIBERTY COUNTIES, MONTANA

By J. Fred Smith, Jr., I. J. Witkind, and D. E. Trimble

ABSTRACT

The lower Marias River area includes about 800 square miles in northern Chouteau, southwestern Hill, and southern Liberty Counties, Mont. The mapped area consists of four 15-minute quadrangles between lat 48°15′ and 48°30′ N., and between long 110°15′ and 111°15′ W. Most of the area is a gently rolling terrain of low hills and shallow depressions. In the southwest corner of the mapped area the Marias River has entrenched itself about 200 feet below the upland and has cut a broad valley.

Glacial deposits are widespread and bedrock is exposed principally along the valley walls. The bedrock consists of sedimentary strata that range from the Colorado shale of Early and Late Cretaceous age of which only rocks of Late Cretaceous age are exposed in this area to the Judith River formation of Late Cretaceous age. These formations dip southeastward at about 35 feet to the mile, although locally they have been folded into narrow southeastward-trending flexures. Of these, the most prominent are (1) the Lothair nose, (2) an unnamed syncline, and (3) the Marias River dome.

In places, lenses of gravel tentatively correlated with the South Saskatchewan gravels of Alberta crop out between bedrock and till.

The glacial deposits are divided into two categories: nonstratified drift (till) and stratified drift (glaciofluvial deposits). Two tills are recognized. An older till, the Lothair till, is light tan, tough, and indurated, and was deposited by an ice sheet (the Lothair ice) that overrode the entire area. Embedded in the Lothair till are lenses of sand and gravel and layers of yellow lacustrine silt. A younger till, the Pondera till, is chocolate brown, semiplastic, and overlies the Lothair till in the southwestern part of the area. In many places the tills are separated by a layer of light-buff to yellow silt. Exact limits of the Pondera till are unknown but most of it seems to be restricted chiefly to a broad divide in the southwestern part of the area between the Marias River and Pondera Coulee.

The Pondera till was deposited by a wedge-shaped narrow tongue of ice that advanced from the west as far east as the center of T. 29 N., R. 6 E., and that was marginal to a larger ice sheet to the west. Stratified drift that was deposited during the melt of each ice sheet is divided into two categories: outwash-channel deposits formed away from the ice, and ice-contact deposits formed

against the ice. The outwash-channel deposits consist of poorly to well stratified silt, sand, and gravel flooring shallow elongate valleys cut in till. Ice-contact deposits of the Lothair ice form kames, an esker, crevasse fillings, and other miscellaneous deposits for which no name is available. The ice-contact deposits of the Pondera ice form only kame terraces. Ice-contact deposits of both ice sheets consist of poorly to well bedded silt, sand, and gravel enclosing till blocks.

The Early and Late Cretaceous history of the mapped area was one of alternating marine invasions and withdrawals. During the Tertiary the sedimentary strata were dissected by southeastward-flowing streams, among them the ancestral Marias River and its tributaries. The gorge of this former stream, now filled with till, can be traced eastward across the mapped area for about 50 miles. Other Tertiary drainage courses also were filled with till. When the Pondera ice withdrew the Marias River entrenched itself and in so doing formed four terraces.

Economic deposits in the area consist principally of sand and gravel and minor amounts of poor quality riprap. Small coal seams and thin bentonite beds are exposed but none are of commercial quality.

Strata that produce oil and gas elsewhere underlie the area, but a test well drilled in the Marias River dome was unsuccessful and it was abandoned as a dry hole after it penetrated the Madison limestone at a depth of 2,471 feet. The Eagle sandstone (Late Cretaceous) produces gas in adjacent areas.

INTRODUCTION

LOCATION AND EXTENT OF AREA

The lower Marias River area includes parts of northern Chouteau, southwestern Hill, and southern Liberty Counties, Mont. It consists of four 15-minute quadrangles covering a total area of about 800 square miles, and is between lat 48°15′ and 48°30′ N. and long 110°15′ and 111°15′ W. (fig. 12).

PURPOSE OF INVESTIGATION

The area was studied as part of a broad integrated program of study of the Missouri River drainage basin in connection with development of the basin by the U.S. Bureau of Reclamation. The lower Marias River area includes (1) the site of the Tiber dam (pl. 10) on the Marias River, (2) part of the area that is to be inundated by the reservoir formed behind the dam,[1] and (3) part of the region proposed for irrigation east of the dam. The report presents basic data useful in planning land improvement. As the bedrock exposed in the eastern part of the lower Marias River area had been mapped previously by Pierce and Hunt (1937), considerable emphasis was given in the course of the project to a study of the widespread Quaternary surficial deposits.

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[1] Since this report was prepared, the Tiber dam has been completed and a sector of the Marias River valley in the southwest part of the area is now inundated.

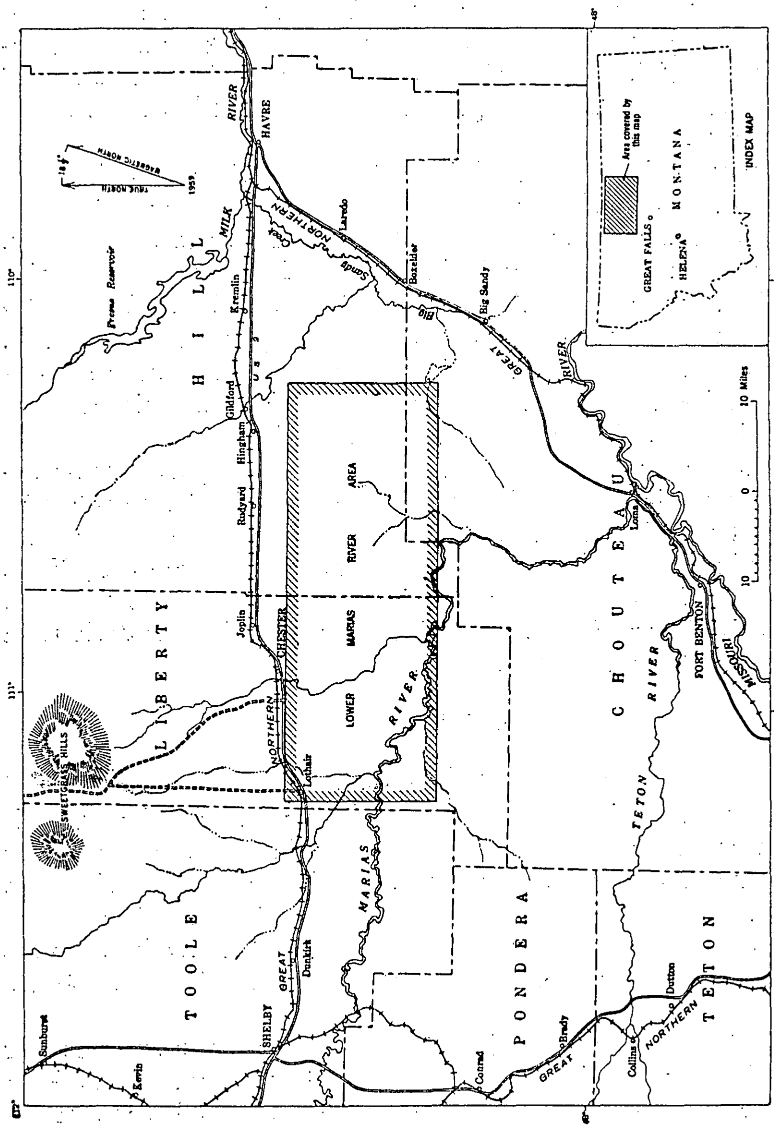

FIGURE 12.—Index map of part of north-central Montana showing location of lower Marias River area.

FIELDWORK AND ACKNOWLEDGMENTS

Most of the geologic mapping was done in 1946 on aerial photographs at a scale of 1:31,680. A land-net map was compiled from General Land Office township plats, and the planimetric and geologic data were transferred by vertical sketchmaster to the land-net base. The quadrangle projection was prepared by the Topographic Division of the U.S. Geological Survey. Because of the scarcity of control points in the area, projection lines on the map are only approximate.

Engineers and geologists of the U.S. Bureau of Reclamation were most cooperative during the course of the work and supplied logs of test holes, topographic maps of parts of the area, and test-pit data. Field conferences regarding the bedrock stratigraphy were held with C. E. Erdmann of the U.S. Geological Survey, and G. W. Beer and J. W. Nordquist, then members of the Geological Survey. A. G. Middleton, district engineer of the Montana State Highway Department, furnished information regarding the use of surficial deposits for road metal. Much information concerning the thickness and character of the surficial deposits and the underlying geologic formations was obtained through the cooperation of local residents who furnished well information. Data on the thickness of the glacial deposits in the easternmost part of the area were obtained by F. A. Swenson of the Water Resources Division of the Geological Survey. Special thanks are due E. G. Duckworth who assisted materially in the course of the fieldwork.

GEOGRAPHY

TOPOGRAPHY

The general region surrounding the lower Marias River area is drained by three main streams that head in the northern Rocky Mountains and flow eastward to empty into the Missouri River. These are the Milk River on the north, the Marias River in the center, and the Teton River on the south (fig. 12). Drainage in the lower Marias River area empties into both the Milk and Marias Rivers.

East of the center line of R. 10 E. (pl. 10) drainage is to Big Sandy Creek, which is outside the area and flows north to the Milk River. Drainage west of the center line of R. 10 E. is south to the Marias River. Except for the Marias River all drainage is intermittent. Maximum relief is about 600 feet, and the general altitude of the upland surface ranges from about 2,800 to about 3,250 feet. The highest part is Dobie Ridge and the lowest part is along the south edge of the mapped area in R. 8 E. where the Marias River leaves the area.

The area is gently rolling to flat except where streams have trenched the glacial drift and the underlying rock strata. Low hills rise above the nearly flat upland surface but have little effect in breaking the general monotony of the plains.

The salient topographic feature is a broad wedge-shaped valley in the southwestern part of the area. This valley, which includes both the Marias River and Pondera Coulee (pl. 10), is 10 to 12 miles wide in R. 4 E. and narrows to about 3 miles near the center of R. 6 E. East of this point the Marias River flows in a narrow valley about 2 miles wide. The wide valley to the west of the center of R. 6 E. is cut in relatively soft shale beds, whereas the narrow valley is cut in more resistant sandstone beds. A line of bedrock exposures rims the north side of the valley. South of these exposures smooth surfaces, formed on till, slope gently toward the Marias River. These surfaces have low southward-facing scarps and are dissected by steep-sided coulees, which form an elaborate dendritic drainage system.

Remnants of 4 gravel-capped terraces border, or are near the Marias River flood plain, and these range from about 40 to about 110 feet above the river. In a few places sand and gravel deposits of glacial origin are at higher altitudes than the terraces. The flood plain is nearly flat, and locally vertical banks 4 to 12 feet high border the river; in places, low alluvial fans are at the mouths of tributary streams along the margins of the flood plain.

The area between the Marias River and Pondera Coulee (pl. 10) is a broad low divide covered by knob-and-kettle topography. Pondera Coulee has a narrow flood plain bordered in most places by steep bluffs of till. South of the coulee, smooth surfaces on till ascend gradually to a rim south beyond the limits of the mapped area. These surfaces are similar to those north of the Marias River and have a well-integrated drainage system established on them. Thus, in this broad valley, the till surfaces north of the Marias River and south of Pondera Coulee are marked by dendritic drainage patterns that reach into the uplands. In contrast, the divide between these drainage ways is an area of relatively undissected knob-and-kettle topography.

CULTURE AND CLIMATE

Wheat farming is the major occupation in the region. Cattle and sheep are pastured in some parts of the area where the ground is rocky or the surface too irregular for convenient cultivation. Hay is raised along the Marias River flood plain and on some of the gravel-covered areas near the river.

U.S. Highway 2 and the Great Northern Railway parallel and are 3 to 5 miles north of most of the area (fig. 12). Chester, the county seat of Liberty County, is about 3 miles north of the mapped area in T. 32 N., R. 6 E.

At Chester the average temperature for January is about 10° F and for July is about 67° F, and the average annual precipitation is about 11 inches (Hambidge, 1941, p. 956). Prevailing winds are from the west and northwest.

As the Marias River is the only perennial stream, water for livestock away from the river is obtained from wells and from reservoirs constructed along tributary stream channels. Water for domestic use is hauled from the Marias River and from the Sweetgrass Hills 30 miles to the north. Most well water derived from the bedrock formations has a high mineral content and is not potable.

DESCRIPTIVE GEOLOGY

The bedrock that underlies most of the area belongs to the Colorado shale and the Montana group of Cretaceous age. Though the preglacial topography as well as the rocks themselves are concealed in most places by glacial deposits, the consolidated sedimentary formations are exposed chiefly along the Marias River and its main tributaries. In ascending order these consolidated sedimentary formations are the Colorado shale of the Lower and Upper Cretaceous series of which only Upper Cretaceous rocks are exposed, the Telegraph Creek formation, the Eagle sandstone (which consists of a lower member, the Virgelle sandstone, and an upper unnamed member), the Claggett shale, and the Judith River formation of the Upper Cretaceous series. (See figure 13.) The surficial glacial deposits include both nonstratified drift (till), and stratified (glaciofluvial) deposits. Locally both the Cretaceous strata and the glacial deposits are mantled by terrace deposits and alluvium.

CRETACEOUS SYSTEM

COLORADO SHALE

The Colorado shale is composed chiefly of very dark gray to black marine shale. Intercalated in the shale are minor thin bentonite beds, lenses of fine-grained sandstone, sandy limestone, and scattered limestone concretions and septaria.

In the lower Marias River area, the Colorado shale crops out west of R. 6 E. along the Marias River and its main tributaries—Pondera Coulee and Willow and Eagle Creeks. Commonly it forms cliffs or very steep slopes.

Bentonite beds that weather to bright-yellow sugary-textured units are striking features in some exposures of the Colorado shale and contrast markedly with the adjacent black shale. The fresh bentonite is gray and forms beds that are commonly 1 to 6 inches thick and

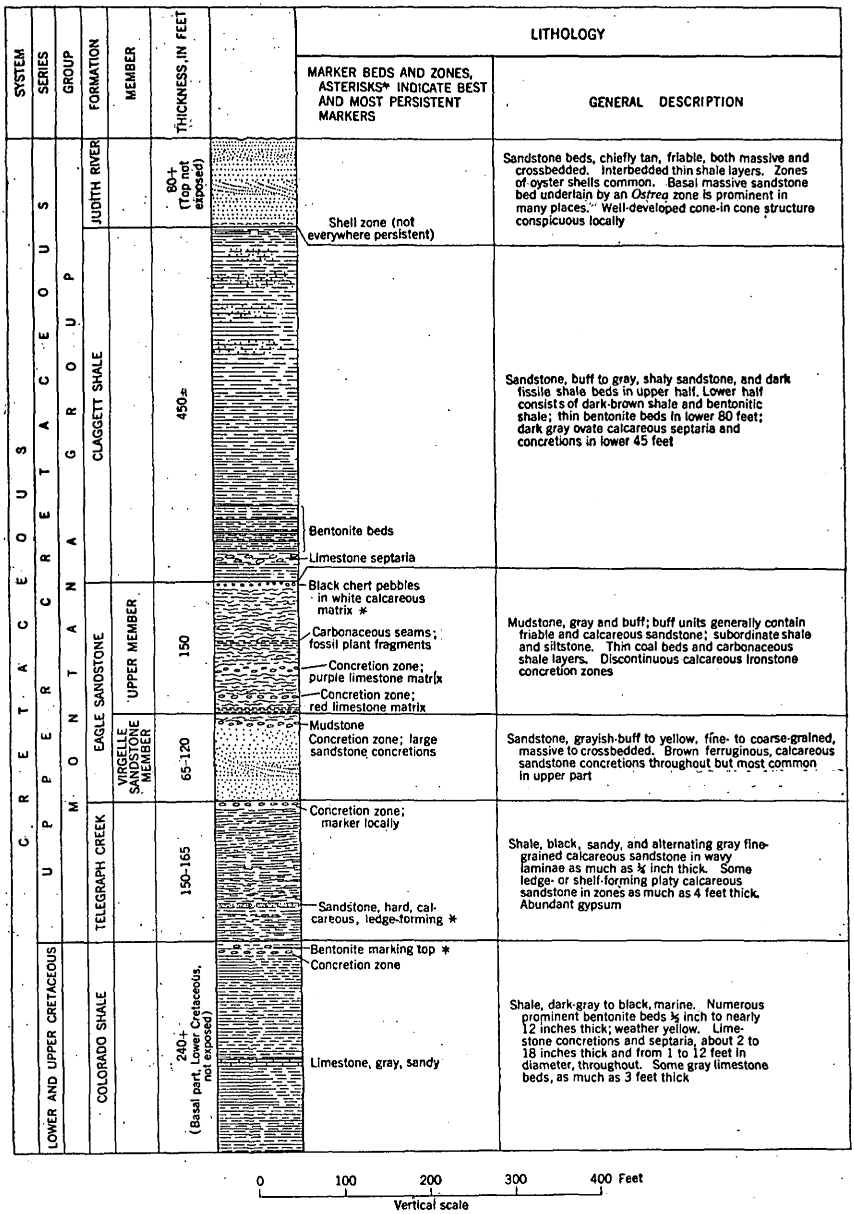

FIGURE 13.—Stratigraphic section of exposed consolidated sedimentary strata in the lower Marias River area.

range in thickness from about ½ to almost 12 inches. Seventeen bentonite beds were observed in exposures of the Colorado shale near the Tiber dam site. Seams of calcite and aragonite form lenses from ¼ to ⅜ inch thick on some bentonite beds, and crop out away from bentonite elsewhere in the formation.

In places the shale is sandy and contains thin beds of fine-grained thinly laminated sandstone. Sandstone lenses 4 to 6 inches thick form the dominant part of some lenticular units that are as much as 5 feet thick. These sandstone lenses are more abundant near the top of the formation.

Beds of bluish-gray sandy resistant concretionary limestone, as much as 3 feet thick, are in the lower 100 feet of the Colorado shale exposed in this area. They form small ledges and create a steplike profile on exposed slopes. Cone-in-cone structures and layers of aragonite are associated with the limestone.

Light-gray discoidal limestone concretions and septaria as much as 12 feet in diameter and about 1½ feet thick form more or less continuous lateral zones throughout the Colorado shale. Locally layers of septaria or of concretionary limestone faithfully reflect the attitude of the deformed rocks. Erdmann (1948) reports three such marker beds in this area. The first is a gray concretionary limestone about 30 feet below the top of the Colorado shale. The second consists of a gray limestone or fibrous calcite bed 112 to 115 feet below the top. The third is a limestone that weathers reddish brown and contains rounded pebbles of argillite and is about 215 feet below the top. In most localities we noted a distinct and persistent zone of concretions, about 1 foot thick, 10 feet below the top of the formation. Commonly, concretions are dispersed through the upper 10 feet of the formation, and many contain invertebrate fossils or fish scales in their centers.

Only the uppermost 240 feet of the Colorado shale is exposed in the lower Marias River area, although on the basis of a test well[2] drilled in sec. 26, T. 29 N., R. 6 E., the unit is about 1,750 feet thick (Erdmann, 1948).

In most places the contact with the overlying Telegraph Creek formation is selected as the top of a light-yellow sandy bentonite bed above a zone of discoidal limestone concretions and septaria. Locally it is about 10 feet above a thin concretionary zone. The change from the black shale of the Colorado shale to the interbedded sandstone and shale beds of the Telegraph Creek formation is gradational through a 10- to 15-foot zone, and in places the exact contact may be difficult to determine unless either the concretionary zone or bentonite bed is present.

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[2] The Texas Co. State Well No. 1.

No fossil collections from the lower Marias River area were studied for this report but specimens of *Baculites*, *Scaphites*, *Inoceramus*, and *Gryphea* were identified in the field; these types are common. Locally, small sharks' teeth and shell fragments are common in the shale and on top of the bentonite beds.

TELEGRAPH CREEK FORMATION

The Telegraph Creek formation of the Montana group is an interbedded sequence of thinly to coarsely laminated fine-grained buff to gray calcareous sandstone and dark-gray to gray sandy shale and shale. The formation crops out in the valley walls of the Marias River and along Cottonwood and Eagle Creeks (pl. 10).

Throughout much of the formation sandstone, shale, and sandy shale strata alternate regularly in beds commonly from 1/4 to 1/2 inch thick. Some sandstone is crossbedded. In places thin-bedded sandstone units are as much as 15 feet thick. Some lenses of platy calcareous sandstone, as much as 4 feet thick, form resistant shelves.

Three thin discontinuous beds of bentonite were noted. The bentonite is gray and sandy and in places has cone-in-cone structures associated with it. Limestone concretions and septaria are scattered throughout the formation. Selenite is common along bedding planes and in many small crevices.

Erdmann (1948) reports two marker beds in the Telegraph Creek formation. The first is about 44 feet above the top of the Colorado shale and is a persistent ledge-forming thinly laminated sandy limestone that locally contains a few yellow to orange-buff septaria. The second marker bed is about 50 feet below the top of the Telegraph Creek formation and consists of a layer of cone-in-cone calcite and a bed of gritty, sandy bentonite. The bentonite is 2½ feet thick, and contains discoidal limestone concretions.

The Telegraph Creek formation is 150 to 165 feet thick in the mapped area.

In many places the contact with the overlying Virgelle sandstone member of the Eagle sandstone is selected as the top of a zone of tan calcareous septaria; elsewhere, the contact is at the uppermost shale below the massive sandstone of the Virgelle.

No fossils were found in exposures of the Telegraph Creek formation in the lower Marias River area, but Cobban (1950) reports the following fauna, collected near Shelby, Mont. (fig. 12), as characteristic of the formation:

Inoceramus lundbreckensis McLearn
Baculites haresi Reeside
Desmoscaphites bassleri Reeside
Puzosia (Latidorsella) mancasensis Reeside
Scaphites cf. *S. hippocrepis* (DeKay)

The beds composing the Telegraph Creek formation originally were included in the Virgelle sandstone member of the Eagle sandstone (Stebinger, 1914, p. 62), but Erdmann and Davis (1939) mapped them as a separate unit and called them the "Transition zone" to reflect the lithologic change occurring in these beds between the Colorado shale and the Virgelle sandstone. Later, Erdmann (1948) tentatively correlated them with the Telegraph Creek on the basis of lithology, and Cobban (1950, p. 1900) substantiated this correlation on the basis of fossils.

EAGLE SANDSTONE

The Eagle sandstone of the Montana group consists of two members: a lower Virgelle sandstone member, and an upper member composed of shale, mudstone, siltstone, and sandstone.

VIRGELLE SANDSTONE MEMBER

The Virgelle sandstone member of the Eagle sandstone is a grayish-buff to yellow fine- to coarse-grained massive to crossbedded friable sandstone. In T. 29 N., R. 6 E. the Virgelle borders the Marias River flood plain; the unit rises westward and is high on the valley walls in Ts. 29 and 30 N., R. 5 E. The Virgelle is also well exposed along Cottonwood Creek (pl. 10). Dissection of the sandstone has formed bold cliffs as much as 40 feet high and steep-walled valleys with box canyons at their heads.

On fresh exposures the sandstone is light buff, but on weathered outcrops it is grayish buff to yellow. The sandstone is chiefly fine grained but locally is coarse grained and in a few places includes thin lenses of pebble conglomerate. It is crossbedded in a manner commonly attributed to fluvial deposits. Both lenticular beds and lateral gradations in lithology are common.

In some exposures thin beds or lenses of light-brown shale, black carbonaceous shale, and lignite are interbedded with the sandstone. The interbeds range in thickness from 2 to about 9 inches. Generally the shaly and lignitic beds are more common in the upper half of the member than in the lower half.

Brown ferruginous, calcareous sandstone concretions, 3 to 8 feet in diameter, are scattered throughout the member, but are most abundant about 15 feet below the top. The concretions are resistant and cap pedestals and mushroom-shaped rocks. A persistent conglomerate lens on the east wall of Cottonwood Creek contains limy sandstone concretions, 1 to 2 inches in diameter, and poorly rounded shale and sandstone pebbles that are from ¼ to ½ inch in diameter. The lens has a maximum thickness of 1 foot, and is in a zone of pronounced crossbedding. Small hematite concretions, 1 to 2 inches in diameter, are common locally. Fragments of petrified wood are scattered irregularly through the Virgelle.

The thickness of the Virgelle sandstone member ranges from 65 to 120 feet in the mapped area. Although in any single stratigraphic section the lithologic differences between the Virgelle and the confining units seem distinct, the lenticularity of the beds causes irregular contacts. This irregularity, to some extent, is responsible for the variable thicknesses. The maximum thickness of 120 feet was measured on Cottonwood Creek and the minimum thickness of 65 feet was measured along the Marias River in the vicinity of the Tiber dam site. No evidence was found to indicate that the unit thickens regularly in any direction.

The upper contact of the Virgelle member is selected as the basal buff to gray mudstone of the mudstone and sandstone sequence composing the upper member of the Eagle sandstone.

UPPER MEMBER

The upper member of the Eagle sandstone consists chiefly of alternating and interfingering beds of shale, carbonaceous shale, mudstone, siltstone, and fine- to medium-grained crossbedded sandstone. The member crops out in the Marias River valley flanking the flood plain in T. 29 N., R. 8 E., and rises westward to a point more than 200 feet above the river in T. 30 N., R. 5 E. Good exposures are also along Cottonwood Creek.

Most of the upper member of the Eagle sandstone consists of buff, gray, greenish-gray, and brownish-purple mudstone lenses that locally are as much as 12 feet thick. Alternating at irregular intervals with this mudstone sequence are lenses of shale, siltstone, and sandstone. The shale beds are carbonaceous in places, and contain many fossil plant fragments. Along Cottonwood Creek (pl. 10) a red calcareous shale about 20 feet above the base of the upper member is a good marker bed. Commonly the sandstone lenses are buff, gray, yellow, or brown, and consist principally of thin-bedded platy friable fine-grained crossbeds that range from 2 inches to 10 feet in thickness. Some of the sandstone lenses include stringers of pebble conglomerate composed principally of shale, siltstone, and sandstone fragments, which range in length from 1/8 to 1 1/2 inches. Carbonaceous lenses and lignite pods about 1 inch thick are scattered at random through some sandstone beds.

In the lower 50 feet of the member, two zones of ironstone concretions in a red and purple calcareous matrix form conspicuous layers. The concretions range from about 6 to 12 inches in diameter and disintegrate readily into small red fragments that form bright-colored float on the surface along and below the outcrops.

The upper member of the Eagle sandstone is about 150 feet thick in the lower Marias River area, but the thickness varies locally where the beds interfinger with those of the underlying Virgelle sandstone member.

In many places the contact between the upper member and the overlying Claggett shale is marked by a conglomerate of small rounded black chert pebbles in a matrix of calcareous sandstone. These pebbles are elongate and oval, well rounded, and smooth, and range in length from ¼ to 1 inch. Generally the conglomerate forms a single bed although locally the pebbles are scattered through a zone several feet thick that marks the top of the upper member of the Eagle sandstone. A few pebbles are in the basal strata of the Claggett shale. Also included in the pebble bed are sharks' teeth, invertebrate shells, and shell fragments. The best exposures of this contact are in sec. 24, T. 29 N., R. 8 E. and in sec. 19, T. 29 N., R. 9 E.

CLAGGETT SHALE

In the lower Marias River area the Claggett shale of the Montana group is divided into two lithologic units. The lower part consists of dark-brown bentonitic shale and thin beds of bentonite. The upper part consists of alternating shale and sandstone lenses; the shale is brown and tan, and the sandstone commonly is buff or gray.

The Claggett is best exposed along Dobie Ridge (pl. 10) in Tps. 30 and 31 N., R. 7 E. where about 100 feet is exposed. About 65 feet of the unit crops out along the Marias River in sec. 24, T. 29 N., R. 8 E., and a similar thickness is in sec. 19, T. 29 N., R. 9 E. The complete stratigraphic section is not exposed in the mapped area.

Seven bentonite beds that range in thickness from 1 inch to 3 feet and average 3 inches are interbedded in, and are characteristic of, the lower part of the Claggett. Three zones of dark-gray ovate limestone concretions and septaria crop out from 12 to 45 feet above the base of the formation. The concretions range from 1 to 6 feet in diameter and weather orange yellow to buff. Cone-in-cone structure is associated with many of the concretions. Good exposures of these three concretionary zones are in sec. 19, T. 29 N., R. 9 E.

The upper part of the Claggett shale, best exposed on the south side of Dobie Ridge (pl. 10), consists of interbedded sandstone, shale, and sandy shale beds. The sandstone beds are buff or light gray, fine to medium grained, crossbedded, and commonly form thin platy lenses. The shale is thinly laminated, chiefly brown and tan, and weathers to a grayish purple along fractures. Locally the shale is sandy and a deeper brown. Oyster shell fragments are in the upper part of the sandy shale beds. Concretionary beds are common in the upper part and consist of oval concretions composed principally of limestone and sandstone.

As the unit is not exposed in its entirety in the mapped area, its thickness is unknown. About 17 miles to the east, however, the Claggett is about 400 feet thick, and it thins progressively eastward (Pierce and Hunt, 1937, p. 238–240). If the same eastward thinning occurs in the Marias River area, the Claggett in this area is estimated to be about 450 feet thick.

The contact of the Claggett shale with the overlying Judith River formation is gradational, but a coquina layer, consisting mainly of oyster-shell fragments, is arbitrarily selected as a boundary near the base of a massive crossbedded sandstone. The best exposures of the contact are on Dobie Ridge.

No fossils were found in the Claggett shale in the lower Marias River area but Pierce and Hunt (1937, p. 238) report the following species from an area about 10 miles to the east:

Baculites ovatus
Baculites compressus
Inoceramus barabina cf. *sagensis*
Liopistha montanensis
Corbula perundata

JUDITH RIVER FORMATION

Only the lower part of the Judith River formation of the Montana group is exposed in the lower Marias River area. It consists chiefly of tan to gray lenticular beds of friable fine- to medium-grained sandstone alternating with dark-gray shale. The formation is best exposed in sec. 7, T. 30 N., R. 10 E., and along the crest of Dobie Ridge (pl. 10).

The sandstone beds are massive, crossbedded, calcareous, and in many places contain lenses of brown sandstone concretions. Commonly the sandstone beds weather to ledges, benches and caprocks. Much of Dobie Ridge is supported by a massive sandstone bed of the Judith River formation. Thin gray to brown shale lenses, generally less than 3 feet thick, are intercalated in the sandstone. Locally the shale lenses are sandy and tend to be thin bedded and platy. Fossil plant matter is disseminated through the shale lenses. Well-developed cone-in-cone structure is conspicuous locally in the sandstone beds, particularly along the crest of Dobie Ridge.

The maximum thickness of the Judith River formation in this region is about 600 feet (Pierce and Hunt, 1937, p. 232). On Dobie Ridge only about the lower 65 feet is exposed. Farther east, in sec. 7, T. 30 N., R. 10 E., about 80 feet of basal Judith River strata crops out in an area largely covered by a thin veneer of glacial drift. The formation here consists predominantly of beds of somber gray to black locally bentonitic shale, but the basal 2 to 3 feet is brown calcareous sandstone.

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QUATERNARY SYSTEM

Most of the lower Marias River area is well covered with glacial drift of Pleistocene age deposited during two independent ice advances, which came chiefly from the north and northwest. The uplands are covered by drift for which the term "older drift" is used in this report. Younger glacial deposits, called the "younger drift," are restricted chiefly to a broad divide in the southwestern part of the area between the Marias River and Pondera Coulee (pl. 10). The till of the younger drift overlies till of the older drift and in many places is separated from it by a layer of bedded silt.

Silt deposits of three ages crop out in the lower Marias River area. Of these, the first is in the Lothair till (intratill silt), the second separates the tills (intertill silt), and the third is silt deposited on till (supertill silt) in ephemeral lakes formed during late Pleistocene or Recent time. The silt deposits are similar lithologically but differ in their stratigraphic positions. Gravel deposits of several ages are exposed; some underlie till whereas others overlie till. The age of the gravel deposits below till is unknown, but the age of those on till is Pleistocene and Recent.

The thickness of the drift differs from place to place despite the fact that the present land surface formed on the drift is relatively even. This difference in thickness reflects the uneven base of the drift. Further, it implies that a moderately dissected preglacial[3] topography was developed on the Cretaceous strata before the Lothair ice advanced across the mapped area. In places the older drift filled former valleys so completely that no surface indications of their presence remain (pl. 10). Elsewhere, buried valleys are reflected at the surface by shallow sinuous elongate depressions. In those places where the Lothair till is exposed from top to bottom of the valley wall (sec. 31, T. 30 N., R. 5 E.), the present course of the Marias River coincidentally crosses an ancestral Marias River valley now filled with glacial drift.

SOUTH SASKATCHEWAN(?) GRAVELS OF McCONNELL, 1885

Gravel deposits below till are exposed in four localities along the Marias River valley (pl. 10). These gravel deposits are tentatively correlated with the South Saskatchewan gravels of Alberta (McConnell, 1885, p. 70c; Dawson, 1895, p. 43 and 60), and may also correlate with the Wiota gravels exposed near Fort Peck, Mont. (Jensen, 1952).

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3 As used here the term preglacial is not synonymous with pre-Pleistocene. We intend the term to mean prior to the advance of the first ice (Lothair?) into the mapped area—not late Tertiary.

A significant exposure of the gravels and associated deposits is in sec. 32, T. 30 N., R. 5 E. (pl. 10). Here the gravels unconformably overlie the Colorado shale (fig. 14) and are overlain in ascending order by layers of silt, sand, and clay, which are overlain by till. The gravels, silt, sand, and clay crop out below till for about half a mile before they pinch out to the north against bedrock (fig. 14). To the south they end against a wall of till.

The gravel layer is about 6 feet thick; it consists principally of well-rounded flat oval pebbles, which are chiefly quartzite but include small amounts of chert, limestone, and dolomite, in a matrix of fine- to coarse-grained sand. Quartzite makes up about 83 percent of the gravel, limestone and dolomite about 12 percent, and chert about 5 percent. The gravels range in diameter from about ½ to 6 inches; they are unconsolidated and poorly bedded and sorted. The gravel layer is rust brown due to iron oxide stain on most pebbles and sand grains. A few pebbles have been completely permeated by the rust-brown stain. In a few places stringers of unconsolidated coarse-grained sand are intercalated in the gravel layer. The sand that forms these stringers is identical to the sand matrix of the gravel.

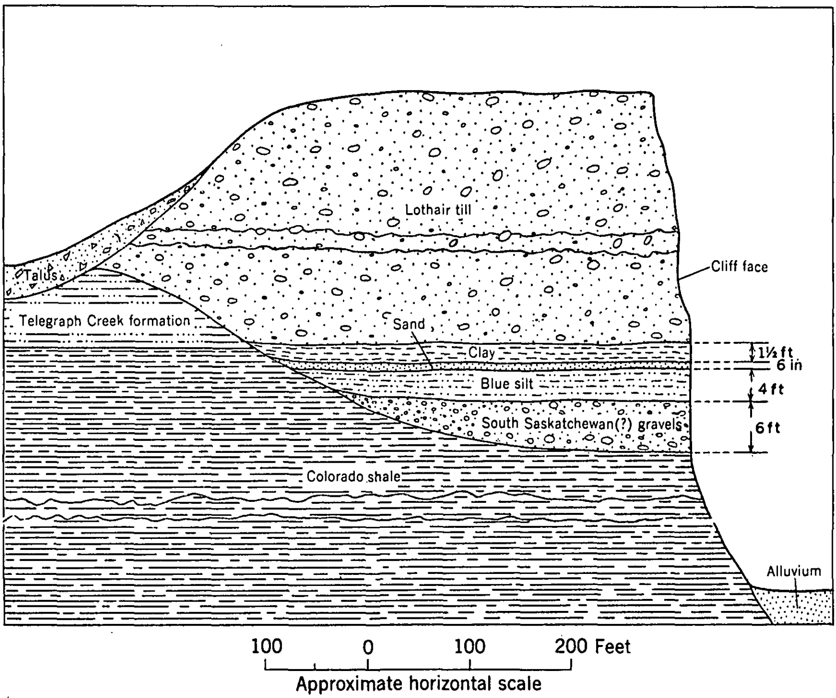

FIGURE 14.—Sketch of south wall of Marias River valley in sec. 32, T. 30 N., R. 5 E., illustrating how South Saskatchewan(?) gravels of McConnell, 1885, pinch out against bedrock.

SILT, SAND, AND CLAY LAYERS

Directly overlying the South Saskatchewan(?) gravels is a layer of bluish-gray massive well-indurated uniform-textured silt. The layer is about 4 feet thick. The contact is sharp with the underlying gravels, but is gradational with the overlying sand layer. This unconsolidated sand layer forms a continuous yellow bed about 6 inches thick composed of fine angular to well-rounded grains of quartz. Thin seams of silt are interbedded in the basal part of the sand layer. The sand grades upward into blue varved clay about 1½ feet thick.

Lothair till overlies these deposits. The till directly above the blue varved clays is tinged a light blue, which differs from the light tan of the rest of the till, and probably is attributable to inclusion of some of the underlying blue clay in the till.

ORIGIN AND AGE

Gravel deposits similar to those exposed along the Marias River have been reported previously from the northern Great Plains. Dawson and McConnell (1884, p. 141c–143c) record several "quartzite shingle" exposures below till on the Oldman River near MacLeod in southwestern Alberta. McConnell (1885, p. 70c) first applied the name South Saskatchewan gravels to these and similar gravels below till in the Cypress Hills–Wood Mountain district. A sequence of fluviolacustrine deposits below till along the South Fork of the Oldman River (Dawson, 1895, p. 43) is similar to the exposures in the lower Marias River area. A sketch of one of those deposits (Dawson, 1895, p. 43) is almost identical to figure 14.

Dawson (1895, p. 59) considered the gravels to be of glaciofluvial origin and reported that they gradually pass into a western "boulder-clay" in approaching the mountain. Calhoun (1906, p. 13, 45, and 49–52) similarly noted deposits of quartzitic gravels below till along the Milk, Marias, and Teton Rivers, and referred to them as the "Quartzite gravels." He considered these gravels to have been deposited by streams in preglacial times (Calhoun, 1906, p. 50). Alden (1932, p. 65) reported "Coarse quartzite stream gravel" below till at widely separated localities, and considered them to be Pleistocene in age and to represent deposits of either the Sangamon or Yarmouth interglacial stages. Witkind (1959) reports similar deposits in northeastern Montana, and Jensen (1951, 1952) also records gravel deposits below till.

In the lower Marias River area the pinch out of the gravels against bedrock on one side and their abrupt termination against till on the other suggests that these gravels represent terrace deposits of a former stream, probably the ancestral Marias River (p. 151).

The association of gravel, silt, sand, and varved clay, all overlain by till, implies that a former river course was dammed and the waters ponded to form a lake.

The age of these gravel deposits below till in the lower Marias River area is unknown; the best that can be said is that they postdate the Cretaceous strata and predate the Lothair ice.

OLDER DRIFT

The older drift is divided into nonstratified drift (Lothair till) and stratified drift (glaciofluvial deposits). The Lothair ice probably came from the north and northwest and plastered a thick layer of basal till over the entire area. This ice apparently was deflected in a few places to the southwest in the lower Marias River area. As it wasted, superglacial till and glaciofluvial deposits were formed.

LOTHAIR TILL

Almost all of the mapped area is well covered with the Lothair till. The Lothair till is here named from the town of Lothair in the northwest corner of the mapped area. The type locality is in the NW¼ sec. 29, T. 30 N., R. 7 E. The surface of the till is marked by a well-integrated drainage system with stream valleys that reach into the uplands. Most of the area gives an impression of gently rolling ground moraine moderately dissected.

The Lothair till crops out in many places along the Marias River valley and in tributary valleys. Commonly the till stands in steep to vertical cliffs. A good, easily accessible exposure is in sec. 2, T. 29 N., R. 5 E. (pl. 10).

The till is light tan but weathers to buff; it is tightly cemented, very hard, and breaks with difficulty into irregular fragments with conchoidal surfaces. It consists of unsorted material ranging from clay-size particles to boulders as much as 3 feet in diameter. Clay and sand-size particles predominate, and in a few places only small amounts of larger rock fragments are included and the till resembles loess.

Quartzite, limestone, and dolomite are the dominant rock types of the larger fragments. Most pebbles and cobbles are manganese stained, although the stain was not conspicuous in those examined. Manganese stain is also along many of the small fractures in the till.

Lenses of sand and of sand and gravel are intercalated in the till and are well exposed in steep cuts. The fluvial material is crossbedded and generally is very clean.

In many exposures of the Lothair till, layers of light-yellow to buff even-bedded massive silt are enclosed in the till. The intratill silt was deposited in lakes formed during a temporary withdrawal of the Lothair ice. The intratill silt is well exposed in the valley walls of Cottonwood Creek in Tps. 30 and 31 N., Rs. 6 and 7 E. Commonly it forms lenses about half a mile long and as much as 50 feet thick. Normally this light-yellow silt stands as steep walls, and contrasts markedly with the more somber till.

The Lothair till is firm and compact when dry. When wet, however, it becomes semiplastic, and travel is difficult on roads built across it.

The Lothair till is commonly about 50 feet thick. Its maximum thickness is unknown, but records of holes drilled for the U.S. Bureau of Reclamation and for water wells indicate that it is as much as 310 feet thick in the buried ancestral Marias River channel and between 100 and 200 feet thick in buried till-filled tributary channels.

SUPERGLACIAL TILL OF THE OLDER DRIFT

In a few places a modified knob-and-kettle topography interrupts the gently rolling ground moraine formed on the Lothair till. One such sector extends across the entire lower Marias River area in R. 8 E. as a northward-trending band about 3 miles wide. Similar areas but much smaller are in T. 29 N., Rs. 4 and 5 E., in T. 29 N., R. 9 E., and in T. 29 N., R. 11 E. (pl. 10). These areas consist of superglacial till. Most of the areas are made up of till knobs 30 to 50 feet in diameter and about 10 feet high, although a few are about 300 feet wide and as much as 40 feet above the surrounding ground surface. In between these till knobs are shallow round kettles. Several small streams head in these areas and many of the kettles are breached.

In some of the till knobs crudely stratified gravel layers about 1 foot thick are enclosed. The crests of many of the knobs are underlain by poorly sorted gravel layers, from which the finest particles have been removed. Crossbedding is common in the gravels, and dips of the crossbeds are as high as 20°. Lithologic types are similar to those in the basal till; chiefly quartzite, limestone, and dolomite.

These knob-and-kettle areas are delineated on the map (pl. 10) principally on the basis of their topographic expression. Although topographic differences are marked in the center of each area, these differences are less apparent along the margins and the change from knob-and-kettle topography to the normal ground moraine surface is gradational.

Most of the superglacial till probably was deposited from stagnant ice during the withdrawal of the Lothair ice sheet. Ablation material accumulated on the top of the marginal ice and was then deposited as the ice melted to leave a heterogeneous mixture of till and thin gravel layers.

GLACIOFLUVIAL DEPOSITS OF THE OLDER DRIFT

OUTWASH-CHANNEL DEPOSITS

The only deposits in outwash channels that can be attributed to melting of the Lothair ice are in the eastern part of the area. Here, outwash deposits of unconsolidated silt, sand, and gravel floor broad shallow valleys with moderate to gently sloping walls. Commonly the bottoms of the valleys are about 25 feet below the upland. The principal outwash-channel deposits trend southwestward through Tps. 30 and 31 N., Rs. 10 and 11 E. and can be traced for as much as 12 miles as narrow bands of silt, sand, and gravel that only locally exceed one-eighth of a mile in width. The deposits range in thickness from 1 inch to 6 feet. All of the deposits overlie till. In places postglacial dissection has removed much of the silt, sand, and gravel; elsewhere much of the outwash is concealed beneath a thin veneer of colluvium.

Near their south ends, the outwash-channel deposits consist principally of unconsolidated sand and silt. Near their north ends, however, pebbles, about a quarter of an inch in diameter, are mixed with the sand and silt.

Some of the outwash-channel deposits head in large irregular-shaped masses of sand and gravel mapped as ice-contact deposits (pl. 10). One such deposit is in secs. 21, 22, 28, and 29, T. 31 N., R. 10 E.; another is in secs. 32 and 33, T. 32 N., R. 11 E. Apparently, melt water deposited the coarser material against the ice in the form of ice-contact deposits and carried the finer material southward and deposited it on the channel floors to form the outwash-channel deposits. A few of the channels are remarkably straight, which may indicate subglacial grooving of the morainal surface and subsequent use of these grooves by melt water.

ICE-CONTACT DEPOSITS

Glaciofluvial deposits of silt, sand, and gravel, which have been formed against ice, are scattered irregularly over the surface of the Lothair till. Included in this group is one esker, several kames, and a crevasse filling, as well as unclassified features of irregular outline. The ice-contact features are not related spatially.

Esker deposit.—A sinuous ridge of sand and gravel in the SE¼ sec. 4, T. 30 N., R. 10 E., (pl. 10) is classified as an esker. The esker trends southeastward, and is about three-fourths of a mile long, about 30 feet wide, and 5 to 15 feet high. Its crest is uneven and the south end is lower.

The esker consists of a moderately well sorted mass of pebbles, cobbles, and boulders of quartzite, limestone, dolomite, and igneous rock types. Small patches of till are along the crest and flanks of the esker, and glacial boulders as much as 3 feet in diameter are scattered across its surface.

Subglacial melt water loaded with debris formed the esker deposit. The till patches and glacial boulders were deposited on the esker when the overlying ice melted.

Kame deposits.—Only two deposits are classified as kames in the lower Marias River area. Both deposits form conical, roughly circular hills. One kame, in the SW¼ sec. 35, T. 32 N., R. 4 E., is about half a mile in diameter, and rises about 100 feet above the adjacent till-covered surface. The other kame, about a quarter of a mile to the southwest, chiefly in sec. 34, T. 32 N., R. 4 E., is about a quarter of a mile in diameter, and rises about 50 feet above the adjacent ground surface. The slopes of the kames are smooth, although the broad crests are irregular and hummocky.

Both kames seem to consist predominantly of buff silt, although good exposures of the main masses are not available. Their surfaces are covered with pebbles, cobbles, and boulders of different shapes that range in size from ¼ inch to 2 feet in diameter. Principal rock types are quartzite, limestone, dolomite, and igneous rocks. Thin till mantles the flanks locally.

These kames could have formed in one of several ways. They may have been formed at the Lothair ice margin by melt water carrying large quantities of rock flour. As the ice melted, the unsupported silt collapsed to form conical mounds. The mantling till, as well as the pebbles, cobbles, and boulders constitute debris dropped by the melting ice. Or possibly the melt water carrying rock flour discharged into shallow basins on the ice surface. In the basins the silt was deposited in even layers. As the ice melted, the silt was let down on the underlying till surface, and slumped to form the conical shapes of typical kames.

Crevasse filling deposit.—Two linear ridges of sand and gravel, which trend eastward through secs. 9 and 10, T. 31 N., R 4 E., are mapped as crevasse fillings. Both probably represent a continuous crevasse filling. If so, this crevasse filling was about 1 mile long, about 150 feet wide, and its even crest is now about 25 feet above the adjacent till surface. The crevasse filling is composed of a heterogeneous mixture of sand and of gravel and boulders of quartzite, limestone, dolomite, and igneous rocks. Boulders as much as 3 feet long and blocks of till are on the surface of the deposit.

The poor stratification and linear form of the deposit suggest that glaciofluvial debris, till, and boulders were deposited in a crevasse in the ice. The mass was then let down onto the ground surface when the ice melted.

Miscellaneous ice-contact deposits.—Several deposits of unconsolidated sand and gravel of irregular outline, which have been mapped as miscellaneous ice-contact deposits, are in the area underlain by the older drift. Although these deposits are not classified their shapes and content imply that they were formed in contact with ice.

Several low knolls composed of silt, sand, and gravel trend southeastward across the south edge of T. 32 N., R. 11 E. The deposit is about 1¼ miles long, about a quarter of a mile wide, and 20 to 50 feet high. At its north end the deposit is about 50 feet above the surrounding ground surface, but at its south end it is only 20 feet high. The crest is uneven and the entire feature is a series of closely connected conical knolls, possibly kames.

The deposit consists of unconsolidated poorly bedded silt, sand, and gravel. Lithologic types are identical to the material forming the other glaciofluvial deposits of the older drift. Maximum pebble diameter observed was 2½ inches, although most pebbles average about 1 inch in diameter.

A thin veneer of colluvium floors most of the depressions between the knolls. Extensive outwash-channel deposits head in this feature (pl. 10).

This ice-contact deposit partly surrounds a large elliptical kettle in the SW¼ sec. 33, T. 32 N., R. 11 E. The kettle is about half a mile long, a quarter of a mile wide, and is about 30 feet deep. Probably it marks the former position of a block of ice that partly supported the ice-contact deposit as it was being formed.

A crudely oval-shaped ice-contact deposit covers parts of secs. 21, 22, 28, and 29 of T. 31 N., R. 10 E. The deposit trends southwestward, and is about 2 miles long and three-quarters of a mile wide. Commonly it is about 40 feet high but in the S½ sec. 21, T. 31 N., R. 10 E. it is about 110 feet high. The crest of the deposit is hummocky, except for its northernmost edge where its consists of a series of closely spaced arcuate ridges.

The deposit consists of poorly sorted, crossbedded, unconsolidated sand and gravel with many included blocks of till. Locally thin till mantles the flanks of the deposit.

The material ranges in size from fine-grained sand to cobbles as much as 3 inches in diameter. Pebbles and cobbles are well rounded. Rock types are similar to those in the other glaciofluvial deposits. The deposits are extremely crossbedded, and locally dips of crossbeds are as steep as 35°.

An outwash channel trends southeastward from this ice-contact deposit (pl. 10). Evidently the coarser fraction was deposited against the ice and most of the finer particles were carried away and deposited as channel outwash by melt water.

The arcuate ridges probably reflect deposition of glacial debris during a series of short withdrawals of an ice margin.

A narrow southeastward-trending line of hills in the NE¼ sec. 13, T. 30 N., R. 8 E. is interpreted tentatively as an ice-contact deposit, although exposures are poor. The ridge is about half a mile long, about 250 feet wide, and about 25 feet high. The deposit is composed of poorly bedded unconsolidated sand and gravel containing well-rounded rock types similar to those of the other ice-contact deposits.

INTERTILL SILT

Silt deposits similar in appearance to the intratill silt occupy a position between the Lothair and Pondera tills. The intertill silt formed in an interval after deposition of the older drift but prior to deposition of the younger drift. This silt is not shown on the geologic map (pl. 10) because the exposures are so small and the bands of outcrop so narrow.

The intertill silt is light yellow to buff, even bedded, and well sorted, and forms massive to thin-bedded deposits that commonly crop out as steep near-vertical exposures. Local lenses of clay and very fine grained sand are included in the silt deposits. Where protected by overlying till the silt tends to stand as vertical cliffs as much as 40 feet high. Where unprotected the unconsolidated silt is dissected rapidly. In places blocks of silt have been displaced and deformed either by slumping or by overriding ice. In the NW¼ sec. 17, T. 29 N., R. 6 E., a block of till is surrounded by silt. The intertill silt ranges in thickness from a pinch-out to as much as 60 feet. The best exposures of the intertill silt are in the valley walls of the Marias River and Pondera Coulee in T. 29 N., Rs. 4 and 5 E.

YOUNGER DRIFT

The younger drift is exposed principally on the broad divide between Pondera Coulee and the Marias River (pl. 10). The younger drift, like the older drift, consists of (1) nonstratified drift (Pondera till) and (2) stratified drift (glaciofluvial deposits). Because colluvium, slope wash, talus, and other debris commonly mask till outcrops, the Pondera till is exposed in only a relatively few localities. In contrast, however, the glaciofluvial deposits of the younger drift are well exposed.

The younger drift was deposited by and around a wedge-shaped narrow tongue of ice (the Pondera ice), which seems to have moved from the northwest and been diverted to the east down the broad valley now occupied by the Marias River and Pondera Coulee (pl. 11). Its easternmost limit was probably near the center of T. 29 N., R. 6 E. Pondera Coulee probably marks its approximate south margin, and a line near Willow Creek its approximate north margin (pl. 10).

PONDERA TILL

The Pondera till is here named from exposures along the north valley wall of the Pondera Coulee in T. 29 N., Rs. 4 and 5 E. The Pondera till is light brown, but weathers chocolate brown to contrast markedly with the light buff of the underlying Lothair till or the yellow of the intertill silt. The Pondera till is darker probably because glacial ice from the west and northwest moved over a broad area of exposure of the dark Colorado shale. Glacial ice from the north or northeast moved across formations that contain much rock that is lighter colored than the Colorado shale.

The Pondera till is best exposed on both sides of the Marias River valley, in secs. 2, 10, and 11, T. 29 N., R. 5 E., and along the north valley wall of Pondera Coulee in T. 29 N., Rs. 4 and 5 E.

This till is semiplastic and consists of clay that contains small amounts of unsorted pebbles, cobbles, and boulders of quartzite, limestone, dolomite, granite, and foliated metamorphic rocks. Lithologically the pebble types are very similar to those in the Lothair till. The included rocks are rounded and average about half an inch in diameter.

Near the surface the Pondera till loses some of its plasticity and becomes hard and slightly brittle. This hardened zone generally extends about 12 inches into a till exposure.

In most places the Pondera till is about 30 feet thick, although it is as much as 60 feet thick in a few exposures.

SUPERGLACIAL TILL OF THE YOUNGER DRIFT

A narrow elongate irregular shaped area on the divide between Pondera Coulee and the Marias River (pl. 10) is covered by an area of knob-and-kettle topography. The knobs consist chiefly of brown semiplastic till. In a few places lenses of gravel about 6 inches thick cover the crests of the knobs or are on their flanks. The kettles are shallow, crudely circular, and undrained. This material is interpreted as superglacial till deposited as the Pondera ice lobe wasted.

GLACIOFLUVIAL DEPOSITS OF THE YOUNGER DRIFT

The glaciofluvial deposits consist of silt, sand, and gravel that overlie till as outwash-channel and kame-terrace deposits. Their volume is considerably less than that of the till.

OUTWASH-CHANNEL DEPOSITS

Two major deposits in outwash channels, formed by melt water of the Pondera ice, are in the lower Marias River area. The western channel is in T. 30 N., Rs. 4 and 5 E. and is here termed the "Rae channel" (pl. 10). This name is taken from the Rae ranch in sec. 20,

T. 30 N., R. 5 E. The eastern channel is in T. 29 N., R. 5 E., and is here termed the "Pugsley channel." This name is taken from the Pugsley ranch and bridge in sec. 11, T. 29 N., R. 5 E. The deposits of these channels have many features in common and possibly were formed contemporaneously.

Deposits in the Rae channel.—The deposits in the Rae channel, which were once continuous for nearly 4 miles, have been separated by postglacial dissection and are now in 2 parts. The northern part occupies most of sec. 13, T. 30 N., R. 4 E., and the southern part is chiefly in sec. 30, T. 30 N., R. 5 E. The deposits curve slightly, but in general trend southeastward and end at the edge of the Marias River valley. The average width is about half a mile, but locally is as much as three-quarters of a mile. It ranges in thickness from about 6 feet to about 25 feet and averages 15 feet.

The deposits consist of unconsolidated poorly bedded sand and gravel packed tightly enough, however, to maintain near-vertical walls locally. Fine to coarse sand forms lenses as much as 50 feet long and 2 feet thick intercalated in the gravels. Most of the gravel consists of well rounded to moderately well rounded pebbles and cobbles of quartzite, limestone, dolomite, and igneous rocks, which range in diameter from ½ to 3 inches. Fine to coarse sand grains fill interstices in the gravels. All pebbles to a depth of about 2 feet below the ground surface have a coating of caliche on their undersides.

Both parts of the deposits in the Rae channel rest on Pondera till. The northern segment is between till valley walls; the southern segment, however, is confined between ridges of sand and gravel interpreted as kame terraces (pl. 10).

Deposits in the Pugsley channel.—The deposits in the Pugsley channel occupy most of the northeast corner of T. 29 N., R. 5 E. They are in a shallow swale about 175 feet above the level of the Marias River and both ends of the channel are truncated by the Marias River valley. The deposits trend southeastward and can be traced for about 4 miles. They average a half a mile in width, although near the western end of the channel they are nearly 1 mile wide, and are about 25 feet thick.

The deposits consist of poorly consolidated sand and gravel identical in most respects to the material forming the deposits in the Rae channel. In a few places the entire thickness of the deposits in the Pugsley channel consists of sand; commonly, however, the sand forms short lenses that are scattered irregularly through the gravels. All the pebbles to a depth of about 4 feet below the surface have their undersides coated with caliche.

The deposits in the Pugsley channel overlie Pondera till (fig. 15), and a layer of till about 10 feet thick also forms the north wall

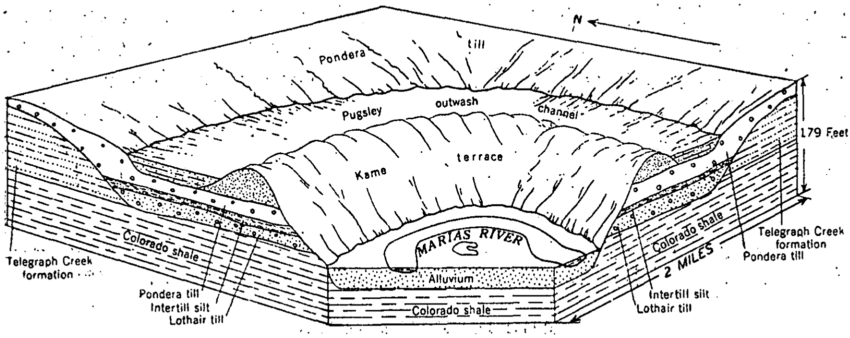

FIGURE 15.—Idealized sketch showing relations of deposits in Pugsley outwash channel to present Marias River flood plain in the northeast corner of T. 29 N., R. 5 E.

confining the deposits. The south edge of the deposits is confined by a ridge of sand and gravel that rises about 25 feet above the floor of the channel deposit; this ridge is interpreted as a kame terrace (pl. 10). Much of the deposits in the Pugsley channel is concealed beneath a thin veneer of colluvial wash from the adjacent valley wall.

Origin of the channel deposits.—The similarity between the deposits in the Rae and Pugsley channels suggests that they were formed in the same manner and contemporaneously. They may be remnants of a former continuous channel fill that sloped to the east. Two hypotheses to explain the formation of outwash-channel deposits flanked by kame terraces are shown in plate 12.

KAME-TERRACE DEPOSITS

Kame terraces flank the Rae and Pugsley channels (p. 144 and pl. 10). The Rae channel is flanked by 3 kame-terrace deposits of unconsolidated silt, sand, and gravel. One is in sec. 14, T. 30 N., R. 4 E.; the second and largest straddles the range line between Rs. 4 and 5 E. in T. 30 N.; and the third is in sec. 19 and 30, T. 30 N., R. 5 E. All parallel the channel and all are about 20 feet above the channel floor. The kame-terrace deposits consist principally of angular to well-rounded pebbles and cobbles of quartzite, limestone, dolomite, and igneous rocks with fine- to coarse-grained sand filling the interstices. The pebbles and cobbles range in diameter from ¼ to 6 inches; most, however, average 1 inch in diameter. Blocks of till are embedded in the sand and gravel and in places massive lenses of silt and sand, as much as 15 feet thick, extend laterally for 25 to 50 feet. Gravels in the uppermost 3 feet of the deposit have their undersides coated with caliche. Bedding is poorly developed and in most places is near horizontal; locally, however, the bedding dips as much as 35°.

Two kame terraces flank the Pugsley channel. A very small one is in sec. 34, T. 30 N., R. 5 E., and a larger one occupies most of sec. 12, T. 29 N., R. 5 E. The larger kame terrace is marked by knob-and-kettle topography, although locally it forms a distinct, relatively even-crested ridge about a quarter of a mile wide and about 30 feet high. It is composed of the same lithologic types found in the kame terraces near the Rae channel and it also has included blocks of till. In a few places the dominant even bedding is disturbed; in these places, dips are as steep as 40°.

Two hypotheses to explain the formation of outwash-channel deposits flanked by kame terraces are shown in plate 12.

AGE OF THE DRIFTS

The age of the drifts in the lower Marias River area is unknown, for the area is distant from regions where correlations and dating of tills are possible. The stratigraphic relations indicate an earlier age for the older drift than for the younger drift.

Previous workers in the area did not recognize two till sheets and they suggested that the drift mantling most of this general region is Wisconsin in age, although similar agreement is lacking as regards substage designations.

Calhoun (1906, p. 52) referred the drift cover of this and adjacent areas to the late Wisconsin. Alden (1932, p. 96) concluded that the deposits in this general region were early Wisconsin. Horberg (1954, p. 1140 and fig. 1) assigns the drift in north-central Montana to the Cary substage of the Wisconsin.

As no evidence bearing on the age of the drifts was found in the course of the work, we cannot assign specific ages to either of the drift sheets.

The two tills in the lower Marias River area differ from one another in their topographic expression, extent of outcrop, and such physical characteristics as color, degree of induration, and concentration of manganese stain on pebbles.

The surface of the Lothair till, wherever exposed, is marked by a well-integrated dendritic drainage system that extends into the uplands. In the areas of superglacial till many of the kettles have been breached and integrated. In contrast, the surface of the Pondera superglacial till is marked by relatively undissected knob-and-kettle topography. Although the kettles are shallow and the knobs are low, the general impression of the terrain is one of newly deposited glacial debris, probably Wisconsin in age.

The older Lothair till is widespread; it fills ancient stream valleys and mantles the upland. The Pondera till is confined wholly to the area between Pondera Coulee and Willow Creek in the southwest corner of the mapped area.

The Lothair till is light tan to light buff and contrasts markedly with the chocolate-brown weathered surface of the overlying Pondera till. The Lothair till is dense, massive, tough, cohesive, and breaks with a conchoidal fracture. In contrast, the Pondera till is semiplastic, easily molded, and barely cohesive. The Lothair till has many pebbles embedded in it, and many of these are stained with manganese. Pebbles are less common in the Pondera till and none are manganese stained.

These differences in induration and weathering between the two tills and the difference in degree of dissection of the till surfaces suggest that considerable time may have elapsed between deposition of the older and younger drifts. However, the evidence is inconclusive.

SUPERTILL SILT

In three areas, silt overlies glacial till. The silt probably was deposited in ephemeral lakes formed during the late Pleistocene or early Recent. The largest lacustrine silt deposit is in Tps. 29 and 30 N., R. 9 E. Next in size is a deposit that occupies the center of T. 30 N., R. 7 E. The third deposit is in T. 31 N., R. 7 E.

In general the deposits are irregular shaped and their margins conform to the topographic irregularities of the surrounding terrain. Their surfaces are almost even and the only surface irregularities are slight, and stem from recent dissection.

The deposits consist of light-tan stratified silt and interbedded local lenses of fine-grained sand and included pebbles. In a few places, thin beds of light-brown to dark grayish-brown clay are interbedded with the silt. Locally near the margins of the deposits, the lacustrine silt grades into sand and gravel. The thickness of the silt is unknown, although about 20 feet is exposed in the SW¼ sec. 33, T. 30 N., R. 9 E.

VALLEY FILL

Alluvium of two ages is in the lower Marias River area: valley fill that resembles till, and a younger alluvium that forms the flood-plain deposits.

Valley fill, consisting of interbedded silt, clay, and sand that includes larger rock fragments, rests on bedrock in secs. 28, 29, 32, and 33, T. 30 N., R. 5 E. This material is largely covered by a thin veneer of slope wash and was recognized first by the U.S. Bureau of Reclamation engineers from drill holes along the Tiber dam site area (pl. 10). The maximum thickness of the deposit is about 50 feet. As this material closely resembles till, similar older alluvial deposits may be elsewhere along the river but have not been recognized.

This valley fill probably was deposited later than the younger drift during a cut-and-fill stage of the Marias River previous to the development of the oldest terrace deposit.

TERRACE DEPOSITS

Remnants of four terraces are along the Marias River in this area. The terrace deposits consist of sand and gravel and are designated on plate 10 from oldest to youngest. In almost all exposures the terrace deposits overlie glacial deposits; in a few exposures they are on bedrock.

The following table shows the approximate general heights of the terraces above the Marias River.

Terrace	Average height above Marias River, in feet	Terrace	Average height above Marias River, in feet
4th (youngest)	40	2d	90
3d	70	1st (oldest)	110

The terrace gravel is unconsolidated, crudely stratified, and poorly to well sorted. Commonly the gravel consists of pebbles that range from ½ to 1½ inches in diameter, but it also contains cobbles as large as 8 inches in diameter. Quartzite pebbles predominate and smaller amounts of granite, porphyry, limestone, dolomite, chert, metamorphic rocks, and sandstone are included. Fine- and medium-grained sand fills interstices between pebbles, and forms lenses of sand or silt. The undersides of the pebbles in the upper 2 or 3 feet of the gravel are coated with a thin hard layer of white caliche.

The gravel deposits average 20 feet in thickness, although the thickness differs in a single terrace remnant and from terrace remnant to terrace remnant. For example, the gravel forming a part of the second terrace in sec. 13, T. 29 N., R. 5 E. ranges in thickness from 10 to 60 feet in a horizontal distance of half a mile.

The terraces bevel the glacial deposits and are developed locally on the old alluvial fill.

RECENT ALLUVIUM

The Recent alluvium forms flood-plain deposits chiefly of sand and gravel, which are overlain in most places by silt generally less than 2 feet thick. The gravel consists predominantly of pebbles of quartzite, sandstone, dolomite, limestone, and chert, and smaller amounts of granite, gneiss, and porphyry. The most common pebble size is about 1½ inches in diameter.

U.S. Bureau of Reclamation test pits in the Marias River flood plain in Tps. 29 and 30 N., R. 5 E. show a maximum depth to bedrock of 14 feet. Within 50 to 100 feet of the river the depth to bedrock is generally 8 to 10 feet.

Alluvium along tributary coulees is predominantly silt and sand.

ALLUVIAL-FAN DEPOSITS

At places, chiefly along the margin of the Marias River flood plain, alluvial-fan deposits are at the bases of steep slopes and at the mouths of short tributary streams. The fans are low and relatively flat. Several are composed of a series of low coalescing fans. The deposits consist of interbedded lenses of light-brown to gray unconsolidated clay, silt, and sand. The maximum thickness of these deposits is not known, but it seems unlikely that the thickness in any fan is more than a few tens of feet. Material composing the fan deposits was derived from nearby exposures of older material.

STRUCTURE

The lower Marias River area is on the east flank of the Sweetgrass arch, a low broad uplift whose axis trends northwestward and passes near Shelby and Great Falls, Mont. In the mapped area the regional dip is eastward at about 35 feet to the mile.

In the western part of the lower Marias River area, Erdmann (1948) has mapped three structures. The first is an anticline known as the Lothair nose, the second is an unnamed syncline, and the third is an elongate dome called the Marias River dome. The Lothair nose trends S. 50° E., and plunges to the southeast in Tps. 30 and 31 N., R. 4 E., with its axis about a quarter of a mile northeast of and parallel to Willow Creek (pl. 10). The Lothair nose is about 7 miles long and can be traced from the west edge of T. 31 N., R. 4 E. to its end in sec. 18, T. 30 N., R. 5 E. where it joins the elongate Marias River dome.

The unnamed syncline is about 1½ miles southwest of the Lothair nose and the same distance west of the Marias River dome. Its axis roughly parallels the axes of these features. The syncline can be traced for about 14 miles as a shallow trough from the west edge of T. 31 N., R. 4 E. to the southwest corner of T. 30 N., R. 5 E.

The Marias River dome trends about S. 25° E., and it can be traced for about 4 miles from its beginning in sec. 18, T. 30 N., R. 5 E. to its end in sec. 9, T. 29 N., R. 5 E. The dome has about 40 feet of vertical closure with its apex in secs. 29 and 32, T. 30 N., R. 5 E.

The regional dip to the east is interrupted along the eastern margin of the area in sec. 11, T. 30 N., R. 11 E. where dips range from very gentle to vertical. The gentle dips are to the west suggesting that this may be a small dome or anticline, the eastern side of which is reflected by the dip slope east of the area. The steeply dipping beds have different strikes which suggest that they have been faulted. The bedrock outcrops are within the area of known thrust faulting as indicated by Pierce and Hunt (1937, pl. 43).

Two small anticlines (on the east flank of the Marias River dome), south of the Marias River in sec. 33, T. 30 N., R. 5 E., have northeast trends but are minor features. Any other structures that may be in the area are not discernible on the surface because of the extensive cover of glacial deposits.

GEOLOGIC HISTORY

The geologic history indicated by the Cretaceous strata exposed in the lower Marias River area is one of alternating deposition of marine and continental sediments. The oldest sedimentary rocks exposed are the marine shales of the Colorado shale of Late Cretaceous age. These were deposited during the last stages of an extensive marine invasion from the southeast. As the seas gradually withdrew, continental and brackish-water sediments were deposited in a near-shore environment. These sediments formed the Telegraph Creek formation. The massive crossbedded sandstone of the Virgelle was deposited in a continental environment after withdrawal of the sea. Continental conditions persisted during the formation of most of the upper member of the Eagle sandstone. Brackish-water sedimentary rocks in uppermost strata of the Eagle, however, indicate a recurrence of marine or marginal-marine deposition. The sea readvanced to the northwest and deposited the sediments that constitute the Claggett shale. As the sea withdrew a second time, fresh- and brackish-water sediments were deposited to form the Judith River formation. Strata of the Judith River are the youngest bedrock exposed. Farther east, however, the stratigraphic section is unbroken through the Wasatch formation of Eocene age. If these Tertiary strata were deposited in the Marias River area, they were removed by erosion before the Lothair ice advanced across the mapped area.

At some time after deposition of the Judith River formation and before deposition of the glacial deposits the strata were slightly deformed locally. The original uplift of the Kevin-Sunburst dome, west of the lower Marias River area, may have been extended to its present limits by late Pliocene diastrophism and at that time the folds of the Lothair nose, the Marias River dome, and the companion syncline were formed (Erdmann, 1948). Faulting and igneous activity in and adjacent to Bearpaw Mountain east of the lower Marias River area occurred in early Tertiary time (Reeves, 1946, p. 1038). It would seem, therefore, that the strata in the lower Marias River area were deformed at some time during the Tertiary.

The dissection of the Upper Cretaceous and Tertiary strata was carried out in great measure by a network of streams that probably flowed southeastward. By late Pliocene or early Pleistocene time these streams were well entrenched and drained a moderately dissected upland. One such stream, the ancestral (preglacial, p. 134) Marias River, flowed across the lower Marias River area. Its probable course is shown on plate 10. It headed in uplands to the north and west, and probably carried gravel derived from the Flaxville gravel (Miocene or Pliocene) and from the Cypress Hills gravel (Oligocene) in Canada. Erdmann (1948) suggests that the stream was established originally on the Flaxville Plain of Miocene and Pliocene age.

The buried ancestral Marias River valley is traced for about 50 miles across the mapped area. Along the present Marias River valley this former stream course is marked by alined till-filled gaps in the bedrock (pl. 10). Farther east its course can be traced in part as a low sag in the till-surfaced upland and in part by the deep water wells that penetrate the gravels that form its floor. The alined till-filled gaps suggest that the stream cut a gorge about half a mile wide. How deep this ancestral Marias River scoured is unknown, but a hole drilled for the U.S. Bureau of Reclamation in the NE¼ sec. 6, T. 29 N., R. 5 E. penetrated 310 feet of buff till, fine sand, and gravel without reaching bedrock (Fox, 1946, p. 1194). The bottom of the hole was more than 200 feet below the bedrock floor of the Marias River flood plain and at least 650 feet below the upland surface.

Through parts of T. 30 N., Rs. 4 and 5 E., the course of the ancestral Marias River parallels both the axis of the unnamed syncline west of the Marias River dome and the Lothair nose (p. 149). Erdmann (1948) notes that this collinearity can be traced for about 14 miles and suggests that the course of the ancestral stream may have been on a surface that was undergoing warping.

A tributary of the ancestral Marias River is now traced by a part of Cottonwood Creek (pl. 10). Pondera Coulee may also be along a similar ancestral tributary.

The Lothair ice advanced from a northerly direction across the lower Marias River area. It dammed rivers, filled broad valleys first with ice and then till, and modified the topographic irregularities. This ice deposited a layer of basal till—the Lothair till—across the entire area.

On the withdrawal of this ice the former moderately dissected upland appeared as gently rolling hills and valleys. In places, the ancestral valleys were completely filled with till and no indications of their former courses showed on the surface. Elsewhere the fill was not as complete and elongate sinuous depressions reflected the former drainage ways. It seems likely that the Lothair ice withdrew spasmodically; melting back locally at least to expose a till-covered surface and then readvancing. During these withdrawals silt was deposited in lakes formed in existing depressions. A slight readvance of the ice mass covered the silt with Lothair till. These former lake beds are now exposed as the intratill silt.

During the interval between the melting of the Lothair ice and the advance of the Pondera ice the broad valley now occupied by the Marias River and Pondera Coulee was dammed and the intertill silt was deposited. Drainage probably formed on the surface of the older drift and a larger stream may have flowed down this broad valley after the intertill silt was deposited. No direct evidence indicates the nature of this drainage or the degree of erosion that may have accompanied it.

The Pondera ice advanced from the northwest into the lower Marias River area as a narrow tongue moving eastwards down the broad valley. It was a marginal tongue of the main ice mass that moved southward farther west (pl. 11 and p. 142). In its advance it disrupted the established drainage and deposited a layer of somber-colored till—the Pondera till—in places over the intertill silt and elsewhere directly on the Lothair till. This marginal ice tongue probably advanced as far east as the center of T. 29 N., R. 6 E.

During the waste of the Pondera ice, glaciofluvial deposits, such as channel outwash and kame terraces, were formed along its margins. The melt water came from the northwest and in places flowed on ice, and elsewhere on the existing ground surface. Those deposits on ice were dissipated with the melt of the ice; those on the ground are now preserved as isolated remnants whose alinement reflects the former course of the melt water.

As the Pondera ice melted and freed the drainage ways, the melt water began to flow either in valleys recently freed of ice or maintained itself in those valleys established by the glacial diversion of streams. As the Marias River reestablished itself it began a history of cutting and filling that has continued to the present. All the terrace deposits postdate the Pondera till, and it seems likely that several of the terraces were formed while ice was still in the general region to the west and northwest. Slow dissection of the upland surface has continued since the Pondera ice sheet melted. Over parts of the area knob-and-kettle topography, formed as a direct result of glacial action, remains virtually unmodified. Only in the deeper valleys and coulees, as along the Marias River valley, have streams cut through the cover of glacial deposits to expose the underlying bedrock of Cretaceous age.

ECONOMIC GEOLOGY

SAND AND GRAVEL

Large quantities of sand and gravel are in the area. The best sources are the terrace, kame-terrace, and glacial-outwash deposits along the Marias River. Other sources include the ice-contact deposits, the flood plain of the river, and scattered gravel deposits in the till.

The Montana State Highway Department has used sand and gravel from most of these sources, both as road metal and as concrete aggregate. Caliche coats pebbles and cobbles in the upper 3 feet of the deposits. Gravel from below this zone makes good concrete aggregate. Deposits that contain chert and siliceous dolomite deserve special study before use because of possible deleterious reactions between chert and some kinds of cement. Tests run by the U.S. Bureau of Reclamation indicate that the gravel from the kame terraces and the outwash channel in sec. 30, T. 30 N., R. 5 E. is suitable for use as concrete aggregate. The sand samples from the same area were found to be suitable for use "as concrete aggregate provided they are vigorously washed to remove excess silt, properly graded, and used with low alkali cement" (Skillman, 1948).

RIPRAP

Glacial cobbles and boulders that are gathered into piles as fields are cleared for cultivation may be suitable for use as riprap on bridge approaches or other small construction jobs. Also, concretions from the Colorado shale, the Telegraph Creek formation, and the Eagle sandstone might possibly be used as riprap for similar small jobs.

BENTONITE

The Colorado and Claggett shales contain beds of bentonite. Seventeen bentonite beds were observed in that part of the Colorado shale exposed in this area but most do not exceed 1 or 2 inches in thickness. Seven bentonite beds are in the lower 80 feet of the Claggett shale. Commonly, these are 2 to 3 inches thick and locally are as much as 3 feet thick. As of 1955 none of the exposed beds is of commercial grade but thicker or more persistent beds may be buried under the cover of glacial deposits.

COAL

In this region coal of subbituminous rank is generally in thin beds of local extent in the upper member of the Eagle sandstone and in the lower 200 feet of the Judith River formation (Pierce and Hunt, 1937, p. 261; Combo and others, 1949). Exposures of the Judith River formation are small in the mapped area and that part of the formation beneath the extensive cover of glacial deposits may contain better and more continuous coal beds. Only very thin irregular coal beds crop out in the lower Marias River area, and as of 1955 none are of commercial grade.

OIL AND GAS POSSIBILITIES

Because of the glacial cover little is known about the structural details of the bedrock. The regional dip is to the east. Minor flexures or reversals might afford possible oil traps. In the lower Marias River area the only known structure with vertical closure is the Marias River dome in Tps. 29 and 30 N., Rs. 4 and 5 E. (Erdmann, 1948). On this structure the Louis B. O'Neil–Pugsley well was drilled in the SW¼ sec. 29, T. 30 N., R. 5 E. This well penetrated the Madison limestone at a depth of 2,471 feet. There were no shows of oil or gas.

Several wells have been drilled in the general region but none has produced oil in commercial quantity. Near Kremlin (fig. 12) gas was found in the Eagle sandstone and gas has been produced from the same formation from other localities near the mapped area (Pierce and Hunt, 1937, p. 261).

If oil or gas is produced, it probably will be from formations stratigraphically lower than those exposed in the mapped area. The following table lists the formations below the Montana group. These data were compiled by Erdmann (1948) from two wells drilled adjacent to the lower Marias River area. The wells are the Texas Co. State Well No. 1 in sec. 26, T. 29 N., R. 6 E., and the Texas Co. Nick Laas Well No. 2, in sec. 14, T. 33 N., R. 4 E.

Formations below the Montana group

[From Erdmann, 1948]

System	Series	Formation and member	Thickness, in feet
Cretaceous	Upper Cretaceous	Colorado shale Upper member Blackleaf sandy member [1]	1,745± 825± 920±
	Lower Cretaceous	Kootenai formation	340±
Jurassic		Morrison formation	65±
		Ellis group Swift formation (Ribbon sand) Rierdon and Sawtooth formations, undifferentiated (calcareous shale).	255± 38± 215±
Mississippian		Madison limestone	1,000±
Devonian		Potlatch anhydrite	215±
		Jefferson formation	1,000±
Cambrian		Limestone and shale	?

[1] In part Lower Cretaceous.

According to Erdmann (1948) possible production zones "are 'sands' in the Blackleaf sandy member of the Colorado shale, the Sunburst sand in the Kootenai formation, the Ribbon sand (Swift formation) in the Ellis group, the eroded upper part of the Madison limestone or 'contact', and zones near the base of the Potlatch anhydrite and top of the Jefferson formation."

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