BRIGHAM

YOUNG

UNIVERSITY

# GEOLOGY STUDIES

Volume 23, Part 1—October 1976

## CONTENTS

# Brigham Young University Geology Studies

Volume 23, Part 1—October 1976

## Contents

A publication of the
Department of Geology
Brigham Young University
Provo, Utah 84602

Editor

W. Kenneth Hamblin

*Brigham Young University Geology Studies* is published semiannually by the department. *Geology Studies* consists of graduate-student and staff research in the department and occasional papers from other contributors. *Studies for Students* supplements the regular issues and is intended as a series of short papers of general interest which may serve as guides to the geology of Utah for beginning students and laymen.

ISSN 0068-1016

Distributed September 15, 1976

*Price $5.00*

(Subject to change without notice)

9-76 600 13879

# Paleoenvironments of the Colton Formation, Colton, Utah*

ALLEN R. PETERSON

ABSTRACT.—The Colton Formation near Colton, Utah, contains an exceptionally well-exposed vertical sequence of fresh water deltaic sediments. The Colton Formation intertongues with the Green River Formation above and the Flagstaff Limestone below. During Late Paleocene to Early Eocene, streams flowing from the south and southwest advanced across the site of Lake Flagstaff and developed a prograding delta complex at the present site of the study area. Most of the fluvial deltaic sediments occur in the lower one-third of the formation and are the primary concern of this study. Vertical exposures in road cuts along U. S. Highway 50-6, railroad cuts, and natural escarpments allow detailed analysis. Within what are interpreted to be upper deltaic plain sediments are exposed sinuous channel-fill sandstones that display typical point bar migration, and floodplain deposits that are exposed as rooted claystone and siltstone. Also included in the lower part of the formation are lacustrine pro-deltaic claystone and siltstone, and frontal sandstone units which are overlain by lower deltaic plain straight-channel-fill sandstone. Flat-bottomed splay and overflow sandstone and siltstone are discontinuous and are the most common features in the Colton beds. Two lobes of deltaic sediments separated by a lacustrine transgression are documented in the study area. Gastropods, bivalves, and plant remains are rare but can be found in lacustrine deposits and channel fills associated with the lower deltaic plain.

CONTENTS



*A thesis presented to the Department of Geology, Brigham Young University, in partial fulfillment of the requirements for the degree Master of Science, August 1975. Thesis chairman, J. Keith Rigby.

## INTRODUCTION

The Lower Eocene Colton Formation exposes what is interpreted to be one of the few recognized fresh water deltaic sequences of rock in the geologic record. The small size of the delta and accessibility of its exposures permit detailed study of its paleoenvironments.

The Colton Formation is a sequence of dominantly brownish red, fine-grained, micaceous, feldspathic sandstone, siltstone, and claystone, but with some gray green beds as well. Sandstone units are lens-shaped, cross-bedded and laterally nonpersistent. Red, green, and purple siltstone and claystone appear to be lenticular and nonpersistent and are exposed between the sandstone units. The Colton Formation is considered to be the result of fluvial sedimentation within a delta as evidenced by channel sandstones and floodplain sandstones, siltstones, and claystones representing splays, overbank deposits and natural levees. These rock units grade laterally and vertically into prodeltaic and lacustrine siltstones and argillaceous limestones. Along with vertical and lateral rock types, sedimentary and paleontological relationships allow documentation and interpretation of the upper and lower deltaic plain environments of deposition.

Stratigraphically, the Colton Formation intertongues with the Flagstaff Formation below and the Green River Formation above. The intertonguing relationship between the Flagstaff and Colton formations can be seen very well in the study area. Spieker (1946) noted intertonguing relationships between the Green River and Colton formations on the basis of color.

### Acknowledgments

The author wishes to express gratitude to Dr. J. Keith Rigby and Dr. W. K. Hamblin of the Department of Geology who served on the thesis committee. Mr. J. L. Walker and Dr. R. T. Matheny of Lake Mountain Industries, Provo, provided aerial photography of the thesis area. Thanks is extended Larry Smith, John Woffinden, Chris Collins, and Patrice Casebolt, who assisted in the field work. Gene Clark aided in fossil plant identification. Ralph Bohn assisted in disaggregating samples for the heavy mineral analysis.

### Previous Work

Very little detailed stratigraphic or sedimentary environmental work has been done on the Colton Formation beyond regional generalizations. Most previous studies have discussed mainly boundary relationships with the underlying Flagstaff Formation and the overlying Green River Formation.

E. M. Spieker (1946, p. 139) formally proposed the Colton Formation for the exposures near Kyune, southeast of the study area. He studied the intertonguing relationships between the Colton, Flagstaff, and Green River formations, and concluded that the Colton is chronologically equivalent to the lower part of the Green River elsewhere. He also noted fresh water mollusks within the Colton Formation and dated the Colton as possibly Wasatchian (Spieker, 1946, p. 139).

Prescott (1958) mapped the pinchouts of the Colton west of Soldier Summit, Utah, and studied the geology of the northwest quarter of the Soldier Summit Quadrangle. Henderson (1958) mapped the northeast quarter of the Soldier Summit Quadrangle and some Colton beds.

Marcantel and Weiss (1968) did a lithologic study of the formation on the Gunnison Plateau far to the southwest. The principal purpose of their study was to find lithologic differences between the Flagstaff Formation and the Colton Formation. Their criteria for separation of the Flagstaff and Colton beds were based on rock type, color, and fossils or lack of fossils.

These earlier stratigraphic studies do give good lithologic descriptions and set a regional frame for this study.

Many papers have been written on the sedimentary features of modern and ancient deltas that have also been helpful. Among the most significant of these are papers by Gould (1970), Ferm (1970), Coleman and Gagliano (1964) and Fisher, Brown, Scott, and McGowen (1969).

### Location

The study area is located at the head of Price River Canyon about 2 miles southeast of the townsite of Colton, Utah, on U.S. Highway 50-6. It is in the east central part of the Soldier Summit Quadrangle in Sections 22 through 26, T. 11 S, R. 8 E, and in Sections 29 through 32, T. 11 S, R. 9 E, of the west central part of the Kyune Quadrangle, Wasatch County, Utah. The study area is accessible via U.S. Highway 50-6 and the Colton beds are well exposed in road cuts and railroad cuts. The investigated escarpment exposes the lower one-third of the formation and generally parallels Price River and U.S. Highway 50-6.

### Methods of Study

Ten detailed sections were measured with a meter stick on the northwestern end of the study area within the well-exposed road cut east of the townsite of Colton. Nine additional detailed sections were measured on the southeastern end near Kyune Junction, and one other section was measured in the center of the study area. These sections provide control for the spatial relationships of the different rock units. In addition to the sections, analysis of low altitude oblique aerial photographs and detailed photographs taken on the ground provide control for making correlation drawings of lithologic bodies.

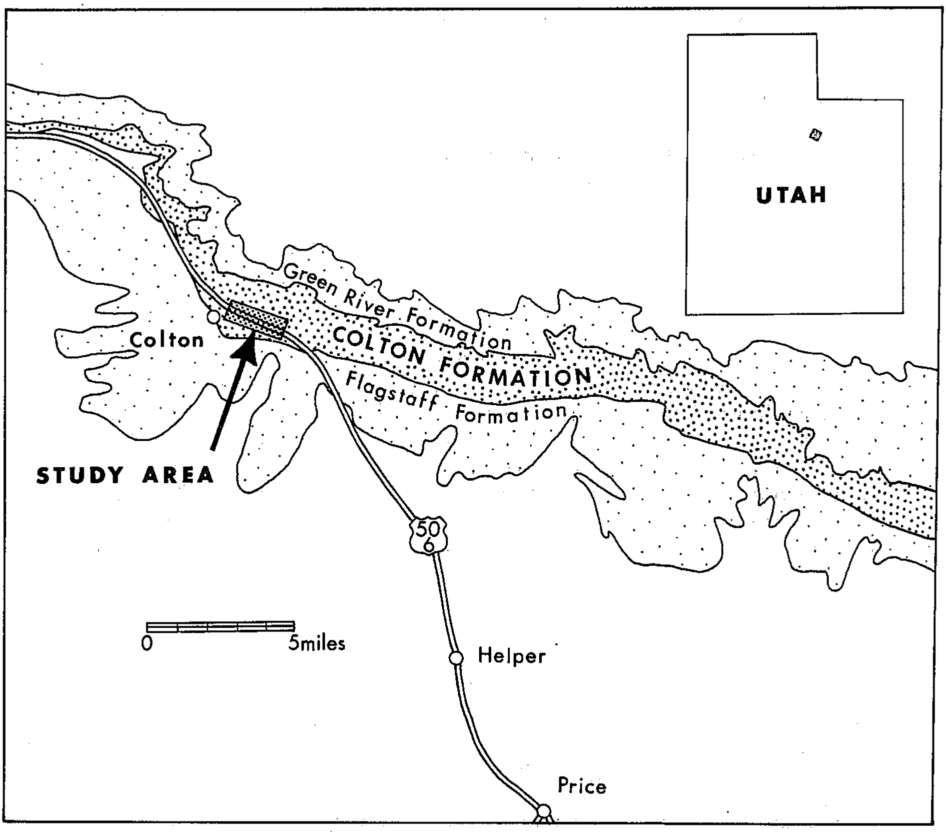
Thin-sections were made of samples from the lower channels and overbank sandstones in the road cut, and from the major sandstone bodies throughout the area. Sandstone thin sections were analyzed with a petrographic microscope for composition and fabric relationships. Siltstones and claystones were examined, both wet and dry, with a binocular microscope. Siltstone and claystone samples were then disaggregated in Quaternary O for five days, and sieved through a 200-mesh screen for possible microfossils.

Sandstones from the major sand bodies were disaggregated and grains were separated in heavy liquids and centrifuged in a reconnaisance investigation of heavy minerals.

One representative measured stratigraphic section through the northwestern end and one section through the southeastern end of the area are included in the appendix.

## DESCRIPTION OF LITHOLOGIC BODIES

Sediments in the study area occur as lenticular sandstone bodies and sheet deposits. A few of these lenticular sandstone bodies are composed of a series




TEXT-FIGURE 1.—Index map.

of asymmetrical imbricate sandstone lenses but most lack such lenses. Lenticular sandstone also occurs in flat-bottomed, convex-up features. Sheet deposits in the Colton Formation are flat bottomed and flat topped. They occur as multiple sheet sandstones and siltstones, single sheet sandstones, and sheet siltstones and claystones.

### Lenticular Sandstone Bodies

Most lenticular sandstone bodies in the Colton Formation are symmetrical, flat topped, and convex down, although biconvex lenses do occur. These lenses are flanked by sandstone, mottled siltstone, and claystone. The average width to depth ratio of the lenses is approximately 32 (Table 1).

Coarsest detritus in the delta occurs in these lenticular units. In general, the dominantly fine-grained sandstone becomes fine upward; however, some lenses are capped by medium-grained sandstone (Plate 1, fig. 1) which fines upward rapidly and grades into siltstone. Sandstone and siltstone in the lenses are moderate to well sorted and are composed of angular to subangular grains. The matrix in these sediments is calcite and iron oxide cement. Iron-coated grains provide the characteristic red color of the rocks. Composition of the

TABLE 1
STREAM CHARACTER RELATIONSHIPS

| Channel | F (w/d) | w (m.) | d (m.) | l (m.) | s (m./km.) |
|---|---|---|---|---|---|
| 1 | 43.5 | 87 | 2 | 1987.60 | .79 |
| 2 | 12.0 | 12 | 1 | 257.70 | 1.60 |
| 3 | 6.0 | 12 | 2 | 178.40 | .84 |
| 4 | 33.3 | 50 | 1.5 | 1184.99 | 1.06 |
| 5 | 34.3 | 137 | 4 | 2411.21 | .40 |
| 6 | 18.8 | 75 | 4 | 1156.00 | .41 |
| 7 | 25.0 | 100 | 4 | 1642.00 | .41 |
| 8 | 29.0 | 87 | 3 | 1612.90 | .54 |
| 9 | 37.5 | 75 | 2 | 1669.40 | .80 |
| 10 | 31.3 | 125 | 4 | 2156.10 | .40 |
| 11 | 42.2 | 175 | 4 | 3190.00 | .39 |
| 12 | 30.0 | 112 | 4 | 2053.00 | .44 |
| 13 | 25.0 | 50 | 2 | 1017.95 | .81 |
| 14 | 37.5 | 75 | 2 | 1669.39 | .80 |
| 15 | 62.0 | 62 | 1 | 1910.90 | 1.50 |
| 16 | 43.5 | 87 | 2 | 1987.60 | .79 |
| 17 | 37.5 | 225 | 6 | 3560.40 | .27 |
| 18 | 50.0 | 100 | 2 | 2371.30 | .79 |
| 19 | 37.5 | 150 | 4 | 2693.20 | .40 |
| 20 | 15.6 | 125 | 8 | 1492.96 | .21 |
| Average | 32.6 | | | | .69 |

*$l = 18\,(F^{.53}\,w^{.69})$ Where l = meander wavelength
F = width to depth ratio of channel
w = channel bank-full width

*$s = 30\left(\frac{F^{.95}}{w^{.98}}\right)$ Where s = channel gradient

siltstones and sandstones is 60 percent quartz, with minor amounts of plagioclase feldspar, alkali feldspar, mica, and heavy minerals. The bottoms of lenticular units sometimes have clasts of claystone that are round to subround and show no preferred orientation.

Large-scale trough cross-bedding is the dominant sedimentary structure within the sandstone lenses (Plate 4, figs. 10 and 15). Current directions determined from measured cross-beds are unimodal and indicate a downstream direction (Text-figs. 4, 5, and 6). In broad perspective, the lenticular bodies are horizontally stratified and massive near the bottom, but as the sediments begin to fine upward, cross-bedding becomes more apparent on the edges of the lens and then ultimately toward the center (Plate 4, figs. 8 and 17). Cross-beds are best preserved in the upper parts of the sandstone lenses. Planar cross-beds rarely occur, and are usually small scale and difficult to distinguish from trough cross-beds. Sole marks occur but are rare, and can be seen on the bottoms of the lenses preserved as positive relief, convex down features. Small diapiric structures sometimes appear in the lower parts of some lenses where laminations consist of alternating sandstone and claystone layers (Plate 4, fig. 5). The bottoms of all lenticular bodies are intensely burrowed.

Two lenticular bodies in the study area have a series of imbricate pods or lenses that occur on one side and dip toward the center of the body (Plate 4, figs. 6 and 17). In cross section, these lenticular bodies and associated lenses are convex down at the bottom and slightly concave up on top.

Imbricate lenses are composed of fine-grained sandstone that fines upward to siltstone at the top. Small clasts of claystone are present near the bottom of the lenses. Each sandstone lens is separated by laminated and horizontally stratified siltstone with very thin cross-bedded siltstone layers on top. Sandstone in these lenses appears to be massive and structureless. Siltstone between sandstone lenses is mottled, and is gray green to very light gray.

The last saucer-shaped feature (Plate 4, Cross Section B, Unit 26) in these lenticular sandstone bodies fines upward and is structureless near the base. Throughout the rest of the accumulation, trough cross-beds are common and have a unimodal current direction. Crossbeds give way to very light gray, horizontally stratified sandstone and siltstone near the top. This unit contains fine grains of organic material disseminated throughout the matrix.

Lenticular sandstone bodies which are flat bottomed and convex up crop out as medium-bedded sandstone, interbedded with thin siltstone layers (Plate 4, fig. 4, and Cross Section B, Unit 21). Laterally and vertically they grade into siltstone and claystone and usually occur near other lenticular sandstone units.

Sandstone beds of these bodies are lenticular and laterally discontinuous. They fine upward and grade into siltstone near their top. The sandstone is fine grained and composed of subangular grains; it is generally structureless but may be finely laminated.

Siltstone beds within the sandstone lenses are mottled, and highly oxidized. Silt grains are surrounded by a matrix of clay.

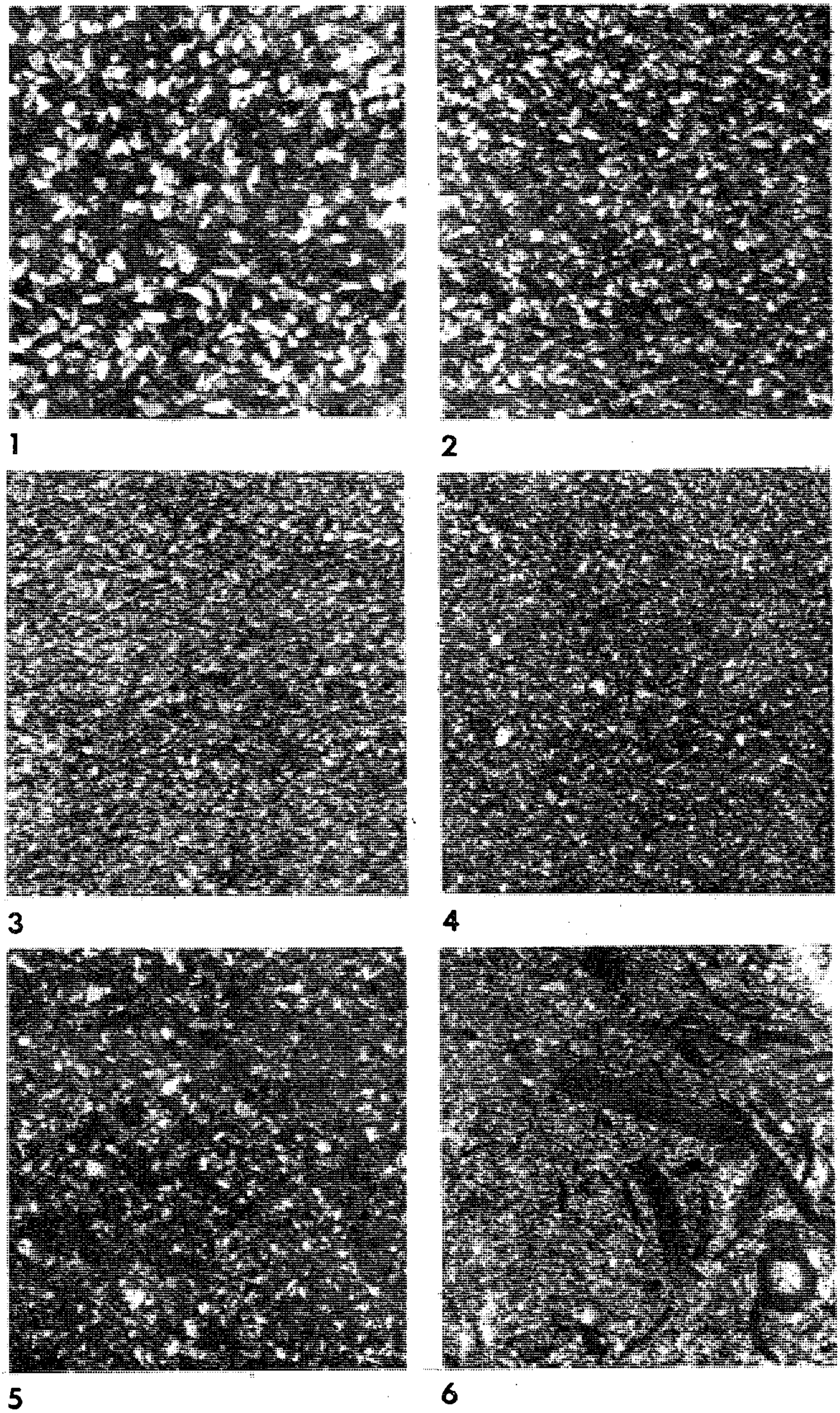
Lenticular sandstone bodies in the Colton Formation are interpreted as channel fillings and splay deposits. The lateral and vertical sequence of imbricate lenses flanking some channel fills suggests that such lenses are point bars deposited in meandering channels. However, the majority of channel fillings

EXPLANATION OF PLATE 1
PHOTOMICROGRAPHS

(All 5x crossed nicols)

FIG. 1.—Upper part of channel 1 (Plate 4, Cross Section A and B), showing well-sorted, angular to subangular, medium-grained sandstone.
FIG. 2.—Lower part of channel 1 (Plate 4, Cross Section A and B), showing well-sorted, angular to subangular, fine-grained sandstone.
FIG. 3.—Channel 7 (Plate 4, Cross Section A), showing well-sorted, angular to subangular, very fine-grained sandstone.
FIG. 4.—Delta front sandstone (Plate 4, Cross Section A), showing poorly sorted, very fine-grained, silt-rich sandstone.
FIG. 5.—Overbank sandstone (Plate 4, Cross Section B, Unit 10), showing poorly sorted, silt-rich sandstone.
FIG. 6.—Lacustrine siltstone (Plate 4, Cross Section B, Unit 5), showing broken fossil remains in the matrix.

PLATE 1



are not flanked by lenses and are considered to have been nonmeandering or relatively straight channels. Sediments deposited in these channel fills are the major frame builders on the delta. Lenticular sandstone bodies in the Colton Formation that are flat bottomed and convex up are interpreted as crevasse splay deposits.

### Sheet Deposits

The most continuous and laterally persistent frame builders in the studied part of the Colton escarpment are the multiple sheet sandstone deposits. Multiple sheet sandstones are flat bottomed and flat topped. They appear as separate sheets of sandstone ranging from fifty to one hundred centimeters thick and separated by thin layers of siltstone. Each sheet pinches and swells in thickness and grades laterally and vertically into siltstone and claystone. These sandstone units coarsen upward slightly and are usually structureless. Planar and trough cross-beds, when present, are restricted to sandstone near the bottom of the units, as well as to very fine-grained siltstone in between the sandstone layers. Cross-beds observed are usually multidirectional.

Multiple sandstone sheets in the Colton Formation are fine grained and are composed of subangular to subround grains. These units are poorly sorted, with silt incorporated around the sand grains (Plate 1, fig. 4). Quartz comprises fifty to sixty percent of the rock, and alkali feldspar is common, comprising ten to twenty percent of the rock. The remaining grains are minor amounts of plagioclase feldspar and mica, with small amounts of organic material. The underneath parts of these units contain gastropods and other macerated fossil debris (Plate 2, fig. 3).

Claystone and siltstone occur below multiple sandstone sheets, and are typically gray green. They are poorly to moderately sorted and contain minor amounts of disseminated organic material. These rocks are massive and contain no apparent sedimentary structures.

Single sheet sandstones occurring in the Colton Formation are laterally discontinuous and vary in thickness (Plate 4, Cross Section B, Unit 10). They are stratigraphically equivalent to channel fills and are consistently flat bottomed and flat topped. Sandstone in the sheet is poorly sorted and is composed of subangular grains in a matrix of calcite, iron oxide, and clay (Plate 1, fig. 5). Quartz grains are typically coated with iron oxide which produces the reddish brown color of the units.

Sheet siltstones are typically mottled. Samples that are not disaggregated contain green siltstone infillings. Because of the turbated nature of sheet siltstone units, any sedimentary structures which they may have contained are

---

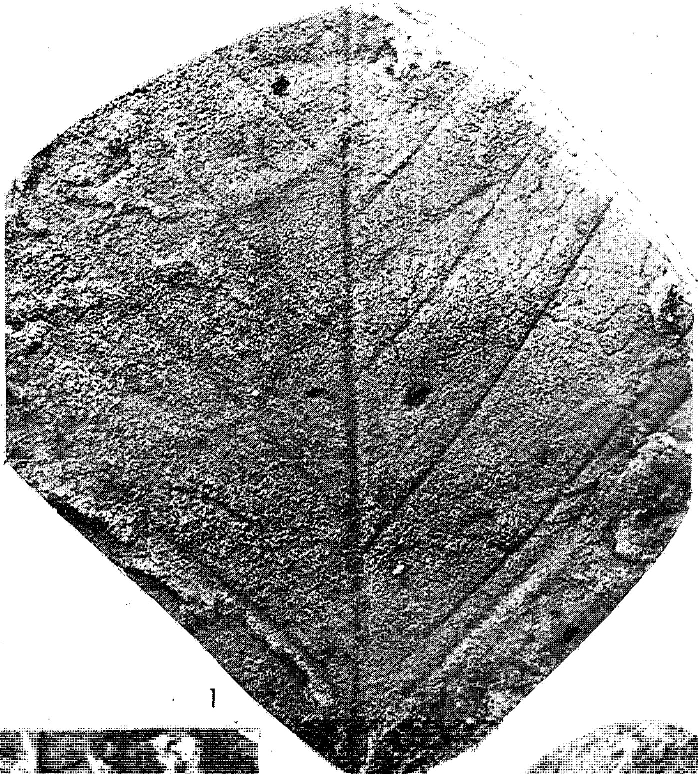
### EXPLANATION OF PLATE 2
### FOSSILS

FIG. 1.—Leaf imprint of *Betula stevensoni* (?) Lesquereux found in channel 6 (Plate 4, Cross Section A). Natural size.

FIG. 2.—Root infilling in sandstone below channel 19 (Plate 4, Cross Section A) in the southeastern end of the study area along the dirt trail. Note pen for scale.

FIG. 3.—Siltstone internal molds of *Hydrobia* (?) found on the underside of the frontal sandstone unit near channel 6 (Plate 4, Cross Section A). Natural size.

PLATE 2



1

2

3

obliterated. Most siltstone units contain an abundance of clay in the matrix. If clay is dominant, the rock weathers with a spheroidal surface. Some siltstone beds contain round to subround clasts of clay.

Organic claystone beds within single sheet siltstones are the most continuous layers of nonclastic deposits in the Colton Formation. These deposits are characteristically black to dark gray, and are very thin bedded, never exceeding 30 centimeters in thickness. They are laterally discontinuous and are usually near lenticular sandstone bodies.

. Claystone of these units is somewhat fissile, and mottled. The abundance of what is probably macerated plant material gives the claystone a dark gray color. Organic claystones are highly effervescent in dilute HCl, indicating considerable calcite cement in the matrix.

Multiple-sheet sandstone bodies in the Colton Formation of the study area are interpreted as delta front sandstones (Plate 4, Cross Section A). These units formed as a result of close spaced distributary channels on the delta front. Claystone and siltstone found below frontal sandstone beds are interpreted as prodeltaic sediments. Gray green color indicates reducing conditions and reflects the abundance of organic material. Single-sheet sandstone, siltstone, and claystone deposits are interpreted as overbank deposits produced by periods of flooding on the delta. Quantitatively these units are the dominant facies in the study area. Organic claystones are interpreted as marsh deposits reflecting long periods of nonclastic deposition.

## MECHANICS OF SEDIMENTATION

### Channels

When water flows through a channel in equilibrium, the amount and type of sediment transported in the water is a function of the stream flow velocity (Oomkens, 1970, p. 207). If the water velocity is decreased due to either abandonment of decrease in water supply, then deposition in the channel will result. The first sediments to be deposited are the coarser and more dense bed-load. The smallest sediments held in suspension will be deposited upon complete abandonment of the channel.

Channels without point bars in the Colton Formation appear to be similar to those described by Schumm (1960), where the width to depth ratio is about 14. According to Schumm (1960, p. 182), as coarser sediments are deposited upstream the percent silt increases downstream. When concentration of silt reaches greater than 50 percent, deposition of silt occurs farther downstream from where the coarser sediments are deposited. Two types of deposits in this type of channel were recognized by Schumm (1960): finer sediments on the banks and coarser sediments on floor of the channel. During later stages of filling, all the deposited material is silt. Schumm noted that sediments in these types of channels will be horizontally stratified on the bottom with lateral deposition occurring near the sides and top of the channel.

Channel fills in the Colton Formation without point bars have low sinuosity (Table 1) and probably flowed on the lower deltaic plain. Meandering is not as common on the lower deltaic plain.

Within meandering channels, water flowing through the channel will move faster on the outer concave bank of the channel than on the inner convex bank (Leopold and Wolman, 1960). Controlling mechanisms for meandering are not totally understood, but most workers consider helical circulation to be the dominant controlling factor in meandering streams (Leopold and Wolman, 1960). Following periods of flooding, point bars develop on the inner bank of the channel. When flooding subsides, gradual decrease in velocity causes sediment-laden water to become less competent as it flows over the inner bank of the channel. The net effect of this process is a series of point bar lenses dipping toward the center of the channel representing multiple periods of point bar development or flooding. Lenticular body 3 in Cross Section B (Plate 4) displays what is interpreted by the author to be point bar lenses.

Harmes and Fahnestock (1965) studied point bars on the Rio Grande River and determined the following sequence of bedding (bottom to top): (1) ripples, (2) small-scale, trough cross stratification, (3) horizontal stratification, (4) large-scale, trough cross stratification, and (5) tabular sets. The upper flow regime on point bars described by Harmes and Fahnestock (1965) is similar to the upper flow regime evidenced on point bars in the study area (Text-fig. 2). Ripples and small-scale, trough crossbeds of the lower flow regime are not apparent in the Colton examples.

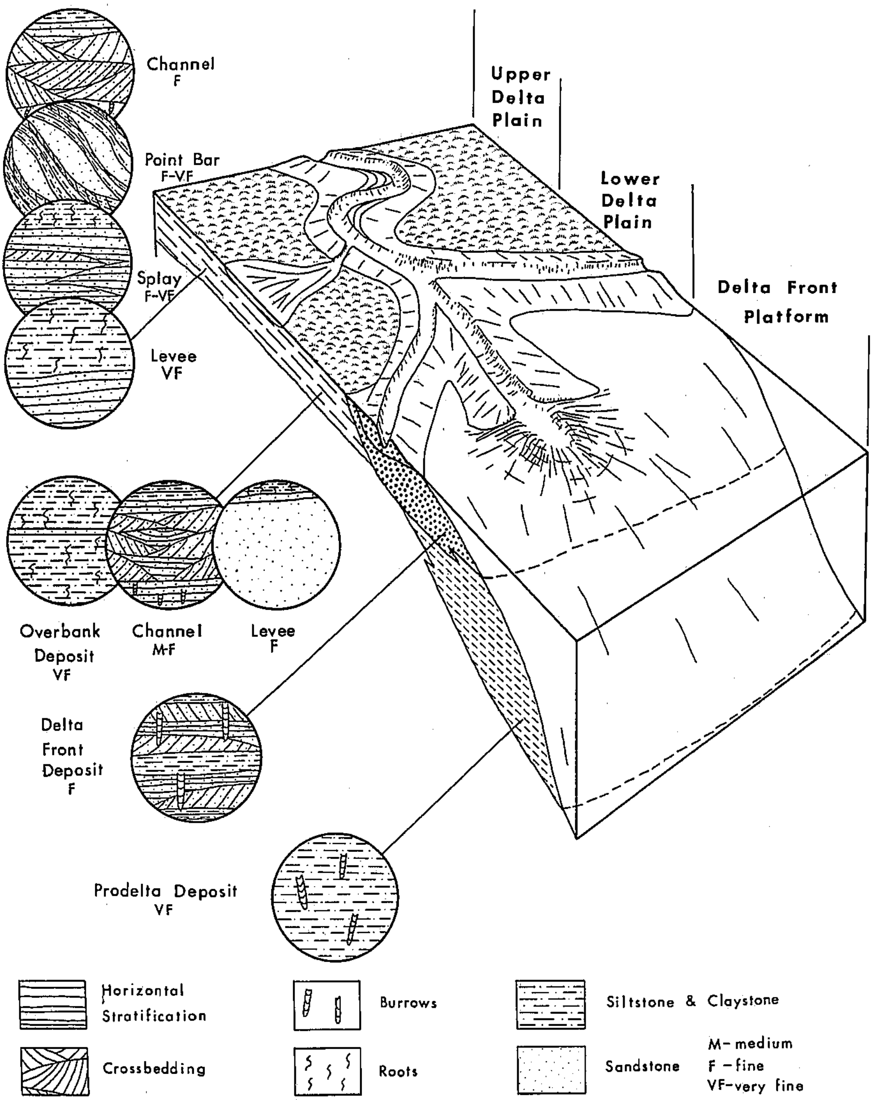
Point bar channel fills in the study area closely follow the flow regime model proposed by Visher (1965). In vertical sequence he stated the following should be encountered (bottom to top): (1) trough cross-beds, (2) horizontal stratification, and (3) ripples. Colton point bar channel-fills in the study area do not display ripples but horizontal stratification and trough crossbeds are apparent (Text-fig. 2). Visher (1965) noted that below the trough cross-bedded zone in channel fills, the sediments are structureless and contain pebbles, clay chips, and pieces of wood and bone. He described sequences similar to those seen in the Colton study area. Visher (1965, p. 48) determined that migration and suspension of bed forms produced trough and planar crossbeds and that the horizontally stratified zone is the final waning or settling out stage of deposition in the channel.

Point bar or meandering channels are common to the upper deltaic plain (Fisher et al., 1969, p. 15) and have sinuosities as illustrated in Table 1 (Channels 3 and 9).

### Delta Front Facies

Delta front sand and prodelta clay accumulates where one or more channels empty into a larger body of water and disperse their sediments (Text-fig. 2). This dispersion forms a continuous body of sand around the front of the delta while silt and clay are swept farther out into the prodelta zone (Gould, 1970, p. 11). Through progressive outbuilding, the sand sheet moves over older prodeltaic clays while clay continues to be deposited farther out into the lake or ocean.

In vertical sequence of a prograding delta, pro-deltaic claystone coarsens upward into delta front sandstone. Each successive sandstone layer will coarsen upward as progradation occurs. Gould (1970, p. 11) observed that Lafourche-Mississippi Delta prodelta claystones are massive and thick bedded, and sandstones are clean, laminated and cross bedded. Delta front sandstone units in the study area do not appear to be as clean as those described by Gould (1970) in the Lafourche-Mississippi Delta, but they are laminated and cross-bedded. Delta front sandstone units in the Lafourche-Mississippi Delta contain thin layers of organic debris and plant fragments similar to those seen in the study area.




TEXT-FIGURE 2.—Block diagram illustrating lithologies and sedimentary structures of the major facies in the study area.

Natural Levees, Splays, Distributaries, Overbank Deposits

Deposition of levees occurs when a stream overflows its banks. The velocity of the water moving over the bank is checked so that not all the original load can be transported and sediment is thus deposited adjacent to the channel banks. Coarsest debris is laid down close to the channel and the finer material farther from the stream (Allen, 1965, p. 121).

Levees are best developed on concave banks of streams. On point bars of convex bank they are rarely so well preserved as to cover the point bars completely (Allen, 1965, p. 121). Natural levees on channels in the study area were probably formed on convex surfaces and are therefore inconspicuous, although convex relationships are not seen in outcrop. Well-developed textural relationships where natural levees should occur are not available, making analysis difficult.

As successive floods increase the height of the natural levee, the channel becomes more confined and higher above the floodplain (Derr, 1974, p. 31). During strong floods, the stream may break through the natural levee and seek a new course on the lower deltaic plain. Once a break is initiated, flood water develops a system of distributary channels which are arborescent. Because of the distributary nature of the splay, a cross section through the splay will produce individual pods or lenses of sandstone (Text-fig. 2 and Plate 4, Cross Section B, Unit 21) that fine upward, representing the settling out stage as the flood subsides. These lenses may be covered by other lenses representing multiple periods of flooding through the same break in the channel.

If the break in the natural levee results in permanent change in the course of the stream, the earlier channel will be abandoned. Since very few channels occur on the same stratigraphic horizon in the study area, most channel fills are probably the result of avulsion rather than part of a distributary system.

Channels that do occur on the same stratigraphic horizon were probably distributary channels related to each other; they are located on the delta front (Plate 4, channels 6, 7, and 8). Although not readily apparent from rocks exposed in the study area, the process of distributary channel formation was probably similar to that described by Fisher et al. (1969) on the Mississippi Delta. Distributary channels form as a result of bifurcation of the main channel farther upstream. Bifurcation is created by bed load that is deposited at the mouth of the stream in distributary mouth bars, causing reduction in cross sectional area. To accommodate the subsequent flow, the stream takes a course around the newly formed bar.

Overbank deposits represent a long accumulation of fine, suspended silt and clay that has settled after reaching low-lying basins which may flank natural levees (Allen, 1965, p. 150). Such deposits fine upward, reflecting the settling out stages following flooding (Text-fig. 2). During strong periods of flooding, sand-bearing water may top the banks and fill the adjacent basins.

During periods of nonflooding, the delta plain is subjected to invasion by vegetation. Roots from plants churn the overbank deposits leaving the mottled appearance in the rock. When periods of nonflooding are prolonged, plant remains may accumulate and form thin layers of organic claystone or even coal. This usually occurs on the upper deltaic plain where gradients are low and sediments are not affected by lacustrine processes.

## FOSSILS

Fossils are relatively rare and poorly preserved in the study area. High energy conditions in the channels were not conducive to good preservation. Hence, most fossils found in the study area are in deposits of low energy subaerial and subaqueous environments on the marshy delta plain, lacustrine embayments, or delta front. Whole fossils are rare. Most fossils are fragmented and worn, making generic and specific identification difficult.

Fossils found in the Colton beds include macerated plant remains, roots, bivalve fragments, gastropods, fish fragments, and numerous trace fossils.

Fossils in the study area occur mainly in sandstone units. Siltstone and claystone units were nearly completely churned and mottled by roots so that organisms originally present have been destroyed. Trace fossils are by far the most common remaining evidence of life. These fossils are postdepositional and are restricted mainly to sandstone bodies.

### Plants

Plant remains in Colton beds are usually highly macerated and are preserved as carbon films and imprints in channels associated with the delta front and as root fillings on the delta plain. Occasionally, carbonized stems and unbroken carbonized leaves were observed, but margins and secondary veins on leaves are usually not preserved, making specific identification impossible.

One moderately well-preserved leaf impression was found in sandstone lens 6 (Plate 4) on the delta front. The leaf was identified as possibly *Betula stevensoni* Lesquereux 1878 (Plate 2, fig. 1). The leaf margin is not preserved but primary and secondary veination is preserved. *Betula stevensoni* is typical of Paleocene floras found in the Livingston Formation in Montana and in the lower part of the Fort Union Formation in Wyoming (Brown, 1962). This leaf originated from a deciduous tree, probably on the delta plain. It is unlikely the leaf was transported very far and was probably close to its place of origin at the time of deposition. Extreme long distance transportation would have destroyed the leaf completely.

Roots and impressions of roots are common in the study area and were probably more abundant than now seen in the rock record. Mottled and churned siltstone and claystone suggest that sediments on the delta plain were constantly subjected to plant modification. Roots are preserved as reduced gray green siltstone fillings. Those observed range from 1 mm to 2 cm in diameter and 1 cm to 40 cm long (Plate 2, fig. 2). The best preserved roots are found in units 1 and 2 (Plate 4, Cross Section B) in the road cut on the northwestern end and in road cuts on the southeast end of the study area.

### Mollusks

Gastropods found in the study area are probably *Hydrobia* Hartmann 1821 (Plate 2, fig. 3). These gastropod shells are typically small, elongate, dextrally coiled, with whorls that are slightly convex. Apertures and surface ornamentation are not preserved on collected material. Gastropods and gastropod fragments occur as siltstone casts and as unaltered shells in the frontal sandstone sheet and lacustrine units of the study area.

*Hydrobia* does not seem to have had any particular ecologic preference but is fairly common in early Flagstaff Lake sediments and much less common in late Flagstaff Lake sediments (LaRoque, 1960, p. 31). Gastropods found in the study area were probably shallow, quiet water forms as suggested by their occurrence in the delta front sheet sandstone and lacustrine units.

### Trace Fossils

Trace fossils in the study area occur as dominichnid and fodinichnid types. Dominichnia are permanent shelters dug by vagile animals procuring food from outside the sediment as predators, scavengers, or suspension feeders. Fodinichnia are burrows made by hemisessile, deposit feeders reflecting the search for food and fitting the requirement for shelter (Seilacher, 1964).

*Dominichnia.*—*Arenicolites*-like burrows occur in the Colton Formation (Plate 3, figs. 1 and 2) and are full-relief, cylindrical, U-shaped burrows that have a diameter of about 1 cm and range from 10 to 100 cm long. They are restricted to sandstone units. Upper ends of the burrows are moundlike and circular (Plate 3, fig. 2). The burrowing organism apparently burrowed downward until it reached the sandstone-siltstone interface, then it burrowed upward and out of the sandstone unit. These burrows are found mainly in the sheet sandstone unit associated with lenticular sandstone 11 (Plate 4, Cross Section A). These fossils are probably burrows of worms similar to those described by Seilacher, (1964, p. 311) which have been interpreted to be indicative of tidal to very shallow water marine environments. *Arencolites*-like burrows are found in the Colton Formation in what are interpreted as overbank sandstone units associated with channels on the lower deltaic plain.

*Fodinichnia.*—*Thalassinoides*-like burrows in the Colton Formation are convex hyporelief features that are common in lenticular sandstone bodies in the study area. These burrows, as preserved, are approximately 20 to 40 mm long and appear to be Y-shaped (Plate 3, fig. 4) and are approximately 5 mm in diameter. They occur in abundance on the bottoms of lenticular sandstone bodies and are usually fragmented and broken.

Burrows occur that are similar to *Bifungites* Desio 1940, but they are rare in the study area. These burrows are also restricted to the bottoms of lenticular sandstone bodies. *Bifungites*-like burrows in the Colton rocks are arrow-shaped, convex, hyporelief features (Plate 3, fig. 3).

## ENVIRONMENTAL DESCRIPTION OF ROAD CUT

Exposures in the road cut east of the townsite of Colton, Utah, are the most easily accessible excellent exposures in the study area (Plate 4, figs. 17 and 18). These beds contain most representative lithologies and sedimentary features seen within the Colton delta and show relationships very well. Description of a detailed measured section of the road cut is given in Section 1 of the appendix.

Lowermost exposures in the road cut are yellowish and purplish gray sheet siltstone and claystone units. They are represented as units 1 through 4 on Cross Section B of Plate 4. Siltstone beds contain grains that are limonite and hematite stained. In addition, small clay pebbles are dispersed throughout the silt. Claystone beds usually weather into crude spheres and contain gray green siltstone infillings. Lumped together, these siltstone and claystone units are about 4 meters thick.

Rocks laterally equivalent to the upper part of channel fill 1 consist of sheet siltstone and claystone units and one sandstone unit (Units 6 through 10). The siltstone and claystone units are similar to units 1 through 4 described previously. The sandstone unit (Unit 10) is very light gray but weathers reddish brown. It is fine-grained, indurated, and slightly cross-bedded, but is structureless for the most part. When the sandstone unit is traced to the northwest toward channel fill 1, it gradually loses thickness and pinches out about 3 meters from the channel, about where the natural levee of channel fill 1 should be (dots on the cross section), and is roughly stratigraphically equivalent to the medium-grained sandstone which tops channel fill 1. The sandstone (Unit 10) becomes lost beneath alluvium as it is traced to the east.

About 3 meters of mottled, yellowish and purplish gray siltstone also occurs above unit 10 (Units 11 through 15) and is similar to siltstone and claystone deposits described previously.

All previously mentioned siltstone and claystone units probably represent floodplain or overbank deposits. The fine-grained nature of the rocks suggests that sediments were allowed to settle in relatively quiet water following periods of flooding. Presence of small clay pebbles suggests that water moving over or along channel banks was fast enough to rip up part of the clay of the natural levees or banks which had been deposited during previous flooding These floodplain and overbank sediments were bioturbated by roots subsequent to deposition, as evidenced by their mottled appearance, and accumulated in an oxidizing environment as suggested by hematite and limonite coatings on grains. The sandstone unit (Unit 10) is interpreted as an overbank deposit resulting from a higher velocity flood. Maximum thickness of the sandstone unit is 60 to 70 cm, suggesting that water depth was probably not much more than that during the flood.

A very light greenish gray, sheetlike, very fine-grained siltstone bed that is about 15 cm thick (Plate 4, Cross Section B, Unit 5) occurs above the lowermost siltstone and claystone units (Units 1 through 4). This unit is a key marker bed in the road cut and can be easily identified on both sides of the road. It is continuous, except where cut by lenticular or channel-fill sandstone units. Gastropod, bivalve, and other fossil fragments are common and can be seen in hand samples. The bed is highly calcareous and contains traces of organic material.

Unit 5 may represent a minor lacustrine inundation of the delta as a result of subsidence, compaction, or rise in lake level (Text-fig. 3A). Rocks in this unit are strikingly similar to the lacustrine Flagstaff Formation below and may have been deposited in shallow water, reducing lacustrine conditions. Whole shells were possibly broken and fragmented by penetration of plant roots from overlying horizons. The relative thinness of this unit suggests that either sedimentation was not very rapid or that the lacustrine inundation did not last very long, and that perhaps the unit was related to floods and changes in distributary channel directions over the subsided area.

## EXPLANATION OF PLATE 3
## TRACE FOSSILS

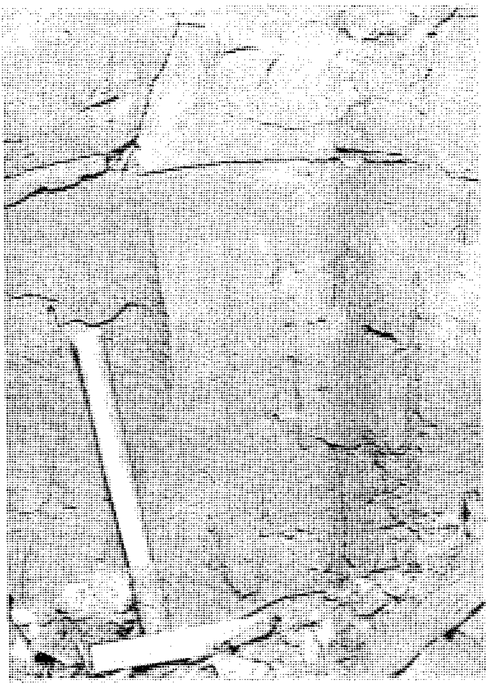
FIG. 1.—*Arenicolites*-like burrows found in the overbank sandstone unit adjacent to channel 11 (Plate 4, Cross Section A). Note hammer for scale.

FIG. 2.—Vertical view of *Arenicolites*-like burrows found in channel 11 (Plate 4, Cross Section A). Note pen for scale.

FIG. 3.—*Bifungites*-like burrow found on the underside of channel 2 (Plate 4, Cross Section A and B). Natural size.

FIG. 4.—*Thalassinoides*-like burrows found on the underside of channel 8 (Plate 4, Cross Section A). Natural size.

PLATE 3

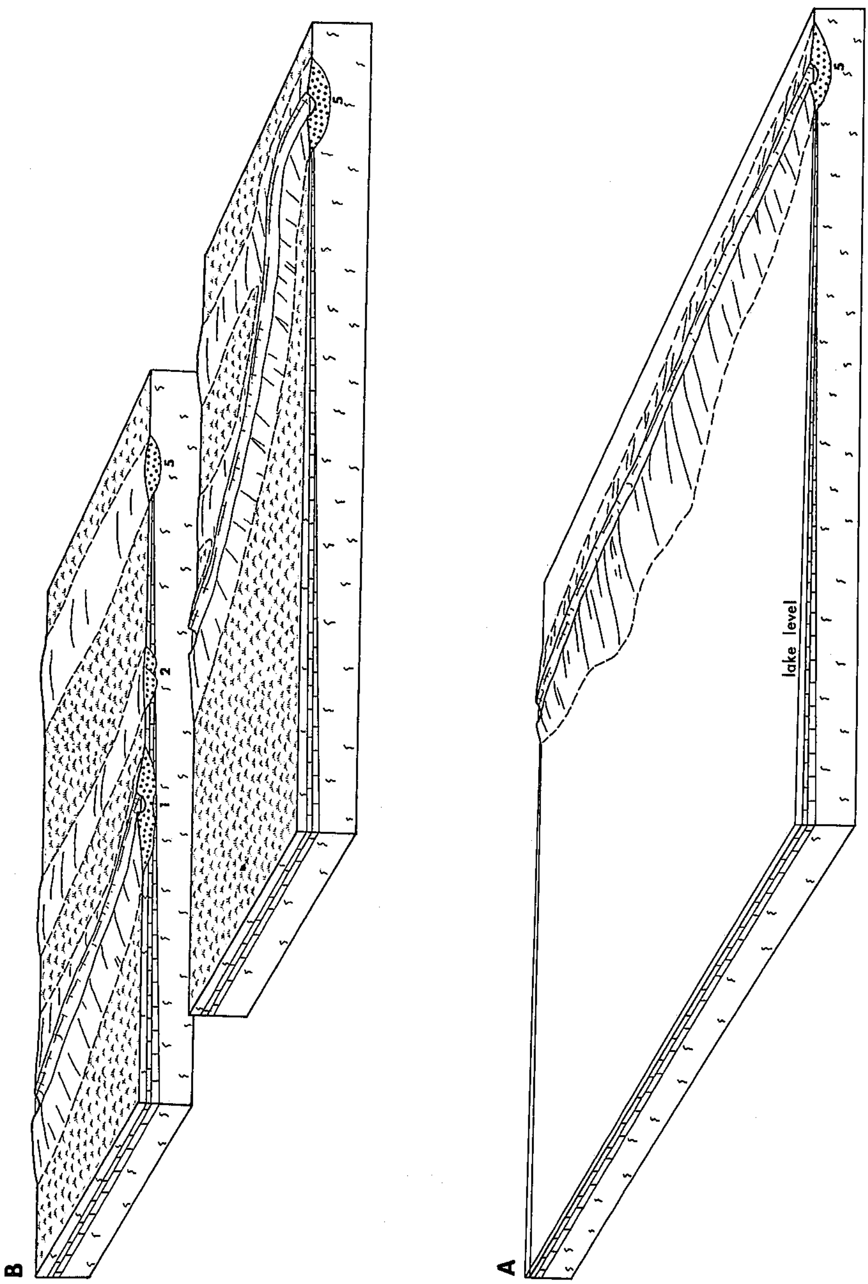


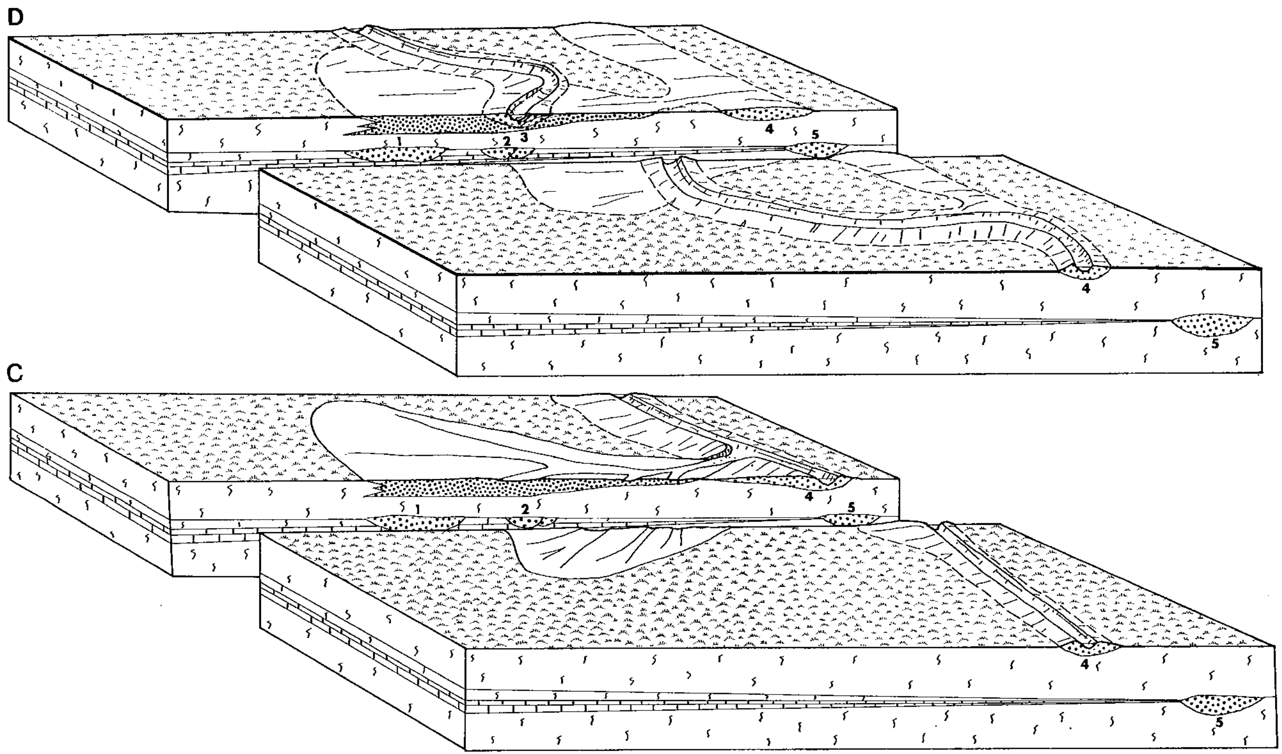
1

2

3

4


B
5
2
1
5
A
lake level
5




TEXT-FIGURE 3.—Diagramatic interpretation of the lower part and upper part of Cross Section B on Plate 4. A, channel 5 is flowing on lower deltaic plain. Channel 5 is flanked by natural levees and a lacustrine inundation. B, abandonment of channel 5 by channels 1 and 2. C, channel 4 and subsequent splay is flowing across the upper deltaic plain. D, abandonment of channel 4 by channel 3 on the marshy upper deltaic plain.

In the west and westcentral part of the road cut, the lacustrine unit (Unit 5) is cut by two younger lenticular sandstone bodies. The southeasternmost lens, channel 2 in Cross Section B on Plate 4, consists of two lenses that are about 2 meters thick and are biconvex. Internally, the sandstone is slightly laminated, in part, and consists of two pods separated by siltstone. The westernmost lens appears to be slightly younger and cuts the eastern lens.

Lenticular sandstone 1 in Cross Section B of Plate 4 is composed of fine-grained sandstone that is very light gray but weathers red brown. This lens is convex down and is nearly flat topped. Within the lower one and one-half meters, grain size decreases upward from fine-grained sandstone to very fine-grained siltstone. Sediments near the bottom are massive and horizontally stratified. The top of the body is covered by medium-grained sandstone that is trough cross-bedded. This lenticular sandstone unit crops out on both sides of the road and to the southeast of the road cut. Current directions as indicated by crossbeds are dominantly from the southwest and are illustrated in Text-figure 4.

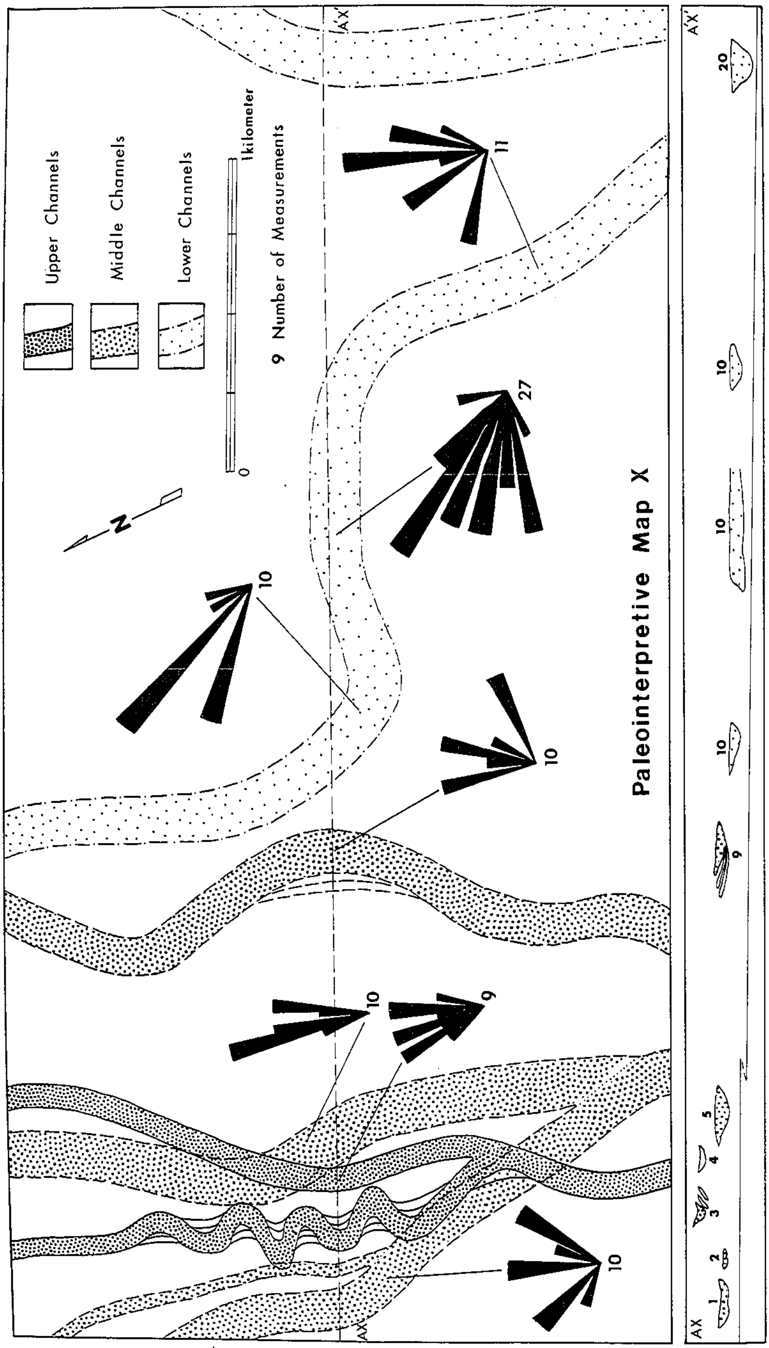
These two lenticular sandstone bodies are interpreted as channel fills and are stratigraphically equivalent to the upper part of channel fill 5 (Plate 4, Cross Section A) farther to the southeast. Abandonment of channel 5 during later stages may have produced channels 1 and 2. When this occurred, channel 1 cut across overbank and lacustrine sediments that flanked channel 5. The two lenses in channel 2 probably represent two unsuccessful attempts of abandonment of channel 1. These relationships are illustrated in Text-figure 3B.

Sinuosities of these channels (Table 1) and the presence of lacustrine sediments on the flanks suggest that these channels flowed over the lower deltaic plain. The medium-grained sandstone on top of channel 1 suggests a second pulse of water through the channel and the sandstone may have been deposited during a floodstage on the delta.

Two thin beds of organic claystone occur directly above unit 15 and are separated by a thin claystone unit (Units 16 through 18). Organic claystone probably represents marsh deposits that accumulated on the flanks of a channel when clastic sedimentation was at a standstill. Their relative thinness suggests that the standstill, or period of nonflooding, did not last long. The lowermost organic claystone unit rests directly on top of the overbank siltstone units and may be indicative of the ultimate settling stage following flooding.

A unit of interbedded sandstone and siltstone occurs above the organic claystone beds and ranges in thickness from a few centimeters to 2 meters (Unit 21). Sandstone in this unit is thinly bedded and is sometimes lens-shaped. Sandstone lenses and beds fine upward to siltstone near the top and appear to be massive. Siltstone in unit 21 is mottled and may be slightly cross-bedded.

Unit 21 is interpreted to be a crevasse splay. It may have originated from channel 4 (Plate 4, Cross Section A) as illustrated in Text-figure 3C. The presence of many beds and stacked lenses of sandstone suggests the splay had many pulses of flooding. Sandstone and siltstone beds were subjected to plant modification after each pulse of flooding as evidenced by the mottled and churned texture within finer sediments in the splay. Since splays are not erosional but rather depositional features (Coleman and Gagliano, 1964, p. 74-76), the varying thickness and irregularity of the underside of the splay provide an indication of the paleotopography on the delta plain at the time




TEXT-FIGURE 4.—Paleointerpretive map of the lower one-third of the studied section illustrating channels and measured crossbed directions. Channel numbers on cross section at the bottom refer to the numbers on Cross Section A on Plate 4.

of deposition. This surface was apparently irregular and hummocky, with small areas of high and low relief.

The crevasse splay unit (Unit 21) is cut by channel fill 3. This channel fill displays a series of imbricate lenses of sandstone on its southeastern side. Each sandstone lens fines upward to siltstone on top. The last saucer-shaped deposit (Unit 26) is capped by a white to gray green siltstone (Unit 27). The gray green siltstone fines upward into siltstone and claystone (Units 28 through 31).

Channel 3 is probably a point bar channel resulting from meandering on the delta plain. Channel 3 is stratigraphically equivalent to the upper part of channel 4 (Plate 4, Cross Section A) and may be the result of abandonment of channel 4 (Text-fig. 3D). White to gray green siltstone (Unit 27) on top of the channel represents the final waning stage of channel filling following channel abandonment. The gray green color of unit 27 suggests reducing or stagnant conditions. The fine-grained texture and occurrence of fragments of organic material suggests that this part of the channel became an oxbow lake following complete abandonment of the channel by the stream.

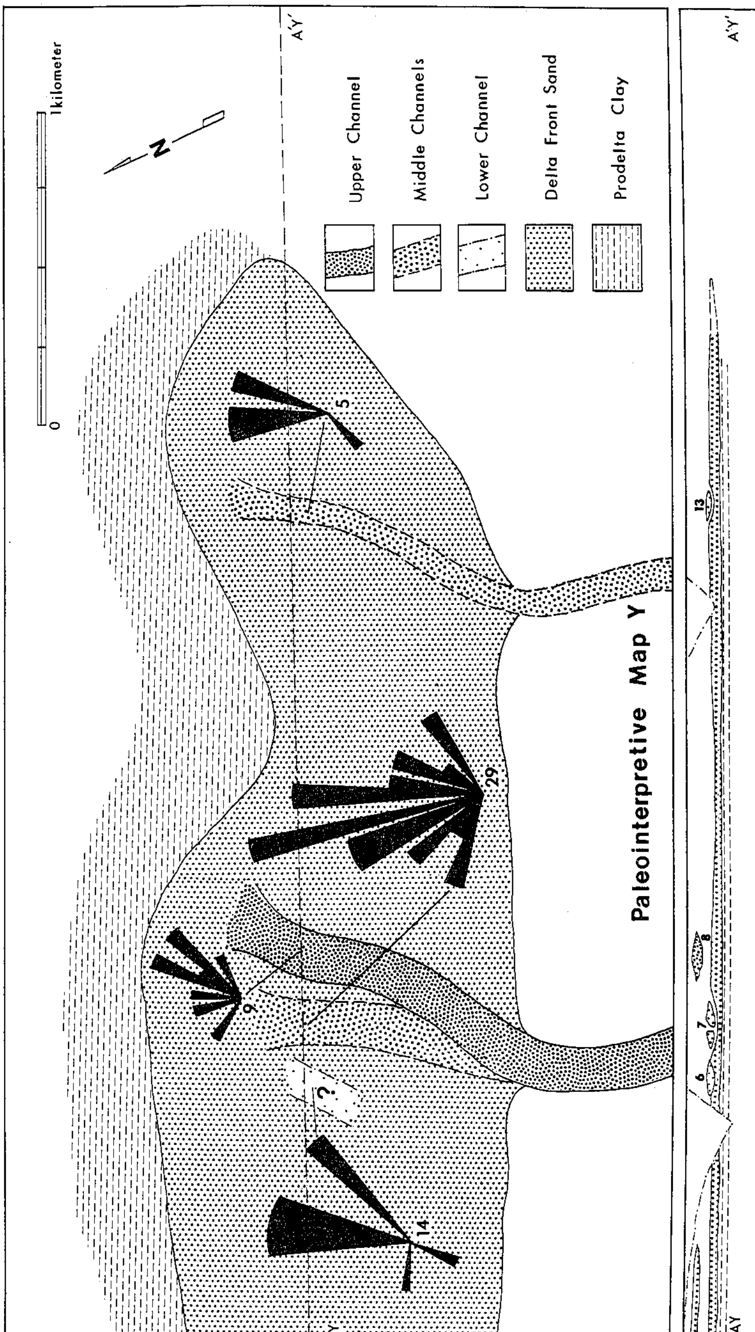
Sediments in this road cut reflect a progradational sequence on the delta. The lowermost channel fills (1 and 2) rest upon and cut lacustrine and overbank sediments indicating the streams of the channels flowed on the lower deltaic plain. As advancement of the delta took place in the lake, the lower deltaic plain formed farther toward the north over what had been the lake, and the upper deltaic plain formed over sediments which had accumulated on the lower deltaic plain. Upper deltaic plain deposits may be present as evidenced by the point bar channel, organic claystone units, and splay sandstone in the upper part of the road cut. Point bar channels and organic claystones are common to the upper deltaic plain on the Mississippi Delta (Fisher et al., 1969, p. 15).

## HISTORY OF THE DELTA

During the Late Paleocene to Early Eocene, streams flowing from the south and southwest advanced into Lake Flagstaff over a prograding delta complex at the present site of the study area. The channels and associated sediments preserved in the study area are analogous to those produced in modern delta systems.

Rocks in the studied escarpment reflect three distinct periods of deltaic progradation. Two lobes separated by a lobe partially inundated by a lacustrine transgression can be seen in the area and are illustrated in Text-figure 7. Together, these sediments display the abandonment and lateral migration of lobes on the delta. The process of distributary channel migration and abandonment resulted in a complex system of overlapping lobes like that described in the Mississippi Delta (Coleman and Gagliano, 1964; Gould, 1970) and like that documented in ancient Alleghenian deltaic deposits by Ferm (1970).

Deltaic deposits in the Colton formation show evidence of both upper and lower deltaic plains of deposition. According to Coleman and Gagliano (1972, p. 5), the upper deltaic plain shows evidence of channels and associated deltaic plain sediments that are not affected by marine currents, tides, and wave action. Lower deltaic plain sediments are those that are affected by marine processes, or in the case of the Colton delta, by lacustrine processes. It is likely that the dominant lacustrine process affecting the lower deltaic plain was small




TEXT-FIGURE 5.—Paleointerpretive map of the middle one-third of the studied section illustrating channels and measured crossbed directions.

fluctuations in lake level due to either seasonal influx of water or subsidence as a result of compaction of sediment. Winds may have created currents strong enough to affect the front of the delta.

The first channels to prograde into the area resulted in rapid deposition on the lower deltaic plain. These channels are illustrated as the lower channels on Text-figure 4 and as channels 10 and 20 in Cross Section A on Plate 4. Channels 10 and 20 are probably related distributaries of a single stream and are relatively straight or slightly sinuous (Table 1). Upon abandonment of these channels, major deposition in the delta shifted slightly to the northwest, as indicated by development of channels 1, 2, 5, and 9. These channels were in the lower deltaic plain, as evidenced by the lacustrine sediments through which the channels cut. Channels 1, 2, and 5 are relatively straight or slightly sinuous (Table 1). As the delta advanced into the lake, upper delta plain sediments were deposited over the lower deltaic plain. Moderately high sinuosity and the presence of point bars in channel 9 indicates this channel began to meander and may be the first suggestion that the upper deltaic plain environment was moving over the lower deltaic plain. The upper channels (3 and 4) further suggest that delta migration was to the northwest in this area. Channel 3 is highly sinuous (Table 1) and cuts across a splay sandstone which in turn overlies organic claystones. These relationships suggest that the upper delta plain had overridden the lower delta plain as progradation of the lobe continued. The net effect of continuous abandonment and migration of channels to the northwest is the *en echelon* pattern of channel fillings seen in the lower part of Cross Section A (Plate 4). These relationships are represented by delta lobe A in Text-figure 7.

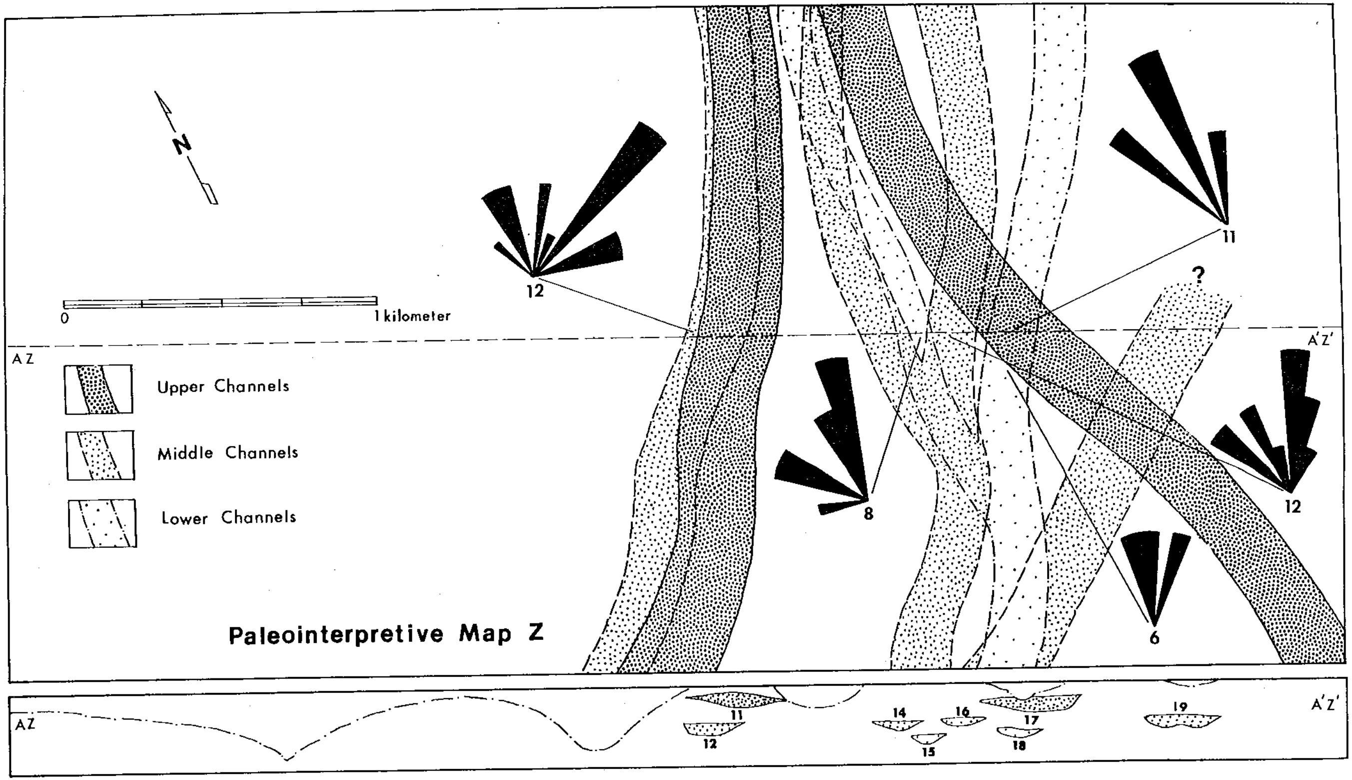
Sandstone, siltstone, and claystone between channels in this part of the formation are overbank sediments reflecting periods of flooding. In addition, flooding may have been the major cause of channel abandonment and migration. Splays in the Colton deposits are limited to association with upper deltaic plain channels where, apparently, meanders were more likely to initiate breaks in the natural levee.

Clastic deposition in the northwestern half of the delta in the study area essentially stopped for a period of time. This may have occurred because of major changes in distributary flow toward the northeast. The southeast half of the delta in the study area has many overbank sandstone and siltstone units suggesting the major course of the delta was in this area during that time. The northwestern half of the delta in the study area subsided or compacted or the lake level rose, creating a lacustrine transgression in this area.

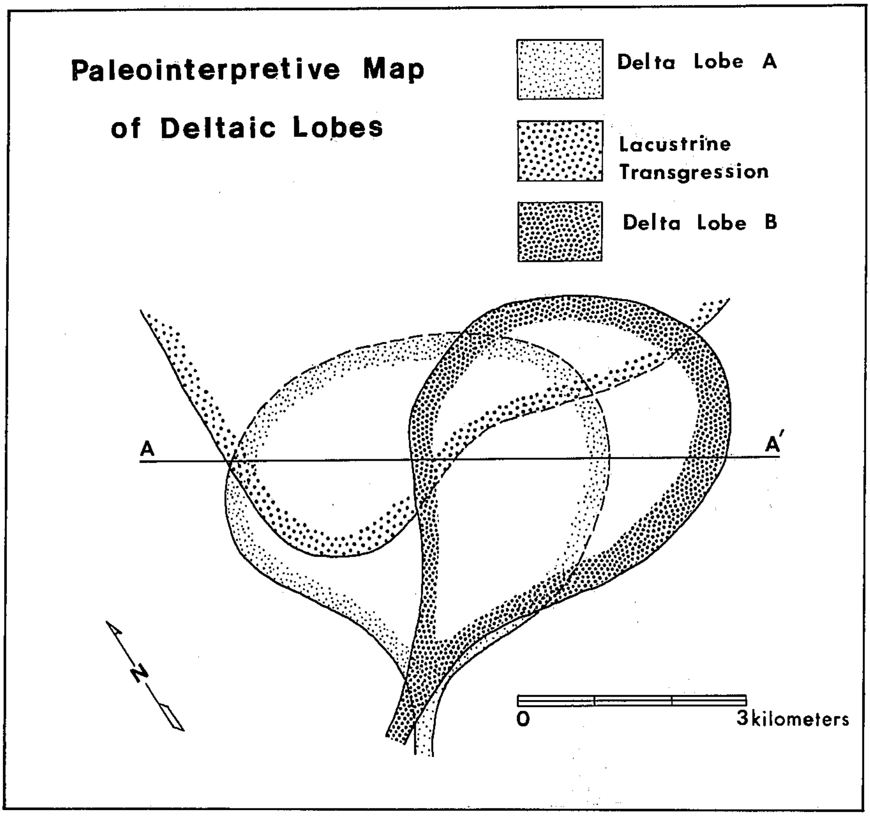
When major fluvial sedimentation resumed in the northwestern part of the study area, the delta front sandstone and siltstone seen in Cross Section A (Plate 4) was produced (Text-fig. 5). The close-spaced lower, middle, and upper channels (6, 7, 8, and 13) then advanced over the front of the delta (Text-fig. 5).

The last lobe (Text-fig. 7, Lobe B) of the deltaic advancement in the studied area shifted again to the southeast. The northwestern part of the delta was receiving overbank sandstone and siltstone which probably originated from channels in the southeast during periods of flooding.

Channels in the last lobe appear to be relatively straight or slightly sinuous (Table 1 and Text-fig. 6). Channel fill 15 may have been the first




TEXT-FIGURE 6.—Paleointerpretive map of the upper one-third of the studied section illustrating channels and measured crossbed directions.




TEXT-FIGURE 7.—Paleointerpretive map of deltaic lobes.

channel in this lobe in the study area. Channel fill 18 is closely associated with channel 15, but is slightly higher stratigraphically and may have formed as a result of abandonment of channel 15. Channels 12, 14, 16, and 19 appear to be roughly on the same stratigraphic level, although channel 14 is slightly older than channel 16. These channels may have been distributaries of each other, channel 16 eventually abandoning channel 14.

Channel 11 is slightly younger than channel 17. Channel 11 and the overbank sandstone unit associated with it are intensely burrowed by dominichnia which suggest a long period of stillstand in shallow water following abandonment.

## SOURCE OF SEDIMENT

About 100 heavy mineral grains from major sandstone bodies in the study area were identified from 7 samples. The majority of the grains identified are quartz, muscovite, and biotite. Very minor amounts of chromite, hornblende, and olivine are also present in the samples. One grain of epidote (?) is also present. Henderson (1958, p. 7) also examined heavy minerals of the Colton Formation and found they comprise less than 2 percent in the upper part of the formation. The most common heavy minerals reported by him are olivine and pyrite.

The suite of heavy minerals found in the study area suggests an igneous rather than metamorphic source for the terrigenous debris. The nearest igneous source in the Lower Eocene was probably in west central Nevada. Lohrengel (1969, p. 69) suggested west central Nevada for a source in Upper Cretaceous-Paleocene deltaic rocks of the Kaiparowits Formation in southern Utah. Colton beds may have had a similar source.

## STREAM CHARACTER

Using the cross section dimensions of a channel, estimations on the probable paleochannel gradient and meander wavelength can be made (Schumm, 1972). Channels described in the study area are well exposed in cross section, permitting moderately accurate measurement of width and depth.

Channels measured on the Great Plains of the western United States indicate that only a part of the width and a fraction of the valley-fill deposit can be related to the stream that transported the sediment (Schumm, 1972, p. 106). Therefore, in most cases the cross sectional area, width, and depth of a lens-shaped sand body is greater than that of the stream that transported the sediment (Schumm, 1972, p. 106). This relationship is probably the case in channels described in the Colton beds as well. Hence, widths and depths of paleochannels measured in the study area are of the largest channel that could have existed in each case.

Measured widths and depths are tabulated in Table 1. Using equations derived by Schumm (1972), the estimated meander wavelength and channel gradients have been calculated for the 20 channels represented in Cross Section A (Plate 4). Meander wavelength gives the observer an indication of the sinuosity of the streams flowing over the delta. It is interesting to note that channel 3 is interpreted as an upper deltaic plain channel, based upon the presence of point bars and its location high in the lower one-third of the section, and has a high sinuosity (low meander wavelength) as one might expect on the upper deltaic plain.

The average gradient of channels in the study area is calculated to have been 0.69 m/km, which is a relatively low gradient such as might be expected in a delta. For comparison, Spanish Fork River in Central Utah has a gradient of approximately 0.95 m/km over its delta into Utah Lake. The lower reaches of Provo River has a gradient of approximately 1.9 m/km as calculated from topographic maps.

## SUMMARY

The Colton Formation contains an exceptionally well-exposed fresh water deltaic sequence. Two lobes of deltaic sediments, separated by a lacustrine transgression, are present in the study area. Records of both upper and lower deltaic plains of deposition appear to be present. As progradation of the delta occurred into the lake, lower deltaic sediments formed over prodeltaic sediments and the upper deltaic plain formed over the lower deltaic plain.

An *en echelon* pattern of lenticular sandstone bodies is represented in vertical sequence in the lower one-third of the formation. Lenticular sandstone bodies are interpreted to be channel fills. Those with imbricate lenses are interpreted as point bar channel fills and those without imbricate lenses are interpreted to be relatively straight channel fills. In addition, some lenticular sandstone units are flat bottomed and convex up. These are interpreted to be splay sandstone lenses.

Sheet deposits comprise the bulk of the Colton Formation, and occur as multiple sheet sandstone and single sheet sandstone, siltstone, and claystone. Multiple sheet sandstone is interpreted to be delta front deposits. Single sheet deposits are interpreted to be overbank deposits.

Gastropods, bivalves, and plant remains are relatively rare and poorly preserved, but do occur in lacustrine deposits and channel fills. Trace fossils are the most common fossils in the Colton beds.

Sediments in the Colton Formation may have been derived from a terrain including igneous rocks far to the southwest as suggested by paleocurrent directions and heavy minerals.

## APPENDIX

### Section 1

Section 1 is a representative stratigraphic section through the well-exposed road cut east of the townsite of Colton, Utah. Because of the steepness and height of the upper one-third of this section, measurements were made from photographs and samples were taken from lateral counterparts of each bed east and west of the measured section.

| *Unit* | *Description* | *cm* | *total* |
|---|---|---|---|
| 31 | Siltstone: reddish brown, very fine grained, micaceous, slope former. | 40 | 1045 |
| 30 | Claystone: gray black, abundant organic material, rooted, slope former. | 10 | 1005 |
| 29 | Siltstone: reddish brown, very fine grained, micaceous, ledge former. | 35 | 995 |
| 28 | Siltstone: grayish red, very fine grained, fragmented, rooted, slope former. | 50 | 960 |
| 27 | Siltstone: whitish gray green, very fine grained, rooted, reduced, slope former. | 20 | 910 |
| 26 | Sandstone: gray green, weathers pale red, fine grained, micaceous, massive, ledge former. | 40 | 890 |
| 25 | Siltstone: gray green, very fine grained, micaceous, rooted, slope former. | 10 | 850 |
| 24 | Sandstone: gray green, weathers pale red, fine grained, micaceous, massive, cross-bedded on top, ledge former. | 10 | 830 |
| 23 | Siltstone: reddish brown, very fine grained, rooted, slope former. | 15 | 830 |
| 22 | Siltstone: gray green, very fine grained, intensely rooted, slope former. | 20 | 815 |
| 21 | Sandstone: pale red, fine grained, less than 10 percent clay, ledge former. | 25 | 795 |
| 20 | Siltstone: reddish brown, very fine grained, micaceous, rooted, slope former. | 30 | 770 |
| 19 | Siltstone: white and reddish brown, very fine grained, micaceous, slope former. | 40 | 740 |

| | | | |
|---|---|---|---|
| 18 | Claystone: dark gray and black, well sorted, very argillaceous, abundant organic material, minor amounts of biotite, moderately calcareous, slope former. | 5 | 700 |
| 17 | Claystone: reddish brown, very fine grained, micaceous, slope former. | 25 | 695 |
| 16 | Claystone: dark gray and black, well sorted, very argillaceous, abundant organic material, minor amounts of biotite, rooted, moderately calcareous, slope former. | 20 | 670 |
| 15 | Siltstone: reddish brown, very fine grained, moderately argillaceous, well sorted, hematite and limonite coated grains, moderate amounts of biotite and muscovite, highly calcareous. | 60 | 650 |
| 14 | Siltstone: reddish brown, very fine grained, moderately argillaceous, well sorted, hematite coated grains, moderate amounts of muscovite and biotite, highly calcareous, rooted, weathers in spheres, ledge former. | 40 | 590 |
| 13 | Siltstone: reddish brown, very fine grained, moderately argillaceous, well sorted, hematite and limonite coated grains, traces of organic material, highly calcareous, rooted, orange clay pebbles throughout. | 45 | 550 |
| 12 | Siltstone: brownish white, very fine grained, moderately argillaceous, well sorted, subrounded grains, traces of organic material, minor amounts of biotite and muscovite, highly calcareous, rooted, yellow clay pebbles throughout. | 35 | 505 |
| 11 | Siltstone: brownish red, very fine grained, moderately argillaceous, well sorted, subangular grains, traces of organic material, moderate amounts of biotite and muscovite, rooted, slope former. | 120 | 470 |
| 10 | Sandstone: pale reddish brown, fine grained moderately sorted, angular grains, abundant biotite and muscovite, traces of organic material, ledge former. | | |
| 9 | Claystone: pale red and white, very fine grained, highly argillaceous, well sorted, traces of organic material, moderate amounts of biotite and muscovite, moderately calcareous, slope former. | 30 | 290 |
| 8 | Siltstone: gray green, very fine grained, moderately argillaceous, medium sorted, subangular grains, moderate amounts of biotite and muscovite, slightly calcareous, slope former. | 20 | 260 |
| 7 | Claystone: reddish brown, well sorted, moderate amounts of biotite and muscovite, slope former. | 30 | 240 |
| 6 | Claystone: gray brown, well sorted, traces of organic material, slope former. | 35 | 210 |
| 5 | Siltstone: white and gray green, very fine grained, well sorted, subangular grains, traces of organic material, moderate amounts of biotite and muscovite, highly calcareous, fish, gastropod and bivalve fragments, ledge former. | 15 | 175 |

| | | | |
|---|---|---|---|
| 4 | Siltstone: yellowish, purplish, and gray, very fine grained, medium sorted, subangular to subrounded grains, traces of muscovite and biotite, highly calcareous, slope former. | 20 | 160 |
| 3 | Siltstone: yellowish, purplish, and gray, very fine grained, medium sorted, angular grains, highly calcareous, yellow clay pebbles throughout. | 10 | 140 |
| 2 | Claystone: yellowish, purplish, and gray, very fine grained, medium sorted, angular grains, highly calcareous. | 40 | 130 |
| 1 | Siltstone: yellowish purple, very fine grained, medium sorted, subangular to subrounded grains, traces of organic material, limonite stained grains. | 90 | 90 |

Section 2

Section 2 is a representative stratigraphic section through the southeastern end of the study area. It was measured approximately one kilometer northwest of the picnic area.

| *Unit* | *Description* | *cm* | *total* |
|---|---|---|---|
| 59 | Sandstone: reddish brown, fine grained, micaceous, ledge former, burrowed. | 200 | 8160 |
| 58 | Siltstone: grayish red, very fine grained, fragmented, slope former. | 1100 | 7960 |
| 57 | Sandstone: pale red, fine grained, micaceous, subangular grains, crossbedded near the top, ledge former. | 60 | 6860 |
| 56 | Siltstone: pale red, very fine grained, calcareous, slope former. | 90 | 6800 |
| 55 | Sandstone: grayish red, fine grained, ledge former. | 30 | 6710 |
| 54 | Sandstone: grayish red, fine grained, ledge former. | 100 | 6680 |
| 53 | Claystone: grayish red, very fine grained, micaceous, moderately calcareous, slope former. | 80 | 6580 |
| 52 | Sandstone: grayish red, fine grained, moderately calcareous, slope former. | 90 | 6500 |
| 51 | Siltstone: grayish red, very fine grained, moderately calcareous, slope former. | 140 | 6410 |
| 50 | Siltstone: pale red, very fine grained, slope former. | 70 | 6270 |
| 49 | Sandstone: grayish red, fine grained, well sorted, subangular to subround grains, ledge former. | 90 | 6200 |
| 48 | Siltstone: grayish pink, very fine grained, highly calcareous, micaceous, slope former. | 120 | 6110 |
| 47 | Sandstone: pale brown, very fine grained, slightly calcareous, well sorted highly argillaceous, ledge former. | 80 | 5990 |
| 46 | Siltstone: pale red to light red, very fine grained, argillaceous, micaceous, slope former. | 110 | 5910 |
| 45 | Siltstone: pale red, very fine grained, argillaceous, micaceous, slope former. | 90 | 5800 |
| 44 | Siltstone: yellowish gray, very fine grained, argillaceous, highly calcareous, slope former. | 70 | 5710 |

| | | | |
|---|---|---|---|
| 43 | Siltstone: light gray, very fine grained, argillaceous, highly calcareous, slope former. | 40 | 5640 |
| 42 | Siltstone: pale red, pale yellowish orange, and pale greenish yellow, very fine grained, limonite coated grains, highly calcareous, yellow clay clasts, slope former. | 90 | 5600 |
| 41 | Siltstone: grayish red, pale yellowish orange; very fine grained, hematitic, highly calcareous, slope former. | 95 | 5510 |
| 40 | Siltstone: grayish red, very fine grained, argillaceous, highly calcareous, slope former. | 35 | 5415 |
| 39 | Siltstone: light bluish gray, very fine grained, highly calcareous, slope former. | 40 | 5380 |
| 38 | Siltstone: grayish red, very fine grained, hematitic calcareous, slope former. | 90 | 5340 |
| 37 | Sandstone: grayish red, fine grained, well sorted, angular grains, micaceous, ledge former. | 70 | 5250 |
| 36 | Siltstone: grayish red, very fine grained, highly calcareous, slope former. | 55 | 5180 |
| 35 | Claystone: light bluish gray and grayish red, carbonaceous, micaceous, slope former. | 50 | 5125 |
| 34 | Claystone: grayish red, very fine grained, subrounded grains, micaceous, slope former. | 250 | 5075 |
| 33 | Siltstone: light gray, very fine grained, well sorted, grayish red, fine grained, well sorted, slope former. | 100 | 4825 |
| 32 | Siltstone: dark yellowish orange, yellowish gray, and grayish red, very fine grained, well sorted, slope former. | 350 | 4725 |
| 31 | Sandstone: grayish red, fine grained, well sorted, carbonaceous, micaceous, ledge former. | 65 | 4375 |
| 30 | Sandstone: light gray, fine grained, slightly argillaceous, well sorted, subangular grains, highly calcareous, ledge former. | 100 | 4310 |
| 29 | Sandstone: light gray, fine grained, well sorted, subangular grains, unstructured, ledge former. | 350 | 4210 |
| 28 | Siltstone: light blue gray, medium grained, moderately sorted subangular grains, foliated, clay balls. | 15 | 3860 |
| 27 | Siltstone: gray red and pale greenish yellow, very fine grained, mottled, slope former. | 30 | 3845 |
| 26 | Siltstone: gray red, very fine grained, well sorted, weathers in spheres, slope former. | 115 | 3815 |
| 25 | Siltstone: gray red, very fine grained, slope former. rooted slope former. | 500 | 3700 |
| 24 | Sandstone: pale red, fine grained, well sorted subangular grains, slightly calcareous, slope former. | 70 | 3200 |
| 23 | Siltstone: gray red and pale red, very fine grained, rooted, slope former. | 150 | 3130 |
| 22 | Sandstone: grayish red, fine grained, micaceous, highly calcareous, ledge former. | 40 | 2980 |
| 21 | Siltstone: grayish red, very fine grained, rooted, slope former. | 160 | 2940 |

| | | | |
|---|---|---|---|
| 20 | Siltstone: pale red, very fine grained, rooted, slope former. | 120 | 2780 |
| 19 | Sandstone: light bluish gray, fine grained, clean, well sorted, ledge former. | 20 | 2660 |
| 18 | Siltstone: pale red, very fine grained, slope former. | 250 | 2640 |
| 17 | Sandstone: grayish red, fine grained, interbedded with silt, micaceous, ledge former. | 200 | 2390 |
| 16 | Claystone: pale red, highly calcareous, micaceous, slope former. | 250 | 2190 |
| 15 | Siltstone: grayish red, very fine grained, micaceous, slope former. | 300 | 1940 |
| 14 | Sandstone: grayish red, fine grained, micaceous, ledge former. | 60 | 1640 |
| 13 | Claystone: pale red, rooted, calcareous, slope former. | 30 | 1580 |
| 12 | Siltstone: light bluish gray, very fine grained, calcareous, slope former. | 20 | 1550 |
| 11 | Siltstone: grayish red, very fine grained, calcareous, micaceous, slope former. | 70 | 1530 |
| 10 | Siltstone: yellowish orangish gray, very fine grained, siltstone clasts (2 cm), slope former. | 100 | 1460 |
| 9 | Siltstone: light grayish brown, very fine grained, calcareous, slope former. | 50 | 1360 |
| 8 | Siltstone: light gray, very fine grained, slope former. | 30 | 1310 |
| 7 | Siltstone: reddish brown, very fine grained, slope former. | 30 | 1280 |
| 6 | Siltstone: light gray, very fine grained, calcareous, slope former. | 140 | 1250 |
| 5 | Siltstone: grayish red, very fine grained, micaceous, calcareous, slope former. | 110 | 1110 |
| 4 | Siltstone: light bluish gray, very fine grained, micaceous, slope former. | 30 | 1000 |
| 3 | Siltstone: grayish red, fine grained, slope former. | 100 | 970 |
| 2 | Sandstone: grayish red, fine grained, slope former. ceous, discontinuous, ledge former. | 270 | 870 |
| 1 | Siltstone: grayish red, very fine grained, slope former. | 600 | 600 |

## REFERENCES

Allen, J. R. L., 1965, A review of the origin and characteristics of Recent alluvial sediments: Sedimentology, v. 5, no. 2, p. 89-191.

Brown, R. W., 1962, Paleocene flora of the Rocky Mountains and Great Plains: U. S. Geol. Survey, Prof. Paper 375, 119 p., 69 plates.

Coleman, James M., and Gagliano, Sherwood M., 1964, Cyclic sedimentation in the Mississippi River deltaic plain: U. S. Gulf Coastal Studies, Technical Report 16, part G, 13 p.

Derr, Michael E., 1974, Sedimentary structure and depositional environment of paleochannels in the Jurassic Morrison Formation near Green River, Utah: Brigham Young Univ. Geol. Studies, v. 21, part 3, p. 3-37.

Ferm, John C., 1970, Allegheny deltaic deposits, *in,* Morgan, James P. (ed.), Deltaic sedimentation modern and ancient: Soc. of Econ. Paleont. and Mineralogists, Spec. Pub. 15, p. 246-55.

Fishere, W. L., Brown, L. F., Scott, A. J., and McGowen, J. H., 1969, Delta systems in the exploration for oil and gas, a research colloquium: Bureau of Econ. Geol., The Univ. of Texas at Austin, 78 p.

Gagliano, S. M., and McIntire, W. G., 1968, Report on the Mekong River Delta, *in,* Saxena, R. S., Ferm. J. C., and Coleman, J. M. (eds.), Deltas, recent and ancient: Symposium, Louisiana State Univ., Baton Rouge, Louisiana, 151 p.

Gould, H. R., 1970, The Mississippi delta complex, *in,* Morgan, James P. (ed.), Deltaic sedimentation modern and ancient: Soc. of Econ. Paleon. and Mineralogists, Spec. Pub. 15, p. 3-30.

Hantzschel, Walter, 1962, Trace fossils and problematica: Treatise on invertebrate paleontology (w) miscellaneous, Moore (ed.): Geol. Soc. of America, Univ. of Kansas Press, p. W177-232.

Harmes, J. C., and Fahnestock, R. K., 1965, Stratification, bed forms, and flow phenomena (with examples for the Rio Grande), *in,* Middleton, G. V., (ed.), Primary sedimentary structures and their hydrodynamic interpretation: Soc. of Econ. Paleont. and Mineralogists, Spec. Pub. 12, p. 84-115.

Henderson, Gerald V., 1958, Geology of the northeast quarter of the Soldier Summit Quadrangle, Utah: Brigham Young Univ. Geol. Studies, v. 5, no. 5, 40 p., map.

LaRoque, Aurele, 1960, Molluscan faunas of the Flagstaff Formation of Central Utah: Geol. Survey of America, Memoir 78, 87 p.

Leopold, L. B., and Wolman, M. G., 1957, River channel patterns braided, meandering, and straight: U. S. Geol. Survey, Prof. Paper 282-B, 51 p.

Lohrengel, C. Frederick, 1969, Palynology of the Kaiparowits Formation, Garfield County, Utah: Brigham Young Univ. Geol. Studies, v. 16, part 3, p. 61-180.

Marcantel, E. L., and Weiss, M. P., 1968, Colton Formation (Eocene: fluviatile) and associated lacustrine beds, Gunnison Plateau, Central Utah: Ohio Jour. of Science, v. 68, no. 1, p. 40-9.

Oomkens, Eppo, 1970, Depositional sequences and sand distribution in the postglacial Rhone delta complex, *in,* Morgan, James P. (ed.), Deltaic sedimentation modern and ancient: Soc. of Econ. Paleont. and Mineralogists, Spec. Pub. 15, p. 198-212.

Prescott, Max W., 1958, Geology of the northwest quarter of the Soldier Summit Quadrangle, Utah: Brigham Young Univ. Geol. Studies, v. 5, no. 2, 44 p. map.

Schumm, S. A., 1960, The effect of sediment type on the shape and stratification of some modern fluvial deposits: American Jour. of Science 288, p. 177-84.

———, 1972, Fluvial paleochannels, *in,* Rigby, J. K., and Hamblin, W. K. (eds.), Recognition of ancient sedimentary environments: Soc. of Econ. Paleont. and Mineralogists, Spec. Pub. 16, p. 98-107.

Seilacher, A., 1964, Biogenic sedimentary structures, *in,* Imbrie, J., and Newell, N. D. (eds.), Approaches to paleoecology: John Wiley and Sons, Inc., New York, p. 269-316.

Spieker, E. M., 1946, Late Mesozoic and Early Cenozoic history of Central Utah: U. S. Geol. Survey, Prof. Paper 205-D, p. 122, 139.

Visher, G. S., 1965, Use of vertical profile in environmental reconstruction: Bull. American Assoc. of Petroleum Geologists, v. 49, no. 1, p. 41-61.