CORRELATION OF ALLUVIAL LENSES ALONG THE KANSAS RIVER BETWEEN TOPEKA AND OGDEN, KANSAS

by

CHARLES DWINNELL SEILER

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INTRODUCTION

The development and intensive study of sedimentary petrography has come forward to play an important part in geological science. The delay in recognizing the value of of laboratory study of sediments and sedimentary rocks has slowly been corrected. The realization that sediments have definite physical and chemical characteristics and are susceptible of analysis by quantitative methods has become widespread.

Close coordination between the field and laboratory work was for the purpose of substantiating the following objectives: (1) careful measurement and description of the alluvial lenses along the Kansas River, (2) a quantitative mineral analysis of the alluvial lenses, (3) interpretation of the quantitative mineral analysis to correlate the alluvial lenses along the river, and (4) the general study of alluvial material (not considering features already mentioned).

The science of sedimentary petrography has made great strides within the last few years, but only methods well established and generally familiar were used in the following material. It was perhaps inevitable some limits were encountered during the progress of the work, however, every available source was used for the purpose of the outlined objectives.

REVIEW OF LITERATURE

That tectonics have controlled the nature of sedimentation has been accepted by several investigators. Diastrophism in general has been considered the prime factor of sedimentary deposits. According to Pettijohn (1), tectonics determine the rates of erosion and sedimentation.

Moore (10) divided continents into two major tectonic elements; "(A) the stable continental platform and (B) relatively mobile belts of geosyncline and geanticline mainly peripheral to the platform". He divided the stable continental platform into two divisions, one negative and one positive. The positive areas are the so-called "shield" areas where pre-Cambrian rocks are exposed. The negative areas are the pre-Cambrian rocks where they are concealed by thin sediments of subhorizontal strata. Pettijohn (1) called the sediments epicontinental, and they include the major sediments formed in epicontinental seas. The main processes were physical, chemical and organic with the sediments over an area often highly variable. In some places a single deposit may have covered an area for miles, while in other places the material may have been extremely jumbled with silts, clays, sand and boulders all thoroughly mixed (Twenhofel, 2).

The epicontinental seas were usually about two hundred fathoms deep. At this depth the abyssal sediments are missing and only sediments in the littoral and pelagic zones are present (Grabau, 9). Because of the shallow depth, the area frequently was subjected to slight elevations and subsidences, "with resultant cyclical transgressions and regressions of the sea" (Pettijohn, 1).

> Common observations have been extended and systemized by students of the earth and its features; and it has become a fundamental tenet in geologic doctrine that not only the channel, but the valley in which it lies, is fashioned by the stream. There was a time, indeed, when pioneer geologists, misled by the magnitude of the work and the minitude of the agent, ascribed the origin of valleys to rock-fissuring produced by profound earth movement; but since the days of Lyell the competence of streams to excavate the broadest valleys and deepest canyons have been recognized (McGee, 11).

Rivers begin as small gullies which gradually become large by cutting V shaped valleys from their sources to the sea. The river is constantly wearing away its bed and reducing its gradient; this continues until base level is reached, first at the mouth and much later at the source. During the approach to base-level, aggradation, caused by reduction in stream velocity, began in the river channel at the mouth and gradually worked its way toward the source, thus as the gradient flattened out, large pebbles were gradually dropped.

Krumbein (13) stated:

> The distance transported is a function of the roundness of the pebbles, also rocks may have

> different resistances and the velocities of the waters may be different. The size and shape respond to the dynamical conditions at the immediate site of deposition, whereas, roundness is a function of the abrasion suffered by the particles over the distance traveled.

The coarse material was covered with finer alluvium and thus it becomes finer the higher it is above bedrock. With the reduction of size was included a normal sequence of fine gravel upward to fine clay. This process may have been repeated in the flood plain (Raeburn and Milner, 8).

River terraces are low level steps along the valley wall and have the approximate gradient of the river forming them and "it is the presence of a gradient that distinguishes these fluviatile features from lake terraces or elevated sea beaches" (Raeburn and Milner, 8).

Hoover (12) considered the terraces along the Kansas River of fluviatile origin and with the aid of histograms concluded that the material was from well sorted upland deposits, also that the surface levels of the terraces showed a profile similar to that of the Kansas River. Stratification is lacking in the deposits according to Hoover (12) due to weathering.

The classification of both Raeburn and Milner (8) and Twenhofel (2) for the Kansas River valley would probably be considered a "valley flat". By definition, "the alluvial deposits here described as valley flats must have bedrock below the level of the stream responsible for their formation:

this implies that the stream rests on alluvium" (Raeburn and Milner, 8).

The valley flat environment may be divided into the flood plain and channel. The stream channel consists of deeps and shallows where different sedimentary processes are acting at different times. "Flood plain deposits depend upon the sediments supplied and the local climatic conditions. The sediments supplied depend upon terrain, topography, climatic conditions of the places of origin and transportation" (Twenhofel, 2). The flood plain sediments ranged from clay to sand with occasional gravel while the channel sediments depended upon physical deposition and ranged from gravel to clay.

Raeburn and Milner (8) quoted from Webster's dictionary of 1923 for their definitions of alluvium and alluvial: "alluvium - a deposit of earth, sand or other material made by the ordinary mechanical action of running water", and "alluvial - pertaining to or contained in or composed of alluvium; relating to the deposits made by flowing water, washed away from one place and deposited in another".

Harned (14) considered the Kansas River alluvium had a high degree of mixing with sediments of glacial origin and the A horizon of the soil was directly above the stratified alluvium. According to Harned's research (14), the alluvium contained all the minerals present in upland and terrace mantle with an admixture of rounded and angular grains caused by deposition of both glacial and stream worked material. "The Smoky Hill and Republican alluvium shows a considerable smaller grade size than does the Kaw alluvium, indicating that the Kaw River has not been entirely dependent upon these streams for its source of sediment"(Harned, 14).

Rittenhouse (15) gave four reasons for the size distribution of heavy minerals in fluvial deposits as, "(A) its relative availability in each size gradient in stream load, (B) its equivalent hydraulic size, (C) the hydraulic conditions at the time and place of deposition and (D) some factor or factors now unknown."

Glacial material along the Kansas River and some of its tributaries was considered to have been deposited continuously from the Kansas glacial age to Recent. Frye and Swineford (19) of Kansas thought "the prominent high deeply dissected terrace along the Kansas River Valley to be composed of Kansas glacial outwash classifiable as Meade formation." In Nebraska, the units called Grand Island formation and Sappa formation corresponded to the Meade formation in Kansas. The Iowa Survey correlated the Sappa, Pearlette ash, Crete sand, and Loveland formation as the Yarmouth age. Some difference in age of the Pearlette ash was noted, however, its general time relationship was established as either the base of the Loveland formation or the upper part of the Meade formation; but according to the Nebraska Survey (Condra et al., 20), the Crete-Loveland cycle of erosion and valley filling started after the ash was deposited. "The gumbotil, peat and soils on the Nebraskan and Kansan tills, and the soils on the Aftonian-Fullerton, Kansan-Sappa, Loveland, and Peoria formation are good horizon markers where they occur; i.e., were not removed by erosion, and the Pearlette volcanic ash seems to be the best time marker in the Pleistocene of Nebraska" (Condra, 20).

Later Pleistocene material was restricted to the principal valley such as the Big Blue, with the Solomon, Saline and Smoky Hill carrying no late Pleistocene outwash. One tributary (Republican River) of the Kansas River was affected (Swineford, 21), and "a few intermediate terrace remnants along middle reaches of the Kansas River Valley may be Crete" (Frye et al., 19).

Stratification of sediments may have ranged from thin to extremely thick, however, thickness is not always a measure of the rate of deposition. A thin layer of sediment in one place may correspond to a thick layer of sediment at another place. Sedimentation is rarely continuous and uniform, but varies with environments of deposition, seasonal control, character of composing sediments, and numerous other factors. Large and coarse grained sediments make for greater variations in thickness and limited distribution, while fine grained sediments are considered to have had a larger areal extent with a more uniform thickness (Pettijohn, 1; Twenhofel, 2).

"The basic principles underlying the techniques of differentiating or correlating strata by means of their stable mineral components are essentially those fundamental to the science of geology" (Milner, 6). According to Milner, these principles were incorporated in the idea of the geographical cycle and geological interpretation. The geographic cycle presents the concept of "terrestrial uplift of a base-levelled or peneplaned region; consequent reanimation of the forces of denudation: their slow operation in wearing down this newly formed land surface; and the persistence of these forces until a new base level is once more attained" (Milner, 6).

Now if the parent rock was characteristic in mineral composition throughout the cycle of erosion, then it follows that a sediment will be equally characteristic in composition and the sediments formed by change of stable accessory minerals furnish a criterion for the subdivision of the material (Milner, 6). Therefore it follows that to have any value in correlation the heavy minerals of sediments need to have a restricted range in space and time.

If samples are collected in a vertical sequence, they are related to time and may have correlation value. "If the variations are observed in synchronous samples they are related to place, and may be called spatial variations. The change (decrease or increase) in percentages of a given mineral from place to place may be termed a mineral gradient" (Krumbein and Pettijohn, 5).

The three causes of mineral changes along a river considered by Krumbein and Pettijohn (5) are (A) contamination, (B) selective abrasion, (C) selective transportation. Contamination is caused by increase or decrease in percentage of certain minerals from the addition of new material at the junction of two streams, from areas with different petrographic character. The percentages of some minerals may be depressed while other minerals common to both sediments will be augmented.

Flood plain contamination in any stream depends on two factors: "(A) the amount of sediment added by bank cutting or channel scour in comparison with the amount of sediment in transit and (B) the amount and kinds of heavy minerals in the eroded and transit sands" (Rittenhouse, 16).

The mineral composition of a stream depends upon the amount, size, and kind of minerals in the source rocks; the manner in which the source rocks disintegrated during transportation; or the absolute and relative rates of transportation of different minerals and different sizes of minerals; and on the hydraulic condition that occurs at the place and time of deposition (Rittenhouse, 15). "In any case the interaction of all the factors involved results in the maintenance of a nearly uniform mineral composition excepting for local differences resulting from variations in grain size and degree of sorting" (Russell, 17).

According to Twenhofel (2) and Grout (3) there were five classes of sediments: terrigenous, organic, volcanic, cosmic or metoric, and magmatic. Of the several listed, probably only two include the scope of the material necessary for review, the clastic materials which were ejected by volcanoes, and the terrigenous sediments which resulted from decomposition of the rocks on the earth's surface.

"The clastic materials ejected by volcanoes are considered sediments when deposited from the atmosphere, if they have cooled sufficiently so as not to cohere" (Pettijohn, 1). The larger material is called lappilli, cinders and bombs, however, the larger particles soon settled. The ash or glass which forms curious curved spicule-like forms termed shards (Pettijohn, 1), was blown into the upper atmosphere and carried great distances from the original source (Grout, 3). Large ash beds are found in the states of Kansas and Nebraska far removed from volcanoes (Twenhofel, 2). Ash falling in marine water may be altered to bentonite.

"Terrigenous sediments result from the destruction of rocks on the surface and in the outer parts of the earth's crust" (Twenhofel, 2). The rocks affected by the destructive forces are igneous, sedimentary, and metamorphic rocks. Sediments vary with the material destroyed, and the manner of destruction, "the environmental conditions of the places of production, and the distances and duration of transportation" (Twenhofel, 2).

"When heavy minerals are liberated by weathering of their parent rock, resistant species show relative concentrations and less resistant species decrease in relative abundance or disappear completely. The change in relative abundance of various minerals from fresh rock to the weathered products is a measure of their comparative resistance to weathering" (Dryden and Dryden, 18).

The minerals of sediments may be divided into two groups. The first group originate from a foreign source and have been transported to the site of deposition. The origin of this group may be from either sedimentary, igneous, or metamorphic rocks and the minerals are called detrital or allogenic. The second group of minerals are generated at the place found and are called authigenic (Pettijohn, 1; Twenhofel, 2; Twenhofel and Tyler, 4; and Krumbein and Pettijohn, 5).

The allogenic minerals may sometimes be traced to their origin. They aid in the study of the environmental conditions which released them from their parent rock. Allogenic minerals are also a great aid for the purposes of correlation, and the study of ancient geography, climate, and zoning of sedimentary sequences (Twenhofel, 2).

Russell (17) pointed out the "persistent" detrital minerals in rivers appeared to be those that are more resistant to chemical processes than to mechanical action.

"The authigenic minerals may give some evidence of the conditions of deposition of the sediments of which they form a part and certainly of the environmental conditions that led to the development of these minerals. Unfortunately knowledge of the developmental conditions of authigenic minerals leaves much to be desired" (2).

Twenhofel (2) and Pettijohn (1) have slightly different classifications of minerals; however, they agree on the stable or primary minerals and the precipitated or authigenic minerals.

Some of the most common primary minerals are andalusite, apatite, augite, chlorite, diopside, epidote, garnet, hornblende, hypersthene, enstatite, ilmenite, kyanite, leucoxene, magnetite, muscovite, rutile, sphene, staurolite, tourmaline, zircon, zoisite, feldspars, and quartz (Pettijohn, 1; Twenhofel, 2).

The most abundant mineral of arenaceous sediments is quartz, followed by feldspars (Grout, 3; Pettijohn, 1; and

Twenhofel, 2). Pettijohn (1) considers muscovite, biotite, hornblende, augite, and hypersthene as some of the most common of the heavy minerals, but he also considers zircon, rutile, tourmaline, and apatite as the most stable minerals with garnet, staurolite and kyanite as relatively unstable. Grout (3) also considered some of the commonest residuals to be zircon, tourmaline, magnetite, and apatite.

A total of 1,500 different minerals is known to science. It is surprising in some respects how many species fail to survive weathering and transportation. A study of the records of alluvial minerals all over the world shows the restrictions of mineral species in sediments caused by destructive chemical and mechanical forces (Milner, 6).

> Most heavy-mineral investigations have one or more of the following objectives: (A) to describe the mineral composition of a particular deposit; (B) to establish the similarity or dissimilarity of samples, generally for the purpose of geologic correlation; (C) to determine the change in mineral composition within a series of related samples so that factors related to the occurrence of heavy minerals may be discovered and evaluated; (D) to locate the sources or to evaluate the relative importance of various sources of a deposit; (E) to provide data from which the past history of a deposit may be interpreted; and (F) to find and aid in the exploitation of economically useful minerals (15).

"Outline for Identification of Minerals" (Rogers and Kerr, 7).

- Description of mineral to be identified
- Associated minerals
    - Color (if opaque)
    - Transparent
        - Properties if transparent
            - Color
            - Pleochroism
            - Shape or form
            - Cleavage
            - Indices of refraction
            - Isotropic or anisotropic
            - If anisotropic:
                - Birefringence or double refraction
                - Twinning (if present)
                - Elongation (if any)
            - Optical classification
                - Uniaxial
                    - Positive or negative
                    - 2V (or 2E)
                    - Dispersion
                - Optical orientation
- Conclusion.

Practically every author agreed approximately on the outline of procedure which has to be used for the processing of common sediments for study. Briefly the steps recommended were the following: (A) quarter the sample, (B) weigh out portion, (C) treat with weak acid, (D) wash (decant), (E) screen material, (F) separate with bromoform, (G) identify the minerals in oils or permanent mounts made in air or balsam, (H) diagram results (Milner, 6; Twenhofel and Tyler, 4; Twenhofel, 2; Krumbein and Pettijohn, 5; Grout, 3; and Pettijohn, 1).

FIELD AND LABORATORY METHODS

Field Methods

Work in the field covered an area of approximately 50 miles along the Kansas River. Sites were about 10 miles apart with the exception of the Wamego cut and the cut 3½ miles east of Wamego.

Equipment. The equipment used in the field consisted of a shovel, a sharp shooter, small hand trowels, a measuring tape, sample bags, and a field notebook. A rope was used at times to assist in climbing up and down steep banks along the river.

Sites. Six sites were selected for the final investigation. Each site was chosen because of its location, accessibility, stratigraphic appearance, and vertical depth before excavation was necessary to obtain a true picture of the lenses in the alluvium.

(1) Location. The first two sites were: (A) A cross section about a mile east of the Valencia, Kansas, bridge on the north side of the river, and (B) A cross section approximately 5 miles west of Manhattan, Kansas, on the north side of the river.

After the two sections had been thoroughly analyzed, it was decided to make the two sites the boundaries and attempt to select sites within the boundaries which might solve the problems of the mineralogical analysis and correlation of the lenses in the alluvial materials within the area.

(2) Accessibility. The accessibility of the sites was a major issue. Because of the large amount of rain during the period of sample collection, dense under growth and swampy areas were encountered along the river.

Several pieces of equipment were needed at each site and the samples collected from the site increased the weight; therefore the cross sections were picked as close to a road as possible.

All the sites but one were located near bridges.

(3) Stratigraphic Appearance. After the location and accessibility reconnaissance for an area had been made, a suitable stratigraphic section along the river had to be considered. Usually the surface appearance along the sides of the banks determined the place for the cross section. If the area appeared to be undisturbed by man, it was chosen as a place to study.

(4) Vertical Depth. Vertical depth also was another factor taken into account. The greater the vertical depth, the smaller the amount of excavation before water level was reached. For preliminary inspection for location of sites, a fairly vertical bank was necessary. All cross sections were chosen at cut banks in order to obtain as long sections as possible.

Measurements. Each cross section was measured from the ground surface down to the water level, and the measurements were made in tenths of feet. Lenses varied from 7 feet to 1/10 of a foot in size; however, the greatest number of lenses varied from 2 feet down to 6/10 of a foot. Size and number of the lenses depended upon the section measured. Some cross sections had large lenses with few small lenses, while several cross sections had numerous small lenses.

Samples. Each sample was carefully labeled and marked according to location and lens, also the mark was duplicated on each sample at least twice and on some samples four times. Such precautions were used to prevent loss of identification and mistaken identification.

All samples taken were channel samples except samples of two lenses in the Valencia cross section. These lenses were spot sampled to see if there was a great difference of mineral distribution in a thick lens. All the lenses of the remaining cross sections were treated as units and samples of each lens was taken by the channel method.

Limits. There was one limiting factor, however, the water level. Samples could not be taken below the level of the water because equipment for such work was not available.

Laboratory Methods

In general, the methods used in the laboratory were processes which have long been used for the treatment of similar material.

The following steps were used for each sample:

Raw sample dried
Quartered and weighed
Dispersed by mechanical shaking
Sample settled and clay siphoned off
Sample wet sieved
Gently boiled in HCl for five minutes
Sample washed free of acid
Dried in oven
Dry sieved
Bromoform separation for light and heavy minerals
Minerals dried on filter paper
Permanent slides prepared
Mineralogical analysis of slides

Raw Sample Dried. Each sample was dried seven to nine hours in a drying oven to make sure that no moisture remained in the material. Although accurate weight and volume were not taken into account, it was thought desirable to keep the amount of all the samples rather constant. Since moisture content for some of the samples could have been quite high, all samples were given the same treatment to keep the moisture level constant.

Quartered and Weighed. Each sample, after being dried, was thoroughly stirred into a homogeneous mixture. The sample was then carefully quartered and requartered until the approximate amount of material required for separation remained. From quartered material, a hundred grams was weighed out for the next step. If the sample appeared to be unusually high in clay or had a large amount of large sand, the amount used was two hundred grams.

Dispersed by Mechanical Shaking. The sample was placed in a sixteen ounce bottle, forty cubic centimeters of a liquid solution of sodium silicate (10 grams of sodium silicate to 400 cubic centimeters of distilled water) were added, and the bottle filled with water. The samples were then shaken for an hour and a half in a mechanical shaker. Since the material used was unconsolidated, a greater amount of time was not necessary to produce complete dispersion.

Sample Settled and Clay Siphoned Off. This step was not used except in cases where it was necessary to save the clay. After dispersion, the sixteen ounce bottles were taken from the mechanical shaker and the sample allowed to settle for twenty minutes. The clay was then siphoned off into a large flat pan for drying. The pan was put into the drying oven, and, when it was dried, the clay was ground and sieved to pass a two hundred and thirty mesh screen. The material which passed through the screen was saved for use in the Differential Thermal Analysis machine and the charts were analyzed later.

Sample Wet Sieved. The samples, after settling, were wet sieved to retain the size material necessary for petrographic examination. The sieves used were the one hundred and twenty mesh sieve and the two hundred and thirty mesh sieve. All the material caught on the two hundred and thirty mesh sieve was saved for final examination. If the original sample was extremely coarse or fine, a larger raw sample was used in order to have a suitable amount captured on the two hundred and thirty mesh sieve. The sample retained on the two hundred and thirty mesh sieve had to be large enough to satisfy the needs for the light and heavy mineral separation in bromoform.

Gently Boiled in HCl for Five Minutes. The material, after wet sieving, was then gently boiled in HCl for a period of five minutes to remove all calcium carbonate and any coatings of iron oxide. The solution used contained about ten drops of commercially pure HCl added to about thirty cubic centimeters of water.

Sample Washed Free of Acid. After the material had been boiled in acid, it was necessary to eliminate all the acid by washing. The samples were allowed to settle, the water was decanted, and this process was continued with the material being stirred each time. Usually three rinses were sufficient for small samples while seven or eight were necessary for the larger samples. The amount of calcium carbonate in the sample affected the results and caused the procedure to vary slightly.

Dried in Oven. Drying the sample was important because, in the bromoform separation for light and heavy minerals, it was separated or split according to the specific gravity of the minerals present in the sample. Care was taken during this drying period to be absolutely positive the specimen was dry. Actually, the time in the drying oven depended upon the size of the sample. Six hours or less was required to insure that samples were free from moisture. The drying of the sample often caused some lumping, and because of this, a dry sieving step became necessary immediately following the drying.

Dry Sieved. The sample was crushed with a spatula and sieved once again on a dry sieve. All material disintegrated by the acid passed through the two hundred and thirty mesh sieve and only the remainder was saved for the bromoform process.

Bromoform Separation for Light and Heavy Minerals. Bromoform had a specific gravity of approximately 2.89. All minerals with a specific gravity less than the bromoform float and these include quartz, chalcedony, orthoclase, microcline, plagioclase, and volcanic ash. The heavy minerals had specific gravities higher than the bromoform and therefore sink. Some of the more important minerals in this group were magnetite, ilmenite, zircon, topaz, hornblende, epidote, muscovite, biotite, garnet, augite, kyanite, titanite, tourmaline, rutile sillimanite, enstatite, and lamprobolite.

The procedure and apparatus used for separation were as follows: three funnels, rubber tubing, pinch-cock, filter paper, bromoform and alcohol. The bromoform was poured in a funnel with a short hose and pinch-cock at the bottom. The sample was placed in the bromoform and the natural separation due to the difference in specific gravity of the minerals took place. If the samples were large, the liquid was stirred several times. The liquid was allowed to come to rest and the heavy minerals which had settled to the bottom were drawn off onto a filter paper. The light minerals floated and were washed off onto another filter paper. The pure bromoform was saved for reuse and the separated samples were washed free of bromoform with alcohol. The alcohol and bromoform were also saved as they may be separated with water and the bromoform used again.

Minerals Dried on Filter Paper. The specimens, after separation and washing with alcohol were then placed in the oven for drying. The drying step was to prepare the material for making permanent slides of the samples. Any moisture on the minerals may cause incomplete coating on the surfaces of the minerals by the Canada balsam.

Permanent Slides Prepared. After the samples had been dried they were ready for the next step, the making of Canada balsam slides for petrographic study of the samples. The glass slides were placed on a heater, and the balsam was cooked on the slides until deemed ready for the sample. The sample was taken from the filter paper with a nonmagnetic spatula and dusted on the cooked balsam. The minerals were stirred into the balsam to prevent air bubbles from forming around the minerals. A cover slide was carefully placed over the area containing the minerals.

Each slide was labeled according to the location and the lens of the stratigraphic cross section. The labeled slides could now be stored and reexamined at any future date.

Mineralogical Analysis of Slides. A quantitative count of the particles on the slides was made to determine the percentage of minerals in each slide. To the rotating stage of the petrographic microscope was attached a mechanical stage, which by means of two thumb screws permitted movements of a slide in two directions at right angles to one another. The mechanical stage made possible a reliable count of the minerals present without fear of counting some minerals twice, or of skipping the less noticeable minerals.

GENERAL DESCRIPTIONS OF CROSS SECTIONS AND MISCELLANEOUS MATERIAL

A general description of each cross section has been given which includes: a table of the quantitative mineral analysis, a detailed section to scale, a section to scale showing the dominate minerals in each lens of the cross section, a diagrammatic cross section of the Kansas River flood plain at each cross section, and a general discussion of each cross section pointing out the important minerals of each lens in the cross section.

The same general form was followed with the material collected from terraces along the Kansas River, and with material that was collected from the Saline River, Solomon River and Salt Creek.

A map of the area locating all the collecting sites has been included.

During the study, the minerals were combined to help correlate lenses in the cross sections. All minerals were joined into the following ten groups: (1) quartz, (2) chalcedony, (3) feldspars, (4) volcanic ash, (5) opaquea, (6) amphiboles and pyroxenes, (7) muscovite and biotite, (8) epidote, (9) garnet, and (10) a remaining mineral group which included all the minerals not mentioned in the nine previous groups.

EXPLANATION OF PLATE I

Map locating sample sites

(1) Valencia cross section,
SE$\frac{1}{4}$ SW$\frac{1}{4}$ sec. 16, T. 11 S., R. 14 E.

(2) St. Mary's cross section,
NW$\frac{1}{4}$ SW$\frac{1}{4}$ sec. 28, T. 10 S., R. 12 E.

(3) Cross section east of Wamego,
SW$\frac{1}{4}$ SE$\frac{1}{4}$ sec. 1, T. 10 S., R. 10 E.

(4) Wamego cross section,
SW$\frac{1}{4}$ NW$\frac{1}{4}$ sec. 10, T. 10 S., R. 10 E.

(5) St. George cross section,
SE$\frac{1}{4}$ SW$\frac{1}{4}$ sec. 8, T. 10 S., R. 9 E.

(6) Skyline cross section,
NE$\frac{1}{4}$ SE$\frac{1}{4}$ sec. 7, T. 11 S., R. 6 E.

(7) First terrace south of Wamego,
NE$\frac{1}{4}$ NW$\frac{1}{4}$ sec. 28, T. 10 S., R. 10 E.

(8) Top terrace south of Wamego,
SE$\frac{1}{4}$ SW$\frac{1}{4}$ sec. 28, T. 10 S., R. 10 E.

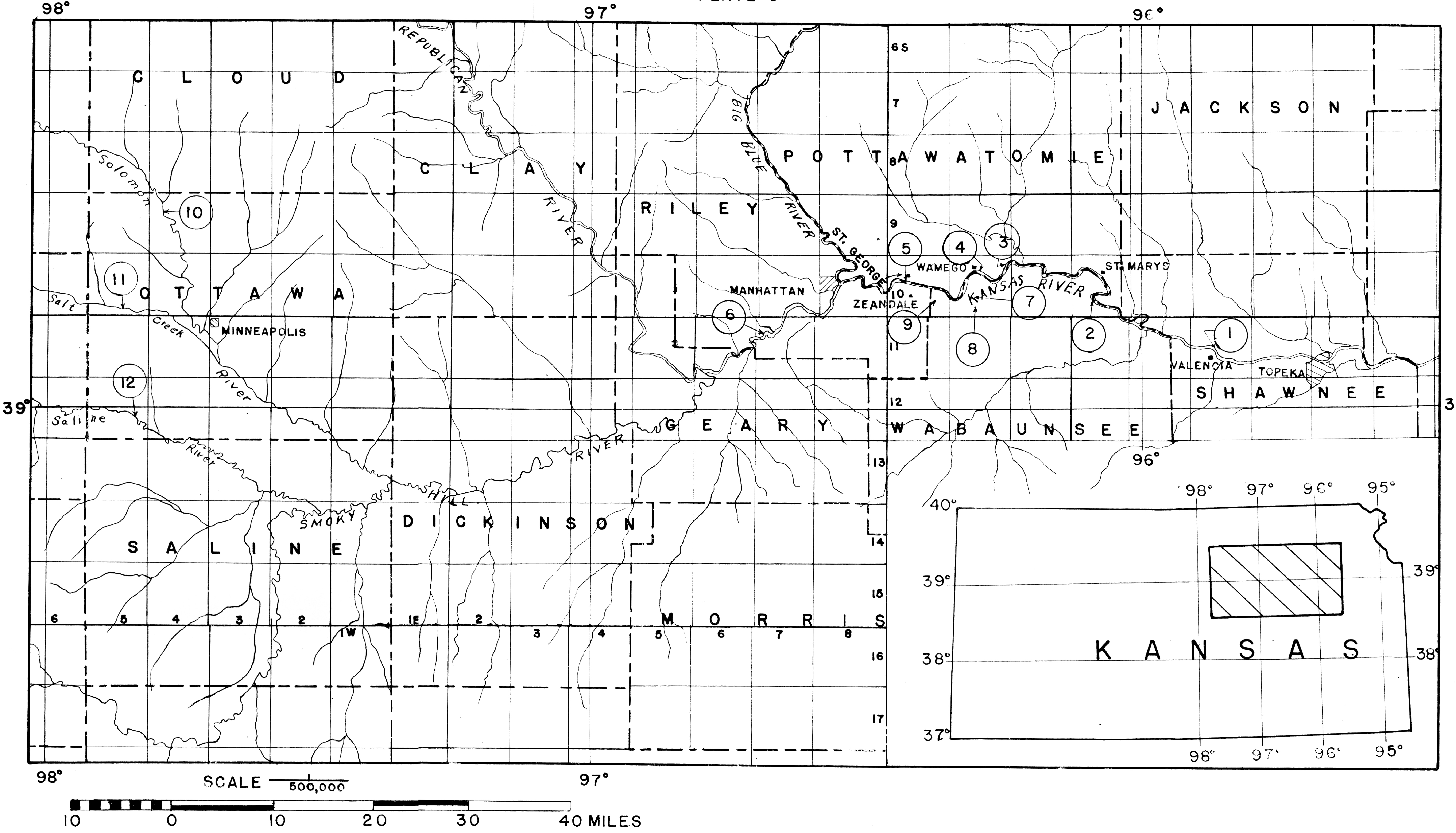
(9) Terrace east of Zeandale,
SE$\frac{1}{4}$ NE$\frac{1}{4}$ sec. 26, T. 10 S., R. 9 E.

(10) Solomon River sample site,
NE$\frac{1}{4}$ SW$\frac{1}{4}$ sec. 8, T. 9 S., R. 4 W.

(11) Salt Creek sample site,
SE$\frac{1}{4}$ NW$\frac{1}{4}$ sec. 34, T. 10 S., R. 5 W.

(12) Saline River sample site,
SE$\frac{1}{4}$ SE$\frac{1}{4}$ sec. 23, T. 12 S., R. 5 W.

PLATE I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CLOUD
CLAY
JACKSON
POTTAWATOMIE
RILEY
OTTAWA
GEARY
WABAUNSEE
SHAWNEE
DICKINSON
SALINE
MORRIS
REPUBLICAN RIVER
BIG BLUE RIVER
KANSAS RIVER
SMOKY HILL RIVER
Solomon
Salt Creek
River
Saline River
MANHATTAN
ST. GEORGE
WAMEGO
ZEANDALE
ST. MARYS
VALENCIA
TOPEKA
MINNEAPOLIS
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38°
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96°
95°
KANSAS
SCALE 1/500,000
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10
20
30
40 MILES

Valencia Cross Section

The Valencia cross section was located approximately a mile east of the Valencia bridge on the north side of the river. Examination of the cross section was made during the latter part of May, 1950, and the depth of the cross section was 14 feet.

Upper lenses of the section contained coarse to fine grain size sand particles. An unusually light color was due to the large amount of quartz which the mineral count later disclosed. Quartz (57 to 67 per cent) was the dominant mineral in the light fraction of the upper lenses (A), (B), (C), (D), and (E), chalcedony varied from 13 to 18 per cent, the feldspars varied from 18 to 30 per cent, and volcanic ash varied from 0 to 2 per cent. The heavy minerals showed the opaques 13 to 21 per cent; amphiboles and pyroxenes 48 to 55 per cent; muscovite and biotite 3 to 11 per cent; epidote 12 to 25 per cent; garnet 1 to 4 per cent; and the remaining minerals, 0 to 6 per cent.

The first silt layer, lens (F) was 0.20 ft. thick and 4.5 ft. below the surface. In this lens the light minerals consisted of 13 per cent quartz, 36 per cent chalcedony, 8 per cent feldspars, and 43 per cent volcanic ash. Muscovite and biotite were the only heavy minerals detected in this lens.

Just below the silt lens (F) was a 1.4 ft. coarse sand lens (G). Light minerals in this lens were 71 per cent quartz, 22 per cent chalcedony, 5 per cent feldspars, and 2 per cent volcanic ash. This lens had heavy minerals as follows: 34 per cent opaques, 39 per cent amphiboles and pyroxenes, 2 per cent muscovite and biotite, 15 per cent epidote, 5 per cent garnet, and 5 per cent remaining minerals.

One foot was the total thickness of lenses (H), (I), and (J). Lens (H) showed a slight diminishing of volcanic ash compared to lenses (I) and (J). Lens (H) had 10 per cent quartz, 75 per cent chalcedony, 5 per cent feldspars, and 10 per cent volcanic ash. Lenses (I) and (J) had 3 to 7 per cent quartz, 47 to 70 per cent chalcedony, 0 to 7 per cent feldspars, and 29 to 40 per cent volcanic ash. Muscovite and biotite exceeded 90 per cent in each of the lenses (H), (I), and (J) in the heavy fraction.

Coarse sand was the texture of lens (K) which was only 0.20 ft. thick and had approximately the mineral composition of the upper lenses (A), (B), (C), (D), and (E). The light minerals in lens (K) were 46 per cent quartz, 22 per cent chalcedony, 30 per cent feldspars, and 2 per cent volcanic ash. In the heavy mineral fraction were 14 per cent opaques, 58 per cent amphiboles and pyroxenes, 14 per cent muscovite and biotite, 8 per cent epidote, 1 per cent garnet, and 5 per cent remaining minerals.

Silty material, 0.20 ft. thick, was characteristic of lens (L) which had a muddy appearance. Chalcedony, 76 per cent, was the predominant light mineral. The other light minerals were 13 per cent quartz, 5 per cent feldspars, and 6 per cent volcanic ash. In this lens the heavy minerals were 6 per cent opaques, 20 per cent amphiboles and pyroxenes, 65 per cent muscovite and biotite, 6 per cent epidote, 1 per cent garnet, and 2 per cent remaining minerals.

Lens (M) was coarse sand and its total thickness was 0.60 ft. Quartz, 68 per cent, and chalcedony, 20 per cent, were the predominant minerals in the light fraction with 10 per cent feldspars and 2 per cent volcanic ash present to complete the slide. One-half of the heavy minerals were amphiboles and pyroxenes plus 23 per cent opaques, 1 per cent muscovite and biotite, 12 per cent epidote, 6 per cent garnet, and 6 per cent remaining minerals in the slide.

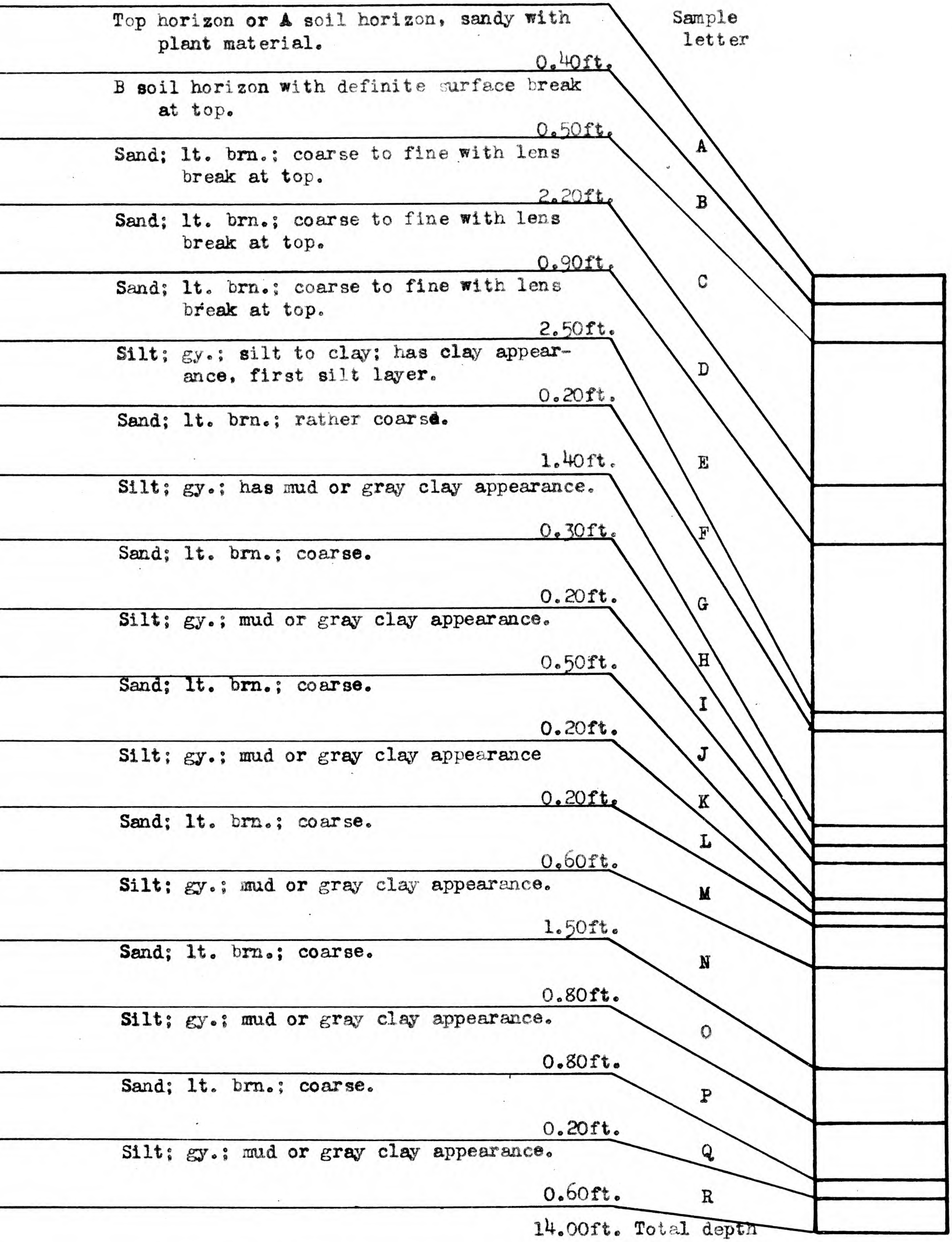
Silt appeared in lens (N) which was 1.5 ft. thick. This lens was high in chalcedony, 80 per cent, the other minerals were quartz 11 per cent, feldspars 9 per cent, and volcanic ash 1 per cent. Lens (N) had 25 per cent opaques, 36 per cent amphiboles and pyroxenes, 17 per cent muscovite and biotite, 12 per cent epidote, 4 per cent garnet, and 6 per cent of the remaining minerals in the heavy mineral slide.

Lenses (O) and (P) were practically identical in mineral counts. Lens (O) was 0.80 ft. thick and lens (P) was 0.20 ft. thick. Over two-thirds of the light fraction was quartz and the remainder of the minerals was 19 to 30 per cent chalcedony, 9 to 18 per cent feldspars, and 0 to 4 per cent volcanic ash.

In this lens the heavy minerals consisted of 42 to 45 per cent opaques, 31 per cent amphiboles and pyroxenes, 9 to 11 per cent epidote, 2 to 5 per cent garnet, and 10 per cent of the remaining minerals.

The total thickness of lens (Q) was 0.80 ft. In the light mineral fraction were 67 per cent quartz, 20 per cent chalcedony, 12 per cent feldspars, and 1 per cent volcanic ash. Amphiboles and pyroxenes were over 30 per cent in the heavy mineral fraction with the other minerals as follows: 46 per cent opaques, 1 per cent muscovite and biotite, 7 per cent epidote, 5 per cent garnet, and 11 per cent remaining minerals.

Lens (R) was 0.60 ft. thick. Quartz and chalcedony made up 82 per cent of the light mineral fraction with 13 per cent feldspars and 5 per cent volcanic ash finishing out the slide. The heavy mineral fraction had 24 per cent opaques, 37 per cent amphiboles and pyroxenes, 11 per cent muscovite and biotite, 13 per cent epidote, 2 per cent garnet, and 13 per cent of the remaining minerals.



Top horizon or A soil horizon, sandy with plant material.
0.40ft.

B soil horizon with definite surface break at top.
0.50ft.

Sand; lt. brn.; coarse to fine with lens break at top.
2.20ft.

Sand; lt. brn.; coarse to fine with lens break at top.
0.90ft.

Sand; lt. brn.; coarse to fine with lens break at top.
2.50ft.

Silt; gy.; silt to clay; has clay appearance, first silt layer.
0.20ft.

Sand; lt. brn.; rather coarse.
1.40ft.

Silt; gy.; has mud or gray clay appearance.
0.30ft.

Sand; lt. brn.; coarse.
0.20ft.

Silt; gy.; mud or gray clay appearance.
0.50ft.

Sand; lt. brn.; coarse.
0.20ft.

Silt; gy.; mud or gray clay appearance
0.20ft.

Sand; lt. brn.; coarse.
0.60ft.

Silt; gy.; mud or gray clay appearance.
1.50ft.

Sand; lt. brn.; coarse.
0.80ft.

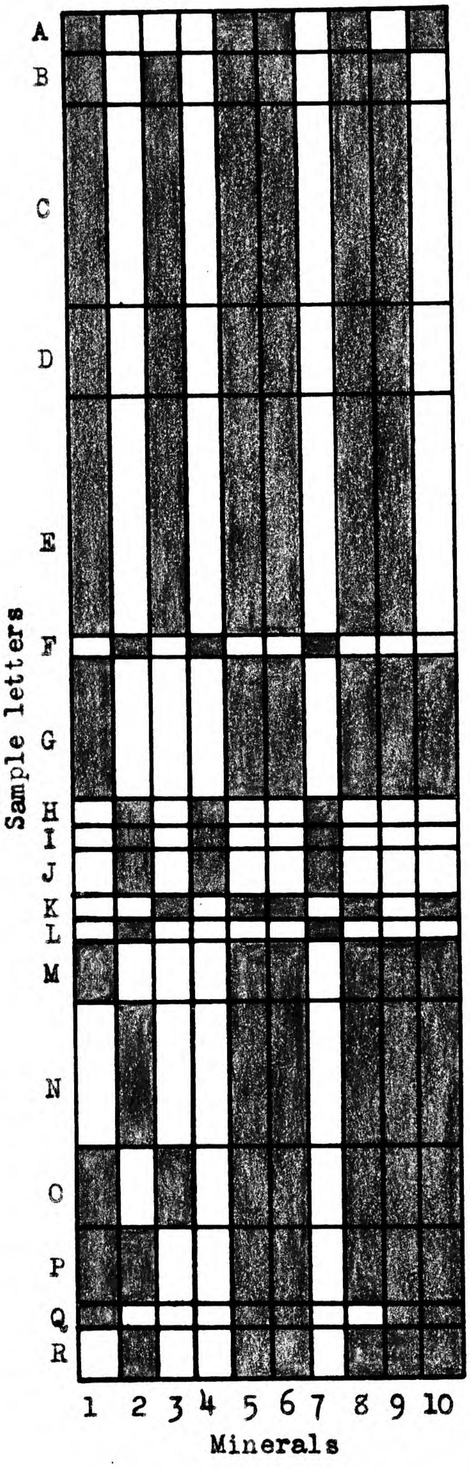
Silt; gy.; mud or gray clay appearance.
0.80ft.

Sand; lt. brn.; coarse.
0.20ft.

Silt; gy.; mud or gray clay appearance.
0.60ft.

14.00ft. Total depth

Fig. 1. Valencia cross section, detailed section, scale 1 in. equals 2 ft.



Key:

1. Quartz	50% or over
2. Chalcedony	25% or over
3. Feldspars	17% or over
4. Volcanic ash	10% or over
5. Opaques	10% or over
6. Amphiboles & Pyroxenes	30% or over
7. Muscovite & Biotite	50% or over
8. Epidote	8% or over
9. Garnet	2% or over
10. Remaining minerals	5% or over

Fig. 2. Valencia cross section, dominant minerals in each lens are shown on cross section, scale 1 in. equals 2 ft.

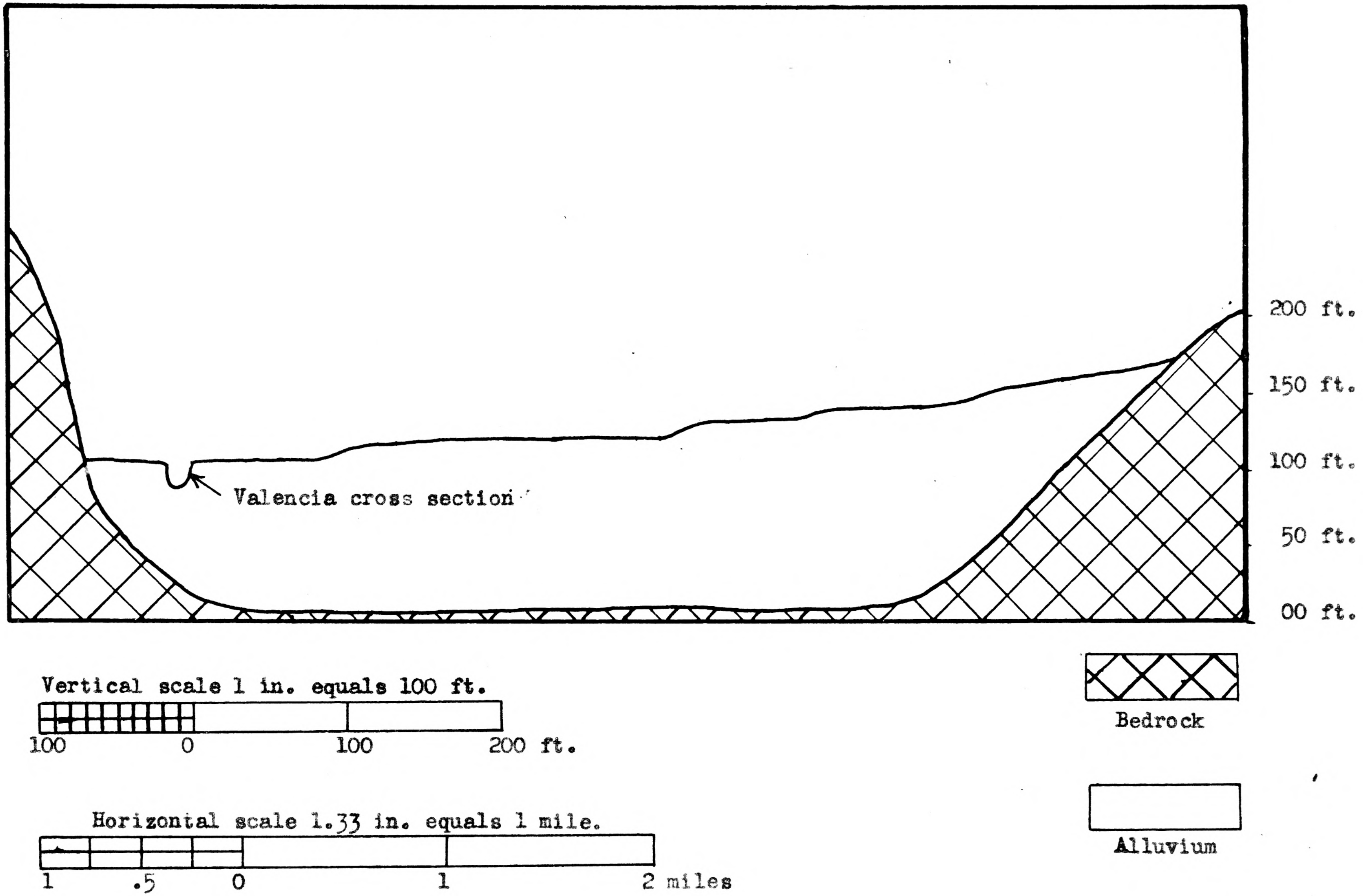


Fig. 3. Diagrammatic cross section of Kansas River flood plain at Valencia cross section.

Table 1. Valencia cross section, quantitative mineral analysis.

Minerals	Sample letters																	
	A	B	C	D	E	F	G	H	I	J	K	L	M	N	O	P	Q	R
Heavy fraction																		
Hematite	0	0	0	1	0	0	0	0	0	0	0	0	0	4	2	0	0	0
Magnetite	2	3	4	4	1	0	5	0	0	0	1	1	3	5	15	4	15	4
Ilmenite	4	13	10	7	5	0	21	0	1	1	2	3	13	8	16	6	30	17
Zircon	1	0	0	1	1	0	0	0	0	0	0	0	0	0	1	0	0	0
Topaz	2	0	0	1	1	0	0	0	0	0	1	0	0	0	0	1	0	0
Hornblende	34	45	48	46	57	0	31	2	2	1	50	17	35	32	28	46	25	28
Epidote	24	19	24	11	12	0	15	1	1	0	8	6	12	12	11	9	7	13
Muscovite	2	2	0	8	8	96	2	68	96	98	12	65	1	12	2	5	1	8
Biotite	3	1	3	5	3	4	0	28	0	0	3	1	0	6	0	2	0	3
Garnet	1	4	4	2	2	0	5	0	0	0	1	1	6	4	3	5	5	2
Augite	1	0	0	2	1	0	1	0	0	0	0	0	0	4	0	1	1	0
Kyanite	0	0	0	1	0	0	0	0	0	0	0	0	1	0	0	0	0	0
Titanite	1	0	0	1	1	0	2	0	0	0	2	1	5	6	8	6	8	8
Tourmaline	3	1	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0
Rutile	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Sillimanite	0	0	0	0	1	0	1	0	0	0	0	0	0	0	0	0	0	0
Enstatite	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1
Lamproblite	5	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	2	3
Zoisite	0	1	0	0	0	0	1	0	0	0	0	0	3	1	2	4	2	0
Hypersthene	8	7	0	0	0	0	8	0	0	0	6	3	11	4	2	3	1	5
Clinozoisite	0	0	0	0	0	0	0	0	0	0	2	1	3	0	2	2	1	3
Leucoxene	8	3	7	10	7	0	8	1	0	0	12	1	7	8	8	5	1	3
Tremolite-Actinolite	0	0	0	0	0	0	0	0	0	0	0	0	0	0	2	1	1	2
Light fraction																		
Quartz	66	63	62	67	57	13	71	10	7	3	46	13	68	10	63	57	67	35
Chalcedony	17	17	18	14	13	36	22	75	47	68	22	76	20	80	19	30	20	47
Orthoclase	4	3	8	3	15	6	5	1	1	0	14	3	4	3	5	1	1	3
Microcline	4	6	2	2	0	0	0	2	2	0	7	2	4	2	3	4	5	3
Plagioclase	8	11	10	13	13	2	0	2	3	0	9	0	2	4	10	4	6	7
Volcanic ash	1	0	0	1	2	43	2	10	40	29	2	6	2	1	0	4	1	5

St. Mary's Cross Section

The St. Mary's cross section studied in August of 1950 was located on the south bank and was approximately 200 yards west of the St. Mary's bridge which was washed out during the 1950 flood.

Nearly all the section appeared to contain fine material with no extremely coarse sand apparent. All the lenses were thick with only one small silt layer in the entire section. The lower layers contained iron concretions with numerous iron stains scattered through the lower two lenses. After the mineral count had been completed and the material compiled, it became apparent the entire section contained a large amount of chalcedony and volcanic ash with large amounts of muscovite and biotite masking the other heavy minerals.

A large amount of chalcedony and quartz made up about three-fourths of the entire light minerals in lens (A) with 15 per cent feldspars and 1 per cent volcanic ash completing the count. The heavy minerals were 9 per cent opaques, 22 per cent amphiboles and pyroxenes, 58 per cent muscovite and biotite, 7 per cent epidote, 1 per cent garnet, and 3 per cent of the remaining minerals.

Lens (B), a fine to medium size sand lens, was 1.7 ft. thick. Volcanic ash was 48 per cent in the light mineral fraction and the other minerals were 23 per cent quartz, 18 per cent chalcedony, 11 per cent feldspars. In this lens the heavy minerals were 2 per cent opaques, 9 per cent amphiboles and pyroxenes, 88 per cent muscovite and biotite, and 1 per cent epidote.

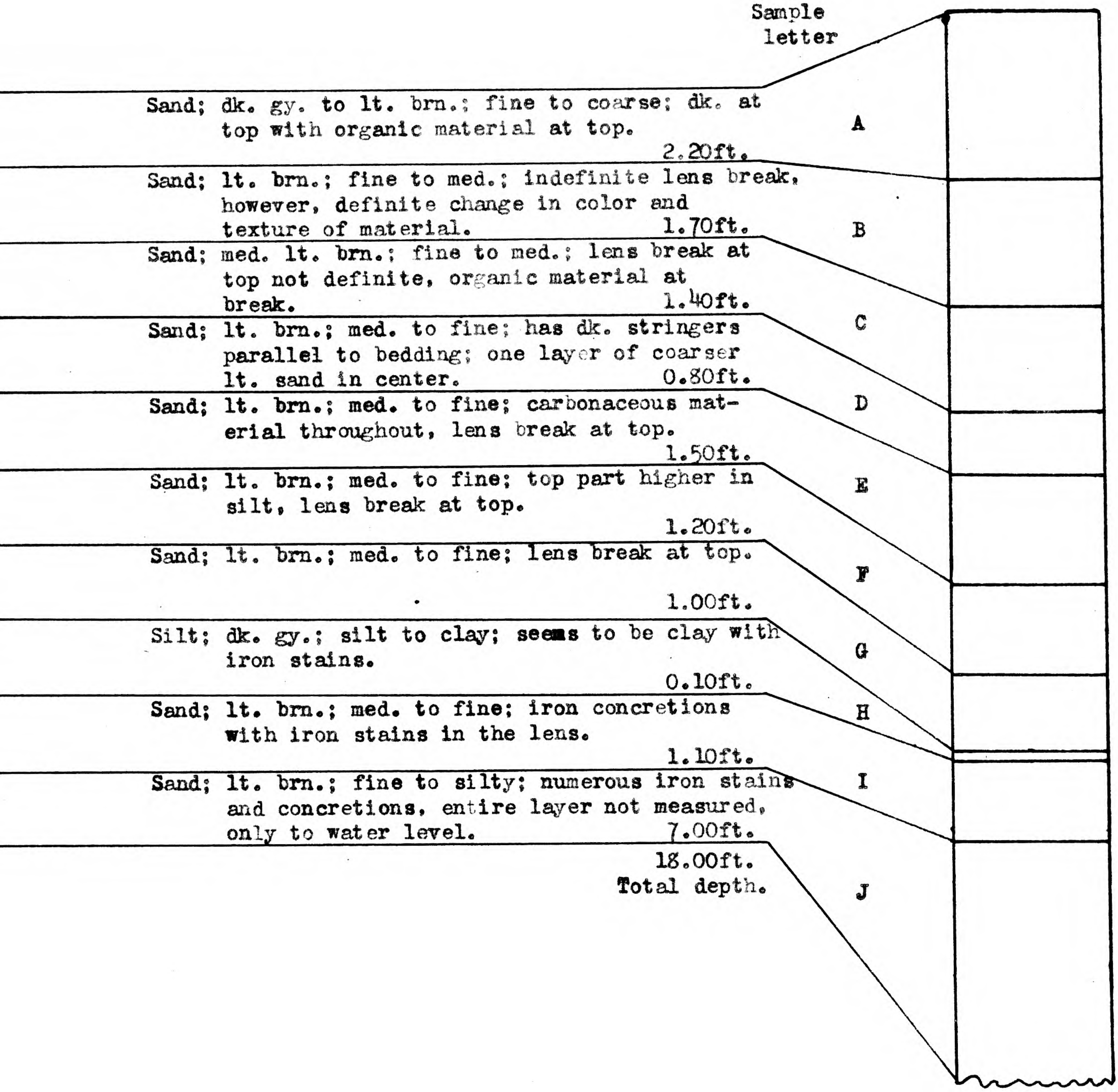
With little change in appearance, lens (C) 1.40 ft. thick did have a definite change in mineral composition. Light minerals in this lens were 55 per cent quartz, 27 per cent chalcedony, 14 per cent feldspars, and 4 per cent volcanic ash. Muscovite and biotite decreased to 48 per cent as compared to 89 per cent in lens (B), also the other heavy minerals showed an increase to 8 per cent opaques, 35 per cent amphiboles and pyroxenes, 3 per cent epidote, 1 per cent garnet, and 5 per cent of the remaining minerals.

Next was lens (D) which was 0.80 ft. thick and slightly coarser in texture as compared to lens (C). Lens (D) had 18 per cent quartz, 29 per cent chalcedony, 2 per cent feldspars, and 51 per cent volcanic ash in the light mineral fraction. In the heavy mineral slide were 10 per cent opaques, 15 per cent amphiboles and pyroxenes, 71 per cent muscovite and biotite, 3 per cent epidote, and 1 per cent of the remaining minerals.

The lenses (E), (F), (G), and (H) had a total thickness of 3.8 ft. All the lenses had large amounts of volcanic ash, muscovite, and biotite. Volcanic ash which ranged from 35 to 68 per cent was the predominant mineral in the light fraction and chalcedony varied from 14 to 28 per cent, quartz varied from 3 to 44 per cent, and the feldspars varied from 1 to 7 per cent. Muscovite and biotite, 85 to 98 per cent, completely masked the other minerals in the heavy fraction.

Iron concretions and stains were found in lens (I) which was 1.1 ft. thick. The light minerals showed quartz 48 per cent, chalcedony 25 per cent, feldspars 14 per cent, and volcanic ash 13 per cent. Lens (I) had the following heavy minerals: 3 per cent opaques, 49 per cent amphiboles and pyroxenes, 32 per cent muscovite and biotite, 12 per cent epidote, and 4 per cent of the remaining minerals.

Silty in appearance with iron concretions and stains, lens (J) was 7.00 ft. from the water level and extended below to make a total measurement of the lens impossible. Perhaps this lower part of the cross section was a portion of an old river channel. In the light mineral fraction were 55 per cent quartz, 19 per cent chalcedony, 7 per cent feldspars, and 19 per cent volcanic ash. Again muscovite and biotite, 88 per cent, masked the other heavy minerals.



Sand; dk. gy. to lt. brn.; fine to coarse; dk. at top with organic material at top. 2.20ft.

Sand; lt. brn.; fine to med.; indefinite lens break, however, definite change in color and texture of material. 1.70ft.

Sand; med. lt. brn.; fine to med.; lens break at top not definite, organic material at break. 1.40ft.

Sand; lt. brn.; med. to fine; has dk. stringers parallel to bedding; one layer of coarser lt. sand in center. 0.80ft.

Sand; lt. brn.; med. to fine; carbonaceous material throughout, lens break at top. 1.50ft.

Sand; lt. brn.; med. to fine; top part higher in silt, lens break at top. 1.20ft.

Sand; lt. brn.; med. to fine; lens break at top. 1.00ft.

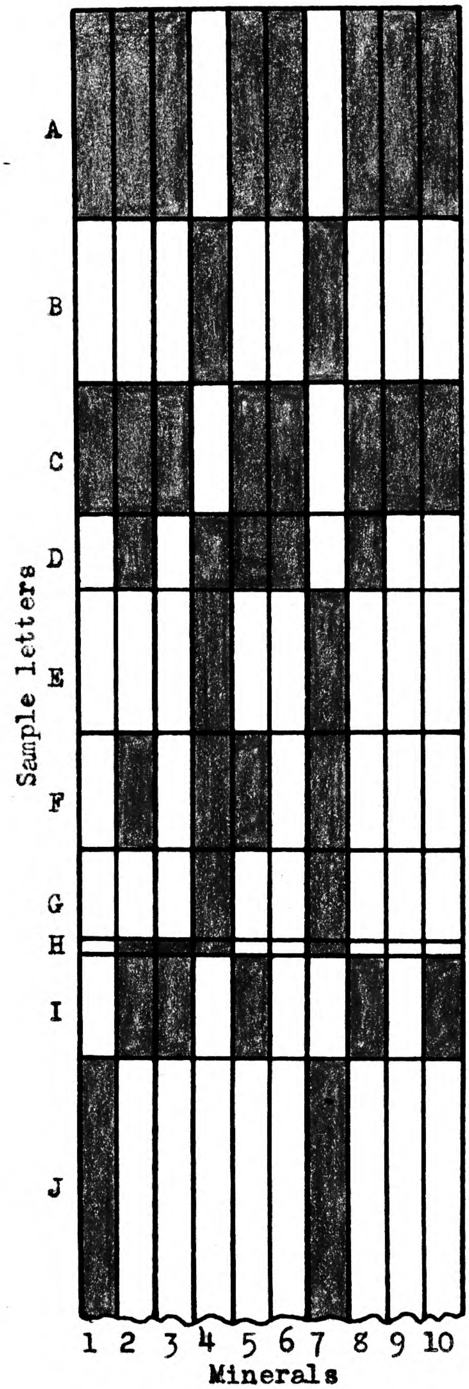
Silt; dk. gy.; silt to clay; seems to be clay with iron stains. 0.10ft.

Sand; lt. brn.; med. to fine; iron concretions with iron stains in the lens. 1.10ft.

Sand; lt. brn.; fine to silty; numerous iron stains and concretions, entire layer not measured, only to water level. 7.00ft.

18.00ft.
Total depth.

Fig. 4. St. Mary's cross section, detailed section, scale 1 in. equals 2 ft.



Key:

1. Quartz	50% or over
2. Chalcedony	25% or over
3. Feldspars	14% or over
4. Volcanic ash	35% or over
5. Opaques	7% or over
6. Amphiboles & Pyroxenes	10% or over
7. Muscovite & Biotite	85% or over
8. Epidote	3% or over
9. Garnet	1% or over
10. Remaining minerals	3% or over

Fig. 5. St. Mary's cross section, dominant minerals in each lens are shown on cross section, scale 1 in. equals 2 ft.

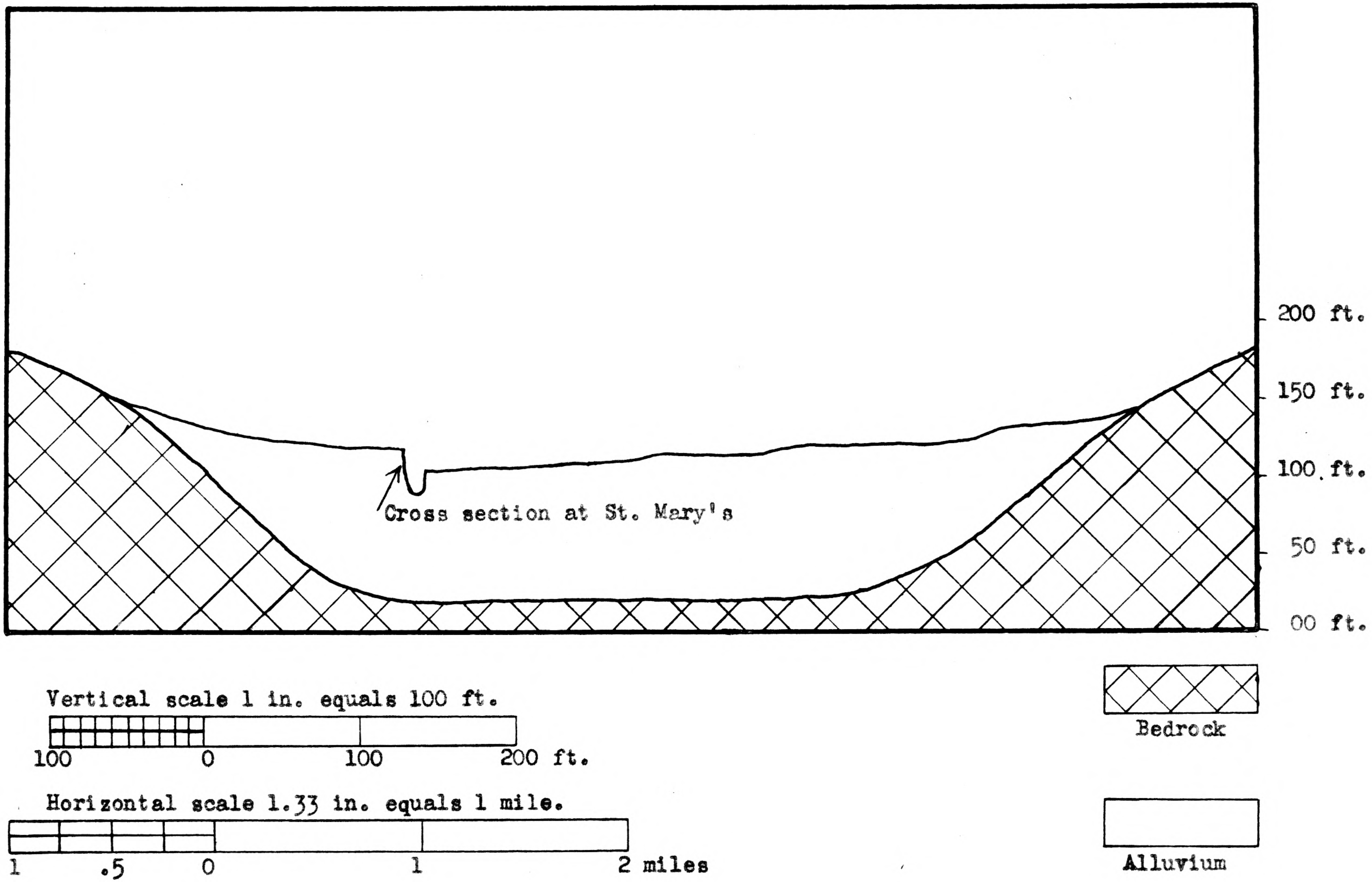


Fig. 6. Diagrammatic cross section of Kansas River flood plain at St. Mary's cross section.

Table 2. St. Mary's cross section, quantitative mineral analysis.

Minerals	Sample letters									
	A	B	C	D	E	F	G	H	I	J
Heavy fraction:										
Hematite	0	2	4	1	0	0	0	0	0	0
Magnetite	0	0	0	0	0	2	0	0	1	0
Ilmenite	7	0	3	2	0	0	0	0	0	2
Zircon	2	0	0	1	0	0	0	0	2	0
Topaz	0	0	3	0	0	0	0	0	0	0
Hornblende	18	6	25	6	1	3	5	0	40	5
Epidote	7	1	3	3	0	1	0	0	12	2
Muscovite	42	48	24	34	50	48	72	46	26	56
Biotite	14	40	24	37	48	37	17	52	6	32
Garnet	1	0	1	0	0	0	0	0	0	0
Augite	1	0	0	0	0	1	0	0	1	0
Kyanite	0	0	1	0	0	0	0	0	0	0
Titanite	0	0	1	0	0	0	0	0	1	0
Tourmaline	0	0	0	0	0	0	0	0	0	1
Rutile	1	0	0	0	0	0	0	0	0	0
Enstatite	2	0	1	2	0	0	0	0	1	0
Lamproblite	1	2	4	1	0	0	0	0	0	1
Zoisite	0	0	0	0	0	0	1	0	1	0
Hypersthene	2	1	4	5	0	3	3	0	3	1
Leucoxene	2	0	1	8	1	5	2	2	2	0
Tremolite-Actonlite	0	0	1	0	0	0	0	0	4	0
Light fraction:										
Quartz	59	23	55	18	34	20	44	3	48	55
Chalcedony	25	18	27	29	14	26	18	28	25	19
Orthoclase	5	2	3	1	0	4	1	0	5	2
Microcline	5	4	5	1	2	2	2	1	3	3
Plagioclase	5	5	6	0	3	1	0	0	6	2
Volcanic ash	1	48	4	51	47	47	35	68	13	19

Cross Section East of Wamego

The cross section was 3.5 miles east of Wamego on the north side of the river. Lenses in the section contained a large amount of coarse sand and collection of the samples was made in August of 1950.

Lens (A) contained the A soil horizon and was 2.90 ft. thick. Quartz was 44 per cent, chalcedony was 29 per cent, feldspars were 23 per cent, and volcanic ash was 4 per cent in the light mineral fraction. Minerals of the heavy fraction were 14 per cent opaques, 46 per cent amphiboles and pyroxenes, 14 per cent muscovite and biotite, 10 per cent epidote, 5 per cent garnet, and 11 per cent of the remaining minerals.

The thickness of lens (B) was one foot. It contained a large amount of clay and silt. In this lens the light minerals consisted of 46 per cent quartz, 23 per cent chalcedony, 12 per cent feldspars, and 19 per cent volcanic ash. The heavy fraction had 87 per cent muscovite and biotite and small amounts of the following: 3 per cent opaques, 4 per cent amphiboles and pyroxenes, 2 per cent epidote, and 4 per cent of the remaining minerals to complete the count.

Lenses (C) and (D) were similar in mineral count. Lens (C) was 0.75 ft. thick and lens (D) was 0.30 ft. thick. Both lenses appeared to have large amounts of clay silt. The light minerals were 42 to 50 per cent quartz, 16 to 19 per cent chalcedony, 9 to 14 per cent feldspars and 25 to 26 per cent volcanic ash. Heavy minerals were masked with muscovite and biotite over 93 per cent in both slides.

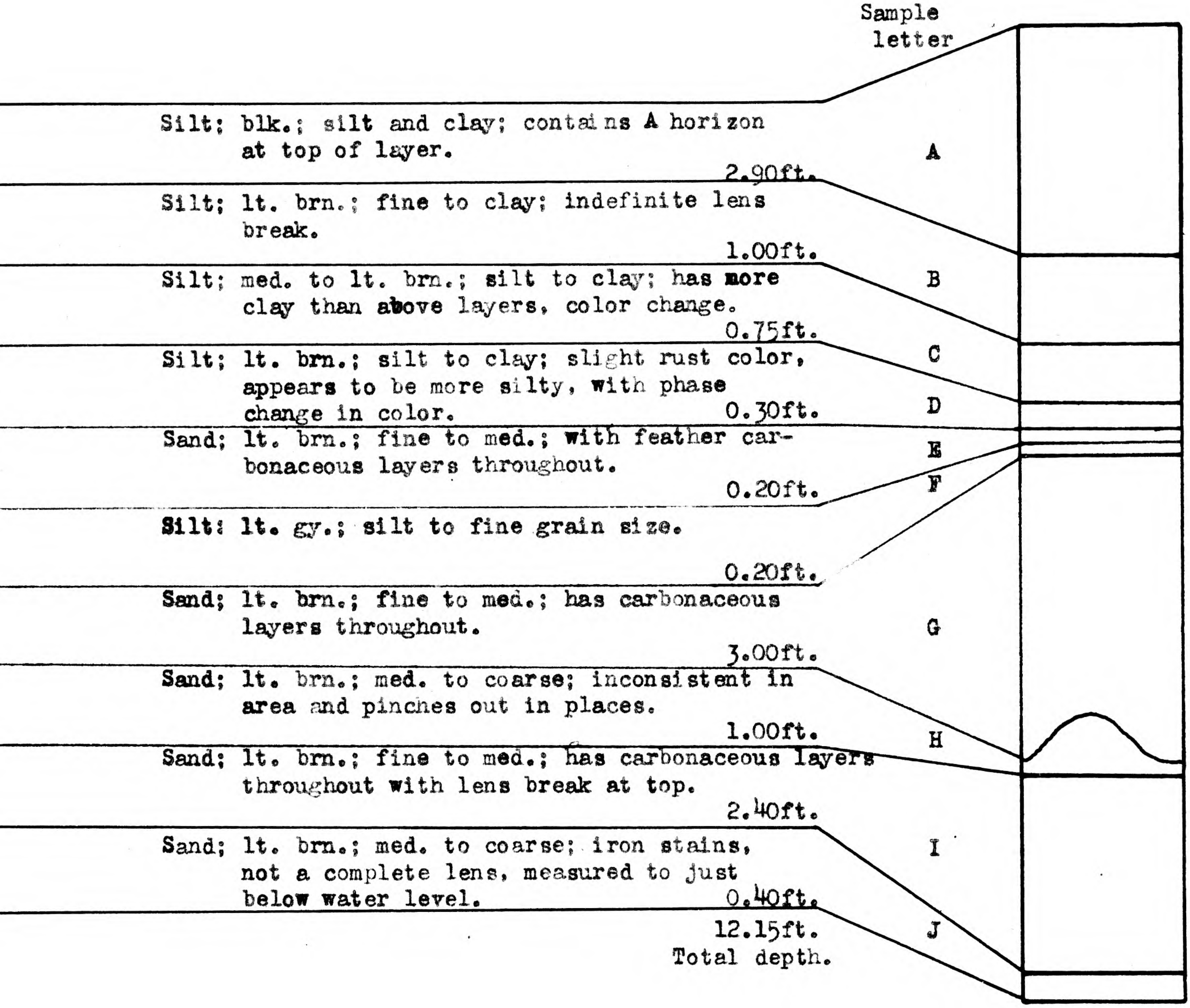
Only 0.20 ft. thick, lens (E) had an increase in grain size with a change in mineral composition compared to lenses (C) and (D). Quartz was a predominant mineral in the light fraction with the other minerals as follows: 21 per cent chalcedony, 20 per cent feldspars and 6 per cent volcanic ash. Amphiboles and pyroxenes were 33 per cent in the heavy mineral fraction with 9 per cent opaques, 43 per cent muscovite and biotite, 8 per cent epidote, 1 per cent garnet, and 7 per cent of the remaining minerals completing the count.

Next lens (F) only 0.20 ft. thick had the texture of silt. In the light minerals were 46 per cent quartz, 22 per cent chalcedony, 12 per cent feldspars, and 20 per cent volcanic ash. Lens (F), in the heavy minerals, had the following count: 6 per cent opaques, 15 per cent amphiboles and pyroxenes, 71 per cent muscovite and biotite, 3 per cent epidote, 2 per cent garnet, and 2 per cent of the remaining minerals.

Three feet thick and coarse sand were the characteristics of lens (G). Chalcedony was 26 per cent in the light mineral fraction and the other minerals were 53 per cent quartz, 16 per cent feldspars, and 5 per cent volcanic ash. Epidote was 16 per cent in the heavy mineral fraction, and the other minerals showed 21 per cent opaques, 37 per cent amphiboles and pyroxenes, 8 per cent muscovite and biotite, 4 per cent garnet, and 14 per cent remaining minerals.

Lens (H) throughout the area ranged from a foot in thickness to nothing. There was an increase in quartz to 66 per cent, chalcedony was 18 per cent, and feldspars were 16 per cent in the light mineral fraction. Opaques constituted 32 per cent in the heavy mineral fraction and the amphiboles and pyroxenes were 34 per cent. Muscovite and biotite were absent from the heavy mineral fraction, but epidote showed 14 per cent, garnet 7 per cent, and the remaining minerals 13 per cent.

The total thickness of lenses (I) and (J) was 2.80 ft. Lens (I) was 2.40 ft. thick and lens (J), the lowest lens, extended below the water level and could not be completely measured. Mineral composition of both lenses (I) and (J) were approximately identical. Minerals in the light fraction were 63 to 68 per cent quartz, 15 to 24 per cent chalcedony, and 13 to 17 per cent feldspars. In these lenses the heavy minerals were 10 to 13 per cent opaques, 47 to 53 per cent amphiboles and pyroxenes, 6 to 7 per cent muscovite and biotite, 11 to 22 per cent epidote, 1 to 3 per cent garnet, and 14 to 15 per cent remaining minerals.



Silt; blk.; silt and clay; contains A horizon at top of layer. 2.90ft.

Silt; lt. brn.; fine to clay; indefinite lens break. 1.00ft.

Silt; med. to lt. brn.; silt to clay; has more clay than above layers, color change. 0.75ft.

Silt; lt. brn.; silt to clay; slight rust color, appears to be more silty, with phase change in color. 0.30ft.

Sand; lt. brn.; fine to med.; with feather carbonaceous layers throughout. 0.20ft.

Silt; lt. gy.; silt to fine grain size. 0.20ft.

Sand; lt. brn.; fine to med.; has carbonaceous layers throughout. 3.00ft.

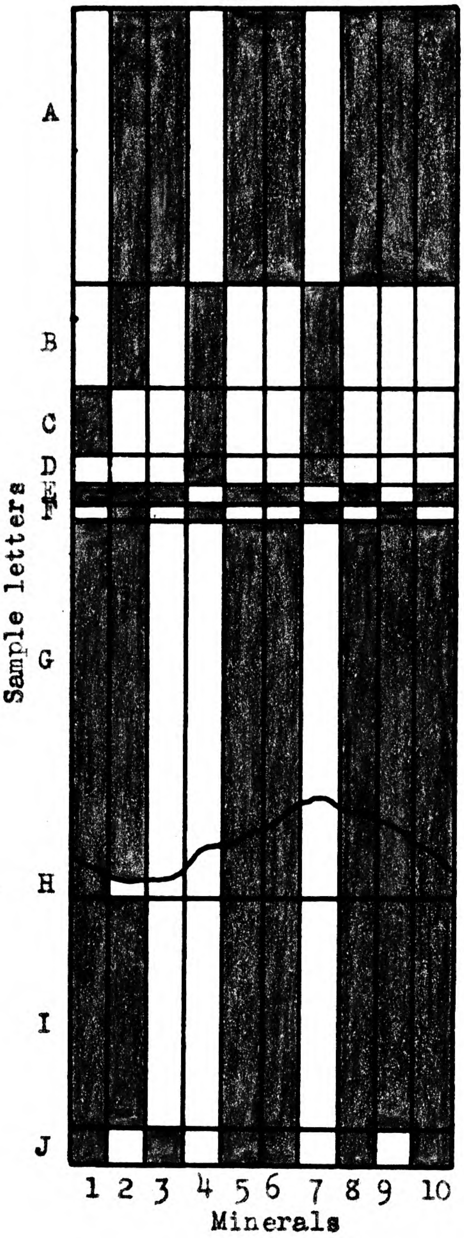
Sand; lt. brn.; med. to coarse; inconsistent in area and pinches out in places. 1.00ft.

Sand; lt. brn.; fine to med.; has carbonaceous layers throughout with lens break at top. 2.40ft.

Sand; lt. brn.; med. to coarse; iron stains, not a complete lens, measured to just below water level. 0.40ft.

12.15ft. Total depth.

Fig. 7. Cross section east of Wamego detailed section, scale 1 in. equals 2 ft.



Key:

1.	Quartz	50% or over
2.	Chalcedony	20% or over
3.	Feldspars	17% or over
4.	Volcanic ash	19% or over
5.	Opaques	8% or over
6.	Amphiboles & Pyroxenes	30% or over
7.	Muscovite & Biotite	70% or over
8.	Epidote	8% or over
9.	Garnet	3% or over
10.	Remaining minerals	7% or over

Fig. 8. Cross section east of Wamego, dominant minerals in each lens are shown on cross section, scale 1 in. equals 2 ft.

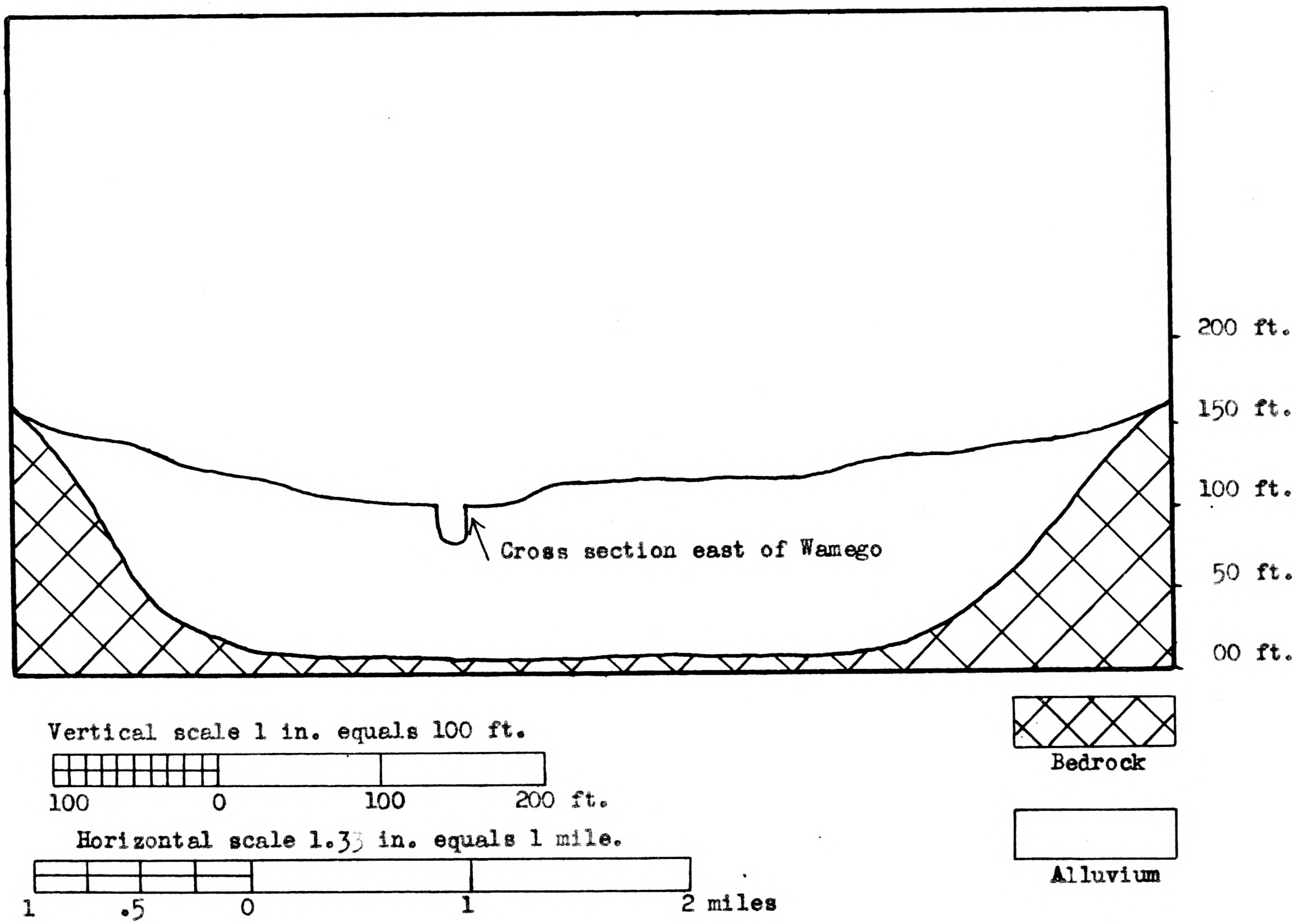


Fig. 9. Diagrammatic cross section of Kansas River flood plain at cross section east of Wamego.

Table 3. Cross section east of Wamego, quantitative mineral analysis.

Minerals	Sample letters									
	A	B	C	D	E	F	G	H	I	J
Heavy fraction:										
Hematite	0	0	0	0	0	0	0	0	0	0
Magnetite	2	0	0	0	2	0	6	5	1	3
Ilmenite	5	0	0	0	2	1	11	17	6	4
Zircon	1	0	0	0	0	1	4	5	1	2
Topaz	1	2	0	0	1	0	0	0	4	3
Hornblende	32	3	4	3	23	11	31	28	35	30
Epidote	10	2	1	0	8	3	16	14	20	11
Muscovite	10	61	82	63	25	51	6	0	4	4
Biotite	4	26	12	31	17	20	2	0	3	3
Garnet	5	0	0	0	1	3	4	7	3	1
Augite	2	0	0	0	0	2	0	0	1	1
Kyanite	3	1	0	0	1	0	0	1	2	2
Titanite	3	1	0	1	1	0	3	4	5	5
Tourmaline	2	0	0	0	2	1	1	2	2	1
Rutile	0	0	0	0	1	0	1	0	0	0
Enstatite	1	1	0	0	3	1	0	1	0	0
Lamproblite	3	0	0	0	4	0	2	2	1	9
Zoisite	2	0	0	0	1	0	5	1	0	2
Hypersthene	6	0	0	0	3	1	3	3	7	12
Leucoxene	7	0	1	3	5	5	4	10	4	6
Tremolite-Actonlite	1	3	0	0	0	0	1	0	1	1
Light fraction:										
Quartz	44	46	50	44	53	46	53	66	63	68
Chalcedony	29	23	16	16	21	22	26	18	24	15
Orthoclase	8	2	1	3	5	4	7	4	3	6
Microcline	7	7	7	6	8	1	6	7	2	6
Plagioclase	8	3	1	5	7	7	3	5	8	5
Volcanic ash	4	19	25	26	6	20	5	0	0	0

Wamego Cross Section

The cross section at Wamego was located about a half mile east of the Wamego bridge on the north side of the river. Total depth of the cross section was 21 ft. and samples from the cross section were collected in August of 1950. Large calcareous stringers were encountered throughout the lenses (A) and (B) in the cross section, also the lenses (A), (B), and (C) appeared to contain a large amount of silt and clay.

The top lens (A) was 4.60 ft. thick, it appeared high in clay content, and had calcareous stringers extending downward. In this lens the light mineral fraction consisted of 73 per cent quartz, 12 per cent chalcedony, 11 per cent feldspars and 4 per cent volcanic ash. Heavy minerals were the following: 15 per cent opaques, 45 per cent amphiboles and pyroxenes, 8 per cent muscovite and biotite, 14 per cent epidote, 2 per cent garnet, and 16 per cent of the remaining minerals.

Calcareous stringers were extended into lens (B). The total thickness of lens (B) was 2.40 ft. Quartz was 56 per cent, chalcedony was 19 per cent, feldspars were 24 per cent, and volcanic ash was 1 per cent in the light minerals. Composition of the heavy minerals was 8 per cent opaques, 43 per cent amphiboles and pyroxenes, 32 per cent muscovite and biotite, 3 per cent epidote, and 14 per cent remaining minerals.

Next was lens (C) which was 1.80 ft. thick. Similar in composition to lens (B), lens (C) showed 60 per cent quartz, 23 per cent chalcedony, 15 per cent feldspars, and 2 per cent volcanic ash in the light minerals. The heavy minerals were 10 per cent opaques, 32 per cent amphiboles and pyroxenes, 37 per cent muscovite and biotite, 9 per cent epidote, 1 per cent garnet, and 10 per cent of the remaining minerals.

With a slight increase in the grain size and a decrease in the amount of clay, lens (D) appeared to be only a color change from the layer above. In all, the lens was 3.30 ft. thick. Light minerals in this lens were 59 per cent quartz, 18 per cent chalcedony, 19 per cent feldspars and 4 per cent volcanic ash. Muscovite and biotite were 81 per cent of the heavy mineral fraction, and the other minerals were 7 per cent opaques, 3 per cent amphiboles and pyroxenes, 2 per cent epidote, and 7 per cent of the remaining minerals.

Next was lens (E) with a thickness of 1.80 ft. Volcanic ash was 62 per cent with 5 per cent quartz, 30 per cent chalcedony, and 3 per cent feldspars completing the mineral count of the light mineral fraction. Minerals of the heavy fraction were muscovite and biotite.

Lenses (F) and (G) were similar in mineral count, and lens (F) contained a few iron stains. Lens (F) was 1.10 ft. thick and lens (G) was 0.60 ft. thick. Chalcedony varied from 91 to 95 per cent and dominated the light mineral fraction. In the heavy mineral fraction were 6 to 13 per cent opaques, 5 to 9 per cent amphiboles and pyroxenes, 76 to 87 per cent muscovite and biotite, 0 to 1 per cent garnet, and 1 to 2 per cent remaining minerals.

The bottom layer (H), over 6.00 ft. thick, extended below the water level and was not entirely exposed. This lens had 33 per cent quartz, 57 per cent chalcedony, 9 per cent feldspars, and 1 per cent volcanic ash in the light minerals. Heavy mineral composition was 3 per cent opaques, 27 per cent amphiboles and pyroxenes, 59 per cent muscovite and biotite, 1 per cent epidote, and 10 per cent of the remaining minerals.

Silt to clay; blk.; silt to clay grain size; seems to be the top A horizon, however, entire layer is unusually high in clay content with calcareous stringers.

4.60ft.

Sand; brn. to tan; fine to silt; actually only definite color break, appears to be mainly clay material.

2.40ft.

Silt; rusty brn.; silty to clay; actually appears to be mainly clay.

1.80ft.

Sand; lt. brn.; fine to med.; slightly carbonaceous layer at 0.40ft. from bottom; mainly a color change for lens with an increase in grain size.

3.30ft.

Sand; med. lt. brn.; med. to fine; definite lens break at top.

1.80ft.

Silt; lt. gy.; silt to clay; has iron stains.

1.10ft.

Silt; dk. gy.; silt to clay; appears to be a clay lens.

0.60ft.

Silt; dk. gy.; silt to clay; actually appears to be clay, definite lens break at top, lens goes down to and below water level, not all of lens measured.

6.30ft.

21.90ft.
Total depth.

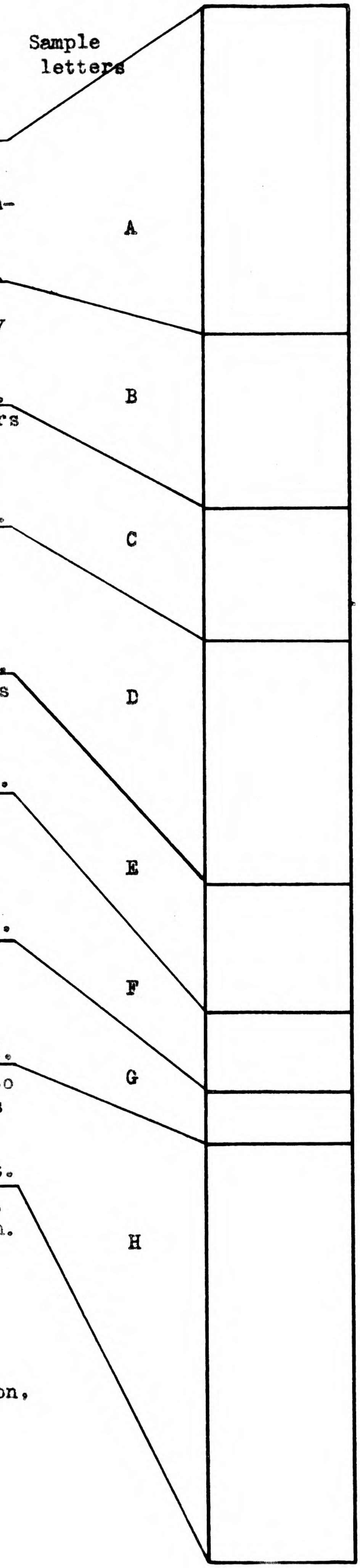
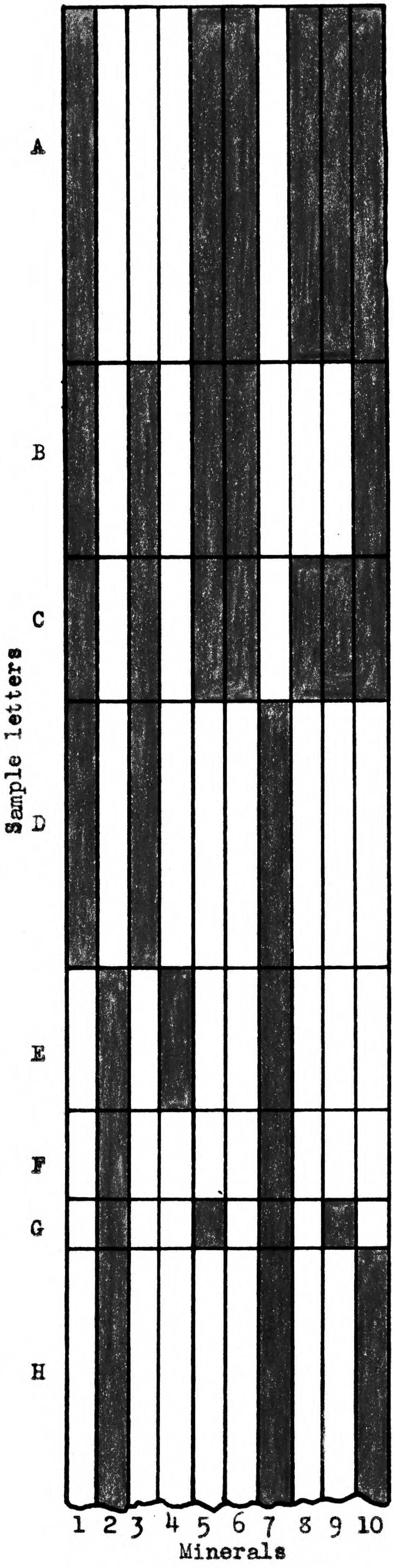


Fig. 10. Wamego cross section, detailed section, scale 1 in. equal 2 ft.



Key:

1.	Quartz	50% or over
2.	Chalcedony	25% or over
3.	Feldspars	15% or over
4.	Volcanic ash	10% or over
5.	Opaques	8% or over
6.	Amphiboles & Pyroxenes	30% or over
7.	Muscovite & Biotite	60% or over
8.	Epidote	8% or over
9.	Garnet	1% or over
10.	Remaining minerals	10% or over

Fig. 11. Wamego cross section, dominant minerals in each lens are shown on cross section, scale 1 in. equals 2 ft.

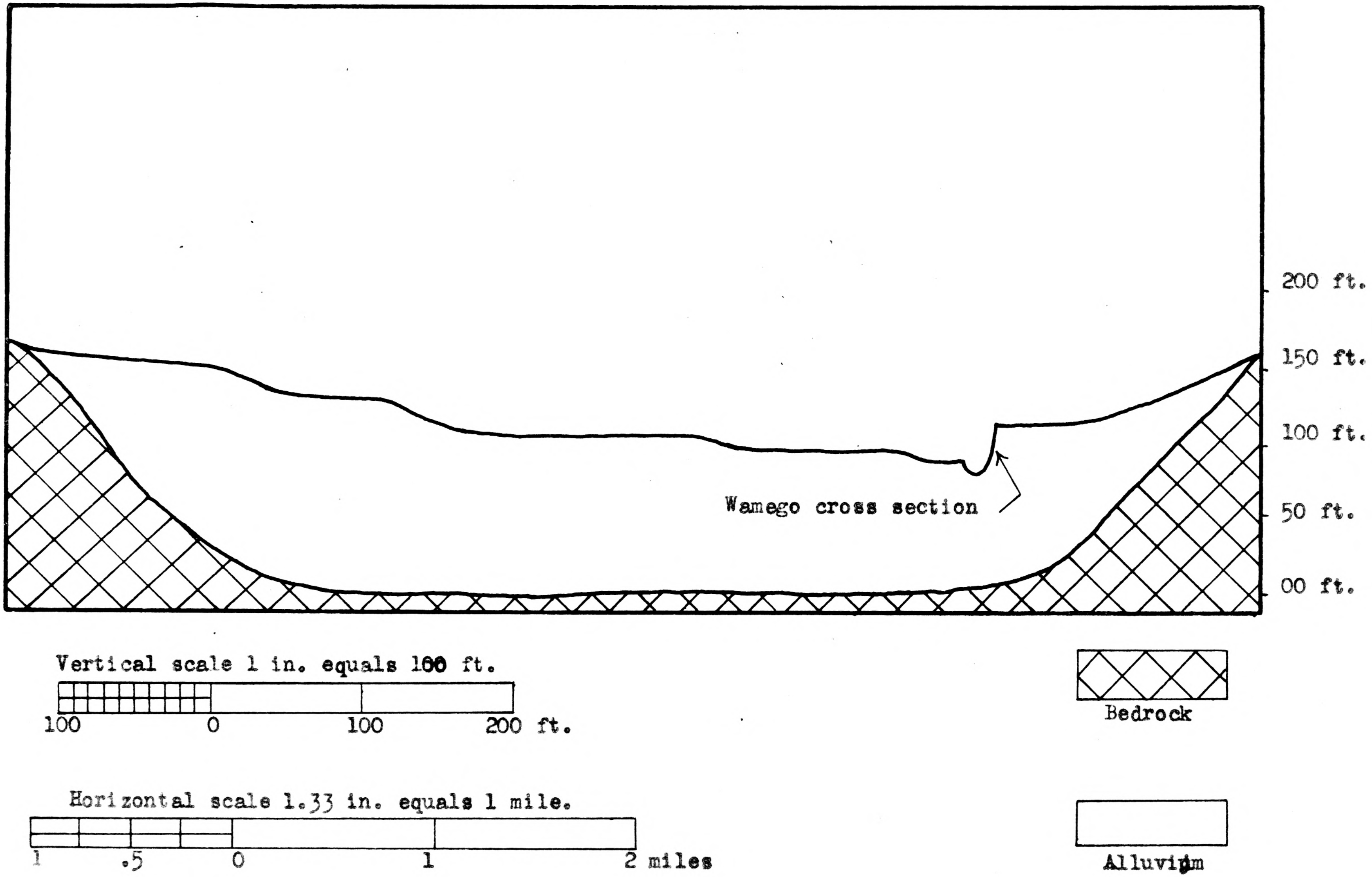


Fig. 12. Diagrammatic cross section of Kansas River flood plain at Wamego cross section.

Table 4. Wamego cross section, quantitative mineral analysis.

Minerals	Sample letters							
	A	B	C	D	E	F	G	H
Heavy fraction:								
Hematite	1	0	0	0	0	0	0	0
Magnetite	3	0	1	0	0	1	1	0
Ilmenite	3	0	2	0	0	1	5	1
Zircon	0	1	1	0	0	0	0	0
Topaz	2	3	0	0	0	0	0	0
Hornblende	34	35	16	2	0	3	7	20
Epidote	14	3	9	2	0	0	0	1
Muscovite	6	24	27	50	48	63	43	29
Biotite	2	8	9	31	52	23	33	30
Garnet	2	0	1	0	0	0	1	0
Augite	0	0	2	0	0	1	0	0
Kyanite	0	0	1	0	0	1	0	2
Titanite	3	2	0	0	0	0	0	2
Tourmaline	2	2	2	4	0	1	0	4
Sillimanite	0	1	2	0	0	0	1	0
Enstatite	2	1	2	0	0	0	1	2
Lamproblite	3	1	3	0	0	0	0	3
Zoisite	9	6	6	3	0	0	0	2
Hypersthene	6	5	9	1	0	2	1	2
Leucoxene	8	8	7	7	0	4	7	2
Light fraction:								
Quartz	73	56	60	59	5	5	3	33
Chalcedony	12	19	23	18	30	91	95	57
Orthoclase	4	7	6	10	1	1	0	1
Microcline	2	10	6	7	1	0	0	5
Plagioclase	5	7	3	2	1	1	1	3
Volcanic ash	4	1	2	4	62	2	1	1

St. George Cross Section

St. George cross section was located about 100 yards west of the St. George bridge on the south side of the river. The section was studied in August of 1950 and again during November of 1950. Most of the lenses in the cross section contained fine sand. The total depth was 15.5 ft.

Lenses (A) to (E), inclusive, are described together as their compositions are very similar. Total thickness for all the lenses was 3.15 ft. Minerals in the light fractions were: quartz 52 to 61 per cent, chalcedony 18 to 32 per cent, feldspars 15 to 24 per cent, and volcanic ash 0 to 5 per cent. In these lenses, the heavy minerals were 11 to 23 per cent opaques, 35 to 57 per cent amphiboles and pyroxenes, 6 to 23 per cent muscovite and biotite, 7 to 12 per cent epidote, 0 to 6 per cent garnet, and 10 to 19 per cent of the remaining minerals.

With a silty texture, lens (F) has a thickness of 0.20 ft. Lens (F) had 44 per cent quartz, 31 per cent chalcedony, 13 per cent feldspars, and 12 per cent volcanic ash. Opaques 1 per cent, amphiboles and pyroxenes 16 per cent, muscovite and biotite 72 per cent, epidote 4 per cent, garnet 1 per cent, and the remaining minerals 6 per cent were the composition of the heavy mineral fraction.

Coarse and sandy in appearance, lens (G) was 0.50 ft. thick. The light minerals were 52 per cent quartz, 26 per cent chalcedony, 21 per cent feldspars, and 1 per cent volcanic ash.

In the heavy mineral fraction opaques were 39 per cent, amphiboles and pyroxenes were 30 per cent, muscovite and biotite were 1 per cent, epidote was 11 per cent, garnet was 4 per cent, and the remaining minerals were 15 per cent.

Fine and sandy lens (H) had a thickness of 0.20 ft. Minerals of the light fraction had the following count: 50 per cent quartz, 26 per cent chalcedony, 13 per cent feldspars, and 11 per cent volcanic ash. Composition of the heavy minerals was 20 per cent opaques, 33 per cent amphiboles and pyroxenes, 16 per cent muscovite and biotite, 14 per cent epidote, 1 per cent garnet, and 16 per cent of the remaining minerals.

Silty in appearance, lenses (I) and (J) were 0.65 ft. thick, and iron stains were present in lens (J). While the light minerals were different in these two lenses the heavy minerals were approximately the same. Lens (I) light minerals were 19 per cent quartz, 37 per cent chalcedony, 4 per cent feldspars, and 40 per cent volcanic ash. The next lens (J), in the light mineral fraction, had 51 per cent quartz, 22 per cent chalcedony, 7 per cent feldspars, and 20 per cent volcanic ash. Heavy minerals in Lenses (I) and (J) consisted of 2 to 5 per cent opaques, 9 to 14 per cent amphiboles and pyroxenes, 75 to 78 per cent muscovite and biotite, 2 to 7 per cent epidote, 0 to 2 per cent garnet, and 2 to 5 per cent of the remaining minerals.

Next was lens (K) which was silty in appearance and 0.30 ft. thick. Percentages of the light mineral fraction were 21 per cent quartz, 54 per cent chalcedony, 10 per cent feldspars and 15 per cent volcanic ash. In the heavy minerals were 11 per cent opaques, 26 per cent amphiboles and pyroxenes, 45 per cent muscovite and biotite, 8 per cent epidote, 3 per cent garnet, and 7 per cent of the remaining minerals.

Nearly identical in light mineral count, and with a slight variation in the heavy minerals, lenses (L) and (M) totaled 0.30 ft. in thickness. Light minerals in the lenses included 44 to 46 per cent quartz, 27 to 28 per cent chalcedony, 15 to 19 per cent feldspars, and 9 to 12 per cent volcanic ash. In lens (L), the heavy mineral fraction contained 20 per cent opaques, 38 per cent amphiboles and pyroxenes, 11 per cent muscovite and biotite, 18 per cent epidote, 4 per cent garnet, and 9 per cent remaining minerals. A slight increase of muscovite and biotite from 11 to 31 per cent was the difference in the mineral composition of lenses (L) and (M) with the other persistent minerals each decreasing slightly for the change.

Lenses (N) and (O) appeared to be similar, both were silty to fine sand in texture and dark brown in color. Lens (N) was 0.30 ft. thick, and lens (O) had a thickness of 2.00 ft. Quartz varied from 57 to 73 per cent, chalcedony varied from 12 to 20 per cent, feldspars varied from 13 to 19 per cent, and volcanic ash varied from 2 to 4 per cent in the light mineral fraction. Variations of the heavy mineral fraction were 22 to 32 per cent opaques, 35 to 37 per cent amphiboles and pyroxenes, 2 to 5 per cent muscovite and biotite, 14 to 22 per cent epidote, 4 to 8 per cent garnet, and 7 to 13 per cent of the remaining minerals.

Coarse sand and 0.90 ft. thick were the characteristics of lens (P). Mineral count of the light fraction was 66 per cent quartz, 21 per cent chalcedony, and 13 per cent feldspars. The heavy minerals were 39 per cent opaques, 33 per cent amphiboles and pyroxenes, 3 per cent muscovite and biotite, 2 per cent epidote, 10 per cent garnet, and 13 per cent of the remaining minerals.

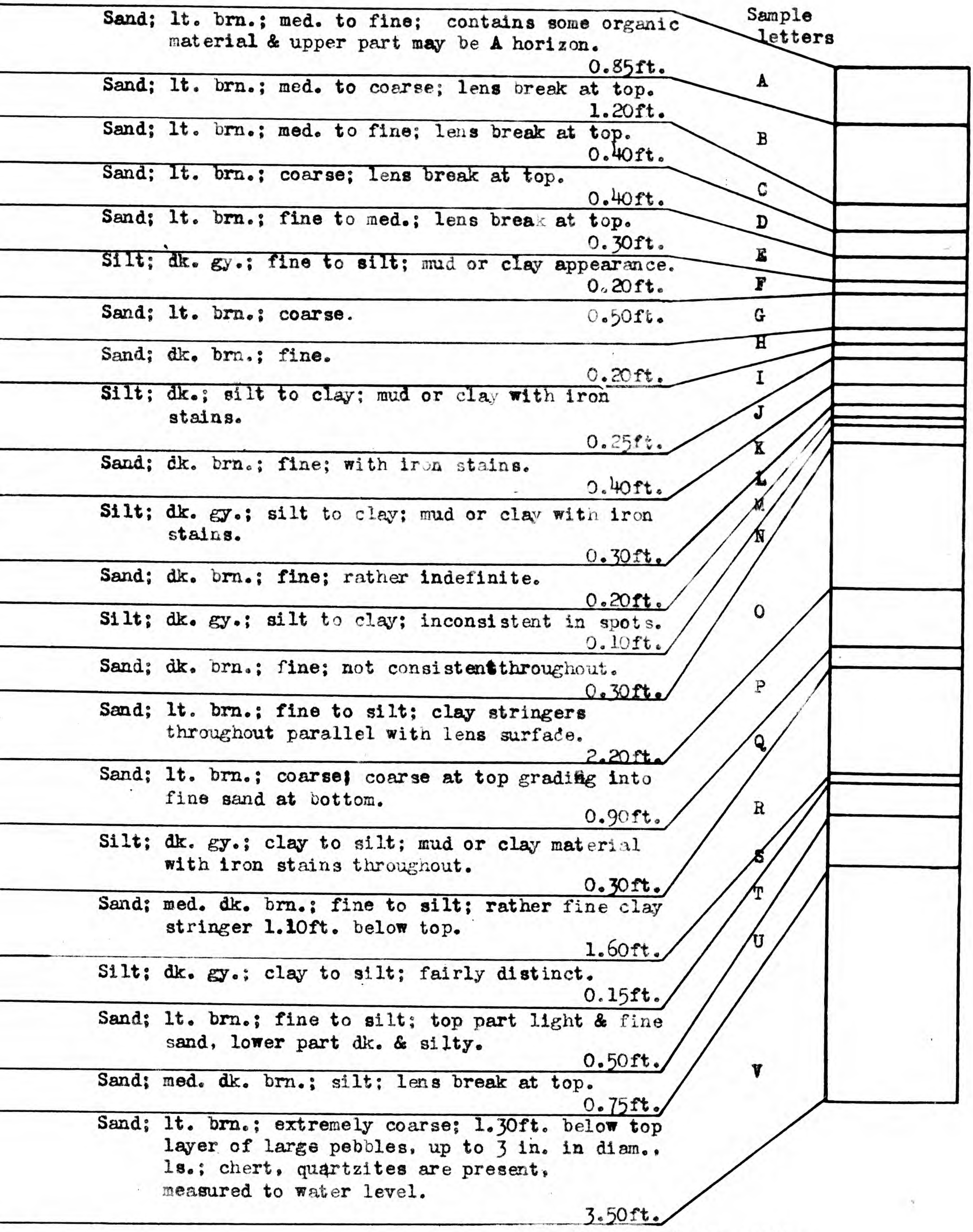
Lens (Q), silty in appearance, had a thickness of 0.30 ft. Included in the light minerals were 43 per cent quartz, 37 per cent chalcedony, 13 per cent feldspars, and 7 per cent volcanic ash. Composition of the heavy minerals showed 9 per cent opaques, 16 per cent amphiboles and pyroxenes, 66 per cent muscovite and biotite, 4 per cent epidote, 2 per cent garnet, and 3 per cent remaining minerals.

A lens of fine sand and 1.60 ft. thick were the characteristics of lens (R). Displayed in the light mineral fraction were 46 per cent quartz, 25 per cent chalcedony, 16 per cent feldspars, and 13 per cent volcanic ash. The heavy minerals showed 8 per cent opaques, 42 per cent amphiboles and pyroxenes, 39 per cent muscovite and biotite, 7 per cent epidote, 1 per cent garnet, and 3 per cent of the remaining minerals.

Lens (S) was a silt layer and 0.15 ft. thick. Chalcedony in the light minerals was 85 per cent and the other minerals were 14 per cent quartz, and 1 per cent feldspars completing the slide. The heavy minerals showed 24 per cent opaques, 42 per cent amphiboles and pyroxenes, 7 per cent muscovite and biotite, 13 per cent epidote, 5 per cent garnet, and 9 per cent remaining minerals.

Lenses (T) and (U) totaled 1.25 ft. in thickness, and were silty in appearance. Only slight variations showed in the light mineral fractions, which were 46 to 53 per cent quartz, 22 to 24 per cent chalcedony, 12 to 17 per cent feldspars and 12 to 13 per cent volcanic ash. Some difference was apparent in the heavy mineral slides which contained 6 to 15 per cent opaques, 36 to 54 per cent amphiboles and pyroxenes, 17 to 23 per cent muscovite and biotite, 9 to 18 per cent epidote, 2 to 5 per cent garnet, and 4 to 8 per cent of the remaining minerals.

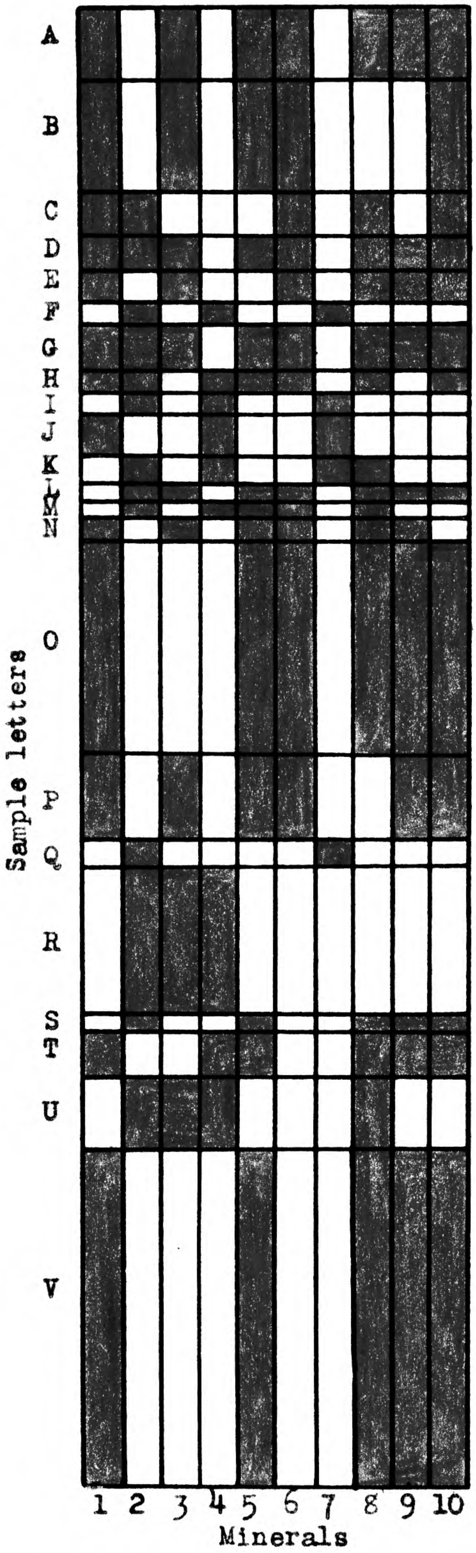
The last lens (V) was not completely measured, it was 3.50 ft. to the water level. Within the layer large pebbles, some at least 3 inches in diameter were found 1.30 ft. below the top of the lens. The pebbles consisted of chert, limestone, and quartzites, and the texture of the lens was coarse sand. The composition of the light mineral fraction was 62 per cent quartz, 22 per cent chalcedony, 15 per cent feldspars, and 1 per cent volcanic ash. In the heavy minerals were 55 per cent opaques, 22 per cent amphiboles and pyroxenes, 8 per cent epidote, 5 per cent garnet, and 10 per cent remaining minerals.



Sand; lt. brn.; med. to fine; contains some organic material & upper part may be A horizon.	0.85ft.
Sand; lt. brn.; med. to coarse; lens break at top.	1.20ft.
Sand; lt. brn.; med. to fine; lens break at top.	0.40ft.
Sand; lt. brn.; coarse; lens break at top.	0.40ft.
Sand; lt. brn.; fine to med.; lens break at top.	0.30ft.
Silt; dk. gy.; fine to silt; mud or clay appearance.	0.20ft.
Sand; lt. brn.; coarse.	0.50ft.
Sand; dk. brn.; fine.	0.20ft.
Silt; dk.; silt to clay; mud or clay with iron stains.	0.25ft.
Sand; dk. brn.; fine; with iron stains.	0.40ft.
Silt; dk. gy.; silt to clay; mud or clay with iron stains.	0.30ft.
Sand; dk. brn.; fine; rather indefinite.	0.20ft.
Silt; dk. gy.; silt to clay; inconsistent in spots.	0.10ft.
Sand; dk. brn.; fine; not consistent throughout.	0.30ft.
Sand; lt. brn.; fine to silt; clay stringers throughout parallel with lens surfade.	2.20ft.
Sand; lt. brn.; coarse; coarse at top grading into fine sand at bottom.	0.90ft.
Silt; dk. gy.; clay to silt; mud or clay material with iron stains throughout.	0.30ft.
Sand; med. dk. brn.; fine to silt; rather fine clay stringer 1.10ft. below top.	1.60ft.
Silt; dk. gy.; clay to silt; fairly distinct.	0.15ft.
Sand; lt. brn.; fine to silt; top part light & fine sand, lower part dk. & silty.	0.50ft.
Sand; med. dk. brn.; silt; lens break at top.	0.75ft.
Sand; lt. brn.; extremely coarse; 1.30ft. below top layer of large pebbles, up to 3 in. in diam., ls.; chert, quartzites are present, measured to water level.	3.50ft.

15.50ft. Total depth.

Fig. 13. St. George cross section, detailed section, scale 1 in. equals 2 ft.



Key:

1.	Quartz	50% or over
2.	Chalcedony	25% or over
3.	Feldspars	17% or over
4.	Volcanic ash	10% or over
5.	Opaques	15% or over
6.	Amphiboles & Pyroxenes	30% or over
7.	Muscovite & Biotite	45% or over
8.	Epidote	8% or over
9.	Garnet	4% or over
10.	Remaining minerals	8% or over

Fig. 14. St. George cross section, dominant minerals in each lens are shown on cross section, scale 1 in. equals 2 ft.

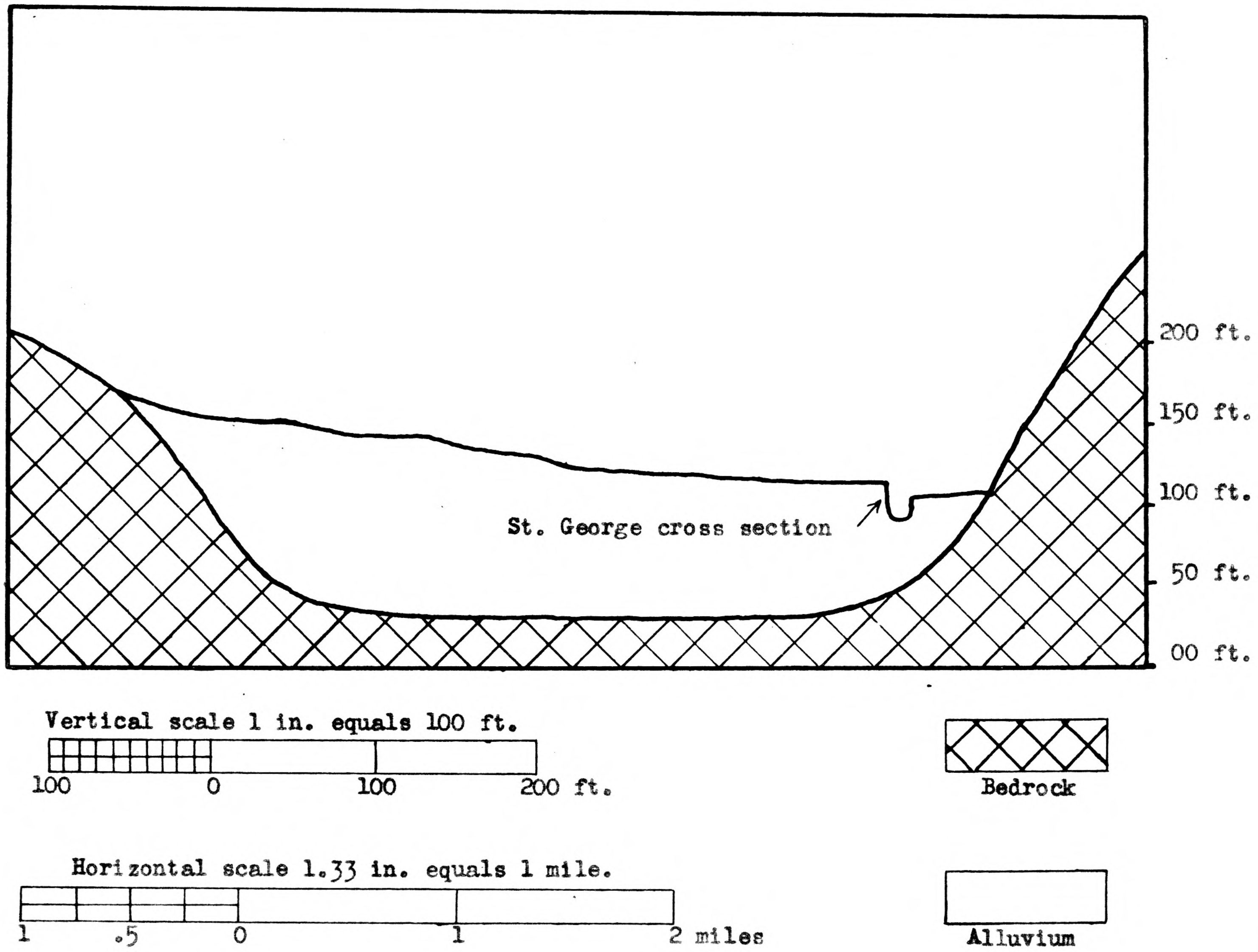


Fig. 15. Diagrammatic cross section of Kansas River flood plain at St. George cross section.

Table 5. St. George cross section, quantitative mineral analysis.

Minerals	A	B	C	D	E	F	G	H	I	J	K
Heavy fraction											
Hematite	4	0	0	0	0	0	0	0	0	0	0
Magnetite	5	4	2	3	3	0	12	4	0	0	2
Ilmenite	7	10	4	11	4	1	23	7	1	1	9
Zircon	2	2	0	1	1	0	4	1	0	1	2
Topaz	0	1	1	1	0	0	1	0	0	0	1
Hornblende	26	38	39	32	24	10	22	22	11	8	20
Epidote	11	7	8	11	12	4	11	14	2	7	8
Mucsovite	4	6	5	11	15	50	0	10	53	48	39
Biotite	3	7	7	4	7	22	1	6	26	26	6
Garnet	4	1	0	6	6	1	4	1	2	0	3
Augite	0	0	1	1	0	1	1	1	0	0	0
Kyanite	2	1	4	1	4	0	0	1	0	0	0
Titanite	4	4	3	5	2	0	5	2	1	0	1
Tourmaline	4	2	2	3	3	3	2	5	0	0	0
Rutile	0	1	0	0	0	0	2	1	0	1	1
Sillimanite	0	0	0	0	0	0	0	0	0	1	0
Enstatite	1	1	1	1	2	3	1	1	0	0	0
Lamproblite	4	3	6	2	5	1	1	4	2	0	1
Zoisite	8	2	3	0	4	3	1	6	1	3	2
Hypersthene	6	5	9	1	4	0	5	5	1	0	5
Clinozoisite	0	0	0	0	0	0	0	0	0	0	0
Leucoxene	5	5	5	5	4	0	4	9	0	4	0
Tremolite-Actinolite	0	0	0	1	0	1	0	0	0	0	0
Light fraction											
Quartz	61	54	59	52	58	44	52	50	19	51	21
Chalcedony	18	20	25	27	19	31	26	26	37	22	54
Orthoclase	2	6	3	3	4	5	5	2	1	0	2
Microcline	13	11	5	9	9	5	9	7	1	3	3
Plagioclase	6	7	7	7	5	3	7	4	2	4	5
Volcanic ash	0	2	1	2	5	12	1	11	40	20	15

Table 5. (concl.)

Minerals	Sample letters										
	L	M	N	O	P	Q	R	S	T	U	V
Heavy fraction											
Magnetite	6	2	3	6	7	1	0	4	2	0	16
Ilmenite	10	9	15	11	27	4	5	15	10	2	36
Zircon	2	2	1	5	8	0	1	3	3	0	6
Topaz	1	0	1	2	0	0	0	0	0	0	0
Hornblende	32	26	28	28	26	13	39	36	31	46	18
Epidote	18	16	22	14	2	4	7	13	18	9	8
Muscovite	7	25	3	0	2	54	22	4	17	18	0
Biotite	4	5	2	2	1	12	17	3	0	5	0
Garnet	4	1	8	4	10	2	1	5	5	2	5
Augite	0	0	1	0	0	0	0	0	2	0	0
Kyanite	1	1	0	0	0	2	0	0	0	2	0
Titanite	1	2	2	2	5	1	0	4	2	0	2
Tourmaline	4	0	1	2	0	0	0	0	0	3	1
Rutile	0	1	0	0	0	0	0	0	0	0	0
Enstatite	1	1	0	2	0	0	2	1	0	2	0
Lamproblite	4	2	4	4	3	3	0	1	2	2	1
Zoisite	0	0	2	0	2	0	2	2	3	0	1
Hypersthene	1	2	3	1	2	0	1	3	2	4	3
Leucoxene	4	5	4	14	5	4	3	5	3	4	3
Tremolite-Actinolite	0	0	1	0	0	0	0	1	0	1	0
Light fraction											
Quartz	44	46	57	73	66	43	46	14	53	46	62
Chalcedony	28	27	20	12	21	37	25	85	22	24	22
Orthoclase	8	5	5	3	6	4	2	0	4	3	5
Microcline	9	10	12	6	5	4	11	1	5	9	8
Plagioclase	2	0	2	4	2	5	3	0	3	5	2
Volcanic ash	9	12	4	2	0	7	13	0	13	12	1

Skyline Cross Section

This cross section taken along the Kansas River was on the north bank, 5 miles west of Manhattan, Kansas on U. S. Highway No. 40. The total depth of the cross section was 12.30 ft., and it was studied in May, 1950.

The two top lenses (A) and (B) appeared to be similar in mineral composition and had a total thickness of 2.50 ft. In the light mineral fraction were 43 to 53 per cent quartz, 30 to 33 per cent chalcedony, 16 to 21 per cent feldspars, and 1 to 3 per cent volcanic ash. The heavy minerals were 36 to 43 per cent opaques, 28 to 36 per cent amphiboles and pyroxenes, 13 per cent epidote, 7 to 9 per cent garnet, and 6 to 9 per cent remaining minerals.

Lens (C), rather similar to lenses (A) and (B), had a slight variation in the mineral count and had a thickness of 1.30 ft. Quartz was 45 per cent; chalcedony was 17 per cent; the feldspars were 36 per cent; and volcanic ash was 2 per cent in the light mineral fraction. This lens in the heavy minerals had 12 per cent opaques, 49 per cent amphiboles and pyroxenes, 7 per cent muscovite and biotite, 7 per cent epidote, 10 per cent garnet, and 15 per cent of the remaining minerals.

Fine sand and 1.30 ft. thick were characteristics of lens (D). Contained in the light minerals were 21 per cent quartz, 34 per cent chalcedony, 2 per cent feldspars and 43 per cent volcanic ash. Minerals of the heavy fraction were 4 per cent opaques, 26 per cent amphiboles and pyroxenes, 60 per cent muscovite and biotite, 1 per cent epidote, 1 per cent garnet, and 8 per cent remaining minerals.

Next was lens (E), it consisted of fine sand and was 1.00 ft. thick. Composition of the light mineral fraction was 11 per cent quartz, 33 per cent chalcedony, 6 per cent feldspars, and 50 per cent volcanic ash. The heavy minerals consisted of 31 per cent opaques, 14 per cent amphiboles and pyroxenes, 42 per cent muscovite and biotite, 4 per cent epidote, 4 per cent garnet, and 5 per cent of the remaining minerals.

Lens (F) was a small slit lens and 0.20 ft. thick. Material in the light minerals was 11 per cent quartz, 15 per cent chalcedony, 5 per cent feldspars, and 69 per cent volcanic ash. Composition of the heavy minerals was 18 per cent opaques, 26 per cent amphiboles and pyroxenes, 40 per cent muscovite and biotite, 9 per cent epidote, 2 per cent garnet, and 5 per cent remaining minerals.

Lens (G) was 1.00 ft. thick and contained coarse sand. The light minerals were 17 per cent quartz, 36 per cent chalcedony, 7 per cent feldspars, and 40 per cent volcanic ash. Percentages in the heavy minerals were 14 per cent opaques, 57 per cent amphiboles and pyroxenes, 11 per cent muscovite and biotite, 10 per cent epidote, 2 per cent garnet, and 6 per cent remaining minerals.

Similar in mineral count, lenses (H) and (I) in thickness totaled 0.80 ft. Mineral percentages of the light mineral fraction were 33 to 39 per cent quartz, 39 to 42 per cent chalcedony, 18 to 22 per cent feldspars, and 3 to 4 per cent volcanic ash. In the heavy mineral fraction was 16 to 18 per cent opaques, 37 to 53 per cent amphiboles and pyroxenes, 8 to 15 per cent muscovite and biotite, 11 to 12 per cent epidote, 0 to 2 per cent garnet, and 13 to 18 per cent remaining minerals.

Coarse sand and 0.60 ft. thick were features of lens (J). Quartz and chalcedony were 68 per cent of the light minerals as the following: 12 per cent feldspars, and 20 per cent volcanic ash completed the slide. Muscovite and biotite totaled 63 per cent, the opaques were 7 per cent, the amphiboles and pyroxenes were 26 per cent, epidote was 3 per cent, garnet was absent, and the remaining minerals were 1 per cent in the heavy mineral fraction.

Silty in appearance, lens (K) had a thickness of 1.60 ft. In this lens, the light mineral fraction was 6 per cent quartz, 39 per cent chalcedony, 5 per cent feldspars, and 50 per cent volcanic ash. Materials making up the heavy mineral fraction were 12 per cent opaques, 37 per cent amphiboles and pyroxenes, 34 per cent muscovite and biotite, 7 per cent epidote, 2 per cent garnet, and 8 per cent of the remaining minerals.

The next lens (L) was coarse sand and had a thickness of

0.30 ft. Quartz and chalcedony, as in lens (J), were a large portion of the light mineral fraction in lens (L). They constituted 76 per cent of the light minerals with the others as follows: 12 per cent feldspars, and 12 per cent volcanic ash. Heavy minerals of this lens consisted of 17 per cent opaques, 46 per cent amphiboles and pyroxenes, 12 per cent muscovite and biotite, 8 per cent epidote, 4 per cent garnet, and 13 per cent remaining minerals.

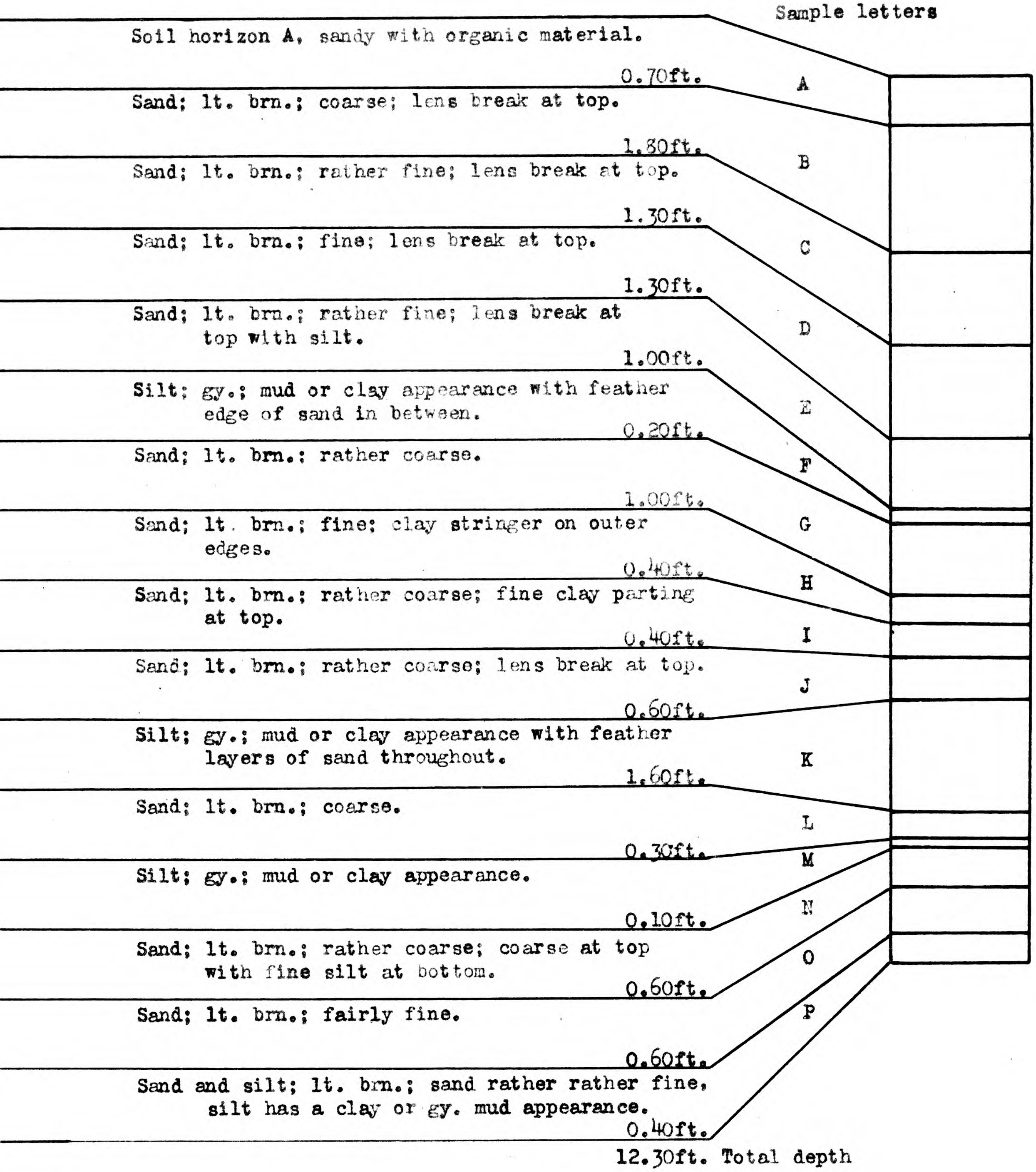
Lens (M) was silty and only 0.10 ft. thick. Composition of the light mineral fraction was 4 per cent quartz, 13 per cent chalcedony, 1 per cent feldspars, and 82 per cent volcanic ash. In this lens, the heavy mineral fraction had 9 per cent amphiboles and pyroxenes, 88 per cent muscovite and biotite, 1 per cent garnet, and 2 per cent of the remaining minerals.

Sand, with a coarse texture, and 0.60 ft. thick were characteristics of lens (N). This lens in the light mineral fraction had 2 per cent quartz, 76 per cent chalcedony, and 22 per cent volcanic ash. The heavy minerals were 7 per cent opaques, 36 per cent amphiboles and pyroxenes, 47 per cent muscovite and biotite, 6 per cent epidote, 2 per cent garnet, and 2 per cent of the remaining minerals.

Texture of lens (O) was fine sand with a thickness of 0.60 ft. In the light mineral fraction there was 28 per cent quartz, 33 per cent chalcedony, 22 per cent feldspars, and 17 per cent volcanic ash. Percentages of the heavy minerals were

8 per cent opaques, 43 per cent amphiboles and pyroxenes, 37 per cent muscovite and biotite, 7 per cent epidote, 1 per cent garnet, and 4 per cent remaining minerals.

With silt and clay as the composition of lens (P), the thickness was 0.40 ft. The light mineral fraction had 13 per cent quartz, 33 per cent chalcedony, 14 per cent feldspars, and 40 per cent volcanic ash. Composition of the heavy minerals showed 2 per cent opaques, 5 per cent amphiboles and pyroxenes, 91 per cent muscovite and biotite, 1 per cent epidote, and 1 per cent of the remaining minerals.



Soil horizon A, sandy with organic material.
0.70ft.

Sand; lt. brn.; coarse; lens break at top.
1.80ft.

Sand; lt. brn.; rather fine; lens break at top.
1.30ft.

Sand; lt. brn.; fine; lens break at top.
1.30ft.

Sand; lt. brn.; rather fine; lens break at top with silt.
1.00ft.

Silt; gy.; mud or clay appearance with feather edge of sand in between.
0.20ft.

Sand; lt. brn.; rather coarse.
1.00ft.

Sand; lt. brn.; fine; clay stringer on outer edges.
0.40ft.

Sand; lt. brn.; rather coarse; fine clay parting at top.
0.40ft.

Sand; lt. brn.; rather coarse; lens break at top.
0.60ft.

Silt; gy.; mud or clay appearance with feather layers of sand throughout.
1.60ft.

Sand; lt. brn.; coarse.
0.30ft.

Silt; gy.; mud or clay appearance.
0.10ft.

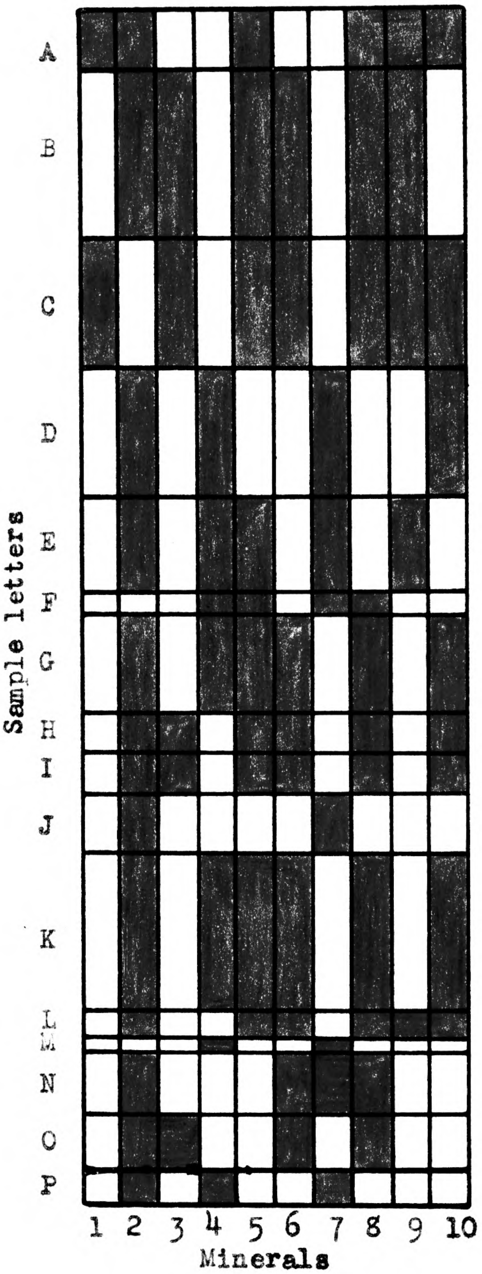
Sand; lt. brn.; rather coarse; coarse at top with fine silt at bottom.
0.60ft.

Sand; lt. brn.; fairly fine.
0.60ft.

Sand and silt; lt. brn.; sand rather rather fine, silt has a clay or gy. mud appearance.
0.40ft.

12.30ft. Total depth

Fig. 16. Skyline cross section, detailed section, scale 1 in. equals 2 ft.



Key:

1.	Quartz	45% or over
2.	Chalcedony	25% or over
3.	Feldspars	17% or over
4.	Volcanic ash	35% or over
5.	Opaques	10% or over
6.	Amphiboles & Pyroxenes	30% or over
7.	Muscovite & Biotite	40% or over
8.	Epidote	6% or over
9.	Garnet	4% or over
10.	Remaining minerals	7% or over

Fig. 17. Skyline cross section, dominant minerals in each lens are shown on cross section, scale 1 in. equals 2 ft.

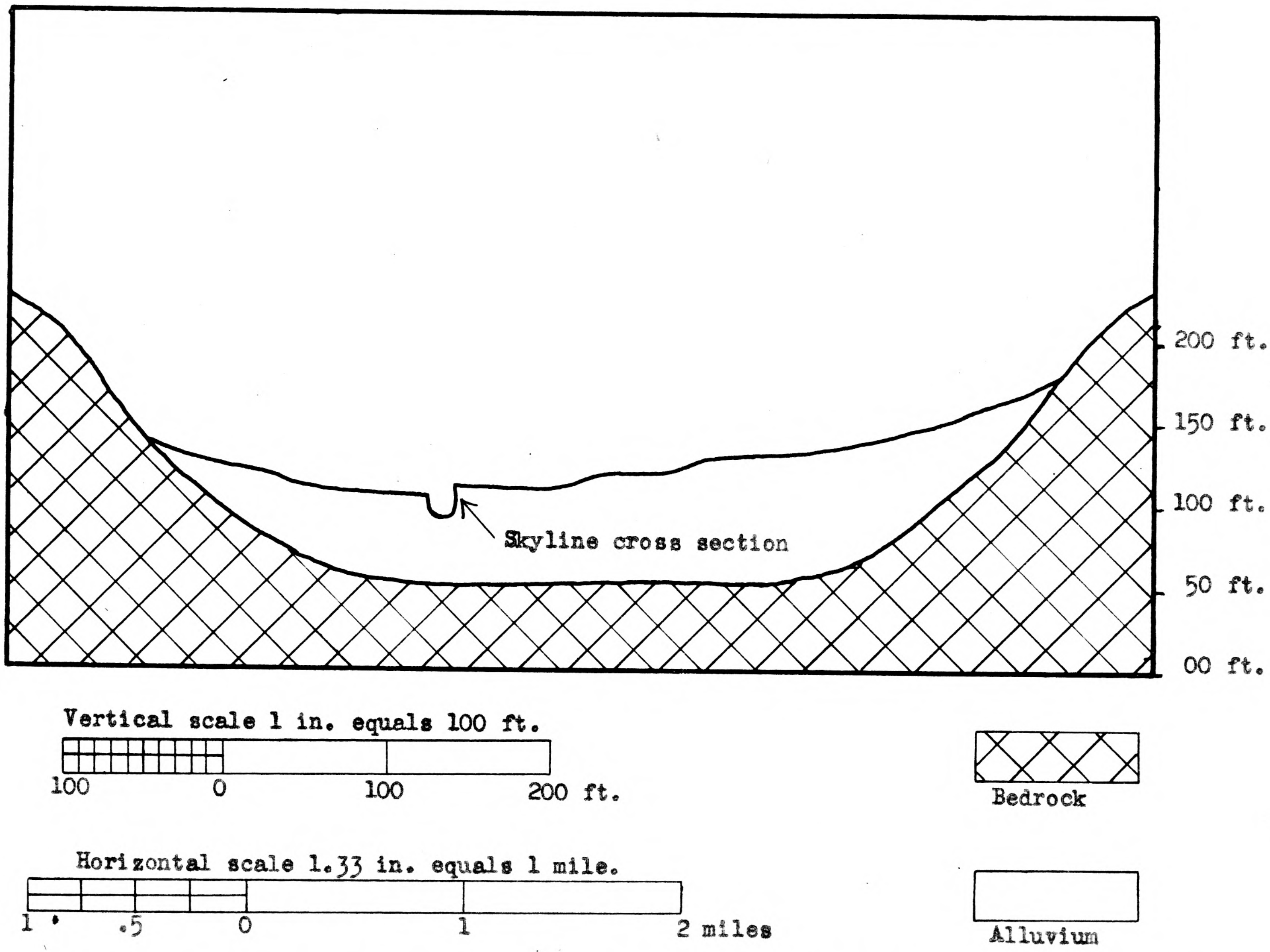


Fig. 18. Diagrammatic cross section of Kansas River flood plain at Skyline cross section.

Table 6. Skyline cross section, quantitative mineral analysis.

Minerals	A	B	C	D	E	F	G	H	I	J	K	L	M	N	O	P
Heavy fraction																
Hematite	0	0	0	0	2	0	0	0	0	0	0	0	0	0	0	0
Magnetite	8	11	5	1	7	6	4	3	2	2	5	2	0	2	1	0
Ilmenite	30	21	6	1	12	9	5	7	10	2	5	8	0	3	3	1
Zircon	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0
Topaz	2	0	1	0	1	0	2	0	2	0	0	8	0	1	0	0
Hornblende	20	30	36	18	9	24	39	33	22	18	28	27	7	25	30	3
Epidote	12	13	7	1	4	9	10	11	11	3	7	8	0	6	7	1
Muscovite	0	0	7	45	23	30	10	6	6	55	27	9	82	40	29	83
Biotite	0	0	0	15	19	10	1	2	8	8	7	3	6	7	8	8
Garnet	7	9	10	1	4	2	2	0	2	0	2	4	1	2	1	0
Augite	2	1	2	0	0	0	0	2	3	1	2	0	0	1	1	0
Kyanite	0	0	4	0	0	0	0	1	0	0	0	0	0	0	0	0
Titanite	3	1	5	2	1	2	2	7	3	1	2	0	1	0	0	0
Sillimanite	0	0	0	0	0	0	0	0	2	0	1	1	0	0	0	1
Enstatite	3	0	1	0	1	0	0	2	0	0	2	2	0	1	0	0
Lamproblite	2	0	0	2	2	0	7	4	2	2	0	3	1	2	4	0
Zoisite	4	0	1	6	2	2	1	0	7	0	5	4	1	0	0	0
Hypersthene	2	5	8	6	1	2	11	9	9	5	5	12	1	7	7	2
Clinozoisite	2	3	3	0	1	1	1	4	5	0	0	1	0	1	4	0
Leucoxene	3	3	2	2	10	3	5	7	6	3	2	7	0	2	4	1
Tremolite-Actinolite	0	3	1	0	1	0	0	2	0	0	0	1	0	0	1	0
Light fraction																
Quartz	53	43	45	21	11	11	17	39	33	34	6	36	4	2	28	13
Chalcedony	30	33	17	34	33	15	36	39	42	34	39	40	13	76	33	33
Orthoclase	2	5	26	1	2	1	4	4	9	4	1	8	0	0	5	9
Microcline	10	10	0	1	2	3	2	10	9	6	3	0	1	0	6	2
Plagioclase	4	6	10	0	2	1	1	4	3	2	1	4	0	0	11	3
Volcanic ash	1	3	2	43	50	69	40	4	3	20	50	12	82	22	17	40

Miscellaneous Material

Three tributaries of the Kaw were sampled in order to see if they would throw any light on the origin of the minerals on the flood plain of the Kansas River. Samples were also collected from higher terraces along the river, two known floods (1935 and 1950), and dust on a porch, which had accumulated over a period of several months, to assist in the mineral analysis of the lenses in the flood plain along the Kansas River.

Air transported dust collected from a porch contained the following minerals in the light fraction: 47 per cent quartz, 28 per cent chalcedony, 20 per cent feldspars, and 5 per cent volcanic ash. Composition of the heavy minerals was 5 per cent opaques, 38 per cent amphiboles and pyroxenes, 39 per cent muscovite and biotite, 7 per cent epidote, 1 per cent garnet, and 9 per cent of the remaining minerals.

Minerals, of the 1935 flood, in the light fraction were 23 per cent quartz, 67 per cent chalcedony, 8 per cent feldspars, and 2 per cent volcanic ash. The heavy minerals were 9 per cent opaques, 39 per cent amphiboles and pyroxenes, 40 per cent muscovite and biotite, 5 per cent epidote, 1 per cent garnet, and 6 per cent of the remaining minerals.

The 1950 flood showed some difference in mineral composition as compared to the 1935 flood. In the light mineral fraction were 64 per cent quartz, 15 per cent chalcedony, and 21 per cent feldspars. Contained in the heavy minerals were 13 per cent opaques, 43 per cent amphiboles and pyroxenes, 9 per cent muscovite and biotite, 12 per cent epidote, 4 per cent garnet, and 19 per cent of the remaining minerals.

Directly south of Wamego, Kansas, samples were collected from terraces of the Kansas River.

The first terrace sampled was 2.8 miles directly south of Wamego, Kansas (on Kansas Highway No. 99), and had the following minerals in the light fraction: 72 per cent quartz, 12 per cent chalcedony, and 26 per cent feldspars. In the heavy mineral fraction were 50 per cent opaques, 7 per cent amphiboles and pyroxenes, 4 per cent muscovite and biotite, 20 per cent epidote, 6 per cent garnet, and 13 per cent of the remaining minerals.

Channel samples from two levels were collected from the top terrace on the Kansas River flood plain, one near the top and one near the bottom. This collection site was 3.6 miles directly south of Wamego, Kansas (on Kansas Highway No. 99).

Minerals of the upper sample in the top terrace had 20 per cent quartz, 60 per cent chalcedony, and 20 per cent feldspars in the light fraction. Count of the heavy minerals was 11 per cent opaques, 16 per cent amphiboles and pyroxenes, 55 per cent muscovite and biotite, 8 per cent epidote, 2 per cent garnet, and 8 per cent of the remaining minerals.

In the lower part of the top terrace, the light mineral fraction showed 57 per cent quartz, 34 per cent chalcedony, and 9 per cent feldspars. Percentages of the heavy mineral fraction were 19 per cent opaques, 19 per cent amphiboles and pyroxenes, 39 per cent muscovite and biotite, 13 per cent epidote, 1 per cent garnet, and 9 per cent remaining minerals.

East of Zeandale, Kansas, 4.9 miles (on Kansas Highway No. 29), samples were collected from terrace deposits. Channel samples, one near the top and one near the bottom, were obtained.

Light minerals of the upper part contained 57 per cent quartz, 32 per cent chalcedony, 10 per cent feldspars, and 1 per cent volcanic ash. In the upper part the heavy minerals were 41 per cent opaques, 7 per cent amphiboles and pyroxenes, 30 per cent muscovite and biotite, 3 per cent epidote, 4 per cent garnet, and 15 per cent of the remaining minerals.

Sample material collected from the lower part of the terrace showed 73 per cent quartz, 17 per cent chalcedony, and 10 per cent feldspars in the light mineral fraction. Heavy minerals of the lower sample were 59 per cent opaques, 6 per cent amphiboles and pyroxenes, 13 per cent muscovite and biotite, 7 per cent epidote, 5 per cent garnet, and 10 per cent of the remaining minerals.

The following was material obtained from the cut banks of the Solomon River, Saline River, and Salt Creek. These samples show the mineral compositions in the flood plains of the two rivers and the creek. At each site of collection three samples were procured; top, middle, and lower part of the flood plain exposed.

Obtained from the Saline River were the following channel samples collected from the upper, middle, and lower part of the flood plain exposed along the banks of the river.

Upper portions of the Saline River showed 66 per cent quartz, 25 per cent chalcedony, 8 per cent feldspars, and 1 per cent volcanic ash. In the heavy minerals were 31 per cent opaques, 28 per cent amphiboles and pyroxenes, 6 per cent muscovite and biotite, 10 per cent epidote, 2 per cent garnet, and 23 per cent of the remaining minerals.

Minerals of the light fraction, in the middle part of the Saline River, were 60 per cent quartz, 24 per cent chalcedony, and 16 per cent feldspars. The heavy minerals had 30 per cent opaques, 26 per cent amphiboles and pyroxenes, 17 per cent muscovite and biotite, 10 per cent epidote, 4 per cent garnet, and 13 per cent remaining minerals.

Material collected from the lower part of the Saline River flood plain contained 71 per cent quartz, 14 per cent chalcedony, 14 per cent feldspars and 1 per cent volcanic ash in the light mineral fraction. Composition of the heavy mineral fraction was 41 per cent opaques, 24 per cent amphiboles and pyroxenes, 15 per cent muscovite and biotite, 4 per cent epidote, 3 per cent garnet, and 13 per cent remaining minerals.

Three samples were collected from the Solomon River: top, middle, and bottom portion, in the flood plain exposed by the river. Collection sites have been marked on the location map (Plate I).

In the upper part of the Solomon River, samples there were 45 per cent quartz, 29 per cent chalcedony, and 26 per cent feldspars in the light mineral fraction. Minerals of the heavy fraction were 15 per cent opaques, 41 per cent amphiboles and pyroxenes, 18 per cent muscovite and biotite, 13 per cent epidote, and 13 per cent of the remaining minerals.

Lenses of the middle section in the Solomon River had 55 per cent quartz, 26 per cent chalcedony, 17 per cent feldspars, and 2 per cent volcanic ash. In the heavy minerals were 12 per cent opaques, 39 per cent amphiboles and pyroxenes, 31 per cent muscovite and biotite, 6 per cent epidote, 2 per cent garnet, and 10 per cent remaining minerals.

Material collected from the lower part in the flood plain of the Solomon River had 38 per cent quartz, 31 per cent chalcedony, 19 per cent feldspars, and 12 per cent volcanic ash in the light mineral fraction. The lower part had 25 per cent opaques, 24 per cent amphiboles and pyroxenes, 32 per cent muscovite and biotite, 8 per cent epidote, 1 per cent garnet, and 10 per cent remaining minerals in the heavy mineral fraction.

Salt Creek, a tributary of the Solomon River, and the Solomon River were slightly dissimilar in mineral composition. Three samples were collected from the bank exposed at the collection site; top, middle, and bottom.

The light mineral fraction from the upper part of Salt Creek had 51 per cent quartz, 40 per cent chalcedony, and 9 per cent feldspars. In this part of the section, the heavy minerals were 35 per cent opaques, 24 per cent amphiboles and pyroxenes, 12 per cent muscovite and biotite, 3 per cent epidote, 2 per cent garnet, and 24 per cent of the remaining minerals.

Mineral composition of the light fraction in the middle part of Salt Creek was 56 per cent quartz, 35 per cent chalcedony, 8 per cent feldspars, and 1 per cent volcanic ash. Opaques were 31 per cent, amphiboles and pyroxenes were 15 per cent, muscovite and biotite were 28 per cent, epidote was 5 per cent, and the remaining minerals were 21 per cent in the heavy mineral fraction.

Material from the lower part of Salt Creek had 71 per cent quartz, 23 per cent chalcedony, 5 per cent feldspars, and 1 per cent volcanic ash in the light mineral fraction. The heavy minerals were 59 per cent opaques, 11 per cent amphiboles and pyroxenes, 4 per cent muscovite and biotite, 3 per cent epidote, 1 per cent garnet, and 22 per cent of the remaining minerals.

Table 7. Miscellaneous descriptions, quantitative mineral analysis.

Minerals	Dust from porch	1950 flood	1935 flood	First terrace south of Wamego
Heavy fraction				
Hematite	0	0	1	2
Magnetite	0	6	5	11
Ilmenite	2	4	2	14
Zircon	1	4	0	2
Topaz	1	2	2	0
Hornblende	25	35	31	7
Epidote	7	12	5	20
Muscovite	35	8	35	4
Biotite	3	1	4	0
Garnet	1	4	1	6
Augite	0	0	1	0
Kyanite	0	0	0	2
Titanite	0	5	2	2
Tourmaline	0	5	0	4
Enstatite	2	1	0	0
Lamproblite	5	0	1	0
Zoisite	3	2	0	4
Hypersthene	6	6	7	0
Clinozoisite	3	1	2	0
Leucozene	4	3	1	22
Tremolite-Actinolite	0	1	0	0
Moissanite	2	0	0	0
Light fraction				
Quartz	47	64	23	72
Chalcedony	28	15	67	12
Orthoclase	9	6	0	11
Microcline	8	5	7	3
Plagioclase	3	10	1	2
Volcanic ash	5	0	2	0

Table 7. (cont.)

Minerals	Top terrace south of Wamego, Sample A	Top terrace south of Wamego, Sample B	Terrace east of Zeandale, Sample A	Terrace east of Zeandale, Sample B
Heavy fraction				
Hematite	0	0	0	3
Magnetite	1	2	2	3
Ilmenite	2	4	1	6
Zircon	2	2	2	1
Topaz	0	2	0	0
Hornblende	12	13	3	3
Epidote	8	13	3	7
Muscovite	53	35	28	12
Biotite	2	4	2	1
Garnet	2	1	4	5
Kyanite	0	1	2	3
Titanite	1	0	0	1
Tourmaline	2	2	4	3
Rutile	0	0	1	0
Sillimanite	0	0	1	0
Enstatite	2	1	2	0
Lamproblite	1	2	0	1
Zoisite	3	2	6	1
Hypersthene	1	2	1	1
Leucoxene	8	13	38	47
Tremolite-Actinolite	0	1	0	2
Light fraction				
Quartz	20	57	57	73
Chalcedony	60	34	32	17
Orthoclase	9	4	7	5
Microcline	9	5	2	4
Plagioclase	2	0	1	1
Volcanic ash	tr	0	1	0

Table 7. (concl.)

Minerals	Saline River samples			Solomon River samples			Salt Creek samples		
	Upper	Middle	Lower	Upper	Middle	Lower	Upper	Middle	Lower
Heavy fraction									
Hematite	0	0	0	2	0	2	3	5	6
Magnetite	5	4	6	3	0	0	5	3	4
Ilmenite	5	4	5	3	2	3	12	7	17
Zircon	8	0	0	0	0	0	3	2	3
Topaz	0	1	2	2	0	5	6	7	2
Hornblende	19	19	17	29	32	15	13	14	7
Epidote	10	10	4	13	6	8	3	5	3
Muscovite	6	16	10	10	30	12	8	20	2
Biotite	0	1	5	8	1	20	4	8	2
Garnet	2	4	3	0	2	1	2	0	1
Augite	0	1	1	2	0	0	0	0	1
Kyanite	4	1	2	4	2	1	3	2	0
Titanite	1	3	3	1	1	1	1	1	2
Tourmaline	4	3	2	4	1	0	4	7	4
Rutile	0	0	0	0	0	1	0	0	0
Sillimanite	0	0	0	0	0	1	0	0	0
Enstatite	0	0	1	1	1	1	1	0	0
Lamproblite	2	2	0	2	2	0	3	0	1
Zoisite	1	0	4	1	3	1	2	0	8
Hypersthene	7	4	5	7	4	5	5	1	1
Clinozoisite	4	5	0	1	3	2	2	2	3
Leucoxene	21	22	30	7	10	20	15	16	32
Corundum	1	0	0	0	0	0	3	0	0
Tremolite-Actinolite	0	0	0	0	0	2	0	0	1
Light fraction									
Quartz	66	60	71	45	55	38	51	56	71
Chalcedony	25	24	14	29	26	31	40	35	23
Orthoclase	3	6	7	12	5	8	4	5	3
Microcline	3	7	5	8	8	6	4	1	1
Plagioclase	2	3	2	6	4	5	1	2	1
Volcanic ash	1	0	1	0	2	12	0	1	1

CORRELATION OF LENSES

Origin of Kansas River Alluvium

Nearly all the material studied and examined during this research indicates that a major part of the alluvium and alluvial material in the Kansas River flood plain is of Pleistocene origin.

According to Frye and Swineford (19) "the prominent high deeply dissected terrace along the Kansas River Valley appears to be composed of Kansas glacial outwash" which is Pleistocene in age. Also Swineford and Frye (21) by petrographic study showed the Republican River to contain Pleistocene alluvium. The Saline River, Solomon River, and Smoky Hill River were included in their investigation (21). These three rivers they stated did not contain later Pleistocene sediments.

The minerals of the samples collected from the Saline River, Solomon River, and Salt Creek, during this study, showed a lower percentage of amphiboles and pyroxenes, and less garnet than the Kansas River flood plain. A larger percentage of the more persistent minerals indicated that the flood plains of these rivers contained alluvium of an older origin than the Kansas River flood plain. The mineral analysis of the lenses in the alluvium and alluvial material in the Kansas River flood plain showed high percentages of amphiboles and pyroxenes, as well as garnet, and with these minerals present in large amounts, a parent material (glacial) of recent origin is indicated.

Another possible means of establishing the origin of the Kansas River alluvium was the volcanic ash which fell during the Pleistocene age, and was found in the light mineral fraction of the alluvium of the Kansas River flood plain. Swineford and Frye (21) have studied and described the petrographic properties of the Pleistocene volcanic ash (Pearlette) and the volcanic ash in the lenses of the Kansas River alluvium seemed to agree with their description of the Pearlette ash.

Age of Kansas River Alluvium

After the mineral analysis of the Kansas River flood plain sediments was completed, a possible correlation of the lenses in the flood plain on the basis of age became apparent.

As stated previously, Swineford and Frye (21) studied and described the petrographic properties of the Pearlette ash and it seemed to agree with the petrographic properties of the volcanic ash in the Kansas River alluvium.

Particular lenses in the flood plain contained large amounts of volcanic ash, which in one case was 82 per cent of the light mineral fraction. Two possible processes could explain the high percentages of volcanic ash which appear in the lenses; either the volcanic ash was deposited on the flood plain in the initial ash fall, or the volcanic ash on the flood plain was reworked, and added to the volcanic ash that was eroded from sources near the flood plain. The volcanic ash initially deposited on the flood plain could have been reworked, and by hydraulic action deposited in the manner found in the flood plain lenses.

The introduction of volcanic ash into the light mineral fraction from foreign sources made it possible to correlate lenses into certain periods of deposition. Both the Kansas and Nebraska Geological Surveys have used Pearlette ash as one of the principal marker beds in the Pleistocene loess. Two interpretations have been made of the age of the Pearlette ash; some thought it should be placed at the top of the Meade formation, while others thought it should be at the bottom of the Loveland formation. The Nebraska Survey (Condra et al., 20) determined that the Crete-Loveland cycle of erosion and valley filling started after the ash was deposited.

With the volcanic ash in the alluvial material of the Kansas flood plain identified as probably Pearlette ash in age, it was possible to attempt correlation of the lenses of the alluvium.

The following age chart of the flood plain was devised (Fig. 19):

"post-Volcanic ash"
"Volcanic ash"
"pre-Volcanic ash"

After the following division of the flood plain sediments had been made, an attempt to examine them for any mineral trend was made. Figure 20 shows the divisions in relation to the volcanic ash present in the lenses.

Numerous mineral variations in the lenses of the cross sections were discovered. In some instances the depth of the cross section and the terrace level of the cross section seemed to affect the mineral distribution.

Every cross section had at least one or more lenses at the top of the section which are included in the age division "post-Volcanic ash" (Fig. 10).

The average composition of the light mineral fraction of the lenses of "post-Volcanic ash" time in the flood plain of the Kansas River was calculated (Fig. 20). In the light mineral fraction were the following percentages: quartz 55 per cent, chalcedony 22 per cent, feldspars 20 per cent and volcanic ash 3 per cent. Similar treatment was given the heavy mineral fraction of the alluvium and alluvial material deposited during the "post-Volcanic ash" period of deposition. The average heavy mineral percentages were opaques 17 per cent, amphiboles and pyroxenes 36 per cent, muscovite and biotite 23 per cent, epidote 11 per cent, garnet 4 per cent and the remaining minerals 9 per cent.

Next the average of the mineral percentages was computed for the period when the "Volcanic ash" was deposited in the lenses of the Kansas River flood plain (Fig. 20). In these lenses on the flood plain, the light mineral fraction averaged: quartz 25 per cent, chalcedony 32 per cent, feldspars 7 per cent, and volcanic ash 36 per cent. The average of the heavy minerals in the heavy mineral fraction contained: opaques 6 per cent, amphiboles and pyroxenes 12 per cent, muscovite and biotite 75 per cent, epidote 3 per cent, garnet 1 per cent, and the remaining minerals 3 per cent.

Some factor must have caused the muscovite and biotite to be deposited with the volcanic ash in the sediments of the depositional period "Volcanic ash". Perhaps the hydraulic action of the water and the similar physical properties of the volcanic ash, and flakes of muscovite and biotite caused them to be simultaneously deposited on the flood plain.

The lenses in the "Volcanic ash" period of deposition were recalculated with a basis of 3 per cent volcanic ash in the light mineral fraction, and 25 per cent muscovite and biotite in the heavy mineral fraction. In the light mineral fraction the recalculated mineral percentages were quartz 38 per cent, chalcedony 49 per cent, feldspars 10 per cent, and volcanic ash 3 per cent. The heavy mineral fraction contained opaques 18 per cent, amphiboles and pyroxenes 36 per cent, muscovite and biotite 25 per cent, epidote 9 per cent, garnet 3 per cent, and the remaining minerals 9 per cent.

When the "Volcanic ash" lenses had their mineral percentages recalculated with volcanic ash 3 per cent, and muscovite and biotite 25 per cent, the mineral percentages of all three periods of deposition seemed quite similar and appeared to have the same origin.

Again the minerals for the lenses in the Kansas River flood plain deposited during "pre-Volcanic ash" were calculated for the average percentages of the minerals in the lenses of the cross sections (Fig. 20). Lenses in this time of deposition showed quartz 44 per cent, chalcedony 38 per cent, feldspars 12 per cent, and volcanic ash 6 per cent in the light mineral fraction. The average percentages for the heavy mineral fraction of these lenses were opaques 15 per cent, amphiboles and pyroxenes 32 per cent, muscovite and biotite 34 per cent, epidote 9 per cent, garnet 2 per cent, and the remaining minerals 8 per cent.

In the lenses of "pre-Volcanic ash" period of deposition volcanic ash was 6 per cent. This amount may be considered slightly large for normal conditions, but it should be noted that ash is present in very recent deposits. The dust collected from the porch (Table 7) showed that the air in recent years has contained as much as 5 per cent volcanic ash. This probably comes from the erosion of local materials. The erosion of volcanic ash from older deposits, possibly even Pliocene in age, could supply the 6 per cent volcanic ash for the "pre-Volcanic ash" sediments.

After the percentages for the three periods of deposition had been determined an attempt was made to record any changes in the mineral compositions of the Kansas River flood plain before and after the deposition of the volcanic ash fall. The following changes in "pre-Volcanic ash" and "post-Volcanic ash" deposition were noted in the light mineral fraction. The "pre-Volcanic ash" alluvium and alluvial lenses held 25 per cent less quartz, and 42 per cent more chalcedony. Differences in the heavy mineral fractions of the "post-Volcanic ash" and "pre-Volcanic ash" time of deposition in the flood plain of the Kansas River were determined. The heavy mineral fraction of the alluvium of "pre-Volcanic ash" time has 35 per cent more muscovite and biotite. These differences are probably not significant since quartz may weather to chalcedony and differences in hydraulic conditions at the sites samples may account for differences in the flaky minerals.

In Fig. 20 the average mineral percentages of the samples obtained from the flood plains of the Solomon River, Saline River, and Salt Creek are recorded. Differences in the average mineral percentages (Fig. 20) between the Kansas River flood plain and the three tributaries in the light mineral fraction showed nothing of importance. In the heavy mineral fraction, however, the differences were 47 per cent more opaques, and 40 per cent more remaining minerals. The comparison of these average mineral percentages indicates that the flood plains of the Solomon River, Saline River, and Salt Creek differ in age and in source material from the Kansas River flood plain. The larger amounts of opaques, and remaining minerals (zircon, tourmaline, rutile, corundum, topaz, titanite) in the flood plains of the three tributaries imply that they are older, since the opaques are probably the result of the weathering of amphiboles and pyroxenes and the remaining minerals are the most stable and resistant minerals. If there is any material in the Kansas River flood plain similar to these tributaries it must be below the material examined.

In Table 7 two floods have been recorded (1935 and 1950). They show the percentages of minerals now being deposited. The difference in the mineral percentages of the two floods may be due to the fact the 1950 flood was a channel flood, and in 1935 the flood rose above the river banks.

	Valencia cross section Lenses	St. Mary's cross section Lenses	East of Wamego cross section Lenses
"post-Volcanic ash" (age-period)	(A), (B), (C), (D), (E)	(A)	(A)
"Volcanic ash" (age-period)	(F), (G), (H) (I), (J)	(B), (C), (D), (E), (F), (G) (H)	(B), (C), (D), (E), (F)
"pre-Volcanic ash" (age-period)	(K), (L), (M), (N), (O), (P), (Q), (R)	(I), (J)	(G), (H), (I), (I)

Fig. 19. Showing separation of lenses in cross sections, according to age relationship.

	Wamego cross section Lenses	St. George cross section Lenses	Skyline cross section Lenses
"post-Volcanic ash" (age-period)	(A), (B), (C), (D)	(A), (B), (C), (D), (E), (F), (G), (H)	(A), (B), (C)
"Volcanic ash" (age-period)	(E)	(I), (J), (K)	(D), (E), (F), (G), (H), (I), (J), (K), (L), (M), (N), (O), (P)
"pre-Volcanic ash" (age-period)	(F), (G), (H)	(L), (M), (N), (O), (P), (Q), (R), (S), (T), (U), (V)	

Fig. 19. (concl.)

	100% Light mineral fraction				100% Heavy mineral fraction					
	1.	2.	3.	4.	5.	6.	7.	8.	9.	10.
"post-Volcanic ash" (age-period)	55	22	20	3	17	36	23	11	4	9
"Volcanic ash" (age-period)	25	32	7	36	6	12	75	3	1	3
"Volcanic ash" recalculated for 3% ash and 25% muscovite and biotite	38	49	10	3	18	36	25	9	3	9
"pre-Volcanic ash" (age-period)	44	38	12	6	15	32	34	9	2	8
Average mineral percentages for the Saline and Solomon Rivers and Salt Creek	57	27	14	2	32	26	18	7	2	15

Key:

1. Quartz
2. Chalcedony
3. Feldspars
4. Volcanic ash
5. Opaques
6. Amphiboles and pyroxenes
7. Muscovite and biotite
8. Epidote
9. Garnet
10. Remaining minerals

Fig. 20. Average mineral percentages of alluvium and alluvial lenses for each division of age, and the tributaries; the Saline and Solomon Rivers and Salt Creek.

Variations of Mineral Distribution in the Lenses

The mineral distribution in the flood plain lenses may have varied for several reasons. From the literature the following conditions were compiled, and considered to be important causes of variable mineral distribution in the present study.

Availability of material to be eroded
Availability of different sizes of material
Hydraulic conditions at the time and place of deposition
Terrace level in the flood plain
Unknown conditions

Availability of Material to be Eroded. The available material to be eroded and deposited on the Kansas River flood plain was considered to be mainly glacial materials of Pleistocene age. According to Frye and Swineford (19) the high dissected terrace along the Kansas River Valley is of Plesitocene age. Mineral distribution in Table 7 showed the upper terraces along the Kansas River flood plain contained the same minerals found in glacial materials. Also Swineford and Frye (21) considered that the Republican River, an important tributary of the Kansas River, contained material of Pleistocene age, while the Solomon River, Saline River, and Smoky Hill River had no later Pleistocene material. Harned (14) stated: "The (Kansas River) alluvium contains all the minerals present in upland and terrace mantle". Three examples of mineral percentages of terrace material along the Kansas River flood plain were recorded in Table 7. Samples from the top terrace along the south valley wall and the next terrace below (recorded as first terrace south of Wamego, Table 7) were collected south of Wamego. Samples were also collected from a terrace east of Zeandale (Table 7). The samples showed the mineral percentages of material immediately available for redeposition on the Kansas River flood plain.

After the average mineral percentages had been calculated for the two periods of deposition, "post-Volcanic ash" and "pre-Volcanic ash" (Fig. 20), and the average mineral percentages were recalculated for the "Volcanic ash" (Fig. 20) period of deposition, it became apparent that the material available for all three periods of deposition was of glacial origin. Volcanic ash in the period of deposition was of glacial origin. Volcanic ash in the period of deposition recorded as "pre-Volcanic ash" (Fig. 20) was 6 per cent. The erosion of older volcanic ash beds may have been sufficient for this amount. Dust (Table 7) collected from a porch shows that the air may contain 5 per cent volcanic ash even at the present time.

The average mineral percentages of the Solomon River, Saline River, and Salt Creek flood plains (Fig. 20) are quite different from the material of the Kansas River flood plain and indicated that they are older in age and from a different source. If sediments like the Solomon River, Saline River, and Salt Creek flood plain are present at all on the Kansas River flood plain they must be below the material examined.

In Table 7, mineral percentages of two floods are recorded. These mineral percentages show the minerals available for deposition at the present time. The difference in mineral composition of the two floods may be due to the fact the 1950 flood was a channel flood and in 1935 the flood water rose above bank level.

Availability of Different Sizes of Material. Available size of the material to be deposited should have had some effect on the mineral distribution on the flood plain. Glacial loess, from the highly dissected terraces along the Kansas River (Frye and Swineford, 19) and from its tributaries (Swineford and Frye, 21) plus glacial sand (and eratics in lens V (Fig. 13) seemed to have contributed the major portion of the sediments in the lenses on the flood plain.

Hydraulic Conditions at the Time and Place of Deposition. Hydraulic conditions on the flood plain had a great effect on the mineral distribution in the lenses. At each cross section, some particular set of hydraulic conditions must have existed during the deposition of the sediments to cause the mineral percentages in the lenses.

The Valencia (Fig. 1), St. George (Fig. 13), and Skyline (Fig. 16) cross sections had more lenses than the other cross sections indicating a possible different type of hydraulic conditions at these areas in the flood plain.

Lenses in the cross sections at Valencia (Table 1), St. George (Table 5), and the Skyline (Table 6) contained larger percentages of amphiboles and pyroxenes, epidote, and the remaining minerals in the heavy mineral fraction, while the cross sections at St. Mary's (Table 2), the one east of Wamego (Table 3), and Wamego (Table 4) had larger percentages of muscovite and biotite in the heavy mineral fraction.

Lenses in the Kansas River flood plain with large percentages of volcanic ash also contained large percentages of muscovite and biotite. Hydraulic action of the water and similar physical properties probably made the simultaneous deposition possible. Another notable characteristic was that all the lenses with large percentages of volcanic ash, and large percentages of muscovite and biotite had a silty appearance.

The Skyline cross section (Table 6) had some lenses with large percentages of volcanic ash and small percentages of muscovite and biotite but these lenses are sandy in appearance. This might be caused either by the difference in material available for deposition in the area, or by different hydraulic conditions at the time of deposition. Since these lenses are not silty in appearance hydraulic conditions are probably responsible.

Some lenses (lens J at St. Mary's, Table 2; lenses G and H at Wamego, Table 4; and lens Q at St. George, Table 5) had large percentages of muscovite and biotite without large percentages of volcanic ash. All of these lenses, however, according to the age division devised, were deposited prior to the heavy ash fall. This indicates that large amounts of volcanic ash were not available during this period for deposition, and that hydraulic action was not responsible for the absence of volcanic ash in these lenses.

Terrace Levels on the Flood Plain. Two general types of terraces were examined; the highest level terrace south of Wamego, Kansas (Kansas Highway No. 99) and two terraces, one below the highest terrace south of Wamego and one 4.9 miles east of Zeandale, Kansas (on Kansas Highway No. 29).

In the highest level terrace no stratification was observed and glacial boulders were seen in the exposed parts of the terrace. Mineral percentages (Table 7) of the highest level terrace showed that it contained minerals of typical glacial material.

The next terrace below the highest level terrace (called first terrace south of Wamego, Table 7) and the Zeandale terrace (Table 7) showed no stratification and the mineral composition was more or less intermediate between typical glacial material and the typical Kansas River alluvium.

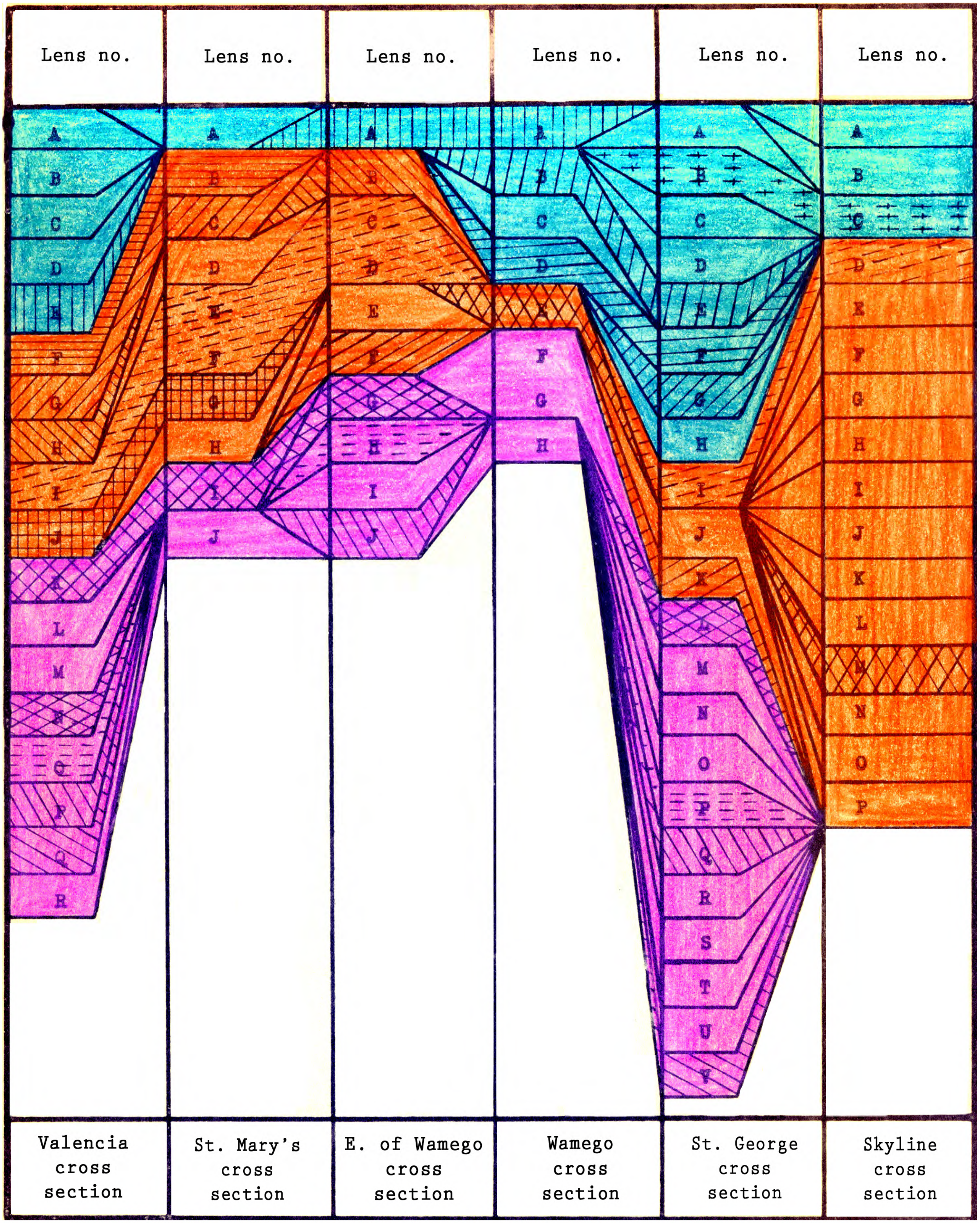
Unknown Conditions. One of the conditions producing variations could have been the chance errors of sampling. Some minerals slides were rechecked for mineral count at a later date, and variations were not over 5 per cent. Rittenhouse (15) gave mode of transportation, either traction or suspension, as one manner of variation, which might affect the heavy mineral composition. Other unknown conditions could have affected the deposition of the minerals in the lenses on the flood plain; however, in the present study little evidence has been obtained for conditions causing variation other than those discussed.

Plate II has been devised to show a possible correlation according to the variable mineral distribution in the lenses of the cross sections studied.

EXPLANATION OF PLATE II

A possible correlation of the lenses in the cross sections according to their mineral distributions. The three colors indicated the three periods of deposition (Figs. 19 and 20), "post-Volcanic ash" (blue), "Volcanic ash" (red), and "pre-Volcanic ash" (lavendar). Lenses with the same hatching in the different cross sections were the lenses that might possibly be similar according to mineral composition. The lenses not hatched, because of their mineral composition, did not seem to extend beyond any other cross section than the one where it was deposited. The separate mineral distributions of each lens were recorded in the following tables: Valencia cross section, Table 1; St. Mary's cross section, Table 2; Cross section east of Wamego, Table 3; Wamego cross section, Table 4; St. George cross section, Table 5; and the Skyline cross section, Table 6. The diagram has no relation to depth, however, the thickness of each lens and the depth of the cross sections were recorded in the following figures: Valencia cross section, Fig. 1; St. Mary's cross section, Fig. 4; Cross section east of Wamego, Fig. 7; Wamego cross section, Fig. 10; St. George cross section, Fig. 13; and the Skyline cross section, Fig. 16.

PLATE II


Lens no.
Lens no.
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Lens no.
A B C D E F G H I J K L M N O P Q R
A B C D E F G H I J
A B C D E F G H I J
A B C D E F G H
A B C D E F G H I J K L M N O P Q R S T U V
A B C D E F G H I J K L M N O P
Valencia cross section
St. Mary's cross section
E. of Wamego cross section
Wamego cross section
St. George cross section
Skyline cross section

SUMMARY AND CONCLUSION

Correlation of the lenses in the alluvial deposits of the Kansas River flood plain appeared possible after the mineral distributions in the lenses were studied. Correlations of the lenses were attempted on the following bases: (1) Correlation based on origin, (2) Correlation based on age, (3) Variations in mineral composition of the lenses, and (4) Differences between Kansas River alluvium and the alluvium of its tributaries.

Correlation Based on Origin

The correlation according to origin was made possible by the presence of minerals in the lenses which gave an indication of the parent material. Large percentages of relatively unstable heavy minerals, amphiboles and pyroxenes, epidote, and garnet, in the lenses (Tables 1, 5, 6) gave an indication that the parent material was rather recent in age (Pleistocene). Volcanic ash (probably Pearlette) was present in quantity in some lenses (Tables 1, 2, 3, 4, 5, 6). In Table 7, mineral percentages are recorded of minerals present in the Solomon River, Saline River, and Salt Creek flood plains. These three rivers are thought to contain pre-Pleistocene alluvium.

Correlation Based on Age

Study of the minerals showed volcanic ash in the light mineral fraction, and the ash was thought to be of Pleistocene age (Pearlette). It was then possible to separate the lenses of the flood plain into three periods of deposition:

"post-Volcanic ash"
"Volcanic ash"
"pre-Volcanic ash"

After the lenses were divided into this sequence (Fig. 19), an attempt was made to distinguish any difference in the average mineral composition (Fig. 20) during the three periods of deposition. When the mineral composition of the light fraction of the "Volcanic ash" period was recalculated to contain the same amount of volcanic ash as the sequence above and below it, its similarity to these sequences became apparent. The recalculation of the mineral composition of the heavy suite from the "Volcanic ash" period to a similar amount of muscovite and biotite as the sequences above and below it revealed the similarity of the heavy fractions of all three periods of deposition. Although a small difference in average mineral percentages was noted in the lenses of the three periods of deposition, it became apparent that all three periods of deposition show the same suite of minerals and the small change in the average mineral percentages of the unstable minerals (Fig. 20) indicates that the accumulation of the deposits on the flood plain occurred rather recently. Terrace samples (Table 7) south of Wamego and east of Zeandale show the mineral percentages characteristic of local glacial material, and represent the sort of material available for redeposition on the present day Kansas River flood plain.

The floods of 1935 and 1950 (Table 7) gave an indication of the material now being eroded and now being deposited on the present day Kansas River flood plain.

Variations in Mineral Composition of the Lenses

Five conditions, (A) Availability of material to be eroded, (B) Availability of different sizes of material, (C) Hydraulic conditions at time and place of deposition, (D) Terrace level on the flood plain, and (E) Unknown conditions, seemed to affect the mineral distribution in the lenses on the flood plain. After study of the mineral distributions (Tables 1, 2, 3, 4, 5, 6) in the cross sections was completed, the arrangement of the lenses into what was considered the best possible manner of correlation was made (Plate II).

Differences Between Kansas River Alluvium and the Alluvium of Its Tributaries

Comparison of the average mineral percentages for the Solomon River, Saline River, and Salt Creek with the average mineral percentages for the Kansas River flood plain indicates that the tributaries are different in both source and age. The larger percentages of the more resistant minerals in the flood plains of the three tributaries indicate that they are older in age. If such material is present at all on the Kansas River flood plain, it would have to be below the material now exposed.

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CORRELATION OF ALLUVIAL LENSES ALONG THE KANSAS RIVER BETWEEN TOPEKA AND OGDEN, KANSAS

by

CHARLES DWINNELL SEILER

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During the research six cross sections along the channel of the Kansas River were measured from the top of the bank to water level. The cross sections were spaced approximately ten miles apart except the cross section 3.5 miles east of Wamego and the cross section at Wamego. Each section was excavated vertically to the water level along the bank of the river and accurate measurement of each lens in the cross section was made. From each lens measured a sample of the material was collected for mineral analysis. The lenses in each cross section were described according to color, grain size and general characteristics. Samples also were collected from terrace deposits and deposits of the Saline River, the Solomon River, and Salt Creek to aid in correlation of the lenses.

The samples were dried, weighed, and then dispersed in a mechanical shaker. After shaking each sample was sieved to save the grain size best suited for mineralogical study under a petrographic microscope. Iron stains and calcium carbonate were removed by boiling the sample for five minutes in hydrochloric acid. Next, the samples were washed free of acid and dried for specific gravity separation in bromoform. Bromoform has a specific gravity of approximately 2.89 and all minerals with a lower specific gravity floated while the minerals with a higher specific gravity sank. The minerals that floated on bromoform were called the light minerals and consisted of the following: quartz, feldspars, chalcedony, and volcanic ash. Ilmenite, hornblende, zircon, epidote, muscovite, biotite, garnet, tourmaline, titanite, and hypersthene are heavier than bromoform and sank in the liquid.

After the minerals had been separated a microscopic slide of the light and heavy minerals of each sample was made. Canada balsam was used as a mounting medium. A minimum of a hundred grains or more were counted and identified on the microscopic slides with the aid of the petrographic microscope. Percentages of the minerals in the slides were calculated for use in correlation of the lenses of the cross section.

Correlation of the lenses in all the cross sections was attempted by comparing percentages of the minerals in the lenses. Presence, dominance, and absence of minerals in certain lenses helped to establish correlation along with the percentages of the minerals in lenses. Material collected from the terraces and tributaries aided in the establishment of origin and age of the material along with the correlation of the lenses in the Kansas River alluvium.