V. GEOLOGY

David J. Barr

A. Introduction

1. Scope

The geology section of the LMVD contract consists of the following components:

1. Classification and mapping of surficial soil materials along the Mississippi River from Alton, Illinois to the Gulf of Mexico, including the Atchafalaya River; Appendix H.
2. Preparation of geologic profile of river bed soil strata along the study reach from existing borings; Appendix I.
3. Map of the bedrock and bluff geology in that portion of the study reach above Cairo, Illinois; Appendix J.

All geologic materials mapping has been accomplished with previously existing data and without the benefit of field investigation. Consequently, mapping detail as well as mapping accuracy is variable throughout the study reach. The geologic mapping has served to pinpoint those areas for which existing geologic data are deficient.

2. Relation to Morphology Study

The geology study was conducted in close association with the morphology study. Maps produced in response to study requirements were all made to the same 1:62,500 scale ratio. Inasmuch as geologic and morphologic river parameters are interrelated, the several map overlays can be superimposed to provide a graphic means of correlating morphologic response to geologic condition.

B. Surficial Soil Mapping

1. Sources of Information

Surficial soil maps of the entire study reach were prepared entirely from interpreted aerial photography. No field investigation was conducted. The general character of the alluvial materials was such that small scale color infrared photography was deemed to be the most suitable data from which to interpret surficial soil materials, as well as many associated morphologic features. The primary photographic sources of data were obtained from four NASA high altitude aircraft missions encompassing the study reach. Pre-1973 flood and post-1973 flood color infrared photography was obtained for the initial map preparation. In August of 1975, it was learned that high altitude color infrared photography was flown for the Corps of Engineers in the fall of 1974. Inasmuch as this was low water photography it, without a doubt, represented the most recent and best available data for surficial soil materials interpretation and mapping. Thus, selected frames of this photography were obtained to revise and complete the surficial mapping objective. The three NASA missions are identified and described as follows:

Pre-1973 Flood

NASA Flt: 73-027, 25 Feb. 1973, Frames 9131-9195, EROS I.D. 573000987, Aerochrome Infrared, 2443 film.

Post-1973 Flood

NASA Flt: 73-057, 11 April 1973, Frames 8898-9008, EROS I.D. 573001087, Aerochrome Infrared, 2443 film.

NASA Flt: 73-058, 12 April 1973, Frames 9025-9087, EROS I.D. 573001092, Aerochrome Infrared, 2443 film.

NASA Flt: 74-014, 4 Feb. 1974, Frames 5774-5853, EROS I.D. 574001598, Aerochrome Infrared, 2443 film.

Low-Water Photography

NASA Mission 289, Fall 1974, Color Infrared Film

This NASA photography has been reproduced at an approximate 1:62,500 scale ratio with full coverage provided to each of the Lower Mississippi River Division Corps Districts. Since each District has a flight line map and an established frame code corresponding to 15' topo. quad. sheets, the following table includes the 15' quad. name on some portion of which a surficial soil materials map has been prepared; the Corps of Engineers, Quad. No.; and the NASA Mission 289 line, roll and frame number corresponding to the topo. quad. overlay.

Quad. Name	T-1 Project Overlay No.	Quad No.	NASA Flight	Film Roll No.	Frame No.
*Baldwin	SM 1	Q-0	69	08	158, 160
*Alton	SM 2	P-0.3	68	08	143
--		P-0.2	68	08	139,141
--		O-0.2	67	08	106, 108
Kimmswick	SM 3	O-0.1	67	08	110
Crystal City	SM 4	O-0.0	67	08	112, 115, 117
Renault	SM 5	P-0	68	08	137
Weingarten	SM 6	P-1	68	08	131, 133, 135
Chester	SM 7	Q-1	69	08	162, 164
Campbell Hill	SM 8	R-1	70	09	034
Altenburg	SM 9	R-2	70	18	023
				09	032
Alto Pass	SM 10	S-2	71	09	072
Cape Girardeau	SM 11	R-3	70	18	019, 021
Jonesboro	SM 12	S-3	71	09	078
Thebes	SM 13	S-4	71	09	074, 076
Charleston	SM 14	S-5	71	09	080
Cairo	SM 15	T-4	72	09	093, 095, 097
Wickliffe	SM 16	T-5	72	09	097
Hickman	SM 17	T-6	51	18	094
Bayouville	SM 18	S-6	51	09	087, 084, 086
Reelfoot Lake	SM 19	S-7	50	18	026, 028
New Madrid	SM 20	R-6	49	18	011
Portageville	SM 21	R-7			
Caruthersville	SM 22	R-8	70	18	013, 015
Hales Point	SM 23	R-9	49	18	003, 005, 007
Blytheville	SM 24	Q-9	48	18	169, 171
Osceola	SM 25	Q-10	48	18	173
Evadale	SM 26	P-10	47	17	156, 158, 160
Millington	SM 27	Q-11	48	12	011
				18	175
Jericho	SM 28	P-11	47	12	014
Memphis	SM 29	P-12	47	12	016, 018
Edmondson	SM 30	O-12	46	12	034, 036
Horseshoe Lake	SM 31	O-13	46	12	032
Clayton	SM 32	O-14	46	02	168
				12	028, 030

*Omitted because majority of area is urban in nature and insufficient data were available for overlay.

Quad. Name	T-1 Project Overlay No.	Quad No.	NASA Flight	Film Roll No.	Frame No.
Latour	SM 33	N-14	45	12	065, 067
Farrel	SM 34	N-15	45	12	069, 071
Hennico	SM 35	L-16	43	12	148, 150
				17	084
Modoc	SM 36	M-15	44	12	108
Mellwood	SM 37	M-16	44	12	106
Pace (Gunnison)	SM 38	M-17	44	12	100, 102, 104
Big Island	SM 39	L-17	43	12	150, 152
Lamont	SM 40	L-18	43	12	154
Greenville	SM 41	L-19	43	12	156
Readland (Avon)	SM 42	L-20	43	12	158, 160
Lake Province	SM 43	L-21	43	12	162
Alsatia (Fitler)	SM 44	L-22	43	12	164
Talla Bana	SM 45	L-23	43	12	166
Vicksburg	SM 46	M-23	44	07	214, 216
Yokena	SM 47	M-24	44	07	218, 220
Davis Island	SM 48	L-24	34	12	168
				18	108
St. Joseph	SM 49	L-25	11	07	193
			43	16	110, 112
Locust Ridge	SM 50	K-25	42	16	083, 085
Natchez	SM 51	K-26	10	06	005
Kingston	SM 52	K-27	10	06	007, 009, 011
Ferriday	SM 53	J-26	9	06	61
Monterey	SM 54	J-27	9	06	059
Artonish	SM 55	J-28	9	07	055, 057
Batchelor	SM 56	J-29	9	07	170
Fordoche	SM 57	J-30	9	07	172, 174
St. Francisville	SM 58	K-29	10	06	013
New Roads	SM 59	K-30	10	06	015, 017, 019
Cross Lake (Grosse Tete)	SM 60	K-31	10	06	021
Zachary	SM 61	L-30	11	07	183, 185
Baton Rouge	SM 62	L-31	11	14	001, 003
White Castle	SM 63	L-32	11	14	005, 007
Donaldsonville	SM 64	M-32	12	14	030
Thibodeaux	SM 65	M-31	12	05	032, 034
Mount Airy	SM 66	N-32	13	03	016, 018
Bonnet Carre	SM 67	O-32	14	02	128, 130
Hahnville	SM 68	O-33	14	02	122, 124, 126
New Orleans	SM 69	P-33	15	02	099, 101, 103
Garataria	SM 70	P-34	15	02	105
St. Bernard	SM 71	Q-33	16	02	077
Pt. La Hache	SM 72	Q-34	16	02	075
Ft. Livingston	SM 73	Q-35	16	02	069, 071, 073
Black Bay	SM 74	R-34	17	02	060
Empire	SM 75	R-35	1	02	062, 064
Venice	SM 76	S-35	18	02	043
West Delta	SM 77	S-36	18	02	037, 039, 041
East Delta	SM 78	T-36	19	02	025, 027
Greton Island	SM 79	T-35	19	02	021, 023

ATCHAFALAYA

Quad. Name	T-1 Project Overlay No.	Quad. No.	NASA Flight	Film Roll No.	Frame No.
Moreariville	SM 80	I-28	8	07	158
Odenburg	SM 81	I-29	8	07	156
				06	073
Palmetto	SM 82	I-30	8	06	075
				07	077
Arnaudville	SM 83	I-30	8	06	077
Maringovin	SM 84	J-31	9	07	174, 176
				14	028
Loreanville	SM 85	J-32	9	14	024, 026
Lake Chicot	SM 86	K-32	10	06	023
Centerville	SM 87	K-33	10	06	025
Belle Isle	SM 88	K-34	10	06	027, 029
Morgan City	SM 89	L-34	11	14	009, 011, 013
Point Aufer	SM 90	K-35	10	06	031

Other reference photography was obtained from a variety of sources especially for the Morphology study. Key contacts for sources of aerial imagery are summarized as follows:

1. U.S. Army Corps of Engineers
   Office of the Chief Engineers
   Mr. Jack Jarman
   Mr. David Penick

2. U.S. Army Engineer Topo. Labs
   Mr. Robert Nichols, Chief Liaison

3. U.S. Army Corps of Engineers
   Lower Mississippi Valley Division
   Mr. Dusty Rhodes

4. Defense Mapping Agency
   Mr. Carmen Di Carlo, Headquarters

5. U.S. Air Force
   Lt. Col. John Dutton, Hq. USAF Operations
   Mr. Junior Hicks, Rome Air Dev. Center

6. Environmental Protection Agency
   Col. Vern Webb, Chief EPIC

7. U.S. Geological Survey
   Mr. Fred Doyle, Headquarters, Topo.: Reston, VA
   Mr. Don Orr, Sioux Falls, SD

2. Map-Making Methods

The surficial materials maps were prepared from small-scale color infrared photographs using accepted photo interpretation techniques.

Photo pattern elements were evaluated to yield a logical deduction as to the most probable landform-parent material existing throughout the study reach. Topographic form, drainage, vegetation and photo tones and textures, as well as boundary conditions and regional associations, were evaluated. Major landform-parent material units and those man-made features evident on the photography were delineated and marked as indicated on the key presented in fig. 5.1.

3. Significance of Map Units

The general surficial soil material descriptions and logic of interpretation of the landform units are summarized as follows:

a. Oxbow Lakes--Water-filled meander cutoffs and channels, now abandoned and removed from the active channel, were mapped as oxbow lakes. Arcuate swampy features with dark image tones indicative of high soil-water contents were also included when, in the opinion of the interpreter, they were more characteristic of oxbows than backswamp or channel fill.

b. Channel Fill--Filled arcuate meander sears with no apparent standing water were mapped as channel-fill deposits. Fine-grained sediments associated with the cutoff plugs and organics were inferred from the apparent poor drainage and dark image tones. Clay plugs would be expected to be located at ends of such filled channels or oxbows.

c. Backswamps--The low, swampy areas generally lying behind natural levee deposits were classified as backswamps when dark image tones indicated standing water, high soil moisture content and/or organic clayey soil materials.

d. Natural Levee--The topographically high, better-drained portions of natural levees were mapped as discrete landforms, whereas the

Fig. 5.1 - MAJOR LANDFORM-PARENT MATERIAL UNITS AND MAN-MADE FEATURES

KEY

*Note - Man-Made Feature symbols represent visually interpreted features only.

Bluff Line	
Levees	PRINCIPAL / OTHER
Dikes	
Revetments	REV
River Channel	
Oxbow Lakes	OL
Channel Fill	CF
Backswamp	BS
Natural Levee	NL
Ridge and Swale Deposits	RS
Sand Bar	SB
Natural Levee Deposits	NLD
Backswamp - Deltaic Deposits	BSD
Borrow Pits	BORROW

broad, gently-sloping deposits lying generally between the active channel and the backswamp were mapped as "natural levee deposits." In the case of the discrete natural levee, light image tones generally indicated relatively coarse-grained material intermediate in size between point bar (ridge and swale) and channel-fill deposits.

e. Ridge and Swale--This terminology was used to identify the characteristic high and low relief arcuate features associated with point bar deposits. The bars are indicated on the photography by pattern and light tone, whereas the swales are generally low dark toned. In general the bars contain relatively coarse-grained material. The swales are high in organics, clays and moisture content.

f. Sandbars--Channel deposits evident on low-water stage photography as light-toned features of an alluvial nature were mapped as sandbars. Although the particle size distribution of such landforms would vary with their position in the channel and their location downstream, such deposits should contain relatively coarse materials.

g. Natural Levee Deposits--These materials were inferred as a component of natural levee deposition. The broad expanses which generally slope away from the channel were characterized as being darker in color than the topographic levee and as having a more random image texture. It was inferred that these deposits have more variability of particle size and are generally finer grained.

h. Backswamp-Deltaic Deposits--In the lower Mississippi and Atchatalaya portion of the study reach, this symbol is used to delineate those features exhibiting Deltaic characteristics. Specific detailed Delta units were not interpreted.

The preceding units were chosen as being most suitable for interpretation and delineation from aerial photography without the benefit of field investigation. They are similar to those units used by R.T. Saucier in his report 3-659, "Geological Investigation of the St. Francis Basin", W.E.S., Sept., 1964. Inasmuch as no field investigations were made and no subsurface data used in compiling the surficial materials map, inferences from the maps alone as to subsurface geology should not be made. The mechanics of the surficial materials map-making process were simplified with the use of a Bausch and Lomb Zoom Transfer Scope. Color infrared transparencies were positioned on a lighted easel for projection on 15-minute topo. quad. sheets. By varying the light intensity and using scale variations the projected images were interpreted, landforms delineated, and resultant boundaries traced on overlays all in one operation. A surficial materials overlay was thus prepared for all imaged portions of those topo. quads. representing the study reach. Three photo interpreters were employed in making the surficial materials maps.

4. Accuracies and Precision

The surficial materials maps are reconnaisance maps. The small-scale color infrared photography was not rectified or otherwise corrected. Scale matching to the 15-minute topo. base sheets was accomplished with the Zoom Transfer Scope. The geometric quality of the surficial materials maps is good and is entirely consistent with the reconnaisance nature of the interpreted products. Many changes in the location of the river as well as physical features were observed and mapped. The overlays represent conditions as they existed in the fall of 1974. In those cases where the river position has changed since the date of preparation of the base map, the overlays indicate 1974 conditions.

C. River Bed Geologic Profile

1. Introduction

The primary objective of this portion of the study was to prepare a profile of the geologic materials that make up the various soil strata beneath the river bottom from existing data. The method of presentation consists of a series of boring logs plotted on large cross-section sheets where information is available. Each Corps of Engineers District Office, the U.S. Geological Survey, the State Highway Departments of States adjoining the river and the Waterways Experiment Station, Vicksburg were checked as possible sources of river bed boring data. The search indicated that a large amount of data are available adjacent to the river but a very limited amount is available in the channel.

2. Sources of Data

The specific sources of data used for preparing the cross sections are boring logs from the State Highway Departments of States adjacent to the river as indicated on the boring logs; the Corps of Engineers' Technical Report, "Geological Investigation of the Mississippi River Area, Artonish to Donaldsonville, La.", 5.69-4; "Geological Investigation of the Boeuf-Tensas Basin Lower Mississippi Valley", by R. T. Saucier, 3-757; and the Corps of Engineers Technical Report, "Investigation of Under-Seepage, Mississippi River Levees, Alton to Gale, Ill.", including the levee borings from Alton to Gale, Illinois.

3. Methods of Profile Preparation

Due to the small number of borings available in the channel, a profile of selected levee borings from Alton to Gale, Ill. is presented for subsurface information in the St. Louis District. Since the river is fairly restricted within the bluff lines, it was felt that the levee borings would be a fair indication of the material which probably exists below the river bed. However, this is still only a general indication of river bottom materials because of the great variability of soil configuration in an alluvial deposit. Attempts to use levee and revetment borings as a source of data for the preparation of river bed profiles and river cross sections proved to be unreliable. Available river channel borings from bridge crossings in the Memphis, Vicksburg, and New Orleans Districts were collected and presented in specific cross-sections along the river. The cross sections consist of:

a. Boring log profiles from Alton to Gale, Illinois with eight miles of the river shown on each sheet. The borings are spaced at a minimum of 1500-2000 ft. and are plotted on a vertical scale of 1 inch = 20 feet. The channel invert profile is shown as a dashed line for reference. Each sheet also displays a plan view of the eight-mile section of the river with the location of each boring noted on the plan view.

b. Bridge borings are presented as a cross section of the river bottom from levee to levee (or levee to bluff) with selected borings along the section. The river channel cross section at the time the borings were made is shown as a dashed line for reference. In addition to the cross-section borings, a location map for each district is presented, indicating the location of each cross section.

4. General Accuracy and Precision of Cross Sections and Profiles

   The location of the boring log profiles are presented to the nearest 0.2 mile and the elevations in mean sea level are to the nearest 2.0 feet. The cross-section borings are presented to the nearest 50 feet and elevations are as accurate as the sources of information.

D. Conclusions and Recommendations for Surficial Soil and Riverbed Geology Studies

The amount of information available for a study of the river bed materials is very limited. A large amount of data exists from levee, dike and revetment borings but a very small amount is available in the river channel itself. Due to the high degree of variability of soil deposits in an alluvial environment, extrapolation of soil profiles from the river bank borings has proven to be unreliable. It is recommended that additional borings be secured in the river channel to provide a reliable profile of river bed materials. This would allow a better estimate of river bed stability as well as indicate stretches of river likely to be problem scour and fill areas during times of flood.

1. Conclusions

   Small scale color infrared photography is an excellent data source from which to interpret and infer probable surficial soil types. When coupled with field investigation, it can provide for very efficient engineering soils data collection. The interpretation of surficial soils was accomplished with no major difficulties using established interpretative procedures. The products are necessarily only reconnaissance in nature. Thus, coarse and fine - grained material can be inferred from an analysis of landform type.

2. Recommendations

Inasmuch as small scale photography is relatively easy to procure, it is recommended that reconnaissance-type floodplain surficial materials maps be prepared at perhaps 5 to 10 year intervals. Such maps could easily be used to incorporate land-use change data. Channel shifts and deposits could be monitored at a much greater frequency to yield flood damage information. However, other than for monitoring flood damage and land use change, the surficial soils maps represent conditions that should remain stable for some time and as such should be used for planning any desired field investigations. It is further recommended that consideration be given to a study of interrelationship between surficial materials, stream morphology and land use change. Such a study could be facilitated by using the prepared geology, morphology and energy dissipater overlays for a mechanical comparison of the mapped parameters.

E. The Bedrock Valley of the Mississippi--Alton Through Thebes Gorge

Thomas R. Beveridge

This study is divided into two phases, contour maps of the valley bedrock surface and a compilation of bluffline geologic mapping. A third phase, study of the sedimentary valley fill, was abandoned because of the lack of modern deep drilling data.

1. Bluffline Geology

No geologic mapping was done as part of this project. Mapping was transcribed from published and unpublished maps, the majority of them from the Missouri and Illinois Geological Survey files and publications. Mapping spans more than 50 years; therefore, standardization of the stratigraphic units and intervals used on the various maps were impractical. The composite rock columns and mapping symbols correlation shown on Plate G-1 were designed with practicality having a higher priority than the niceties of stratigraphic nomenclature. Areas left blank are highly faulted with no detailed mapping available. An example is on the Missouri side of the Thebes Gorge where spot mapping has indicated faulting comparable to that on the Illinois side.

2. Valley Bedrock Surface

The lowest available elevations of the bedrock surface are 277 feet above sea level near Alton and 154 feet on the Alto Pass Quadrangle. These figures exemplify the need for more data, as the Alton figure is in the northern part of the quadrangle where more concentrated borehole data are available from Locks and Dam No. 27, whereas less closely spaced data downstream do not give as low a figure on the same quadrangle. The Alto Pass Quadrangle figure of 154 is lower than available figures downstream in the Cape Girardeau area where 159 feet above sea level is the lowest. Data on the Chester Quadrangle are insufficient to show whether the rock thalweg is on the east or west side of the valley and the location of the thalweg on the Jonesboro Quadrangle is shown very approximately. Countouring does show that figures of what appeared to be unusually high or low bedrock are in most cases reliable; the thalweg is so narrow that the probability of encountering it in random drilling is not great. Modern "rock islands" such as Tower Rock and Fountain Bluff on the Altenburg and Alto Pass Quadrangles give credence to the existence of a varied locally high rock. Time did not permit obtaining all of the boring data that are probably available, especially those from construction activities and water wells not on public record. Because of the lack of data on depth to rock in major tributaries, no consistent attempt was made to assure fidelity in plotting main valley contours as related to alluvial fill in tributaries. Data are sufficient to show that Fisk (28) working with less data in the 1940's does not have the valley as deeply entrenched as do the maps of this report. His lowest contour, using a 25-foot interval, is the 200-foot in the Cape Girardeau area, whereas the lowest contour on the present report is the 140-foot in the same area (projected from the 154-foot figure on the Jonesboro Quadrangle). More detailed data will probably show more complex channel shiftings and possibly superposition of channels which crossed older buried channels in response to glacial activity.

3. Studies Needed

The present study has impressed the writer with the lack of modern data as contrasted with much of the area farther downstream where extensive and intensive borings and studies have been made. Boring data were so sparse in the stretch between Thebes Gorge and Cairo that no attempt was made to contour the bedrock surface. Borings showing detailed sediment lithology between the bottom range of levee borings and bedrock were so scarce that no meaningful study could be made of the deeper part of the fill. The Cairo-Alton stretch of the Mississippi is somewhat of a data orphan as contrasted with the downstream stretch to the Gulf. The bedrock valley, nature of the fill, and geologic history cannot be the object of much further study until further data are available. The highest priority for data would include boreholes across the valley to delineate the thalweg more accurately and to determine the nature of the sedimentary fill. Seismic and/or resistivity geophysical studies would be very useful tools, and, if used in conjunction with existing or future borings, could be relatively low-cost data sources. The Alton-Cairo stretch of the Mississippi poses a number of unanswered questions of an academic nature. Is the original valley preglacial, or Pleistocene in origin? The writer, from buried valley studies in Iowa, suspects it is preglacial. How much influence does geologic structure and lithology have on the present and past locations of the thalweg? A geologic map of bedrock between the blufflines would be a necessary part of such a study. How much influence did glaciation have in forcing the river out of the older channels? The Mississippi, above Cairo, is a fruitful area for classic studies like those of Fisk and Saucier, but such studies cannot be made without a great amount of new subsurface data.

F. Data Sources

1. Board of Examination and Survey of the Mississippi River, 1908, Mississippi River from St. Louis, Mo. to Cairo, Ill., Charts 1-17: House
2. Brill, Kenneth J., Jr., 1960, Manuscript Reconnaissance Geologic Mapping, St. Louis County: Mo. Geol. Survey Files, Rolla, Mo.
3. Bergstrom, Robert E. and Walker, Theodore R., 1956, Groundwater Geology of the East St. Louis Area: Ill. Geol. Survey, R.I. 191.
4. Schict, R.J., 1965, Groundwater Development in East St. Louis Area, Illinois: Ill. State Water Survey Division, R.I. 51.
5. Lutzen, Edwin E. and Rockaway, John D. Jr., 1971, Engineering Geology of St. Louis County, Missouri: Mo. Geol. Survey, Engr. Geol. Ser. No. 4.
6. Bowman, Isaiah, 1907, Water Resources of the East St. Louis District: Ill. Geol. Survey, Bull. 5.

7. Fenneman, N.M., 1911, Geology and Mineral Resources of the St. Louis Quadrangle Missouri-Illinois: U.S. Geol. Survey, Bull. 438.
8. Baxter, James W., 1965, Limestone Resources of Madison County, Illinois: Ill. Geol. Survey, Circ. 390.
9. Brill, Kenneth J., Jr., 1966, St. - Its Geologic Aspect: Geotimes, pp. 11-15, April.
10. Brill, Kenneth J., Jr., Wallace, G.E., and Frank, A.J., 1960, Middle Mississippian and Pennsylvanian Stratigraphy of St. Louis and St. Louis County, Missouri: Assoc. of Mo. Geologists, Seventh Ann. Meeting Sponsored by Dept. of Geology and Geological Engineering, Institute of Technology, St. Louis University, St. Louis, Mo.
11. Martin, James A. and Wells, Jack S., 1966, Middle Ordorician and Mississippian Strata, St. Louis and St. Charles Counties, Missouri: Ann. Meeting Amer. Assoc. of Pet. Geologists Guidebook, Mo. Geol. Survey R.I. 34.
12. U.S. Army Engineer District, St. Louis, 1973, Upper Mississippi River Basin: River-Alton, Illinois, Locks and Dam No. 26 (Replacement), Design Memorandum No. 7 - Cofferdam Ph. I, Top of Rock Contour Map; Top of Illinoian Ice Contact Deposits, June.
13. Missouri Geological Survey; Well Log Files, Rolla, Mo.
14. Illinois State Geological Survey; Well Log Files, Urbana, Ill.
15. Illinois State Highway Department: Drill Data Files, Springfield, Ill.
16. Missouri State Highway Department; Drill Data Files, Jefferson City, Missouri.
17. U.S. Army Engineer District, St. Louis; Core and Quarry Data Files, St. Louis, Mo.
18. Miller, Don E. <u>et al.</u>, 1974, Water Resources of the St. Louis Area, Missouri: Mo. Geol. Survey and U.S. Geol. Survey, Water Resources Dept. 30.
19. Weller, Stuart and Weller, J. Marvin, 1939, Preliminary Geological Maps of the Pre-Pennsylvanian Formations in Part of Southwestern Illinois; Waterloo, Kimmswick, New Athens, Crystal City, Renault, Baldwin, Chester, and Campbell Hill Quadrangles: Ill. Geol. Survey, R.I. 59.
20. Knight, G.L., 1923, Unpublished Manuscript Geologic Map, Kimmswick 15' Quadrangle; Mo. Geol Survey.
21. Schmitz, R.J., 1965, Unpublished Manuscript Geologic Map Selma 7½' Quadrangle: Mo. Geol. Survey.
22. Schmitz, R.J., 1966, Unpublished Manuscript Geologic Map Danby 7½' Quadrangle: Mo. Geol. Survey.
23. Lutzen, Ed, 1968, Unpublished manuscript Geologic Map Herculaneum 7½' and Northwestern Portion Vallmeyer 7½' Quadrangles: Mo. Geol. Survey.
24. Stinchcomb, G.L., 1966, Unpublished Manuscript Geologic Map Oakville 7½' Quadrangle: Mo. Geol. Survey.
25. Weller, Stuart, and St. Clair, Stuart, 1922, The Geology of Ste. Genevieve County and Parts of Perry and St. Francois Counties: Mo. Bur. Geol. and Mines, Vol. 22.
26. Weller, J. Marvin, and Ekblaw, G.E., 1940, Preliminary Geologic Map of Parts of the Alto Pass, Jonesboro, and Thebes Quadrangles: Ill. Geol. Survey, R.I. 70.

27. Pryor, W.A., and Ross, C.A., 1962, Geology of the Illinois Parts of the Cairo, LaCenter, and Thebes Quadrangles: Ill. Geol. Survey Circ. 332.
28. Fisk, H.N., 1944, Geological Investigation of the Lower Missippi River: Miss. River Comm., War Dept.
29. Stoll, J.K. and Brown, R.D., 1975, Inventory of Physical and Cultural Elements, Middle Mississippi River Floodplain (River Reach-St. Louis, Missouri, to Cairo, Illinois): Envir. Effects Lab., U.S. Army Waterways Exp. Sta., Vicksburg, Miss., (prepared for U.S. Army Engr. Dist., St. Louis); Misc. Paper Y-75-1.
30. Johnson, C.H., 1962, Guidebook to the Geology in the Vicinity of Cape Girardeau, Missouri including Crowleys Ridge: Assoc. of Mo. State Geologists, 9th Ann. Field Trip, Southeast Mo. State Coll., Cape Girardeau.
31. Willman, H.B. et al., 1975, Handbook of Illinois Stratigraphy: Bull. 95.
32. Howe, W.B. and Koenig, J.W., 1961, The Stratigraphic Succession in Missouri: Mo. Geol. Survey, Vol. XL, 2d Ser.
33. Horberg, C.L., 1950, Bedrock Topography of Illinois: Ill. Geol. Survey, Bull. 73.
34. Piskin, Kemol, and Bergstrom, R.E., 1967, Glacial Drift in Illinois: Thickness and Character: Ill. Geol. Survey, Circ. 416.
35. Collinson, C.W., 1957, The Illinois Geological Society Field Trip to the Ordovician, Silurian, Devonian and Mississippian Rocks of Western Illinois: Ill. Geol. Survey.
36. Swann, D.H., 1956, Southern Illinois Field Trip: Ill. Geol. Society.
37. Bergstrom, R.E. (editor), 1968, The Quaternary of Illinois: Univ. of Ill., Coll. of Agriculture, Special Public. No. 14, Urbana, Ill.
38. Marshall, J.H., Jr., 1950, Geology In and Adjacent to Cape Girardeau, Cape Girardeau, Missouri: Unpublished Master's Thesis, Univ. of Mo., Columbia.
39. Gealy, J.R., 1955, Geology of Cape Girardeau and Jonesboro Quadrangles, Southeastern Missouri: Unpublished Doctoral Diss., Yale Univ., New Haven Conn.
40. Satterfield, I.R., 1973, Unpublished Manuscript Geologic Map McClure and Cape Girardeau Quadrangles: Mo. Geol. Survey.
41. Flint, R.F., 1925, Unpublished Manuscript Maps, Altenburg and Campbell Hill Quadrangles, Mo. Geol. Survey.