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National Uranium Resource Evaluation

POPLAR BLUFF QUADRANGLE ARKANSAS AND MISSOURI

Geochemex
Boulder, Colorado

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PREPARED FOR THE U.S. DEPARTMENT OF ENERGY
Assistant Secretary for Nuclear Energy
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This report is a result of work performed by Geochemex, through a Bendix Field Engineering Corporation subcontract, as part of the National Uranium Resource Evaluation. NURE was a program of the U.S. Department of Energy's Grand Junction, Colorado, Office to acquire and compile geologic and other information with which to assess the magnitude and distribution of uranium resources and to determine areas favorable for the occurrence of uranium in the United States.

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NATIONAL URANIUM RESOURCE EVALUATION
POPLAR BLUFF QUADRANGLE
ARKANSAS AND MISSOURI

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PREPARED FOR THE U.S. DEPARTMENT OF ENERGY
GRAND JUNCTION AREA OFFICE
GRAND JUNCTION, COLORADO 81502

This is the final version of the subject-quadrangle evaluation report to be placed on open file. This report has not been edited. In some instances, reductions in the size of favorable areas on Plate 1 are not reflected in the text.

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ABSTRACT

Uranium resources of the Poplar Bluff Quadrangle, in southeastern Missouri and northeastern Arkansas, were evaluated to a depth of 1500 m using all available surface and subsurface geologic information. No uranium occurrences had been reported. On the surface, a scintillometer survey and a geochemical sampling program were conducted and these data, as well as data from the Hydrogeochemical and Stream Sediment Reconnaissance program, were evaluated for anomalous radioactivity and uranium occurrences. The subsurface was evaluated for favorability using gamma-ray logs, descriptive logs prepared from analyses of well sample cuttings, and previously published and new groundwater sample data.

One area of uranium favorability was delineated within the quadrangle. The basis for delineation included uranium source, medium of transportation, host rock, and precipitating conditions. This area lies in the delta-platform facies of the Cretaceous McNairy Sand. No uranium occurrences were found within the favorable area, probably because of limited subsurface data. Geologic units considered unfavorable include all Quaternary, Tertiary, and Cretaceous (except the McNairy Sand) formations, and all Paleozoic rocks extending to the Precambrian basement rocks.

INTRODUCTION

PURPOSE AND SCOPE

The purpose of this investigation is to identify and delineate areas in the Poplar Bluff Quadrangle, Missouri and Arkansas (Fig. 1), that are favorable for uranium deposits. All geologic environments to a depth of 1500 m (5,000 ft) were evaluated by means of surface investigations and subsurface data. All units were categorized as either favorable or unfavorable for uranium deposits, based on criteria obtained from the study of uranium deposits worldwide (Mickle and Mathews, eds., 1978).

Evaluation of the Poplar Bluff Quadrangle was subcontracted to Geochemex by Bendix Field Engineering Corporation (BFEC) for the National Uranium Resource Evaluation (NURE) program, managed by the Grand Junction Area Office of the U.S. Department of Energy (DOE). The evaluation began in March 1978 and ended in February 1980. Time spent in research, field work, evaluation of data, and preparation of the final report totaled 48 man-months.

ACKNOWLEDGMENTS

Members of the Arkansas Geological Commission are thanked for their cooperation in providing access to electrical logs and subsurface cuttings samples. We are also indebted to the Missouri Department of Natural Resources, Geological Survey, for access to electrical logs and subsurface cuttings samples. Information was also obtained from the U.S. Geological Survey, Water Resources Division.

PROCEDURES

An examination of all surface and subsurface data was required to evaluate the uranium potential in the Poplar Bluff Quadrangle. Objectives of surface geologic investigations were: a geochemical analysis of soil and rock samples, a detailed study of the geologic environments exposed in outcrop, and a scintillometer survey to determine background readings from each geologic unit of interest and to determine any anomalous regions in the quadrangle (App. L). Subsurface objectives included a study of all available geophysical, sedimentologic, and drillers' logs; a sampling program to investigate the geochemistry of the ground water; a geochemical and sedimentologic examination of well cuttings; and an investigation of Hydrogeochemical and Stream Sediment Reconnaissance (HSSR) ground-water results.

Surface Evaluation

In carrying out these objectives, a literature search was first conducted on the area to determine the local stratigraphy and structure. Samples of surface water, soil, and rocks were collected and analyzed by Skyline Labs, Inc., of Wheat Ridge, Colorado (App. B). A scintillometer survey was employed to measure gross-gamma counts over the entire quadrangle. These data were used to determine a background reading for each specific geologic unit and to

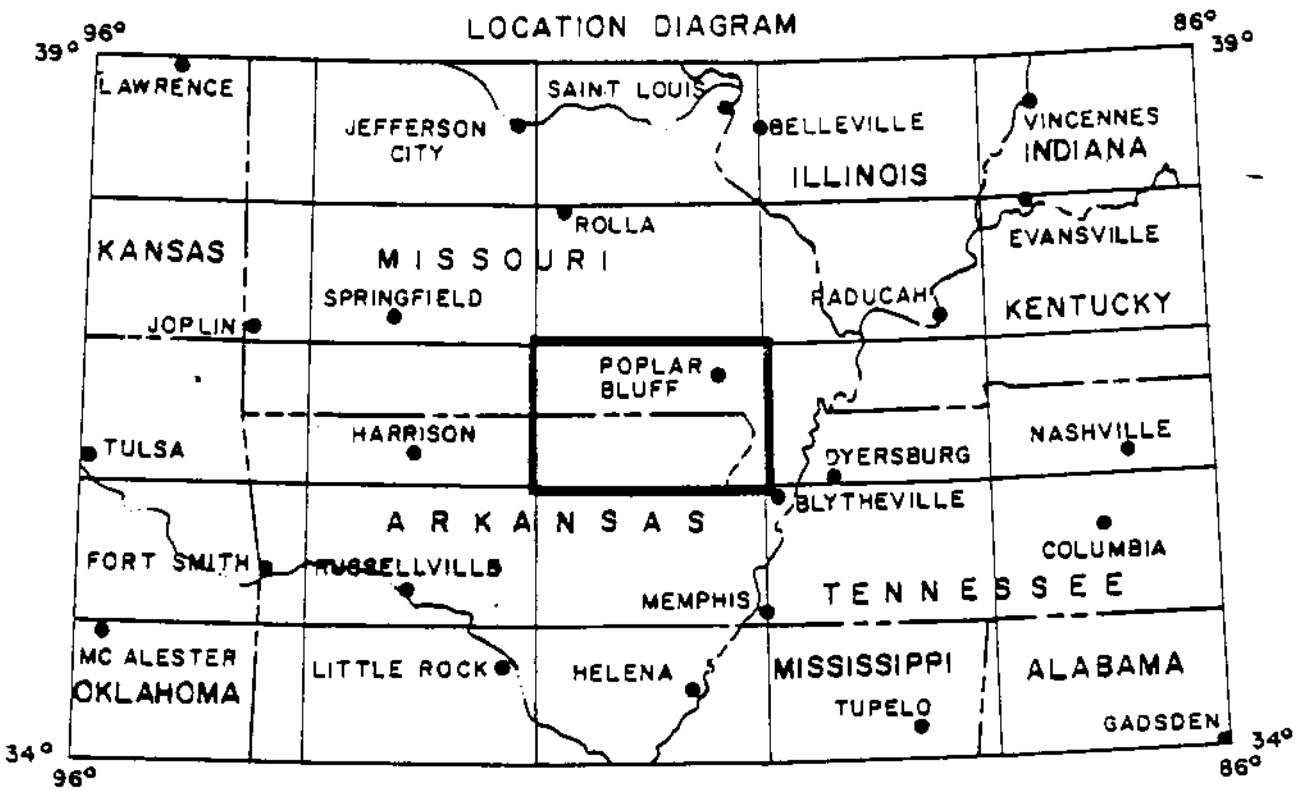

Figure 1. Poplar Bluff Quadrangle location map.

ascertain any anomalous zones. The outcrops of each formation of interest were traversed on foot, and rock samples were taken at an average spacing of 50 m. All outcrops were examined in the field, and special emphasis was given to environment of deposition and lithology. Office examinations were made using a microscope to confirm field observations. Thin sections were made of selected samples and were examined for detailed lithology and microstructure.

Subsurface Evaluation

Geophysical, sedimentologic, and drillers' logs were used to determine the structure of the deeply buried Paleozoic rocks for making cross sections (App. K) and determining ground-water flow. The sedimentologic logs were also used to ascertain the depositional environment of the sediments buried deep in the embayment and to perceive facies changes in the subsurface. Gamma-ray logs were examined for anomalous background radiation (App. J). Well cuttings were analyzed for uranium and other elements that indicate a uranium deposit and (or) a reducing environment (App. B).

Hydrogeochemical ground-water data were examined for evidence of an oxidation-reduction (redox) interface (App. I). Historic data were analyzed first, and, through the use of geochemical parameters, a redox interface was determined.

This region was reanalyzed in Geochemex's sampling program. Ground-water samples were taken from water wells in the area. Conductivity, pH, alkalinity, and temperature were taken on-site; the samples were then sent to Skyline Labs for further analysis. These samples were also analyzed with an Eh meter to document the redox interface and with a radon detector, the EDA RD-200, to detect anomalies.

A followup of the HSSR program was achieved by resampling anomalous wells and sampling wells updip and downdip to bracket the anomaly and determine any trends in the ground-water geochemistry (App. H).

GEOLOGIC SETTING

The Poplar Bluff $1^{\circ} \times 2^{\circ}$ Quadrangle, an area of 20,300 km^2, is in southeast Missouri and northeast Arkansas between lat 36°00'00"N. and 37°00'00"N., and long 90°00'00"W. and 92°00'00"W. (Fig. 1). The quadrangle is separated into two physiographic provinces by the Ozark Escarpment: the Salem Plateau to the northwest and the Coastal Plain to the southeast (Fig. 2).

The landform varies greatly in this quadrangle, ranging from a gentle upland karst terrain in the northwest to flat lowlands in the southeast. The elevation drops from a high of 400 m on the Salem Plateau to 75 m at the Mississippi River. The flat lowland plain is interrupted only by Crowley's Ridge.

The survey area lies on the south flank of the Ozark Uplift (or Dome) (Fig. 3), a broad, positive tectonic feature that influenced the depositional patterns across this region of the midcontinent. The apex of this structure lies in the St. Francois Mountains of southeastern Missouri, an exposed mass

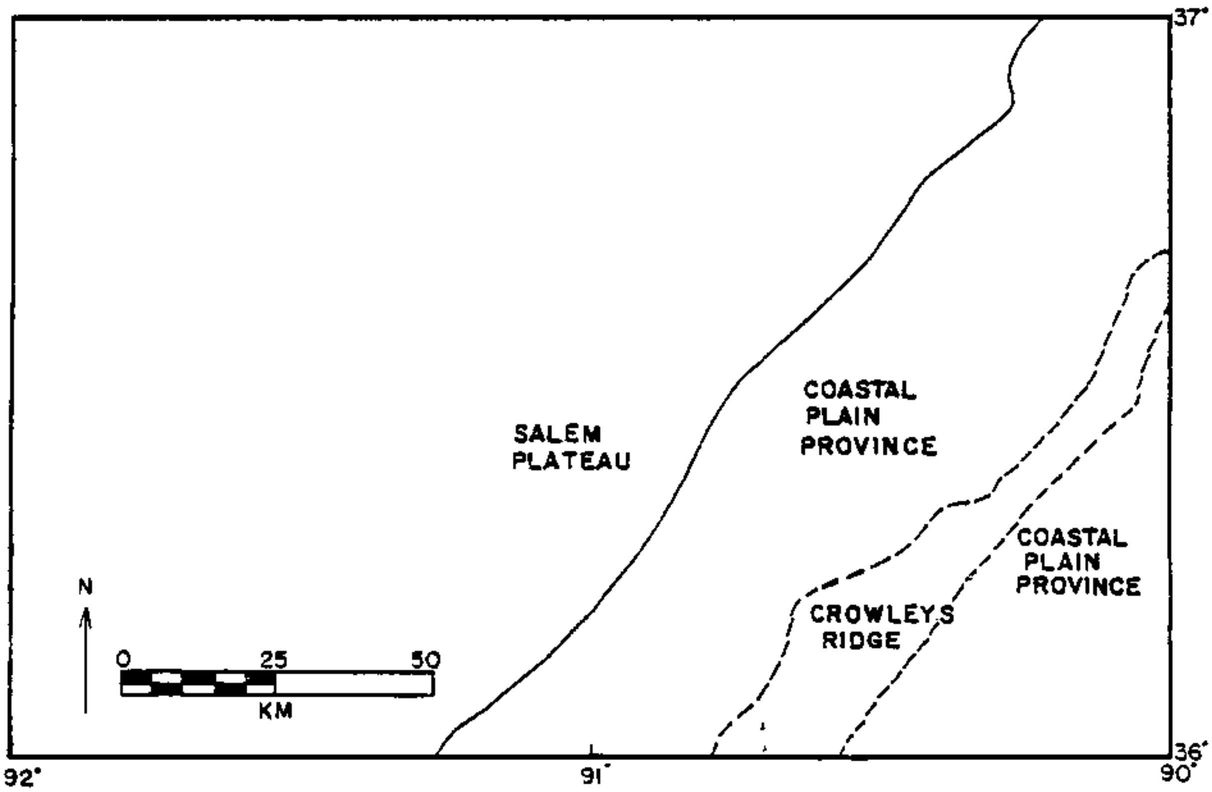

Figure 2. Physiographic regions.

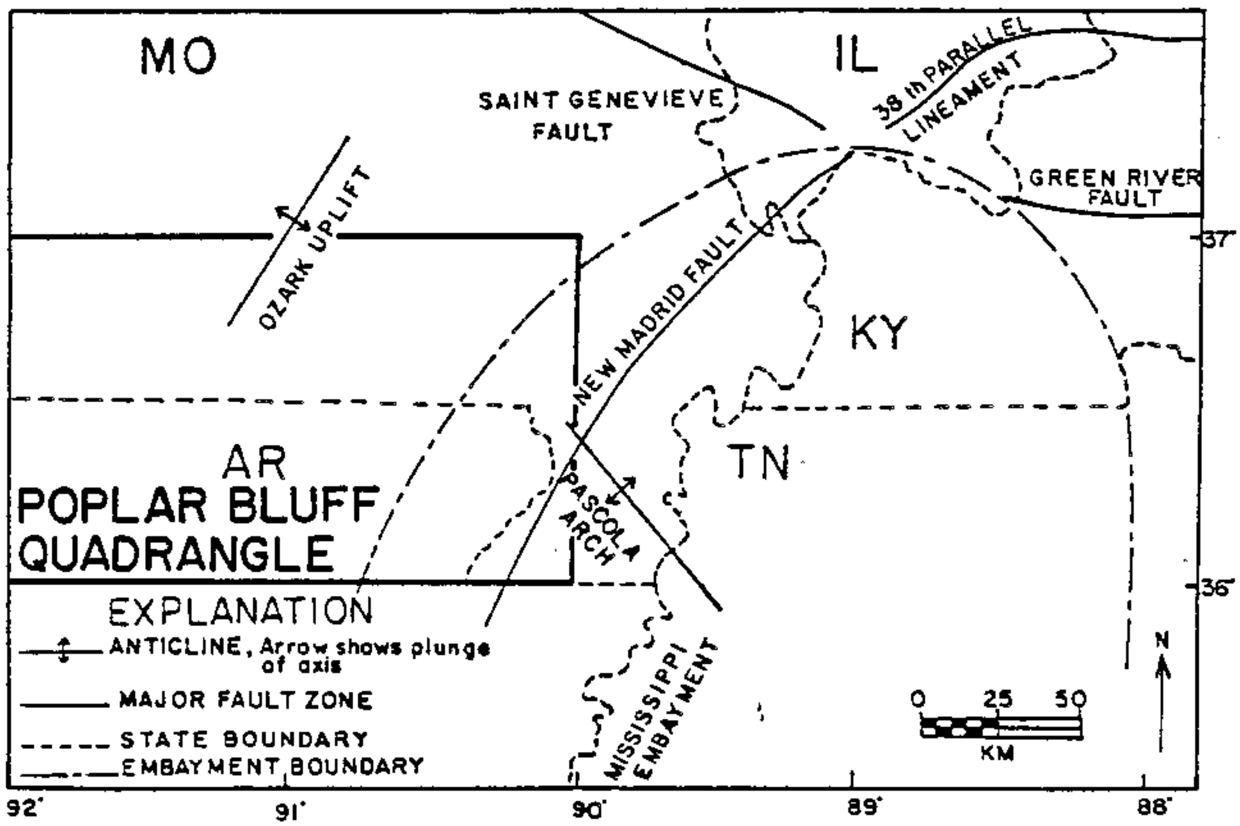

Figure 3. Tectonic setting.

of Precambrian igneous rocks. These rocks, however, are rare within the quadrangle. The Paleozoic strata are quaquaversal with respect to these mountains, the dip steepening on the southern and eastern sides of the mountains (McCracken, 1971).

During Cambrian time, sediments were deposited on Precambrian knobs, hills, and ridges. Regional subsidence began and continued sporadically to the end of the Pennsylvanian. Subsidence seems to have kept pace with deposition, which produced predominately shallow-water marine sediments.

Sediments of Mesozoic and Cenozoic age were deposited in this geosyncline (the Mississippi Embayment), which was developed on faulted, folded Paleozoic rocks at the close of the Paleozoic. Faulting and folding accompanied each depositional interruption.

The Mississippi Embayment is a broad arm of the Gulf Coastal Plain, which extends up the valley of the Mississippi River from the Gulf of Mexico to southeastern Missouri and southern Illinois. It is a spoon-shaped, down-warped trough, believed to have formed at the close of the Paleozoic through reactivation of the Reelfoot Rift, a late Precambrian aulacogen, and its subsequent subsidence. The axis of the trough, developed on the Paleozoic surface, trends N. 30° E.

Paleozoic rocks exposed in the Salem Plateau region dip gently southward. Near the Ozark Escarpment, the dip becomes more southeastward, as the influence from the embayment becomes stronger. In general, the attitude of the Paleozoic sequence is attributed to the syndepositional and (or) postdepositional southward tilt of the basement between the Ozark Uplift and the Arkoma Basin. The maximum depth of the Paleozoic rocks is approximately 900 m.

Cretaceous, Tertiary, and Quaternary strata unconformably overlie the Paleozoic strata. They commonly have a southeastward dip, toward the axis of the geosyncline, of about 5 m/km. They trend in crescent-shaped bands running from N. 30° E. to almost east-west (Grohskopf, 1955). Tertiary and Cretaceous rocks are exposed on Crowley's Ridge and on the Ozark Escarpment.

The rocks of Poplar Bluff Quadrangle can be grouped into two major stratigraphic sequences: a shallow-water marine sequence of Paleozoic rocks, and a Mesozoic and Cenozoic series of detrital clastics. The Paleozoic section consists chiefly of limestones, dolomites, marine sandstones, siltstones, clays, and shales. The post-Paleozoic strata are primarily unconsolidated to poorly consolidated sandy clays, clays, and some carbonates, capped by silts, gravels, and minor lignites. Stratigraphic nomenclature and generalized lithologic descriptions are summarized in Figure 4. It will be noted that the group terms "Upper Knox Group" and "Lower Knox Group" have been informally applied to groups of Knox correlative rocks, although these rocks are formally known by more detailed names or by "Arbuckle" terminology, varying from state to state.

ERA	SYSTEM	FORMATION	LITHOLOGY	DESCRIPTION
CENOZOIC	QUA-TER-NARY	Undivided		Unconsolidated fluvial and alluvial debris.
	TERTIARY	Wilcox		Sand and clay.
		Midway: Porters Creek		Clay, silt and sand.
		Midway: Clayton		Limestone and clay.
MESOZOIC	CREATCEOUS	Owl Creek		Silty clay.
		McNairy Sand*		Sand, clay, gravel.
		Unnamed.		Sand, clay, and sandy soil.
PALEOZOIC	MISS-ISSI-PPIAN	Mississippian Undiv.		Limestone and chert.
	ORDOVICIAN	Middle Undivided		Limestone and dolomite.
		St. Peter		Sandstone.
		Everton		Dolomite.
		"Upper Knox Group"		Dolomite and sandy dolomite.
		Roubidoux		Sandstone and dolomite.
		Gasconade		Dolomite and sandstone in basal unit, Gunter Member.
	CAMBRIAN	"Lower Knox Group"		Dolomite
		Bonneterre		Dolomite
		Lamotte		Quartzitic sandstone and arenaceous dolomite.
Precambrian				Igneous and Metamorphic rocks.

*Favorable for uranium deposition.

Figure 4. Stratigraphic column.

ENVIRONMENT FAVORABLE FOR URANIUM DEPOSITS

In the Poplar Bluff Quadrangle, the deposit model is for a Texas roll-type deposit (Subclass 242, Austin and D'Andrea, 1978) in the Coastal Plain Province. One area in the Upper Cretaceous McNairy (Area A, Pl. 1), containing deltaic sediments, displays a favorable environment for this type of deposit.

The McNairy Sand fulfills the three overall criteria necessary for a roll-type deposit in a sandstone: a source for the uranium, a host rock capable of transmitting the uranium-bearing solutions, and a precipitant.

The lithology is a nonmarine and nearshore marine-sand sequence. The grain size varies from medium to coarse, with poor sorting. Carbonaceous matter and pyrite are common. The depositional environment ranges from the delta platform through the delta slope (Pl. 8).

Bar-finger complexes are not unusual in deltaic sequences. Claystones and shales deposited in interchannel deposits have been noted in the samples examined.

The tectonic setting of the McNairy Sand is the coastal plain. The occurrence of normal faulting and the existence of grabens is highly likely, the New Madrid and Saint Genevieve fault systems lying to the east and north, respectively, of the quadrangle (Fig. 3).

Devitrified tuffs in the overlying Porters Creek Clay are the source of uranium. The presence of a contact between reduced and oxidized zones (the redox interface), constructed using the interpretation of historical and field data (Pl. 9), provides the geochemical cell for the reduction of hexavalent uranium to tetravalent uranium. The interface was defined on the basis of pH, sulfate and bicarbonate ion content, and the oxidation potential (Eh) of the ground water in the McNairy Sand.

No uranium or uranium-bearing minerals were noted in the well cuttings examined. Molybdenum and arsenic were usually below minimum detection limits (2 ppm and 500 ppm, respectively) and could therefore not be used in the evaluation. Only a few anomalous uranium concentrations were detected in ground-water and soil samples, as described below.

TECTONIC SETTING

The tectonic setting of the McNairy Sand is similar to the geologic setting for the conformable sedimentary formations of post-Paleozoic age that overlie the Paleozoic unconformity and that onlap the Paleozoic rocks forming the Ozark Dome in the northwestern part of the quadrangle. In this regard, the coastal plain of the upper Mississippi Embayment closely correlates to the Gulf Coastal Plain Province.

The predominant structural pattern of the coastal plain part of the quadrangle is that of the upper Mississippi Embayment; a shallow, open-ended, intercratonic basin plunging southwestward at a N. 30° E. trend, the Mississippi River following the general trend of the axis (Grohskopf, 1955).

The sediments thicken markedly southward, increasing from less than 30 m (100 ft) at the western limit of the outcrops to more than 90 m (300 ft) in northern Mississippi. The strata commonly dip southeastward at 5 m/km.

In spite of its substantial distance from the Gulf of Mexico, the McNairy Sand occupies a tectonic setting highly similar to that of the Cretaceous and younger formations in South Texas.

DOMINANT LOCAL STRUCTURES

The depositional history and the tectonics of the coastal plain part of the Poplar Bluff Quadrangle have resulted in the occurrence of a number of down-to-the-coast normal faults, which were formed as the Mississippi Embayment syncline slowly subsided. In addition, other fault systems have been noted which appear related to the New Madrid and Saint Genevieve fault systems lying to the east and north, respectively, of the quadrangle (Fig. 3).

HOST ROCK

The McNairy Sand is composed of a series of nonmarine sands, sandy clays, and clays to the southeast. Deeper in the embayment, it is more marine in character, becoming more calcareous and fossiliferous.

Where the McNairy crops out in Missouri, it is roughly divisible into three parts: a basal gravel; a middle unit that is a series of thinly bedded light-gray clays interbedded with thin layers of fine- to medium-grained orange sand; and, near the top, a light-yellow to orange sandstone that is medium to coarse grained and subangular. The upper part of this sand is commonly silicified. In Missouri, the upper portion of the McNairy is a succession of five alternating sandstone and clay beds that can be differentiated on the surface only. These alternating sandstones and clays establish rates of flow and patterns of movement for the ground water. The sandstones range from a yellow to brown, clayey sandstone to a white to yellow, fine-grained, micaceous sandstone. The clays are a light-gray to brownish-black, lignitic clay and a brown, lignitic, sandy clay.

Organic matter is present throughout the McNairy Sand. Varying amounts of carbonaceous plant remains and carbonaceous flakes are found in the shales, claystones, and sandstones. Also present in the McNairy Sand are streaks and stringers of pyrite found in the shales and claystones, and pyrite that actually composes a small portion of the matrix of the sandstones.

The McNairy Sand of Late Cretaceous (Gulfian) age covers an area of approximately 10,000 km^2 in the Poplar Bluff Quadrangle. These sediments are the result of deltaic deposition. The McNairy Delta (Pryor, 1960), situated in the northeastern portion of the Mississippi Embayment, dispersed sediments to the southwest because of subsidence of the embayment. Two depositional environments can be interpreted from studying the McNairy sediments in well cuttings in the eastern half of the quadrangle. These are a delta-front platform and delta slope (Pl. 8).

The delta-front platform is subaerial to subaqueous. The grain size is medium to fine sand with commonly better sorting at the delta front, and fine sand to clay near the delta slope. Glauconite is evident, and the percentage of carbonaceous material is low. Farther to the southeast, fossils, especially foraminifera, become abundant, indicating a gradual increase in water depth. This environment, the delta shelf, consists of calcareous sandstones and shales and minor amounts of limestone. Fossils, such as brachiopods, are numerous.

Sedimentary structures in the coarse clastics of the McNairy Sand include cross-stratification, ripple marks, cut and fill structures, and minor structures, such as clay galls and clay pebbles.

The most abundant sedimentary structure is cross-stratified layers, which may be separated by a layer of normally stratified sand or clays. They usually occur in sets of two or more in vertical succession. These cross-stratified beds vary in length from less than 2 m to more than 10 m and in width from less than 30 cm to more than 3 m. The foreset strata are commonly separated by planes occupied by concentrations of mica and clay pebbles. The foreset laminations are commonly tangential with the underlying strata. Most of the cross-laminated units are slightly wedge shaped. Thicknesses for each unit were measured, and an average of 20 to 40 cm was found. These cross-stratified units seem to thicken toward the source area (Peletier, 1958).

Ripple marks are commonly abundant and are associated with clay laminations or sediments partly cemented by iron oxides. Three types are found: asymmetrical, symmetrical, and interference, the first two being the more common.

Cut and fill structures are the second most abundant sedimentary structure. They are usually trough shaped and plunge in the direction of adjacent cross-stratification inclination (Pryor, 1960).

ASSOCIATED ROCKS

The Upper Cretaceous McNairy Sand is a thick, nonmarine and nearshore marine transgressive-regressive sand sequence. It lies below the Owl Creek Formation, which is similar in lithology in most of the quadrangle. Porters Creek Clay overlies the Owl Creek and the McNairy. Older Cretaceous sediments underlie the McNairy in the deeper parts of the embayment. In the shallower parts of the embayment, the McNairy directly overlies Paleozoic strata.

The pre-McNairy Cretaceous beds are both nonmarine and marine in origin and consist of unconsolidated to partially consolidated sand, marl, clay, and thin limestone beds. These rocks are found in the subsurface only, and have been tentatively correlated with the Coffee and Selma Formations of Tennessee and the Ozan and Marlbrook-Saratoga units of the Arkansas section. For this report, they will be known as the pre-McNairy Cretaceous (subsurface only). In the Crowley's Ridge area, there is sharp unconformity, and the McNairy overlaps rocks of Paleozoic age.

A possible source for uranium within the McNairy is the overlying Porters Creek Clay, "a massive, homogeneous, dark gray clay" (Koenig and others, 1961), derived in part from rhyolitic, tuffaceous material (Farrar and others, 1935; App. F). The original content of volcanic material is unknown. A present content of 60% montmorillonitic clay is realistic. It is judged that half the montmorillonite is diagenetic after tuff, which has been leached by ground water.

The overall thickness of the formation is 30 to 90 m. Volcanic shards and glass bubbles altered to montmorillonite are distinct in the Porters Creek Clay outcrop at Ardeola, Missouri (about 30 km to the northeast of the Poplar Bluff Quadrangle), as shown in a petrographic analysis conducted as part of this study (App. F) and by Farrar and others (1935). Table 1 shows the results of the geochemical analyses of the Ardeola section (samples MIN 101 through 127 from App. B), which displays uranium values typical of a devitrified tuff. According to Pryor and Glass (1961), volcanic activity was widespread during the Late Cretaceous and Tertiary.

By comparing this source rock with the Catahoula Tuff of South Texas, a measure of the amount of uranium available for mineralization of the underlying McNairy Sand can be derived. Galloway and others (1979) suggested that the original uranium content of the Catahoula Tuff was 7 to 10 ppm. This compares well with the Porters Creek Clay. Weathering and early diagenesis reduced this to 6 ppm, of which 4 ppm are mineralogically bound, leaving 2 ppm available for mobilization. A similar concept can be used for the Porters Creek Clay. If the uranium available for mobilization (the 2-ppm fraction) were transported into the McNairy, it may be concentrated in a roll-type deposit by geochemical factors discussed below. Additional evidence for the ability of the Porters Creek Clay to serve as a source for uranium is shown in samples from the Monroe Gas Rock, a Cretaceous unit in the northern Louisiana part of the Mississippi Embayment, which has a stratigraphic relationship similar to that of the Porters Creek Clay; it underlies the Tertiary Midway Group, the basal unit of which is rock and time correlative to the Porters Creek Clay. Gamma-ray logs run in this area show anomalous intercepts at the top of the Monroe. Therefore, a set of core samples from a typical well into the Monroe Gas Rock was analyzed for uranium content (Table 2). The two uppermost samples are anomalously high in uranium, with one reaching 75 ppm uranium. Uranium evidently was mobilized out of the basal Midway Group and precipitated by the reducing hydrocarbon gas in the Monroe Gas Rock.

HYDROLOGY AND ALTERATION

The McNairy Aquifer is an important aquifer in southeast Missouri. It is overlain by the Porters Creek Clay, but occasionally separated therefrom by the thin Clayton Formation. In other places, the thin Owl Creek Formation is present above the McNairy, but, in spite of a somewhat more clayey lithology, the Owl Creek sand units still permitted connate water from the Porters Creek Clay to percolate through and enter the McNairy Sand during stages of compaction.

The direction of water movement within the McNairy Aquifer in the Gulf Coastal Plain Province of the quadrangle is south to southeast and exhibits a local pattern due to permeability variations. The aquifer is recharged by rain water and surface waters at its outcrops.

TABLE 1. CHEMICAL ANALYSES OF THE ARDEOLA SECTION

Unit	Sample no.	Elevation (m)	U_3O_8 (ppm)
Porters Creek Clay	MIN 127	147	1
Porters Creek Clay	MIN 126	146	3
Porters Creek Clay	MIN 125	145	1
Porters Creek Clay	MIN 124	144	1
Porters Creek Clay	MIN 123	143	< 1
Porters Creek Clay	MIN 122	142	< 1
Porters Creek Clay	MIN 121	141	2
Porters Creek Clay	MIN 120	140	2
Porters Creek Clay	MIN 119	139	1
Porters Creek Clay	MIN 118	138	3
Porters Creek Clay	MIN 117	137	1
Porters Creek Clay	MIN 116	136	1
Porters Creek Clay	MIN 115	135	1
Porters Creek Clay	MIN 114	134	1
Porters Creek Clay	MIN 113	133	3
Porters Creek Clay	MIN 112	132	12
Porters Creek Clay	MIN 111	131	1
McNairy Sand	MIN 110	130	1
McNairy Sand	MIN 109	129	1
McNairy Sand	MIN 108	128	1
McNairy Sand	MIN 107	127	1
McNairy Sand	MIN 106	126	< 1
McNairy Sand	MIN 105	125	1
McNairy Sand	MIN 104	124	1
McNairy Sand	MIN 103	123	1
McNairy Sand	MIN 102	122	1
McNairy Sand	MIN 101	121	< 1

TABLE 2. CHEMICAL ANALYSES OF THE MONROE GAS ROCK OF LOUISIANA

BFEC SAMPLE NO.	MIN276	MIN277	MIN278	MIN279	MIN280	MIN281
Geologic Code	Monroe Gas Rock - Louisiana					
U_3O_8	19	75	2	<1	<1	<1
Depth	2278	2280	2285	2295	2299	2304
Well Name	Richland Seed Co., Inc. #19					
Well Location	Moorehouse Parish, S6 18N 6E					
AG	<1	<1	<1	<1	<1	<1
AL	30000	2000	5000	3000	5000	3000
AS	<500	<500	<500	<500	<500	<500
B	50	<10	10	<10	10	<10
BA	50	<10	<10	10	10	20
BE	<2	<2	<2	<2	<2	<2
CA	>200000	>200000	>200000	>200000	>200000	>200000
CO	<5	<5	<5	<5	<5	<5
CR	100	10	20	30	100	50
CU	15	10	30	2	50	<2
FE	20000	1000	1500	5000	10000	5000
LA	70	30	20	20	20	20
LI	10	<10	<10	<10	<10	<10
MN	1000	500	500	700	500	500
MO	<2	<2	<2	<2	<2	<2
NA	3000	700	1000	1000	700	500
NB	<20	<20	<20	<20	<20	<20
NI	100	<5	<5	<5	<5	<5
PB	30	10	50	<10	20	<10
SB	<100	<100	<100	<100	<100	<100
SC	15	<10	<10	<10	<10	<10
SN	<10	<10	<10	<10	<10	<10
SR	1000	200	500	700	1000	1000
TI	1000	100	300	500	700	500
V	100	20	20	50	20	50
W	<50	<50	<50	<50	<50	<50
Y	100	<10	<10	<10	<10	<10
ZN	<200	<200	<200	<200	<200	<200
ZR	50	<20	<20	20	30	20

In order to determine the location of redox interfaces within the gently dipping McNairy Sand, historical ground-water data were first used. The raw data were available from the state and federal geologic surveys, but rarely included more than the most conventional constituents, such as alkali metals, calcium, and magnesium and anions such as carbonate, bicarbonate, and sulfate; unfortunately, no data were available for Eh or for ferrous-to-ferric ratios. Still, it was possible to select conventional ground-water data of very high quality and submit those data for statistical geochemical analysis. It was found that sulfate content is related to the ground-water Eh with a discontinuity at interface between oxidizing and reducing conditions. One hypothesis for this relationship is the bacterial reduction of sulfate downdip of the interface, which would keep the sulfate content low as compared to the sulfate-reducing bacteria-free environment updip of the interface. Oxidation of pyrite updip of the interface probably also contributes to the sulfate discontinuity.

Further, it was found that the bicarbonate content changed over the interface, increasing discontinuously downdip. The bacterial hypothesis mentioned above may also provide a viable explanation for this effect. Below the redox interface, carbon dioxide will be formed as a byproduct of the sulfate-reducing bacterial metabolism; the carbon dioxide in combination with water will dissolve carbonate from the calcareous components of the McNairy Sand and form bicarbonate ions. As a consequence also, the pH of the ground water varies, but the relationship is less distinct. The bicarbonate ion concentration from historic data was from 124 to 677 ppm, the discontinuity was at about 200 ppm. The sulfate ion concentration was from 1 to 67 ppm, the discontinuity being indistinct.

In August 1979, Geochemex conducted confirmation field sampling over the area involving the historical ground-water data (App. I). The McNairy Sand was sampled in a commonly north-south-trending line of city water wells in southeastern Missouri. These city wells were sampled because of their depth, which was sometimes as deep as 500 m. Shallower aquifers are tapped between these city wells. The Eh readings of these city wells were used in determining the redox interface in this area (Pl. 9). The results confirmed the location of a geochemical cell as well as the utility of the method.

One resampled HSSR well in the McNairy Sand was confirmed to contain an anomalous U_3O_8 value of 2 ppb. The HSSR sample number is MOSD 591, and the BFEC sample number is MIN 238.

FAVORABLE AREA A

Favorable Area A of the McNairy Sand covers approximately 418 km^2 and is in the northeastern corner of the Poplar Bluff Quadrangle (Pl. 1, Area A). The McNairy does not crop out in this area. Thickness of the unit increases from 75 m (250 ft) in the south to 120 m (400 ft) in the north (Pl. 7). If the upper 10 m (30 ft) of the McNairy is considered optimal for uranium mineralization, the total favorable volume would be approximately 4 billion m^3. Depth to the top of the McNairy varies from 30 m (100 ft) in the north to 60 m (200 ft) in the southeast (Pl. 10).

The McNairy Sand is considered favorable for a South Texas deposit model, Subclass 242, because of geologic similarities. However, one major difference is present; South Texas has a sub-arid climate, whereas Poplar Bluff Quadrangle displays a sub-humid climate. Similarities or differences in climate during and after deposition are unknown, but weathering patterns in overlying rocks bear strong similarities.

Ground-water samples taken by Geochemex in the Poplar Bluff Quadrangle include 22 samples from the McNairy Sand. Of these, six are within Area A; one is anomalous, that is, it contains uranium in excess of the mean plus two times the standard deviation. The one anomalous ground-water sample has a value of 2 ppb U_3O_8 (sample MIN 238) in the favorable area.

Surface rock and soil anomalies which might indicate a roll-type deposit cannot be expected in the highly oxidizing surface conditions of the Poplar Bluff Quadrangle. Subsurface samples, such as well cuttings and deep ground-water samples, are normally good indicators of elemental concentrations in this environment; however, due to the wide spacing and limited number of deep wells in the favorable area, no primary evidence for uranium deposits was found.

ENVIRONMENTS UNFAVORABLE FOR URANIUM DEPOSITS

Environments unfavorable for uranium deposits are all sedimentary units within the Poplar Bluff Quadrangle, except the McNairy Sand in Area A (Pl. 1).

LAMOTTE SANDSTONE

The Upper Cambrian Lamotte Sandstone is the lowermost Paleozoic sedimentary formation in the Poplar Bluff Quadrangle. It has some characteristics of a good host rock: a shallow-marine sandstone deposit with scattered fluvial deposits; a lithology that is predominantly quartzose sandstone, grading laterally into an arkose and conglomerate in many places; and red to purple silty shale locally present that provides a barrier to ground-water movement (Koenig, 1961). Recharge for the Lamotte is from the waters draining the St. Francois Mountains, where some of the granites have been reported to have a high uranium content. As reported by Odland and Millard, Jr. (1979), in a study conducted on the uranium and thorium content of sedimentary and igneous rocks of the Rolla $1^o \times 2^o$ Quadrangle (directly north of the Poplar Bluff Quadrangle), the basal arkose and conglomerate of this sandstone contain the highest amounts recorded in the Lamotte of these elements. Most of this uranium and thorium is interpreted to be contained in the detrital Precambrian granitic grains and fragments incorporated in the onlap sediments of the Lamotte Sandstone.

A path for ground-water flow is not present in this aquifer. The Lamotte was deposited on the Precambrian surface, so it is deepest in the ancient valleys and thin in places where it rests on Precambrian topographic highs. In some places, it was removed by erosion and is not present at all. This variable thickness and lack of through-going permeability in the Lamotte Sandstone makes it an unfavorable environment for a uranium deposit.

BONNETERRE FORMATION

The Bonneterre Formation, of Late Cambrian age, consists of medium-bedded dolomite with relatively pure limestone in some areas. Locally, parts are glauconitic and shaly, the shale occurring in beds less than 2 in. thick. Where the Bonneterre has been deposited near or directly on the Precambrian surface, it contains fragments of igneous rocks, much of which is felsite. On the flanks of Precambrian lows, the Bonneterre overlaps the underlying Lamotte Sandstone. Most Bonneterre exposures lie north and east of the St. Francois Mountains, and the formation is concealed by younger rocks in the Poplar Bluff Quadrangle (Koenig, 1961).

The Bonneterre Formation is considered unfavorable, as it is almost entirely a carbonate sequence and lacks the necessary qualifications for a good host rock capable of transmitting and precipitating a uranium deposit.

LOWER KNOX GROUP

The shales, siltstones, and dolomites that compose the rocks of the Upper Cambrian Elvins Group, Potosi Formation, and Eminence Formation of the Lower Knox Group were considered environments unfavorable for a uranium deposit because of their lithologies. They do not qualify as good host rocks, nor are there precipitants for a roll-type deposit.

GUNTER SANDSTONE MEMBER

The Gunter Sandstone Member of the Gasconade Dolomite is Early Ordovician in age. In the Poplar Bluff Quadrangle, it is primarily an arenaceous dolomite with varying amounts of sands. Although the Gunter contains sandy units, it lacks laterally continuous beds and, thus, through-going permeability. Therefore, it is not a likely host rock.

GASCONADE DOLOMITE

This formation is unfavorable due to its dolomite lithology.

ROUBIDOUX FORMATION

The Roubidoux Formation of Ordovician age comprises sandstone, dolomitic sandstone, and cherty dolomite. In the Poplar Bluff Quadrangle, the major lithology is dolomite. Recharge for this aquifer is from its outcrops, which are extensive in southern Missouri in the region south of the St. Francois Mountains. Both the Black and St. Francis Rivers, which drain the St. Francois Mountains, contribute to the recharge of this formation, which provides a potential source for a uranium deposit in the Roubidoux. However, the ground-water flow pattern is variable and difficult to determine because of the extensive fracturing of the rocks and the karst features in the subsurface. These factors, along with its lithology, exclude the Roubidoux Formation from consideration as a favorable environment.

UPPER KNOX GROUP AND EVERTON FORMATION

The formations that compose the Upper Knox Group--the Jefferson City, Cotter, Powell, and Smithville Formations--and the Everton Formation consist of dolomites and some interbedded thin sandstone units. They are unfavorable due to the carbonate nature of the rocks.

ST. PETER SANDSTONE

The St. Peter Sandstone is a coarse-grained, friable sandstone. It is unfavorable due to the lack of a source rock. Lithologically, the St. Peter Sandstone has the potential to be a good host rock, but the permeability is too great, and it contains no organic matter for a reductant.

MIDDLE ORDOVICIAN UNDIVIDED AND MISSISSIPPIAN UNDIVIDED

Examination of the Ordovician and Mississippian section reveals a carbonate lithology (limestones and dolomites) that is not conducive to a uranium deposit. For this reason, they are unfavorable.

CRETACEOUS UNNAMED

These Cretaceous sediments are unfavorable due to the lack of a source rock and their predominately clay lithology.

OWL CREEK FORMATION

The Owl Creek Formation in the Poplar Bluff Quadrangle is not a favorable unit, primarily because of its lithology. In this area, the Owl Creek consists of a massive, sandy, micaceous, marine clay. It is exposed along Crowley's Ridge and dips southeastward into the subsurface. Its clay lithology does not permit ground water to flow easily, as the permeability is very low. For this reason, this formation was categorized as unfavorable.

MIDWAY GROUP

The Midway Group is composed of the Clayton Formation below and the Porters Creek Clay above. In its outcrop area in Missouri, the Clayton is a fossiliferous, calcareous sand and clay. In the subsurface, it becomes a glauconitic limestone. The thickness of this unit varies from a few inches to 10 ft in the outcrop area to as much as 20 ft in the subsurface (Grohskopf, 1955). This unit is unfavorable because of its limestone lithology.

The Porters Creek Clay is a massive, dark-gray clay that maintains a very uniform lithology throughout its extent. The thickness ranges from 200 ft in the outcrop area to 650 ft in the subsurface. Porters Creek Clay is considered an excellent source rock for a uranium deposit in the McNairy Sand below it.

WILCOX GROUP

The Tertiary Wilcox Group consists of three formations: Old Breastworks Formation, Fort Pillow Sand, and Flour Island Formation as the lower, middle, and upper components of the group, respectively. The Flour Island and Old Breastworks Formations are predominantly clay and silty clay. The Fort Pillow Sand is a medium to coarse glauconitic sand. The Fort Pillow lithology is acceptable as a host rock, and the presence of lignite provides a reductant for a roll-type deposit. However, the Fort Pillow Sand lacks a source for the uranium. Discharge from the St. Francois Mountains, a possible source of uranium, does not recharge this aquifer. Recharge for the Wilcox Group is at the outcrop area, along Crowley's Ridge, in the southeastern section of Poplar Bluff. Thus, the Wilcox Group is an unfavorable environment because of the lack of a uranium source.

QUATERNARY DEPOSITS

The alluvium, fluviatile terrace deposits, sand dunes, and continental deposits of Quaternary age are unfavorable environments for a uranium deposit because of the absence of a source for the uranium and because of the extensive flushing of the units in the sub-humid climate.

RECOMMENDATIONS TO IMPROVE EVALUATION

Uranium resource evaluation of the Poplar Bluff Quadrangle can be improved by acquiring additional subsurface geologic and hydrogeologic information.

For the McNairy Sand, two methods of investigation could be used to improve the evaluation. The data derived from these studies could be used to improve the quality of information available for evaluation and thereby more exactly delineate the favorable areas in the McNairy Sand.

The first objectives would be resampling well cuttings from the top 30 m (100 ft) of the McNairy Sand. Although samples from the McNairy were analyzed over 30-m (100-ft) intervals, budget restrictions did not allow more closely spaced analyses.

The second objective would be to drill a series of drill holes in the favorable area. This would result in data specific for the area of favorability, including geologic sample data, geophysical and electric-log data, and hydrogeochemical data. A cored section of the top 20 m of the McNairy Sand would allow detailed lithologic description and an analyses of ground water directly beneath the source rock.

In conjunction with this drilling project, older wells which penetrate the McNairy could be relogged with modern logging equipment to provide additional control.

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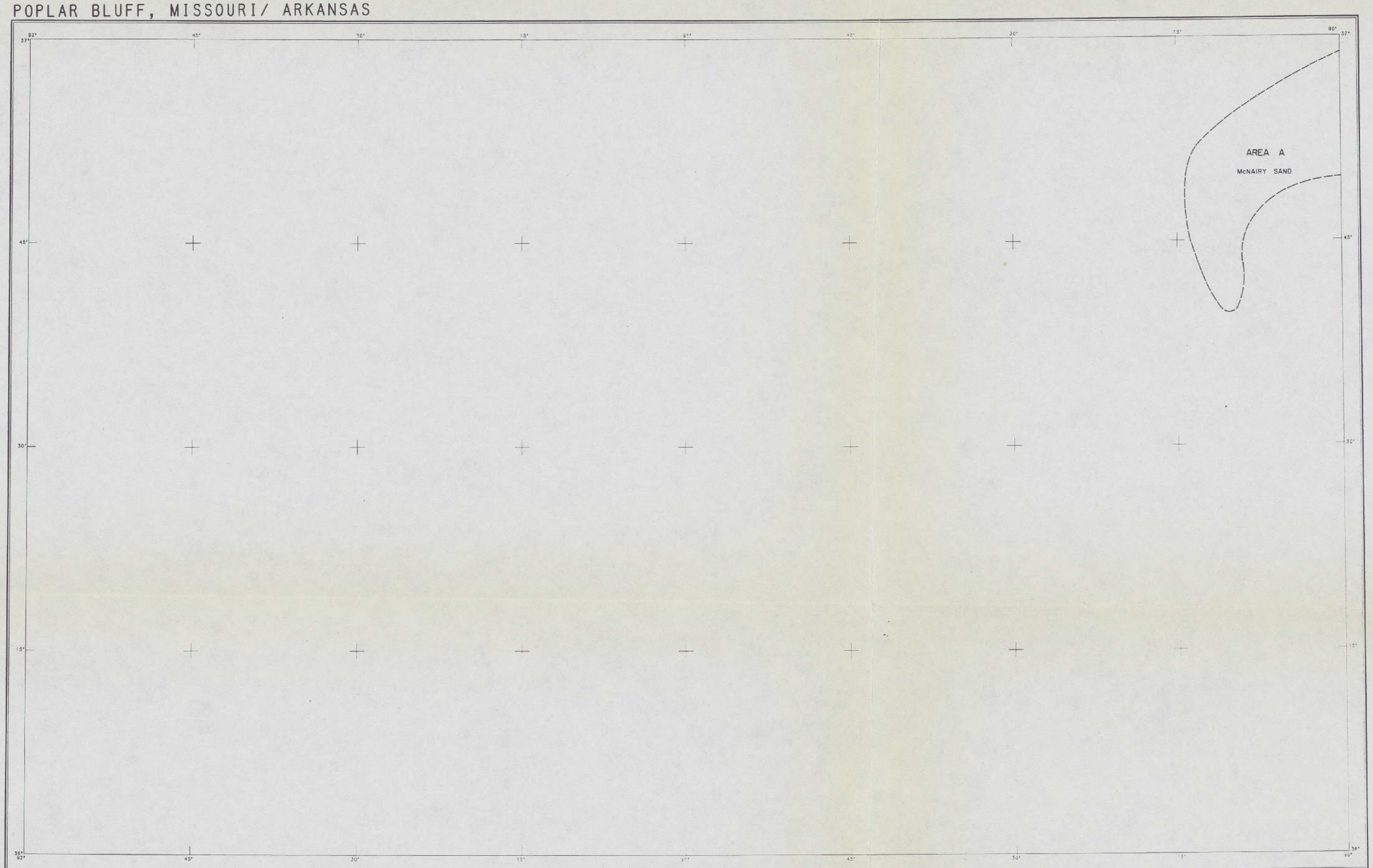
POPLAR BLUFF, MISSOURI/ ARKANSAS



URANIUM RESOURCE EVALUATION
ISSUED BY THE U.S. DEPARTMENT OF ENERGY

5 0 5 10 15 20 25 MILES

5 0 5 10 15 20 25 KILOMETERS

J.B. Gustavson
Boulder, Colorado
Principal Investigator

Plate I. AREAS FAVORABLE FOR URANIUM DEPOSITS

February 1980
Plate I.

POPLAR BLUFF, MISSOURI/ ARKANSAS

URANIUM RESOURCE EVALUATION
ISSUED BY THE U.S. DEPARTMENT OF ENERGY

BASE MAP CONTROL FROM USGS

5 0 5 10 15 20 25 MILES

5 0 5 10 15 20 25 KILOMETERS

J.B. Gustavson
Boulder, Colorado
Principal Investigator

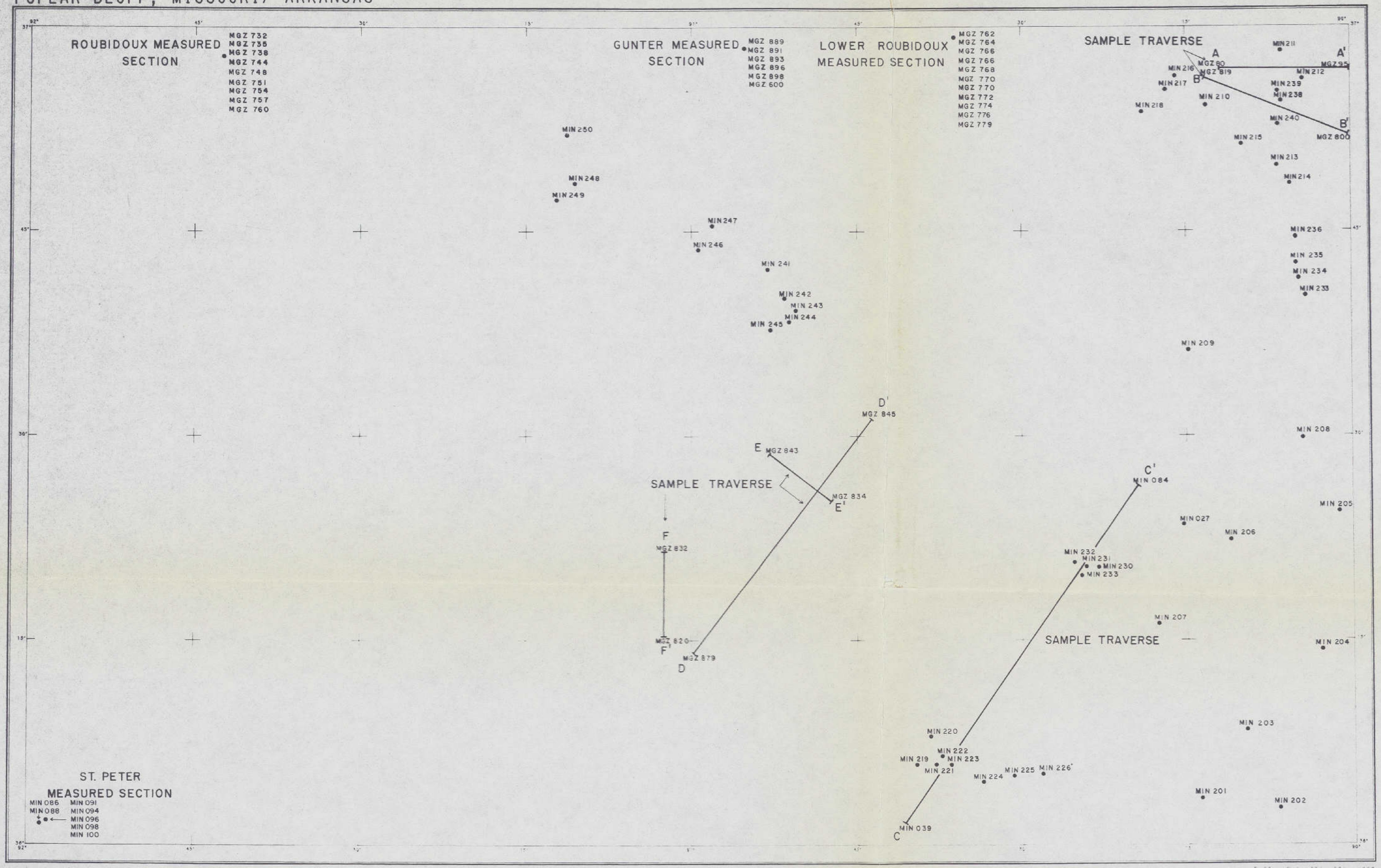
Plate 2. URANIUM OCCURRENCES

EXPLANATION

URANIUM OCCURRENCES	CLASSIFICATION			
	Sedimentary	Plutonic	Volcanic	Other
Minor prospect or mineral occurrence	□	△	⬠	☼
Prospect or mine, production unknown	⬓	▲	⬟	✹
Significant prospect or mine reporting minor production	◩	▲	◑	✹
Mine having production over 200,000 pounds U_3O_8	■	▲	⬟	✹
Not visited	□Y	△Y	⬠Y	☼Y
Not found	□X	△X	⬠X	☼X
Mining District	(- - -)			

February 1980
Plate 2.

POPLAR BLUFF, MISSOURI/ ARKANSAS



URANIUM RESOURCE EVALUATION
ISSUED BY THE U.S. DEPARTMENT OF ENERGY

5 0 5 10 15 20 25 MILES
5 0 5 10 15 20 25 KILOMETERS

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Boulder, Colorado
Principal Investigator

Plate 3. LOCATION MAP OF GEOCHEMICAL SAMPLES (GROUND WATER, ROCK, AND SOIL)

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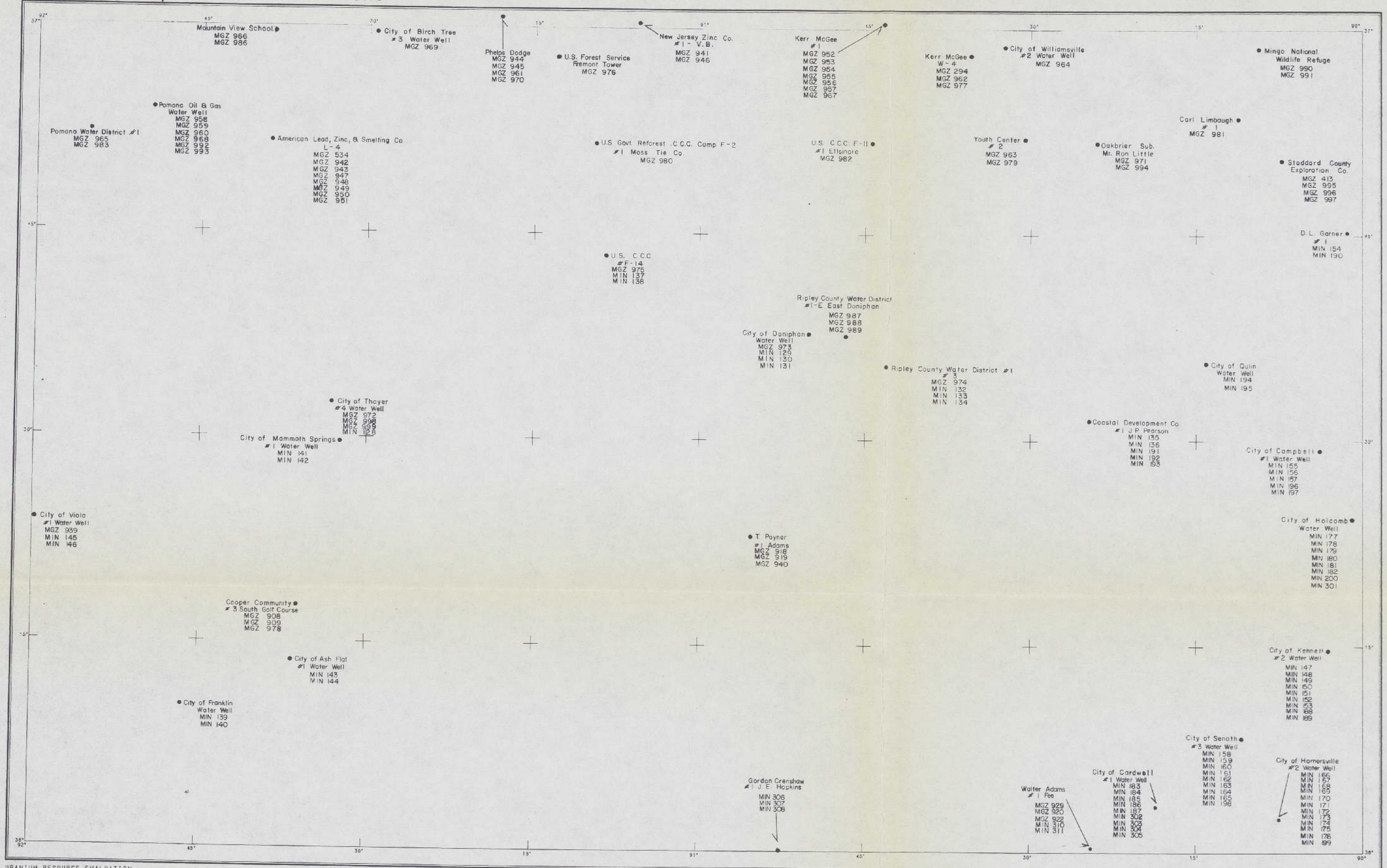
Plate 3

POPLAR BLUFF, MISSOURI/ ARKANSAS



URANIUM RESOURCE EVALUATION
ISSUED BY THE U.S. DEPARTMENT OF ENERGY

BASE MAP CONTROL FROM USGS

5 0 5 10 15 20 25 MILES
5 0 5 10 15 20 25 KILOMETERS
TRANSVERSE MERCATOR PROJECTION

J.B. Gustavson
Boulder, Colorado
Principal Investigator

Plate 4. LOCATION MAP OF GEOCHEMICAL SAMPLES (CUTTINGS)

February 1980
Plate 4

POPLAR BLUFF, MISSOURI/ ARKANSAS

URANIUM RESOURCE EVALUATION
ISSUED BY THE U.S. DEPARTMENT OF ENERGY

BASE MAP CONTROL FROM USGS

5 0 5 10 15 20 25 MILES

5 0 5 10 15 20 25 KILOMETERS

Plate 5. DRAINAGE

February 1980
Plate 5.

EXPLANATION

CENOZOIC
- Qal — Alluvium (HOLOCENE; QUATERNARY)
- Q — Quaternary deposits undivided (PLEISTOCENE; QUATERNARY)
- Qt — Fluviatile terrace deposits (PLEISTOCENE; QUATERNARY)
- Qds — Sand dunes (PLEISTOCENE; QUATERNARY)
- QTc — Continental deposits (includes "Lafayette" gravel) (PLIOCENE(?); TERTIARY)
- Tw — Wilcox Formation (EOCENE; TERTIARY)

MESOZOIC
- Ku — Cretaceous(?) undivided (CRETACEOUS)

PALEOZOIC
- Mbn — Boone Formation (MISSISSIPPIAN)
- Opj — Plattin Limestone and Joachim Dolomite (ORDOVICIAN)
- Ose — St Peter Sandstone and Everton Dolomite (ORDOVICIAN)
- Opw — Powell Dolomite (ORDOVICIAN)
- Ojc, -SB- — Cotter Dolomite and Jefferson City Dolomite (-SB- indicates contact [in Arkansas] between Cotter and Jefferson City Dolomite) (ORDOVICIAN)
- Or — Roubidoux Formation (ORDOVICIAN)
- Og — Gasconade Formation (ORDOVICIAN)
- Cep — Eminence and Potosi Formations (CAMBRIAN)

PRECAMBRIAN
- Granite
- Felsite - probably Rhyolite

SYMBOLS

- Contact
- Fault, U, upthrown side, D, downthrown side, dashed where approximate, dotted where concealed
- Nomenclature change
- Anticline, arrow denotes plunge
- Syncline, arrow denotes plunge

1:250,000

5 0 5 10 15 20 Statute miles

5 0 5 10 15 20 25 30 Kilometers

CONTOUR INTERVAL 100 FEET

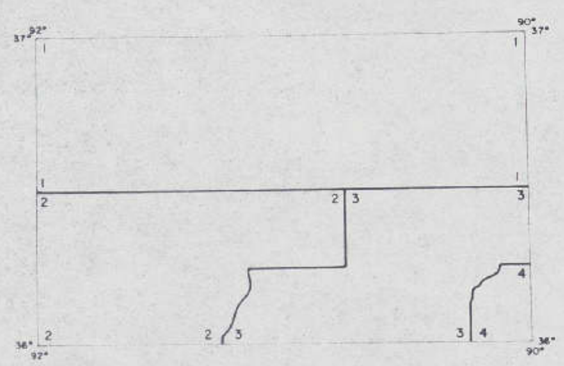


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Plate 6. GEOLOGY OF THE POPLAR BLUFF QUADRANGLE

By

TROLLINGER GEOLOGICAL ASSOCIATES INC.
In Accordance With BFEC Specification #1125

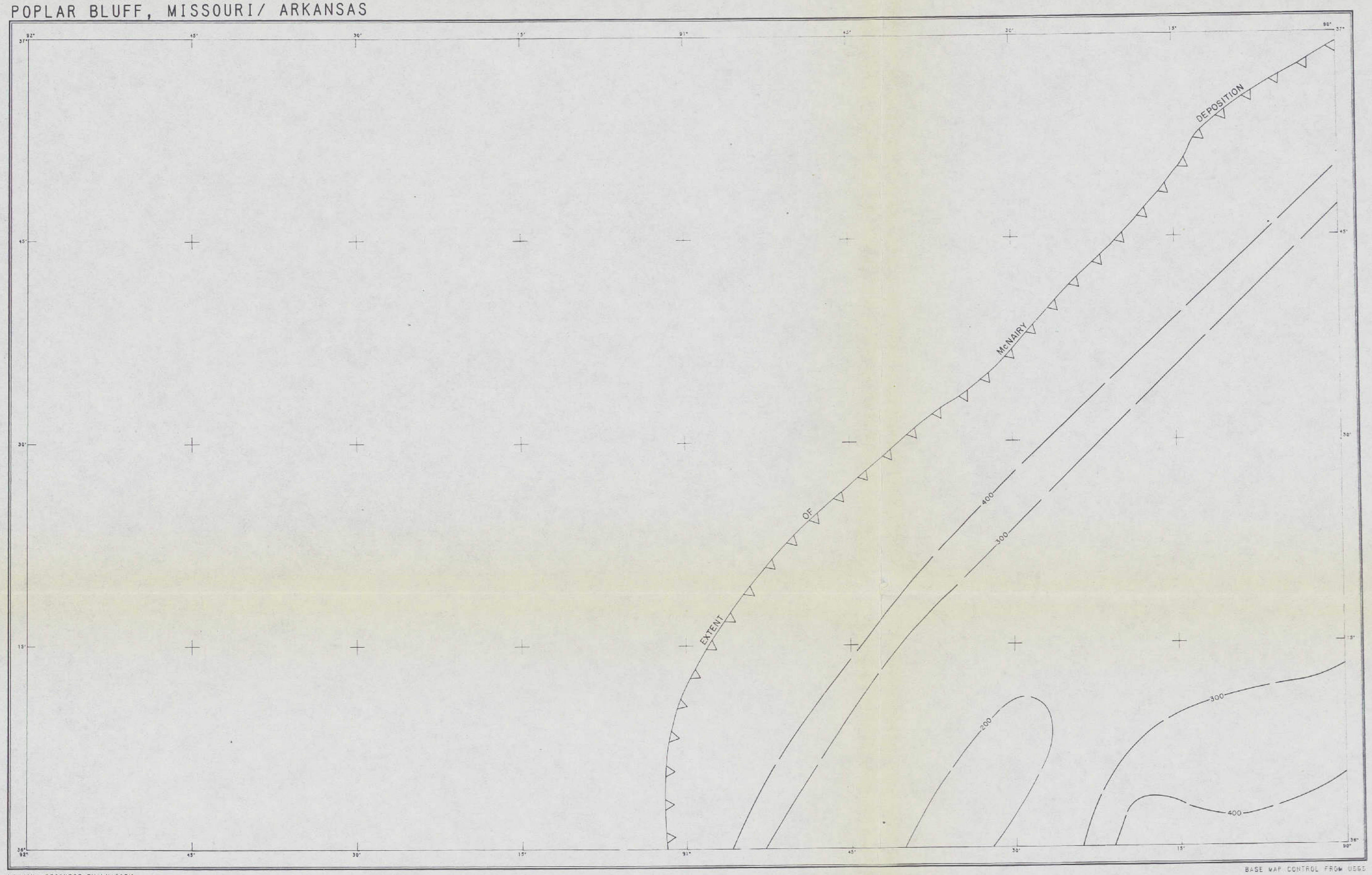
For

UNITED STATES DEPARTMENT OF ENERGY

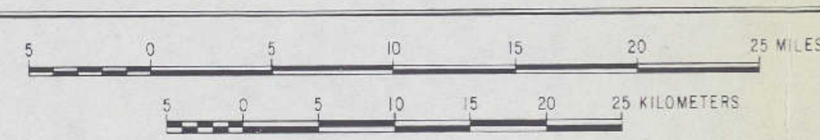
J.B. Gustavson
Boulder, Colorado
Principal Investigator

1965 MAGNETIC DECLINATION FROM TRUE NORTH FOR THIS SHEET VARIES FROM 6° (110 MILS) EASTERLY FOR THE CENTER OF THE WEST EDGE TO 5° (90 MILS) EASTERLY FOR THE CENTER OF THE EAST EDGE

POPLAR BLUFF, MISSOURI/ ARKANSAS



URANIUM RESOURCE EVALUATION
ISSUED BY THE U.S. DEPARTMENT OF ENERGY



J.B. Gustavson
Boulder, Colorado
Principal Investigator

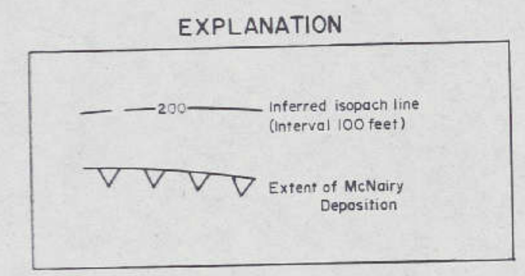
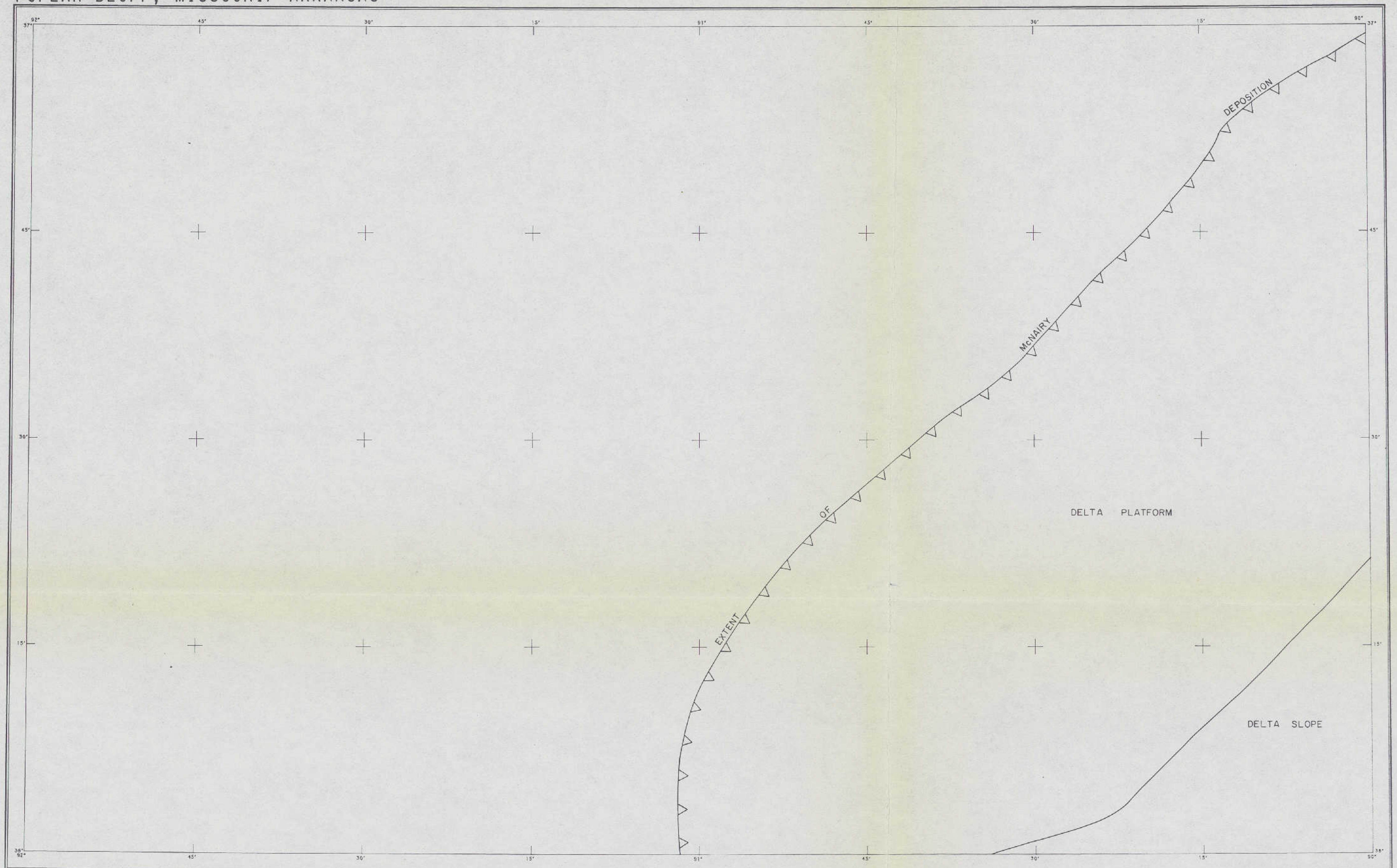


Plate 7. THICKNESS OF THE McNAIRY SAND

February 1980
Plate 7

POPLAR BLUFF, MISSOURI/ ARKANSAS



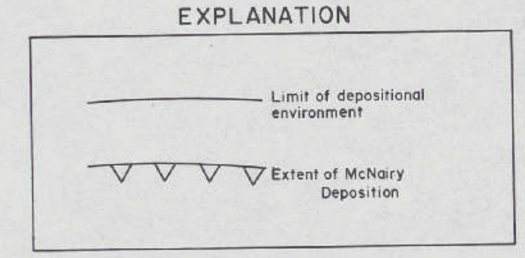
URANIUM RESOURCE EVALUATION
ISSUED BY THE U.S. DEPARTMENT OF ENERGY

BASE MAP CONTROL FROM USGS

5 0 5 10 15 20 25 MILES

5 0 5 10 15 20 25 KILOMETERS

EXPLANATION



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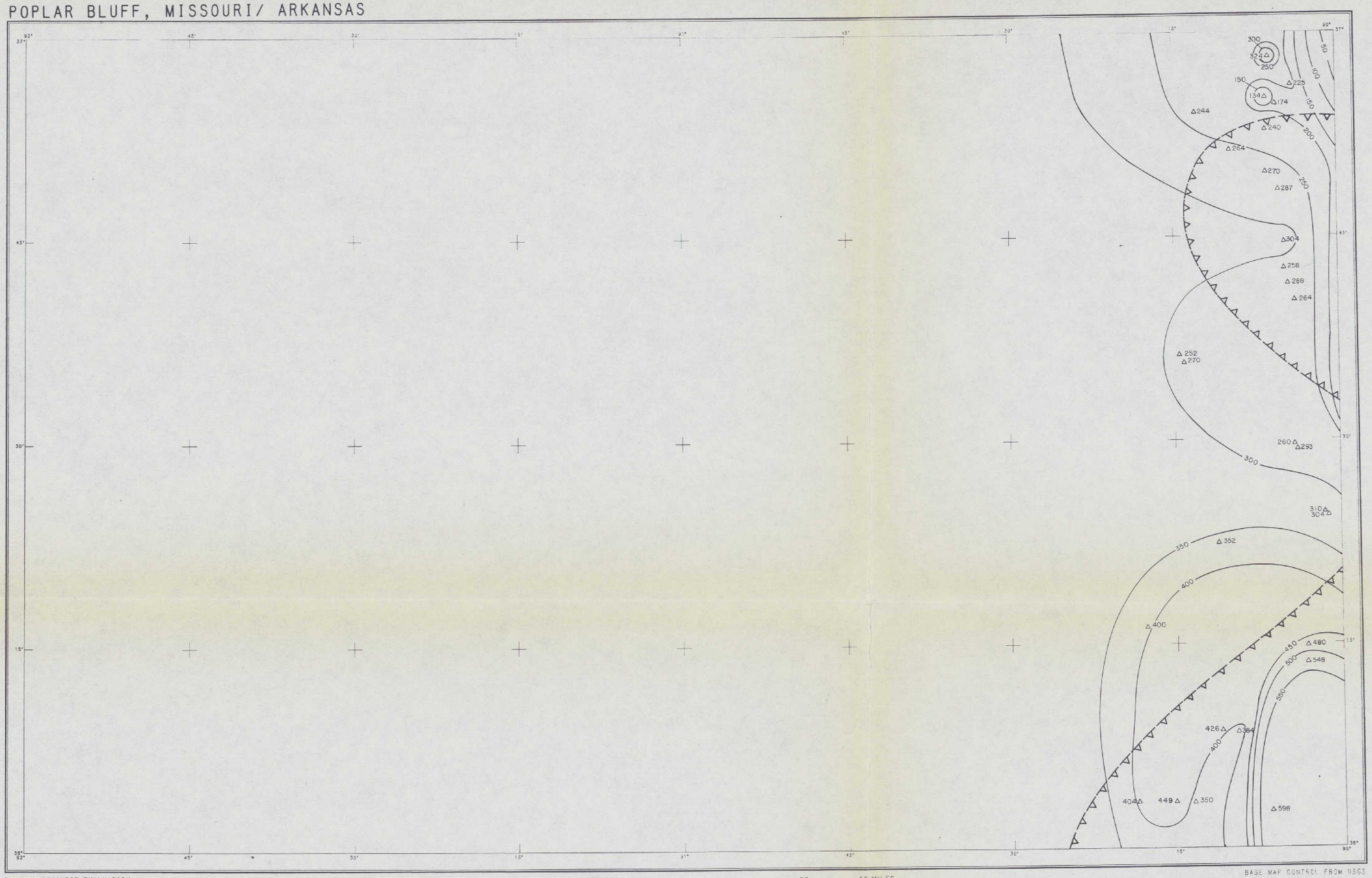
Principal Investigator

Plate 8. DEPOSITIONAL ENVIRONMENT OF THE McNAIRY SAND

February 1980
Plate 8

POPLAR BLUFF, MISSOURI/ ARKANSAS



URANIUM RESOURCE EVALUATION
ISSUED BY THE U.S. DEPARTMENT OF ENERGY

5 0 5 10 15 20 25 MILES

5 0 5 10 15 20 25 KILOMETERS

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Boulder, Colorado
Principal Investigator

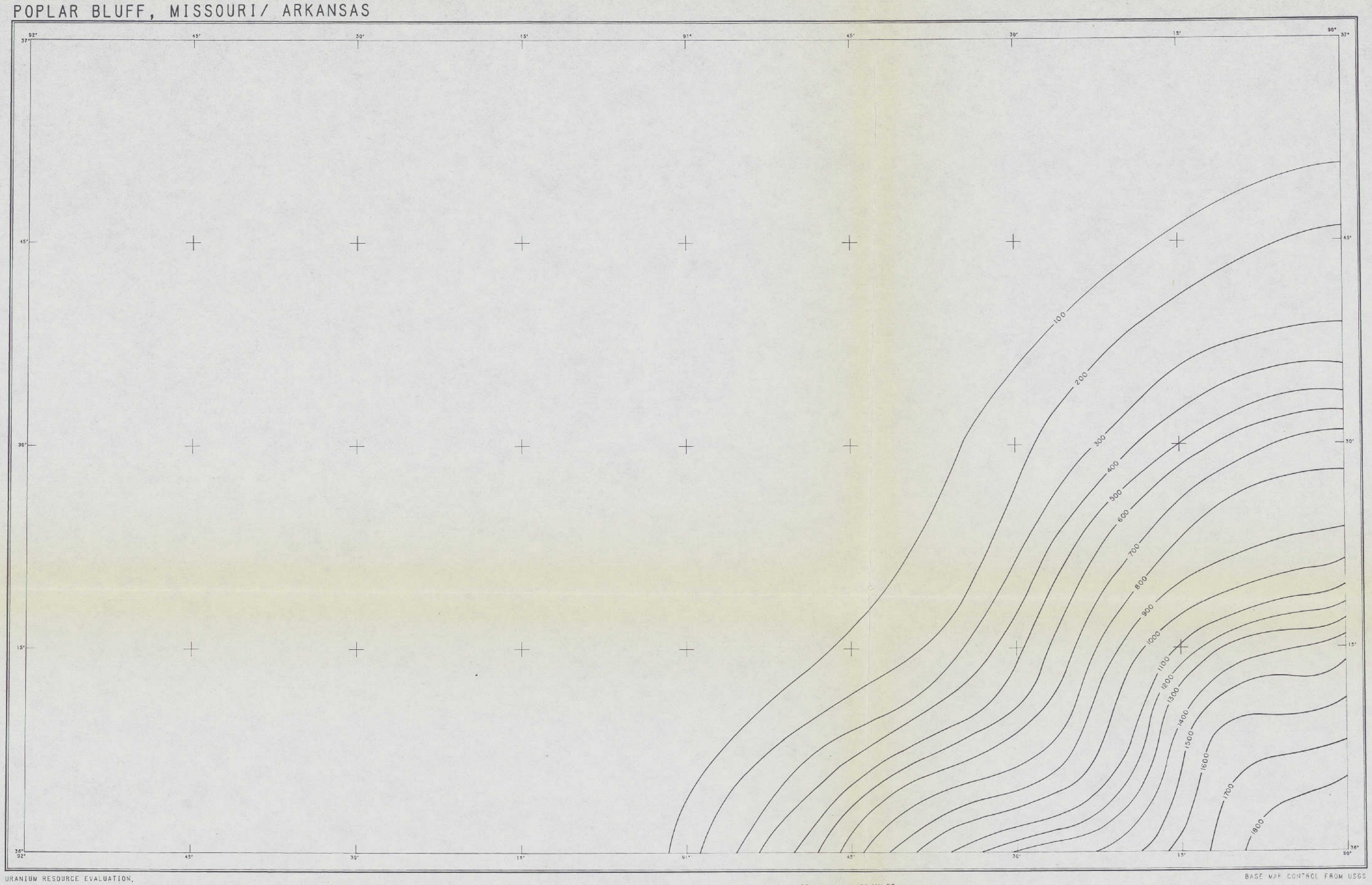
EXPLANATION

△	Location of Water Well
△293 or	Bicarbonate content (ppm)
260△	Bicarbonate content (ppm)
——200——	Bicarbonate contour (50 ppm interval)
▽ ▽ ▽ ▽	Approximate location of oxidation-reduction interface (Teeth indicate reduced area)

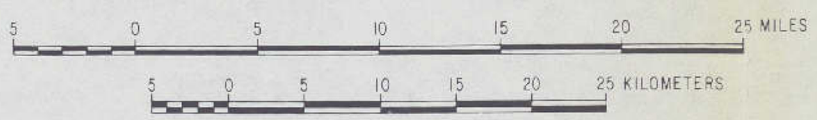
Plate 9. OXIDATION-REDUCTION INTERFACE OF THE McNAIRY SAND

February 1980
Plate 9.

POPLAR BLUFF, MISSOURI/ ARKANSAS



URANIUM RESOURCE EVALUATION,
ISSUED BY THE U.S. DEPARTMENT OF ENERGY



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EXPLANATION

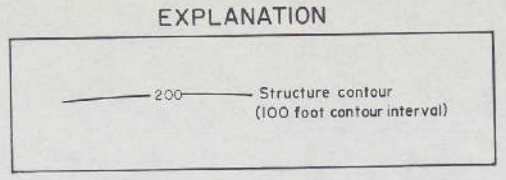
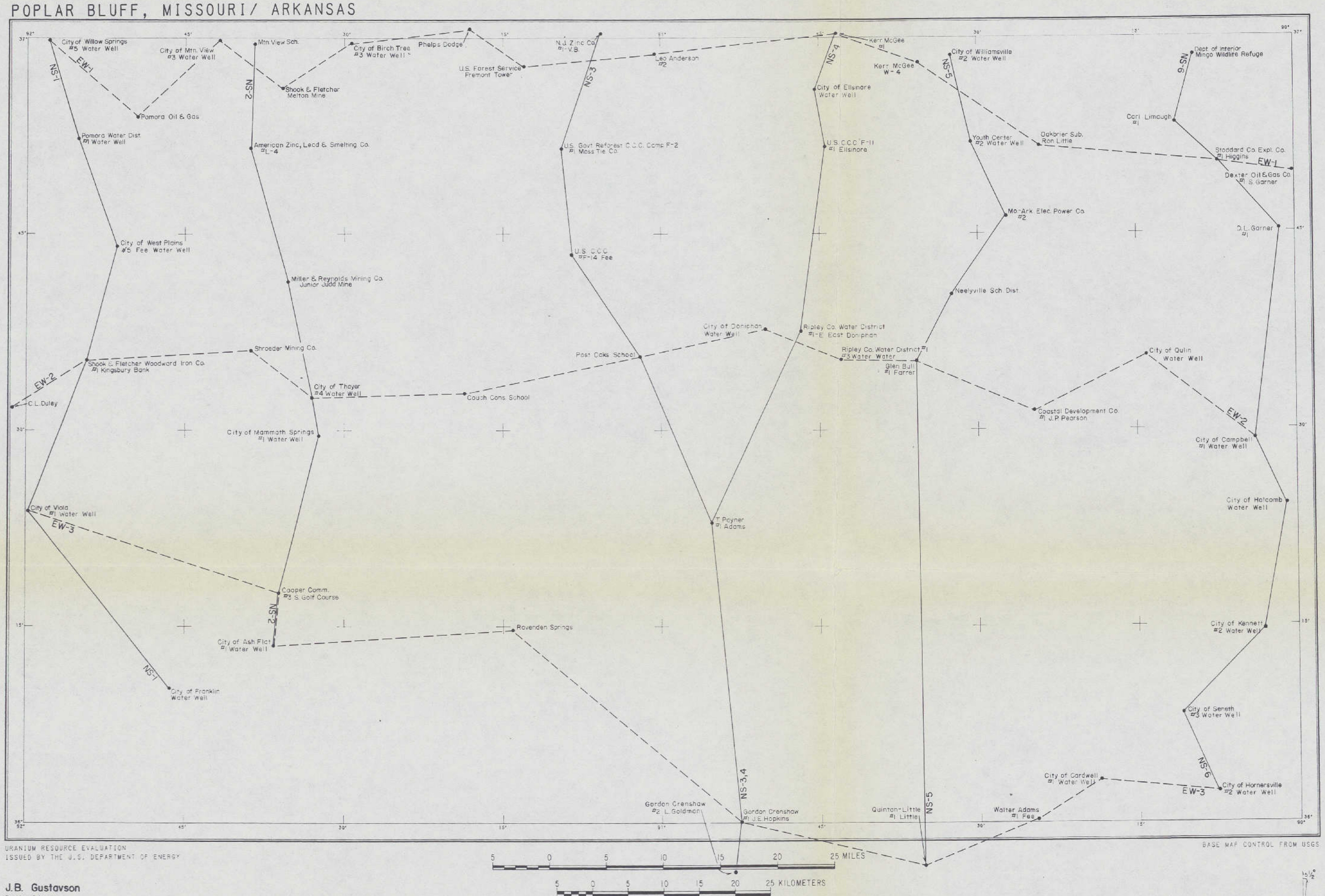


Plate 10. STRUCTURE ON TOP OF THE McNAIRY SAND

February 1980
Plate 10.

POPLAR BLUFF, MISSOURI/ ARKANSAS



EXPLANATION

- • Location of Well
- • Glenn Bull - Operator; #1 Farrer - Well number and farm name
- ——— North-South Cross-Section
- — — — East-West Cross-Section

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Boulder, Colorado
Principal Investigator

Plate II. LOCATION MAP OF CROSS-SECTIONS

February 1980

Plate II

POPLAR BLUFF, MISSOURI/ ARKANSAS

GEOLOGIC CODE

Sand, reduced	Shale
Sand, oxidized	Carbonate or Qu

VERTICAL SCALE 1:3600
HORIZONTAL SCALE 1:250,000

————————	Contact
- - - - - - - - - -	Inferred contact
— — ⇄ — —	Fault showing relative movement
∿∿∿∿∿	Unconformity

STRATIGRAPHIC CODE

Qu	Quaternary Undivided	Omu	Middle Ordovician Undivided
Tcf	Cockfield Formation	Ose	St. Peter Sandstone & Everton Dolomite
Tcm	Cook Mountain Formation	Oku	Upper Knox Group
Tcl	Claiborne Group	Or	Roubidoux Formation
Tw	Wilcox Group	Og	Gasconade Dolomite
Tpc	Porters Creek Clay	Ogg	Gunter Sandstone Member of the Gasconade Dolomite
Tc	Clayton Formation	Ꞓkl	Lower Knox Group
Koc	Owl Creek Formation	Ꞓb	Bonneterre Formation
Km	McNairy Sand	Ꞓlm	Lamotte Sandstone
Ku	Cretaceous Undivided	pꞒ	Precambrian
Mu	Mississippian Undivided		

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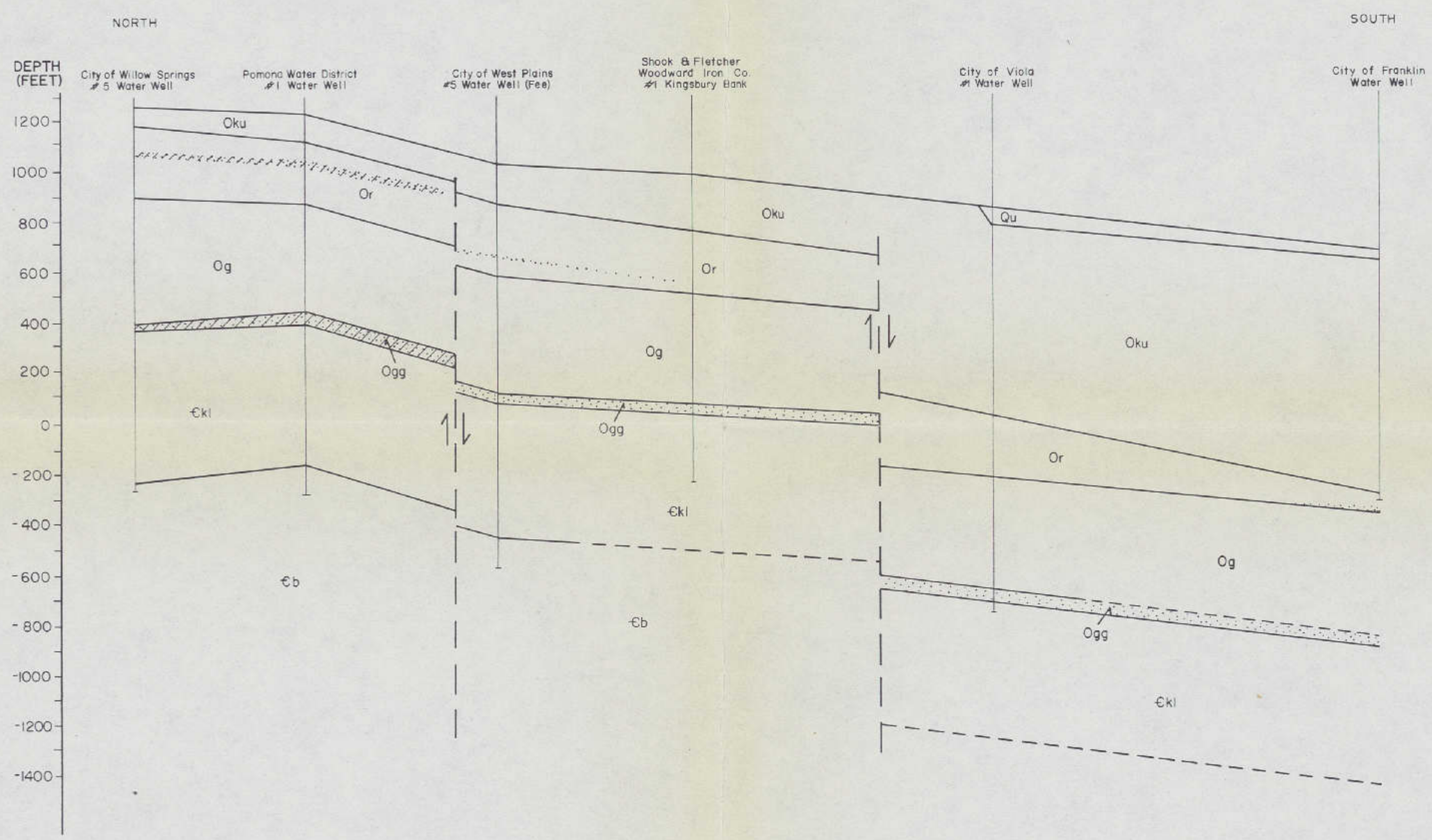
Boulder, Colorado
Principal Investigator

Plate 12. EXPLANATION OF CROSS-SECTIONS

February 1980
Plate 12.

POPLAR BLUFF, MISSOURI/ ARKANSAS



Refer to Plate 11. for Location of Cross-Sections

Refer to Plate 12. for Explanation

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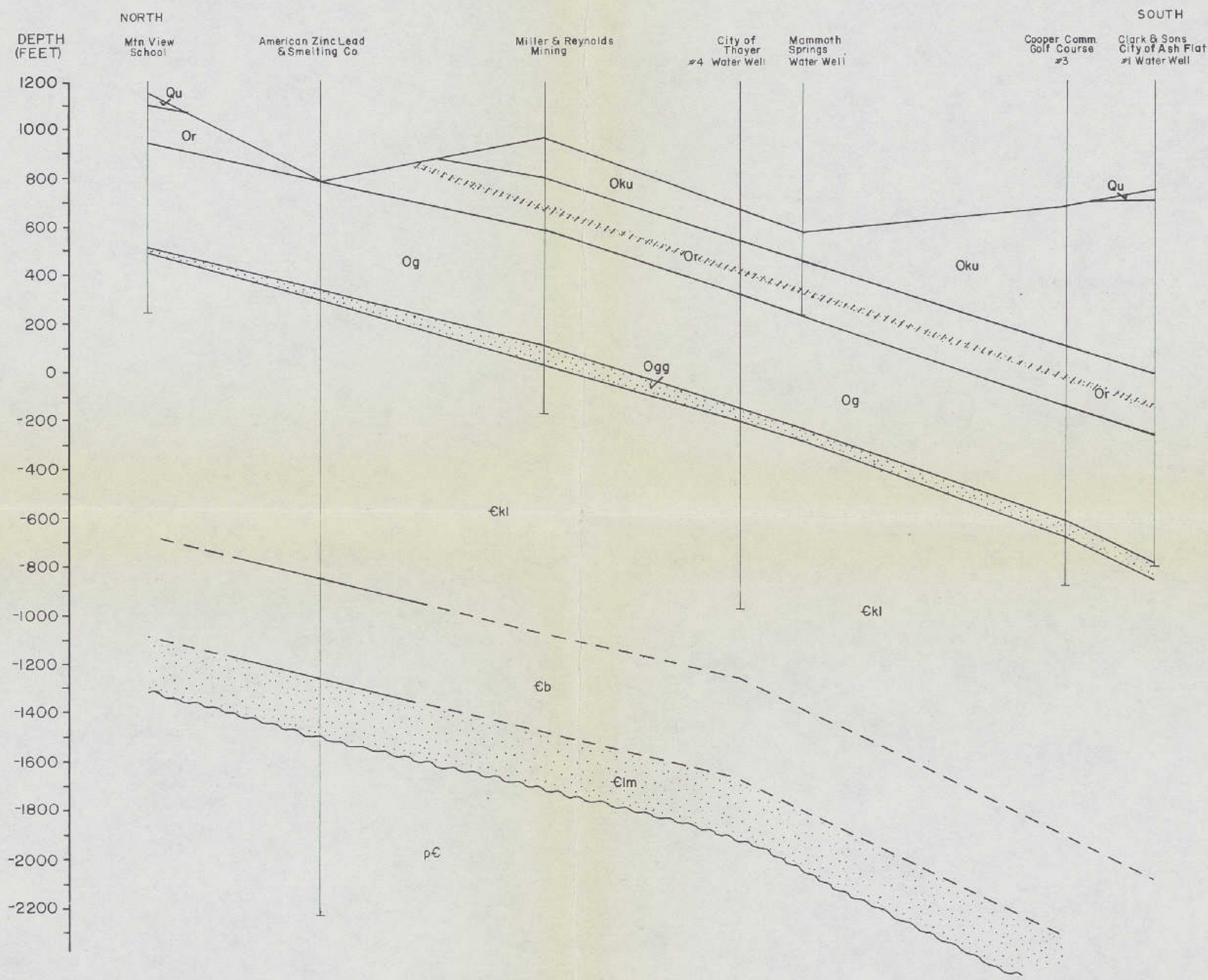
Plate 13. NORTH - SOUTH I

February 1980
Plate 13.

POPLAR BLUFF, MISSOURI/ ARKANSAS



Refer to Plate 11. for Location of Cross-Sections

Refer to Plate 12. for Explanation

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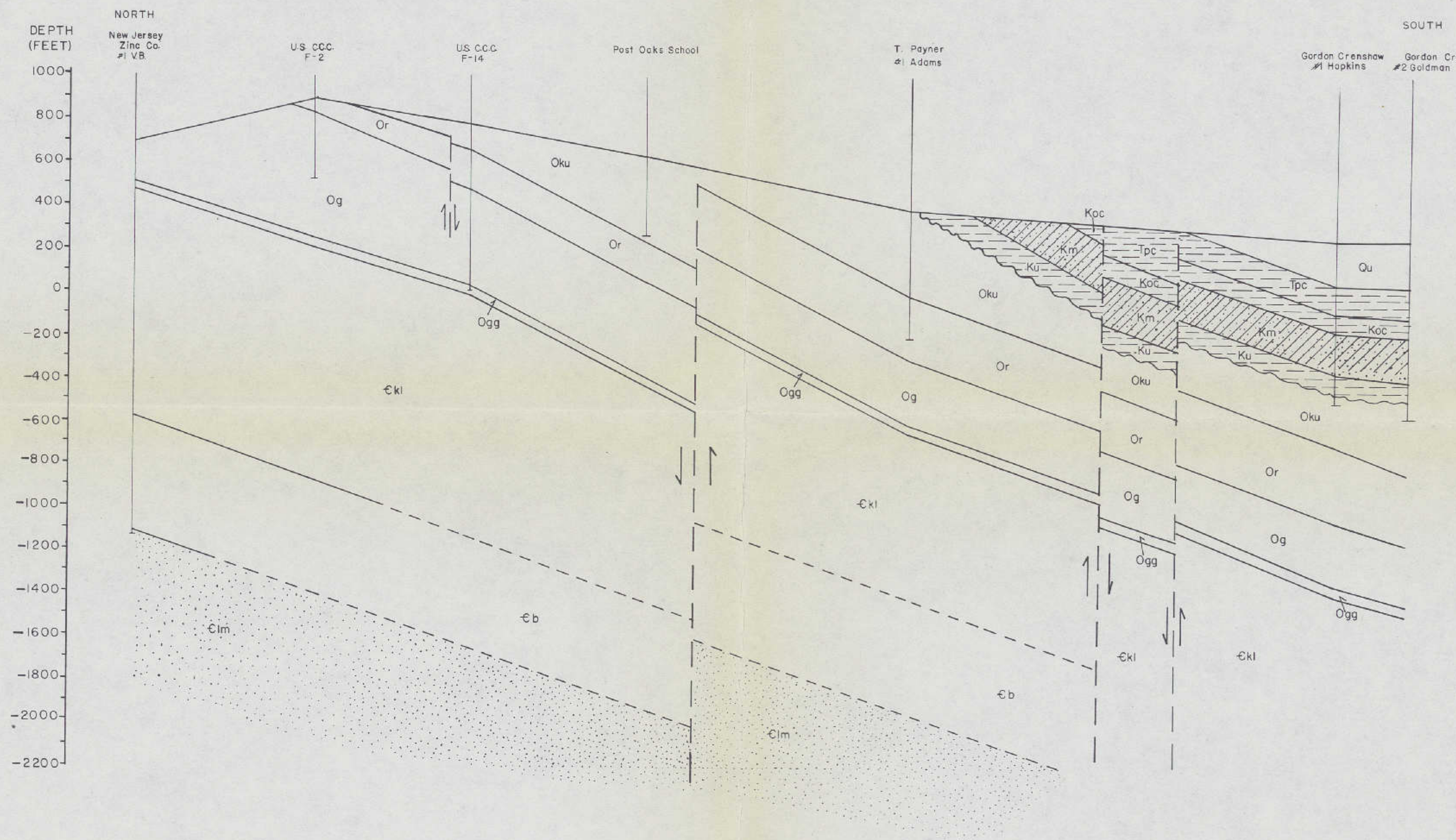
Plate 14. NORTH-SOUTH 2

February 1980
Plate 14.

POPLAR BLUFF, MISSOURI/ ARKANSAS



Refer to Plate 11. for Location of Cross-Sections

Refer to Plate 12. for Explanation

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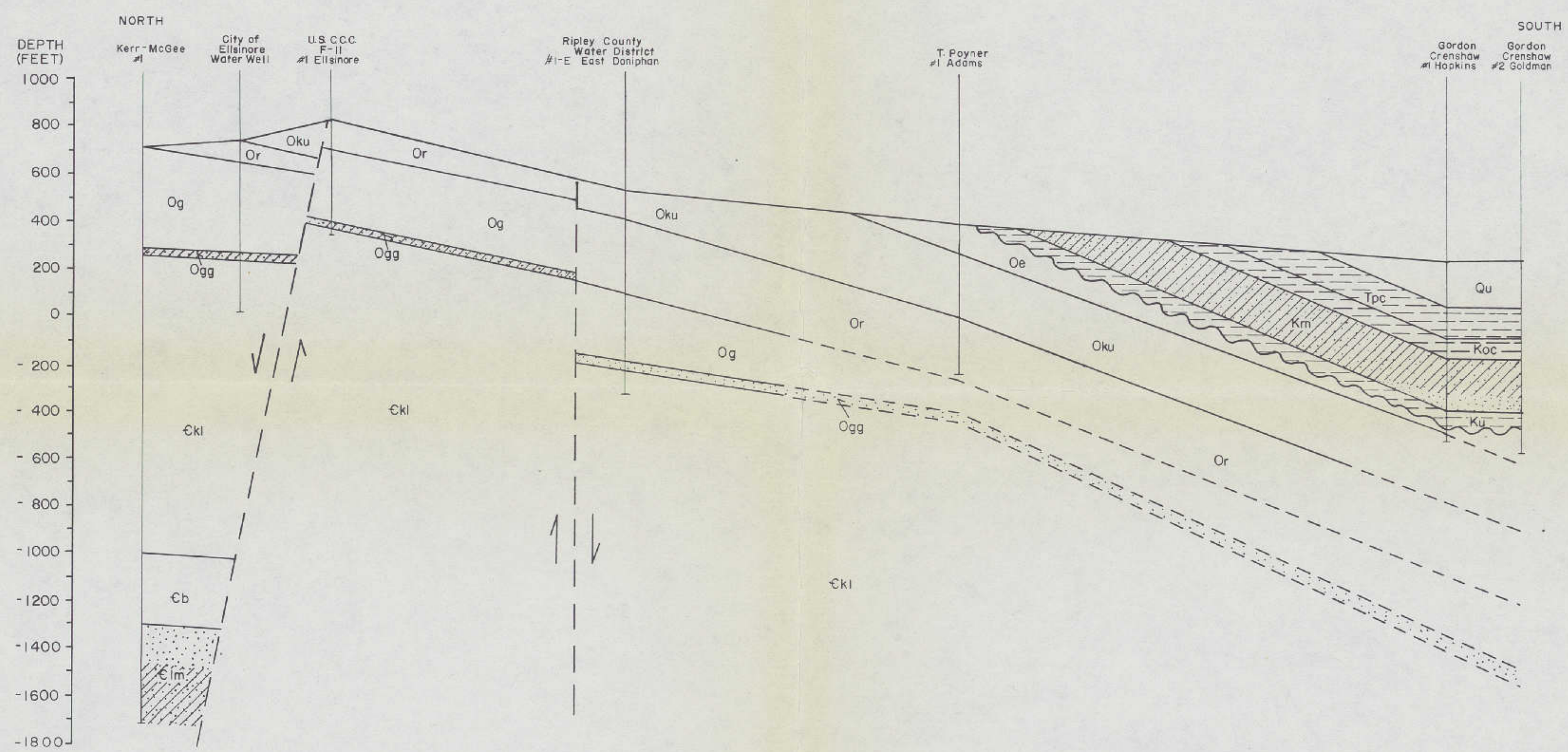
Plate 15. NORTH-SOUTH 3

February 1980
Plate 15.



Refer to Plate 11. for Location of Cross-Sections

Refer to Plate 12. for Explanation

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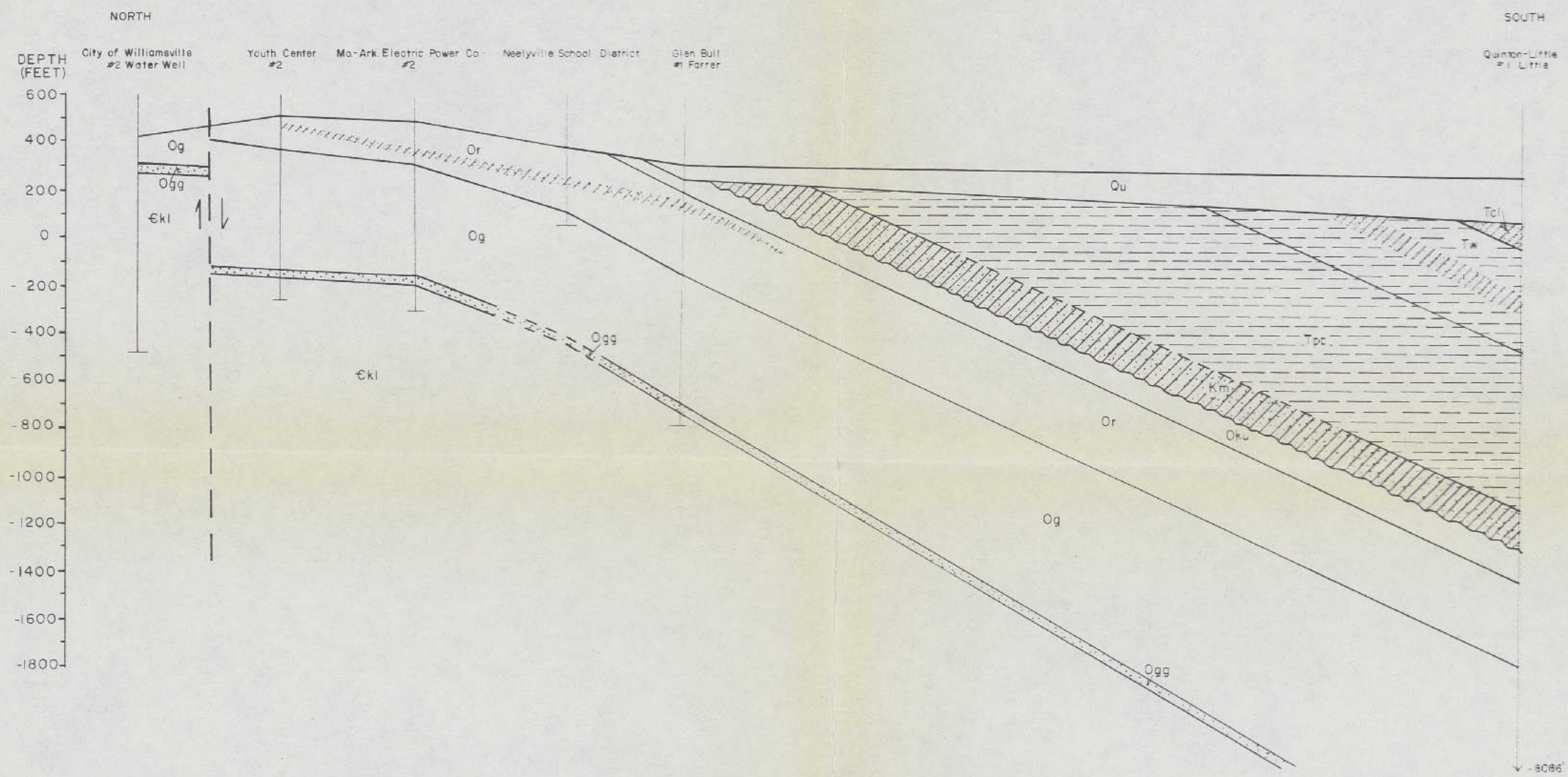
Plate 16. NORTH-SOUTH 4

February 1980
Plate 16.

POPLAR BLUFF, MISSOURI/ ARKANSAS



Refer to Plate 11. for Location of Cross-Sections

Refer to Plate 12. for Explanation

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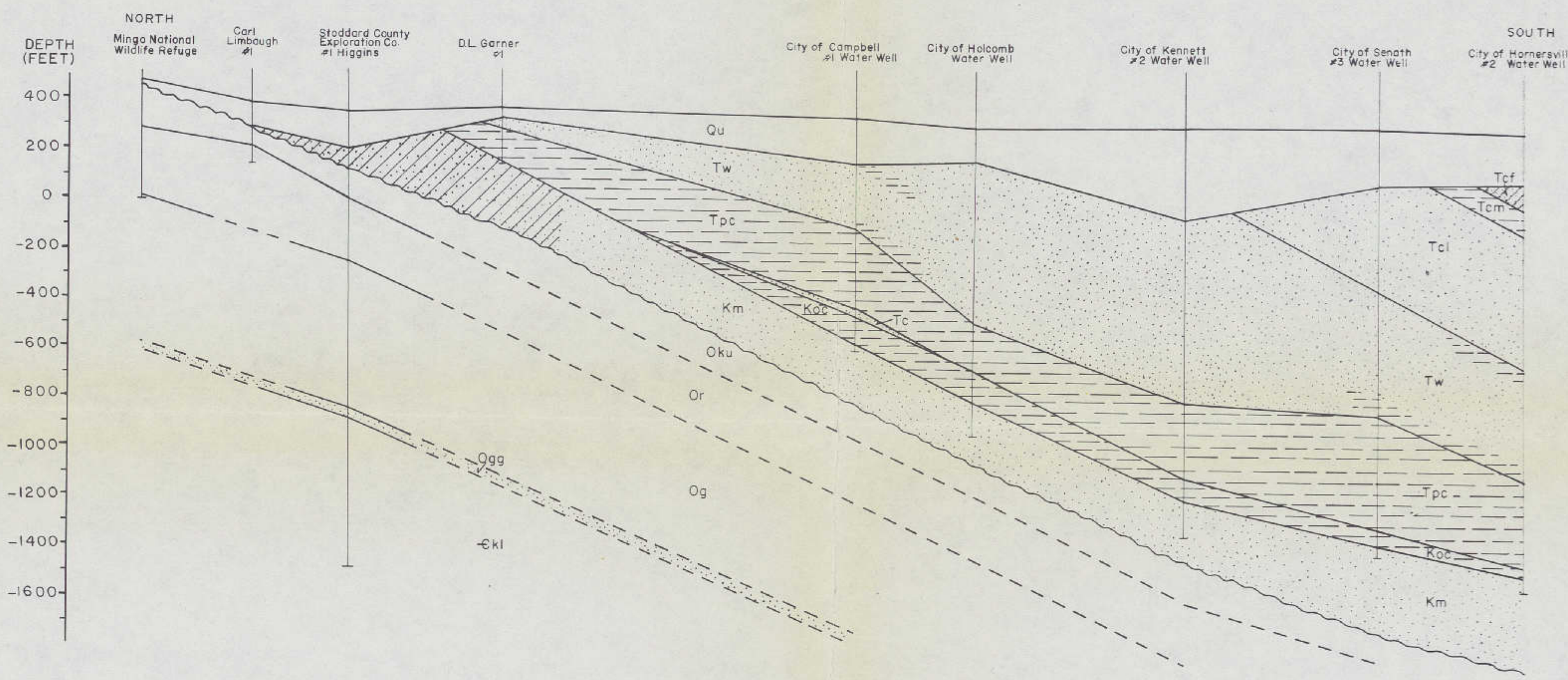
Plate 17. NORTH-SOUTH 5

February 1980
Plate 17.

POPLAR BLUFF, MISSOURI/ ARKANSAS



Refer to Plate 11. for Location of Cross-Sections

Refer to Plate 12. for Explanation

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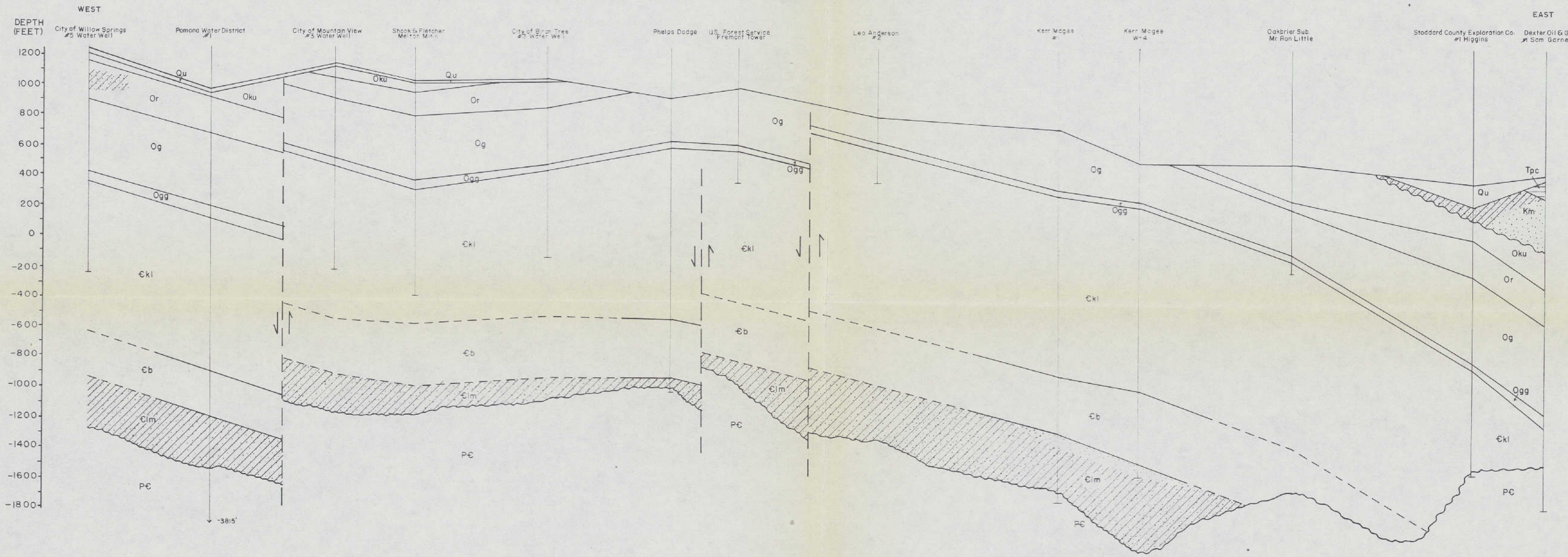
Plate 18. NORTH-SOUTH 6

February 1980
Plate 18.

Poplar Bluff

POPLAR BLUFF, MISSOURI/ ARKANSAS



Refer to Plate 11. for Location of Cross-Sections

Refer to Plate 12. for Explanation

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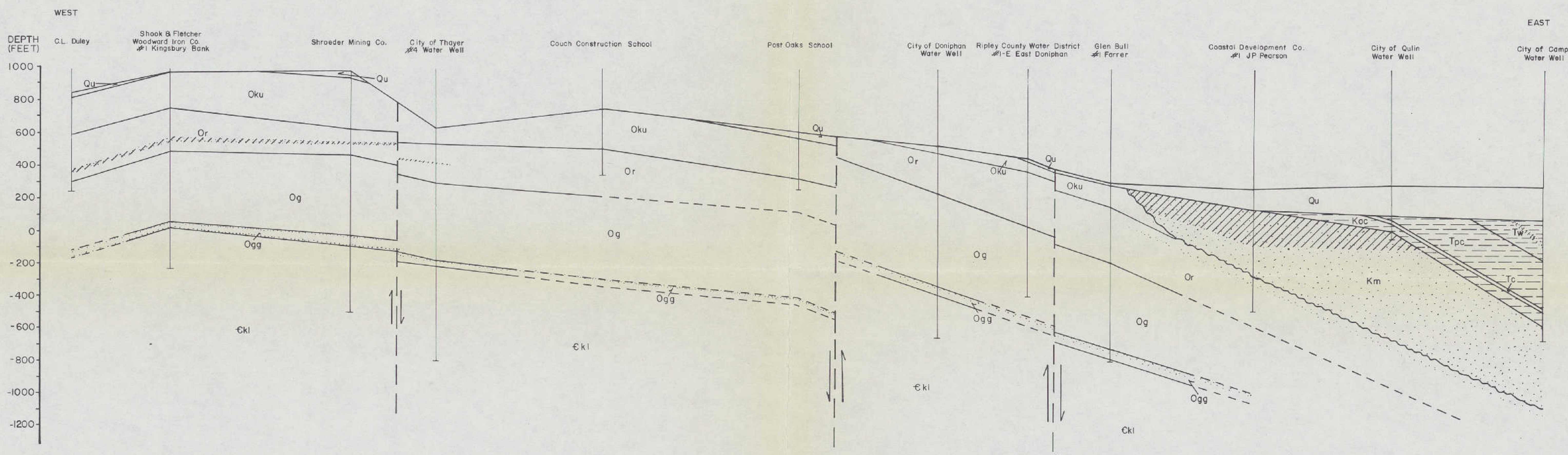
Plate 19. EAST-WEST 1

February 1980
Plate 19.

Poplar Bluff

POPLAR BLUFF, MISSOURI/ ARKANSAS



Refer to Plate 11. for Location of Cross-Sections

Refer to Plate 12. for Explanation

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Plate 20. EAST - WEST 2

February 1980
Plate 20.

POPLAR BLUFF, MISSOURI/ ARKANSAS

Refer to Plate 11. for Location of Cross-Sections

Refer to Plate 12. for Explanation

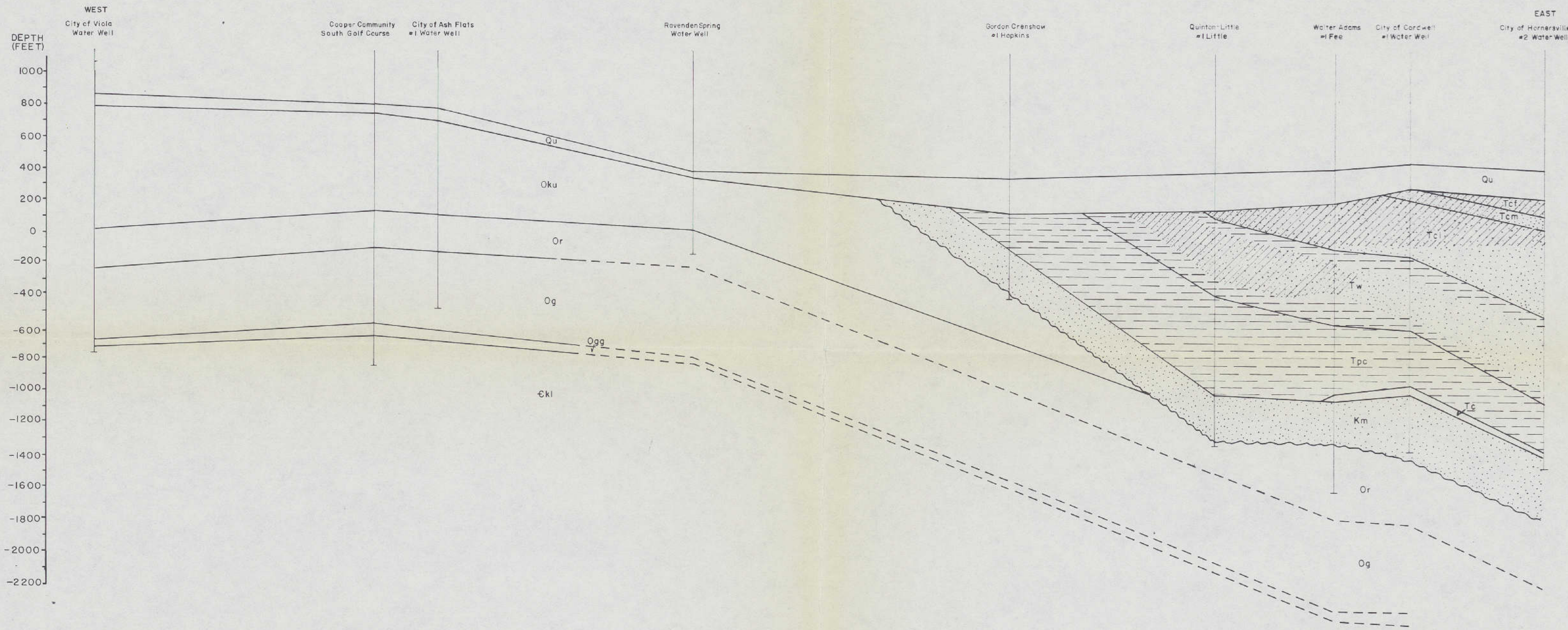

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Plate 21. EAST - WEST 3

February 1980
Plate 21.

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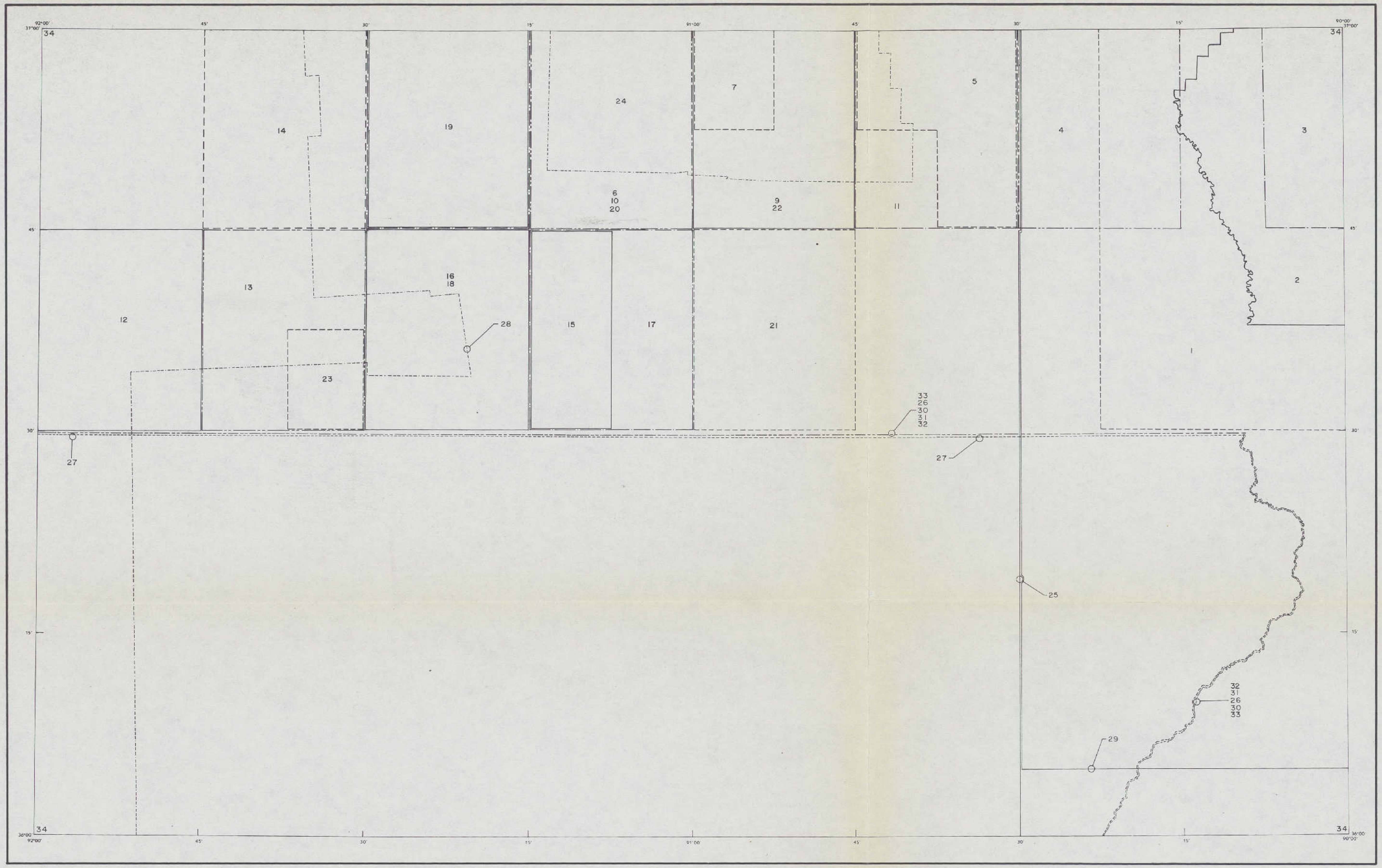
See Appendix E



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Principal Investigator

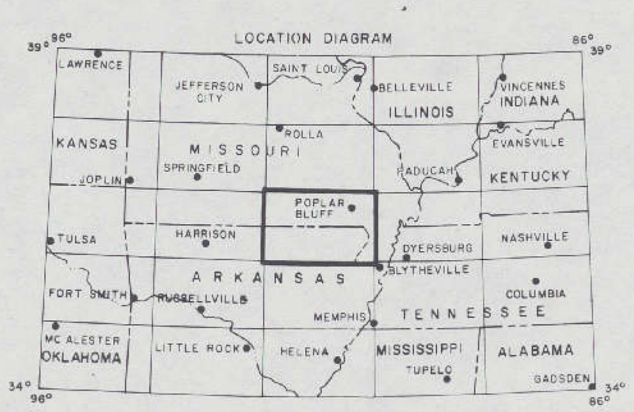
1:250,000

Statute miles

Kilometers

CONTOUR INTERVAL 100 FEET

Plate 22. GEOLOGIC MAP INDEX

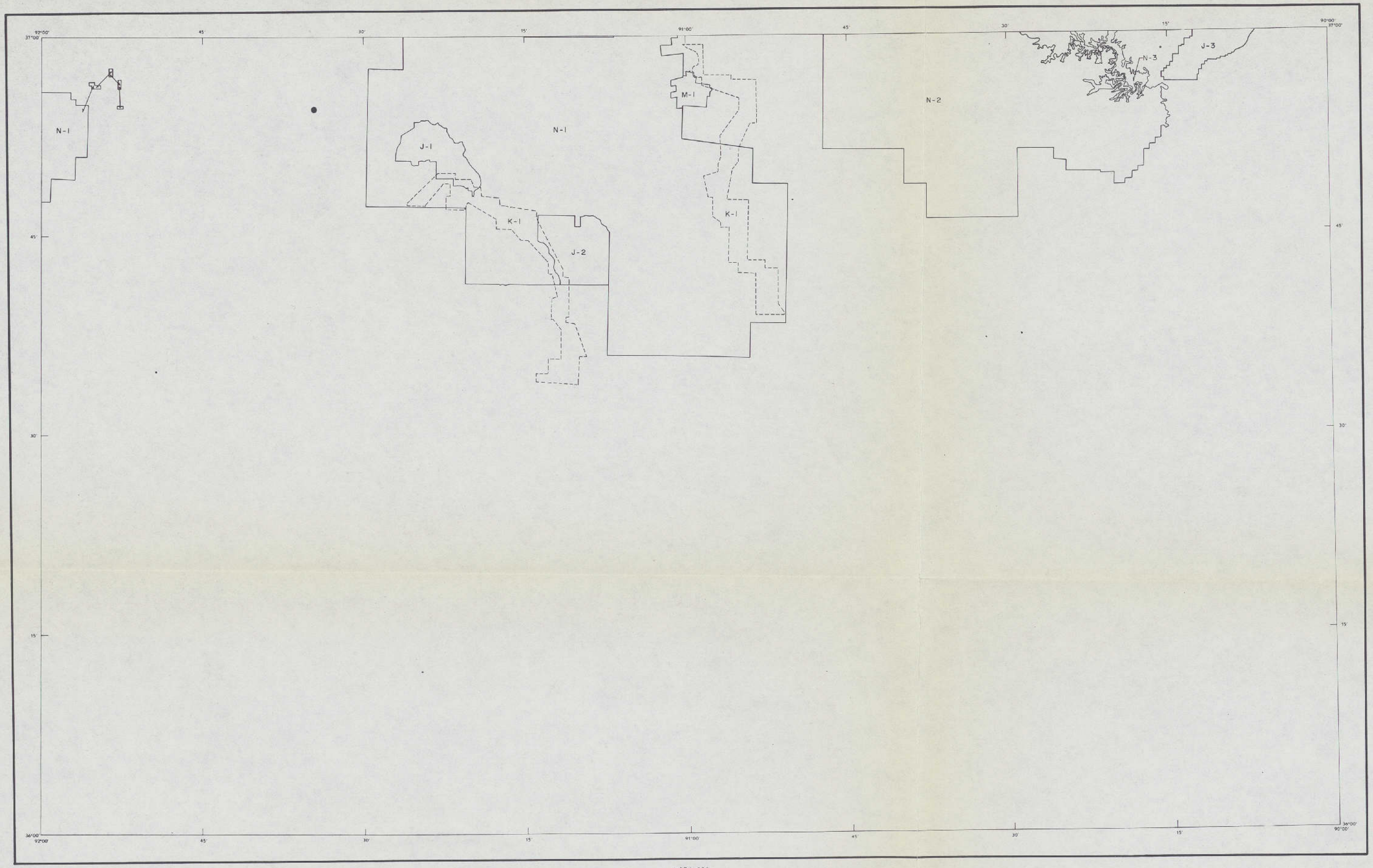


By
GEOCHEMEX, Memphis, TN.
Under Subcontract No. 78-138-S With BFEC
For
THE U.S. DEPT. OF ENERGY

1965 MAGNETIC DECLINATION FROM TRUE NORTH FOR THIS SHEET VARIES FROM 6° (110 MILS) EASTERLY FOR THE CENTER OF THE WEST EDGE TO 5° (90 MILS) EASTERLY FOR THE CENTER OF THE EAST EDGE.

February 1980
Plate 22

POPLAR BLUFF, MO.; ARK.



EXPLANATION

J-1 Eleven Point State Game Refuge
J-2 Wilderness State Game Refuge
J-3 Mingo National Wildlife Refuge

K-1 Ozark National Scenic Rivers

M-1 Big Spring State Park

N-1 Mark Twain National Forest
N-2 Clark National Forest
N-3 Lake Wappapello

(Mining subject to U.S. Corps of Engineers authority under Rivers and Harbors Act of 1899 and Federal Water Pollution Control Act Amendments of 1972.)

1:250,000

CONTOUR INTERVAL 100 FEET

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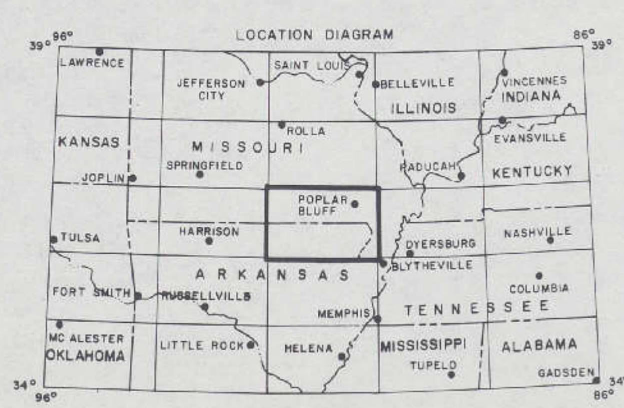
Principal Investigator

Plate 23. GENERALIZED LAND STATUS



By
GEOCHEMEX, Memphis, TN.
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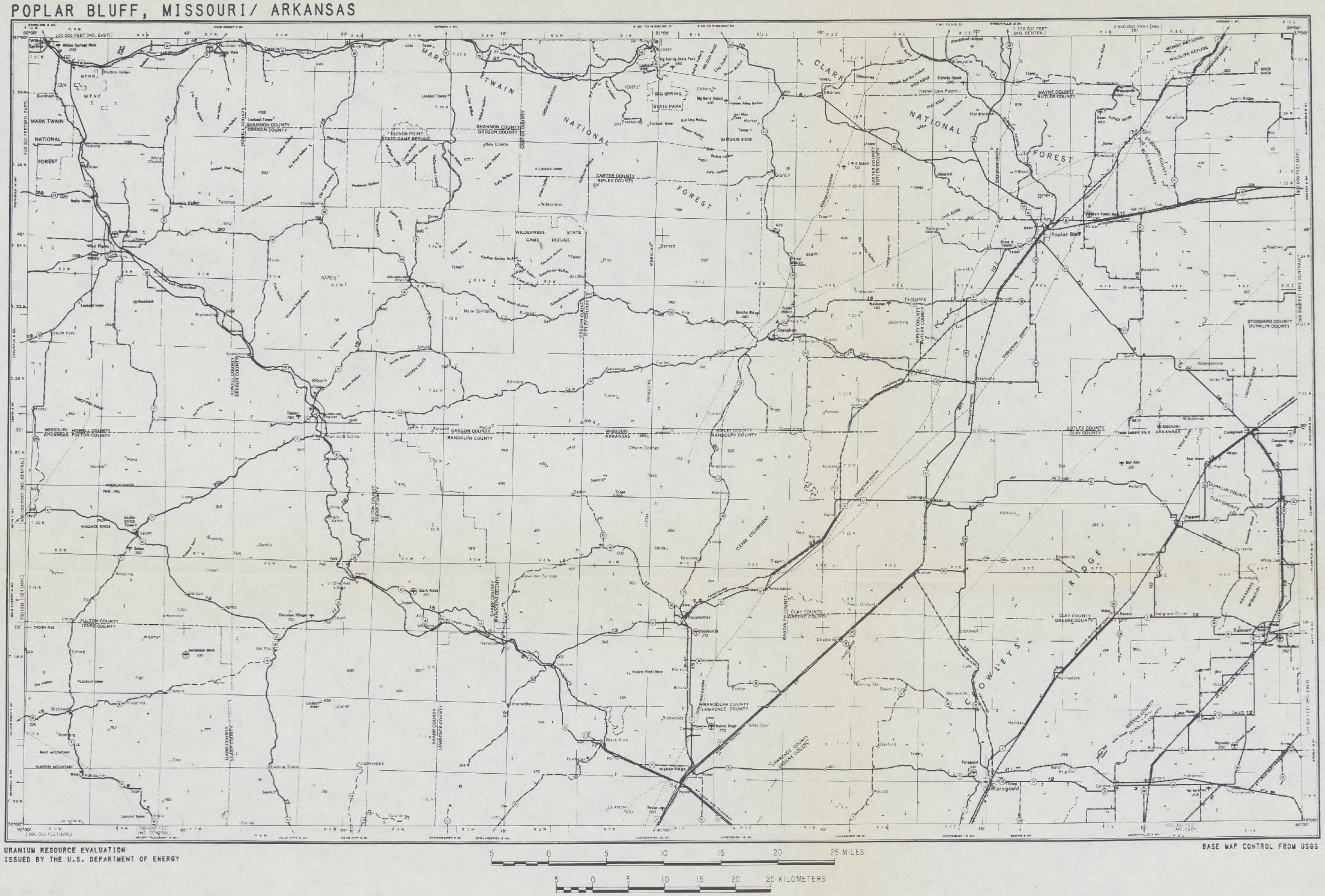
1965 MAGNETIC DECLINATION FROM TRUE NORTH FOR THIS SHEET VARIES FROM 6° (110 MILS) EASTERLY FOR THE CENTER OF THE WEST EDGE TO 5° (90 MILS) EASTERLY FOR THE CENTER OF THE EAST EDGE.

February 1980
Plate 23.

POPLAR BLUFF, MISSOURI/ ARKANSAS



URANIUM RESOURCE EVALUATION
ISSUED BY THE U.S. DEPARTMENT OF ENERGY

BASE MAP CONTROL FROM USGS

Plate 24. CULTURE

February 1980
Plate 24.