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JUN 1 4 1949

AEC-366/9

Dr. Phillip L. Merritt, Assistant Manager,
Raw Materials Operations,
U. S. Atomic Energy Commission,
P. O. Box 30, Ansonia Station,
New York 23, New York.

Dear Phil:

Transmitted herewith are copies 1 through 6 of a report by John M. Nelson and Edward V. Stratton, entitled "Preliminary report of Trace Elements Reconnaissance in Indiana, Illinois, Missouri, Arkansas, and Kentucky," Trace Elements Investigations - Report 34.

Copies 7 and 8 of this report are being forwarded to Mr. John K. Gustafson in accordance with his request of February 25, 1949.

Sincerely yours,

Thomas B. Nolan
Assistant Director.

Enclosure

Orig. & 5 cc - Merritt, N.Y.
2 cc - Gustafson, AEC, Wash.

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UNITED STATES DEPARTMENT OF THE INTERIOR

GEOLOGICAL SURVEY

TRACE ELEMENTS RECONNAISSANCE IN INDIANA, ILLINOIS, MISSOURI, ARKANSAS, AND KENTUCKY

Preliminary Report

by

John M. Nelson and Edward V. Stratton

May 1949

Trace Elements Investigations - Report 34

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TRACE ELEMENTS RECONNAISSANCE IN INDIANA, ILLINOIS, MISSOURI, ARKANSAS, AND KENTUCKY

PRELIMINARY REPORT

by

John H. Nelson and Edward V. Stratton

ABSTRACT

Numerous shales, coals, igneous rocks and a few metallic and non-metallic ores were examined in Indiana, Illinois, Missouri, Arkansas, and Kentucky in October and November 1946. In other regions, some materials of these types had proved to be sufficiently radioactive to warrant examination of similar materials in the region of this investigation.

The examination consisted largely of testing radioactivity at the outcrop and by car traversing. Samples were taken of the more highly radioactive materials.

The investigation increased information on the distribution of radioactivity in the Chattanooga shale and revealed two radioactive coals in Indiana and several radioactive mineralized zones in hydrothermally altered alkalic rocks near Magnet Cove, Arkansas.

Although the maximum radioactivity of coals and associated shales is only 0.006 percent equivalent uranium, the amount of radioactivity is sufficient to suggest that some study should be made to determine if there is a correlation between such radioactive coals and their particular stratigraphic and geologic position that might have some general application.

The best part of the Chattanooga shale in Indiana contains about 0.006 percent equivalent uranium. This is more than the radioactivity of the formation at the points where it was tested in Ohio, Illinois, and Missouri, but less than in east-central Tennessee where the best parts of the formation contain about 0.011 percent equivalent uranium.

The radioactivity of the complex lead, zinc, copper, cobalt, and nickel ores of the Fredericktown district, Missouri, and rocks and manganese ores of the Batesville district, Arkansas, is generally less than 0.003 percent equivalent uranium. The source of radon in the spring waters at Hot Springs seems to be the Polk Creek shale, which locally contains 0.008 percent equivalent uranium.

At Magnet Cove, Arkansas, white hydrothermally altered zones in the alkalic igneous rocks contain a maximum of 0.019 percent equivalent uranium and, at places, the soil in this area is abnormally radioactive. The tonnage of radioactive material that was found appears insignificant, and considerable detailed work would be required to determine whether radioactive zones of altered rock are present to a significant extent.

The radioactivity of nepheline syenite and other alkalic rocks in the vicinity of Potash Sulphur Springs, Arkansas, and of fluorspar deposits and the Warsaw formation in Illinois and Kentucky is too slight to warrant further investigation of these materials.

INTRODUCTION

Field work for the present investigation of radioactive rocks and ores in Indiana, Illinois, Missouri, Arkansas, and Kentucky, was limited to the months of October and November, 1946. Its purpose was to investigate numerous shales, coals, igneous rocks, and metallic ores which had proved radioactive in other areas and to improve the techniques of measuring the radioactivity of rocks in the field.

FIELD METHODS

Many methods have been developed for determining the radioactivity of rocks in the field. Each technique has its special purpose and its limitations. The results of the present investigation were obtained by using the techniques described below.

Car traverse tests.--The car traverse test was used as a rapid method of estimating the relative radioactivity of the rocks adjacent to the road. Equipment consisted of a large gamma tube having a normal background of about 400 counts per minute connected in a ratemeter circuit. The gamma tube was mounted above the engine hood of the field car and the ratemeter was placed in front of the observer. The equipment was sufficiently sensitive to differentiate between the low radioactivity of normal sandstones and the higher radioactivity of normal shales at speeds of 10 to 15 miles per hour. The equipment was developed in the field and was in use only during the latter half of the field trip. The radioactive Polk Creek shale and the radioactive soils of Magnet Cove were discovered using this method.

Outcrop tests.--The gamma radioactivity of the rocks at the outcrop was measured by placing a Geiger-Mueller tube of a portable counter on the outcrop for a period of five minutes and recording the number of pulses per minute registered by the counter. The pulses per minute were converted into percent equivalent uranium by the method described in Trace Elements Investigations Report No. 22.

Sample tests.--Rocks indicated to be abnormally radioactive by outcrop test were sampled, and the gamma radioactivity of the samples was determined in the field. Beta radioactivity measurements of the samples were made in the laboratory in Washington, D. C.

The accuracy of the radioactivity measurements varied with method. The car traverse tests were the fastest and least accurate. They were used to screen large areas for abnormally radioactive rocks and not to determine quantitatively the actual radioactivity of the rocks. The outcrop tests had an average reproducibility of about 0.001 percent equivalent uranium but, as expressed in percent equivalent uranium, were subject to errors as large as 0.003 percent equivalent uranium owing to varying size and outcrop shape of the radioactive rocks. The gamma sample tests in the field were reproducible to within 0.002 percent eqivalent uranium but non-representative sampling may have introduced much larger errors. The laboratory beta tests are usually accurate to within 0.001 percent equivalent uranium but again non-representative sampling may have introduced large errors.

Localities referred to by numbers in this report and at which samples were collected are shown on the index map (plate 1).

GENERAL RESULTS OF THE INVESTIGATION

Coals and shales of Indiana

The block coals of Indiana, the Number 1, Minshall, Number 3, Number 3a, and several unnamed coals and their associated shales were investigated. The following table shows the stratigraphic position of these coals.

The Pennsylvanian coals of Indiana

AGE	FORMATION	COAL
Post-Allegheny	Merom	Merom
	Shelburn	Sommerville limestone Coal VIII
Allegheny	Petersburg	Coal VII (Millersburg) Coal VI Coal Va (Petersburg) Coal IVa
	Staunton	Coal IV (Linton) Coal IIIa Coal III (Seelyville)
Pottsville	Brazil	Coal II (Upper Minshall) Minshall coal Upper Block coal Lower Block coal
	Mansfield	Coal I

Radioactivity measurements at the outcrops indicate that the shales adjacent ot the No. 1, Lower Block, Upper Block, Hinshall, and No. 3 coals, as well as the coals themselves, are not abnormally radioactive (localitites 1, 2, 3, 4, 6, 7, 8, 10, 11, 12).

Of greater interest was an unidentified coal near Gentryville (locality 5). The coal is well-exposed and ranges in thickness from about 8 inches to slightly more than 1 foot. The top of the coal is eroded and shows a local relief of from 1 to 3 inches. A coarse massive sandstone rests on the eroded upper surface of the coal. Downward, the coal grades through a one-inch coaly shale into several feet of soft light-greenish-gray shale. The lateral extent of the coal is not known. Traverses on nearby side roads failed to find it. Its radioactivity at the outcrop and in a sample is about 0.003 percent equivalent uranium. The overlying and underlying sediments are not unusually radioactive.

The abnormally radioactive black shale above Coal IIIa at locality 9 is also of interest. Approximately 2.5 feet of this shale has an average radioactivity of 0.004 percent equivalent uranium. The radioactive part of the black shale has about the same stratigraphic position as the Oak Grove limestone found in many places above Coal IIIa.

The limited field work has proved the presence of a radioactive coal and a radioactive shale in Indiana as well as two radioactive shales in Kentucky. /

/ Nelson, J. M. and Brill, K. G., Radioactivity of the Chattanooga shale east of the Mississippi River and south of the Ohio River, interim report: U. S. Geological Survey, Trace Elements Investigations Rept. 22, unpublished, August, 1947.

In all probability the radioactive coals and shales referred to above have not been tested where they are the most radioactive, and the limited number of radioactivity tests in the Eastern Interior Coal Basin probably have not found all of the radioactive coals and shales. Further work in this area would be desirable.

In the future it would be desirable to test all exposed coals and shales in two or more 10-mile wide belts across the basin and to determine the areal extent and grade of the known radioactive coals and shales.

A study of this type would serve the dual purpose of locating and determining the extent and grade of radioactive sediments and would introduce a new and valuable method for correlating coals.

Chattanooga shale of Indiana, Illinois, and Missouri

In Indiana the Chattanooga shale (New Albany shale) ranges from 100 to 140 feet in thickness and extends from the town of New Albany in southeastern Indiana northward to Delphi in the north-central part of the State. Structurally, it lies on the western flank of the Cincinnati arch and disappears under the Eastern Interior Coal Basin. Its low westerly dip gives the shale an outcrop width of from 5 to 20 miles. For the most part the shale is covered with a superficial layer of glacial debris, and only in the southern part of the State are exposures plentiful.

In southern Indiana, tests at the outcrop indicate that the radioactivity of the shale ranges from 0.004 to 0.010 percent equivalent uranium (localities 14 and 15). Samples collected from the most radioactive parts of the shale at these two localities contain 0.006 percent equivalent uranium. In the north-central part of the State (locality 13) about 4 feet of the shale is exposed in a roadside trench. A four-foot channel sample indicates that the shale contains 0.002 percent equivalent uranium.

The data at hand suggest that the Chattanooga shale of Indiana is less radioactive than in parts of Tennessee and Kentucky but more radioactive than in Ohio, Illinois, or Missouri. In east-central Tennessee the best parts of the Chattanooga shale contain about 0.01 percent equivalent uranium. More data on the Chattanooga shale (New Albany shale) of Indiana could be obtained by measuring the radioactivity of drill hole samples or by logging wells for radioactivity.

In southern Illinois and northern Missouri the Chattanooga shale (also called the Grassy Creek, Sweetland Creek, James River, Hamilton, Noel, and Mountain Glen shales) lies unconformably upon limestones, cherts, and shales of pre-Mississippian age. Structurally the shale flanks the Ozark dome and in this area dips to the east and northeast under the Eastern Interior Coal Basin. Well records indicate that the shale is about 100 feet thick under the Eastern Interior Coal Basin and that it thins toward the Ozark dome. Across the Ozark dome itself, the shale is absent.

In southern Illinois and northern Missouri the radioactivity of the shale was measured at outcrops 17, 19, and 20 and ranged from 0.001 to 0.007 percent equivalent uranium. Samples of the most radioactive parts of the shale at each outcrop contain from 0.003 to 0.005 percent equivalent uranium. Where the Chattanooga shale wedges out on the flank of the Ozark dome the next higher formation, the Sewerton shale, lies unconformably upon pre-Mississippian sediments. The Saverton shale was tested at locality 18 and has a low radioactivity of 0.002 percent equivalent uranium. Further work on the Chattanooga shale in this area does not appear to be warranted.

Ores and rocks of the Fredericktown district, Missouri

Galena, chalcopyrite, sphalerite, linnaeite, and siegenite are the ore minerals of this lead, zinc, copper, cobalt, nickel area. They form replacement deposits in the basal portion of the Bonneterre dolomite and sometimes in the uppermost portion of the underlying La Motte sandstone of Cambro-Ordivician age.

At the St. Louis Smelting and Refining Company mine near Fredericktown, locality 22, the ores and associated rocks were tested underground for their radioactive content in the number 3 shaft, 087 stope, Chrian track. The siegenite ore (cobalt nickel sulphide), the enclosing Bonneterre dolomite, and the underlying La Motte sandstone contain 0.001 percent equivalent uranium or less. Ore dumps on the surface, containing galena, chalcopyrite, sphalerite, linnaeite, and siegenite have a low radioactivity of 0.001 percent equivalent uranium. Many tons of sacked cobalt nickel concentrates in the warehouse contain less than 0.001 percent equivalent uranium.

At Mine La Motte mine north of Fredericktown, locality 21, the ore minerals are predominantly galena and chalcopyrite. Their geologic occurrence is similar to that described above. Tests in the mine indicated that the galena, chalcopyrite, dolomite, and sandstone contain 0.001 percent equivalent uranium or less. However, green glauconitic, chloritic, shaly, and dolomitic siltstones in the transition zone between the La Motte sandstone and Bonneterre dolomite contain up to 0.003 percent equivalent uranium.

Further work on the ores of the Fredericktown district does not seem warranted. However, the moderately radioactive transition zone between the La Motte sandstone and the Bonneterre dolomite should be checked in other areas at some future time.

Car traverses across the igneous rocks of the re-exhumed pre-Cambrian St. Francis Mountains indicate that the large masses of syenite and porphyry are not abnormally radioactive.

Ores and rocks of the Batesville district, Arkansas

In the Batesville district, manganese oxide ores occur as lenses in depressions on the upper surface of the Fernvale limestone; as lenses, pods, and nodules in the unconformably overlying Cason shale; and as small replacement deposits in the uppermost part of the Fernvale limestone. The ore and host rocks are of Ordovician age.

Outcrop tests at locality 23 indicate that the Fernvale limestone and manganese ore in the Cason shale contain 0.001 percent equivalent uranium. The basal phosphatic four feet of the Cason shale has a higher radioactivity of 0.003 percent equivalent uranium. Overlying brown shale of lower phosphate content and dumps of manganiferous Fernvale limestone contain about 0.001 percent equivalent uranium.

Available spectrographic analyses by J. C. Rabbitt of the U. S. Geologic Survey show that samples from five ore stockpiles and one pile of tailings contain abnormally high percentages of the oxides of beryllium 0.00X to 0.01, cobalt 0.05 to 0.3, germanium less than 0.001 to 0.005, molybdenum 0.002 to 0.05, nickel 0.1 to 0.2, tin 0.005 to

0.08, thallium less than 0.001 to 0.001, vanadium 0.02 to 0.2, and zirconium 0.05 to 0.1. Less than 0.001 percent of the oxides of antimony, cadmium, mercury, tantalum, and tungsten were found in the same samples.

The phosphatic portions of the Cason shale are slightly radioactive but not sufficiently radioactive to be of primary interest at the time of writing. Further testing of the shale may be warranted at some future time.

Springs and rocks near Hot Springs, Arkansas

The spring waters at Hot Springs, Arkansas, contain 0.46 millimicrograms of radon per liter and only one three hundred-thousandths the amount of radium required to produce the radon./. The absence

/ Schlundt, H., The radioactivity of the spring water on the Hot Springs Reservation, Hot Springs, Arkansas: Am. Jour. Sci., 5th ser., vol. 30, pp. 45-50, 1935.

of the radon's parent element in the spring waters indicates that it must be present in the rocks traversed by the spring waters at depth.

The rocks through which the spring waters rise include the Bigfork chert, Polk Creek shale, Missouri Mountain shale, Arkansas novaculite, and Hot Springs sandstone. These rocks were tested at their outcrop north of Hot Springs, locality 26, and the Polk Creek shale was found to contain up to 0.004 percent equivalent uranium. The remainder of the formations mentioned contain less than 0.002 percent equivalent uranium.

The Polk Creek shale may be a partial source of the radon in the spring waters and possibly may be the sole source. Under the city of Hot Springs, the Polk Creek shale is at a depth of approximately 1,000 feet.

The calcareous spring sinter deposits were also checked at their outcrop, locality 24, and were found to contain between 0.002 and 0.003 percent equivalent uranium. Schlundt / also found that the

/ Schlundt, H., op. cit., 1935.

older spring sinter was not highly radioactive.

Rocks and minerals of Magnet Cove, Arkansas

Magnet Cove is an area of alkaline igneous rocks approximately 2½ miles in diameter. It is about 10 miles southeast of Hot Springs, Arkansas. The radioactivity of the rocks and soils was measured by the car traverse method on all open roads, by outcrop tests at known mineral localities, and by sample tests of the rocks from localities showing abnormal radioactivities.

Of most interest was the rutile strip mine where the alkaline rocks are well exposed. Outcrop tests in the stripped area indicate that several white hydrothermally altered zones up to 5 feet wide bordering faults or joints are highly radioactive. A sample of the white material, 28-1, contains 0.019 percent equivalent uranium. Samples of rutile and pyrite from the altered zones, 28-2 and 28-3, contain less than 0.002 percent equivalent uranium. The radioactivity of the nepheline syenite country rock ranges from 0.001 to 0.003 percent equivalent uranium.

Outcrop tests at the calcite quarry indicate that the calcite, wollastonite, and nepheline syenite contain less than 0.003 percent equivalent uranium, but the brown soil above the quarry was more radioactive. A sample of the brown soil, 27-1, contains 0.007 percent equivalent uranium. The source of the brown soil is unknown. A sample of rutile crystals, 27-2, collected from the brown soil, contains 0.001 percent equivalent uranium.

A sample of the soil at the magnetite locality, 29-2, contains about 0.004 percent equivalent uranium. A sample of white clay from a hydrothermally altered zone contains 0.003 (gamma) and 0.008 (beta) percent equivalent uranium, and a sample of the magnetite is essentially non-radioactive.

Road traverses show that the soil is highly radioactive on the low knoll between the highway and the rutile mine. More radioactive soil was found in the vicinity of the Jesse Albritton house in the center of sec. 17.

Although one zone of radioactive altered rock contains 0.019 percent equivalent uranium and some of the soil is abnormally radioactive, additional work would be necessary before the significance of this area can be determined. Such work should determine whether the radioactive areas of soil mark underlying zones of radioactivity in the bed rock or are the result of residual concentration by weathering, and should determine the size and distribution of the radioactive zones.

Rocks of Potash Sulphur Springs, Arkansas

Potash Sulphur Springs is situated on the eastern margin of a nepheline syenite stock. The stock is nearly symmetrical and about 1 mile in diameter. A variety of alkalic dike rocks are found in the sedimentary rocks adjacent to the nepheline syenite stock.

Car traverses across the stock indicated that the mass of rock was not abnormally radioactive. Outcrop tests on two igneous dikes, locality 25, about 1 mile west of the stock also indicated a low radioactivity. One dike, a fourchite, contains about 0.001 percent equivalent uranium, and the other dike, a nepheline syenite, contains about 0.003 percent equivalent uranium. Nearby tests on the darker portions of the Stanley shale indicated radioactivities ranging from 0.001 to 0.003 percent equivalent uranium.

Further work in this area appears unnecessary.

Fluorspar deposits of Illinois and Kentucky

The radioactivity of fluorspar dumps and fluorspar concentrate dumps was measured at nine localities, 30 to 38, in southern Illinois, western Kentucky, and central Kentucky. The radioactivity of the material tested was consistently below 0.001 percent equivalent uranium. No further work on the fluorite deposits of the mid-continent region is recommended.

Warsaw formation near Fort Knox, Kentucky, and Grafton, Illinois

The Warsaw formation of Mississippian age was tested in the highway cut about 1 mile west of Colesburg, Hardin County, Kentucky, locality 39. The formation consists of limestone, shaly limestone, and shale beds. Outcrop tests indicate that the shale beds contain up to 0.002 percent equivalent uranium. The remainder of the formation including the geode beds has a lesser radioactivity.

The geodes of the Warsaw formation were also tested in the town of Grafton, Illinois, locality 16, where they were used to build a stone wall. Here again the geodes were not noticeably radioactive.

No further work on the Warsaw formation is indicated.

Summary of material tested

Locality number	Material tested	Latitude	Longitude	Range in radioactivity, percent equivalent uranium	See pages
1	Coal and shale	37°56'	86°44'	0.002-0.003	6, 17
2	Coal and shale	37 56	86 44	0.000-0.001	6, 17, 18
3	Coal and shale	37 59	86 47	0.001-0.002	6, 18, 19
4	Coal and shale	38 00	86 49	0.000-0.002	6, 19, 20
5	Coal and shale	38 05	87 01	0.001-0.003	6, 20
6	Coal and shale	38 04	86 59	0.000-0.002	6, 20, 21
7	Coal and shale	38 10	86 59	0.000-0.002	6, 21
8	Coal and shale	39 33	86 59	0.001-0.002	6, 21, 22
9	Coal and shale	39 30	87 11	0.000-0.006	6, 22
10	Coal and shale	39 34	87 12	0.001-0.002	6, 23
11	Coal and shale	39 36	87 06	0.001-0.002	6, 23
12	Coal and shale	39 27	87 04	0.000-0.002	6, 23, 24
13	Chattanooga shale	40 34	86 41	0.002-0.004	8, 24
14	Chattanooga shale	39 06	85 54	0.005-0.007	7, 24, 25
15	Chattanooga shale	38 43	85 48	0.002-0.010	7, 25
16	Geodes from Warsaw formation	38 58	90 26	0.000	15, 25
17	Chattanooga shale	39 31	90 35	0.003-0.006	8, 25, 26
18	Saverton shale	39 20	90 48	0.002	9, 26
19	Chattanooga shale	39 31	90 58	0.001-0.006	8, 26, 27
20	Chattanooga shale	39 23	90 55	0.002-0.007	8, 27, 28
21	Lead copper ore	37 38	90 17	0.000-0.003	9, 28
22	Siegenite ore	37 33	90 16	0.000-0.001	9, 28
23	Manganese and phosphate	35 51	90 30	0.001-0.003	10, 29
24	Hot springs	34 30	93 04	0.002-0.003	12, 29, 30
25	Fourchite and syenite dikes	34 28	93 03	0.001-0.003	25, 30
26	Polk Creek shale	34 31	92 59	0.004	11, 30
27	Calcite quarry, Magnet Cove	34 29	92 53	0.001-0.007	13, 30
28	Rutile mine, Magnet Cove	34 30	92 52	0.000-0.019	12, 31
29	Magnetite, Magnet Cove	34 30	92 51	0.000-0.008	13, 31
30	Fluorite	37 27	88 23	0.001	14, 31
31	Fluorite	37 25	88 21	0.000	14, 31
32	Fluorite	37 29	88 11	0.000	14, 32
33	Fluorite	37 20	88 10	0.000	14, 32
34	Fluorite	37 21	88 11	0.006	14, 32
35	Fluorite	37 19	88 10	0.006	14, 32
36	Fluorite	37 17	88 13	0.000	14, 32
37	Fluorite	37 53	84 49	0.000	14, 32
38	Fluorite	37 53	84 46	0.000	14, 32, 33
39	Warsaw formation	37 47	85 47	0.000-0.002	14, 33

Description and radioactivity of rocks at each locality

Because the radioactivity measurements were made with several different methods (see section on Field Methods) and the accuracy differs according to method, each radioactivity measurement in this section will be followed by a letter, a to e, denoting the method used and therefore the probable accuracy of the measurement. The key to each letter follows:

- a Car traverse test
- b Outcrop test, gamma
- c Outcrop test, beta
- d Sample test, gamma
- e Sample test, beta

Locality	Location and rock description	Feet above base	Percent equivalent uranium
G 1	Road cut north of Cannelton on highway 237 about 1.6 miles from highway 66, Perry County, Indiana.		
	Pottsville formation		
	Top of exposure	6.0	
	Dark-gray thin-bedded silty shale.	6.0	0.002e
	" " " " " "	5.0	0.002e
	" " " " " "	3.0	0.002e
	" " " " " "	1.0	0.003e
	" " " " " "	0.0	
	Base of exposure.	0.0	
	Sampled 0.0' to 2.0'.		0.003d
G 2	Fire clay mine north of Cannelton on highway 237 about 1.3 miles from highway 66, Perry County, Indiana.		
	Pottsville formation (Observations underground)		

Locality	Location and rock description	Feet above base	Percent equivalent uranium
S 2	Cross-bedded sandstone, top not exposed . .	6.6	0.000e
	" " " , base of	6.1	
	Bituminous coal, top of	6.1	
	" " , (No.1 coal)	5.5	0.000e
	" " , base of	5.0	
	Light-gray silty fireclay, top of	5.0	
	" " " "	4.0	0.001e
	" " " " , base not exposed	0.0	
	Not sampled		
S 3	Road cut west of Tell City on highway 66 about 1.3 miles west of highway 37, Perry County, Indiana.		
	Pottsville formation		
	Top of exposure	59.5	
	Light-gray thin-bedded coarse sandstone .	59.5	
	" " " " " " .	55.5	0.002e
	" " " " " " , base of	51.5	
	Black thin-bedded fissile shale, top of. .	51.5	
	" " " " "	50.5	0.002e
	" " " " " , base of .	49.5	
	Light-buff coarse siltstone, top of . . .	49.5	
	" " " "	48.0	0.001e
	" " " " , base of	46.5	
	Black fissile silty shale, top of.	46.5	
	" " " "	45.5	0.002e
	" " " " , base of	44.5	
	Light-gray siltstone with sandstone lenses, top of	44.5	
	Light-gray siltstone with sandstone lenses	39.0	0.002e
	" " " " " " , base of	33.5	
	Light-gray thin-bedded sandstone, top of .	33.5	
	" " " " "	33.0	0.002e
	" " " " " , base of.	32.5	
	Light-buff massive sandstone, top of . . .	32.5	
	" " " "	32.0	0.001e
	" " " " , base of. . .	30.0	
	Light-gray coarse-grained siltstone, top of	30.0	
	" " " " " . . .	28.0	0.002e
	" " " " " , base of	26.0	

Locality	Location and rock description	Feet above base	Percent equivalent uranium
B 3 (con't.)	Olive drab coarse-grained siltstone, top of	26.0	
	" " " " "	24.0	0.002e
	" " " " " , base of	20.5	
	Buff sandstone, top of.	20.5	
	" "	20.0	0.001e
	" " , base of	19.5	
	Medium-gray thin-bedded siltstone with sandstone lenses, top of.	19.5	
	Medium-gray thin-bedded siltstone with sandstone lenses	18.0	0.001e
	Medium-gray thin-bedded siltstone with sandstone lenses, base of	16.5	
	Black fissile shale with seams of coal, top of .	16.5	
	" " " " " " " . . .	14.5	0.002e
	" " " " " " " , base of .	12.5	
	Buff sandstone, top of	12.5	
	" "	12.0	0.001e
	" " , base of	11.5	
	Light-gray thin-bedded siltstone, top of. .	11.5	
	" " " " "	8.5	0.002e
	" " " " " , base of .	5.5	
	Medium-gray fissile siltstone, top of . . .	5.5	
	" " " "	3.0	0.002e
	" " " " , base of. . .	0.0	
	Not sampled		
B 4	Road cut on highway 66 west of Tell City and about 4.0 miles west of highway 37, Spencer County, Indiana		
	Pottsville formation		
	Top of exposure	9.3	
	Buff cross-bedded sandstone	9.3	
	" " " "	8.0	0.000e
	" " " " , base of	6.3	
	Bituminous coal, top of	6.3	
	" "	6.2	0.000e
	" " , base of.	6.0	
	Brownish dark-gray silty shale, top of. . .	6.0	
	" " " " "	5.3	0.002e
	" " " " " , base of . .	4.5	
	Dark-brown to black shale, top of	4.5	
	" " " " "	3.8	0.002e
	" " " " " base of	3.0	

Locality	Location and rock description	Feet above base	Percent equivalent uranium
# 4 (con't.)	Light-gray shale, top of	3.0	
	" " "	1.5	0.002e
	" " " , base of.	0.0	
	Not sampled		
# 5	Road cut on highway 45 about 1.0 miles south of Gentryville, Spencer County, Indiana.		
	Rocks of Allegheny age		
	Top of exposure	15.4	
	Buff cross-bedded sandstone	15.4	
	" " " "	10.0	0.001e
	" " " " , base of. . . .	7.4	
	Unconformity with several inches of relief.	7.4	
	Bituminous coal, eroded top of.	7.4	
	" "	7.2	0.003e
	" "	7.2	0.002e
	" "	7.2	0.003e
	" "	6.8	0.002e
	" "	6.8	0.002e
	" "	6.8	0.002e
	" "	6.2	0.002e
	" " , base of.	6.0	
	Light greenish-gray shale, top of	6.0	
	" " " "	5.5	0.002e
	" " " "	5.0	0.002e
	" " " "	2.0	0.002e
	" " " " , base of exposure.	0.0	
	Sampled 6.0 to 7.4		0.003d
	" " " "		0.002e
# 6	Mulzer Mines - strip mines about 2.6 miles south of Gentryville on highway 45 and 3.9 miles east on gravel road, Spencer County, Indiana.		
	Allegheny formation		
	Black canneloid slate	6.5	0.002e
	" " "	5.0	0.001e
	" " "	4.0	0.002e
	" " " , base of...	3.3	

Locality	Location and rock description	Feet above base	Percent equivalent uranium
# 6 (con't.)	Bituminous coal, top of	3.3	
	" "	3.0	0.001e
	" "	2.0	0.000e
	" "	1.0	0.001e
	" " , base of	0.0	
	Ash from coal		0.001e
	Not sampled		
# 7	Marish Mill Super Block Coal Co. East of Dale on highway 62 for 0.3 miles and southeast on highway 245 for 2.9 miles, Spencer County, Indiana.		
	Allegheny formation		
	Light-gray clay, top of exposure.	8.5	0.001e
	" " " , base of.	7.5	
	Dark-gray clay, top of.	7.5	
	" " "	6.5	0.002e
	" " "	5.5	0.002e
	" " "	4.5	0.002e
	" " "	3.5	0.002e
	" " " , base of	3.0	
	Block coal and shaly coal, top of	3.0	
	" " " " "	2.5	0.001e
	" " " " "	2.5	0.001e
	" " " " " , base of.	1.9	
	Upper Block coal, top of.	1.9	
	" " "	1.3	0.001e
	" " "	0.0	0.000e
	Base not exposed		
	Not sampled		
# 8	Road cut on highway 40, 0.3 miles west of Pleasant Gardens, Putnam County, Indiana.		
	Pottsville formation		
	Buff sandstone, base of	4.5	
	Medium-gray thin-bedded shale, top of	4.5	0.002b
	" " " " "	3.5	0.002b
	" " " " "	2.5	0.001b
	" " " " "	1.5	0.002b
	" " " " " , base of.	0.5	

Locality	Location and rock description	Feet above base	Percent equivalent uranium
Q 8 (con't.)	Bituminous coal, top of	0.5	
	" "	0.2	0.002b
	" " , base of.	0.0	
	Light-gray clay, top of.	0.0	0.002b
	Base of exposure		
	Not sampled		
Q 9	Lone Star Strip Mine near Staunton, Clay County, Indiana.		
	Allegheny formation overlain by Pleistocene drift.		
	Pleistocene drift, top of exposure.	41.0	
	" " , base of.	26.6	0.001b
	Unconformity	26.6	
	Brecciated black shale, top of.	26.6	
	" " "	23.6	0.002b
	" " "	22.6	0.001b
	" " " , base of	21.6	
	Hard black laminated shale, top of.	21.6	
	" " " "	21.1	0.002b
	" " " "	18.1	0.001b
	" " " "	17.6	0.002b
	" " " "	17.1	0.003b
	" " " "	16.6	0.004b
	" " " "	16.1	0.004b
	" " " " , base of	15.1	
	Hard massive dark-gray shale, top of.	15.1	
	" " " " "	14.7	0.006b
	" " " " " , base of	14.3	
	Hard black thin-bedded slate, top of.	14.3	
	" " " " "	13.1	0.001b
	" " " " " , base of	11.6	0.001b
	Bituminous coal (Coal III a), top of.	11.6	
	" " " "	11.0	0.001b
	" " " " , base of	10.3	
	Medium-gray soft shale, top of.	10.3	
	" " " "	9.6	0.002b
	" " " "	8.3	0.002b
	" " " "	6.3	0.002b
	" " " " , base of	5.1	
	Dark-gray thin-bedded soft shale, top of.	5.1	
	" " " " " "	4.2	0.001b
	" " " " " " , base of	3.5	
	Bituminous coal (No. 3 coal), top of	3.5	0.001b
	" " " "	2.2	0.000b
	" " " "	0.6	0.000b
	Base of exposure	0.0	
	Not sampled		

Locality	Location and rock description	Feet above base	Percent equivalent uranium
@ 10	Rio Grande Mine No. 2, near McClelland, Vigo County, Indiana		
	Allegheny formation (mine closed)		
	Cinder and ash dump, Minshall coal.		0.002b
	" " " " " "		0.001b
	" " " " " "		0.002b
	Black roof slate dump		0.002b
	" " " "		0.001b
	Not sampled		
@ 11	Brazil Block Coal and Clay Co. at north edge of Carbon, Clay County, Indiana.		
	Allegheny formation		
	Base of glacial drift	16.0	
	Unconformity		
	Dark-gray thin-bedded shale, top of.	16.0	
	" " " " "	6.0	0.002b
	" " " " ", base of	5.0	
	Upper block coal, top of	5.0	
	" " "	3.5	0.001b
	" " "	1.6	0.001b
	" " ", base of	1.0	
	Light-gray clay, top of.	1.0	
	" " "	0.0	0.002b
	Base not exposed		
	Not sampled		
@ 12	Bradway Coal Company on highway 42 about 2.4 miles east of highway 59, Clay County, Indiana.		
	Allegheny formation		
	Top of exposure / Dark-gray fissile shale	5.5	0.000b
	" " " "	3.5	0.002a
	" " " "	2.8	0.001b
	" " " ", base of	2.5	

Locality	Location and rock description	Feet above base	Percent equivalent uranium
# 12 (con't.)	Lower Block coal, top of.	2.5	
	" " "	1.5	0.000b
	" " ", base of	0.5	
	Light-gray clay, top of	0.5	
	" " "	0.0	0.002b
	Base not exposed		
	Not sampled		
# 13	Road cut on highway 25 about 0.3 miles southwest of Delphi, Carroll County, Indiana.		
	New Albany shale		
	Top of exposure	4.0	
	Dark brownish black hard fissile shale. . . .	4.0	0.004e
	" " " " " " . . .	3.0	0.004e
	" " " " " " . . .	2.0	0.004e
	" " " " " " . . .	1.0	0.004e
	" " " " " " . . .	0.5	0.004e
	" " " " " " . . .	0.0	0.004e
	Base of exposure		
	Sampled 0.0 to 4.0		0.004e
	" " " ".		0.002d
# 14	Gully exposure on highway alternate 31 about 2.2 miles south of Waynesville, Bartholomew County, Indiana.		
	New Albany shale and Pleistocene drift		
	Glacial till, base of	17.0	
	Unconformity.	17.0	
	Black fissile shale, top of.	17.0	0.004e
	" " "	16.0	0.004e
	" " "	15.0	0.005e
	" " "	14.0	0.006e
	" " "	13.0	0.006e
	" " "	12.0	0.006e
	" " "	11.0	0.007e
	" " "	10.0	0.007e
	" " "	9.0	0.007e
	" " "	8.0	0.007e
	" " "	7.0	0.006e
	" " "	6.0	0.007e
	" " "	5.0	

Locality	Location and rock description	Feet above base	Percent equivalent uranium
@ 14 (con'td.)	Covered interval, top of	4.8	
	" " , base of	2.2	
	Dark brownish black fissile shale.	2.2	
	" " " " "	2.0	0.007e
	" " " " "	1.0	0.007e
	" " " " "	0.0	0.007e
	Base not exposed		
	Sampled 8.5 to 10.5		0.006d
	" " " "		0.006e
@ 15	Quarry on highway 31 about 1.8 miles south of Austin, Scott County, Indiana.		
	New Albany shale		
	Top of exposure	14.0	
	Light-gray shale containing phosphatic nodules and grading downward into the black New Albany shale	14.0	0.002b
	Black fissile shale	12.0	0.005b
	" " "	11.0	0.007b
	" " "	10.0	0.010b
	" " "	9.0	0.007b
	" " "	8.0	0.007b
	" " "	7.0	0.005b
	" " "	6.0	0.007b
	" " "	5.0	0.007b
	" " "	4.0	0.007b
	" " "	3.0	0.007b
	" " "	2.0	0.004b
	" " "	1.0	0.007b
	Base of exposure	0.0	
	Sampled 9.0 to 11.0		0.006d
	" " " "		0.006e
@ 16	Rock wall in Grafton, Jersey County, Illinois.		
	Stone wall built of geodes from the Warsaw formation		0.000b
	Not sampled		
@ 17	Outcrop in creek about ½ - mile south of Bedford on road to Pearl, Pike County, Illinois.		
	New Albany shale		

Locality	Location and rock description	Feet above base	Percent equivalent uranium
# 17 (con't.)	Top of exposure	20.0	
	Weathered soft tan to black shale	20.0	0.003b
	Brownish gray to black fissile shale.	18.0	0.003b
	" " " " " "	16.0	0.004b
	" " " " " "	14.0	0.003b
	" " " " " "	12.0	0.004b
	" " " " " "	10.0	0.003b
	" " " " " "	8.0	0.003b
	" " " " " "	6.0	0.003b
	" " " " " "	4.0	0.003b
	" " " " " "	2.0	0.003b
	" " " " " "	1.0	0.006b
	" " " " " "	0.0	0.005b
	Base of exposure		
	Sample 0.0 to 2.0		0.004d
	" " " "		0.005e
# 18	Quarry 8.7 miles north of Hamburg on highway 96, Calhoun County, Illinois.		
	The Saverton shale of Mississippian age unconformably overlies chert of Devonian age and the Chattanooga shale is absent.		
	Saverton shale, top of exposure		
	Light-gray non-calcareous shale	13.0	0.002b
	" " " " "	10.0	0.002b
	" " " " "	8.0	0.002b
	" " " " "	6.0	0.002b
	" " " " "	4.0	0.002b
	" " " " "	2.0	0.002b
	" " " " "	1.0	0.002b
	" " " " "	0.0	0.002b
	Unconformity		
	Devonian chert		
	Not sampled		
# 19	Outcrop in creek off highway 96 just north of Atlas, Pike County, Illinois.		
	Chattanooga shale		
	Top of exposure	18.0	
	Medium-gray soft shale grading down into . .	18.0	
	Dark-gray to dark brown fissile shale . . .	16.0	0.002b

Locality	Location and rock description	Feet above base	Percent equivalent uranium
S 19 (con't.)	Dark-gray to dark brown fissile shale	14.0	0.001b
	" " " " " " " , base of .	12.0	0.003b
	Black to dark-brown fissile shale, top of .	12.0	
	" " " " " "	10.0	0.004b
	" " " " " " , base of .	7.5	0.004b
	Single intermittent ½ - inch layer of iron sulphides	7.5	
	Dark-gray to dark-brown fissile shale, top of	7.5	
	" " " " " " " , . . .	6.0	0.005b
	" " " " " " " , base of	5.6	
	Scattered 1-inch iron sulphide nodules along bedding	5.6	
	Dark-gray to dark-brown fissile shale, top of	5.6	
	" " " " " " " , . . .	5.0	0.005b
	" " " " " " " , base of	4.7	
	Scattered ½ - inch iron sulphide nodules along bedding	4.7	
	Black to dark-brown fissile shale, top of. .	4.7	
	" " " " " "	4.0	0.004b
	" " " " " "	3.0	0.005b
	" " " " " "	2.0	0.004b
	" " " " " "	1.0	0.004b
	" " " " " " , base of.	0.0	0.003b
	Base of Chattanooga shale.	0.0	
	Unconformity		
	Pre-Mississippian shale and limestone. . . .	0.0	
	Sample 5.0 to 6.0		0.003a
	" " " "		0.006a
S 20	Outcrop in river bluff above highway 79 just north of Clarksville, Pike County, Missouri.		
	Chattanooga shale		
	Base of overlying medium-bedded gray calcareous chert..	5.0	
	Light-Gray medium-bedded calcareous shale, top of. .	5.0	
	Light-gray medium-bedded calcareous shale .	4.0	0.002b
	" " " " " " , base of	3.1	
	Top of Chattanooga shale	3.1	
	Dark-brown fissile non-calcareous shale, top of. .	3.1	
	Dark-brown fissile non-calcareous shale . .	2.0	0.004b

SECRET

Locality	Location and rock description	Feet above base	Percent equivalent uranium
@ 20	Dark-brown fissile non-calcareous shale . .	1.0	
	" " " " " ", base of ..	0.3	
	Massive hard dark-brown shale with hackly fracture, top of. . . .	0.3	
	Massive hard dark-brown shale with hackly fracture, base of . . .	0.0	
	Base of Chattanooga shale		
	Top of underlying clay and limy chert		
	Sample 0.0 to 3.1		0.003d
	" " "		0.007e
@ 21	Mine La Motte Mine north of Fredericktown, Madison County, Missouri		
	The lead-copper ores, gangue, and host rocks were tested underground.		
	Dolomite with disseminating galena		0.000c
	Galena vein ½-inch thick in dolomite		0.000e
	Thin-bedded chloritic or glauconitic sandy dolomite		0.003e
	Vein ½-inch wide of chalcopyrite, pyrite, and galena in dolomite host rock.		0.001e
	The transition of the basal dolomite of the Bonneterre formation into the underlying upper portion of the La Motte sandstone was also tested.		
	White crystalline dolomite.	6.0	0.001e
	Sandy dolomite	5.0	0.000e
	Green thin-bedded silty sandstone.	4.0	0.003e
	Green massive fine-grained sandstone . . .	3.8	0.002e
	" " medium- " " . . .	0.0	0.001e
	Not sampled		
@ 22	St. Louis Smelting and Refining Co. Mine near Fredericktown, Madison County, Missouri.		
	Number 3 shaft - 087 stope - Obrian track		
	Siegenite ore in dolomite.		0.001b
	Unmineralized dolomite (Bonneterre formation)		0.001b
	Underlying white sandstone (La Motte sandstone). . . .		0.000b
	Surface stockpile of siegenite ore		0.001b
	" " " sacked cobalt-nickel concentrates.		0.000b
	Not sampled		

SECRET

Locality	Location and rock description	Feet above base	Percent equivalent uranium
# 23	Hankin's Hollow west of Cushman, Batesville district, Independence County, Arkansas.		
	Dumps of manganese oxides and limestone		0.001b
	Dump of manganiferous and phosphatic Cason shale		0.002b
	Outcrop on road to Cushman		
	Top of exposure of Ordivician	4.6	
	Cason shale. Chocolate-brown shale		0.002b
	Base of chocolate-brown shale	4.0	
	Soft light-brown and greenish-brown thin-bedded phosphatic shale, top of . . .	4.0	
	Soft light-brown and greenish-brown thin-bedded phosphatic shale	2.6	0.003b
	Soft light-brown and greenish-brown thin-bedded phosphatic shale, base of. . .	1.9	
	Brown, medium-bedded phosphatic shale and phosphate rock, top of	1.9	
	Brown, medium-bedded phosphatic shale and phosphate rock	1.6	0.003b
	Brown, medium-bedded phosphatic shale and phosphate rock, base of		
	Black shale and manganese oxides, top of. .	0.5	
	" " " " "	0.3	0.001b
	" " " " " , base of Cason shale	0.0	
	Unconformity		
	Fernvale limestone		0.001b
	Not sampled		
# 24	Hot springs at Hot Springs National Park, Garland County, Arkansas.		
	Spring Number 42 artificially enclosed under bath house by blocks of calcareous sinter. Gamma tube held above water		0.002b
	Spring Number 46 enclosed with tile under bath house. Gamma tube held above water.		0.002b
	Springs Numbers 33 and 34 in the open and only slightly modified by blocks of calcareous sinter. Gamma tube held above water.		0.003b

Locality	Location and rock description	Feet above base	Percent equivalent uranium
# 24 (con't.)	Spring Number 32 in the open and only slightly modified. Gamma tube held above water.		0.003h
	Vein of manganese oxide about 1 to 2 feet wide and situated about 150 feet uphill from Spring Number 37. Gamma tube in center of vein		0.002b
	Not sampled.		
# 25	Road cut and quarry on highway 270 about 5 miles southeast of Hot Springs and ½ mile west of bridge over Gulpha Creek, Garland County, Arkansas.		
	Dike of fourchite (Number 40 of Hot Springs folio)		
	Stanley shale on east edge of dike		0.001b
	East edge of dike		0.002b
	Center of dike		0.002b
	West edge of dike.		0.001b
	Stanley shale on west edge of dike		0.003h
	Dike of nephelite syenite (Number 39 of Hot Springs folio)		0.003b
	Not sampled.		
# 26	Outcrops along paved road through North Mountain about 2 miles northeast of Hot Springs, Garland County, Arkansas.		
	Car traverse across Polk Creek shale, Missouri Mountain shale, and Arkansas novaculite showed the blacker portions of the Polk Creek shale to be abnormally radioactive.		
	Polk Creek shale		0.004d
	" " "		0.004e
# 27	Calcite quarry on highway 270 in Magnet Cove, Hot Springs County, Arkansas.		
	Brown soil on northeast edge of quarry		0.007b
27-1	Soil sampled		0.007d
27-2	Rutile sampled		0.001d

The remainder of the [illegible] (calcite, wollastonite, nepheline syenite) showed a radioactivity of less than 0.003% e. u.

SECRET

Locality	Location and rock description	Feet above base	Percent equivalent uranium
@ 28	Rutile mine north of highway 270 in Magnet Cove, Hot Springs County, Arkansas.		
	Hydrothermally altered zones in the deeply weathered nephelite syenite of the rutile strip mine are abnormally radioactive.		
@28-1	Sample of one altered zone		0.019d
	" " " " "		0.011e
	The nephelite syenite, rutile concentrates, and pyrite were essentially non-radioactive		
@28-2	Rutile sample		0.002d
	" "		0.001e
@28-3	Pyrite sample.		0.000d
@ 29	Magnetite locality on north edge of highway 270 in Magnet Cove, Hot Springs County, Arkansas.		
	The soil at the top of the small hill is abnormally radioactive but the magnetite veins do not appear to be radioactive.		
@ 29-1	White altered clay.		0.003d
	" " "		0.008e
@ 29-2	Brown soil.		0.004d
	" "		0.003e
@ 29-3	Magnetite		0.000d
	"		0.001e
@ 30	Fluorite mine on highway 34, about 1.1 miles north of highway 146, Hardin County, Illinois.		
	Fluorite dump		0.001b
	Not sampled		
@ 31	Rosiclare Lead and Fluorspar Refining Company at Rosiclare, Hardin County, Illinois.		
	Dump of about 100 tons of nearly white fluorite concentrates		0.000d
	Not sampled		

Locality	Location and rock description	Feet above base	Percent equivalent uranium
@ 32	Crystal Fluorspar Company, Cave in the Rock district, Hardin County, Illinois.		
	Dumps of fluorite ore and fluorite concentrates are not radioactive		0.000a
	Not sampled.		
@ 33	Keystone Fluorspar mine about 0.9 miles west of highway 60 on highway 297 and thence ½ - miles southward, Crittenden County, Kentucky.		
	Dump containing about 40 tons of fluorite ore		0.000b
	Not sampled.		
@ 34	L. Conyer fluorite mine on highway 297 about 1.7 miles west of highway 60, Crittenden County, Kentucky.		
	Dumps of fluorite ore		0.000b
@ 35	Martin fluorspar mine on highway 60 about 0.8 miles west of highway 297, Crittenden County, Kentucky.		
	Fluorite ore, ½-ton dump		0.000b
	Not sampled		
@ 36	Fluorspar mines and dumps along highway 60, about 2.7 miles east of Salem, Crittenden County, Kentucky.		
	All dumps and mine roads show essentially no radioactivity		0.000a
@ 37	Gobel Bean Fluorite property, on the southwest side of the Kentucky River, Mercer County, Kentucky.		
	10-ton dump of fluorite ore.		0.000b
	Not sampled.		
@ 38	Mundays Landing fluorite mine, Woodford County, Kentucky.		

Locality	Location and rock description	Feet above base	Percent equivalent uranium
C 38 (cont'd)	5-ton dump of fluorite ore		0.000b
	5-ton dump of fluorite concentrates.		0.000b
	Not sampled.		
C 39	Highway cut about 1-mile west of Colesburg, Hardin County, Kentucky.		
	Warsaw formation		
	Limestone average		0.000e
	Shaly limestone, average		0.001e
	Shale, average		0.002e
	Geode beds, average		0.000e

GEOGRAPHICAL INDEX

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GEOLOGICAL SURVEY

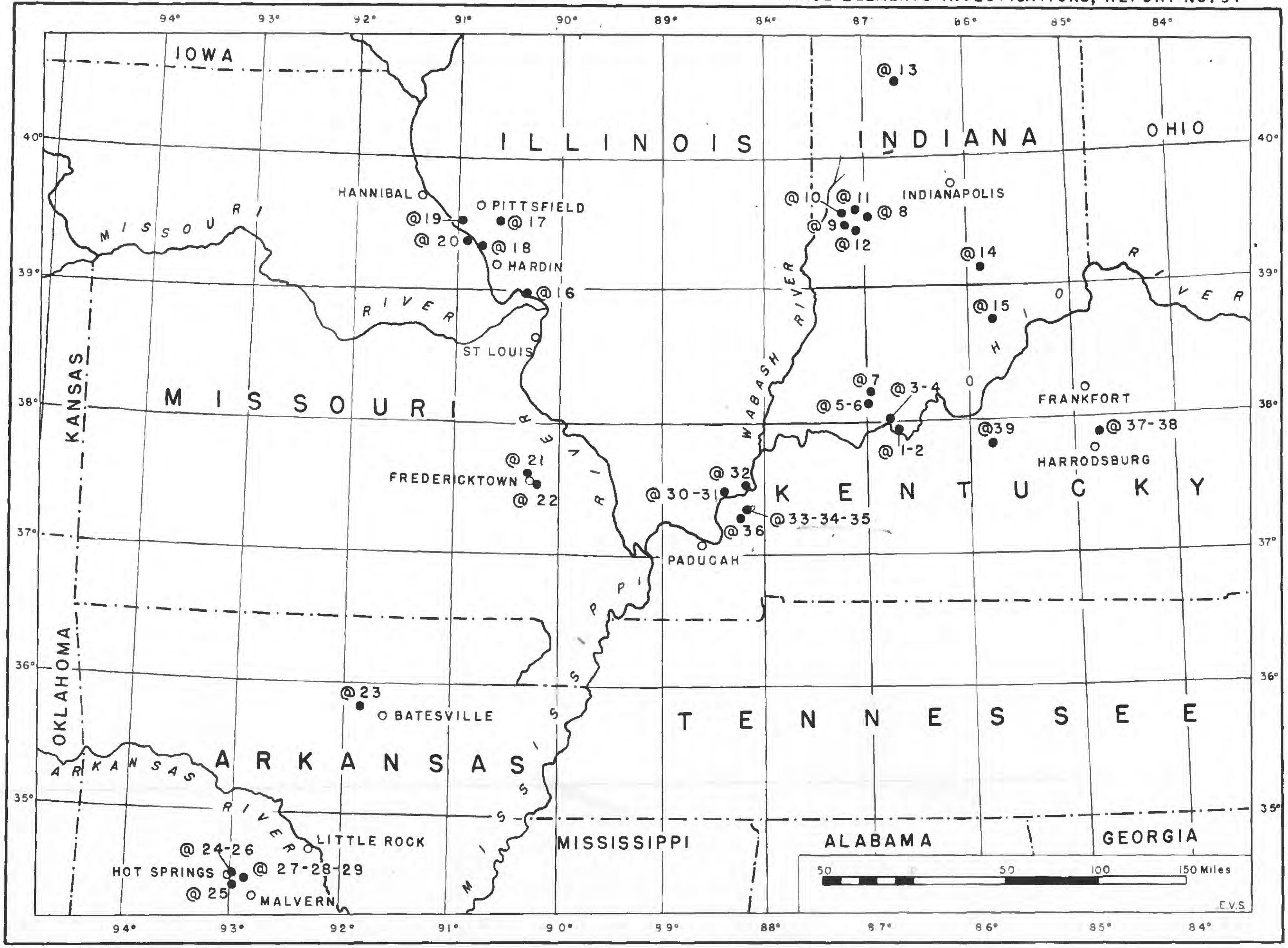

PLATE I INDEX MAP OF LOCALITIES

TEI-34