U. S. Geological Survey

Reports open file.

No. 187

UNITED STATES
DEPARTMENT OF THE INTERIOR
U.S. GEOLOGICAL SURVEY

NIOBIUM (COLUMBIUM) AND TITANIUM AT MAGNET COVE AND POTASH SULPHUR SPRINGS, ARKANSAS

by

Verne Charles 1920- Richard Stanley 1924- Edward Peale 1912-

V. C. Fryklund, Jr., R. S. Harner, and E. P. Kaiser

MINERAL DEPOSITS BRANCH
Denver, Colorado
1953

OPEN FILE

This report is preliminary and has not been edited or reviewed for conformity with U. S. Geological Survey standards and nomenclature.

TABLE OF CONTENTS Page

ILLUSTRATIONS

Opposite Page

TABLES

ABSTRACT

This work was done because niobium (columbium) has been found in several of the minerals and rocks of the Magnet Cove and Potash Sulphur Springs areas. Niobium is in demand for use in high-temperature and non-creep steels.

The Magnet Cove and Potash Sulphur Springs areas are in central Arkansas between Malvern and Hot Springs. They are underlain by similar alkaline igneous complexes consisting of nepheline syenite, more basic alkaline rocks, and calcite rock or carbonatite. The igneous rocks intrude Paleozoic sedimentary rocks and are truncated by a Late Cretaceous erosion surface.

At Magnet Cove deposits of rutile (TiO_2) occur within the igneous complex; two deposits of brookite (TiO_2) occur in quartzite of the Arkansas novaculite formation of probable Devonian and Mississippian age, near the margin of the complex. Perovskite (calcium titanate) occurs in several places in the igneous complex.

Niobium is present in rutile, brookite, and perovskite, and also probably in other minerals not yet analyzed.

In order to determine the distribution and average content of niobium in the larger titanium deposits, drill core and channel samples were analyzed for niobium, titanium, and other elements; and average figures were calculated. Concentrates and single crystals were also analyzed. Material from drill cores of perovskite-bearing magnetite-pyroxene rock on the Mo-Ti Corporation property was studied and analyzed. The Kimsey calcite quarry area was mapped, and channel samples and single crystals were analyzed. Channel samples from trenches on the Wilson prospect at Potash Sulphur Springs were analyzed.

The areas studied contain large resources of titanium and niobium, of low grade. The major results of the analytical work are summarized in the following table.

Locality and material	Niobium average	Niobium maximum
Magnet Cove		
Magnet Cove Titanium Corp. property		
rutile crystals	1.2	1.7
rutile concentrates	1.2	-
material in rutile deposit, drill core samples	.04	.12
Christy brookite property		
brookite crystals	2.0	9.6
brookite concentrate	1.2	-
material in brookite deposit, drill core and channel samples	.05	.45
Kilpatrick brookite property		
material in brookite deposit, channel samples	.04	.46
Mo-Ti Corporation property		
perovskite rock (one sample)	.03	.56
Kimsey calcite quarry area		
perovskite crystals	6.9	8.8
perovskite-bearing calcite rock, channel samples	.01	.07
Potash Sulphur Springs		
Wilson prospect		
weathered material, grab and channel samples	?	1.6

INTRODUCTION

Location and general geologic features

Magnet Cove is a shallow topographic basin about three miles in diameter near the center of Arkansas in Hot Spring County (see fig. 1).

Figure 1. Map showing location of Magnet Cove and Potash Sulphur Springs in Arkansas.

It is 12 miles east of Hot Springs and 7 miles northwest of Malvern. U. S. highway 270 passes through the center of the Cove. The Hot Springs branch of the Chicago, Rock Island, and Pacific Railroad skirts the southern edge of the Cove. The Potash Sulphur Springs area is about six miles west of Magnet Cove.

Magnet Cove and the Potash Sulphur Springs area are underlain by igneous complexes which have intruded folded sediments of Paleozoic age, ranging from the Silurian to the Mississippian. The sediments and igneous rocks were truncated by a Late Cretaceous erosion surface which was then covered by Late Cretaceous and Tertiary sediments of the Coastal Plain. The Coastal Plain sediments crop out a few miles to the south of Magnet Cove.

The igneous complexes consist of rocks unusually rich in sodium and titanium; they are part of an alkaline igneous province extending from the syenites in the vicinity of Little Rock and Bauxite, Arkansas, to Magnet Cove and Potash Sulphur Springs. The diamond peridotites and associated rocks of Pike County, Arkansas, which are relatively rich in titanium, may be considered as part of this province.

The Magnet Cove rocks, and those of the smaller but similar complex at Potash Sulphur Springs, consist chiefly of varieties of nepheline syenite and related rocks. They also include rocks of doubtful origin consisting chiefly of calcite; rocks of this type are sometimes called carbonatites. The Magnet Cove and Potash Sulphur Springs rocks thus are similar to several other alkaline complexes in Colorado, Norway, Germany, South Africa, and other places, which also contain nepheline-bearing rocks in association with calcite rock or carbonatite. The presence of abundant titanium is common to all these complexes; the presence of niobium in unusually large proportions is characteristic of many of them.

The calcite rocks associated with these complexes have been interpreted as blocks of sedimentary carbonate, but in the last few years they have been more commonly described as material introduced by either hydrothermal or intrusive action.

Associated with the Magnet Cove complex are deposits of rutile and brookite, which contain not only resources of titanium but also an appreciable proportion of niobium. Samples containing niobium and uranium have been found at Potash Sulphur Springs, but little is known of the occurrence of these elements in that area.

The element niobium was formerly called columbium (Cb) in the United States; a recent international agreement standardized the name niobium and the symbol Nb. Niobium is in demand for use in high-temperature and non-creep steels.

Previous work

The Magnet Cove and Potash Sulphur Springs areas were first described by Williams (1891) whose comprehensive and accurate monograph on the igneous rocks of Arkansas still remains a classic of the geologic literature. Williams' map of Magnet Cove is of valuable assistance in studying the area. Additional petrographic discussion was contributed by Washington (1900, 1901) and more recently by Landes (1931) and Ross (1941).

Williams described the various rare and unusual rocks and minerals in detail and presented chemical analyses. The presence of niobium in perovskite (dysanalite) was first reported by Mar (1890, p. 403).

Little geologic work was done on the rutile and brookite deposits until the work of Fryklund and Holbrook (1950), which depended in part on data made available by test pitting and by Bureau of Mines drilling. This work has established the nature and approximate grade of the rutile and brookite deposits.

Present work

As part of the U. S. Geological Survey's program of studying niobium resources, the rutile, brookite and perovskite areas at Magnet Cove were studied, sampled, and in part mapped, in order to establish the approximate abundance and habit of the niobium. The Wilson prospect at Potash Sulphur Springs was also mapped and sampled. This work was done during February and March, 1952, by Verne C. Fryklund, Jr., Harvey L. Sobel, and E. P. Kaiser. Splits of samples from drill core were obtained from the U. S. Bureau of Mines station at Rolla, Missouri; splits of channel samples from pits were obtained from the Arkansas Division of Geology. Spectrographic analyses were made by Richard S. Harner, K. J Murata, and R. G. Havens. The results of field and laboratory study and of analysis are presented in this report.

Acknowledgments

The writers are indebted to the U. S. Bureau of Mines for a number of drill hole samples of the Magnet Cove Titanium Corporation area and the Christy brookite property; to Mr. Norman F. Williams, Director of the Division of Geology, Arkansas Resources and Development Commission, for splits of samples taken by the senior author in the Kilpatrick brookite property, for the use of a power auger, and for many other courtesies; and to Mr. Wynne Christy for samples from the Christy brookite property. It is a pleasure to acknowledge the help of Mr. Joseph W. Kimsey and Mr. Lawton Kimsey of Magnet Cove.

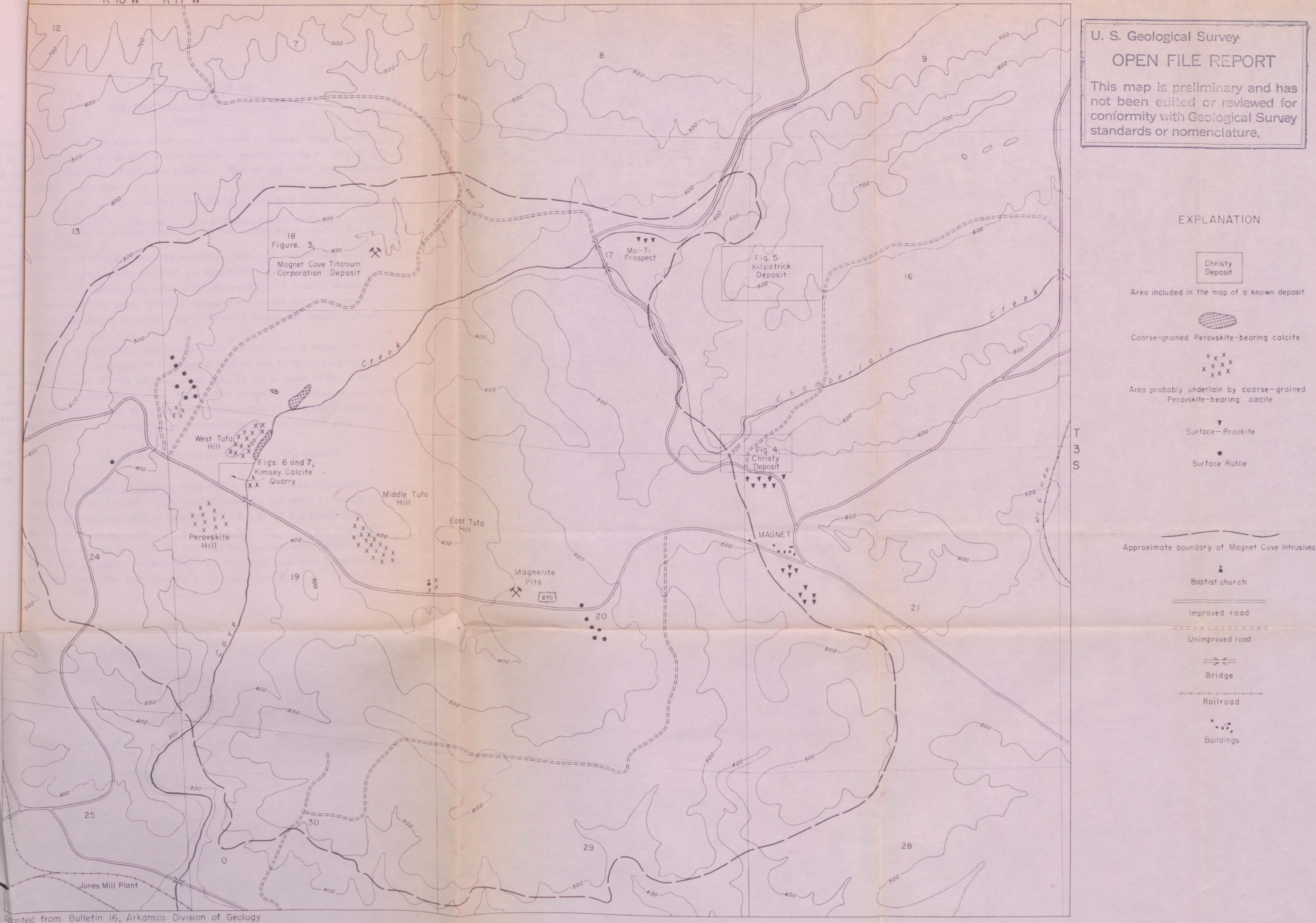


FIG. 2 — TOPOGRAPHIC MAP OF MAGNET COVE

SHOWING THE LOCATION OF KNOWN NIOBIUM—BEARING AREAS AND SURFACE RUTILE AND BROOKITE

HOT SPRING COUNTY, ARKANSAS

SCALE

2000 1000 0 2000 4000 6000 Feet

CONTOUR INTERVAL 100'

TRUE NORTH MAGNETIC NORTH

MAGNET COVE, ARKANSAS

Description of titanium-niobium deposits

General

Niobium and titanium occur together at Magnet Cove, and in fact all the niobium of possible economic interest occurs as part of the crystal structure of titanium minerals. The two materials are, therefore, described together.

The titanium-niobium deposits of Magnet Cove (fig. 2) consist chiefly of rutile and brookite deposits. The only known large deposit of rutile is on the property of the Magnet Cove Titanium Corporation, which also includes unexplored areas where rutile is locally abundant in the soil. The major brookite deposits are on the Christy property and the Kilpatrick property. Other areas of rutile and brookite float are shown on figure 2.

Figure 2. Topographic map of Magnet Cove showing the location of known niobium-bearing areas and surface rutile and brookite, Hot Spring County, Arkansas.

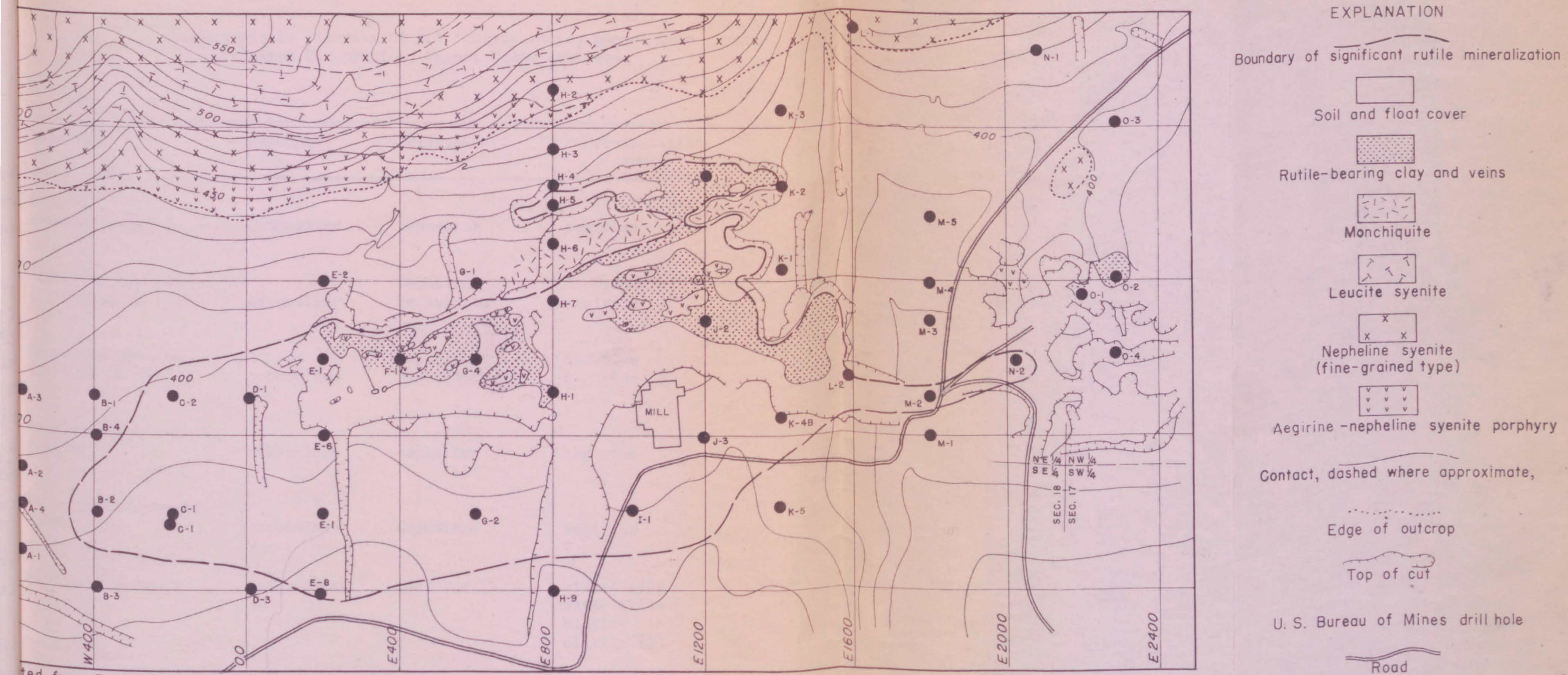
Rutile-brookite-feldspar veins and molybdenite veins cut perovskite-bearing magnetite-pyroxene rock on the Mo-Ti Corp. property. Although none of this material crops out, it was studied in drill cores.

Because some of the Magnet Cove perovskite contains as much as 8.8 percent niobium, the perovskite-bearing calcite rock and perovskite syenites are of interest and were studied during the current work.

Magnet Cove Titanium Corporation rutile deposit

Location and extent.--The Magnet Cove Titanium Corporation deposit, the only major rutile deposit known in the area, is mainly in the east-central part of sec. 18, T. 3 S., R. 17 W., about three-quarters of a mile north of U. S. highway 270 (fig. 2). The property is now controlled by Mr. C. H. Scott of Denver, Colorado. About 5,188 short tons of rutile concentrates were recovered from this property between 1931 and 1944. The mill has since been dismantled.

17



ted from Bulletin 16, Arkansas Division of Geology

GURE 3.--TOPOGRAPHIC AND GEOLOGIC MAP OF THE MAGNET COVE TITANIUM CORP. DEPOSIT, HOT SPRINGS COUNTY, ARKANSAS, SHOWING THE LOCATION OF THE BUREAU OF MINES DRILL HOLES

400 0 400 800 1200 FEET

Contour interval 10 feet

. S. Geological Survey

OPEN FILE REPORT

his map is preliminary and has
ot been edited or reviewed for
onformity with Geological Survey
tandards or nomenclature.

Table 1.--Characteristic minerals of the igneous rocks, Magnet Cove Titanium Corporation, Magnet Cove, Arkansas.

Rock type	Feldspar	Feldspathoid	Ferro-magnesian minerals
Aegirine-nepheline syenite porphyry	orthoclase	nepheline	aegirine
Nepheline syenite (fine grained type)	orthoclase	nepheline cancrinite	diopside aegirine
Nepheline syenite (Diamond Jo type)	orthoclase	nepheline cancrinite	diopside aegirine
Leucite nepheline syenite	orthoclase	nepheline	aegirine
Nepheline tinguaite dikes	orthoclase	nepheline	aegirine
Monchiquite dikes	plagioclase	analcime (?)	titanaugite barkevikite biotite olivine (?)
Fourchite dikes		analcime (?)	titanaugite
Amphibole fourchite dikes		analcime (?)	titanaugite barkevikite

The deposit has been described by Ross (1941) and Fryklund and Holbrook (1950). U. S. Bureau of Mines drilling projects have been described by Spencer (1946) and Reed (1949a). The main deposit (fig. 3) has been partly exposed in two shallow open pits. Outcrops

Figure 3. Topographic and Geologic map of the Magnet Cove Titanium Corporation deposit, Hot Spring County, Arkansas, showing the location of the Bureau of Mines drill holes.

and drill hole information indicate that the known deposit has a long axis striking about east-west, and is about 2500 feet long and up to 800 feet wide. The deposit has been proved by drilling to a depth of 188 feet.

In an area about 1/2 mile southwest of the open pits, old shallow workings can be seen, and rutile is locally abundant in the soil. This area has not been explored by drilling.

Former mining operations utilized the weathered material in which some residual concentration had occurred. Most of this material has been removed.

All drilling has been done in the vicinity of the open pits (fig. 3). The U. S. Bureau of Mines drilled 16 churn drill holes in 1945 and 27 core drill holes in 1948. For the results of sampling and analyses see pages 15 and 16.

Character of the deposit.--The bedrock consists of igneous rock, chiefly nepheline syenite of several types, cut by veins and irregular bodies of feldspar-carbonate rock.

The most common igneous rock is aegirine-nepheline syenite porphyry, which contains scattered inclusions of various igneous and metamorphic rocks. Inclusions of igneous breccia are described by Fryklund and Holbrook (1950, p. 22) and are similar to those in Conway and Perry Counties, Arkansas, described by Croneis (1930, p. 155-161). The igneous rocks and their characteristic minerals are listed in table 1.

Table 1. Characteristic minerals of the igneous rocks, Magnet Cove Titanium Corporation, Magnet Cove, Arkansas.

Table 2.--Primary constituents of veins in Magnet Cove Titanium Corp. deposit.

Name	Constituents	Average grain size in mm.	Rutile content
Coarse-grained biotite-apatite-calcite vein	coarse calcite	2-12	absent
	apatite		
	green biotite		
Sugary-textured albite-dolomite vein	euhedral albite	0.5	up to 5 percent
	euhedral dolomite	.5	
	pyrite		
	apatite		
	molybdenite		
Microcline-calcite vein	microcline	0.04	1 - 2 percent
	calcite	.5-1.0	
	albite		
	apatite		
	sphene		
	pyrite	5-20	
Albite-ankerite vein	albite	1	very abundant, large masses
	ankerite	1	
	pyrite		
Coarse-grained albite-perthite-carbonate vein	albite	2	less than 1 percent
	microcline	2	
	perthite	2	
	carbonate (leached)		
	quartz		
Calcite-rutile vein	calcite	5.	very abundant, disseminated in calcite
	albite	.5	

EXPLANATION

Residual and transported ore

Ins
Nephelene syenite (fine-grained type)

Css
Stanley shale (Penn.)

Chs
Hot springs sandstone (Penn.)

CDan
Arkansas Novaculite (Dev-Miss.)

Smm
Missouri Mountain shale (Silurian.)

Sbs
Blaylock sandstone (Silurian.)

Contact
Dashed where approximate, dotted where inferred

Limit of primary ore

Section Line

40°
Strike and dip of over turned beds

Caved adit

Prospect trench

Caved shaft

x5
Pospect pit

C-6
Drillhole

Improved road

Building

FIG. 4 - GEOLOGIC AND TOPOGRAPHIC MAP OF THE CHRISTY BROOKITE DEPOSIT
HOT SPRING COUNTY, ARKANSAS
SHOWING LOCATION OF DRILL HOLES AND PITS

100 0 100 200 300 Feet.

Contour interval 20 feet.

In the main deposit the rutile occurs in feldspar-carbonate veins of several types that cut the igneous rocks and constitute 50-75 percent of the deposit. For detailed description the reader is referred to Fryklund and Holbrook (1950, p. 26-35). The veins are tabulated according to constituents and rutile content in table 2.

Table 2. Constituents of veins in Magnet Cove Titanium Corporation deposit.

The rutile occurs as single grains and aggregates of acicular rutile, and as veins. The maximum length of acicular rutile is 0.5 mm; the average length is 0.1 mm, but some is barely visible at 360 diameters magnification. Probably 15 to 20 percent of the TiO_2 in the carbonate veins is in the form of leucoxene, an alteration product of rutile.

Christy brookite deposit

Location, geology and extent.--The Christy deposit is near the eastern margin of Magnet Cove. It is about one-half mile north of the town of Magnet, in the SW 1/4 of the SW 1/4 of sec. 16, T. 3 S., R. 17 W. (fig.2). The property is owned by the Malvern Lumber Company of Malvern, Arkansas. The property has been described by Holbrook (1947), Reed (1949b), and Fryklund and Holbrook (1950).

The deposit (fig. 4) contains material of two types, a primary

Figure 4. Geologic and topographic map of the Christy brookite deposits, Hot Spring County, Arkansas, showing the location of drill holes and pits.

deposit and an enriched residual deposit. The primary deposit is in quartzite of the Arkansas novaculite of probable Devonian and Mississippian age. The primary deposit extends about 420 feet north-south and about 900 feet east-west, and has been proved by drilling to a depth of 130 feet. Residual material has crept down slope from the primary deposit and forms a residual deposit about 900 feet long and at least 550 feet wide. The maximum thickness is about 20 feet.

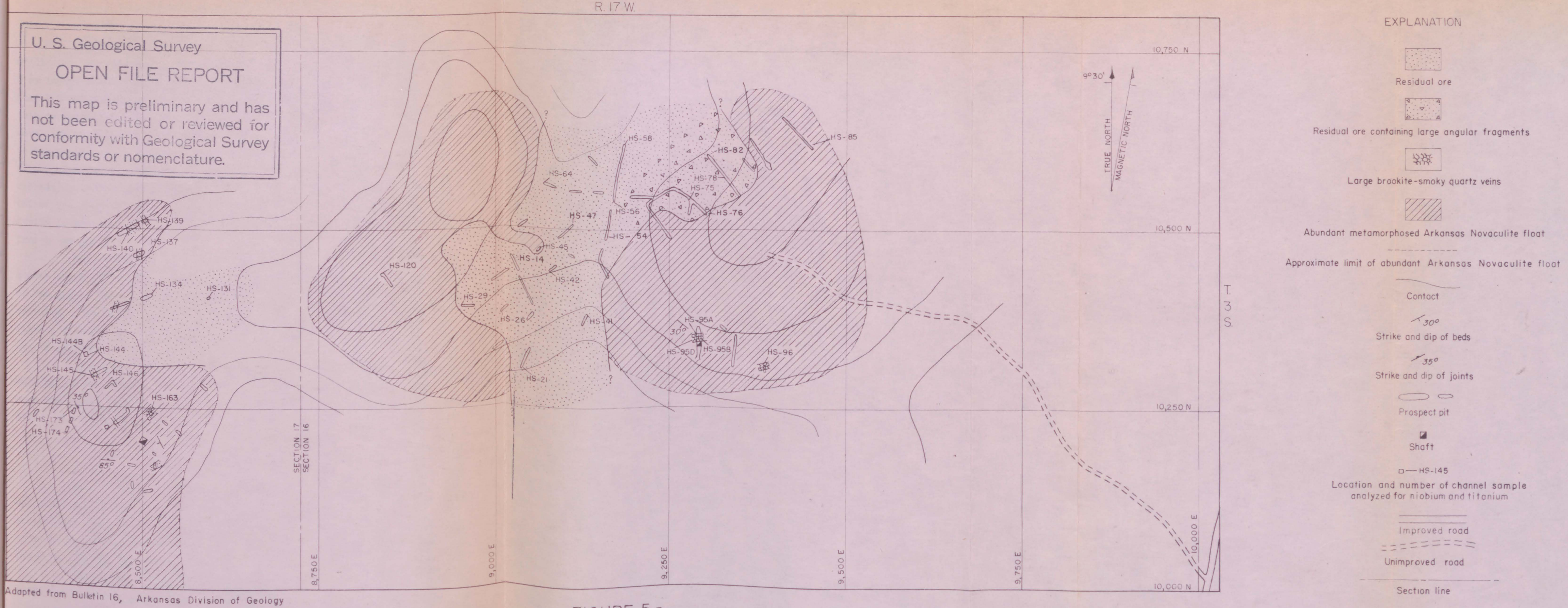


FIGURE 5.-
[GE]OLOGIC AND TOPOGRAPHIC MAP OF THE KILPATRICK BROOKITE DEPOSIT, SHOWING THE LOCATION OF SAMPLES ANALYSED FOR NIOBIUM

100 0 100 200 300 400 500 600 FEET

CONTOUR INTERVAL — 10'

Character of the deposit.--The primary material, as seen in drill core, is composed of brookite-bearing dark quartzite, separated by clay layers containing little or no brookite. The brookite averages less than 0.5 millimeter in diameter and is rarely megascopically visible. In thin sections the quartz grains range from 0.05 millimeter to slightly more than 1 millimeter in diameter. The dark color of the rock is due to the brookite, to abundant very fine-grained acicular rutile, and to altered taeniolite. Taeniolite is a rare magnesian lithium mica containing a small proportion of titanium as an essential constituent (Miser and Stevens, 1938). Rutile inclusions in brookite show that the rutile formed earlier. In thin sections the brookite content varies from a few grains to 10 percent.

The residual material consists of porous quartzite fragments, quartz crystals, brookite crystals, and sand-sized material in a matrix of red clay. The dark quartzite forms at least one-third of the residual material. The largest brookite crystals of the deposit, some of which reach a diameter of 6 or 7 millimeters, are within or perched on the quartz crystals.

No production from this deposit has been recorded. Exploration work has consisted of test pits financed by the RFC in 1944 and of 21 core and bucket drill holes put down by the U. S. Bureau of Mines in 1948. The results of sampling and analysis are given on pages 16 and 17.

Kilpatrick brookite deposits

The Kilpatrick deposits are in sec. 16 and 17, T. 3 S., R. 17 W., one mile north of the town of Magnet (fig. 2). The deposits have been described by Ross (1941) and Fryklund and Holbrook (1950). They have been known in the literature as the Hardy-Walsh deposits, but they are owned by the estate of William Kilpatrick.

The deposits are exposed on a ridge of Arkansas novaculite of Devonian and Mississippian age, at the eastern edge of the Cove. Igneous rocks of several types crop out a few hundred feet north of the deposit.

The ridge consist of several knobs and saddles (fig. 5).

Figure 5. Geologic and topographic map of the Kilpatrick brookite deposits, showing the location of the samples analyzed for niobium.

The knobs consist of novaculite with small quantities of brookite, chiefly exposed in shallow trenches. The saddles are underlain by residual material whose depth is not known. The eastern saddle contains the largest residual deposit, which is at least 450 feet long and 200-300 feet wide.

The primary deposit is in quartzite of the Arkansas novaculite. The material of the primary and residual deposits is similar to that in the Christy deposit.

Exploration work has consisted of test pits and auger holes. The results of the auger drilling are not available. The results of sampling and analysis are given on pages 17 and 18.

Mo-Ti Corporation property

The Mo-Ti Corp. prospect pit is in sec. 17, T. 3 S., R. 17 W., on the south bank of Cove Creek within Magnet Cove (fig. 2). The area has been described by Holbrook (1948) and Fryklund and Holbrook (1950). The pit was flooded during the present work, but drill-core obtained during a drilling program in 1947 was studied by the senior author.

Veins containing rutile, brookite, and molybdenite cut pyroxene-magnetite rock (melteigite). The results of earlier work suggest that mineralized and altered rock underlie a considerable area now covered by gravels.

Pyroxene-magnetite rock containing nepheline and perovskite forms most of the drill core. A large area underlain by this rock is shown on William's map (1891, plate 4, "eleolite mica syenite") but no outcrop was found during the present study. The rock is dark green in color with a maximum grain size of 4 millimeters. A mode of one thin section as determined by the point-counter method is as follows:

Nepheline (and alteration products)	7 percent
Diopside (?) and alteration products	58
Biotite, mainly primary	6
Magnetite	16
Apatite	4
Perovskite	8
Other, mainly garnet and sphene	1
	100 percent

17

The pyroxene is light yellow in color and has no visible pleochroism; $X \wedge c = 52^{\circ}$; the extinction is anomalous and similar to the titanaugite of the area. In other thin sections the perovskite content ranges from 5 to 8 percent.

According to Johannsen's classification the rock is a perovskite melteigite, 3'125 (Johannsen, 1938, vol. 4, p. 327). It was included in the "eleolite syenite" group by Williams (1891, p. 188-189).

Material for analysis was drilled from a perovskite grain in a thin section, and analysis showed 0.56 percent niobium (see p. 18).

Description of calcite rock bodies

General

At several places in the Cove the bed rock consists of coarse-grained calcite with scattered accessory minerals. The accessory minerals include perovskite that contains as much as 8.8 percent niobium, and for this reason the calcite rocks were studied in some detail. Rocks of this type and of doubtful sedimentary origin have been called "carbonatite" (Daly 1933 p. 564), and have been found to contain appreciable concentrations of niobium at several places.

Figure 2 shows the location of known and probable bodies of coarse-grained calcite rock at Magnet Cove. Rock of this type is well exposed only in and near the Kimsey quarry, which is on the west side of Cove Creek and on the north side of highway 270 (see fig. 2). To the north of the Kimsey quarry, coarse-grained calcite rock crops out in two areas along Cove Creek, as shown in figure 2.

Power auger drilling showed that the hill north of the quarry and west of Cove Creek (labelled "West Tufa Hill" on figure 2) is underlain by residual clay to the level of the surrounding gentle slopes. The surface of the hill is littered with boulders of cellular iron-stained siliceous material, which was called "tufa" by Williams (1891, p. 183). Gradation from siliceous material to calcite rock, which can be seen in the outcrop at the northwest corner of the quarry, indicates that the siliceous material is derived from the calcite rock by weathering processes.

The "tufa" can, therefore, be used as evidence for the occurrence of coarse calcite in bedrock. On this basis the hill west of Cove Creek and the hill north of the church, labelled "East Tufa Hill" on figure 2, are underlain at least partly by coarse calcite rock. On East Tufa Hill the "tufa" float is not abundant, and is accompanied by boulders of bleached igneous rock. A power auger hole at the crest of the hill penetrated 40 feet of clay, at the limit of available drill pipe. The hill is only about 40 feet above the surrounding flat.

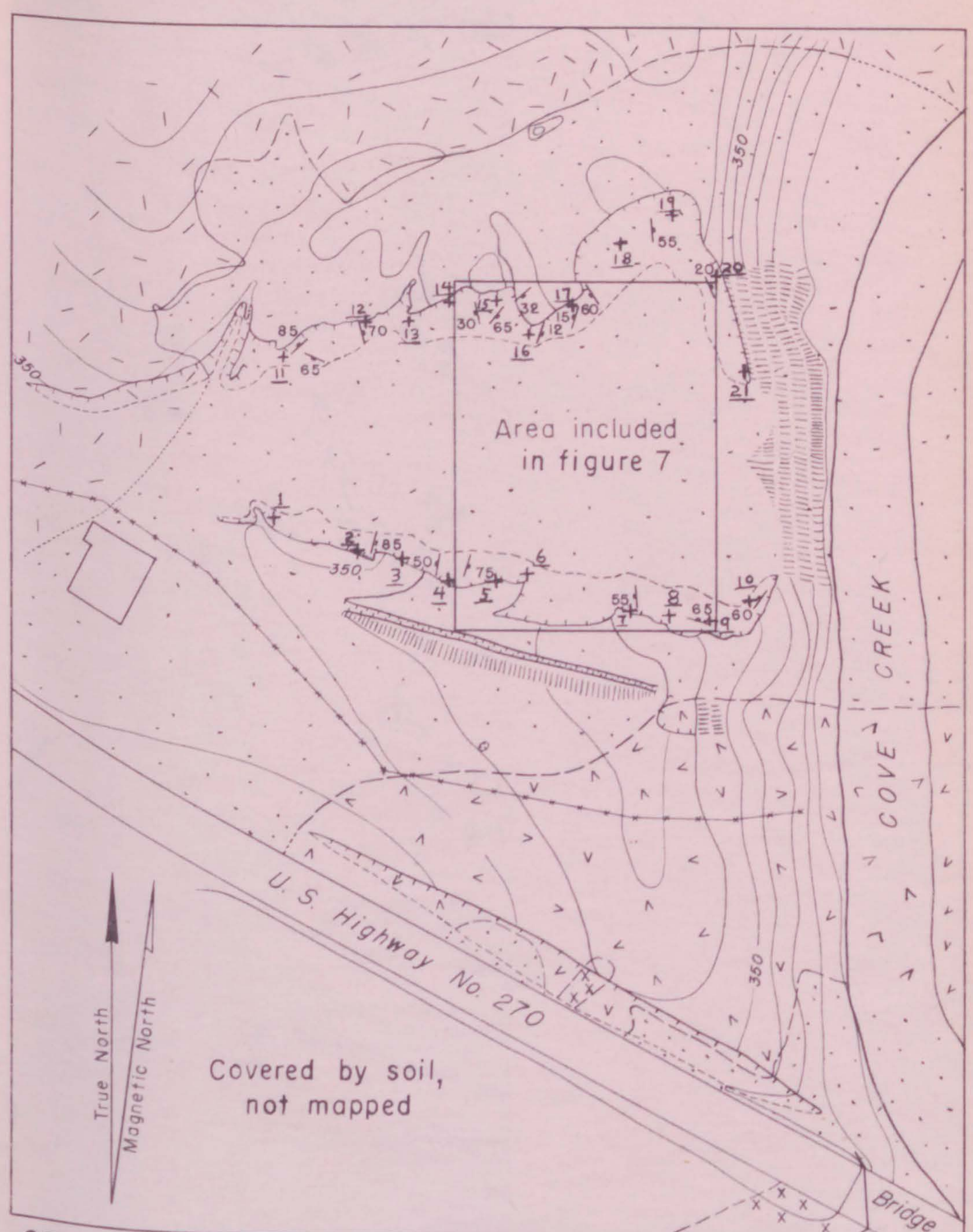
The hill labelled "Middle Tufa Hill" on figure 2 has relatively few float boulders; most of them are igneous rock and quartzite, and a few are "tufa". On the flat south of the hill the soil contains abundant magnetite and some apatite and perovskite. A power auger encountered rock at 20 feet and brought up fragments of apatite. The bedrock is probably at least partly calcite rock.

Calcite rock crops out near the Baptist Church about 3500 feet southeast of the Kimsey quarry (fig. 2). According to Mr. Joseph W. Kimsey, a well near the church penetrated about 50 feet of calcite rock. In the field on the southern side of the highway, south of the calcite quarry, abundant perovskite in the soil indicates that calcite rock forms part or all of the underlying bedrock. This area is called "Perovskite Hill" in the older reports and on figure 2.

In addition to the areas just described, the southwestern part of the area near the pits on the Magnet Cove Titanium Corporation property (fig. 2) is underlain in considerable part by calcite rock. One drill hole penetrated calcite rock to a depth of 161 feet. A water well said to be about 90 feet deep, in the northwest corner of section 19 (fig. 2), penetrated calcite rock. There is no outcrop in the vicinity, but rutile is locally abundant in the soil.

These data indicate that the total area underlain by calcite rock is very large.

79



6 – GEOLOGIC AND TOPOGRAPHIC MAP OF THE KIMSEY CALCITE QUARRY, HOT SPRINGS COUNTY, ARKANSAS

100 0 100 200 Feet

Contour interval 5 feet

EXPLANATION

Coarse-grained calcite

Garnet-nepheline syenite porphyry

Aegirine-nepheline syenite porphyry

Eudialite-nepheline syenite

Contact; dashed where approximate, dotted where concealed

Strike and dip of joint

Top of cut

Bottom of cut

Prospect pit

Dump

Fence

Building

+ 5
Location of sample

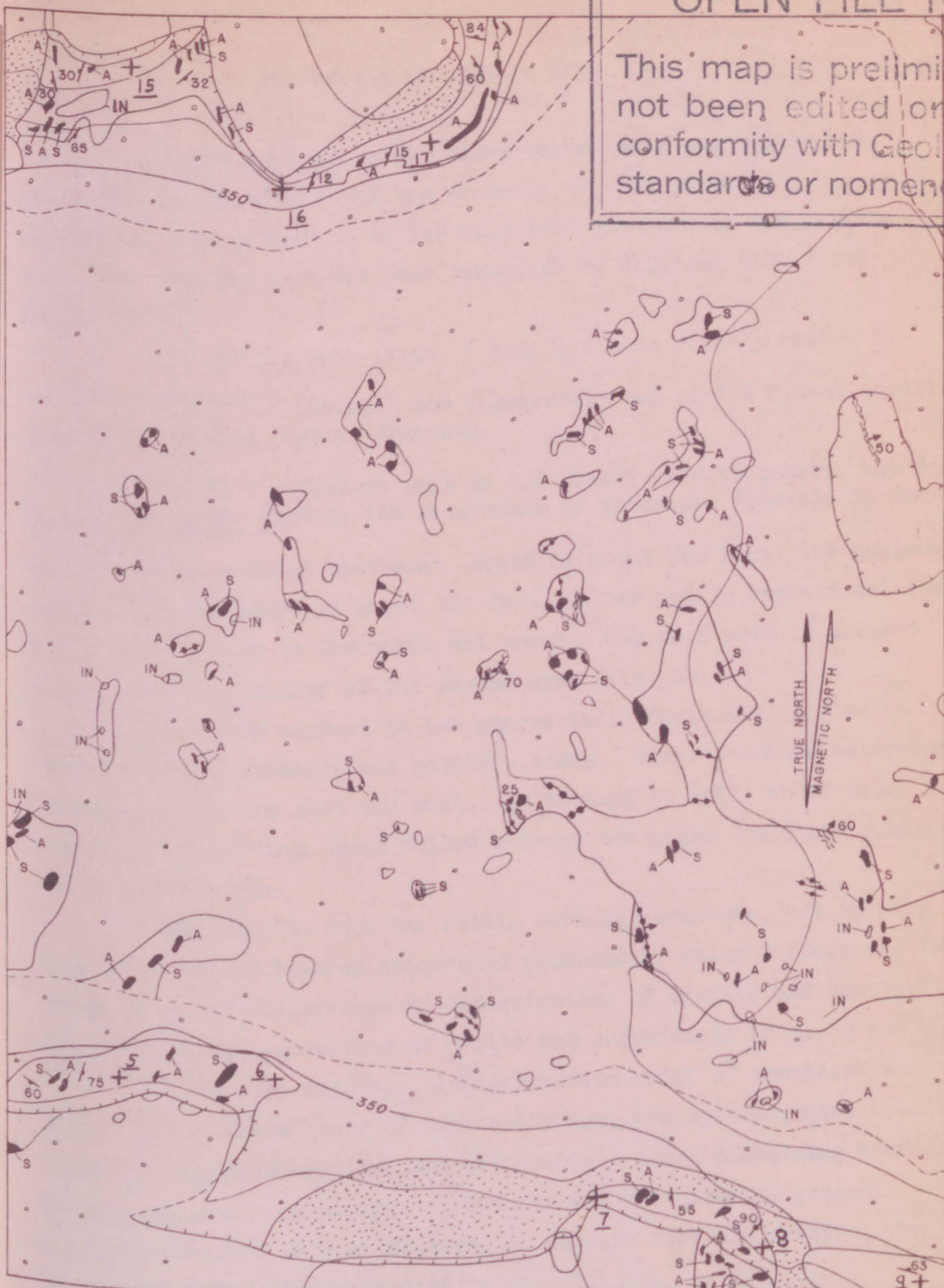


FIGURE 7.– EASTERN PART OF KIMSEY CALCITE QUARRY, HOT SPRINGS COUNTY, ARKANSAS SHOWING THE OCCURRENCE OF ACCESSORY MINERALS IN THE CALCITE

20 0 20 40 FEET

Contour interval 5 feet

EXPLANATION

Cover

Residual clay derived from calcite

Pyrite veins, showing dip where determined

Molybdenite veins, showing dip

Inclusions

Concentrations of silicates (mainly monticellite)

Concentrations of apatite

Calcite *Exposure*

Strike and dip of joints

Top of cut

Foot of cut

Strike of vertical joints

Location of sample

Kimsey calcite quarry area

General geology.--The Kimsey quarry area was mapped and studied in detail because of the presence of niobium-bearing perovskite, and because it is the only good exposure of the calcite rock. The calcite rock has been described by Williams (1891) and Landes (1931).

The calcite body (figs. 6 and 7) trends roughly east-west,

Figure 6. Geologic and topographic map of the Kimsey calcite quarry, Hot Spring County, Arkansas.

Figure 7. Eastern part of the Kimsey calcite quarry, Hot Spring County, Arkansas, showing the occurrence of accessory minerals in the calcite.

with a maximum exposed east-west length of about 360 feet; the maximum north-south dimension is about 300 feet. Other poorly exposed calcite bodies are present to the north and south. One such body is present in the southeast corner of the mapped area (fig. 6).

The body exposed in the quarry is in contact with syenite porphyry on the northern and southern sides. Cover prevents determination of extension to the east and west. An attempt to drill auger holes in the flat east of Cove Creek failed because the auger could not penetrate the coarse gravels.

The calcite rock has little obvious structure, but locally does have a faint layered appearance produced by color differences in the calcite, by differences in concentration of apatite and monticellite, and by local concentrations of pyrite and molybdenite (figs. 6 and 7).

Accessory minerals, in approximate order of abundance and also in approximate order of decreasing age, are apatite, monticellite, biotite, magnetite, pyrite, and perovskite. Zones containing abundant pyrite and those containing molybdenite are only locally present. Pyrrhotite occurs only at contacts of calcite rock and syenite, where it is associated with magnetite.

Inclusions in the calcite rock.--The calcite body contains inclusions of several rock types, ranging in size from a hen's egg to angular blocks 6 to 7 feet long. Small segregations of green biotite may represent digested or replaced inclusions.

Reaction rims of varying thickness are universally present around the larger inclusions. Large blocks may have only a small remnant of the original rock at the center; much smaller blocks of the same rock type may have a reaction rim only 1 to 2 inches wide.

A typical reaction rim from outside inward consists of the following zones:

1. A narrow zone, usually less than 1 inch wide, of magnetite and pyrrhotite lying in a medium-grained calcite matrix.
2. A zone rich in green biotite. Some biotite grains may reach one centimeter in diameter.
3. A fine-grained vesuvianite-rich zone of variable width and in some cases including the whole block. A few large vesuvianite crystals, reaching 3 to 4 centimeters in length, are present in these zones.

In thin section the altered rock shows total replacement of the pyroxene by epidote, muscovite, and vesuvianite; the brown garnet is bleached and partly replaced by vesuvianite. Only a minor amount of carbonate is present.

Origin of the calcite rocks

Bodies of calcite rock or carbonatite associated with and included in alkaline igneous complexes have generally been described as sedimentary inclusions, whose assimilation may have been a factor in the origin of the alkaline rocks (Landes 1931; Daly, 1933, p. 508-509, 564-565; Shand, 1947, p. 303-328). Recent descriptions, however, have emphasized evidence that some calcite bodies of this type are introduced material, formed either as magmatic carbonate intrusives or by hydrothermal replacement (Bowen, 1924; von Eckermann, 1948; Strauss, 1951).

Two lines of evidence indicate that the coarse calcite rock at Magnet Cove is introduced into the igneous rocks. The inclusions of syenite, rimmed by reaction products and veined by calcite, testify that the calcite material was both mobile and reactive after the formation of the igneous rocks, and most likely was introduced later than the igneous rocks.

21

Table 3.--Analyses of samples from the Magnet Cove Titanium Corporation property, Magnet Cove, Arkansas.

[Spectrography by J. K. Murata]

Drill hole (fig.3)	Depth (feet)	Lab. no.	Sample no.	Nb	TiO_2		V_2O_5		Y	La	Rock Type 2/
					Spectro-graphic	Chem-ical 1/	Spectro-graphic	Chem-ical 1/			
B-2	91-95	52-782SW	1333	0.039	4.3	4.95	0.065	0.11	0.008	0.009	Albite-dolomite vein
B-2	110-115	52-783SW	1337	.028	1.1	1.70	.042	.19	.025	.15	Calcite-rutile vein
B-3	27-34	52-784SW	1758	.036	2.4	2.65	.086	0	.014	.054	Albite-dolomite vein
B-3	73-79	52-785SW	1765	.021	1.2	1.05	.025	0	.008	.029	Calcite and feldspar-carbonate veins
BCC-1	54-60	52-789SW	1557	.009	1.1	0	.028	0	.020	.070	Microcline-calcite vein
BCC-2	30-36	52-786SW	1553	.022	2.6	0	.098	0	.006	.012	Syenite porphyry
BCC-2	73-80	52-787SW	1560	.12	9.5	0	.091	0	.013	.008	Albite-dolomite vein
BCC-2	80-86	52-788SW	1561	.026	1.7	0	.032	0	.011	.006	Albite-dolomite vein
D-1	21-24	52-770SW	1633	.021	3.2	2.50	.13	.11	0	.029	Albite-dolomite vein
E-7	48-49.8	52-790SW	1396	.041	2.7	3.20	.13	.05	.013	.033	Feldspar-carbonate vein
E-7	49.8-52	52-791SW	1397	.039	2.0	2.70	.072	.10	.010	.030	Feldspar-carbonate vein
E-7	73-76.5	52-792SW	1405	.015	1.2	1.35	.070	.18	.004	.031	Feldspar-carbonate vein
E-7	108.2-111.4	52-793SW	1418	.021	1.3	2.30	.048	.08	.004	.027	Microcline-calcite vein
F-1	10.7-19.4	52-794SW	1716	.020	1.3	1.10	.030	0	.014	.039	Albite-dolomite vein
F-1	110.4-120.1	52-795SW	1727	.023	1.5	1.55	.021	0	.016	.020	Microcline-calcite vein
G-2	53-56	52-798SW	1218	.014	1.4	1.73	.071	.05	.022	.078	Albite-dolomite vein
G-2	56-58	52-796SW	1219	.042	2.4	2.90	.066	.07	.011	.068	Albite-dolomite vein
G-2	115-118	52-797SW	1234	.022	2.6	2.30	.085	.05	.012	.042	Albite-dolomite vein
G-4	135.8-145	52-799SW	1816	.037	4.1	3.78	.052	.08	.014	.055	Albite-dolomite vein
I-1	20-26	52-800SW	1189	.013	1.2	.88	.098	.07	.006	.11	Albite-dolomite vein
I-1	36-40	52-801SW	1192	.012	1.3	2.35	.033	.05	.010	.006	Albite-dolomite vein
I-1	67-72	52-802SW	1200	.014	1.0	1.15	.022	.05	.004	.005	Albite-dolomite vein
J-1	32.5-35.9	52-803SW	1911	.026	3.3	3.14	.14	.09	.008	.009	Syenite porphyry
J-2	31.8-39.4	52-804SW	1846	.026	2.1	2.38	.024	.07	.017	.068	Albite-dolomite vein
J-3	33-39	52-805SW	1865	.012	1.2	1.00	.030	.08	.006	.018	Albite-dolomite vein
J-3	75-82	52-806SW	1872	.019	2.9	2.62	.11	.08	.008	.013	Syenite porphyry
J-3	96-103	52-807SW	1875	.016	1.7	1.82	.064	.09	.011	.51	Albite-dolomite vein
J-3	103-109	52-808SW	1876	.029	2.7	3.04	.10	.09	.008	.047	Syenite porphyry
K-5	24-29	52-809SW	1491	.016	2.4	2.40	.18	.15	.008	.016	Syenite porphyry
K-5	57.5-67	52-810SW	1496	0	.02	.25	.005	.07	.004	.006	Biotite-calcite vein
L-2	14-21	52-811SW	1965	.062	2.6	3.08	.039	.08	.007	.11	Albite-dolomite vein
L-2	21-28	52-761SW	1966	.075	3.7	3.56	.057	.07	.009	.18	Albite-dolomite vein
M-5	54-61	52-762SW	1885	.009	.51	.49	.012	.08	.31	.041	Albite-dolomite vein
O-2	9.5-11.7	52-763SW	1289	.020	2.9	3.26	.47	.19	.010	.014	Microcline-calcite vein
O-2	27.1-29.1	52-764SW	1296	.071	4.2	5.35	.030	.07	.014	.029	Microcline-calcite vein
O-2	29.1-34.1	52-765SW	1297	.048	2.9	2.67	.025	.05	.020	.064	Microcline-calcite vein
O-2	49.1-52.3	52-766SW	1301	.040	3.0	3.25	.031	.15	.012	.011	Microcline-calcite vein
O-3	23-26.5	52-767SW	1347	.025	.64	.70	.063	.11	0	.005	Diamond Jo type nepheline syenite
O-3	34.3-35.2	52-768SW	1352	.026	1.2	.95	.013	.09	0	0	Albite-perthite-carbonate vein
O-3	59.5-64.5	52-769SW	1365	.034	.97	1.15	.053	.05	0	.011	Fine-grained nepheline syenite

1/ Bureau of Mines analyses from Reed (1949b).

2/ Rock type from Fryklund and Holbrook (1950).

Also, coarse calcite bodies and veins cut the igneous rocks in drill cores from the Magnet Cove Titanium Corporation deposit, and it is apparent that widespread introduction of calcite has taken place here, principally or wholly by hydrothermal action.

The question of magmatic intrusion versus hydrothermal replacement cannot be answered now for the Magnet Cove calcite rocks, but the available evidence favors hydrothermal replacement.

Sampling and analysis

Magnet Cove Titanium Corporation property

The location of drill holes, in the vicinity of the open pits, is shown on figure 3. The results of analysis by the U. S. Bureau of Mines of the cores for TiO_2 and V_2O_5 are discussed and tabulated in Fryklund and Holbrook (1950, p. 39-40 and 82-130).

Splits of 38 samples of core from 18 drill holes were obtained in 1952 through the courtesy of Mr. R. G. Knickerbocker of the U. S. Bureau of Mines at Rolla, Missouri. These splits were analyzed spectrographically for Nb, TiO_2, V_2O_5, Y and La (table 3).

Table 3. Analyses of samples from the Magnet Cove Titanium Corporation property, Magnet Cove, Arkansas.

The original core samples were divided according to the length of core pulled, rather than according to lithology, partly to permit correlation of core and sludge analyses. The igneous rocks contain from 2 to 5 percent TiO_2 in rutile, ilmenite, and silicates, all unrecoverable by milling. In the common case, therefore, where a sample includes both igneous rock and vein, the analysis cannot be interpreted directly and quantitatively.

Adjustment of analytical figures on the basis of type of material indicates that in the main deposit about 3 percent TiO_2 is present as rutile.

Calculation of average grade of niobium likewise cannot be done directly, but a similar adjustment indicates that the niobium grade of the deposit is about 0.04 percent Nb.

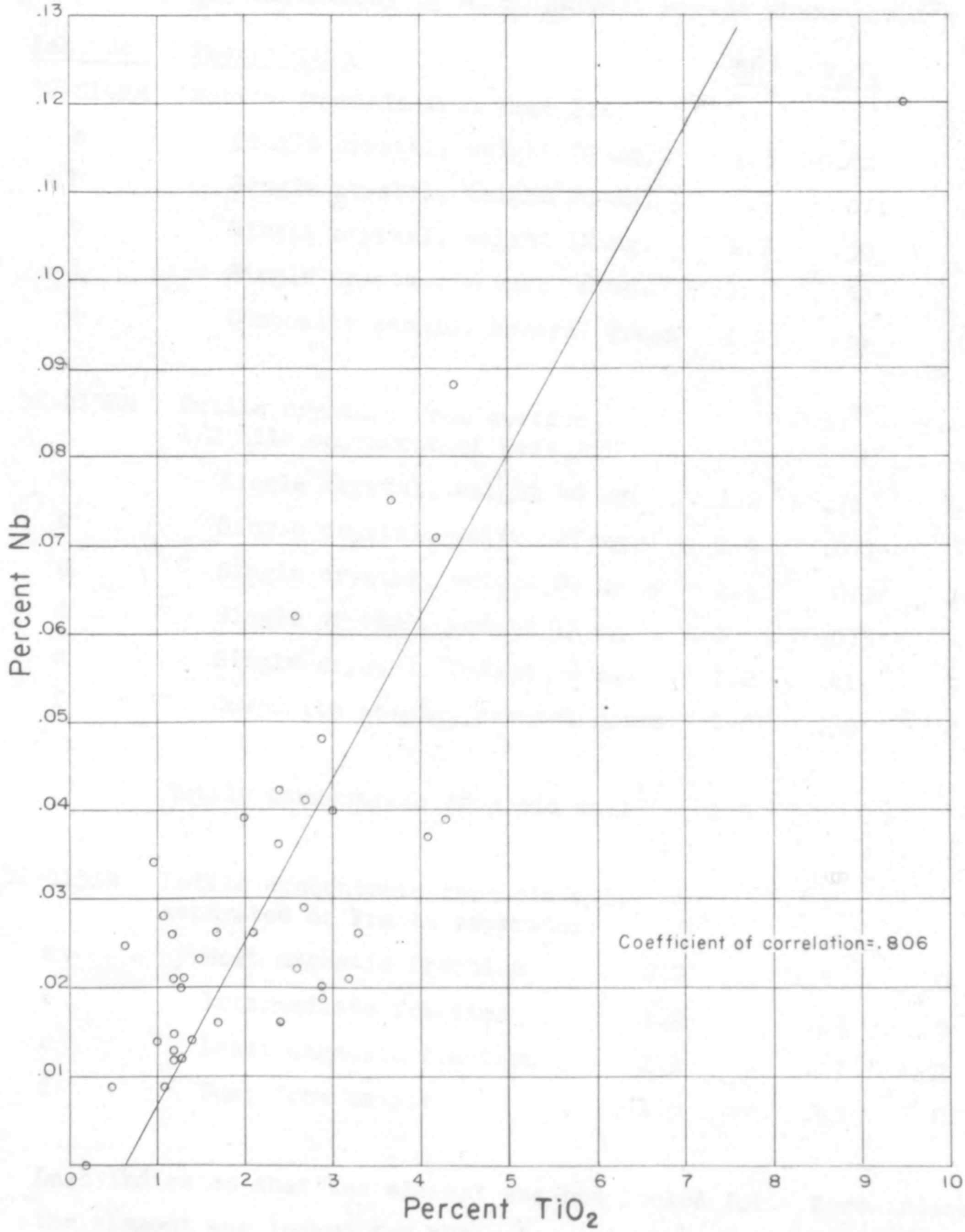


FIGURE 8.—CORRELATION OF Nb AND TiO_2, MAGNET COVE TITANIUM CORPORATION PROPERTY, MAGNET COVE, ARKANSAS.

Table 4.--Analyses of rutile crystals and rutile concentrates from the Magnet Cove Titanium Corporation property, Magnet Cove, Arkansas.

[Spectrography by R. S. Harner, except where noted]

Lab. no.	Description	Nb	V_2O_5	La	Y
52-814SM	Rutile crystals from West Pit				
a	Single crystal, weight 52 mg.	1.3	0.52	-	-
b	Single crystal, weight 20 mg.	.4	.071	-	-
c	Single crystal, weight 12 mg.	1.7	.30	-	-
d	Single crystal, weight 8 mg.	1.7	.30	-	-
e	Composite sample, several grams	1.4	.54	0	0
52-815SM	Rutile crystals from surface, 1/2 mile southwest of West Pit				
a	Single crystal, weight 40 mg.	1.2	.71	-	-
b	Single crystal, weight 27 mg.	1.4	.071	-	-
c	Single crystal, weight 21 mg.	1.4	.071	-	-
d	Single crystal, weight 11 mg.	0	.073	-	-
e	Single crystal, weight 8 mg.	1.2	.41	-	-
f	Composite sample, several grams	1.0	.80	0	0
	Rutile concentrate from old mill 1/	1.3			
52-813SM	Rutile concentrate from old mill, separated on Frantz separator.				
a	Most magnetic fraction	2.2	1.5	0	0
b	Intermediate fraction	1.2	.29	0	0
c	Least magnetic fraction	1.1	.17	0	0
d	Dust from sample	1.6	.43	0	0

Dash indicates that the element was not looked for. Zero indicates that the element was looked for but not found at the limit of sensitivity.

1/ Spectrography by Janet Fletcher.

Table 5.--Analyses of samples from the Christy Property, Magnet Cove, Arkansas.

[Spectrography by R. S. Harner]

Pit no. (fig. 4)	Lab. no.	Nb	TiO_2	V_2O_5	Y
A-1	52-694SW	0.32	13.	0.55	0
A-2	52-695SW	.060	8.0	.29	0
A-3	52-696SW	.15	9.7	1.8	0.016
A-4	52-719SW	.072	6.3	.50	.016
B-1	52-697SW	.032	2.1	.079	.014
B-2	52-698SW	.042	11.	.29	.028
B-3	52-699SW	.096	7.2	.40	0
B-4	52-700SW	.086	6.7	.54	0
B-5	52-720SW	.040	5.0	.34	0
C-1	52-701SW	.058	7.7	.54	0
C-2	52-703SW	.20	12.	1.0	.012
C-3	52-702SW	.080	7.3	.43	0
C-4	52-704SW	.050	5.7	.36	0
C-5	52-705SW	.15	12.	1.3	0
D-1	52-706SW	.026	6.3	.82	0
D-2	52-707SW	.086	8.0	.43	.011
D-3	52-708SW	.042	9.7	.43	.016
D-4	52-709SW	.092	7.7	.29	.016
D-5	52-710SW	.028	4.0	.28	.022
E-2	52-711SW	.20	12.	.15	.016
E-3	52-712SW	.086	9.7	.21	.015
E-4	52-713SW	.24	10.	.55	.013
E-5	52-714SW	.40	18.	.89	.018
E-6	52-721SW	.072	9.7	.36	.013
F-1	52-715SW	.20	9.7	.26	0
F-2	52-722SW	.21	12.	.85	.014
F-3	52-723SW	.086	6.3	.21	.016
F-4	52-716SW	.030	3.3	.32	.019
F-5	52-717SW	0	2.0	.33	.026

Drill hole (fig.)	Depth (feet)	Lab. no.	Sample no.	Nb	TiO_2		V_2O_5		Y
					Spectro-graphic	Chemical[1/]	Spectro-graphic	Chemical[1/]	
C-4	77.5-80.5	52-727SW	419	.18	10.	10.70	.53	0.81	.040
C-4	103-106	52-728SW	427	.20	11.	6.72	.20	.31	.14
C-8	63.5-66	52-724SW	1012	.088	4.4	3.83	.38	.52	.024
C-8	85-86.5	52-725SW	1018	.45	23.	26.30	.25	.38	0
C-8	100.5-102.5	52-726SW	1025	.33	11.	12.25	.30	.42	0

Zero indicates that the element was looked for but not found at the limit of sensitivity.

La less than 0.005 percent in all samples.

1/ Bureau of Mines analyses from Reed (1949a).

The relation between niobium and titania in the samples is shown graphically in figure 8. The lack of straight-line correlation

Figure 8. Correlation of Nb and TiO_2, Magnet Cove Titanium Corporation property, Magnet Cove, Arkansas.

may be due partly to the mixed material analyzed. A more important reason is indicated in table 4, which shows the results of analysis of

Table 4. Analyses of rutile crystals and rutile concentrates from the Magnet Cove Titanium Corporation property, Magnet Cove, Arkansas.

rutile concentrates and single crystals. The single crystals of rutile from the west pit vary from 0.4 to 1.7 percent Nb; those from the float area one-half mile southwest of the pits vary from 0.00 to 1.4 percent Nb. This variation is probably sufficient to explain the scattering shown in figure 8.

Table 4 also contains analyses of two composite samples of rutile, 814-e and 815-f, and analyses of rutile concentrates. These analyses indicate that the average niobium content of rutile concentrates is about 1.2 $\pm$ .2 percent Nb.

Vanadium values in the single crystals vary over a wide range, and it is not surprising that the vanadium content of the drill core samples is also erratic. The lanthanum and yttrium values are probably in apatite.

Christy brookite deposit

The location of drill holes and test pits is shown in figure 4. The results of analysis by the U. S. Bureau of Mines of drill core samples are discussed and tabulated in Fryklund and Holbrook (1950, p. 63 and 131-151).

Splits of 5 samples from drill cores, and 29 samples of residual material from test pits, were analyzed for Nb, TiO_2, V_2O_5 and Y; the results are shown in table 5.

Table 5. Analyses of samples from the Christy property, Magnet Cove, Arkansas.

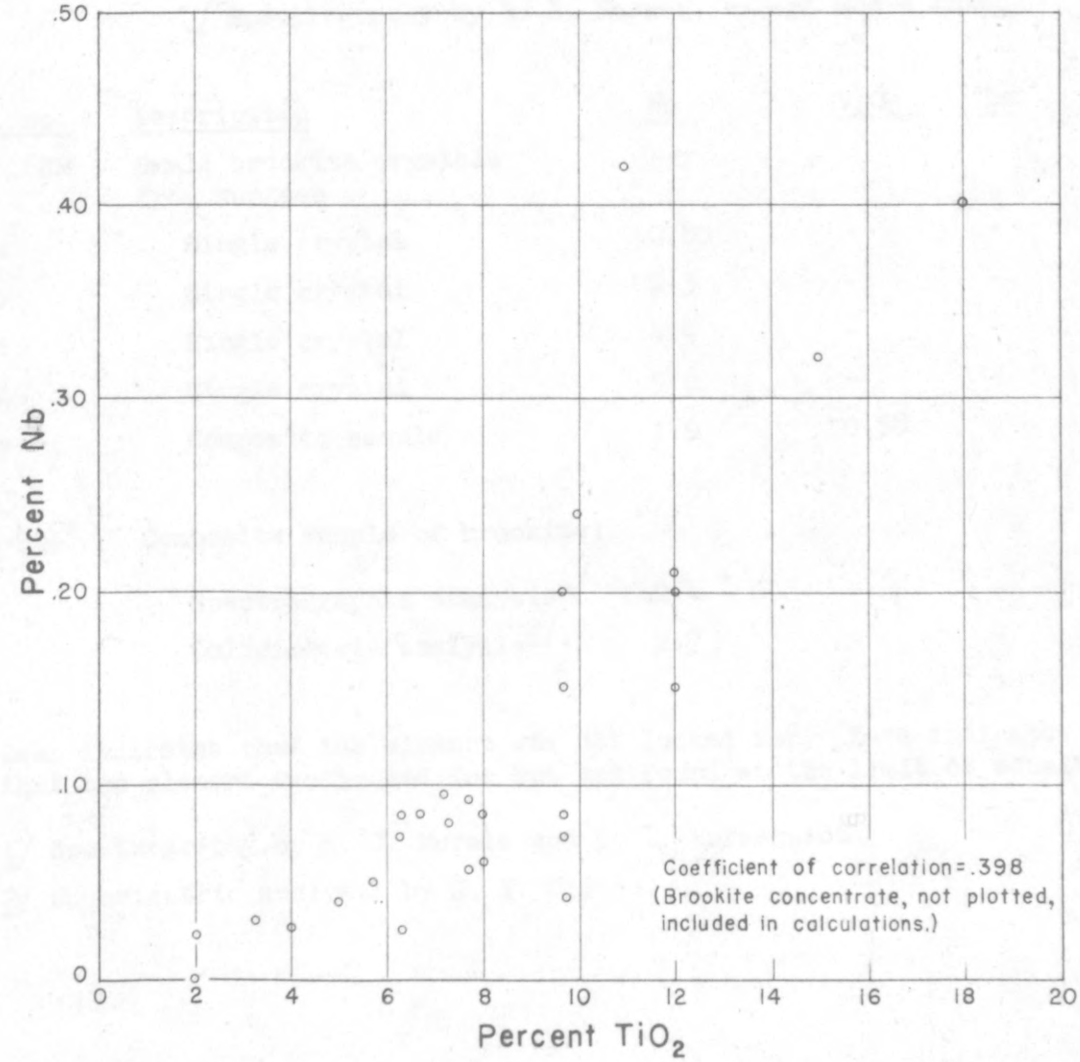


FIGURE 9.— CORRELATION OF Nb AND TiO_2, CHRISTY BROOKITE PROPERTY, MAGNET COVE, ARKANSAS.

Table 6.--Analyses of brookite crystals and composite samples of brookite from the Christy property, Magnet Cove, Arkansas.

[Spectrography by R. S. Harner, except where noted]

Lab. no.	Description	Nb	V_2O_5	La	Y
52-718SM	Small brookite crystals from surface				
a	Single crystal	0.80	-	-	-
b	Single crystal	2.3	-	-	-
c	Single crystal	4.4	-	-	-
d	Single crystal	9.6	-	-	-
e	Composite sample	1.9	0.58	0	0.002
IWS-254	Composite sample of brookite:				
	Spectrographic analysis 1/	2.4 ± 0.3	-	-	-
	Colorimetric analysis 2/	2.7	-	-	-

Dash indicates that the element was not looked for. Zero indicates that the element was looked for but not found at the limit of sensitivity.

1/ Spectrography by K. J. Murata and E. L. Hufschmidt.

2/ Colorimetric analysis by J. I. Dinnen.

Calculations on the basis of the Bureau of Mines figures give an average grade of 5.9 percent TiO_2. Part of this is present as acicular rutile, leucoxene and taeniolite, and therefore is not recoverable.

The correlation of Nb and TiO_2 is shown graphically in figure 9. The lack of good correlation is explained at least in part

Figure 9. Correlation of Nb and TiO_2, Christy brookite property, Magnet Cove, Arkansas.

by the analyses of brookite concentrate and single crystals given in table 6. The single crystals vary from .80 to 9.6 percent niobium.

Table 6. Analyses of brookite crystals and composite samples of brookite from the Christy property, Magnet Cove, Arkansas.

The analyses of composite brookite samples indicate that the average niobium content of brookite concentrates is about 2 percent Nb.

The lanthanum and yttrium are probably in apatite. The vanadium analyses vary greatly. The following analysis shows that at least part of the vanadium is present in brookite.

Analysis of brookite crystal from Christy property by Lee C. Peck, Analyst, Rock Analysis Laboratory, University of Minnesota.

Fe_2O_3	1.13
TiO_2	98.25
V_2O_5	0.41
	99.79

Kilpatrick brookite deposits

The location of test pits and the results of analyses by the U. S. Bureau of Mines of channel samples are shown on plate 4 of Fryklund and Holbrook (1950).

Table 7.--Analyses of samples from the Kilpatrick property, Magnet Cove, Arkansas

[Spectrography by R. S. Harner]

Location (fig. 5)	Lab. no.	Length of channel (feet)	Nb	TiO_2	V_2O_5	Y	La
14	52-757SW	5.0	0.008	3.3	0.092	0	0.009
21	52-729SW	1.7	.028	6.5	.15	0.009	0
26	52-762SW	10.0	.017	6.3	.015	0	.026
29	52-730SW	5.0	.017	4.3	.14	0	0
41	52-731SW	14.0	.032	5.0	.13	.007	0
42	52-732SW	7.0	.026	5.7	.15	.004	0
45	52-733SW	Grab sample	.052	3.0	.21	0	0
47	52-758SW	7.0	.048	5.0	.21	0	0
54	52-759SW	8.0	.011	4.3	.14	0	.040
56	52-734SW	14.0	.026	9.4	.17	.004	0
58	52-735SW	9.0	.008	3.3	.053	0	.028
64	52-736SW	3.0	.012	4.3	.14	0	0
75	52-737SW	7.0	.040	3.7	.39	.017	0
76	52-760SW	4.0	.012	4.3	.21	.034	.076
78	52-738SW	6.0	.20	14.	.27	0	0
82	52-761SW	5.0	.27	9.0	.16	0	.040
85	52-739SW	Quartzite sample	0	.082	.034	0	0
95A	52-740SW	6.5	.084	6.5	.21	0	0
95B	52-741SW	6.0	.074	5.0	.23	.030	0
95D	52-742SW	Chip sample	.12	12.0	.39	0	0
96	52-743SW	4.0	.022	3.2	.39	0	.019
120	52-744SW	3.0	.060	7.7	.29	.026	0
131	52-746SW	4.0	.12	37.	.34	0	0
134	52-747SW	3.0	.042	4.0	.61	.011	.003
137	52-748SW	3.0	.010	2.2	.32	0	.003
139	52-749SW	6.0	.022	2.5	.20	0	0
140	52-750SW	4.0	.017	5.0	.36	0	.004
144	52-751SW	5.0	.46	20.	.27	0	0
144B	52-752SW	6.0	0	3.2	.082	0	.004
145	52-753SW	6.0	.034	3.2	.25	0	.003
146	52-754SW	10.0	.32	12.0	.32	0	0
163	52-755SW	7.0	0	3.0	.19	0	.004
173-174	52-756SW	12.0 (Composite sample)	.038	2.5	.39	0	.003

Zero indicates that the element was looked for but not found at the limit of sensitivity.

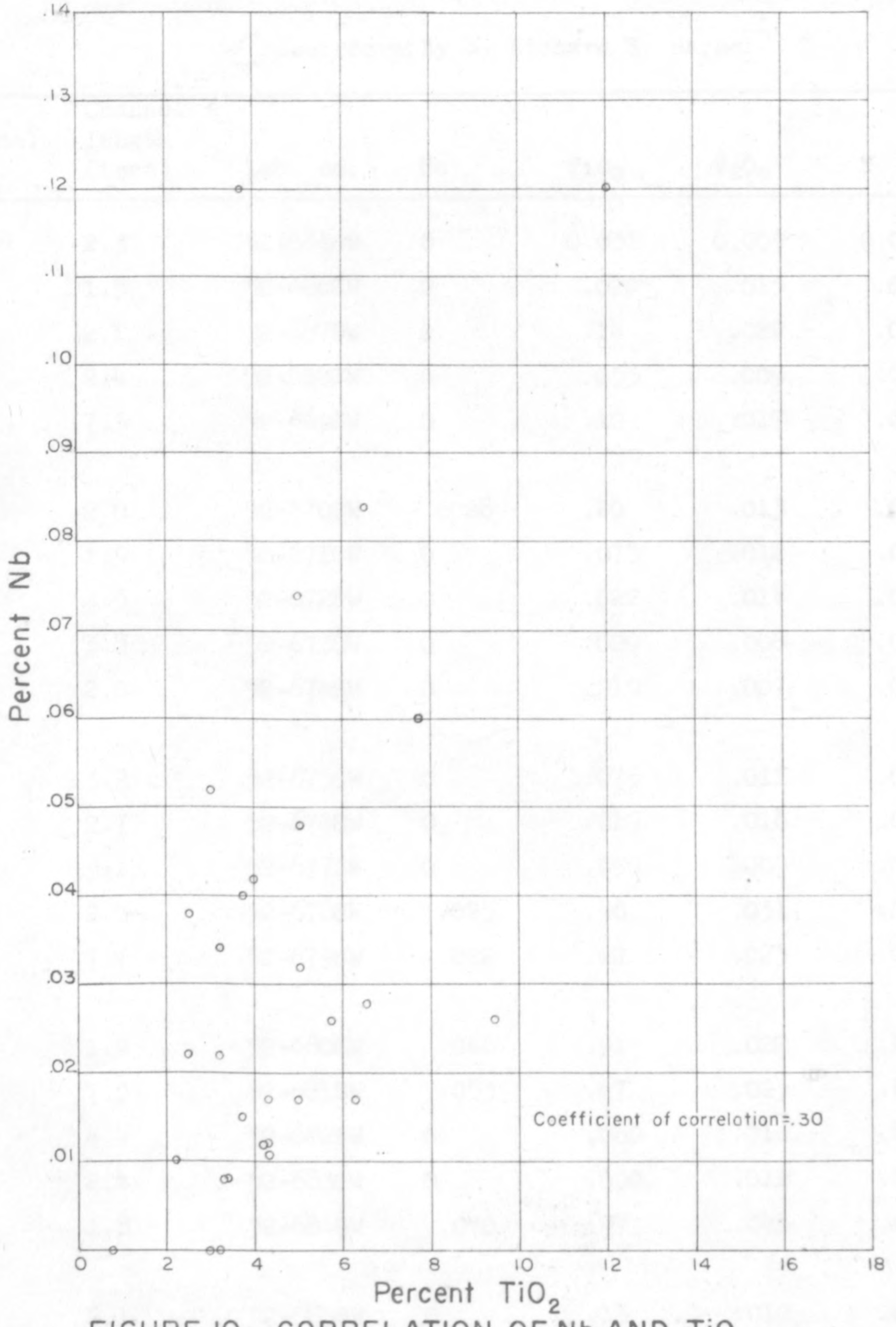


FIGURE 10.— CORRELATION OF Nb AND TiO_2, KILPATRICK PROPERTY, MAGNET COVE, ARKANSAS.

Table 8. -- Analyses of channel samples from the Kimsey calcite quarry Magnet Cove, Arkansas

[Spectrography by Richard S. Harner]

Channel no.	Channel length (feet)	Lab. no.	Nb	TiO_2	V_2O_5	Y	La
1	2.3	52-665SW	0	0.031	0.009	0.003	0.022
2	1.5	52-666SW	0	.020	.015	.006	.037
3	2.1	52-667SW	0	.14	.022	.015	.049
4	2.4	52-668SW	0	.053	.009	.003	.019
5	7.5	52-669SW	0	.10	.017	.006	.038
6	2.0	52-670SW	.028	.20	.013	.006	.034
7	1.9	52-671SW	0	.075	.012	.003	.024
8	4.5	52-672SW	0	.022	.014	.003	.024
9	3.8	52-673SW	0	.029	.008	.003	.022
10	2.0	52-674SW	0	.019	.007	.008	.014
11	3.2	52-675SW	0	.075	.011	.003	.022
12	2.7	52-676SW	0	.019	.016	.008	.033
13	3.1	52-677SW	0	.099	.009	.009	.029
14	2.5	52-678SW	.025	.40	.031	.007	.029
15	7.7	52-679SW	.022	.22	.023	.007	.035
16	1.9	52-680SW	.048	.91	.022	.007	.046
17	7.0	52-681SW	.053	.67	.023	.009	.050
18	4.4	52-682SW	0	.080	.016	.007	.026
19	2.4	52-683SW	0	.050	.011	.006	.010
20	1.8	52-684SW	.070	.97	.045	.015	.062
21	2.1	52-685SW	0	.13	.010	.007	.018

Dash indicates that the element was not looked for. Zero indicates that the element was looked for but not found at the limit of sensitivity.

The location of test pits sampled for niobium is shown in figure 5, and the results of analysis of 33 samples are given in table 7.

Table 7. Analyses of samples from the Kilpatrick property, Magnet Cove, Arkansas.

The average grade of the samples is 5.9 percent TiO_2 and .06 percent Nb. The correlation of Nb and TiO_2 is shown graphically in figure 10; the

Figure 10. Correlation of Nb and TiO_2, Kilpatrick property, Magnet Cove, Arkansas.

scattering is about the same as that in the graph of Christy analyses, figure 9. No analyses of crystals or concentrate have been made.

Mo-Ti Corporation property

No analyses of brookite or rutile-bearing material have been made.

Perovskite-pyroxene-magnetite rock (melteigite) has been seen in drill cores from this property, but no outcrops were found. In 3 thin section the perovskite content ranged from 5 to 8 percent. Material for analysis was drilled from one grain of perovskite in a thin section; it contained 0.56 percent Nb. Assuming that this is an average figure, the rock contains 0.03 to .04 percent Nb in perovskite.

Kimsey calcite quarry

Channel samples and average grade.--Because the perovskite is known to contain niobium, and because utilization of perovskite in calcite rock in other countries is being attempted, the Kimsey calcite quarry was carefully sampled and studied.

Twenty-one channel samples were taken in the sloping walls of the quarry. The channels were cut along lines normal to the trend of the walls, and are located as shown on figures 6 and 7. Quantitative spectrographic analyses for Nb, TiO_2, V_2O_5, Y and La are given in table 8.

Table 8. Analyses of channel samples from the Kimsey calcite quarry, Magnet Cove, Arkansas.

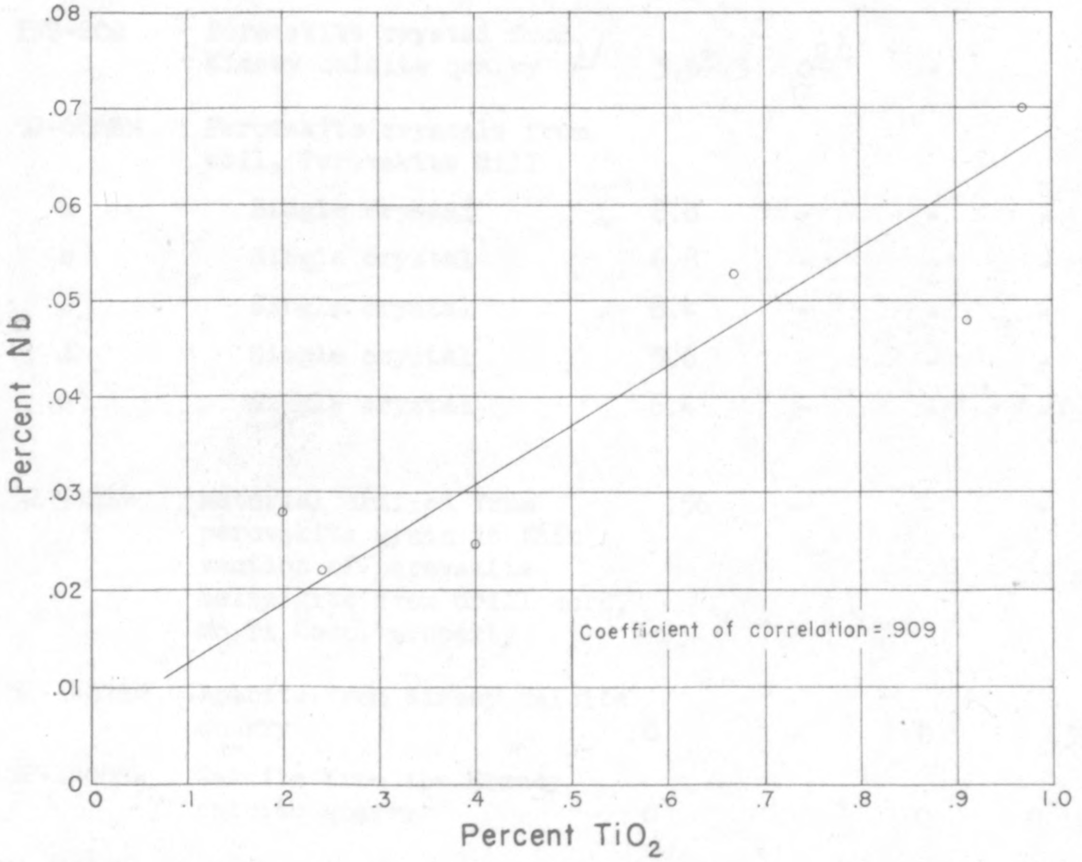


FIGURE 11.—CORRELATION OF Nb AND TiO_2, KIMSEY CALCITE QUARRY, MAGNET COVE, ARKANSAS

Table 9.--Analyses of single crystals from Magnet Cove, Arkansas.

[Spectrography by R. S. Harner, except where noted]

Lab. no.	Description	Nb	Ta	TiO_2	V	La	Y
	Perovskite, Magnet Cove, Ark. (Mar, 1890)	3.1	4.2				
	Perovskite, Magnet Cove, Ark. (Rankama, 1948)	3.3	-	-	-	-	-
IWS-202	Perovskite crystal from Kimsey calcite quarry 1/	5.6±.3	0 2/	-	-	1.2	0.1
52-686SM	Perovskite crystals from soil, Perovskite Hill						
a	Single crystal	8.8	-	-	-	-	-
b	Single crystal	6.8	-	-	-	-	-
c	Single crystal	8.4	-	-	-	-	-
d	Single crystal	5.6	-	-	-	-	-
e	Single crystal	6.4	-	-	-	-	-
52-942SW	Material drilled from perovskite grain in thin section of perovskite melteigite from drill core, Mo-Ti Corp. property	.56	-	-	-	-	-
52-1407SW	Apatite from Kimsey calcite quarry	0	-	0	.39	.38	0
52-1408SW	Calcite from the Kimsey calcite quarry	0	-	0	0	.008	0
52-687SM	Eudialyte from eudialyte syenite near Kimsey calcite quarry	.28	-	1.3	-	-	-
52-688SM	Eudialyte from eudialyte syenite near Kimsey calcite quarry	.30	-	1.2	-	-	-

1/ Spectrography by K. J. Murata.

2/ Ta less than 0.2 percent

Dash indicates that the element was not looked for. Zero indicates that the element was looked for but not found at the limit of sensitivity.

Niobium was detected in only six of the samples. The samples confirmed the visual impression that perovskite, apatite, and monticellite tend to be concentrated in the same zones. The graph of Nb and TiO_2 analyses, figure 11, shows a moderately good correlation between these values.

Figure 11. Correlation of Nb and TiO_2, Kimsey calcite quarry, Magnet Cove, Arkansas.

The average grade of the total channel length is 0.011 percent Nb. The average content of the calcite body is probably about 0.01 percent Nb.

Analyses of perovskite, apatite, and calcite.--Niobium in Magnet Cove perovskite has been reported by several workers, beginning with Mar (1890, p. 403). Available analyses, including the results of the present study, are given in table 9. All values are given as Nb,

Table 9. Analyses of single crystals from Magnet Cove, Arkansas.

rather than as Nb_2O_5. Presumably the samples of Mar and Rankama came from the Kimsey quarry-Perovskite Hill area, as this has been the only collecting ground for loose perovskite crystals. For comparison, an analysis of perovskite from the melteigite at the Mo-Ti pit is also given.

The analyses of previous workers range from 3.1 to 3.3 percent Nb; those of the Geological Survey range from 5.1 to 8.8 percent Nb. The difference probably lies in careful preparation by the Geological Survey analysts of standards for the express purpose of analysis for niobium in the presence of abundant titanium.

Analyses of apatite and calcite from the Kimsey quarry are also given in table 9. Magnet Cove apatite contains rare earths and is probably the source of most of the rare earths in the samples from the rutile and brookite deposits.

Economic factors

Rutile and brookite deposits

A general picture of the occurrence and grade of the three major rutile-brookite deposits has been developed by the drilling, test pitting, and sampling of these deposits. Several areas are known where rutile and brookite occur in the soil (fig. 2), and these invite subsurface exploration. Because rutile and brookite are residual in soil and are easily recognized, it is unlikely that concentrations of these minerals in soil have been overlooked; work now under way in the Cove will test this possibility.

The drilling on the Magnet Cove Titanium Corporation property and the Christy property has been sufficient to indicate the presence of considerable resources of rutile and brookite. It is probable that rutile and brookite deposits at Magnet Cove will be mined eventually.

The present work was done in order to determine the distribution and average grade of niobium in the titanium deposits and associated rocks. In addition the work of the Bureau of Mines and of Fryklund and Holbrook has been summarized, and average grades for TiO_2 and V_2O_5 have been calculated for the deposits. This information is listed in table 10.

Table 10. Summary of analytical data on principal titanium deposits at Magnet Cove, Arkansas.

The U. S. Bureau of Mines has made milling tests on rutile and brookite material from Magnet Cove (Fine, et al, 1949; U. S. B. M. RI 4851). These tests gave low recovery--46 percent for rutile, 55 to 60 percent for brookite; but produced high-grade concentrates of about 92 percent TiO_2 in rutile and brookite. As shown in table 10, the rutile and brookite concentrates will contain about 1.2 percent and 2 percent niobium respectively.

Geologic factors explain much of the poor recovery and suggest that better recovery may not be possible. The chief factor is the occurrence of TiO_2 in several forms. In the rutile deposits, for example, non-recoverable TiO_2 occurs in ilmenite and in silicates. In addition, the rutile occurs in grains of widely varying size and shape and the finer acicular grains are easily broken down into slime sizes that are recoverable only with difficulty. In the brookite deposits, TiO_2 occurs not only in brookite of widely varying sizes but also in very fine-grained acicular rutile, in taeniolite, and in leucoxene.

The vanadium analyses of samples from the rutile and brookite deposits vary widely, and the ratio of concentration of vanadium in concentrates is much lower than that for TiO_2 and Nb. This relation indicates that part of the vanadium is in minerals other than rutile or brookite. The recoverable vanadium is, however, of possible economic value.

Extensive bulk sampling and mill testing under operating conditions will be necessary to determine accurately the recoverable grade of the deposits.

The data presented in this report indicate that niobium is a constant companion of the titanium, and its average grade can be predicted within rather close limits, as shown in table 10.

It is probable that processes for making metallic titanium from the rutile and brookite concentrates will allow separation and recovery of niobium and vanadium. On the other hand, if the rutile and brookite are used for welding rod coatings, the niobium and vanadium will be lost.

Other possible resources of titanium and niobium

Perovskite-bearing rocks in other areas have been considered as possible sources of titanium alone and of both titanium and niobium.

The perovskite-bearing calcite rock exposed in the Kimsey quarry has been studied and sampled as described in this report; the economic results are listed in table 10. Unless the perovskite can be recovered easily as a byproduct of other operations, the TiO_2 and Nb content of this material is probably too low to be of economic interest.

Two localities where perovskite-bearing silicate rock occur are known: the Mo-Ti Corporation locality described in this report, and an area about 1000 feet east of the magnetite quarry, on the north side of highway 270 (fig. 2). The quantity of perovskite-bearing rock in these localities is not known.

FIG. 12--GEOLOGIC AND TOPOGRAPHIC MAP OF THE WILSON PROSPECT, POTASH SULPHUR SPRINGS, GARLAND COUNTY, ARKANSAS

100 75 50 25 0 100 200 300 FEET

Contour interval 10 feet

POTASH SULPHUR SPRINGS AREA

Location and previous work

The Potash Sulphur Springs area is about six miles west of Magnet Cove (fig. 1). The area underlain by igneous rocks is on the north side of U. S. highway 270 and is about one-half mile in diameter. Unlike Magnet Cove, the Potash Sulphur Springs area is rugged and is cut by several deep valleys draining southward to the Ouachita River. About one-half mile north of the highway, near the head of the deepest valley, are the hot springs that give the area its name. The Wilson prospect described in this report (fig. 12) is on the hillside east of the hot springs, above the Wilson residence.

Figure 12. Geologic and topographic map of the Wilson prospect, Potash Sulphur Springs, Garland County, Arkansas.

No outcrop is present in the vicinity of the prospect. Several bulldozer trenches up to ten feet deep expose only heavily weathered rock (saprolite). On the surface are several residual boulders, somewhat similar to the "tufa" boulders near the Kimsey quarry at Magnet Cove. One of these boulders is unusually radioactive, and a grab sample analyzed in December, 1950, by the chemist of the Arkansas Division of Geology, Troy W. Carney, was found to contain a notable quantity of niobium. Later analyses by the U. S. Geological Survey and the University of Arkansas have confirmed the presence of niobium and uranium. The bulldozer trenches were dug in 1951 for Mr. Wilson, the owner of the property.

Geologic relations

The Potash Sulphur Springs area, like Magnet Cove, is underlain by alkaline igneous rocks that have intruded Paleozoic sediments. The geology of the area was described by Williams (1891, p. 344-366). The scant outcrops and float material indicate that the rocks, like those at Magnet Cove, are syenite and more basic alkaline rocks. Calcite rock

Table 11.--Quantitative and semi-quantitative analyses of samples from Wilson prospect, Potash Sulphur Springs, Arkansas.

[Spectrography by R. G. Havens except where noted]

Field no.	Lab no.	Description	Nb	Ti	Y	La	eU[2]	U
1143-B (Ark. Div. Geol.)	51-10745	Grab sample[1] of "discovery boulder", iron-stained siliceous material	1.6 ±.3	-	0.05	0.05	-	-
VF-PS-5	D-67153	9-ft. channel sample	.0X[3]	X.	.00X	.0X	0.011	0.008
VF-PS-6	D-67154	4.5-ft. channel sample	.X	X.	.00X	.0X	.009	.005
VF-PS-7	D-67155	Grab sample	.X	X.	.0X	.X	.007	.005
VF-PS-9	D-67156	1.5-ft. channel sample	.X	X.	.00X	.0X	.004	.005
VF-PS-11	D-67157	Grab sample	X.	X.	.0X	.X	.13	.15
VF-PS-14	D-67158	Grab sample	.0X	.X	.00X	.00X	.005	.002

1/ Spectrography by K. J. Murata.

2/ eU (equivalent uranium) is a measure of radioactivity. It specifies the quantity of uranium in equilibrium with its daughter products that would produce the observed radioactivity.

3/ The "X" in this notation indicates the position of a significant figure. For example:

X. indicates a value between 9. and 1. percent

.X indicates a value between 0.9 and 0.1 percent, etc.

A dash indicates that the element was not looked for.

Table 11.--Quantitative and semi-quantitative analyses of samples from Wilson prospect, Potash Sulphur Springs, Arkansas -- continued.

Field no.	Si	Al	Fe	Mn	P	Ca	Mg
VF-PS-5	XX.	XX.	X.	0.00X	0.X	0.X	0.X
VF-PS-6	XX.	X.	X.	.00X	0	.X	.X
VF-PS-7	XX.	X.	X.	.00X	.X	.X	.X
VF-PS-9	XX.	X.	X.	.00X	.X	.X	.X
VF-PS-11	X.	X.	X.	.0X	X.	X.	.0X
VF-PS-14	XX.	X.	X.	.0X	0	.X	.X

	Na	K	Ba	Be	Ce	Cr	Cu
VF-PS-5	0.X	X.	0.X	Trace	0.0X	0.0X	0.00X
VF-PS-6	.X	X.	.X	0.000X	.0X	.0X	.00X
VF-PS-7	.X	X.	.X	.000X	.X	.0X	.00X
VF-PS-9	.X	X.	.X	.000X	.0X	.00X	.00X
VF-PS-11	.X	X.	.X	.000X	.X	.00X	.00X
VF-PS-14	X.	X.	.X	Trace	0	.00X	.00X

	Ga	Nd	Ni	Pb	Sc	Sr	Zr	V
VF-PS-5	0.00X	0.0X	0	0	0.00X	0.X	0.0X	0.X
VF-PS-6	.0X	.0X	0	0.00X	.00X	.X	.0X	.X
VF-PS-7	.0X	.0X	0	.00X	.0X	.X	.0X	.X
VF-PS-9	.0X	.0X	0	.00X	.00X	.0X	.0X	X.
VF-PS-11	.00X	.0X	0.00X	.00X	.00X	.X	.X	.X
VF-PS-14	.00X	0	0	0	.000X	.0X	.0X	.0X

Looked for but not found in any sample - Ag, As, Au, B, Bi, Cd, Co, Ge, In, Ir, Hf, Hg, Li, Mo, Os, Pd, Pt, Re, Rh, Ru, Sb, Sn, Sm, Ta, Te, Th, Tl, W, and Zn.

A zero indicates that the element was looked for but not found at the limit of sensitivity.

is exposed in the valley near the hot springs. Perovskite, rutile, and brookite have not been reported from the area.

At the Wilson prospect the trenches expose heavily weathered syenite and quartzite, probably along the eastern contact of the igneous complex. The quartzite, probably part of the Arkansas novaculite of Mississippian and Devonian age, is exposed in the eastern part of the long east-west trench (fig. 12). Elsewhere in the trenches heavily weathered syenitic rock is exposed. The presence of dikes of syenite in the quartzite, and of quartzite inclusions in the syenite, indicates that the syenite is intrusive. The syenite is almost completely altered to white and green clay. Irregularly shaped blocks of clay are separated by stringers and veins of iron oxide and clay. The rock may have been a breccia before weathering, or may have developed this structure during weathering and joint-filling.

In hand specimen the least altered material is cream-colored. Orthoclase and microcline phenocrysts up to 2 mm. in diameter are common. In the southern trench biotite books up to 2 inches in diameter are abundant. In the northern trenches the rock is finer grained and biotite is rare or absent.

In thin section the groundmass consists of feldspar grains averaging 0.1 mm. in diameter and of very fine-grained yellowish material, presumably clay minerals. The feldspar contains abundant large apatite inclusions. The rock also contains a few grains of zircon and 1 or 2 percent opaques. Ferromagnesian minerals, if originally present, have been altered to clay minerals. The rock was originally a syenite but cannot be identified further in its weathered condition.

Sampling and analysis

A split of the sample collected by the Arkansas Division of Geology was obtained and analyzed by the Geological Survey. In addition, three channel samples and three grab samples were taken during the present work. The locations of samples are shown on figure 12, and the results of analysis are given in table 11.

Table 11. Analyses of samples from Wilson prospect, Potash Sulphur Springs, Arkansas.

41

53

Sample VF-PS-11 contains a notable quantity of niobium and uranium, and a roughly equal quantity of titanium. These relations suggest that a uraniferous columbate, such as samarskite, is present. Preliminary work has shown that the very fine material washed from the samples is almost as radioactive as the original samples. It is hoped, however, that during further work the minerals containing the niobium and uranium can be isolated from the coarser fractions of the sample.

Conclusions

The lack of outcrop and the limited exposures in the trenches preclude definite geologic interpretation of this interesting occurrence. Material of this type--high in niobium and uranium, and relatively low in titanium -- is not known to occur at Magnet Cove, and therefore no analogies with that area can be drawn.

The results of sampling suggest that material high in both niobium and uranium is not abundant, but that material relatively high (0.1 to 0.9 percent) in niobium may be abundant in the trenched area. Estimates of quantity of material present cannot be made with the information now available. Further work should include diamond drilling to test the presence of similar material below the surface, and to reach unaltered rock.

42

LITERATURE CITED

Bowen, N. L., 1924, The Fen area in Telemark, Norway: Am. Jour. Sci., 5th ser., vol. 8, pp. 1-11.

Croneis, C. G., 1930, Geology of the Arkansas Paleozoic area: Arkansas Geol. Survey Bull. 3, 457 pp.

Daly, R. A., 1933, Igneous rocks and the depths of the earth: McGraw Hill, 598 pp.

Eckermann, Harry von, 1948, The alkaline district of Alnö Island: Sveriges geol. undersökning, Ser. CA, No. 36, pp. 13-163.

Fine, M. M., Kenworthy, H., Fisher, R. B., and Knickerbocker, R. G., 1949, Titanium investigations: The laboratory development of mineral dressing methods for Arkansas rutile: Mining Eng., vol. 1, pp. 447-452.

Fine, M. M., and Frommer, D. W., 1952, Mineral dressing investigation of titanium ore from the Christy property, Hot Spring County, Arkansas: U. S. Bur. Mines Rept. Investigation 4851, 7 pp.

Fryklund, V. C. Jr., and Holbrook, D. F., 1950, Titanium ore deposits of Hot Spring County, Arkansas: Bull. 16, Div. of Geology, Ark. Resources and Development Comm.

Holbrook, D. F., 1947, A brookite deposit in Hot Spring County, Arkansas: Bull. 11, Div. of Geology, Ark. Resources and Development Comm.

______________, 1948, A molybdenite prospect in Hot Spring County, Arkansas: Bull. 12, Div. of Geology, Ark. Resources and Development Comm.

Johannsen, Albert, 1938, A descriptive petrography of the igneous rocks: Univ. of Chicago Press, vol. 4, 573 pp.

Landes, K. K., 1931, A paragenetic classification of the Magnet Cove minerals: Am. Mineralogist, vol. 16, pp. 313-326.

Mar, F. W., 1890, On the so-called perofskite from Magnet Cove, Arkansas: Am. Jour. Sci., 3rd ser., vol. 40, pp. 403-405.

Miser, H. D., and Stevens, R. N., 1938, Taeniolite from Magnet Cove, Arkansas: Am. Mineralogist, vol. 23, pp. 104-110.

Rankama, Kalervo, 1948, On the geochemistry of niobium: Annales Acad. Sci. Fennicae, Ser. A, III, No. 13, pp. 1-57.

Reed, D. F., 1949a, Christy titanium deposit, Hot Spring County, Arkansas: U. S. Bur. Mines Rept. Investigation 4592, 10 pp.

__________, 1949b, Magnet Cove rutile deposits, Hot Spring County, Arkansas: U. S. Bur. Mines Rept. Investigation 4593, 9pp.

47

Ross, C. S.. 1941, Occurrence and origin of the titanium deposits of Nelson and Amherst Counties, Virginia: U. S. Geol. Survey Prof. Paper 198, 59 pp.

Shand, S. J., 1947, Eruptive rocks: Thomas Murby and Co., 3rd ed., 488 pp.

Spencer, R. V., 1946, Exploration of the Magnet Cove Rutile Co. property, Magnet Cove area, Hot Spring County, Arkansas: U. S. Bur. Mines Rept. Investigation 3900, 16 pp.

Strauss, C. A., and Truter, F. C., 1951, The alkali complex at Spitskop Sekunkuniland, eastern Transvaal: Geol. Soc. S. Afr. Trans., vol. 53, pp. 81-130.

Washington, H. S., 1900, Igneous complex of Magnet Cove, Arkansas: Geol. Soc. America Bull., vol. 21, pp. 399-416.

_______________, 1901, The foyaite-ijolite series, Magnet Cove, Arkansas: Jour. Geology, vol. 9, pp. 597-622, 645-670.

Williams, J. F. 1891, The igneous rocks of Arkansas: Annual Rept. of the Geol. Survey of Arkansas for 1890, vol. 2, 457 pp.